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KISILOWSKI J., ZALEWSKI J.: **O pewnej możliwości praktycznego zastosowania stateczności technicznej stochastycznej**; EiN 1/2008, s. 4-6.

Niniejszy artykuł prezentuje spojrzenie na definicję stateczności technicznej stochastycznej (STS) oraz jej użycie w symulacji zarówno modeli matematycznych wagonów kolejowych, jak i samochodów. Zaprezentowano użycie STS w badaniu modelu matematycznego wagonu kolejowego w aspekcie jego stateczności poprzecznej. Przedstawiono również możliwości wykorzystania stateczności technicznej stochastycznej w badaniu modelu matematycznego samochodu.

BATKO W., BORKOWSKI B., GŁOCKI K.: **Zastosowanie systemów bazo-danowych w monitoringu diagnostycznym maszyn**; EiN nr 1/2008, s. 7-10.

Efektywność działania współczesnych systemów monitorujących pracę maszyn jest w istotny sposób określona zaimplementowanymi w nich rozwiązaniami systemów bazo-danowych, wspomagającymi procesy podejmowania decyzji diagnostycznych. W referacie omówiono problem konstrukcji systemu bazo-danowego dla systemu monitorującego prace pracę szlifierki łopatek silników lotniczych, który powstał w ramach realizacji grantu celowego nr: 6T0220005C09545 dla WSK Rzeszów, a także prac nad budową systemu oceny stanu stalowych konstrukcji szybowych w kopalni „RUDNA" KGHM Polska Miedź. Opisano strukturę budowanych systemów, jak i uwarunkowania ich wykorzystania dla potrzeb wnioskowań diagnostycznych.

TIMOFIEJCZUK A.: **Identyfikacja reguł diagnostycznych z zastosowaniem algorytmu ewolucyjnego**; EiN 1/2008, s. 11-16.

Referat dotyczy sposobu identyfikacji reguł asocjacyjnych i diagnostycznych, które opisują relacje między cechami obserwowanych procesów. Reguły są identyfikowane za pomocą metody opartej na zastosowaniu algorytmu ewolucyjnego. Opracowano specjalne sposoby kodowania, operacje genetyczne i ocenę osobników. Podejście opisane w referacie jest częścią metody wnioskowania diagnostycznego z uwzględnieniem kontekstu. Identyfikowane reguły asocjacyjne są przekształcane do postaci reguł diagnostycznych z uwzględnieniem kontekstu.

JURKIEWICZ A., MICEK P., APOSTOŁ M., GRZYBEK D.: **O potrzebie monitorowania procesu sprężania konstrukcji mostowych**; EiN 1/2008, s. 17-22.

W artykule przedstawiono koncepcję systemu monitorowania i rejestrowania przebiegu procesu sprężania z wykorzystaniem układu mikroprocesorowego. W agregatach hydraulicznych stosowanych w technologii sprężania i nasuwania konstrukcji mostowych ASIN (opracowane w KAP AGH) stosowane są nowoczesne sterowniki programowalne, dzięki czemu rozbudowa ich o system monitorowania i rejestrowania przebiegu siły i wydłużenia nie wymaga dużych nakładów. Opracowanie i wdrożenie systemu monitorowania i rejestrowania parametrów procesu sprężania pozwoli, oprócz poprawy jakości i bezpieczeństwa konstrukcji, na zbudowanie bazy wiedzy. Baza ta jest niezbędna dla opracowania metod diagnozowania procesu sprężania. Do opracowania koncepcji systemu wykorzystano wieloletnie doświadczenie autorów artykułu zdobyte przez udział w sprężaniu kilkunastu obiektów mostowych.

GAŁKA T.: **Odwzorowanie stanu technicznego maszyny w ewolucyjnych symptomach diagnostycznych**; EiN 1/2008, s. 23-29.

Charakterystyki drganiowe stanowią ważne źródło informacji o stanie technicznym maszyny. W większości zastosowań dla złożonych maszyn diagnoza opiera się na widmach drgań, jednak wpływ na nie ma, oprócz parametrów stanu, wiele innych czynników. Alternatywnym sposobem uzyskania informacji o stanie technicznym maszyny jest analiza trendów drgań. Można to zrealizować przez zastosowanie tzw. symptomów ewolucyjnych, opisujących ilościowo zależność poziomów drgań od czasu. Z modeli teoretycznych można wywnioskować, że zarówno szybkość narastania, jak i odstępstwo od liniowości mogą być przyjęte jako symptomy diagnostyczne. Ocena eksperymentalnych trendów drgań, uzyskanych dla turbin parowych, potwierdza ten wniosek i wykazuje, że tego rodzaju symptomy pod wieloma względami przewyższają typowe symptomy drganiowe, wykorzystywane w procedurach diagnostycznych.

MICHALSKI R., WIERZBICKI S.: **Analiza degradacji pojazdów w eksploatacji**; EiN 1/2008, s. 30-32.

Pojazdy mechaniczne są stosunkowo złożonymi obiektami technicznymi w których w trakcie funkcjonowania zachodzą złożone procesy zużycia. Intensywność zużycia poszczególnych zespołów pojazdu jest uzależniona nie tylko od ich konstrukcji, ale także od warunków ich eksploatacji. W niniejszym artykule przestawiono mechanizmy i czynniki wpływające na degradację pojazdów mechanicznych.

WYCZÓŁKOWSKI R.: **Inteligentny system monitorowania sieci wodociągowych**; EiN 1/2008, s. 33-36.

W referacie przedstawiono badania związane z budową systemu monitorowania sieci wodociągowych, sygnalizujących pojawienie się awarii sieci i wspomagającego ich lokalizację. Podstawowym założeniem omawianego systemu było przyjęcie metody wykrywania awarii stosowanej dotychczas w diagnostyce technicznej maszyn i procesów przemysłowych, opartej o modele przybliżone obiektu diagnozowanego. Bazując na niewielkiej liczbie czujników przepływu zainstalowanych na sieci wodociągowej i odpowiednio wytrenowanej sztucznej sieci neuronowej pojawiające się awarie sieci są wykrywane i lokalizowane. Opisany został pierwszy etap prac (lokalizacja czujników pomiarowych, przygotowanie i trenowanie klasyfikatora neuronalnego) oraz uzyskane wyniki.

KISILOWSKI J., ZALEWSKI J.: **Wybrane problemy analizy przyczyn wypadków drogowych w Polsce w latach 1995 –2004**; EiN 1/2008, s. 37-43.

W niniejszej pracy dokonano klasyfikacji zderzeń samochodów ze względu na statystycznie najczęściej występujące wypadki oraz testy, jakim poddawane pojazdy są nowo dopuszczane do sprzedaży. Niniejsza praca dotyczy rozważań na temat bezpieczeństwa ruchu drogowego w Polsce. Na jej łamach podjęto próbę analizy przebiegu i skutków najpowszechniej występujących na drogach zderzeń. Ważnym jest problem stateczności jako elementu podlegającego zmianom w przypadku eksploatacji pojazdów powypadkowych. Problem ten jest przedmiotem oddzielnych badań. Kolejnym ważnym punktem jest przedstawienie danych statystycznych i próbę analizy poziomu bezpieczeństwa na ich podstawie. Jako ważny etap należy postrzegać tu chęć porównania niektórych wskaźników w Polsce i we Francji, co pozwoliło na próbę zweryfikowania niektórych opinii o poziomie bezpieczeństwa ruchu na drogach w Polsce.

KISILOWSKI J., ZALEWSKI J.: **On a certain possibility of practical application of stochastic technical stability**; EiN 1/2008, s. 4-6.

This article gives an overview on the definition of stochastic technical stability (STS) and its use in simulation of railway car as well as motor car mathematical models. It presents how the STS was used to examine the mathematical model of railway car in aspects of its lateral stability. It also presents possibilities of using the STS to examine mathematical model of motor car.

BATKO W., BORKOWSKI B., GŁOCKI K.: **Application of database systems in machine diagnostic monitoring**; EiN nr 1/2008, s. 7-10.

The action effectiveness of modern monitoring systems of machine run is essentially defined by database systems they implement, supporting diagnostic decision making process. The paper describes the issue of database construction for the jet engine rotor blade grinder monitoring system that was developed as part of the grant nr.: 6T0220005C09545 for WSK Rzeszow, and also during the development of diagnostic system of the steel shaft construction in the mine „RUDNA", KGHM Polska Miedz. The structure of the systems is described and the conditions of their application to diagnostic decision making.

TIMOFIEJCZUK A.: **Identification of diagnostic rules with the application of an evolutionary algorithm**; EiN 1/2008, s. 11-16.

The paper deals with a way of identification of associative and diagnostic rules, which determine relationships between features of observed processes. Rules are identified by means of a method based on the application of an evolutionary algorithm. Special ways of coding, genetic operations and individual assessments were elaborated. The approach described in the paper is a part of a method of diagnostic inference with the use of contexts. Identified associative rules are transformed into diagnostic rules within given contexts.

JURKIEWICZ A., MICEK P., APOSTOŁ M., GRZYBEK D.: **About the need of the monitoring of the bridge construction prestressing process**; EiN 1/2008, s. 17-22.

The article presents the system conception of the monitoring and course logging prestressing process wit the use of the microprocessor system. In the hydraulic supplying units, which are elaborated by AGH, are used the modern programming controllers which can be used like the base of the elaborating monitoring system.
The elaboration and application of the monitoring and logging system enables the improvement of construction quality and safety as well as the building of the knowledge base. The base is needed to the elaboration of the diagnostic method of the prestressing process. To the elaboration of this conception was used the experiences of the author of this article. This experience was earned by the participation in the prestressing ten or more bridge construction.

GAŁKA T.: **Representation of machine technical condition in evolutionary diagnostic symptoms**; EiN 1/2008, s. 23-29.

Vibration patterns provide an important source of information on machine technical condition. In most applications for complex machines, diagnosis is based on vibration spectra, but they are influence by many factors other than condition parameters. Consequently false alerts can be triggered. Analysis of vibration trends is an alternative way to extract information on machine technical condition. This can be achieved by employing so-called evolutionary symptoms, which describe quantitatively the time dependence of vibration levels. From theoretical models we may conclude that both increase rate and departure from linearity can be accepted as diagnostic symptoms. Evaluation of experimental vibration time histories, obtained for steam turbines, has confirmed this conclusion and shown that such symptoms are in many aspects superior to typical vibration-based symptoms employed in diagnostic procedures.

MICHALSKI R., WIERZBICKI S.: **An analysis of degradation of vehicles in operation**; EiN 1/2008, s. 30-32.

Vehicles are quite complex technical objects and complicated wear processes accompany their exploitation. The intensity of degradation of particular systems of a vehicle depends not only on a construction but also on the exploitation conditions. In the following paper the mechanisms and conditions influencing degradation of vehicles have been presented.

WYCZÓŁKOWSKI R.: **Intelligent monitoring of local water supply system**; EiN 1/2008, s. 33-36.

In the paper an intelligent monitoring system of local water supply system was described. The author took advantage of methods of artificial intelligence and methods known from model-based process diagnostics to decrease the number of indispensable measuring points. Basing on few flow sensors installed on pipeline network and using neural network as a model of pipeline, appeared leakages are approximately localized. The first stage of system building (choosing of sensor localization, neural network preparing and training) and results obtained to-date were shown.

KISILOWSKI J., ZALEWSKI J.: **Chosen problems of road accidents analyses in Poland in the period between 1995 and 2004**; EiN 1/2008, s. 37-43.

This article offers classification of car collisions from the point of view of the most frequent accidents and crash tests. The most important problems are the consequences of incomplete control of a car which has been repaired after an accident. As a result, further use may lead to defective work of systems responsible for steering, driving comfort, and contact with the road surface as well as suspension. Firstly, the article focuses on the safety of road traffic in Poland and presents an attempt to analyze the course of most frequent collisions and their consequences. Stability is an important problem as it changes in a car driven after an accident, and should be analyzed in separate research. Secondly, it gives statistical data and attempts to analyze the level of road traffic safety. Some important indicators are shown here to compare the situation in France and Poland, which enabled verification of some opinions about the safety of road traffic in Poland.

BATKO W., KORBIEL T.: **Eksploatacja zbrojenia szybu górniczego w oparciu o globalny współczynnik tłumienia**; EiN 1/2008, s. 44-48.

W eksploatacji urządzeń górniczych bardzo istotnym czynnikiem jest zachowanie równowagi pomiędzy ekonomią a bezpieczeństwem. Użytkowanie szybu górniczego według stanu związane jest z oceną jego stanu oraz oceną oddziaływań pomiędzy zbrojeniem szybowym a naczyniami wyciągowymi. W ocenie stanu technicznego zbrojenia szybowego wykorzystuje się heurystyczne metody wizyjne, ultradźwiękowy pomiar grubości elementów, pomiar „spokoju jazdy" itp. Nową, proponowaną metodą jest pomiar globalnego współczynnika tłumienia. Ponieważ metoda ta jest metodą selekcyjną, wymaga dodatkowych procedur diagnostycznych. Dobór tych procedur ukierunkowany jest na zmniejszenie niepewności otrzymanych wyników.
W artykule przedstawiono opis metody globalnego współczynnika tłumienia. Algorytm ten został zaimplementowany w przyrządzie pomiarowym. Przedstawiono sposób implementacji z zastosowaniem środowiska LabView oraz metody wirtualnych instrumentów. Wyniki pomiarów importowane są do systemu bazodanowego. Na podstawie zebranych informacji podejmowane są decyzje dotyczące dalszej diagnostyki oraz dalszej eksploatacji zbrojenia szybowego. Prezentowany algorytm jest wdrażany w jednej z kopalni, oraz trwają prace nad jego udoskonaleniem.

BIENIEK J., BANASIAK J.: **Przegląd prac badawczych nad wpływem geometrii nachylonego sita żaluzjowego na jego przesiewalność**; EiN 1/2008, s. 49-52.

W niniejszym artykule przedstawiono prace badawcze poszukujące rozwiązania zapewniające pełną skuteczność segregacji i czyszczenia masy poomłotowej podczas pracy kombajnu na terenach o nachyleniu do 15^0. Badania prowadzono nad zastosowaniem sit żaluzjowych ukształtowanych cylindrycznie, daszkowo i wzdłużnie dwupłaszczyznowo.

LEWITOWICZ J.: **Zarządzanie i sterowanie potencjałem eksploatacyjnym floty statków powietrznych**; EiN 1/2008, s. 53-56.

Każdy system wykorzystywany może być efektywnie, co oznacza uzyskiwanie maksymalnej skuteczności przy minimalnych kosztach. Jest to możliwe odpowiednio wykorzystując skuteczne strategie zarządzania, sterowania i kierowania tym systemem. Strategie te oparte powinny być na ciągłym śledzeniu zmian odpowiednich wskaźników niezawodnościowych, bezpieczeństwa i efektywności eksploatacji systemu z uwzględnieniem ryzyka wykonywania misji (zadań eksploatacyjnych). Takie podejście podatne jest na modelowanie. Rozważono model decyzyjny dotyczących zarządzania, sterowania i kierowania systemem i procesem eksploatacji flotą statków powietrznych.

SZEWCZYK A., WILCZOK G.: **Położenie belki polowej opryskiwacza a rozkład przestrzenny rozpylonej cieczy i pokrycie opryskiwanych powierzchni**; EiN 1/2008, s. 57-60.

W opracowaniu przedstawiono wyniki prac prowadzonych od kilku lat w Instytucie Inżynierii Rolniczej Uniwersytetu Przyrodniczego we Wrocławiu. Celem tych badań było określenie położenia belki polowej opryskiwacza przy zmianie parametrów i warunków pracy. Zmiana ustawienia belki polowej w płaszczyźnie pionowej powoduje zmianę wysokości rozpylania poszczególnych rozpylaczy umieszczonych na belce jak i ich asymetryczne ustawienia w stosunku do opryskiwanych powierzchni pionowych. W związku z tym w wynikach badań przedstawiono również ocenę rozkładu poprzecznego opadu rozpylanej cieczy oraz stopień pokrycia opryskiwanych powierzchni w zależności od ustawienia belki. Wyniki badań wykazały, że każde wychylenie belki w płaszczyźnie pionowej powoduje zdecydowane pogorszenie jakości opryskiwania określanej przez wskaźnik zmienności rozkładu poprzecznego i stopień pokrycia.

LIŠČÁK S., RIEVAJ V., ŠULGAN M.: **Warunki techniczne pojazdu a emisja spalin**; EiN 1/2008, s. 61-63.

Artykuł prezentuje wyniki badań mających na celu znalezienie różnic w emisji spalin dwóch silników o zapłonie iskrowym pojazdów osobowych o różnym roku produkcji. Porównania dokonano podczas poziomego ruchu pojazdów ze stałą prędkością. Podczas prowadzonych badań silnik samochodu pokonywał tylko następujące opory: układu napędowego, toczenia oraz powietrza. Do badań wybrano samochody o porównywalnych masach i powierzchni czołowej. Były to Škoda 105 L wyprodukowana w 1983 roku oraz Toyota Yaris 1,0 VVTi z roku 2003.

LINGAITIS L. P., VAIČIŪNAS G.: **Zmiana złożonych wskaźników gospodarczych zużycia osobowego taboru kolejowego**; EiN 1/2008, s. 64-66.

Szereg kryteriów opisujących stan lokomotywy z różnych perspektyw może być używanych do oszacowania ich stanu. Kilka złożonych albo zintegrowanych kryteriów obrazujących stan ogólny lokomotyw Diesla może też być alternatywnie używanych w takim przypadku. Zintegrowany wskaźnik wyników charakteryzujący stan lokomotyw może być wyrażony przez opisane funkcjonalne zależności. Analiza dostępnych metod dla złożonej oceny stanu taboru kolejowego pokazała, że wydajność całkowita lokomotywy może być opisana przez bezwymiarowy wskaźnik.

OKULEWICZ J., SALAMONOWICZ T.: **Modelowanie profilaktycznego obsługiwania parku samochodów**; EiN 1/2008, s. 67-71.

W referacie przedstawiono metodę utrzymania wymaganej niezawodności parku pojazdów. Założony efekt uzyskano poprzez użycie diagnozowania statystycznego do wskazywania zakresu wymian profilaktycznych. Kryterium wyboru był akceptowalny poziom prawdopodobieństwa uszkodzenia pojazdów podczas realizowania zadań transportowych. Opracowano algorytm wyboru wymienianych składników floty pojazdów. Wykazano, że na poziom niezawodności parku pojazdów można oddziaływać nie tylko poprzez zmianę rzędu kwantyla, ale także poprzez dodawanie odpowiedniej liczby nadmiarowych pojazdów. Dla potwierdzenia wyprowadzonych zależności zastosowano model symulacyjny wymian profilaktycznych.

DROŹDZIEL P.: **Wpływ organizacji pracy samochodu na warunki rozruchu silnika spalinowego**; EiN 1/2008, s. 72-74.

Podczas etapu planowania przewozu określonego rodzaju ładunku, bierze się pod uwagę: uwarunkowania techniczne posiadanych środków transportu, odległości pomiędzy założonymi punktami dowozu, czas i koszt przewozu, a także czasy załadunku i wyładunku. Inne czynniki, związane z warunkami pracy danego środka transportu oraz jego wpływem na otoczenie, najczęściej nie są brane pod uwagę podczas procesu projektowania tras przejazdu. Niniejszy artykuł prezentuje omówienie przeprowadzonych analiz statystycznych wyników eksploatacyjnych badań samochodu dostawczego LUBLIN i jego silnika spalinowego 4CT90. Przeprowadzone analizy miały na celu określenie związków pomiędzy organizacją pracy samochodu a warunkami w jakich występują rozruchy jego silnika spalinowego.

BATKO W., KORBIEL T.: **Maintenance of mining shaft reinforcement based on global damping coefficient**; EiN 1/2008, s. 44-48.

In mining equipment exploitation it is very important to keep balance between payoff and safety. Usage of shaft is related to its state assessment and the evaluation of interactions between shaft reinforcements and transportation vessels. In the reinforcement state assessment heuristic vision methods are used, ultrasonic thickness measurements, run stability measurement etc. Attenuation rate measurement is a proposed new method. Since this method is a selection method it needs additional diagnostic procedures. The choice of procedures is directed towards reduction of results uncertainty.
The article presents the method of global attenuation rate. The algorithm was implemented into the measurement device. The method of implementation by means of LabView environment was presented as well as methods of virtual instruments. The measurement results are imported into database system. Based on the gathered information the decisions are made regarding future diagnostics and exploitation of the shaft reinforcement. The presented algorithm is being introduced in one of the mines and is constantly perfected.

BIENIEK J., BANASIAK J.: **A review of the research work on the impact of the geometry of the inclined adjustable section sieve on its screening ability**; EiN 1/2008, s. 49-52.

The paper reviews the studies aimed at finding the solution to guarantee the full effectiveness of segregation and cleaning of the treshing mass for the combine-harvester operating on the slope up to 15^0. These investigations were carried out with the adjustable section sieves shaped in a cylindrical, canopy or longitudinal two-plane form.

LEWITOWICZ J.: **Management and control of the potential exploitation of fleet aircrafts**; EiN 1/2008, s. 53-56.

Any system can be used effectively, which means maximum effectiveness is reached at a minimum cost. It is feasible if effective strategies of managing, control and administrating the system are suitably applied. The strategies should be based on continuous observation of changes in appropriate reliability and safety rates and those of effectiveness of the system operation, with account taken of the risk of performing a mission (operational task). Such approach is liable to the modelling. Consideration has been given to a decision-making model referring to the management, control and administration of the operational system and process, and to the functioning of the system.

SZEWCZYK A., WILCZOK G.: **Impact of the position of the sprayer field beam on the spatial distribution of the sprayed liquid and the degree of coverage of the treated surfaces**; EiN 1/2008, s. 57-60.

The paper presents the research findings from the studies carried out for a number of years at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences. The aim of the studies was to determine the position of the sprayer field beam when the working parameters and conditions vary. The change of the beam position in the vertical plane results in modifying the spraying height of the particular spray nozzles on the beam. This also leads to their asymmetrical arrangement in relation to the treated vertical surfaces. The research results also include the assessment of the transverse distribution of the sprayed liquid fall and the degree of coverage depending on the beam position. The results proved that each beam deflection in the vertical plane significantly reduced the spraying quality, which is measured by the variability index of the transverse distribution and the degree of coverage.

LIŠČÁK S., RIEVAJ V., ŠULGAN M.: **Vehicle's technical condition and emission**; EiN 1/2008, s. 61-63.

The article presents the research results aimed to get true differences of pollution production between two cars with spark ignition engine depending on the car's age. A car movement by constant speed on horizontal plane was realised for comparison. The vehicle engine must overcome only mechanical transmission losses, air resistance and rolling resistance, too. The air resistance size depends on the speed, the vehicle frontal area and the air resistance coefficient. It was chosen vehicles with approximated equal weight and approximated equal vehicle frontal area for comparison. These conditions fulfil vehicles Škoda 105 L, made in 1983, and Toyota Yaris 10,0 VVTi, made in 2003.

LINGAITIS L. P., VAIČIŪNAS G.: **A change of complex economic indicators of passenger rolling stock deterioration**; EiN 1/2008, s. 64-66.

Various criteria describing the state of a locomotive from various perspectives can be used to assess its performance. Some complex or integrated criteria reflecting a general state of Diesel locomotives can also be used. an integrated performance indicator characterizing the locomotive performance is expressed by the following functional relationship. The analysis of the available methods for complex evaluation of the locomotive condition has shown that overall performance of the locomotive can be described by a dimensionless indicator.

OKULEWICZ J., SALAMONOWICZ T.: **Modelling preventive maintenance for a vehicle fleet**; EiN 1/2008, s. 67-71.

The paper presents a method of means of transport maintenance with a required reliability. Such results are achieved by using statistical diagnosing as a base of preventive replacement of objects in a fleet. The acceptable level of a failure risk while executing transportation tasks has been taken as a criterion. An algorithm for selecting elements for preventive replacement has been developed. It was shown that a level of a fleet reliability can be controlled not only by changing an order of a quantile function but also by adding a number of redundant objects to the fleet. A computer simulation model was used to explicate derived dependencies between a redundancy and a quantile order.

DROŹDZIEL P.: **The influence of the vehicle work organization conditions on the engine start-up parameters**; EiN 1/2008, s. 72-74.

The technical parameters of the means of transport, the distance between particular points of carriage, the time of loading and unloading the cargo, the time and the cost of the transport are taken into consideration during the planning of the transport specified shipment.
Another factors, which are connected with the influence of the working conditions of the means of transport on the natural environment, are not taken into account during the planning of their routes. This paper presents the results of the statistical analysis of the maintenance research of the LUBLIN delivery truck and its engine 4CT90. The conducted analysis aimed at the estimation of the relations between the vehicle work organization conditions and the parameters of the engine start-up.

Jerzy KISILOWSKI
Jarosław ZALEWSKI

O PEWNEJ MOŻLIWOŚCI PRAKTYCZNEGO ZASTOSOWANIA STATECZNOŚCI TECHNICZNEJ STOCHASTYCZNEJ

ON A CERTAIN POSSIBILITY OF PRACTICAL APPLICATION OF STOCHASTIC TECHNICAL STABILITY

Niniejszy artykuł prezentuje spojrzenie na definicję stateczności technicznej stochastycznej (STS) oraz jej użycie w symulacji zarówno modeli matematycznych wagonów kolejowych, jak i samochodów. Zaprezentowano użycie STS w badaniu modelu matematycznego wagonu kolejowego w aspekcie jego stateczności poprzecznej. Przedstawiono również możliwości wykorzystania stateczności technicznej stochastycznej w badaniu modelu matematycznego samochodu.

Słowa kluczowe: *stateczność techniczna stochastyczna, stateczność poprzeczna, model matematyczny, samochód, wagon kolejowy.*

This article gives an overview on the definition of stochastic technical stability (STS) and its use in simulation of railway car as well as motor car mathematical models. It presents how the STS was used to examine the mathematical model of railway car in aspects of its lateral stability. It also presents possibilities of using the STS to examine mathematical model of motor car.

Keywords: *stochastic technical stability, lateral stability, mathematical model, motor car, railway car.*

1. Introduction

The purpose of this paper is to give an overview on the possibilities of using stochastic technical stability (STS) in analyses concerning the behaviour of mathematical models in different conditions.

2. Definition of stochastic technical stability - assumptions

We have the following set of stochastic equations $x(t) = f[x,t,\xi(t)]$ *. For the stochastic process $f(0,t,\xi(t))$ and $t \geq 0$ there is $P\{\int_0^T |f(0,t,\xi(t))| dt < \infty\} = 1, \ \forall T > 0$. There is also a stochastic process $f(X,t,\xi(t))$ hat fulfills the Lipschitz condition for another process $\eta(t)$.

As a result there is only one solution [$t=t_0$, $x(t_0)=x_0$], which is a stochastic process.

2.1. Definition of stochastic technical stability

There are two areas in En: ω – finite and open, Ω – finite and closed, where $\omega \subset \Omega$. It has been assumed that there is also a positive number ε, where $0<\varepsilon<1$. The definition of STS is: if every solution of *, having the initial conditions within ω, lies within Ω with the probability of 1-ε, then the structure is technically stochastically stable in relation to ω, Ω and $\xi(t)$ with the probability of 1- ε (Fig. 2.1).

$$P\{(t,t_0,\bar{x}_0) \in \Omega\} > 1 - \varepsilon \quad for \quad \bar{x}_0 \in \omega \tag{1}$$

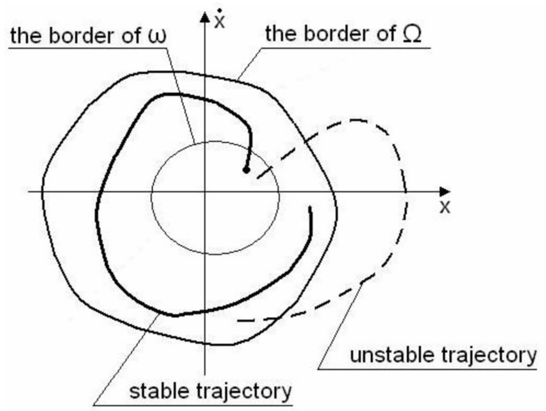

Fig. 2.1. Graphic illustration of stochastic technical stability [3]

The probability of appearance of a wheel set in motion along a straight track was examined. As an occurrence the appearance of three- or four-point contact was considered, for which the instability of the set was assumed. The event of three-point contact between the wheels and the track was examined. Such contact occurs when a set of wheels moves along the Oy_i axis. A four-point contact appears when the wheel set turns around the Oz_i vertical axis. Such a case was analysed in [2] the use of Markov processes.

3. Aspects of stochastic technical stability in the mathematical model of a railway car

STS was used to examine the mathematical model of a railway car (lateral stability). It was presented by E. Kardas-Cinal, PhD, while the basic assumptions were taken from Bogusz definition. The areas of Ω adopted for these analyses are presented in Fig. 3.1 and 3.2.

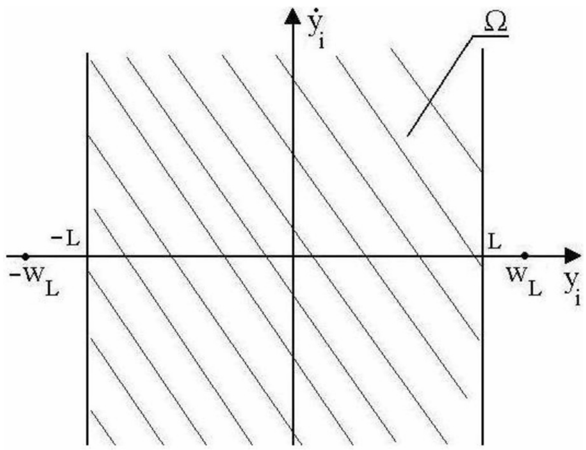

Fig. 3.1. Illustration of Ω for the lateral translation of a railway car [3] $\Omega = \{x : |y_i| \le L\}$

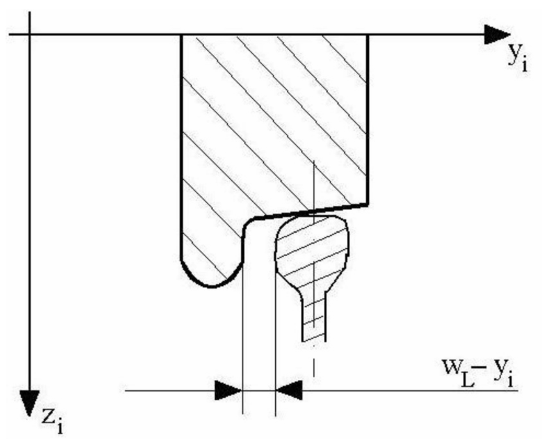

Fig. 3.2. Technical conditions defining the maximum distance L of the set Ω [3]. w_L – the space between the wheel and the rail head

4. Aspects of stochastic technical stability in the mathematical model of a motor car

The mathematical model of a car can be analysed using the concept of technical stochastic stability, where the area of the admissible solutions Ω is determined by the width of the road (Fig. 4.1). The car model will have a disturbed geometry of the car body resulting from a collision and then repair. We shall investigate stability for nominal and disturbed geometric and mass parameters of the car body.

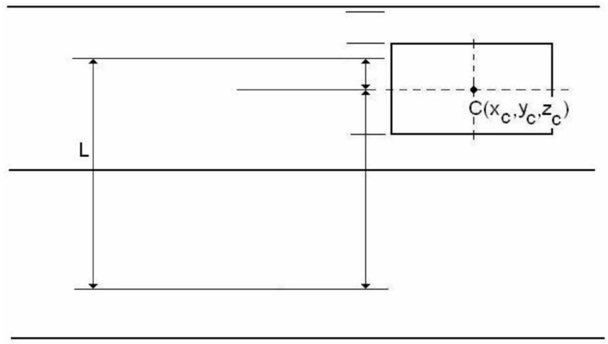

Fig. 4.1. The maximum (admissible) width L of the set Ω between the mass centre of the car model and the roadside: Source: authors' own research

For such assumptions the examination of technical stochastic stability can be conducted for the mathematical model of a car whose motion is disturbed by the irregularity of the road. A method similar to that used in [3] can be employed to determine the probability at which the car motion trajectory will remain in the presupposed area (the width of the road). Some relationships will be obtained between the disturbances of the car body geometry and mass and the stochastic technical stability examined in the process of simulating car mathematical models.

Disturbances resulting from the road appear in the form of irregularities which, according to the assumptions, are the stochastic process. The road is the area of definitivity here, whereas in stochastic signals it is time. The third domain is the wavelength of the road irregularity and, respectively, of the frequency. Thus the disturbances of the road for v=const can be easily transformed into a signal, which is the kinematic constraint of the car mathematical model (the transformation of the stochastic process into a stochastic signal). The same wavelength extorts a different frequency for a different car speed.

The change in the geometry and mass disturbances and their influence on the stability of a car motion will be examined. An analysis will be carried out of the probability with which the trajectory of this motion will remain within the area of admissible solutions Ω (specified width within which the car can move within the road width). In the research we shall assume that the same interactions apply to the steering wheel.

For a real object, car stability is defined by the ISO 8855:1991 standard and it is as follows:

- Non-periodic stability – stability characteristic at a prescribed steady-state equilibrium if, following any small temporary disturbance or control input the vehicle will return to the steady-state equilibrium without oscillation.
- Neutral stability – stability characteristics at a prescribed steady state equilibrium if, for any small temporary disturbance or control input, the resulting motion of the vehicle remains close to, but does not return to the motion defined by the steady-state equilibrium.
- Oscillatory stability – oscillatory vehicle response of decreasing amplitude and a return to the original steady-state equilibrium.
- Non-periodic instability – an ever-increasing response without oscillation.
- Oscillatory instability – an oscillatory response of ever-increasing amplitude about the initial steady-state equilibrium.

As can be seen from the above definitions, we can directly relate the stochastic technical stability of the car mathematical model to the stability defined by the ISO 8855:1991 standard. So, the research being conducted will not be wholly commensurate with the above definitions of the ISO 8855:1991 as it will be an attempt to find the probability with which the trajectory of a car mathematical model in motion, under the accepted assumptions, will remain in the presupposed area of admissible solutions.

However, the answer concerning the lack of stability for model analyses is different from the one defined by the ISO 8855:1991 standard, as it does not provide for a random approach to the phenomena, although the results can be used for various types of analyses. It seems, indeed, that both 'stabilities' have similar criteria when considering the mathematical model and the real object as a mechanical system.

5. Conclusions

The examination of stochastic technical stability of a car mathematical model will allow us to assess of car stability after crash and repair in the aspect of passenger car stability. Research will be conducted with the use of the simulation results. The results will be presented in further publications. They can also be used to control the technical condition of a car.

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ZASTOSOWANIE SYSTEMÓW BAZO-DANOWYCH W MONITORINGU DIAGNOSTYCZNYM MASZYN

APPLICATION OF DATABASE SYSTEMS IN MACHINE DIAGNOSTIC MONITORING

Efektywność działania współczesnych systemów monitorujących pracę maszyn jest w istotny sposób określona zaimplementowanymi w nich rozwiązaniami systemów bazo-danowych, wspomagającymi procesy podejmowania decyzji diagnostycznych. Wynika to ze złożoności procesu wnioskowań diagnostycznych, który oparty jest najczęściej na dużej liczbie obserwowanych sygnałów, podlegających skomplikowanym procedurom ich przetworzeń, w tym potrzebom odwołań do historii ich obserwacji. W referacie omówiono problem konstrukcji systemu bazo-danowego dla systemu monitorującego prace pracę szlifierki łopatek silników lotniczych, który powstał w ramach realizacji grantu celowego nr: 6T0220005C09545 dla WSK Rzeszów, a także prac nad budową systemu oceny stanu stalowych konstrukcji szybowych w kopalni „RUDNA" KGHM Polska Miedź. Opisano strukturę budowanych systemów, jak i uwarunkowania ich wykorzystania dla potrzeb wnioskowań diagnostycznych.

***Słowa kluczowe**: system baz danych, monitoring, diagnostyka.*

The action effectiveness of modern monitoring systems of machine run is essentially defined by database systems they implement, supporting diagnostic decision making process. The process is very sophisticated and based on large number of observed signals, which are processed in sophisticated manner, including the need to reference the observation history or the data describing working conditions of the monitored object in any point of time. The paper describes the issue of database construction for the jet engine rotor blade grinder monitoring system that was developed as part of the grant nr.: 6T0220005C09545 for WSK Rzeszow, and also during the development of diagnostic system of the steel shaft construction in the mine „RUDNA", KGHM Polska Miedz. The structure of the systems is described and the conditions of their application to diagnostic decision making.

***Keywords**: database systems, monitoring, diagnostic.*

1. Introduction

Database systems are currently one of the fastest developing branches of information technology and find their application starting from the mobile phones up to military purposes. In general those sysstems might be classified by the data model they implement:
- network model,
- hierarchical model,
- relational model,
- object model.

First two models (networking and hierarchical) are no loger used for their limitations sake and the most developed and mostly used is relational model. But the object model becomes more and more popular for it allows storing of more complex structures, currently used mostly for multimedia data, like video and audio.

Thanks to their properties database system allows for:
- Redundancy control,
- Unauthorized access limitation,
- Permanent storage space for object used in programs,
- Proper storage structures for effective query processing,
- Data loss protection,
- Multiaccessibility,
- Data relation representation,
- Enforced integrity rules,
- Decision making support, rules based actions.

The main task of the database system is to gather and distribute data and also most important from the diagnostic point of view is the ability to make decisions based on the stored date by application of datamining and warehouse techniques.

By means of relational algebra it is possible to create the live history of the monitoring object. Thanks to proper number of measurements it is possible to do some parametrization of the events by searching for the resemblance of the events during the time. Knowledge of those relations allows building diagnostic patterns which in turn create the possibility of quick assessment of the machine state and foreseeing its behaviour in further exploitation. To make it possible the database needs to contain enough information, which demands a lot of time effort, and that is why the systems needs to allow simulation data introduction for the preliminary patterns building. Such patterns might be corrected later by introduction of the real object data. Thanks to database flexibility it is possible to implement totally new patterns that were not taken into account in the development stage.

2. Examples of task solved with use of the described systems

Good example of application of the described properties of databases is implemented monitoring system of jet engines rotor blades grinder (grant nr.: 6T0220005C09545) in WSK Rzeszow. At the current stage the systems are used mostly for the measurement data gathering and distribution from the tested object (filling the database with the real data). The system has been designed to store large number of data (sampling frequency 500kHz) and all additional data related to the measurement and users analysis results. Data from the measurement device (PUD) are sent to database by means of the networking protocol.

The distribution system was split in two stages (Fig. 1): primary distribution where selected groups of users have direct access to the gathered information and secondary distribution where the selected information is presented. Such solution allows unloading the main server which acquires data from networking measurement devices, which allows easy access level control for selected information. To perform this task two servers are used based on SUSE Linux Enterprise 10 (Database Server) and SUSE Linux Enterprise 9 (Data acquisition server) and the database MySQL 5.0.

given at the user application level and may be any value stored in the database or a range of values.

Access to the gathered information is possible through the user applications which visualize measurement data and add extra description of the information (Fig. 3). They also allow automatically processing of the gathered information with use of external programs (MATLAB). It is also possible to access the data by prepared web-page (Fig. 4). Thanks to that data view is possible from any computer connected to the network without the need of installation of additional application, without forcing the use of one particular operating system, which simplifies and widens possibilities of database access.

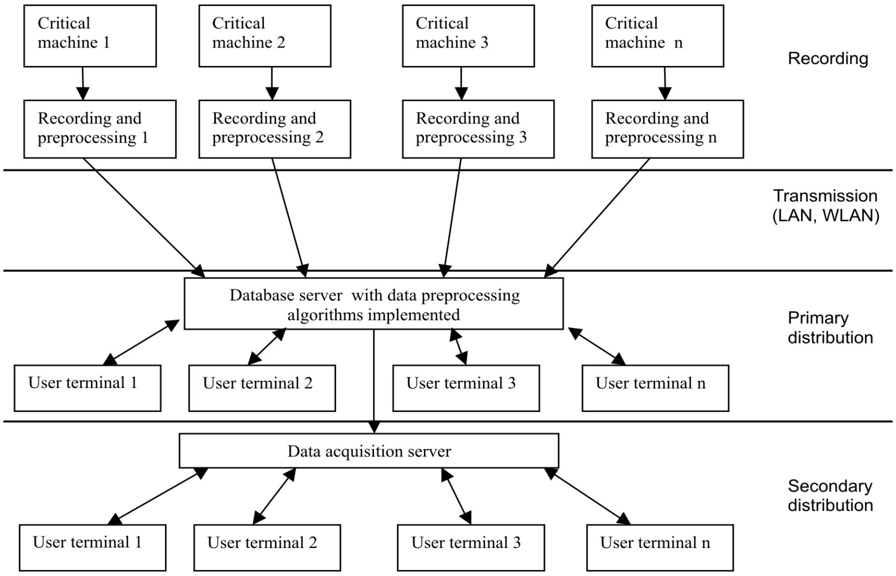

Fig. 1. Monitoring system schematic for jet engine rotor blade grinder (project nr: 6T0220005C09545) WSK Rzeszow

Data from the measurement device are moved directly to the first server. At this stage the data are preliminarily analyzed and made available for selected group of users.

What will be sent to server 2 decides a set of users application which are part of „decision module 1", which control filter transmitting chosen data sets to server (Fig. 2). Structural database stores measurement data (time series recorded on the machine) and all additional information about the recorded signal like date and time of the record, sampling frequency, gain.

The database allows storing additional information for more precise identification of the gathered information that is exact description of the measurement point (machine, sensor location), measurement device information. It is also possible to store results from 8 measurement channels and 3 marker channels and there is no limitation for the number of measurements and calculations for given channel. Each channel recorded during the measurement and stored in the base might be precisely described by forced rules that derive from the structure of the database and they may be information defined on the fly by the user. Such solution allows making groups of the gathered data considering particular criterias: measurement date, type of the analysis made and the groups defined by the user.

The system allows quick access to the gathered information by searching for an interesting information with particular criteria

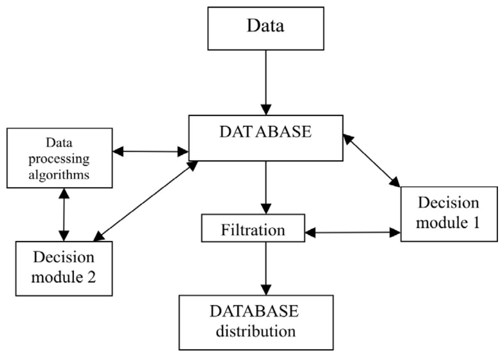

Fig. 2. Data flow model

Another example of database systems application is a assessment system for the steel shaft construction state in the mine „RUDNA" KGHM Polska Miedz.

The designed system stores measurement data, calculation and all data describing tested part, which in this case is a single pilot. Database system allows detailed description of particular element of the whole shaft construction:

- location,
- type of lashing,
- date of lashing,
- another measurement data (eg. thickness).

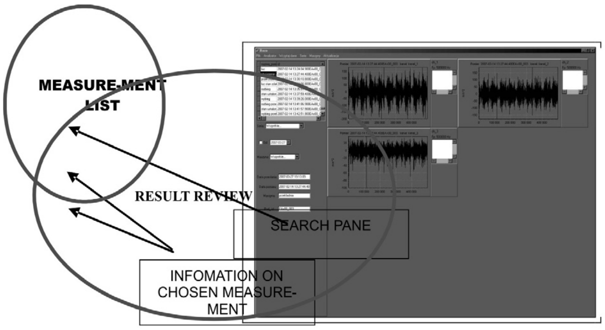

Fig. 3. Main window of the application

Thanks to the database application it is very easy to find information about the particular pilot and conduct its analysis. That is very important because of the large number of data and large number of tested elements (a lot of pilot in one shaft, two sections in one shaft).

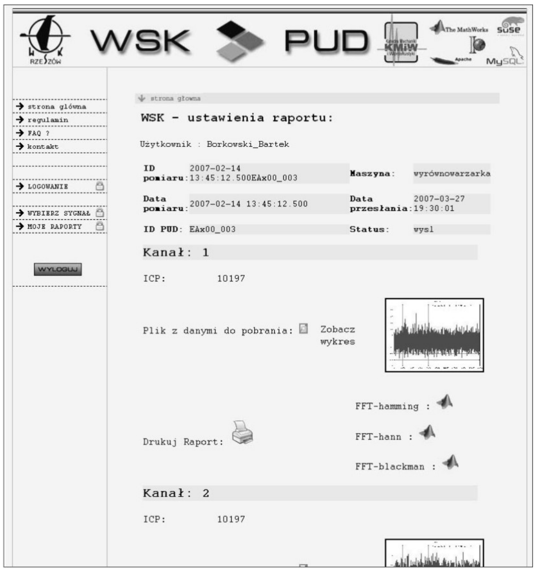

Fig. 4. Web-page report settings – (general information on channels)

Schematic of data transfer is presented below (Fig. 5.). Data from measurement device is sent by internet to the central database and then by intranet is sent to the end-users.

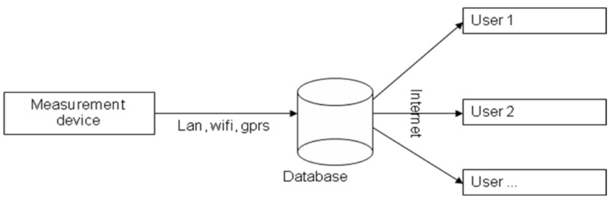

Fig. 5. Data transfer system schematic

The schematic of the database is presented on Fig. 6. Automatic calculations are made on the stored information and the outcomes are also stored in the database. On the results the rules are constructed to make decision about the pilot state. For gathering enough information for rules construction takes time, the system is filled with the simulation data from the laboratory testing.

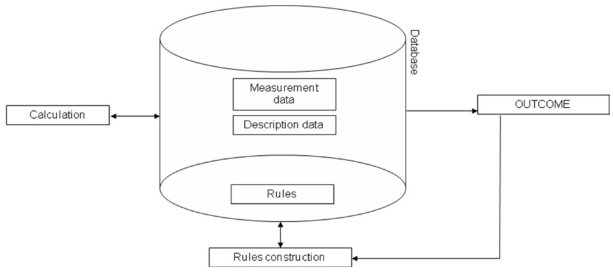

Fig. 6. Schematic of the database

In the figure above a user application is presented which manages gathered information (transfer, acquisition). It allows particular pilot searching, attaching descriptions, comparison of the calculation results and automatic calculations with the external Matlab software.

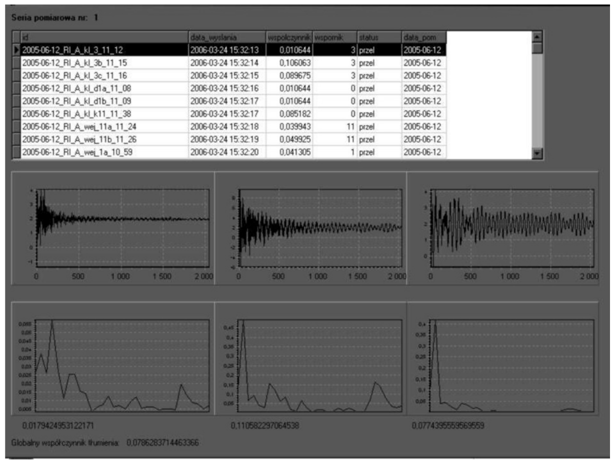

Fig. 7. User application

3. Summary

The article presents proposition of solution for the problem of diagnostic data gathering and processing in monitoring systems based on implemented database system. The main target of this solution is to support the diagnostic recognition process.

The paper contains sample database structure linking description data of the object with the measurement data gathered during the time and the analysis made. The structure allows event history creation which happened during the exploitation time, then, based on it, parametrization of particular symptoms which happened during the exploitation time.

Based on gathered information and during the time it is possible to build diagnostic patterns based on rules system, and such patterns allow current machine state assessment and foreseeing future behavior of the object.

Also by means of the described techniques of data mining the system allows new diagnostic method development which allow effectively search and foresee a particular event.

The whole database system must contain following modules:

- Data gathering, storage and distribution module,
- Pattern building module,
- Pattern search and comparison module.

The main values of the proposed system are better information management, simplifications of decision making process and ability to be used as an expert system for automatic decision making considering the state of the tested object.

That also brings better security and lowering exploitation costs because it is possible to foresee coming failure and precise planning of stoppage and maintenance.

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This work has been executed as part of research project at KBN nr 6T0720005C/06545

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IDENTYFIKACJA REGUŁ DIAGNOSTYCZNYCH Z ZASTOSOWANIEM ALGORYTMU EWOLUCYJNEGO

IDENTIFICATION OF DIAGNOSTIC RULES WITH THE APPLICATION OF AN EVOLUTIONARY ALGORITHM

Referat dotyczy sposobu identyfikacji reguł asocjacyjnych i diagnostycznych, które opisują relacje między cechami obserwowanych procesów. Reguły są identyfikowane za pomocą metody opartej na zastosowaniu algorytmu ewolucyjnego. Opracowano specjalne sposoby kodowania, operacje genetyczne i ocenę osobników. Podejście opisane w referacie jest częścią metody wnioskowania diagnostycznego z uwzględnieniem kontekstu. Identyfikowane reguły asocjacyjne są przekształcane do postaci reguł diagnostycznych z uwzględnieniem kontekstu.

Słowa kluczowe*: wnioskowanie diagnostyczne, identyfikacja reguł, kontekst*

The paper deals with a way of identification of associative and diagnostic rules, which determine relationships between features of observed processes. Rules are identified by means of a method based on the application of an evolutionary algorithm. Special ways of coding, genetic operations and individual assessments were elaborated. The approach described in the paper is a part of a method of diagnostic inference with the use of contexts. Identified associative rules are transformed into diagnostic rules within given contexts.

Keywords*: diagnostic inference, rule identification, context*

1. Introduction

A goal of diagnostic research of technical objects is to identify cause-effect relationships between features of parameters recorded during operation of objects and characteristics of their technical states. Examples of recorded parameters are useful (working) and residual processes, as well as parameters determining object control and supply. An inference process begins with interpretation of results of analysis of these parameters. It requires that both results of the analysis as well as diagnostic knowledge are to be expressed properly. The most common ways is to represent them in the form of rules.

One distinguishes two types of rules. Their definitions were assumed according to an approach presented in the paper. Providing a resulting part of a rule is possible to be determined the rule is called a diagnostic one. One should emphasize that identification of credible diagnostic rules is often impossible. However, in most cases the goal of diagnostic research is to identify relationships between changes of properties or parameters of the object and observed processes, not to determine a particular technical state. Such relationships are called associative rules. They are considered to be a background of determination of new diagnostic rules. The identification of such rules is especially important in cases of large sets of results of the analysis of processes recorded during observation of technical objects.

In such cases the inference process is usually difficult. Even the set of diagnostic (or associative) rules is provided the most crucial stage of this process is to select proper rules. There are numerous approaches to diagnostic inference that takes into account specific rule selection. One of such methods is to choose diagnostic rules in some contexts that represent different conditions of operation.They are also able to focus inference process on some malfunctions or parts of the object. Such method were presented in details in [5, 6, 8]. The inference is realized in two stages, presented in Fig.1.

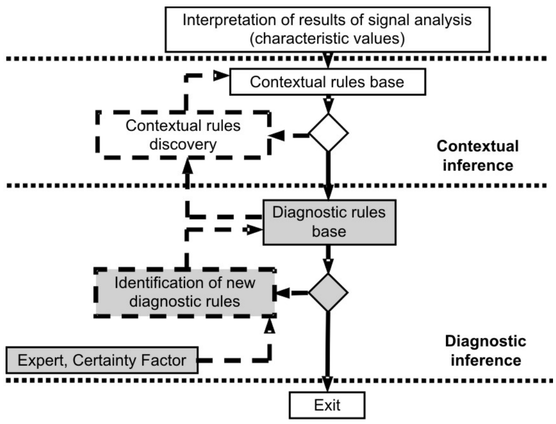

Fig. 1. A scheme of elaborated approach of context based inference

The goal of the first stage is to select an present context. It is performed on the basis of analysis of observations. Within the second stage proper diagnostic rules are being selected. Some characteristic, representing similarity between selected rules and the observation are being calculated. On the basis of these characteristics, results including diagnoses in forms of technical states that are likely to be determined are being provided. In order to make such actions possible a set of diagnostic rules have to be provided.

2. Research problem

A research problem, described in the paper was to elaborate a method that enables us to identify diagnostic rules. The paper deals with a way of identification of associative and diagnostic rules, which determine relationships between features of observed processes. The approach described in the paper is simplified due to some assumptions related to the interpretation of features of observed processes and limitation of sets of data. Presented approach concerns the second stage of the inference process (Fig.1 fields marked with grey).

According to assumptions of the method, to identify a diagnostic rule, a given set of initial diagnostic rules has to be defined. It is necessary in order to establish a conclusion of the rule. In case these rules are unknown only associative rules are possible to be determined.

It is obvious that one of the most important factors of the inference presented in Fig. 1 is to define contexts. Determination and identification of contexts is performed by means of similar methods to these presented in the paper. Details of these operations were presented in [8].

3. Elaborated approach

The identification of rules was performed by means of the application of an evolutionary algorithm. Individuals represent observations and rules to be identified. Having a population whose estimators fulfil our demands, individuals are additionally estimated. Results of these estimations are conclusions that derive from diagnostic rules that were previously defined or approved.

Consecutive populations are being generated on the basis of recorded observations of the object and are evaluated according to the fitness function, determined as a set of conditions. The approach presented in the paper required suitable manners of coding of results of the analysis of observed processes. The most essential aspect of the approach is an appropriate manner of the application of genetic operations, and first of all a suitable definition of a fitness function. Special algorithms, based on commonly applied genetic methods were elaborated [2, 3, 4]. It allows us not only to identify diagnostic and associative rules but also to cluster them automatically according to common criteria. Clustering criteria are related to determined properties of the object or conditions of its operation. The criteria exemplify inference contexts. It lets us to guide the selection of proper diagnostic rules, thus to focus the inference process on selected groups of symptoms of object properties.

It was assumed that results of signal analysis are coded in the form of series of symbols belonging to given sets. Two types of symbols were used, binary and real numbers. In each case results of signal analysis are taken into account within some intervals whose length is constant. Binary coding is simple and makes it only possible to characterize a general trend within the interval [7]. It is not explained in details in the paper. In Fig 2 there are results of signal analysis. These signals were captured simultaneously. They are vibrations measured in two perpendicular directions. This analysis consisted in estimation of mean values, application of time frequency methods and trajectory estimation.

Depending on signal features that are estimated within consecutive intervals determined numbers of symbols are used to code them in the form of one vector, which is called an observation. It is visible in the bottom part of Fig. 2.

To begin identification of associative rules a base of examples must be determined. It gathers observations. Examples do not represent single observations but observations that fulfil some requirements. At this stage of the research it was assumed that one observation belongs only to one example.

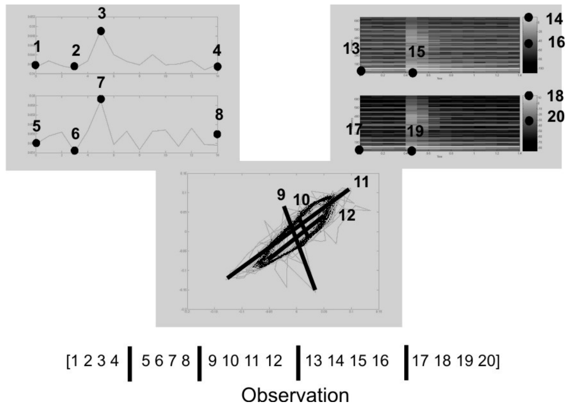

Fig. 2. A way of coding of results of signal analysis

In case of binary coding examples and observations have the same codes [7]. Exemplary if an example gathers ten observations they are all characterized by the same individuals.

In case of coding by means of real numbers examples are defined as some ranges (determined individually for each signal feature). An observation belongs to an example if all values in its code fit to each range. Such an approach has disadvantages which were revealed during the research was performed. However, this approach is correct enough to obtain satisfactory results.

An observation that does not fit to any example becomes an example with single observation.

Each example is additionally characterized by a counter that determines numbers of observations that belong to this example.

Identification of associative rules is performed by means of an evolutionary algorithm. In case of binary coding it was a simple genetic algorithm [7]. Starting population is being selected randomly. It is very important that in case of coding by means of real numbers starting codes (according to signal features) met some requirements. Mean value changes differently comparing to the spectrum or trajectory.

Consecutive populations have different numbers of individuals. They are generated by means of genetic operations (crossover and mutation). These operations have to be determined for each piece of the code (each signal feature) separately. Correctness of this part of the application of evolutionary algorithm strongly influences its convergence and results.

Populations are estimated on the basis of a fitness function that is represented in form of a few conditions. Estimation is performed on the basis of examples and their counters as well as on the basis of contexts that at this stage of the inference process are known. Identification of associative (or diagnostic) rules is performed at the beginning of the inference process and whenever a new observation which does not have its representation in form of associative (or diagnostic rules) is considered.

Such approach has very important property. Each application of evolutionary algorithm during the inference process makes it possible to order a set of rules. Properly defined fitness function enables us to remove rules that are useless and add rules that are of great importance. Such operation is possible because rules are also estimated in contexts.

A population that meets determined criteria (fitness function) is considered to be a set of associative rules. If a set of diagnostic rules is known (it must be determined by an expert of acquired from any other sources) it is also possible to find approximate conclusions for identified rules.

It was assumed that one rule (diagnostic or associative) can be considered within a few contexts. According to these assumptions transformation of an associative rule into diagnostic one (conclusion is determined) must be performed within contexts. The same sets of premises may end with different conclusion in various contexts.

In Fig. 3 and 4 transformation of the associative rules into diagnostic one is shown. To make this stage of rule identification clear, figures present rules coded by means of binary symbols. The rule is estimated within a context. Similarity measures characterize similarity of associative rules to premises of diagnostic rules that belong to the context (Fig. 4). Then consecutive signal features (coded in this case by means of one number) are multiplied by weights, which may be different (for the same features) in different contexts (Fig. 4).

A conclusion (or conclusions) is determined on the basis of measure called certainty factor. It determines the conclusion which fits the best to the set of premises (associative rule).

Context [1 # 1 1 # 0])

Associative rule

1	0	1	1	1	0

Diagnostic rules						
Premises						Conclusions
1	1	1	1	0	0	C1
1	1	1	1	1	0	C2
1	0	1	1	1	0	C3
1	0	1	1	0	0	C4

Similarity measures SM

1	0	1	1	0	1	**4**
1	0	1	1	1	1	**5**
1	1	1	1	1	1	**6**
1	1	1	1	0	1	**5**

Fig. 3. Estimation of similarity measure

Premises						Conclusions
1	1	1	1	0	0	C1
1	1	1	1	1	0	C2
1	0	1	1	1	0	C3
1	0	1	1	0	0	C4

Weights (in context [1 # 1 1 # 1])

0,2	0,1	0,5	0,2	0,8	0,2

Certainty factor

x0,2	x0,1	x0,5	x0,2	x0,8	x0,2	CF
1	0	1	1	0	1	**1,1**
1	0	1	1	1	1	**1,9**
1	1	1	1	1	1	**2,0**
1	1	1	1	0	1	**1,2**

Fig. 4. Identification of an approximate conclusion (in a selected context)

4. Experiment

The method of diagnostic inference with the use of context, and identification of diagnostic rules were applied to data recorded during operation of a laboratory stand RotorKit. The stand was observed during operation in 21 states. They are combinations of different elementary states. The object operated either in steady or unsteady conditions.

During observation of the laboratory stand three signals were recorded. They are rotating speed and vibrations measured in two perpendicular directions. Exemplary results of observation of the object were shown in Fig. 5 and 6. The first three plots represent observation of the stand during operation under constant rotating speed. In plot (b) there are signals recorded while periodical clattering was observed. In plot (c) there are signals that include results of observation of another object in the neighbourhood of the observed one.

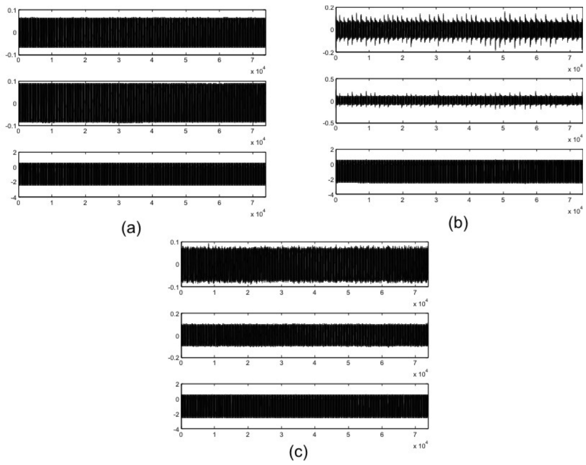

Fig. 5. Examples of recorded signals (constant rotating speed)

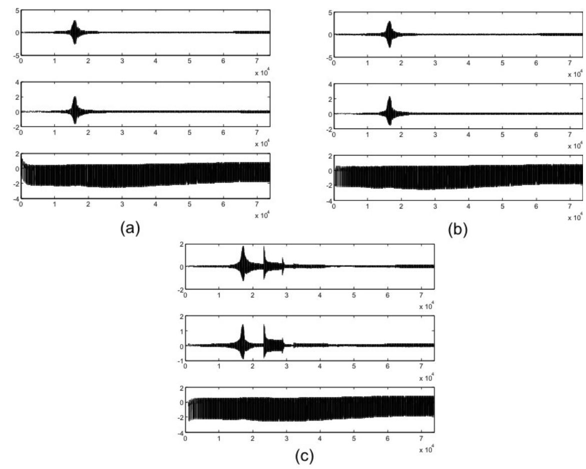

Fig. 6. Examples of recorded signals (varying rotating speed)

Plots shown in Fig. 6 represent observation of the stand during operation under run up conditions. In plot (b) there are signals recorded when another object operated in the neighbourhood of the observed one. In plot (c) there are signals recorded while random clattering was observed.

Fig. 7 and 8 present mean values estimated for above presented signals. In Fig. 9 and 10 there are shown trajectories estimated on the basis of vibration signals. Results of time-frequency analysis (Short Time Fourier Transform) are shown in Fig. 11 and 12.

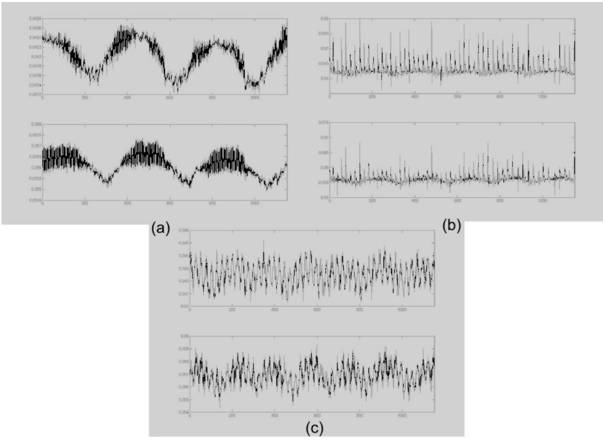

Fig. 7. Mean values of signals from Fig. 5

Results of signal analysis (Fig. 7 – 12) were coded (within constant length intervals) by means of real numbers. 9 diagnostic rules were defined a priori (Tab 1). They were based on well known diagnostic rules defined for rotating machinery [1]. All of them can be considered within more then one context. Contexts were defined according to different conditions of operation. Characteristic of building of a base of examples is presented in the previous paragraph.

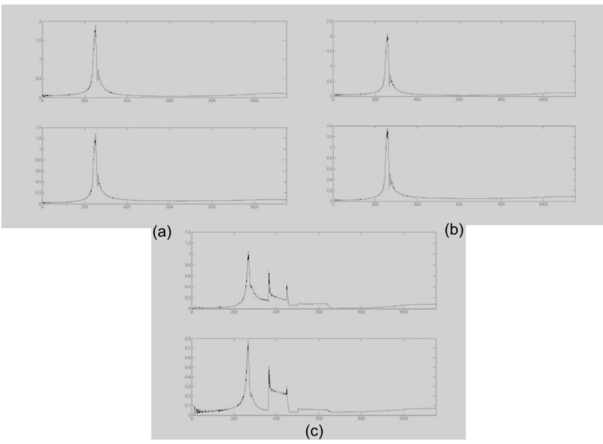

Fig. 8. Mean values of signals from Fig. 6

Tab.1. Diagnostic rules defined a priori

R1	***Constant rotating speed***
R2	***Run up***
R3	***Run down***
R4	***Random values of rotating speed***
R5	***Periodical clatter***
R6	***Other object operates in the neighbourhood***
R7	***Friction***
R8	***Overload***
R9	***Random clatter***

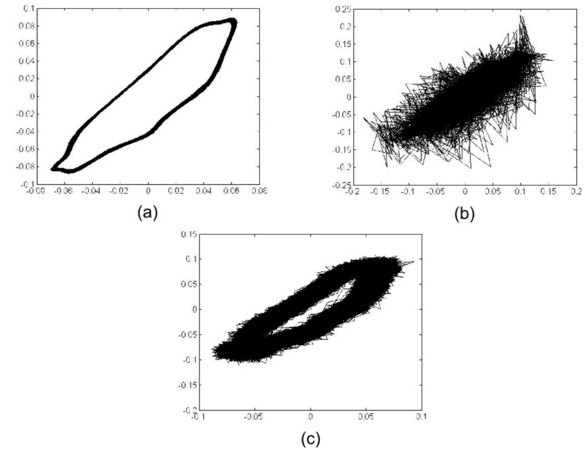

Fig. 9. Trajectories of signals from Fig. 5

Individuals representing observations, examples, rules and contexts have 29 genes. Mean values are coded by means of 4 genes that represent first, last, maximum and minimum values estimated within a given interval. Trajectories are coded by means of four numbers. They express the longest and shortest axes of the trajectory in two perpendicular directions. Trajectories were not averaged. Spectrograms are represented by means of 8 genes. Three most significant components were considered (frequency and magnitude, 6 genes were used). Spectrograms were processed in order to obtain simplified plots. Components are approximate with horizontal lines. One impulse component is taken also into consideration. It was assumed that it is visible as a single vertical line. This component is coded by means of 2 genes (time moment and magnitude). The last gene represents rotatin speed.

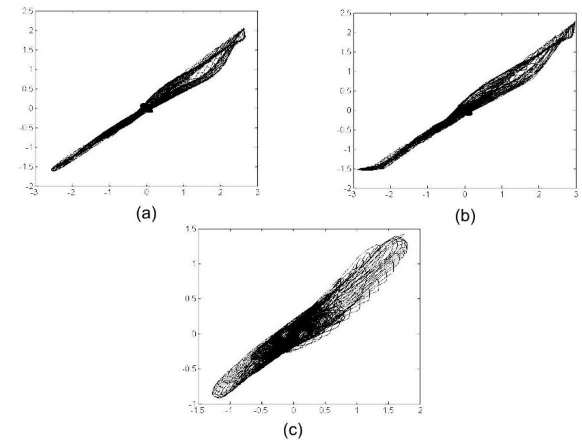

Fig. 10. Trajectories of signals from Fig. 6

Proper way of division of signals into intervals makes the identification of components easier. If any value does not appear in a code it is replaced with a unique value.

Experiment consisted in the application of elaborated procedures for all recorded signals (contexts) separately. Correctness of selection and identification of rules was tested. In such cases, efficiency of rule identification for most contexts was high. However, obtained results let us to state that correct rule identification in most complex conditions (contexts) requires that some features (especially spectral components) have to be more unambiguously coded.

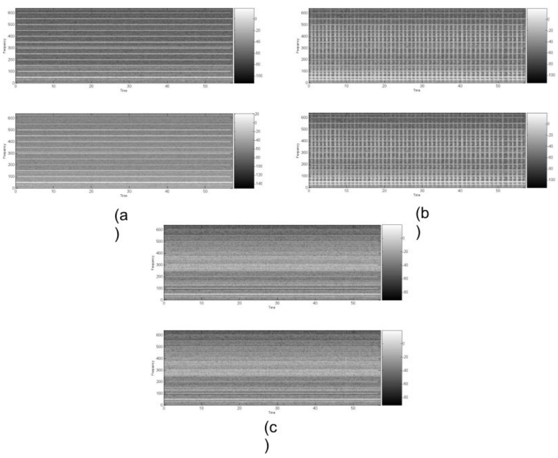

Fig. 11. Spectrograms of signals from Fig. 5

The second part of the experiment consisted in realisation of the following tasks:

- from each signal, representing one of 21 context, a characteristic interval (or intervals) was chosen,
- intervals were joined according to some common conditions (e.g. signals recorded under constant rotating speed),
- new signal were input data for inference process and diagnostic rule identification.

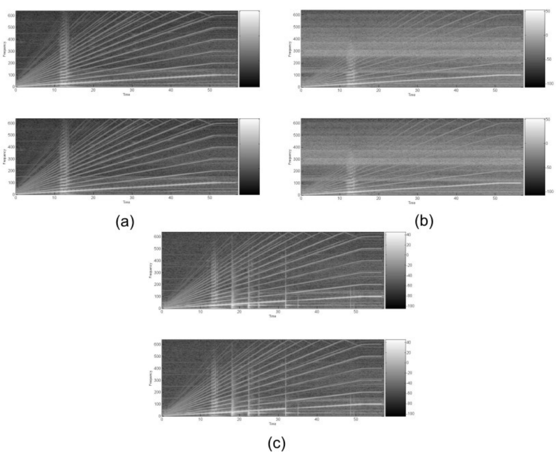

Fig. 12. Spectrograms of signals from Fig. 6

Results of experiments with 9 diagnostic rules defined a priori and 21 contexts let us to draw the following conclusions:

- when only signals recorded in one context were recorded and analysed, context and diagnostic rules were correctly selected and identified,
- efficiency of rule identification was lower when the stand was observed in two contexts (e.g. run up and friction); initial and final intervals of run up and run down were mixed up with steady conditions,
- the rule related to the situation when another machinery operated in the neighbourhood (additional component in spectrogram and characteristic shape of the trajectory) was mixed up with rules related to friction and overload,
- periodical and random clattering were mutually mixed up,
- division of signal into intervals has significant influence on results; if length of these intervals is to long results were always burden with relatively high errors.

General correctness of the proposed approach was proven. Exemplary (for 50 iterations, acceptable error 0.2), for signals shown in Fig. 5 all contexts and assumed diagnostic rules were correctly identified. It is important that analysis of conditions plots (b) and (c) was correct. In these cases two rules were identified in some periods. Results shown in Fig. 6 were also correct. In this case signals presented in plots (a) and (b) were recognized as, signals recorded under the same conditions. Signals shown in plot (c) do not include clattering. Here, one rule was identified for initial and final intervals. This result is not true, and the fault was probably effect of coding.

The second part of experiment in which signals consisted of different signals recorded in different conditions was analyses gave very interesting results. In this case rules related to constant rotating speed and run up or run down are identified unambiguously. When more then one diagnostic rules were analysed within one context, the best results were obtained for random clattering. In other contexts results were not so good.

It must be stressed that in the case of the research presented in the paper contexts are defined a priori. It seems that they strongly influence high correctness of obtained results. Test with contexts identified also by means of evolutionary algorithms gave worse results.

An additional aspect of the research is the fact that owing coding procedures and value diversity data used in the experiments are very difficult. AS the result of that genetic operations had crucial influence on identified rules. Moreover, individuals representing features are relatively long, what makes the application of evolutionary algorithm difficult. In spite of all these shortcomings obtained results shown that the approach may give correct results.

More general conclusion and direction of further research whose goal is to increase effectiveness of the elaborated approach are presented in the next paragraph.

5. Conclusion

Described experiments were performed with different parameters of evolutionary algorithms. Results of these experiments let us to draw conclusions that deal with broad range of signals (not only signal recorded during operation of rotating machinery). Two main tested factors were a number of iterations of the algorithm and different values of acceptable errors. Results obtained at this stage of the research show that correctness of obtained results depends on:

- division of signals into intervals in which signal features are estimated,
- a value of an error of fitting of observation to examples, rules to contexts and associative rules to diagnostic rules; at this stage of the research it was done within defined ranges; In most cases only one common value of error was assumed (values for different signal features were not distinguished); this value must be defined individually for each feature; initial tests shown that better results can be obtained with

the use of a fuzzy measure that characterizes a degree of fitting,

- genetic operations, and especially mutation; it was stated that random way of mutation must be strictly matched with character of a feature; in the opposite case, even when very large number of iterations is performed, the algorithm provides us with faulty results,
- crossover must be also carried out with taking into account a character of changes of a given feature; if this operation is wrongly defined it may happen that a feature whose values are from the range (0,1) will be higher as the result of crossover; such individuals are removed because they do not fulfil fitness function but in case of large populations such operations make the algorithm slower.

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O POTRZEBIE MONITOROWANIA PROCESU SPRĘŻANIA KONSTRUKCJI MOSTOWYCH

ABOUT THE NEED OF THE MONITORING OF THE BRIDGE CONSTRUCTION PRESTRESSING PROCESS

W artykule przedstawiono koncepcję systemu monitorowania i rejestrowania przebiegu procesu sprężania z wykorzystaniem układu mikroprocesorowego. W agregatach hydraulicznych stosowanych w technologii sprężania i nasuwania konstrukcji mostowych ASIN (opracowane w KAP AGH) stosowane są nowoczesne sterowniki programowalne, dzięki czemu rozbudowa ich o system monitorowania i rejestrowania przebiegu siły i wydłużenia nie wymaga dużych nakładów. Opracowanie i wdrożenie systemu monitorowania i rejestrowania parametrów procesu sprężania pozwoli, oprócz poprawy jakości i bezpieczeństwa konstrukcji, na zbudowanie bazy wiedzy. Baza ta jest niezbędna dla opracowania metod diagnozowania procesu sprężania. Dla opracowana koncepcja systemu wykorzystano wieloletnie doświadczenie autorów artykułu zdobyte przez udział w sprężaniu kilkunastu obiektów mostowych.

***Słowa kluczowe**: konstrukcje sprężone, system sprężania, monitorowanie, diagnostyka*

The article presents the system conception of the monitoring and course logging prestressing process wit the use of the microprocessor system. In the hydraulic supplying units, which are elaborated by AGH, are used the modern programming controllers which can be used like the base of the elaborating monitoring system.
The elaboration and application of the monitoring and logging system enables the improvement of construction quality and safety as well as the building of the knowledge base. The base is needed to the elaboration of the diagnostic method of the prestressing process. To the elaboration of this conception was used the experiences of the author of this article. This experience was earned by the participation in the prestressing ten or more bridge construction.

***Keywords**: prestressing, post-tensioning system, monitoring, diagnostic*

1. Introduction

Quality of the carrying out of the structure post-tensioning process is one of the most important factor which decide about the operating characteristics as well as the safety of the structure. Nowadays the monitoring of the post-tensioning process as well as documentation of its course is leaded by check of the tendon elongation after the prestressing force reaches the level of 20, 40, 60, 80 and 100% of the design value. Assessment of process quality is leaded by comparison of real value of the tendon elongations and design value (it is correct if the differences are smaller than 10 %). Appeared during post-tensioning realization dynamic transitory states aren't analyzed if its effects don't cause the exceed permissible difference between real and design force value. On the other hand the analysis of the causes of exceed permissible value is very difficult because the prestressing team have only one information about the exceed of this value. The dynamic states like the step change of post-tensioning force are the standard phenomena which results from the friction between the tendon and the tendon channel. The value of the amplitude of this vibrations is depended from the friction coefficients and the channel shape. The vibration don't effect on quality of post-tensioning process. The decrease of post-tensioning force caused by the scarifying of the tendon or the tendon slip in the anchored block is the emergency state. The definition of the damage kind isn't usually possible, from there the next decisions are made on the basis of the hypothesis. The approval of the post-tensioning process carrying out is leaded on the basis of the post-tensioning journal which is described by the prestressing team which want to get the positive decision from supervision inspector. From there the prestressing team can want to hide the prestressing mistakes.

The conception of monitoring and registration system with use of microprocessor for prestressing process is presented in this article. The modern programmable controllers are used in the hydraulic units which are applied in ASIN technology for prestressing and slide over of bridge structures. Hence, its development for the elaboration of the monitoring and registration system of the force course and string elongation doesn't require a big costs.

In the most applied prestressing systems the control of prestressing force value is realized by hand by the setting of throttle valve on the basis of the manometer indications. Hence, the elaboration of the independent microprocessor system monitoring the parameter values of prestressing process without the interference to this process as well as the prestressing devices construction is needed for these systems.

The elaboration and application of the monitoring and registration system of prestressing process parameters enables, apart from the quality correction and the structure safety correction, the building of the knowledge base. The base is needed to the elaboration of the monitoring methods of prestressing process. Many years experience of authors was used to the elaboration of the system conception.

2. The influence of prestressing process monitoring on the quality of the structure carrying out

2.1. The verification of prestressing program

Suitable stress distribution in the structure (minimization of the tension stress) is the target of prestressing process. Modern design systems using the advanced analysis methods of the stress and displacement distribution (FEM, modal analysis) enable to the optimal choice of the tendon channel shape and the force distribution on the tendon length. The distribution of the prestressing forces is the function of the tendon canal channel as well as coefficients of friction between the tendon and the wall of channel. Defined by norms parameters of the constructions materials and simple models of the structure load are established in the design process of new object. The prestressing process is elaborated on the basis of this ideal assumption. The prestressing process contains: sequence of the cable tension, prestressing forces values, the way of input of prestressing forces (unilateral, bilateral) as well as established elongation of tendons. The real parameters are different from established parameters. The course of the cable channel is different than established because of the carrying out inaccuracy as well as the displacements at the place the concrete stage. The friction coefficients for applied prestressing system are usually established as material constants depend on the applied cable shields and the kind of strings. The state of the shields and strings (rust, dirtiness, cracks, protective coats etc) and atmospheric conditions (humidity, temperature) can effect on friction coefficients values. These differences cause a big divergences between the real distribution of prestressing forces and established distribution in the project. The variety and randomness of factors effecting on prestressing process make impossible its definition in the laboratory research. Hence, the conducting of the research on real object is only possibility.

Verification of prestressing program is carried for the definition of real friction coefficients. Verification is carried out by the experimental prestressing of chosen (characteristic for some object) cable with measurement of prestressing forces on the active and passive side. The prestressing is carried out without the active anchored (on the side of prestressing press) in order

Fig. 1. The force sensor during verification

to obtain the cable lightening, which enables the disassembly of the measurement sensor. The active forces are defined on the basis of characteristic of the tension press. A special, usually strain gauge, force sensors are applied for the forces measurement on the passive anchorage (Fig. 1). The load cycle of tendons during the verification is similar to prestressing process. The measurement of the cable elongations is realized after the active force value reaches value of 20, 40, 60, 80, 100% of design value of the prestressing force.

The determined real coefficients enable to the correction of the prestressing program.

The losses of prestressing forcen (ΔP_{tk}) caused by the cable friction in the shield are determined on the basis of the registered course of the prestressing force on the passive side:

$$\Delta P_{tk} = P_C - P_b \tag{1}$$

The exemplary force courses on active and passive sides are presented in Fig. 2a.

Percentage part of the prestressing force losses is calculate:

$$\eta_{tk} = \frac{P_C - P_b}{P_C} \cdot 100\% = \frac{\Delta P_{tk}}{P_C} \cdot 100\% \tag{2}$$

The exemplary diagrams of the percentage part of the force losses according to prestressing force for two tendons which have different course route is presented in Fig. 2.

a) b)

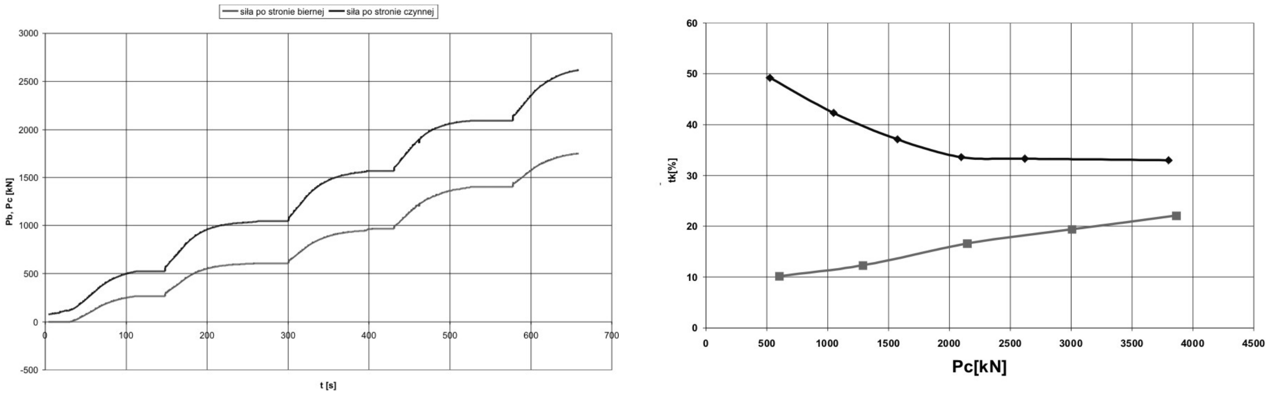

Fig. 2. a) Courses of prestressing force on active and passive sides, b) Force losses according to prestressing force value

A substitute friction coefficients can be determined after the input of measured force courses to the established model (3) of object

$$\Delta P_{tk} = (1 - e^{-(\alpha\mu + \lambda x)})\, P_o + Tx \qquad (3)$$

λ − friction coefficient per unit of cable length, μ − coefficient of friction between the cable and wall channel on the curving, T − the losses of the cable tension force per length unit, independently on the tension value (kN/m), e − Euler function, Po − initial prestressing force, $x = \Sigma a_i + \Sigma \varphi_i r_i$ — cable length from the impose a force point to the section, in which the prestressing force is determined, φ_i − middle angle of i-arch in radians, r_i − radius of i-arch, $\alpha - \Sigma\varphi_i$ [radian].

Presented above mathematical model has infinite number of the solution because it contains 2 unknown coefficients α i λ. The optimization methods are used to the determination of the coefficient values.

The designer can verify the prestressing process on the basis of the real value of the friction coefficients. Histograms of the distribution of the cable elongations for two bridge objects are presented in Fig. 3 and Fig. 4.

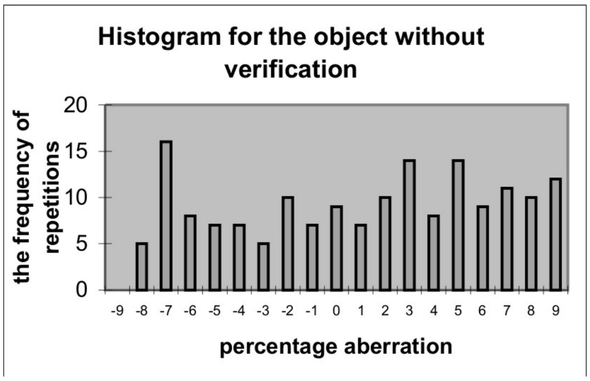

Fig. 3. Histogram of distribution of tendons elongations for object without verification of prestressing program

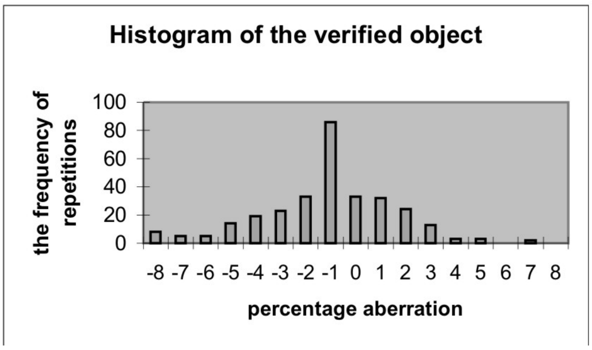

Fig. 4. Histogram of distribution of tendons elongations for object with verification of prestressing program

In the first case the real value of friction coefficients, which was determined in researches, wasn't applied in project. In the second case these coefficients was applied in the project and the prestressing program was verified (Wielicka-Kraków).

The lack of verification of the prestressing program caused the big dispersion of the real cable elongations according to the design value.

The most of results are bigger than the range of ±4%. It means that the part of tendons was overloaded or low-loaded. It can effect on prestressing and the operating parameters of the structure.

2.2. Monitoring of the damages of the prestressing system

The differences between the static friction and kinetic friction as well as the cable elasticity cause the step decrease of the prestressing force during the prestressing of the cable.

This decreases can amount to several percent of the force value. The course of the prestressing force value isn't registered in the most systems. The value of this force is determined on the basis of the indication of manometers which measure the pressure in the input conduit of prestressing press. The force decrease resulting from the string slip according to anchorage as well as the scarifying of the string is comparable with the decrease resulting from change of friction coefficient (relaxation vibrations) in the system consisting of ten or more cable. In this case, the cable and anchorage damages couldn't be notice by operator of the prestressing system. The damage of one or several strings in the cable couldn't be notice in the analysis of the whole cable elongation because the differences between real and design elongation amount to up 10%. The rest of strings are overloaded because it carry this differences. The registration of the prestressing force course and its analysis can solve this problem.

The elaboration of method detecting the system damages enables the analysis of prestressing force course.

2.3. Monitoring of the structure damages

The exemplary damages of the bridge structure caused by misuse prestressing of the object I presented in Fig. 5. The dynamic processes proceeded in the concrete structure during prestressing process as well as the operating of this structure are the sources of acoustic waves emission. The occurrence of acoustic emission don't be researched well. It can be take assumption that the processes of the formation and propagation of micro and macro gaps as well as reciprocal effect of the materials having different parameters (strength, elasticity modulus, hardness) are the sources of the acoustic waves emission.

The diversification of strength and acoustic characteristic of the materials creating the prestressing system (concrete – prestressing steel) have an effect on the diversification of the acoustic wave parameters as well as the modulation of the vibroacoustic signals (different models of the vibroacoustic wave propagation).

Fig. 5. The view of the object damages resulting from the mistakes in the prestressing process

The research of the possibility of the acoustic emission using to the detection of damage appearing in the prestressing process wasn't conducted. On the basis of the experiences of authors it can claim that acoustic wave generated in the prestressing structure are good information carriers.

Experienced operator of system can detect the acoustic effects and he can diagnose the problem. It is subjective assessment, which has had to be confirm by the application objective research methods (diagnostic instruments).

3. Conception of monitoring system of the prestressing process

3.1. Post-tensioned post-tensioning system

The applied in post-tensioned technology hydraulic devices are controlled by throttling with the application of the standard control elements. This devices consist of two hydraulic unit which are connected by flexible hydraulic conduits: tensioning and transporting unit as well as drive and control unit. The work of the tensioning and transporting unit supplied by drive and control unit is cyclic. The normal cycle contains following stages:

- tensioning: strings gripped by internal wedges is stressed up design force value with the measurement of the piston motion,
- bracing, tensioned strings are gripped by external wedges and next tensioning chambers are discharged,
- back, every work of press and hydraulic supplier come back to the initial state.

Both of this unit have the simple and compact building resulting the application of high pressure hydraulic elements. The low efficiency and the heating of work fluid causing the discontinues work are the defects of this units.

Modern ASIN hydraulic drive and control unit have the frequency inverter and microprocessor system (Fig. 6). The structure of this unit consists of standard hydraulic elements. This unit is general-purpose resulting from the connection of the characteristics of the standard hydraulic devices with the modern digital technology. Hence, the unit can be used to different applications and the requirements. Applied digital technology enables software realization (not only hardware) of the algorithms of unit work. These algorithms can be modified without changes of the elements creating system. The harmful dynamic states are decreased by the using of feedback from work pressure during the work cycle. The innovative connection of the inverter drive and microprocessor technique enables the elaboration of the simple and reliable hydraulic structure of the drive and control unit. The control of the supplied flow parameters have the every advantage of the hydraulic proportional control like:

- control of the hydraulic quantities,
- accurate courses of the motions control,
- decrease of the number of the hydraulic elements in unit,
- major durability of mechanical and hydraulic elements,

Additional advantage of this unit solution is the elimination of power losses appearing with the fluid flow changes by elimination of the throttling of the fluid flow. Due to it the work fluid isn't overheated and can be exploited longer.

The elaborated unit have the lower sensitive on the impurity of work fluid in comparison with unit using proportional technique of control. The requirements of the filtration of work fluid are the same like in other standard hydraulic units.

Applied nowadays prestressing systems work according to the described above rules despite of the systems differ in the structure of devices. The view of the prestressing devices during prestressing process is presented in Fig 7.

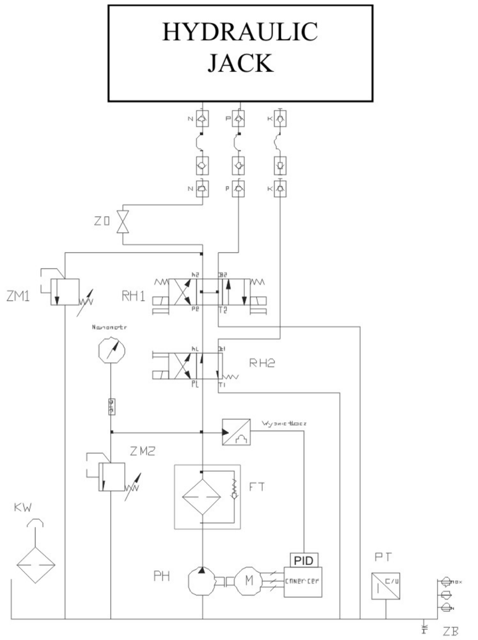

Fig. 6. The schema of drive and control unit for ASIN system

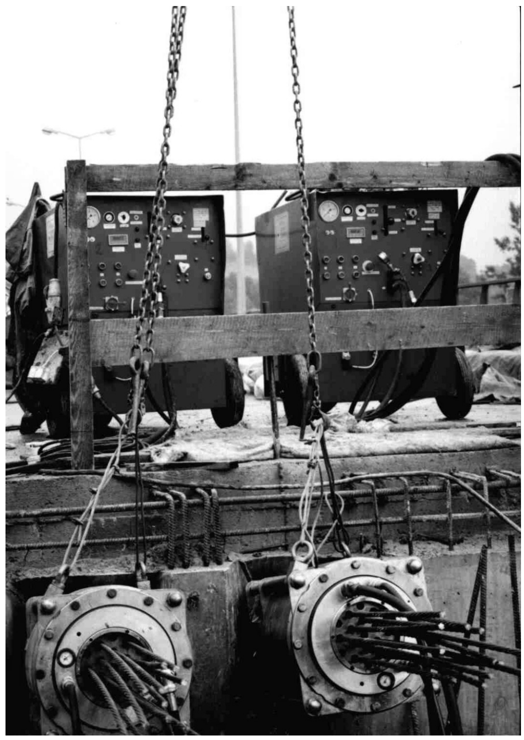

Fig. 7. The view of the prestressing devices during prestressing process (Chabówka viaduct)

3.2. Monitoring system

The following assumption was established to the elaboration of the conception of monitoring system:

1. The system should enable the registration:
   - Courses of the prestressing forces,
   - Courses of the cable aberrations,
   - vibration of the cable string and prestressing press,
   - acoustic waves generated in prestressed structure.
2. Monitoring system don't effect on prestressing process and the work of the prestressing devices.
3. Monitoring system should have the possibility of connection to the every prestressing system without the change of its structure.

Such elaborated monitoring system enables the full diagnostic of prestressing process and it can be used to all of used prestressing system.

The elaboration of independent system equipped with microprocessor, measurement systems as well as the memory for registration of the courses of measured qualities enables meet described above assumptions. The schema of the monitoring system is presented in Fig 8.

4. Conclusions

The elaboration and application of the described above conception is possible for the present technical state. The acquisition of data from the post-tensioning of concrete isn't enough to the quality assurance of this process. Hence, the elaboration of the analysis methods of the measurement results is needed in order to the detection of the damages of the hydraulic jacks, anchorages, tendons as well as stressed structure. The knowledge base about the diagnosis methods of post-tensioning process isn't enough. Hence, the works connected with the elaboration of this methods should be conduct. One of the difficulties which can make difficult the diagnosis is the big complexity of phenomena appearing in the object during the post-tensioning process. Hence, The laboratory research and its verification on real object is needed to the elaboration of this methods. The definition of the connection between the chosen parameters of the acoustic signal and kind of the damages with taking into consideration the anisotropic, nonlinear and no continues characteristics of concrete enables the assessment of quality of post-tensioning process. The possibility of detection of states like the tensile element crack or the slip in the wedge-tensile element system will effect on the increase of post-tensioning structure safety at the manufacturing stage.

The introduction of monitoring system enables the simplification of the supervision work because supervision workers will have the objective dates from the process course. The date from monitoring system will effect on work of stressing company, which workers don't have often knowledge about the responsibility their work.

The choice of the parameters and control of post-tensioning process is other but very important factor. The introduction of potential energy at the level of $5*10^8$J to the post-tensioned object is the very complex process taking into consideration of the friction phenomena, contraction of post-tensioned object as well as shape interactions of the tensile elements in the tendon. This process is no continues and the concrete get energy batch wise which causes vibroacoustic phenomena with big dynamic.

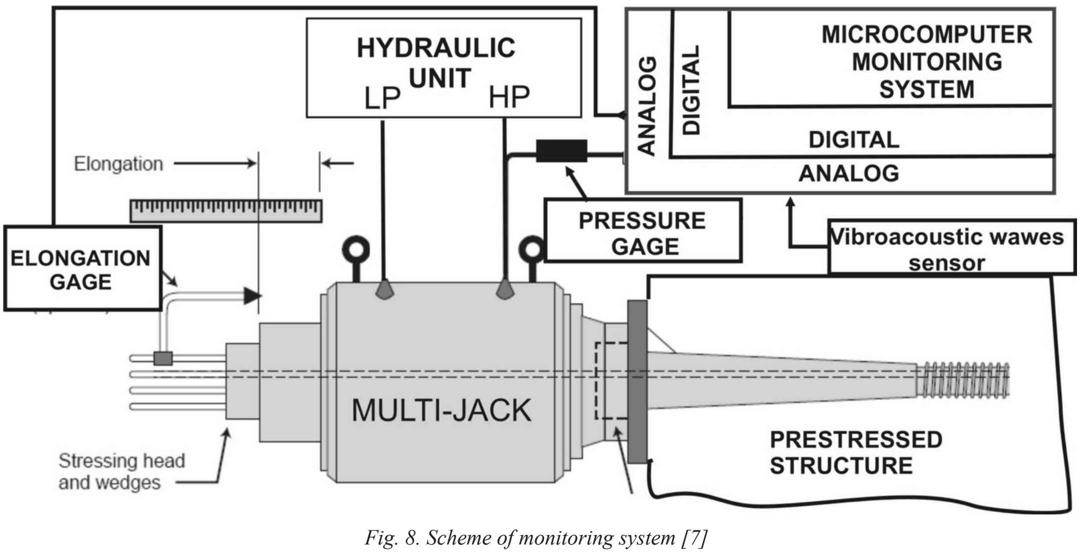

Fig. 8. Scheme of monitoring system [7]

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ODWZOROWANIE STANU TECHNICZNEGO MASZYNY W EWOLUCYJNYCH SYMPTOMACH DIAGNOSTYCZNYCH

REPRESENTATION OF MACHINE TECHNICAL CONDITION IN EVOLUTIONARY DIAGNOSTIC SYMPTOMS

Charakterystyki drganiowe stanowią ważne źródło informacji o stanie technicznym maszyny. W większości zastosowań dla złożonych maszyn diagnoza opiera się na widmach drgań, jednak wpływ na nie ma, oprócz parametrów stanu, wiele innych czynników. Prowadzi to niekiedy do nieuzasadnionych alarmów. Alternatywnym sposobem uzyskania informacji o stanie technicznym maszyny jest analiza trendów drgań. Można to zrealizować przez zastosowanie tzw. symptomów ewolucyjnych, opisujących ilościowo zależność poziomów drgań od czasu. Z modeli teoretycznych można wywnioskować, że zarówno szybkość narastania, jak i odstępstwo od liniowości mogą być przyjęte jako symptomy diagnostyczne. Ocena eksperymentalnych trendów drgań, uzyskanych dla turbin parowych, potwierdza ten wniosek i wykazuje, że tego rodzaju symptomy pod wieloma względami przewyższają typowe symptomy drganiowe, wykorzystywane w procedurach diagnostycznych.

Słowa kluczowe: *drgania, diagnostyka techniczna, stan techniczny, symptomy diagnostyczne*

Vibration patterns provide an important source of information on machine technical condition. In most applications for complex machines, diagnosis is based on vibration spectra, but they are influence by many factors other than condition parameters. Consequently false alerts can be triggered. Analysis of vibration trends is an alternative way to extract information on machine technical condition. This can be achieved by employing so-called evolutionary symptoms, which describe quantitatively the time dependence of vibration levels. From theoretical models we may conclude that both increase rate and departure from linearity can be accepted as diagnostic symptoms. Evaluation of experimental vibration time histories, obtained for steam turbines, has confirmed this conclusion and shown that such symptoms are in many aspects superior to typical vibration-based symptoms employed in diagnostic procedures.

Keywords: *vibration, technical diagnostics, technical condition, diagnostic symptoms*

1. Introduction

Vibration patterns are perhaps the most important source of information on technical condition, especially for complex rotating machines [1]. From the points of view of data acquisition and processing, vibration-based methods are well-developed and employed in both on-line and off-line modes for a wide variety of machines, in particular critical ones, where reliable technical condition assessment is of prime importance.

In most cases it is essential not only to find and identify malfunctions – if any – but also determine their extent or, more generally, evaluate lifetime consumption. This means that quantitative diagnosis is necessary. Quantitative description has to be based on some reference scale, which can be provided by critical symptom values (basic, limit and admissible); such approach is employed in many diagnostic systems. Of the above, limit value is the most important one, as its excess in general indicates condition deterioration to a level that calls for some remedial action [10]. Symptom limit values can be estimated e.g. from statistical analysis, on the basis of the energy processor model and symptom reliability concept (theory and model descriptions can be found in [10], while application example for steam turbines is reported in [4]).

Quantitative assessment of diagnostic symptoms can sometimes, however, become vague. As it shall be shown in the next chapter, for most practical applications symptoms depend not only on machine technical condition parameters, but also on a number of other factors. Sometimes influence of these factors becomes dominant and limit value can be exceeded without any significant change of the technical condition. False alarms can thus be triggered, which is unacceptable for large critical machines. In order to provide reliable diagnosis, alternative symptoms have to be employed.

According to [12], for the particular case of steam turbines, as many as 21 symptom types can be distinguished, of which ten are related to vibration or noise. This can be generalized for a broader class of large rotating machines. One of these types is referred to as 'vibration evolution' which can be more precisely given as 'parameters describing time dependence of vibration patterns'. As we shall see later, such symptoms have certain advantages that can be very important in some applications. We shall call them 'evolutionary symptoms', bearing in mind that they are in a way secondary to those provided directly by vibration patterns, in particular to vibration amplitudes in specific frequency bands.

2. General remarks on the evolution of diagnostic symptoms

2.1. Basic considerations

In order to deal with the evolution of diagnostic symptoms, we have to define the machine life cycle. Essentially it can be understood as a period between two events that change the machine structure, so that we can assume that during this cycle this structure remains unchanged. For a simple object, life cycle is equivalent to the entire life. For complex objects, individual cycles are determined by overhauls or repairs.

Relation between symptoms and condition parameters in its simplest form is given by:

$$\mathbf{S}(\theta) = F[\mathbf{X}(\theta)] \tag{1}$$

where **S** and **X** denote vectors of measurable symptoms and condition parameters, respectively, and θ denotes time. F is an operator, assumed to remain unchanged during the entire object life (also on transition from one life cycle to another). Relation (1) holds only for very simple objects. More general description is provided by [11]:

$$\mathbf{S}(\theta) = F[\mathbf{X}(\theta), \mathbf{R}(\theta), \mathbf{Z}(\theta)] \tag{2}$$

where **R** and **Z** denote vectors of control and interference, respectively. For a given object, relation (2) is usually difficult to identify and simplifying assumptions are necessary.

On the other hand, from the energy processor (EP) model, we have [2]:

$$\left(\frac{V}{V_0}\right) = \left(1 - \frac{\theta}{\theta_b}\right)^{-1} \tag{3}$$

where V denotes the power of residual processes, $V_0 = V(\theta = 0)$ and θ_b denotes time to breakdown, which is determined by unchangeable object properties. V is related to a symptom S via:

$$S(\theta) = \Phi[V(\theta)] \tag{4}$$

where Φ is the symptom operator. With $D \equiv \theta/\theta_b$ this can be rewritten as:

$$S(\theta) = \Phi[V_0(1 - D)^{-1}] \tag{5}$$

D is a quantity important for these considerations, as it can be interpreted as damage advancement or alternatively dimensionless lifetime consumption. It is easily seen that equations (1) and (5) are equivalent if $\mathbf{S} = \{S\}$ and $\mathbf{X} = \{D\}$, i.e. only one symptom is considered and only one object condition parameter is taken into account. Basically, Eq. (5) can be developed to include other factors that influence symptom value, but for actual objects this results in complex and unwieldy formulae that are hardly suitable for applications (see e.g. [4]).

Eqs. (1) to (5) refer to a single life cycle and theoretical $S(\theta)$ function is smooth and monotonically increasing. Transition to the next cycle usually involves a stepwise change of S and basically can be understood as a creation of a new object, characterized by new V_0 and θ_b values. This corresponds to a modification of Eq. (2), where $\mathbf{X}(\theta)$ is replaced by:

$$\mathbf{X}'(\theta) = H[\mathbf{X}(\theta), \mathbf{L}(\theta)] \tag{6}$$

$\mathbf{L}(\theta)$, referred to as the logistic vector, includes all parameters that characterize individual cycles and change only on transition from one cycle to another; H denotes an operator. If the logistic vector is taken into account and a sequence of life cycles is analyzed, $S(\theta)$ becomes discontinuous and takes a form of the type given in Fig.1. Note the 'double' symptom dependence on time, which is very inconvenient in applications, but necessary with such approach, as θ goes down to zero at the beginning of a cycle. Note also that cycle length is determined by θ_0 rather than θ_b, as overhauls are basically performed before the final breakdown, so $\theta_0 < \theta_b$.[1]

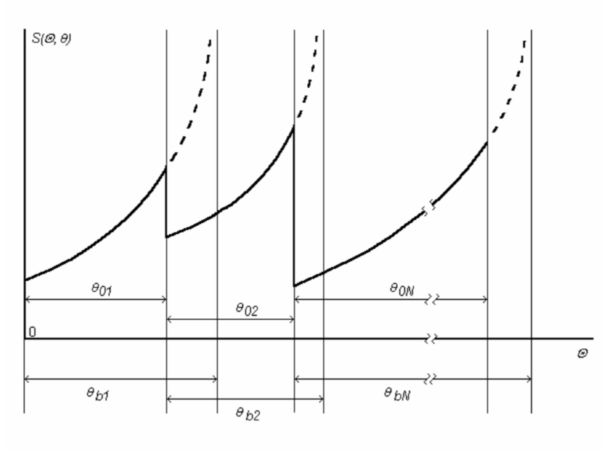


Fig.1. Sequence of life cycles

Discontinuity of the $S(\theta)$ functions and 'double' dependence on time can be eliminated by means of normalization. This will be described in Section 3.

2.2. Influence of control and interference

Basic EP model cannot, in principle, account for the influences of control and interference on the diagnostic symptom value. It can therefore be used for a given symptom S and a given condition parameter X only if we can assume that these influences can be neglected, which means that:

$$\bigwedge_i \frac{\partial S}{\partial R_i} << \frac{\partial S}{\partial X} \tag{7}$$

$$\bigwedge_i \frac{\partial S}{\partial R_i} << \frac{\partial S}{\partial X} \tag{8}$$

In many cases these assumptions do not hold. A good example is provided by the dependence of turbine vibration patterns on active power (load). Fig.2 shows two 23% CPB spectra, recorded at the same measuring point on a 16K260 turbine. It is easily seen that at 230 MW (which is a mere 11% below the rated load) the 50 Hz component, which corresponds to the rotational speed, is about 110 dB and blade components (above about 2 kHz) are moderate. Furthermore, there is a considerable 'hump' about 250 Hz (higher harmonic components). At 104 MW, i.e. 40% of the rated load, the 50 Hz component is higher by some 10 dB and the 'hump' is much less pronounced, but there is a dramatic increase in the blade frequency range, even by one order of magnitude. This is caused by uneven load imposed by steam flow. Close to the rated load, three of four control valves are almost completely opened and the fourth one is closed, while at 104 MW only two valves are opened by about 50% and two are closed. Load distribution changes and so do the vibration patterns. Account of these phenomena and some results of model calculations can be found in [7].

If, for a given symptom S, functions $S = f(R_i)$ can be determined for all control vector parameters that influence the value of S, symptom normalization is possible. More detailed description can be found in [3,6]. Such study was performed for active power influence on absolute vibration patterns of K200 steam turbines [6]. Detailed account is beyond the scope of this paper; general

[1] In fact this assumption results from mathematical reasons, as $S \to \infty$ when $\theta \to \theta_b$, cf. Eq. (3).

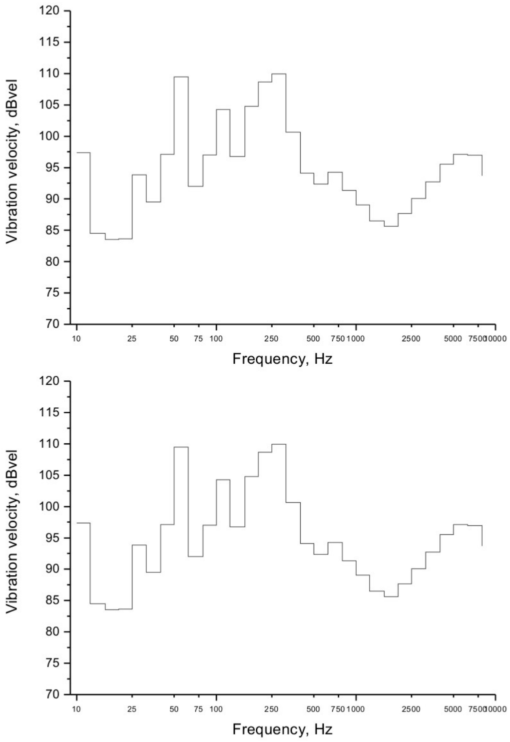


Fig. 2. Vertical absolute vibration spectra, recorded at the HP/IB bearing of a 16K260 turbine at 230 MW (upper) and 104 MW (lower)

conclusion is, however, that normalization procedures for such complex machines are inevitably approximate. Of course,

$$P_u(\theta) = P_u[\mathbf{R}(\theta)] \tag{9}$$

where P_u denotes active power, but various **R** vectors can give the same P_u values. This basically excludes precise normalization for real turbines.

Fig. 3 shows an example for the 50 Hz component of front HP bearing vertical vibration; symptom is given as the relative value S/S_{nom}, where S_{nom} refers to the rated load. It is easily seen that the $S(P_u)$ is by no means monotonic, which is the rule for steam turbines. Certainly, however, influence of the active power cannot be neglected.

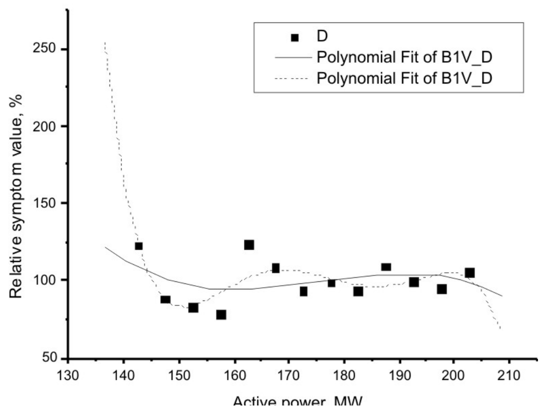


Fig. 3. Example of normalizing functions; 3th (solid) or 5th (dotted line) order polynomial fit; K200 turbine, front HP bearing, vertical vibration, 50 Hz component

As for interference vector **Z**, no normalization is possible. Proper measuring procedures can minimize the effect of interference, but not eliminate it. Therefore it is justified to conclude that normalization can alleviate the problem, but cannot solve it. In practice, cases of sudden stepwise symptom value increase are commonplace. Example is given in Fig. 4. Due probably to some interference (nature of which has not been clarified), vibration velocity amplitude in a frequency band in the blade range increased by one order of magnitude and exceeded the limit level, to return to its initial value almost immediately. No failure was found. Such occurrences are typical for this frequency range and are often caused by steam flow instability.

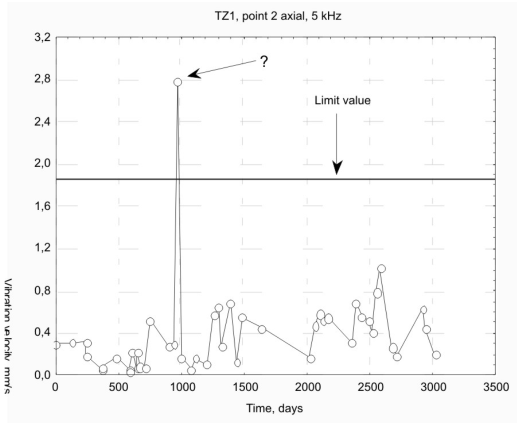


Fig. 4. Sudden increase of vibration amplitude (13CK230 turbine, HP/IP bearing, axial direction, 5 kHz band)

From these considerations we may conclude that there is a need for an alternative approach that could eliminate some of the shortcomings of standard quantitative assessment. Such approach can be based on so-called evolutionary symptoms.

3. Evolutionary symptoms

Before proceeding further, it is necessary to point out that the very term 'evolutionary symptom' is just a proposition. We can define it as a parameter that describes the time history of a diagnostic symptom. All examples refer to vibration-based symptoms, but in the following considerations no particular type is assumed and results can thus be generalized.

Basic assumption can be summed up by stating that information on machine technical condition is contained not only in symptom values (i.e. components of the vector **S**), but also in their time histories. In general, six types of symptom evolution can be distinguished [1,9], namely:

- simple evolution (linear or nearly linear),
- complex evolution (usually variations superimposed on a monotonically increasing curve),
- discontinuous evolution (stepwise changes),
- exponential or almost exponential increase,
- cyclic or nearly cyclic variations,
- rapid random variations.

Moreover, each of these types can be characterized by a 'time constant', which for complex machines designed for long operational life can range from second to months.

From Eq. (6) we can see that a symptom history that we really observe is in fact a combination of two functions:

− continuous evolution resulting from lifetime consumption, which produces a monotonically increasing function, and
− stepwise changes resulting from the logistic vector influence,

if control and interference vectors are neglected. By definition, the logistic vectors characterizes the entire cycle, so that:

$$\bigwedge_i L_i(\theta) = const, 0 \le \theta \le \theta_b \qquad (10)$$

This facilitates relatively simple normalization, as reference measurements can be performed for each cycle at $\theta = 0$. Details of relevant procedures can be found in [5] and example is given in Fig. 5. Possibility of such normalization is important, as discontinuity of the $S(\Theta)$ function and 'double' time dependence (cf. Fig. 1) are eliminated and entire life of the object can be treated as a single cycle.

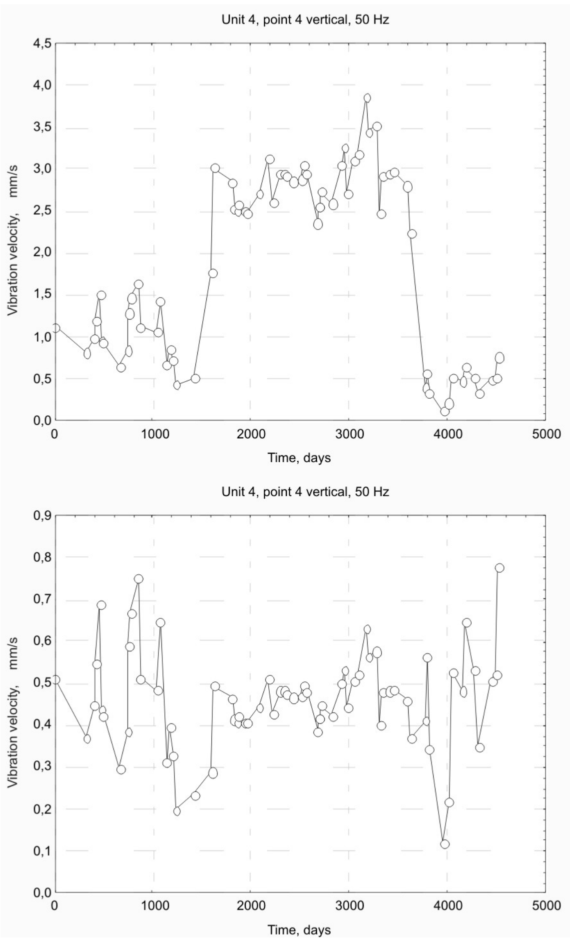


Fig. 5. Symptom time history before (upper) and after (lower) normalization of the logistic vector influence

In the following, we shall consider vibration amplitudes in individual 23% CPB spectral bands (cf. Fig. 2). Amplitudes in bands determined from the vibrodiagnostic model shall be adopted as diagnostic symptoms. Such approach is in particular suitable for rotating machines (turbines, fans, compressors) which generate vibration as a result of both rotating motion and interaction between fluid-flow system and flow of the medium. Vibrodiagnostic model of a steam turbine is described in detail in [11].

As mentioned above, analysis of the EP model leads to relatively simple description, given by Eqs. (3) and (4). As the power of residual processes V is not measurable, some assumptions on symptom operator Φ have to be made. Several operator types have been suggested (see e.g. [10]). For the particular case of steam turbines, it has been shown [4] that:

− for harmonic (low-frequency) components Weibull operator is appropriate, which yields:

$$S(\theta) = S_0\{ln[1/(1-\theta/\theta_b)]\}^{1/\gamma} \qquad (11)$$

− for sub-harmonic and blade (high-frequency) components exponential operator is appropriate, which yields:

$$S(\theta) = S_0 exp[(1/\gamma)(\theta/\theta_b)] \qquad (12)$$

In both these expressions, $S_0 = S(\theta = 0)$; γ is the shape factor that has to be identified.

For a given symptom S, with adequate database (covering sufficiently long period) it is possible to obtain an approximation of $S(\theta)$ and fit an analytical function given by Eq. (11) or (12) (or, more generally, derived from the corresponding symptom operator). Such approach has an important advantage, as influences of control and interference are virtually eliminated, so normalization with respect to them is no longer necessary. In fact, both control and interference vector components have in general no monotonic time trends[2] and it is justified to assume that if $\Delta\theta = \theta - \theta_b$ is sufficiently large, the for each i-th component:

$$\Delta\theta \to \infty \Rightarrow$$
$$\Delta R_i/\Delta\theta = [R_i(\theta_0 + \Delta\theta) - R_i(\theta_0)]/\Delta\theta \to 0 \qquad (13)$$
$$\Delta\theta \to \infty \Rightarrow$$
$$\Delta Z_i/\Delta\theta = [Z_i(\theta_0 + \Delta\theta) - Z_i(\theta_0)]/\Delta\theta \to 0 \qquad (14)$$

Thus, R_i and Z_i will not affect approximation and fitting results to a substantial degree. Moreover, instantaneous $S(\theta)$ peaks of the type shown in Fig. 4 will be 'smoothed' and their effect on results will be negligible.

There is, however, one fundamental problem. The final goal is to determine D, which describes damage progress and allows for a prognosis. Thus, θ_b has to be estimated. Eqs. (11) and (12), however, both contain two unknowns, θ_b and γ, and what is actually determined is their product. Therefore, until γ can be independently estimated with adequate accuracy, no estimation of D can be made.

For small D values we can, however, expand $S(\theta)$ into Taylor power series and truncate higher- order terms. This gives:

$$S(\theta) \approx S_0(\theta/\theta_b)1/\gamma \qquad (15)$$

for the Weibull operator and

$$S(\theta) \approx S_0[1 + \theta/(\gamma \cdot \theta_b)] \qquad (16)$$

for the exponential operator. $S(\theta)$ should thus be linear or almost linear, if $D << 1$ or $\theta << \theta_b$. This suggests that as long as $S(\theta)$ can

[2] This assumption is, to a certain extent, controversial. For example, some older turbines are shifted from base-load to peak operation and are often operated well below rated load. In such cases, $P_u(\theta)$ may exhibit long-term decreasing trend.

be well approximated by a straight line and its slope does not tend to increase, lifetime consumption ratio is small.

The above condition can alternatively be given by $dS/d\theta \approx$ constant or $d^2S/d\theta^2 \approx 0$. This is particularly suitable for on-line diagnostic systems, wherein approximation of $S(\theta)$ derivatives is a relatively simple task. At this point it seems justified to suggest these derivatives, and any other measure of departure from linearity, as evolutionary diagnostic symptoms.

4. Application examples

All examples presented in this section refer to large condensing steam turbines, operated by utility power plants. As mentioned above, some conclusions can be generalized over a broader class of critical rotating machines.

4.1. IP turbine rotor bow

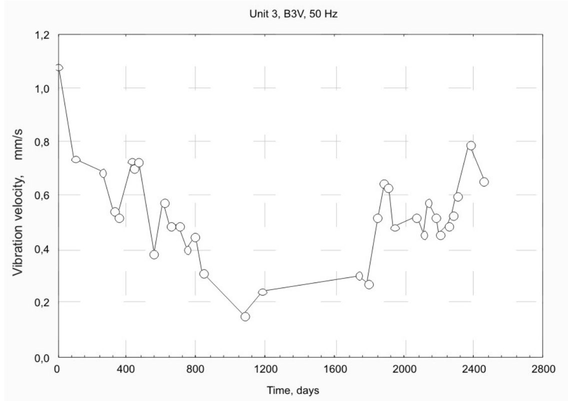
Vibration components from the harmonic (low) frequency range are very sensitive to even small changes of rotor balancing, shaft alignment, bearing position etc. As these parameters are changed during every overhaul or repair, differences between individual life cycles can be very large (cf. Fig. 5).

The following example refers to two comparatively new 13CK230 turbines. Immediately after commissioning, their dynamic behavior was very good. Shortly afterwards, however, one of them (Unit 1) began to exhibit rather intensive increase of the 1st harmonic component (50 Hz) of rear intermediate-pressure (IP) bearing vertical vibration. In the course of approximately three years this component increased by one order of magnitude. The other turbine (Unit 3) behaved in a completely different fashion: although initial level of this component was substantially higher, there was no increase and in fact net trend over a period of over six years has been a decreasing one. Both time histories are shown in Fig.6 (note vertical scales difference).

Due to insufficient database, no symptom normalization could be performed. As we can see, Unit 3 exhibits a short initial ‘running-in’ stage; then, after a period of very low values (most probably caused by problems with load distribution between individual bearings) increase rate is low. Linear approximation slope is about 6.1×10^{-5} (mm/s)/day, which can be considered typical for a turbine in good technical condition.

In order to reduce vibration to an acceptable level, rotor balancing was performed. Results can be clearly seen in Fig. 6, but improvement was only temporary. Both before and after balancing linear approximation slope was about 3×10^{-3} (mm/s)/day. During the overhaul, IP rotor bow was detected. After rotor repair, vibration decreased to the initial level.

Identification of the problem was fairly straightforward, as increase rate was high. We can, however, note that the very form of symptom time dependence can also be an important symptom. As mentioned in the previous section, the ‘time constant’ of vibration-based symptoms can vary within a broad range. In this particular case, this parameter is of the order of months, which excludes a number of possible malfunction causes (e.g. water ingress into turbine, which is the most frequent rotor bow cause). In fact, foundation distortion was initially suggested, as these processes are usually characterized by symptom time histories of similar type.



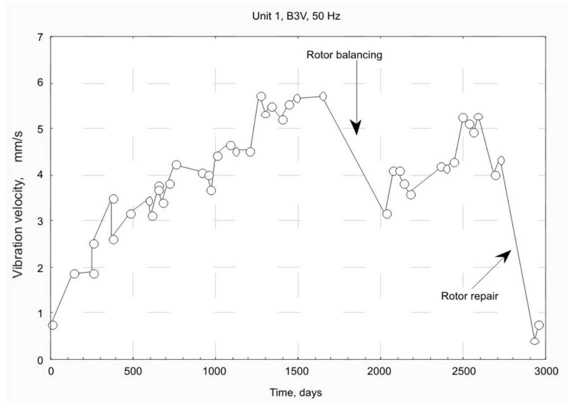


Fig. 6. Time histories for two 13CK230 turbines: Unit 3 (upper) and Unit 1 (lower); rear IP bearing, vertical vibration, 50 Hz component

4.2. Fluid-flow system condition deterioration

Analysis of a large number of symptom time histories has shown that overhauls involving no operations on the fluid-flow system do not affect vibration patterns in the blade frequency range. Therefore histories of the type similar to that shown in Fig. 5 are rare. Life cycles for such symptoms are determined by major overhauls that involve fluid-flow system replacement or repair.

Components from this frequency range are very sensitive to certain interference types, which is usually manifested through behavior similar to that shown in Fig. 4. They are also sensitive to control parameters, like active load (cf. Fig. 2) and, to a lesser extent, condenser vacuum. Due to these factors, $S(\theta)$ values often fluctuate intensively from one measurement to another, but an increasing trend can be traced.

Time histories shown in Fig. 7 for two K200 turbines (both with about 150,000 hours of operation at the starting moment) can be considered typical for the blade frequency range. Despite fluctuations, linear approximation gives good results. Slopes of the order of $10^{-6} – 10^{-5}$ (mm/s)/day are typical for this range with satisfactory technical condition; it should be kept in mind, however, that they should be evaluated individually for each symptom.

Evolution of the fluid-flow system condition in condensing steam turbines is usually rather slow. It accelerates when θ_b is approached and such phenomenon can be observed in old turbines. Fig. 8 shows two examples for K200 units. In both cases an accelerated increasing tendency can be observed before rotor re-

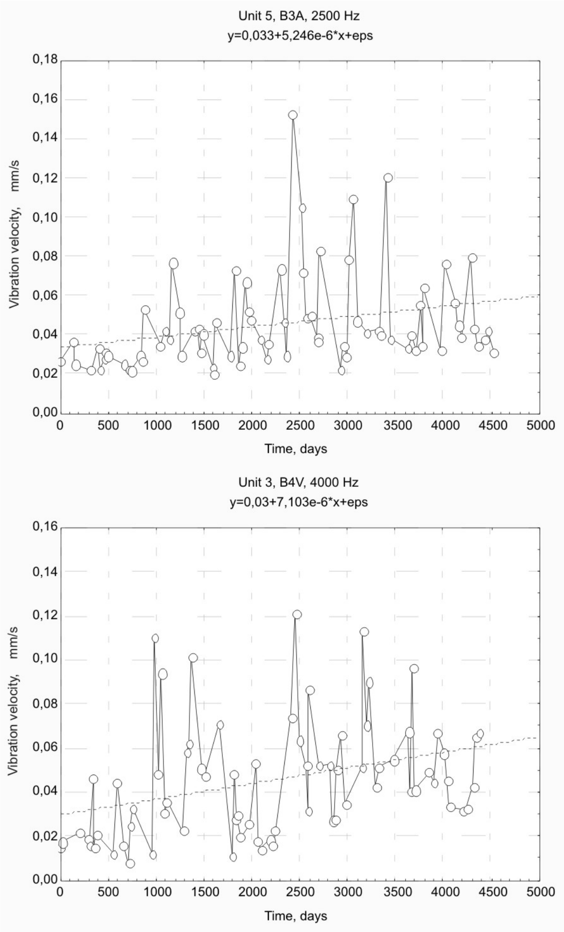


Fig. 7. Time histories for two K200 turbines: Unit 5, rear IP bearing, axial direction, 2.5 kHz band (upper) and Unit 3, front LP bearing, 4 kHz band (lower); broken lines show linear approximations

placement (upper graph refers to the HP rotor and lower to the LP one). It can be easily seen that linear approximation is no longer valid and relevant sections of the *S(θ)* curves are best approximated by exponential functions. In both cases, technical condition deterioration would have certainly been detected with the aid of evolutionary symptoms before limit value was exceeded (in the first case, it was not exceeded before rotor replacement and is above the maximum value on the vertical axis).

Both examples shown in Fig. 8 refer to cases when no damage had occurred and rotors were replaced after a routine examination during a major overhaul. Fig. 9 shows time histories for a 13K215 unit that has suffered a minor damage of the IP rotor last stage. In some preliminary studies on the possibilities of fluid-flow condition assessment with vibration-based symptoms [8], it was

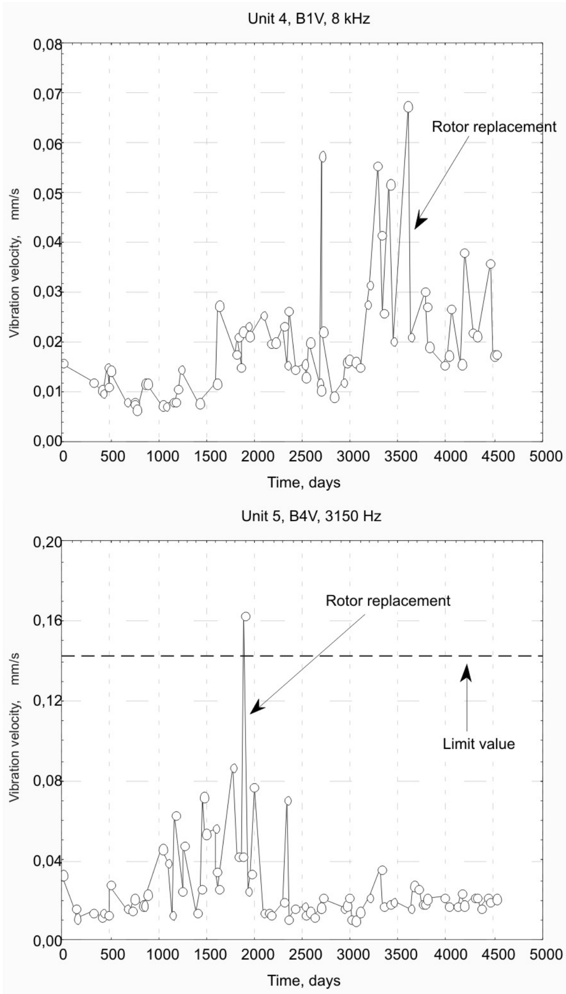


Fig. 8. Time histories for two K200 turbines: Unit 4, front HP bearing, vertical direction, 8 kHz band (upper) and Unit 5, front LP bearing, 3.15 kHz band (lower)

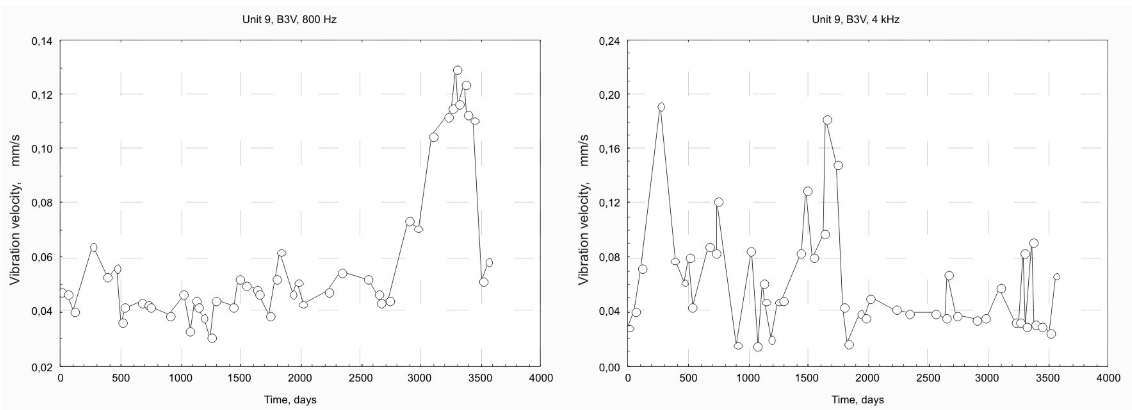


Fig. 9. Time histories for a 13K215 turbine, rear IP bearing, vertical direction: 800 Hz band (left) and 4 kHz band (right)

argued that components produced by interaction between rotor stages and bladed diaphragms are the first to react to condition deterioration. This is confirmed by this case. Vibration velocity amplitude in the 800 Hz band (which contains the component produced by the interaction between last rotor stage and preceding bladed diaphragm) had been increasing rather fast before the fault occurred, which is easily seen in the upper graph. On the other hand, component produced directly by the last stage, apart from fluctuation caused probably by some interference, had shown virtually no significant increase (see lower graph).

4. Conclusion

At the present stage it can be concluded that evolutionary symptoms should provide a useful tool to supplement diagnostic reasoning based on the 'traditional' approach. This refers mainly to the fluid-flow system condition assessment in large rotating machines. In normal operation, repair or replacement of the fluid-flow system components is performed only during some major overhauls, so often the entire machine life can be treated as a single cycle. This eliminates a need for symptom normalization. It should be kept in mind that, for example, in steam turbines fluid-flow system failures are responsible for roughly 50% of forced outages [12]; moreover, repairs of such failures are usually very costly and time-consuming. Any method that would allow for a reliable condition assessment is thus, at least, worth considering.

Further development of diagnostic techniques based on evolutionary symptoms shall certainly include determination of limit values. As mentioned above, in some cases symptom values typical for good technical condition have been estimated, but these are just preliminary observations. Much research, both theoretical and experimental, is still necessary.

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ANALIZA DEGRADACJI POJAZDÓW W EKSPLOATCAJI

AN ANALYSIS OF DEGRADATION OF VEHICLES IN OPERATION

Pojazdy mechaniczne są stosunkowo złożonymi obiektami technicznymi w których w trakcie funkcjonowania zachodzą złożone procesy zużycia. Intensywność zużycia poszczególnych zespołów pojazdu jest uzależniona nie tylko od ich konstrukcji, ale także od warunków ich eksploatacji. W niniejszym artykule przestawiono mechanizmy i czynniki wpływające na degradację pojazdów mechanicznych.

Słowa kluczowe: *stan techniczny, zużycie części, degradacja pojazdu.*

Vehicles are quite complex technical objects and complicated wear processes accompany their exploitation. The intensity of degradation of particular systems of a vehicle depends not only on a construction but also on the exploitation conditions. In the following paper the mechanisms and conditions influencing degradation of vehicles have been presented.

Keywords*: technical state, wear, degradation of vehicle.*

1. Introduction

Changes in the technical condition of a vehicle depend on its sensitivity to degradation processes and the intensity of operational external loads. The effects of external loads originating in various operational situations accumulate during vehicle operation.

Knowing the characteristics of the sensitivity of vehicle elements to physical degradation and the spectrum characteristics of mechanical, heat and physicochemical loads, it is possible to estimate, with certain probability, the time when the state of fitness changes into a state of unfitness.

The change in the technical condition of a vehicle is chiefly a random process, which depends at the same time on various external forces, resulting in damages that can be sudden, accumulated and relaxing. This means that for various vehicles, the change of the examined condition will be different, and it will be characterized by different types of wear curves.

Generally, it can be stated that progressive degradation of a vehicle is a complex process, which depends on the accumulation of various tribological, fatigue, corrosive and other effects.

Therefore, the analysis of vehicle degradation aims at providing information in order to make certain decisions, through generating the data of the vehicle degradation process, which determine the risk of unfitness.

This requires an explanation of the core problems related to an assessment of the physical and mechanical phenomenon of the degradation of vehicle elements and the application of proper models in order to map the course of the vehicle operation process [2, 3, 4].

2. Formulation of the problem

Models representing degradation of vehicles and their elements should allow for long-term forecasting of changes in their conditions, and through this, facilitate optimization of the distribution of financial means allocated for their maintenance. Hence, there are a large number of solutions and degradation models which can be encountered while analysing vehicle maintenance systems. However, they all come down to the strategy of mixed maintenance according to constant schedule of technical inspections and annual standard checks of technical condition.

Generally, the level of vehicle degradation can be described during the i^{th} period of operation by the following relation [2, 4]:

$$D_i = D_p + R_i \cdot \lambda_i - P_i \cdot \mu_i \quad (1)$$

where: D_p – level of vehicle degradation at the beginning of the assessment, R_i – indicator of operational reliability, P_i – a technical inspection parameter, λ_i – intensity of usage, μ_i – intensity of operation, i – i^{th} period of operation.

The essential variables, besides time, influencing degradation processes of a vehicle, are:

- heat load,
- mechanical load,
- chemical processes (corrosion) depending on humidity and other environmental impurities,
- weather conditions, road conditions and random events,
- individual characteristic of a driver (driving style),
- quality of repairs and used appear parts.

Therefore, the process of vehicle degradation depends on many external forces and requires a system analysis.

On the basis of the assessment of the vehicle wear (according to statistical research carried out by experts), the function of degradation is presented in Figure 1.

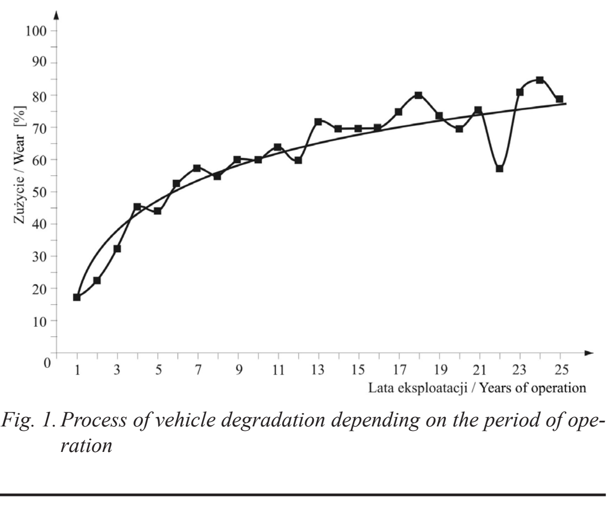

Fig. 1. Process of vehicle degradation depending on the period of operation

On the other hand, on the basis of DIN 31051 standard, the changes in machine wear during the operation is presented in Figure 2.

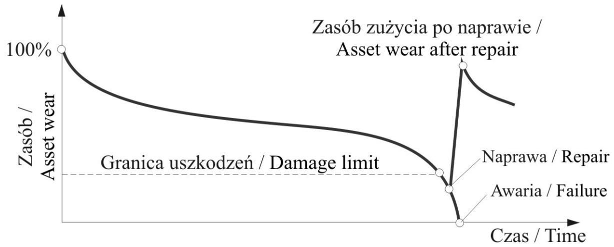

Fig. 2. Change of asset wear during operation [according to DIN 31051]

After [2], degradation degree (S_D) of the vehicle depends on its operational period (t) and the intensity of operational factors:

$$SD = < \lambda(c_i), \quad i = \overline{1,n}, \quad t > \tag{2}$$

The approximation of the model regarding the assessment of the degradation degree of a vehicle should therefore include an assessment of its initial (designed) strength, estimation of the operational factors' history (loads of various types) and an assessment of the residual strength.

Calculations of construction elements strength during the operation under random and accumulated loads requires knowledge of their processes and their distribution in relation to the material of a given construction element. In a diagrammatic form, the issue of operational strength is presented in Figure 3.

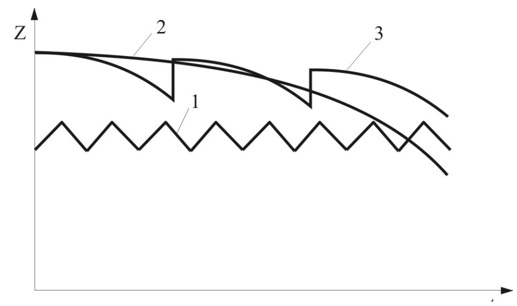

Fig. 3. A diagram describing the effects of external loads: 1 – mechanical loads, 2 – tribological wear, on the vehicle strength, 3 – taking into consideration subsequent repairs

Knowing the characteristics of the resistance of vehicle elements to destruction and spectrum characteristics of external loads, it is possible to estimate, with certain probability, the time when its technical condition will change, taking into consideration various mechanisms of wear. In the vehicle operation, the following mechanisms of element wear are distinguished [2, 4]:

- tribological wear processes (abrasive, oxidation);
- fatigue wear (pitting and fretting);
- cavitational wear (e.g. slide bearings);
- corrosive wear of vehicle elements due to chemical or electrochemical processes;
- thermal wear with intensive oxidation, e.g. elements of exhaust system and with local melting of surface layer, e.g. exhaust valve heads and seats.

3. Types and mechanisms of element destructions

Vehicle elements are operated in a system, the diagram of which is presented in Figure 4.

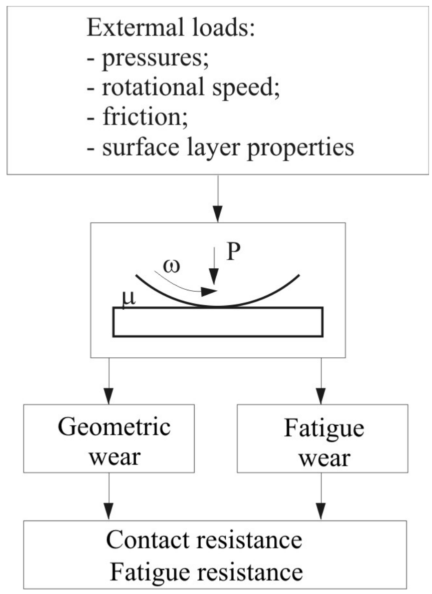

Fig. 4. The diagram of the system of destruction regarding elements of pad-welded vehicles [1]

Working out of the general model of degradation of a vehicle is nowadays practically impossible because of its complex construction and simultaneously wear of particular mechanisms. At present there are worked out the exact models of wear and durability of particular mechanisms. In the paper [4] there are presented the exemplary calculations of the durability of the drive shaft of a vehicle.

Most often, various forms of element wear (quasistatic and dynamic) occur at the same time during the operational period of the machine.

In classical models of wear, a loss in the surface of the material is made in the presence of plastic micro- and macroscopic deformations, leading to cracks. The stress destroying individual roughness protrusions, σ_F, can be described by Griffith-Irvin-Orowan equation:

$$\sigma_F \cong \sqrt{\frac{2E\left(\gamma + \gamma_p\right)}{\pi C}} \tag{3}$$

where: σ_F – breaking stress for roughness protrusions, γ - surface energy, γ_p, σ_F - energy of plastic deformation, C – the length of a possible crack.

For elastic contact the number of cycles to destruction can be determined from expressions 4 and 5 [1]:

$$n_S = \left(\sigma_O / \sigma\right)^{t_S} \tag{4}$$

$$n_S = \left(\sigma_O / \psi\tau\right)^{t_S} \tag{5}$$

where: n_s – the number of cycles to roughness smoothing in elastic contact, σ_o – short-term resistance, σ – normal stress in contact, τ – shearing stress in contact, ψ – coefficient (3÷5), t_s – material constant (3÷14).

In case of plastic contact, typical for low cycle destruction, the number of cycles to destruct roughness in contact is determined from the following relation:

$$n_P = (e_O / e)^{t_P} \tag{6}$$

where: n_p – the number of cycles to roughness smoothing in a plastic contact, e_o – critical strain to the destruction of material, e – deformation as a result of friction, t_p – material constant (2÷3).

The speed of the development of a fatigue crack is a particularly important problem as regards pad welded elements. Padding welds shorten the time of initiating fatigue cracks, therefore information concerning the advancement of crack in them becomes essential. A padding weld partly changes the microstructure of an element and introduces discontinuities and residual stresses. The knowledge of the effects of the above mentioned factors on the speed of the fatigue crack growth can significantly facilitate and increase the accuracy of theoretical forecasting on the stage of designing the durability of pad welded elements.

4. Summary

This study has revealed a lack of a comprehensive view of vehicle degradation in the process of operation.

As follows from theoretical considerations and experimental research, the description of the vehicle degradation process must take into account many qualitative and quantitative aspects of wear and fatigue.

It is necessary to take into consideration the degree of vehicle degradation already at the designing stage, in order to develop a rational operational strategy, which leads to optimization of the allocation of financial means for vehicle maintenance.

Developed models of degradation in the form of a degradation function provide a general relation of the assessment of wear condition to the operational period. The presented curves of degradation, provided in the form of a function, do not take into consideration simultaneous occurrence of mechanical and heat loads, corrosion or renewal elements as part of conducted technical inspections.

In many cases, the vehicle degradation assessment can be based on Wöhler's fatigue strength diagram. It seems that it should be completed by the course of the σ-N line of constant probability (P) of construction destruction, by the effects of the renovation of elements (e.g. pad welding with the use of Smith's chart), etc.

Collected statistical data concerning the process of operating individual types of vehicles do not make it possible to forecast a degradation curve, taking into consideration the intensity of the real loads and accumulation of damage.

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INTELIGENTNY SYSTEM MONITOROWANIA SIECI WODOCIĄGOWYCH

INTELLIGENT MONITORING OF LOCAL WATER SUPPLY SYSTEM

W referacie przedstawiono badania związane z budową systemu monitorowania sieci wodociągowych, sygnalizujących pojawienie się awarii sieci i wspomagającego ich lokalizację. Podstawowym założeniem omawianego systemu było przyjęcie metody wykrywania awarii stosowanej dotychczas w diagnostyce technicznej maszyn i procesów przemysłowych, opartej o modele przybliżone obiektu diagnozowanego. Bazując na niewielkiej liczbie czujników przepływu zainstalowanych na sieci wodociągowej i odpowiednio wytrenowanej sztucznej sieci neuronowej pojawiające się awarie sieci są wykrywane i lokalizowane. Opisany został pierwszy etap prac (lokalizacja czujników pomiarowych, przygotowanie i trenowanie klasyfikatora neuronalnego) oraz uzyskane wyniki.

Słowa kluczowe: *sieci wodociągowe, diagnostyka, wykrywanie i lokalizacja wycieków, sieci neuronowe.*

In the paper an intelligent monitoring system of local water supply system was described. The author took advantage of methods of artificial intelligence and methods known from model-based process diagnostics to decrease the number of indispensable measuring points. Basing on few flow sensors installed on pipeline network and using neural network as a model of pipeline, appeared leakages are approximately localized. The first stage of system building (choosing of sensor localization, neural network preparing and training) and results obtained to-date were shown.

***Keywords**: water supply systems, diagnostics, leakage detection and localization, artificial neural network.*

1. Introduction

Water supply systems are one of the most essential parts of the urban and rural technical infrastructure. It is necessary for them to be reliable, especially because of counteraction of water loss. Finding leaks is one of the typical problems connected with water pipelines maintenance. This task is not simple enough, because quite often leaking water can run deep into ground and therefore pipe failure does not show up on the ground surface. Bearing this in mind one can expect that a diagnostic system, supporting leakage finding would be very useful, especially on an industrial area with coal mining, where leakages are often encountered. Additionally, traditional methods of leakage finding, based on leakage noise detecting and analysing, are less efficient with, nowadays very popular, plastic pipes, which are poor sound conductors.

2. Problem description

In fact, mathematical dependencies between flow and pressure loss in a pipe are known, so it is possible to use it for leakage detection. So that theoretically, if we knew water consumption in all the points of network, it would be possible to calculate pressure and flow in any required point of the network. Comparison of calculated and measured parameters could allow finding leakages and other causes of water loss. For example, the method described in [2].

However, to establish such a kind of a monitoring system it is necessary to measure "on line" all legal water consumption. Although it is possible to decrease number of inputs to the water supply system (and then decrease number of measurement points needed), it must result in much worse accuracy of the monitoring system. It is why this idea of monitoring system is not quite good enough for practical implementation.

3. Concept of monitoring system

To avoid necessity of using measuring system which is big, complex and spread out at significant area of the country, with big number of on-line measuring points, the concept of diagnostic system, which uses approximate approach for modeling the pipeline network and recognizes a leak of water was suggested [5]. The idea of this system is based on methods known from model-based process diagnostics where a model of the object being monitored is used for fault detection [3]. Based on measuring flow and/or pressure in chosen points on pipeline networks and appropriate trained artificial neural network (ANN), the diagnostic system in question would suggest if any leakage exists, and where it is possibly located.

4. Practical application of the proposed method

For practical verification of the proposed method, in collaboration with the local water supply system holder, a prototype diagnostic system is being developed.

The considered system will work within one district of town. The monitored network has about 25km of pipelines with different diameters and supplying about one thousand of water consumers. The scheme of this network is shown in Fig. 1. The monitoring system will be finished at the end of 2007.

[1] The research presented in the paper has been partially supported by EFS under Sectoral Operational Programme „Improvement of the Competitiveness of Enterprises, years 2004-2006" and the Ministry of Education and Scientific Research/Information under grants Nr 4 T07B 018 27

Fig. 1. Monitored pipeline network

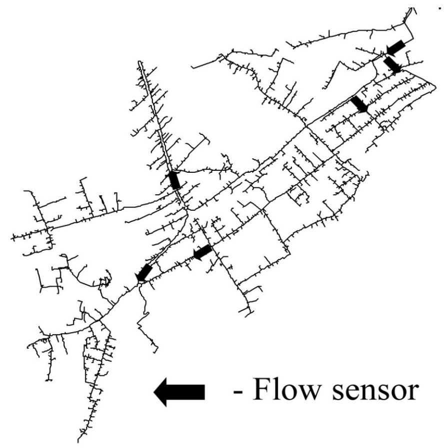

Fig. 2. Flow sensor location

4.1. Numeric model of water supply network

Since the artificial neural network was planned to be used as a model of the real network, the problem of preparing training data should be solved. Because it is difficult and inconvenient to simulate leakage and collect data from real object, the numerical model of the network was built. To build this model the EPANET simulation environment [1] was used. Running this model it was possible to calculate flows and pressure in all the points of the network with a leakage located in any point of it or without leakage at all.

To describe temporary water consumption for every water consumer, an accountant data was used. For each user an average consumption was calculated. To describe consumption changes during all day, a daily time pattern consumption, described in [4] was established. To simulate random changes of water consumption, consumption calculated for each time and each user was randomly changed within the range +/-20%.

4.2. Location of the sensors

Because of economical and technical reasons, the owner of the supply system decided to limit the number of used flow sensors to six. The number of pressure sensors, which are cheaper and much easier to mount, was not limited, but as the first examination showed, they are not useful enough for leakage localization (in the considered network). To find the best location of sensors an optimization with genetic algorithm was used [6].

At first allowed sensor localizations were limited to main network junctions only. In all the main junctions potential flow sensors for each connected link were localized. It provided 45 possible flow sensors locations. Next the sets of points of leakages were chosen at random. For each leakage location flows for all potential sensors locations were calculated. Simulations were repeated for every hour for 30 days.

The genetic algorithm chose the best subset of six sensors. For each subset ANN was trained for leakage location. The percentage of correct location was assumed as a value of the fitness function. The best chosen location of six flow sensors was shown on Fig. 2.

4.3. Approximate model of water supply network

As it was described, the ANN as a model of water supply network was established. The multilayer perceptron was used. Water flows, measured in chosen points of network was taken as input to perceptron, the state of the network (no leakage, leakage in first location, leakage in second location, etc) was taken as an output of this ANN. The numbers of neurons in hidden layer was three times greater than a number of outputs. The tan-sigmoid transfer function in the hidden layer and the log-sigmoid transfer function in the output layer were used. To train ANN a data collected during simulation with EPANET was used.

The other problem was to decide how the potential leakage location should be pointed. At first, during ANN training the exact point of leakage was shown. Obtained results were quite good (about 80% of leakages pointed exactly or with small fault). Some of leakages were found as "undistinguished" – because of small number of installed sensors there was no differences in "measured" water flow in the points of sensor localization. But some of leakages, located in absolutely different places were not distinguished, too. Fig. 3,4,5 show some examples of results.

To avoid these significant mistakes, it was decided to divide the network into some separated areas and point only some area when leakage is located. At the first stage the network was partitioned as shown in Fig. 6.

To avoid these significant mistakes, it was decided to divide the network into some separated areas and point only some area when leakage is located. At the first stage the network was partitioned as shown in Fig. 6.

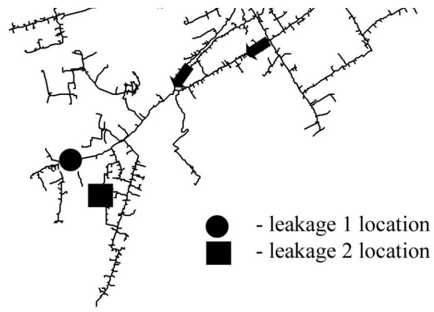

Fig. 3. "Undistinguished" leakages

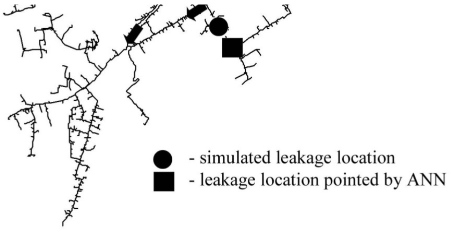

Fig. 4. Leakages pointed with small fault

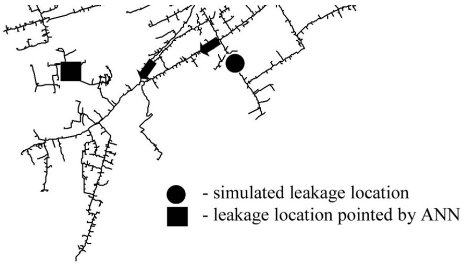

Fig. 5. Leakages pointed with significant fault

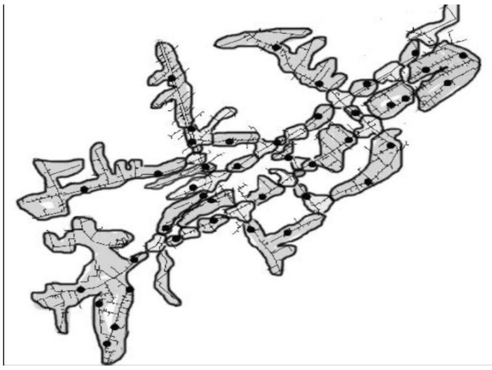

Fig. 6. Divided network – stage one

The obtained results show that in the most cases ANN pointed proper area or pointed the nearest one. But more significant errors still occur. In Fig. 7 system errors histogram was shown. The numbers on X-axis means: 0 – proper area was pointed, 1 – nearest area was pointed, 2 – next to nearest area was pointed, etc.

At the second stage partitioning into leakage area was changed. Neighbors areas were separated by network nodes (Fig. 8). Obtained results were shown in Fig. 9.

Leakages located in most areas were pointed good enough, but in some cases results were poor.

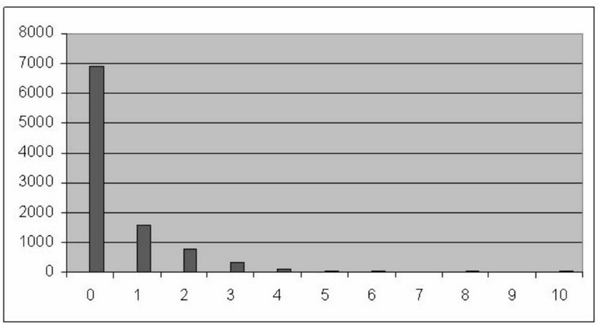

Fig. 7. Histogram of errors (10.000 trials)

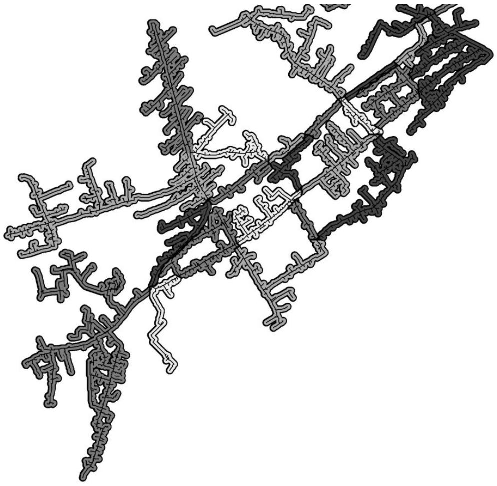

Fig. 8. Divided network – stage two

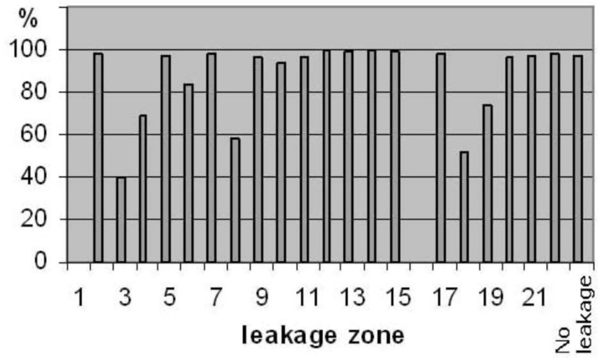

Fig. 9. Classification efficiency

To improve this situation instead one ANN a cascade of ANNs was applied. For each area which was not "recognized" good enough, a separate ANN network was prepared and trained. The comparison of results obtained for one ANN and the cascade of ANNs was shown in Fig. 10.

In Fig. 11 histogram of classification errors for ANNs cascade was shown – it is essential, that system points proper area of leakage localizations or the nearest area at least.

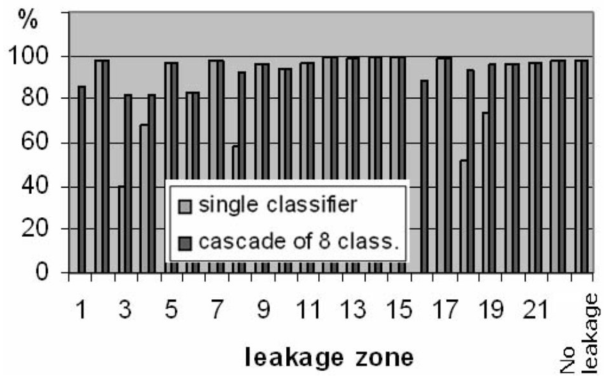

Fig. 10. Classification efficiency

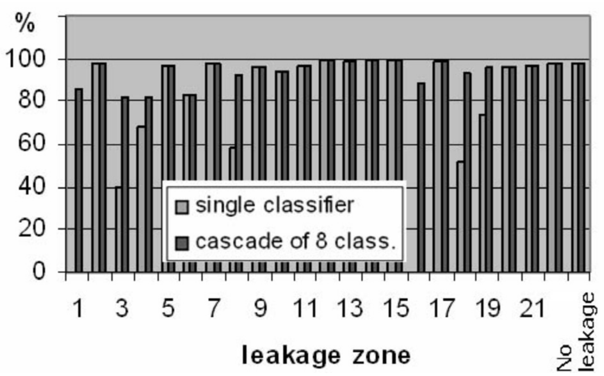

Fig. 11. Histogram of errors for ANNs cascade

10. Further system development

In near future the process of flow sensor installation will be finished, so it will be possible to carry out first practical tests of the monitoring system.

In the next step, after collecting data from installed sensors, it will be possible to improve the system to detect less intensive leakages. The idea is to predict the future flow measured by the given sensor with few hours horizon time. Recurrent errors of prediction can help to determine an additional flow, connected only with potential leakage, and not connected with water consumption.

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WYBRANE PROBLEMY ANALIZY PRZYCZYN WYPADKÓW DROGOWYCH W POLSCE W LATACH 1995 –2004

CHOSEN PROBLEMS OF ROAD ACCIDENTS ANALYSES IN POLAND IN THE PERIOD BETWEEN 1995 AND 2004

W niniejszej pracy dokonano klasyfikacji zderzeń samochodów ze względu na statystycznie najczęściej występujące wypadki oraz testy, jakim poddawane pojazdy są nowo dopuszczane do sprzedaży. Niniejsza praca dotyczy rozważań na temat bezpieczeństwa ruchu drogowego w Polsce. Na jej łamach podjęto próbę analizy przebiegu i skutków najpowszechniej występujących na drogach zderzeń. Ważnym jest problem stateczności jako elementu podlegającego zmianom w przypadku eksploatacji pojazdów powypadkowych. Problem ten jest przedmiotem oddzielnych badań. Kolejnym ważnym punktem jest przedstawienie danych statystycznych i próbę analizy poziomu bezpieczeństwa na ich podstawie. Jako ważny etap należy postrzegać tu chęć porównania niektórych wskaźników w Polsce i we Francji, co pozwoliło na próbę zweryfikowania niektórych opinii o poziomie bezpieczeństwa ruchu na drogach w Polsce.

***Słowa kluczowe**: bezpieczeństwo, wypadki, kolizje, przyczyny, skutki.*

This article offers classification of car collisions from the point of view of the most frequent accidents and crash tests. The most important problems are the consequences of incomplete control of a car which has been repaired after an accident. As a result, further use may lead to defective work of systems responsible for steering, driving comfort, and contact with the road surface as well as suspension. Firstly, the article focuses on the safety of road traffic in Poland and presents an attempt to analyze the course of most frequent collisions and their consequences. Stability is an important problem as it changes in a car driven after an accident, and should be analyzed in separate research. Secondly, it gives statistical data and attempts to analyze the level of road traffic safety. Some important indicators are shown here to compare the situation in France and Poland, which enabled verification of some opinions about the safety of road traffic in Poland.

***Keywords**: safety, accidents, collisions, reasons, consequences.*

1. Introduction

Road traffic safety in Poland has become an important issue due to an increase in both the number of registered cars and road accidents. Efforts to improve road traffic safety have been taken for many years in many countries including Poland. This article presents results of analyses and improvements in driving safety. They were based on an analysis of sample publications describing the actual situation and the main trends for future. Countries leading in research towards better safety are those having the greatest experience in this matter, i.e. Sweden, Germany, France, USA and Great Britain. Thanks to combined work of car manufacturers, organizations such as EuroNCAP (assessment of new car safety) and scientific teams it was possible to create state-of-the-art car bodies offering maximum passenger safety which got top marks in crash tests. Besides, there have been attempts to protect pedestrians from the effects of being hit by a car. Initially, the results were unsatisfactory, but the latest tests show improvements in this area. Examples of dissertation in this area include those by M. Huang [6] and D.C. Viano [11] and many other publications, e.g. by J. Reimpell [9]. Moreover, it is important to refer to scientific conferences in Poland, such as TRANSED 2001. Except for research into better safety of the car body [2] there are activities aimed at improvement of road traffic [1]. These include the building and modernization of road and motorway networks, as well as regulations to adapt the traffic to the surrounding area. Until now, the main parameter in this respect was the speed limit.

The main product of such work in Poland is a stream of publications concerning car body construction, crash mechanics, as well as accident reconstruction and biomechanics of human body at the moment of crash. A different issue is the relationship between road infrastructure [3] and the occurrence of road accidents [4]. There are numerous publications covering this area of research, and those deserving the reader's attention include papers by Prof. J. Wicher [12], and other relating to recreation and analysis of road accidents. Numerous dissertations concerning road vehicle dynamics are also available.

The aim of this article is to describe different kinds of car accidents on the basis of the crash theory and consequences of accidents, especially body deformation. In its further part, the work discusses different causes of road accidents along with the actual level of road safety in Poland, based on an analysis of statistical data [7,8,10,13], comparison between some of the indicators in Poland and France, and the relationship between accidents and the condition of road infrastructure. The statistical analysis was made on the basis of the road accidents database for the period between 1995 and 2005. This database was compiled with the use of the Informix software.

2. Classification of car crashes and the course of the related collisions

Primarily, road accidents involve contact of one body (here a car) with another one or more bodies (car, man, still barrier) or the ground. To present some basic examples of road accidents as crashes of bodies, it is necessary to make a relevant classification which allows distinction of different types of accidents. Following this train of thought, it appears necessary to describe road accidents and their consequences according to the following guidelines.

This classification of car accidents was made on the basis of the existing divisions. J. Wicher divides impacts into front, side, rear and rollover ones, depending on which part of the car body was hit (Fig. 2.1). ISO 6813 (Fig. 2.2) offers a more detailed description of each type of crash, including other incidents, such as fire.

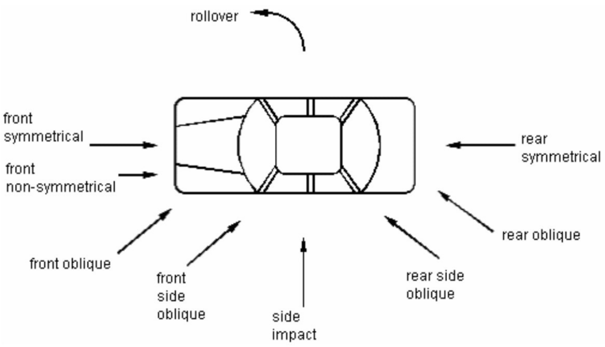

Fig. 2.1. Division of crashes based on direction of collision [12]

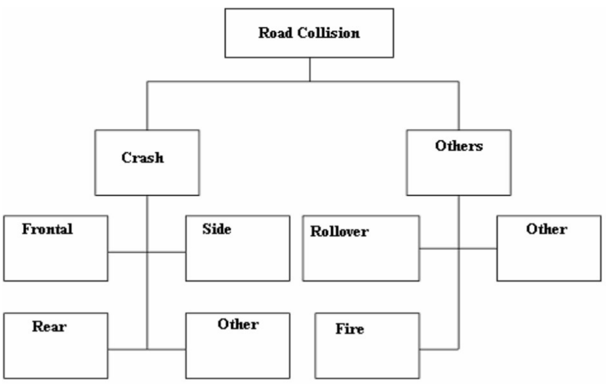

Fig. 2.2. Classification of crashes according to ISO 6813 [12]

In order to present road traffic as examples of two-body crash, it is necessary to use a third classification (Fig. 2.3) showing statistical data for the period between 1995 and 2005. It allowed a certain combination allowing separation of accidents resulting from the movement of road vehicles from other road occurrences.

2.1. Side impact

As it appears from figure 2.3, the side impacts constitute the highest percentage in the general number of accidents. This problem is caused by the increase in the number of cars in towns and cities, which is connected to congestion in these areas. The crash itself usually occurs close to the central pillar marked as B. However, considering the offset in relation to e.g. the driver's R point, we could expect that the resultant force would be received in another place at the side wall of the car. The crash itself can be both perpendicular and oblique. In the former case, the impulse vector of the crashing force is unknown, but the path

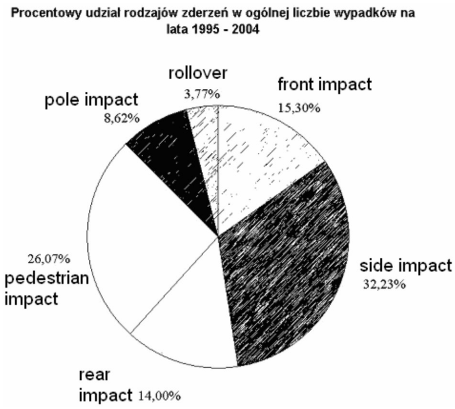

Fig. 2.3. Percentage of crashes in 1995 – 2004, source: own research

of the moving car before the collision is obvious to guess. The moving car is deflected, and the velocities of the cars are also changed. This information is important when considering an accident reconstruction.

As a result of an oblique crash, it is not certain how to define the orientation of the impulse vector. It can be defined only by using the known position of the vector of the car momentum before the crash, as well as some relevant geometric ratios.

Deformations occurring after side impact affect primarily all the closed profiles strengthening the car body construction. These profiles are located in the thresholds of the doorholes, A, B, C and D pillars if the body is a station wagon (Fig. 2.4) [14]. Deformations may also occur in the joints between the side wall of the car and its roof or between the frame of the side wall and the covering sheets.

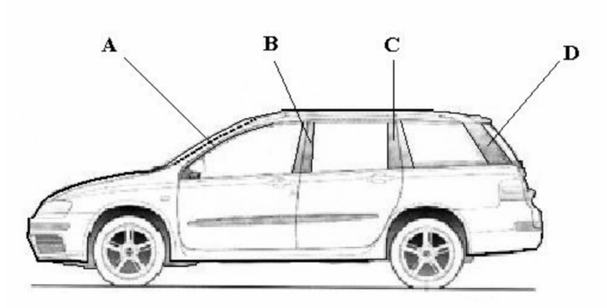

Fig. 2.4. Indication of car pillars, source: own research

Additionally, deformations which may disturb the geometry of the car body can occur in the longitudinal and transverse draw pieces of floorboard. While describing the pillars as energy saving and deformable elements, it is necessary to mention that they occur mainly in closed types of car body (the roof is an integral part of a car and is not disassembled). The number of pillars depends on the type of car body. In open bodies, where the roof can be taken out, there are mainly A pillars.

2.2. Pedestrian impact

This kind of accident holds the second place in the general classification of the number of accidents between 1995 and 2004. It is caused mainly by hitting a pedestrians walking right next to the road in its closest area and on zebra crossings. This type of accident was classified as one of the EuroNCAP tests. The cases of a pedestrian being hit by the front part of a car are taken into account most frequently. Human body has then direct contact with the bonnet, whose deformations do not influence the car body geometry.

The most important criterion in the assessment of safety of a car exposed to pedestrian impact is the collection of characteristic points. They are placed on the bonnet and windscreen of each tested vehicle. Those points are marked with different colours depending on the probability of injuries as a result of contact with the places they cover. Such a situation is presented in figure 2.5

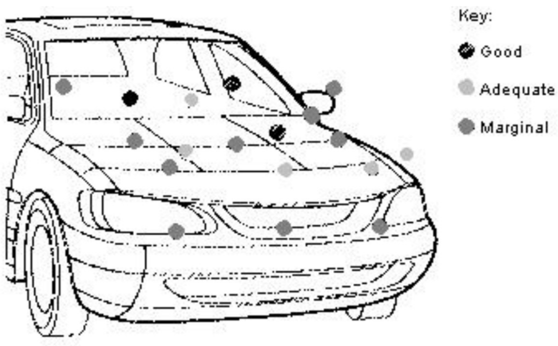

Fig. 2.5. Distribution of the points to evaluate the results of the pedestrian impact, source: www.euroncap.com

An accident with a pedestrian can occur in three phases: contact with vehicle, the flight of the human body and then sliding on the road surface. The most important factors generating the severity of pedestrian injuries are the shape of the front part of the vehicle body and the velocity at which it hits the pedestrian. These factors determine whether he falls down in front of or behind the colliding car, or flies to the side.

2.3. Parallel impacts

Front and rear impacts, also classified as parallel, occur in similar quantity relating to the general number of accidents in the described period. During this type of collision the cars are moving along parallel or nearly parallel paths. As a result of the crash, the parameters of both cars change. Parallel impacts are uniquely characterized by a moment at which the velocities of both cars are equal. The phase before is characterized by the impulse growth of the crashing force and deformations in car body [5]. This first phase is called the deformation phase.

In the second phase, after the velocities of both cars are equal, there is a decrease of the crashing force and the disappearance of deformations, provided the effort in the material of car body has not exceeded.

Deformations that could occur as a result of a crash cover the elements of the engine chamber (front belt, front side profiles often designed to have the suspension fixed to them, front barrier between the engine chamber and the passenger section) along with the elements of external sheets, as well as the additional underframe, front door, A pillars, windscreen and the front part of floorboard. The rear impact is dangerous for the structure of the boot, C and sometimes D pillars, rear window and fragments of external sheets along with the rear parts of the floorboard. In the event of parallel impact, there is the highest probability of change in the geometry of the vehicle body.

2.4. Stiff barrier impact (pole impact)

Those accidents cover 9% of all the road misfortunes registered in the period between 1995 and 2004. This type of impact is especially dangerous, because its consequences may be very serious. Such an accident is very dangerous, especially when the side wall of a car hits the pole. The resulting deformations of the side thresholds, B pillars, roof, door, floorboard in transverse direction and the elements of the interior in the passenger section could cause serious injuries. The assessment of car damage resulting from this type of collision is also carried out by the EuroNCAP. This test is shown in figure 2.6.

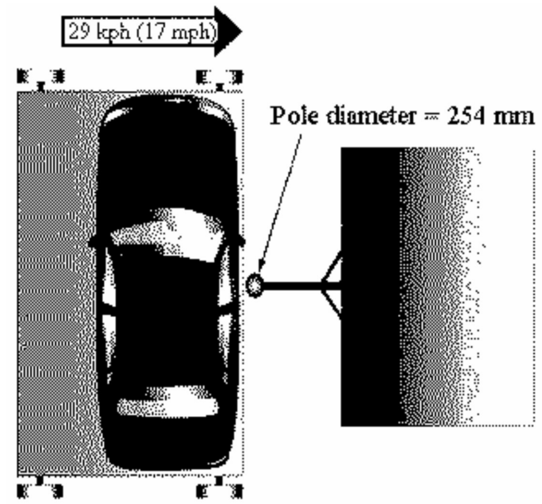

Fig. 2.6. Pole impact by the EuroNCAP, source: www.euroncap.com

2.5. Rollover

The last type of accidents mentioned earlier in the classification constitutes about 3.8% of all accidents from the described period. The rollover is when car hits the ground with its side walls or roof as a result of turning around one of its axis of symmetry. Although occurring less frequently, this type of accident may have very serious consequences, if considering the injury of passengers and the deformation of car body.

The fall on the roof may lead to damage of all pillars and windows, as well as the roof. However, micro deformations and micro cracks might reach as far as the floor board of the car. It can result in the change of the vehicle body geometry.

3. Analysis of statistical data

Road accidents and collisions registered by the police are stored as data in the evidence system of accidents and collisions called sewik. These data are used to update the database at the Warsaw University of Technology, Department of Transportation, created with the use of Informix. On the basis of the statistics received, an attempt to assess the level of road traffic safety in Poland was made. Furthermore, some trends for the future were analysed. A comparison between Poland and France in the years 1998 - 2000 was also developed as France is considered to be the country having better infrastructure and driving culture.

The research results presented in the bibliography contain different aspects concerning analysis of data than those presented in this paper.

3.1. Human factor

It is believed that the blame for most road accidents lies on the human side. Figure 3.1 shows the division of causes for road accidents caused by a human being. In this respect, only pedestrians are a group that really matters. It is noteworthy, however, that while the number of accidents caused by pedestrians fell during the period between 2000 and 2004, those caused by drivers remained at around the same level of 50,000 a year. It is a serious problem and it does not seem that the next years will show any decrease in this area, especially in the face of continuous growth of the number of cars in Poland. The reasons of collisions and accidents should also be searched among factors which influence fluidity and safety of traffic.

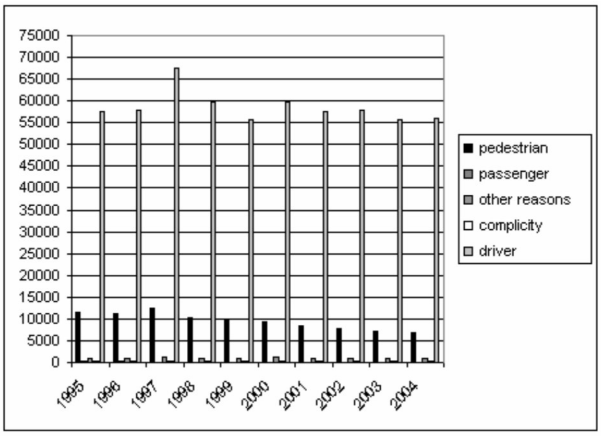

Fig. 3.1. Causes of accidents resulting from human error, source: own research

Figure 3.2 shows the number of killed and injured in road accidents in Poland. The period between 1995 and 2004 was taken into account as the comparison was made by relation to 100,000 registered vehicles. The second half of this period seems to have given better results in terms of both the killed and the injured. A clear decrease was reported in the injured rate, to

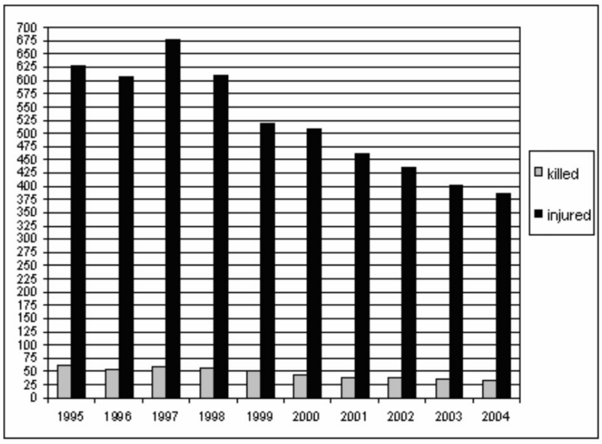

Fig. 3.2. Number of road deaths and injuries per 100,000 registered vehicles between 1995 and 2004, source: own research

about 400 per every 100, 000 vehicles in 2004. By comparison, between 1995 and 1999 this indicator remained at about 600. The relative number of persons killed in road accidents after 2000 has stabilized at the level of around 40. Although there is no evident decrease tendency, we can say that there has been a significant improvement of safety in the period of the last ten years. This is largely due to the development of the car body construction. This factor, along with modern road infrastructure, can lead to further decrease of deaths at the expense of an increase in the number of injuries, e.g. per 100,000 of registered cars. It is also connected with the separation of pedestrians and bicycles from road traffic. In such a case we could expect more side and rear impacts during the lane change. The number of head, pedestrian, and bicycle collisions should decrease. Most rear collisions occur in urban area, so the decrease in their number is connected only with the improvement of the culture and skills of drivers.

The analysis of the changes in the number of road deaths and injuries is continued in Table 3.1, where the factors mentioned previously are shown in relation to 1,000 accidents in Poland in the period of five years. It is important that the number of deaths oscillate around 110 which allows one to predict some stabilization in this area. In the years 2000 – 2004 the number of injuries was around 1,300 per 1,000 accidents.

Tab. 3.1. The number of people killed and injured per 1,000 accidents in Poland, 1995 – 2004, source: own research.

	Year				
	2000	*2001*	*2002*	*2003*	*2004*
deaths	*6294*	*5534*	*5827*	*5640*	*5712*
injuries	*71638*	*68194*	*67498*	*63900*	*64661*
no. of accidents	*55464*	*52022*	*51773*	*49451*	*49414*
people killed per 1,000 accidents	*113,5*	*106,4*	*112,5*	*114*	*115,6*
people injured per 1000 accidents	*1291,6*	*1310,9*	*1303,7*	*1292,2*	*1308,5*

Table 3.2 shows the number of deaths due to accident in Poland in 1998 – 2000. This statistics was made to eliminate the factors having the influence on the road traffic safety mainly because of special characteristics of the Polish infrastructure. It is a noticeable fact that the number of pedestrians, horse-dawn cart drivers and another types mentioned in table 3.2 had fallen. Further comparisons prove that one of the basic assumptions of the improvement of road traffic safety should be the solution to the problem of using the same roads by cars, bicycles and all types of users mentioned in table 3.2. Moreover, limiting the risk of front impacts is also necessary.

Table 3.3 shows a comparison. It analyses the number of accidents, deaths and injuries per 100, 000 registered vehicles from 1998 to 2000 in Poland and France. The period indicating the highest increase in the number of vehicles was chosen. As observed, the relative values for French road traffic are more than two times smaller for the people killed in accidents. As for the injured, in both countries the number per 100, 000 registered vehicles fell in the given period. However, this fall is very signifi-

Tab. 3.2. The number of people killed in accidents in Poland in 1998 – 2000, source: own research.

year	Number of accidents	Deaths				total	Total deaths
		Pedestrians	Motorbike, motorcycle drivers	horse-dawn cart drivers	Front impact		
1998	59649	2655	575	15	1274	4519	7080
1999	53915	2446	643	11	1323	4423	6730
2000	55464	2226	616	9	1286	4137	6294

Tab. 3.3. The victims of accidents for the registered vehicles in the years 1998 – 2000. The minus in some boxes means that the data was unable to find. However, those factors for France are probably very low, source: own research.

	year					
	1998		1999		2000	
	Poland	France	Poland	France	Poland	France
accidents	59649	124000	53915	125000	55464	121220
deaths	7080	8400	6730	8000	6294	8079
deaths minus those in table 3.2	2561	-	2307	-	2157	-
injuries	77560	169000	68449	168000	71638	162000
$\frac{killed}{accidents} \cdot 100\%$	11,8	6,77	12,4	6,4	11,3	6,67
$\frac{injured}{accidents} \cdot 100\%$	130	136,3	127	134,4	129,1	133,6
registered vehicles	12709244	32575000	13169216	33355700	14106078	33601750
accidents per 100 000 vehicles	469,3	380,7	409,4	347,8	393,2	360,8
deaths per 100 000 vehicles	55,7	25,8	51,1	24	44,6	24
deaths per 100 000 vehicles but minus those from table 3.2	20,15	-	17.5	-	15,3	-
injuries per 100 000 vehicles	610,2	518,8	519,8	503,7	507,8	482

cant for Poland – it dropped to 100. It means a great improvement in the area of injuries. As far as deaths are concerned, the matter is still unsolved, as France has more cars and better roads. It does not indicate however, that road traffic safety in France is better than in Poland.

Despite the decrease in the number of accidents per 100,000 cars in Poland between 1998 and 2000, the death rate is still twice as high as in France. France reported fewer deaths, and the number of injured people was slightly lower in Poland. This fact can be explained only by greater average speed at which cars move in France on better roads. When comparing relative values it can be seen that the situation was more beneficial in France where, although three times more cars, the rate of deaths per 100 000 cars was in the given period slightly lower along with its general decrease in both countries.

To make full assessment of road traffic safety in both Poland and France, a comparison between every type of accident would be necessary. The results would probably show a great deal higher number of parallel impacts (mainly rear) in France. This is connected with roads and motorways, on which such accidents occur. On the other hand, old city and town centres are usually closed for traffic. Besides, there are ring roads, whose existence may influence the small number of side and pedestrian impacts in urban traffic. Although some indicators are close in value, there might be different root causes for this.

On the basis of data in table 3.3 some conclusions can be made. If problems of infrastructure in Poland had been solved in a different way, which means separation of bicycles and others from car traffic and roads with bands between lanes of different direction, the number of accident deaths could have fallen even by 60%. It means that by comparing relative values, the number of deaths could fall from 45 – 55 to about 15 – 20 per 100, 000 registered cars.

If one observed a hypothetic decrease of about 5 people over 3 years, then it is obvious how better the situation would be today. The level of road traffic safety would be more competitive in comparison with the countries seen as having cultural drivers.

As for the number of pedestrians, horse-dawn cart drivers, bicycle and motorcycle drivers as well as the victims of front impacts in France, a hypothetical assumption of their lack was made because it was impossible to collect the relevant data. However, it is important to take their existence into consideration but probably at a smaller rate than in Poland.

According to data in table 3.4 the number of injured in car accidents per 100000 vehicles in 2004 was smaller than in Germany and Great Britain. There were also fewer accidents per 100000 vehicles than in those two countries. However it is necessary to mention that there are more cars in both Germany and Great Britain as well as in France. As for the death rate, it seems to be the greatest of all four. Relying on the previous considerations we can assume that, if there was the proper road infrastructure in Poland, then those factors would surely be more competitive, given the smaller number of cars than in compared countries.

Tab. 3.4. The number of accident victims in Poland in 2004 compared with the chosen European countries, source: own research.

	Poland	Germany	Great Britain	France
registered vehicles	16704000	54082000	31950000	38809000
accidents	51069	339310	207410	85390
deaths	5712	5842	3221	5530
injuries	64661	440126	277619	108272
accidents per 100 000 vehicles	305,7	1835	649,17	220
deaths per 100 000 vehicles	34,2	31,6	10,1	14,24
injuries per 100 000 vehicles	387,1	2380,3	868,9	279

3.2. Technical inefficiency

The faults of car as a cause for accident play an unimportant role in the general number of accidents and car collisions. On the basis of data in table 3.5 we can assess how many accidents happen because of technical disabilities on the background of all accidents between 1995 and 2004. These results are presented to show how insignificant those car faults are in relation to the causes of all road accidents.

4. Summary

To answer the question whether the relevant steps towards improvement of road traffic safety were taken, and if they proved to be effective, we should relate to above-mentioned considerations. On the basis of comparing relative values we could ascertain, that despite the growth in the number of cars, the number of accidents, deaths and injuries per 100, 000 vehicles in Poland fell during the given 10 years. Moreover, in the last two years, i.e. from 2002 to 2004, some stability in the number of people killed in accidents can be observed. On this conclusion we could assume a stabilization of road traffic safety on a concrete level. Especially some elements of accident had stabilized.

The analysis relating to accidents and their casualties between Poland and France in 1998 – 2000 does not allow to synonymously state if the safety level in all European countries is the same. The comparison of the number of accidents, deaths, and injuries proves that in the analyzed period the differences were favourable for France. It is necessary to notice the decreasing tendency of the accident and injured factors for both Poland and France. We can predict that until the present their values are close.

5. Conclusions

Taking into account the above-mentioned consequences, the loss of car stability in motion can be expected. The reasons for this phenomenon lie mainly in deformation of a floorboard or a frame of car body. The most important aspect in car reparation after an accident is to make necessary measurements and operations leading to bring the body dimensions back to correct state. Above all it matters when repairing the elements carrying forces and loads.

From the presented statistical data above it is seen that the most frequent are side and pedestrian impacts. However, the second type does not involve great damage of the car, side impacts can lead to widespread deformations and disturbances in car body geometry. It is caused by the direct contact of stiff bodies with rough surfaces.

The analysis let to determine the chosen relations describing the level of road traffic safety in Poland and France. Those are not the results covering all the problems of assessment. Only a few factors were compared. It can be claimed that road traffic safety level (according to those factors) has stabilized on some concrete level, which is comparable with other European countries. As for injuries, there is not a big difference between the French and Polish situations. The matter which needs improvement is the reduction of the number of people killed in accidents. One of the answers to this question is the Polish road infrastructure. The presented results can lead to determine some directions for further improvement.

Tab. 3.5. Proportional participation of the faults detected to the mount of all accidents, source: own research.

	Year									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
the numer of registered vehicles	11185469	11765401	12283503	12709244	13169216	14106078	14724040	15525476	15898983	16701072
the numer of accidents per 100 000 registered vehicles	498	484	526,2	469,3	409,4	393,2	353,3	333,5	311	295,9
The numer of detected faults per 100 000 registered vehicles	10,6	7,6	5,1	3,4	2,6	2,2	1,8	1,67	1,4	2,4

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EKSPLOATACJA ZBROJENIA SZYBU GÓRNICZEGO W OPARCIU O GLOBALNY WSPÓŁCZYNNIK TŁUMIENIA

MAINTENANCE OF MINING SHAFT REINFORCEMENT BASED ON GLOBAL DAMPING COEFFICIENT

W eksploatacji urządzeń górniczych bardzo istotnym czynnikiem jest zachowanie równowagi pomiędzy ekonomią a bezpieczeństwem. Użytkowanie szybu górniczego według stanu związane jest z oceną jego stanu oraz oceną oddziaływań pomiędzy zbrojeniem szybowym a naczyniami wyciągowymi. W ocenie stanu technicznego zbrojenia szybowego wykorzystuje się heurystyczne metody wizyjne, ultradźwiękowy pomiar grubości elementów, pomiar „spokoju jazdy" itp. Nową, proponowaną metodą jest pomiar globalnego współczynnika tłumienia. Ponieważ metoda ta jest metodą selekcyjną, wymaga dodatkowych procedur diagnostycznych. Dobór tych procedur ukierunkowany jest na zmniejszenie niepewności otrzymanych wyników.
W artykule przedstawiono opis metody globalnego współczynnika tłumienia. Algorytm ten został zaimplementowany w przyrządzie pomiarowym. Przedstawiono sposób implementacji z zastosowaniem środowiska LabView oraz metody wirtualnych instrumentów Wyniki pomiarów importowane są do systemu bazodanowego. Na podstawie zebranych informacji podejmowane są decyzje dotyczące dalszej diagnostyki oraz dalszej eksploatacji zbrojenia szybowego. Prezentowany algorytm jest wdrażany w jednej z kopalni, oraz trwają prace nad jego udoskonaleniem.
***Słowa kluczowe**: analiza sygnałów, dekompozycjia falkowa, dekrement tłumienia.*

In mining equipment exploitation it is very important to keep balance between payoff and safety. Usage of shaft is related to its state assessment and the evaluation of interactions between shaft reinforcements and transportation vessels. In the reinforcement state assessment heuristic vision methods are used, ultrasonic thickness measurements, run stability measurement etc. Attenuation rate measurement is a proposed new method. Since this method is a selection method it needs additional diagnostic procedures. The choice of procedures is directed towards reduction of results uncertainty. The article presents the method of global attenuation rate. The algorithm was implemented into the measurement device. The method of implementation by means of LabView environment was presented as well as methods of virtual instruments. The measurement results are imported into database system. Based on the gathered information the decisions are made regarding future diagnostics and exploitation of the shaft reinforcement. The presented algorithm is being introduced in one of the mines and is constantly perfected.
***Keywords:** signal analysis, wavelet decomposition, attenuation decrement.*

1. Origin of the problem

One of the problems with determining the technical condition of a mining shaft is diagnostics of shaft reinforcement, operating under severe conditions and in aggressive, corrosion-inducing environment. The diagnostics may be even more difficult owing to the loss of the linearity of the track of mining vessels caused by tectonic shift.

The primary legal act dealing with the safe operation of mining machines is Ministry of Economy Decree from the 28th of June 2002 regarding health and safety at work and specialist fire precautions in underground mining plants (Dz.U. nr 139 poz.1169). This decree also covers requirements for lift devices, including guidance on the acceptable wear of shaft reinforcement. According to § 460, the elements of steel structure of the reinforcement are to be replaced if the wear exceeds the maximum permissible wear or 50% of primary nominal measure specified in technical documentation. This act has been extended by Minister of Economy Decree form the day 09-06-2006r enabling to specify another permissible wear of reinforcement elements [5]. Thus formed regulation unambiguously determines the assessment criteria, yet the problem remains of how to identify the elements showing the greatest wear. The main reason of this state of the issue is the fact that shaft reinforcement is a complex structure composed of, depending on the mine depth, from several hundred to several thousand elements. Given such numbers, it is difficult to select the elements of the greatest wear.

In maintenance practice it is accepted that the indicator of wear of steel elements of reinforcement is element wall thickness measured by means of various techniques, mainly with the application of ultrasound methods. Such measurements are beset by a number of limitations, including:

- Pointed character of measurement,
- Problems with measurements in case of corroded surfaces cavities etc.,
- No information about the stiffness of the beam being under dynamic excitation,
- Necessity of the proper preparation of the surface.

Examining of each structure element is very time-consuming and virtually impossible within the time expanse of routine controls and maintenance services. Hence, based on maintenance expertise or other circumstances, a limited set of elements is being established. Those elements are subject to periodical controls.

Other elements are assumed to feature similar wear. However, it is plausible that this selection could exclude the most worn out elements, which implies impossible to evaluate errors of the control [4].

Considering the safety measures of vertical transportation and economical aspects, as well as coalmine needs, for several years the Mechanics and Vibroacoustics Department of M&M Academy in Kraków conducted theoretical research and experiments intent on improving the reliability of diagnosis about technical state of shaft reinforcement. One of the objectives of the research is developing the method of quick selection of reinforcement elements and assigning them to the specified usability state. The assumption had been made that the new method should be simple to carry out, possible to apply under different environmental conditions, and the interpretation of the results should be easy. One of the main requirements was also the reduction of examination time as compared to the one in contemporary methods, and the possibility of conducting the method without the necessity of special preparations of the elements examined.

2. Applied methods

At present, knowledge about technical state of shaft reinforcement is gained through the results of the three manners of control [1,2]:

- The first is associated with visual inspection of the state of corrosion advancement. This method provides only simplified information.
- The second one is associated with non-destructive ultrasound tests. In these control procedures a point thickness measurement is carried out on structural elements of shaft reinforcement by means of ultra-sound defectoscope. An appropriate preparation of the installment surface of the transmitting head, onto an examined structural element, plays a very important role in these tests. Surface preparation involves removing contaminations and removing cavities and roughness mechanically. Apart from that, necessary requirement in these examinations is considering the appropriate acoustic feedback between the ultra-sound head and the examined element, which comes down to the application of suitable feedback means.
- Another control procedure providing information on mining-shaft state is examination associated with measurements of acceleration of mining vessels, or measurements of dynamic forces of the influence of mining vessels on shaft reinforcement during their movement. These testes include the evaluation of ride smoothness of lift vessels. The results of horizontal acceleration measurements of moving mining vessels provide data for this evaluation.

The results of acceleration measurements make allowance for both the influence of roughness of guiding rails and the setting of rolls installed into the vessels. Hence in the process of measurements of ride smoothness the setting of rolls is to be controlled and, if need be, adjusted as these rolls significantly affect the result of acceleration measurements of mining vessel.

3. Identification of damping coefficient

Review of articles devoted to the evaluation of structural degradation points to the existing specified areas of analysis, enabling to recognize changes in elements' states, among which the methods of modal analysis are of vast usage. However, in case of degradation of stiff elements of shaft reinforcement, the sensitivity of eigen-frequency changes for their occurrence is relatively low. Better symptom is the analysis of eigen-frequency forms under given circumstances, which generally is very troublesome.

In the analysis of general dynamic equation of diagnosed structural element:

$$M\ddot{x} + C\dot{x} + Kx = f(t) \qquad (1)$$

where: M, C, K – are respectively matrices of masses, damping and stiffness of modeled element, $\ddot{x}, \dot{x}, x$ - vectors of acceleration, speed and replacement respectively, f - vector of exciting force.

It cannot be overlooked that the changes in one matrix are connected to the parameters' change in another one. For example, change in mass of the system caused by the corrosion affects not only to the mass matrix, but also damping and stiffness matrix

In modal analysis estimating parameters of the equation (1), one of the assumptions concerning its carrying out is the requirement of low dumping in the system. In case of examining elements of mining-shaft structure this assumption is not justified and can induce some reservations. So the question arises of the possibility of applying changes of state of shaft reinforcement, as information medium associated with damping occurred in the system, into diagnostics process.

The assessment of possible application of this property into examining elements of shaft structure is the subject of the conducted research. It required estimating the selected measures of vibration damping for diagnosed elements in the process of testing excitations or exploitation excitations.

The application of damping characteristic as a carrier of information regarding technical state of reinforcement is limited by non-stationary character of measurement signal. Good solution in the process of its estimation is the analysis (in time domain) of the response of an examined system for pulse excitation. To explain this issue let us look into the case of free damped vibrations of a point described by equation:

$$m\ddot{x} + c\dot{x} + kx = 0 \qquad (2)$$

where: m, c, k – are parameters determining mass, damping coefficient and stiffness of the point given.

Introducing symbols:

$$\omega_0^2 = \frac{k}{m} \qquad 2n = \frac{c}{m} \qquad (3)$$

we bring the equation (6.2) to the form of :

$$\ddot{x} + 2n\dot{x} + \omega_0^2 x = 0 \qquad (4)$$

characteristic equation determining it:

$$r^2 + 2nr + \omega_0^2 = 0; \qquad (5)$$

allows calculating equation roots:

$$r_{1,2} = -n \pm \sqrt{n^2 - \omega_0^2} = -n \pm i\sqrt{\omega_0^2 - n^2} \qquad i = \sqrt{-1} \qquad (6)$$

which for subcritical damping brings the general solution of the equation (6) in the form:

$$x = e^{-nt}\left[c_1 \cos\sqrt{\omega_0^2 - n^2}\,t + c_2 \sin\sqrt{\omega_0^2 - n^2}\,t\right] \qquad (7)$$

It determines behaviour of the system, which is illustrated in a figure below (Fig. 1).

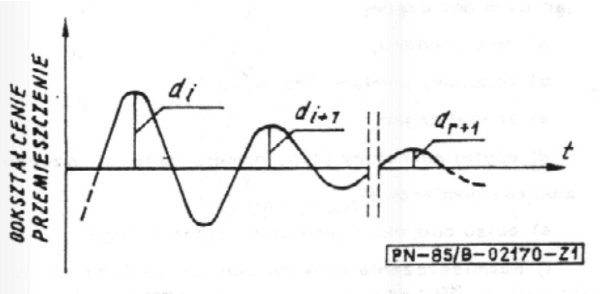

Fig. 1. Method of determining the damping of sinusoidal vibrations

The phenomenon of vibration fading, associated with damping occurring in the system, can be described by various measures. One of them is a logarithm of the consecutive maximum amplitudes. Their average value for r – number of periods (or half-periods) enables to determine the logarithmic decrement:

$$\delta = ln\left(\frac{1}{r}\sum_{i=1}^{r}\frac{d_i}{d_{i+1}}\right) \tag{8}$$

Such evaluations of vibration damping can be generalized and affiliated with the problem of evaluating of energy dissipation in a diagnosed structural element. However, careful attention should be paid to their correctness, in case of mono-harmonic signals' analysis. In the occurrence of exploitation excitation, various vibration frequencies are excited. Additionally, frequencies coming from the excitation could appear in the signal. Therefore the application of this procedure, in the evaluation of vibration damping of elements being examined, requires filtering the individual eigenfrequencies out of mono-harmonic signals. The main difficulty in such analyses could be questions of the requirement of considering phases of individual frequencies in the analyses of diagnostic signals, or conditions associated with non-stationary states [1].

Having the before-mentioned reservations in mind, in the search of method of reinforcement-structure damage detection based upon monitoring of variations in vibration damping in tits elements, authors needed to design algorithms of estimation of damping measure free of those limitations.

One of the best mathematical tools, useful in the estimation of damping in elements of steel construction executed in pulse test, could be new tools of analysis of non-stationary signals, including procedures of transformation measurement signals based on wavelet transformation. Wavelet-function group of given parameters is he core defining this transformation.

In case of estimation of damping coefficient, essential procedure of signal analysis is the process of separation monoharmonic parts. If a wavelet of concise, one-stripe spectrum is used in wavelet transformation, we could obtain information about measurement signal being convergent to a wavelet of known frequency characteristics. Exploiting this mechanism we can manufacture a wavelet filter, featuring no information loss and zero phase displacement in an analyzed signal.

By experimental selection of sequence of a coefficients of its wavelet function applied in the filter, an appropriate frequency range with the assigned resolution could be resulted

In this selection the analysis of PSD (Power Spectral Density) is very helpful. Based on this, number and range of frequencies occurring in a measurement signal.

Covariance method can be applied to the estimation of spectral density. Its application in reference to measurement signals in the discussed research problem brings a result illustrated in charts below (Fig. 2).

For the assessment of degradation of structural elements of reinforcement a critical-damping fraction can be applied. It is used in the assessments of building constructions, as calculated by the formula:

$$\xi = \frac{1}{N}\sum_{N}^{n=1}\frac{\delta_n}{2\cdot\pi} \tag{9}$$

Its estimation is possible after separating monoharmonic components out of diagnostical signal. In this process procedures of wavelet extensions could be exploited, as referring to measurement signals resulted from pulse test. Necessary preliminary stage in the process is determining the required resolution for executed analyses of decomposition of measurement signal. Its carrying out is associated with preliminary identification of eigenfrequencies of a diagnosed structural element.

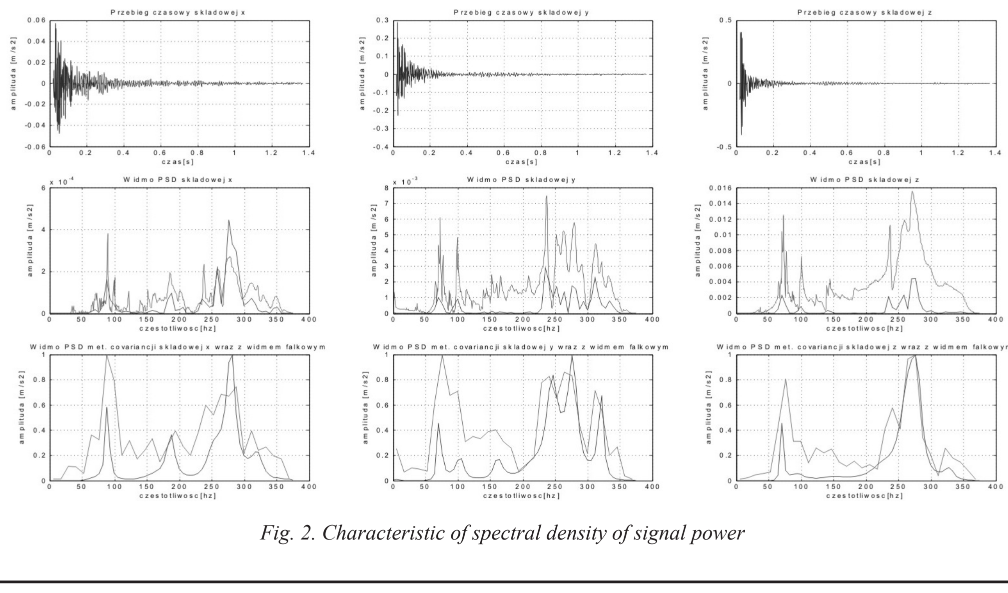

Fig. 2. Characteristic of spectral density of signal power

Based on the analyses, the level of wavelet decomposition for measurement signals has been established on the level 7. Its been stated that, for the process of estimation of damping of the analyzed shaft construction element, this decomposition level would secure the presence of significant frequency components in systems response for pulse excitation. Its been concluded that thus accepted decomposition level would not obstruct the frequencies, significant for calculations of frequency damping measure, reducing the time of their calculations.

The basis of the estimation of damping coefficients is the method of package wavelet decomposition. This method offers vast range of possibilities in signal analysis [3].

In wavelet analysis signal is divided into approximations and details. The approximations are again divided into approximations and details of level II. This process is repeated until reaching a priori assumed decomposition level. For n^{th} analysis level there exist n+1 viable paths of signal decomposition (Fig. 3).

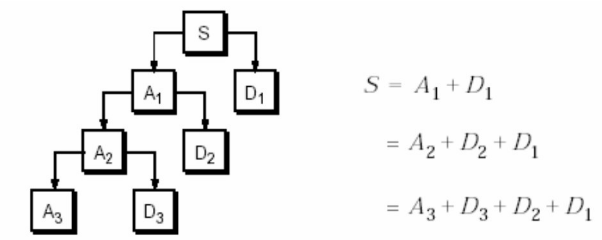

Fig. 3. Diagram of wavelet decomposition of signal

Wavelet decomposition contains properties of square filter of stabile characteristic in the pass band. A single decomposition level divides the signal into equal parts in the frequency domain. Approximations occupy the frequency band from constant component to the half of frequency band, whereas details take the remaining band section. In a package wavelet decomposition details are also divided into approximations and details of the next level (Fig. 4)

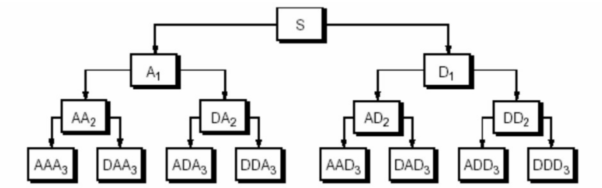

Fig. 4. Diagram of package wavelet decomposition

As a result of package wavelet decomposition of n^{th} level, a signal is decomposed into 2^n components. Symmetric division of the frequency band of an examined signal is being secured in each detail decomposition and approximation. So the bandwidth in the components of the lowest level is $1/2^n$ of Nequist frequency. It provides a possibility of controlling the approximation level and analysis accuracy.

In the case being discussed a package decomposition of 7th level has been applied. For the signal of sampling frequency of 1 kHz the bandwidth of 3,9 Hz was obtained. Analyses STFT and PSD proved that this bandwidth provides monoharmonic property of individual components with assumed accuracy.

In vibrations with eigenfrequencies the energy fluctuates between the individual forms. This effect causes that in the time of vibrations of individual forms there occurs the energy transferring from another vibration form, hence the vibration amplitude increases. In order to eliminate this effect from time characteristic, only those time compartments are accepted in damping analysis, of which the entropy of isolated system is rising. It has been achieved by the examination of individual local extreme values. For those values a logarithmic damping decrement is approximated (Fig. 5).

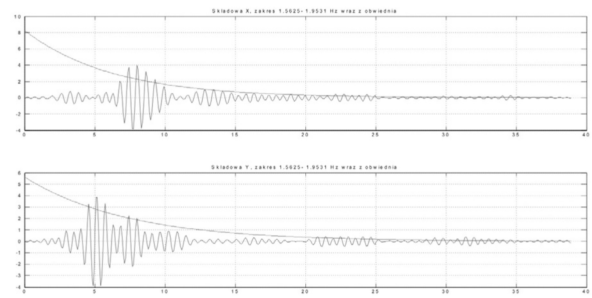

Fig. 5. Time characteristics of selected realization of decomposition (blue) and approximated logarithmic damping decrement (green)

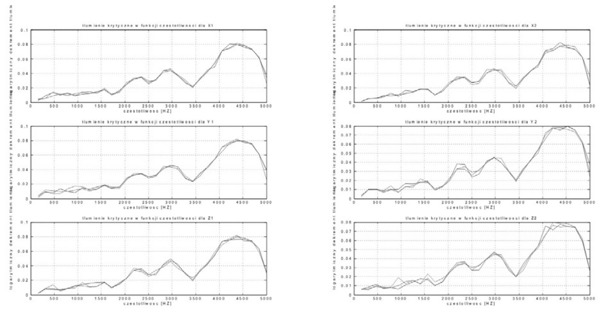

Fig. 6. Logarithmic damping coefficient as a frequency function

After calculating damping coefficient for individual realizations of decomposition we yield vector of size 2^n. It is connected with frequency, therefore it is possible to present damping in the spectral form. In order t obtain one-number damping value, square of spectral damping form is considered.

Package decompositions of individual measurement signals were carried out, with the assumptions settled before. Then for those signals a logarithmic damping decrement was determined. The results of executed calculations of damping decrement characteristic as frequency function, for the pulse-test carried out on one of the elements of shaft construction, are presented below.

It can be regarded as a diagnostical symptom for monitoring changes of condition of diagnosed shaft structure and procedure of detection of damages in reinforcement elements.

4. Analysis of results

Presented algorithm of estimation of global damping coefficient was implemented in portable measurement device. Measurements were carried out in several mining shafts copper ores and hard coal. The analysis assumed the proper condition of the whole reinforcement, and the examinations are to prove the departure from this rule. Confirmation of this assumption was, in a great majority of shafts, the distribution of normal global damping coefficients in a given category of reinforcement element (Fig. 7). Such a statistical distribution offers the possibility of the

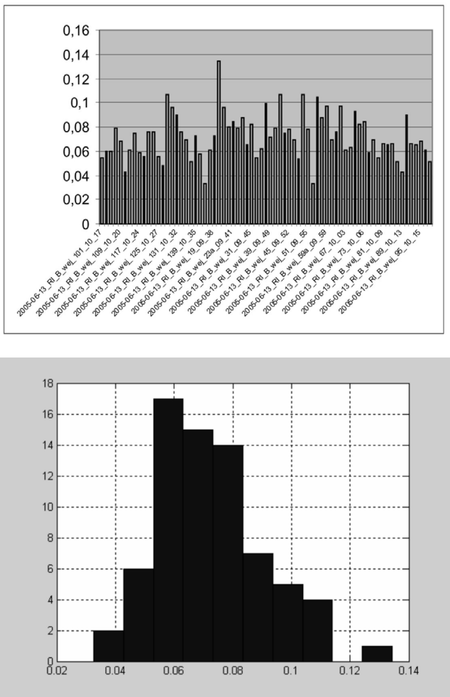

Fig. 7. Results of examination of shaft guide-rails and statistic distribution of the obtained results

application of model 3σ for determining decision compartments. The elements, whose global damping coefficient does not fit into specified standard deviation, are classified as elements intended to be tested by other methods.

Further research and comparing the results with the model ones, indicated high accuracy of diagnosis of shaft reinforcement condition. In many cases the method of global damping coefficient pointed to damages of elements, which were not detected by comparative methods. Check-up examinations confirmed that they were unserviceable.

5. Conclusions

Experimental exploitation of mining shaft based on the method of global damping coefficient revealed a number of positive properties. The most important include reducing the global time of shaft examination. Initially applied method of global damping coefficient as a selection method reduces the number of elements left to be examined by other methods – for example by ultrasonic method. The important advantage of the presented method is determining of dynamic properties not only of the examined object itself but also of its attachment and the surrounding. Thanks to that it is possible to evaluate the quality of screw-joints in shaft reinforcement.

Maintenance of mining shaft with the application of the examination of global damping coefficient significantly improved the operating safety of the shaft. Lowering maintenance cost resulted from both safety improvement and efficient usage of reinforcement elements, as well as repair of only those structure elements that are needed to be repaired.

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This work has been done within the confines of research project Nr PW-004/ITE/07/2005 encompassed by Long-term Programme PW-004

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PRZEGLĄD PRAC BADAWCZYCH NAD WPŁYWEM GEOMETRII NACHYLONEGO SITA ŻALUZJOWEGO NA JEGO PRZESIEWALNOŚĆ

A REVIEW OF THE RESEARCH WORK ON THE IMPACT OF THE GEOMETRY OF THE INCLINED ADJUSTABLE SECTION SIEVE ON ITS SCREENING ABILITY

W niniejszym artykule przedstawiono prace badawcze poszukujące rozwiązania zapewniające pełną skuteczność segregacji i czyszczenia masy poomłotowej podczas pracy kombajnu na terenach o nachyleniu do 15⁰. Badania prowadzono nad zastosowaniem sit żaluzjowych ukształtowanych cylindrycznie, daszkowo i wzdłużnie dwupłaszczyznowo.

***Słowa kluczowe**: sito żaluzjowe, geometria sita, separacja, nachylone poprzeczne i wzdłużne, kombajn zbożowy*

The paper reviews the studies aimed at finding the solution to guarantee the full effectiveness of segregation and cleaning of the treshing mass for the combine-harvester operating on the slope up to 15⁰. These investigations were carried out with the adjustable section sieves shaped in a cylindrical, canopy or longitudinal two-plane form.

***Keyword**: adjustable section sieve, sieve geometry, separation, transverse and longitudinal inclination, combine-harvester*

1. Introduction and research genesis

Now there is careful attention to change the construction of the combine-harvester as it is and will probably still be, considered the main harvesting machine not only in Poland but also all over the world. In fact, these are the separation-cleaning units that are an integral part of the combine harvesters and other treshing machines. To make it possible for the combine-harvesters to collect crop seeds that vary in shape and size, the adjustable section sieves need to be applied. There is no objection to the work of the separation-cleaning sieve unit while it is operating in the horizontal position. The significant negative changes may occur both on the transverse and longitudinal slopes, as the kinematics of the grain screening becomes modified. This leads to reducing the effectiveness of screening and cleaning grain mixtures on flat sieves [5,6,9,11].

There were some earlier solutions to improve the screening effectiveness of the combine harvesters working on the slopes and they were focused on the: automatic body levelling system [10], automatic system of the levelling sieve basket complex [7,8], evening up the grain mass surface by air stream and controlling sieve vibration. Those solutions, and in particular automatic levelling system are, unfortunately, very expensive [1].

The aim of the tests carried out at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences since 1998 was to find such solutions that could guarantee the full segregation and cleaning effectiveness of the threshing mass, while the combine-harvester is operating on the slopes up to 15^0, and application of which will not necessarily increase the machine costs [2].

Due to multidirectional movement of the combine-harvester, there is a need to take into account the impact of both the transverse and longitudinal sieve inclination. Therefore, the working hypothesis has been assumed that the modification of geometric sieve features with maintaining basic kinematic parameters of the flat sieve may prevent the grain mixture from moving. This happens as the components of the gravity force, acting on the material particles both at the plane transverse and longitudinal to the movement, change their values.

The paper presents some of the research achievements in the application of the adjustable section sieves shaped in a cylindrical, canopy or longitudinal two-plane form. When the combine-harvester is operating on the transverse slope (movement along the contour lines), the threshing mass tends to slide down to the lower side of the separator unit. To counteract this problem, it was suggested that the sieve surfaces should have either the cylindrical or canopy shape. On account of the longitudinal inclination it was also considered to apply together two-plane and canopy sieve. The cylindrical sieve was designed as a longitudinal section sieve with changeable angles of section inclination. Figure 1a provides a hypothetical mass distribution on the flat sieve transversely inclined at an angle α. The mass distribution on the sieve having a cylindrical form is presented in Figure 1b [4]. The other solution suggested by the authors is to divide the sieve plane into longitudinal working sections of the canopy shape. Figure 2a shows the cleaned mass on the above-mentioned sieve working in the levelled position. When the sieve is inclined, there is a change in the force distribution acting on the material and this prevents it from moving into the inclination direction (Fig. 2b). It results in reducing the thickness of the mixture and also removing (totally or party depending on the inclination value) the sieve planes out of operation [5].

Two-plane sieve consists of two planes, and it has been assumed that while combine-harvester is operating on the slopes inclined at an angle β (up the hill) the main plane would be working under unfavourable conditions i.e. the screening effectiveness will be reduced. The additional half-open part of the separator will be running at an inclination opposite to the main plane (Fig. 3). During the tests two angles were adjusted: β - deflection angle of the sieve basket main plane in a way to simulate the operational conditions of the combine-harvester moving „up the hill" and „down the hill" and δ - bending angle

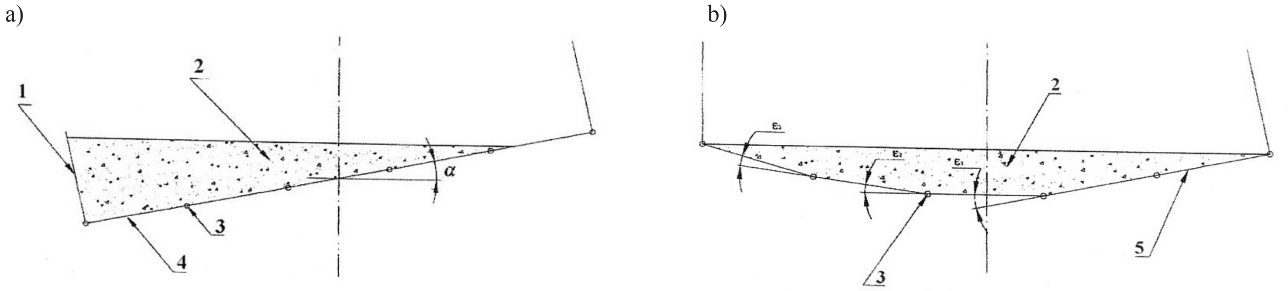

Fig. 1. Distribution of the screened material on the cylindrical sieve in the transverse inclination: a– sections of the cylindrical sieve arranged in a flat way (flat sieve model), b–extremely raised sections, 1- side passive surface, 2- cleaned material, 3- articulated joint of the section, 4- flat-arranged sections, 5- section of the cylindrical sieve, α – inclination angle of the flat sieve, ε_1, ε_2, ε_3, - inclination angle of the cylindrical sieve section

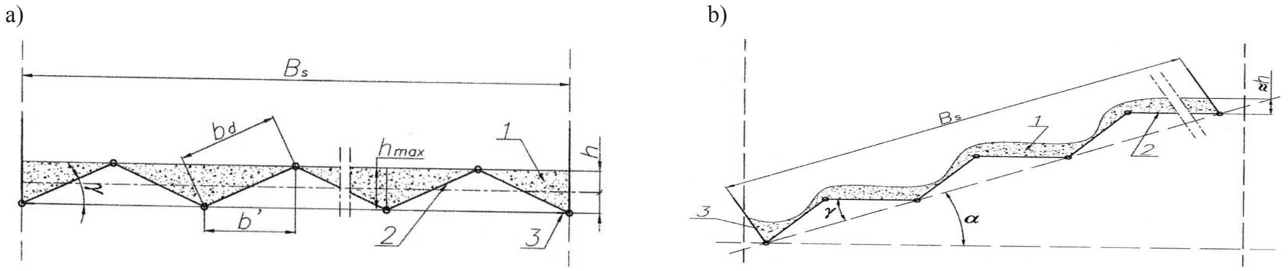

Fig. 2. Distribution of the screened material on the canopy sieve. a- operating in a horizontal position, b- operating inclined at α; 1- cleaned material, 2- element of the canopy sieve section, 3- frame of the sieve basket, B_s- sieve width, b_d- width of the canopy sieve element, h_{max}- maximum thickness of the cleaned mass at the beginning of the process, $h = h_{max} / 2$ – average thickness of the cleaned mass at the beginning of the process, α- angle of the lateral inclination of the sieve basket (≈ land slope), γ- inclination angle of the canopy sieve element

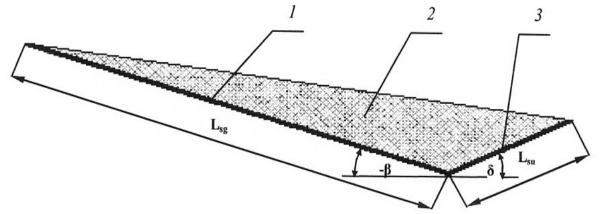

Fig. 3. Distribution of the screened material on the two-plane sieve inclined at β; 1- main sieve plane, 2- grain mass to be cleaned, 3- adjustable half-open part of the sieve, L_{sg}- length of the main sieve plane, L_{su}- length of the half-open part of the sieve, β- inclination angle of the sieve basket (up the hill), δ- angle of the additional sieve plane inclined from the horizontal plane

m o

	X1	X2	X3	X4	X5
Y1	1	1	1	1	1
Y2	2	2	2	2	2
Y3	3	3	3	3	3
Y4	4	4	4	4	4
Y5	5	5	5	5	5
Y6	6	6	6	6	6
Y7	7	7	7	7	7
Y8	8	8	8	8	8
Y9	9	9	9	9	9
Y10	10	10	10	10	10

z

Fig. 4. Position of the measurement zones under the sieves; X1 – X5 number of the sieve section, Y1 – Y10 number of the measurement zone under the sieve section, m o – threshing mass, z - contaminants

of the half-open part from the main plane. Figure 4 shows the range of the applied inclination angles of the main and additional sieve planes from the horizontal and main plane of the sieve, respectively [6].

2. Materials and methods

The tests were carried out at the tilting stand to make it possible to incline the sieve basket in many planes, from 0^0 to 15^0. The inclination angle of a whole stand had been changed to simulate the real conditions on the slope and change the inclination angles of the particular sieve sections. The amounts of the sieved mass were measured at each position of the sieve sections and various sieve inclination simulating the slope. Such measurements were run in five replications. Kinematic design of the stand was presented by the authors before [3]. The main dimensions of the sieve basket and the sieve complied with those applied in the Bizon Z058 combine-harvester. There were also the same kinematic parameters of the sieve basket drive.

During the tests the grain mass with contaminants was delivered into the sieve surfaces. Its quantity and the way of delivering corresponded to the operation of the transverse, radial-tangent threshing unit of a general flow capacity of 6÷8 $kg \cdot s^{-1}$. The following symbols were assumed to determine the angle of the stand frame (sieve) towards the horizontal plane: α – transverse inclination (simulation of the movement along the slope), β – longitudinal inclination (simulation of the movement

„up the hill" and „down the hill"), δ – inclination of the half-open part of the separator from the main sieve.

There were fifty measurement zones, ten along each section, under the main sieve (Fig. 4).

Additional 40 measurement zones were installed in the area of the half-open part of the sieve (Fig.5). Grain mass was recorded at each measuring point. The research results were analysed using the computer statistical package EXCEL and STATISTICA.

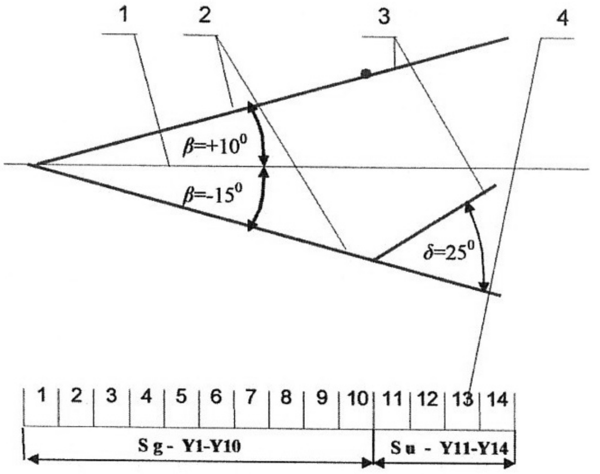

Fig. 5. Deflection scheme for the main and half-open planes' of the two-plane sieve from the horizontal plane β, δ- deflection angle of the half-open plane; 1- horizontal plane, 2- main sieve of the separator, 3- half-open sieve of the separator, 4- measurement points, S g - Y1 – Y10 – measurement zones under the main sieve, S u - Y11 – Y14 - measurement zones under the half-open sieve

3. Discussion

The screening tests with the transversely inclined sieve began with the modification - it was suggested that a cylindrical sieve would be assembled instead of a flat one. The terminal sections of the sieve remained inclined as shown in Figure 1b. The sieve basket frame together with the stand body was due to the changes of the inclination simulating the operation of the side-inclined separator. Distribution of the cleaned mass in the Y1 – Y10 measurement zones seemed to follow the rule of the longitudinal grain movement on the sieve, reaching the maximum at the border of the Y2 – Y4 zones. The load of the longitudinal sieve sections marked as X1 – X5 in Figure 6 increased with the decline of the frame inclination reaching the highest amounts of the cleaned mass on the X4 and X5 sections.

The second part of the tests was directed to assess the screening of the canopy-shaped sieve (Fig. 2). These studies included all combinations of the canopy positions (γ= 0^0, 5^0, 10^0, 15^0) and stand inclination (α= 0^0, 5^0, 10^0, 15^0).

The paper presents grain distribution under the sieve for the example position of the canopy sieve – land slope angle α=10^0 and inclination angle of the section canopies γ=10^0. The distributions achieved prove that the application of the canopy sieve seemed to be beneficial. The adjustable canopy sieve turned to meet the expectations as its application led to improve the effectiveness of grain separation, what is indicated by a better distribution of the mass under the sieve. Improved screening was recorded on the X1 and X2 sections and the grain load reduction - on the X4-X5 sections (Fig.7).

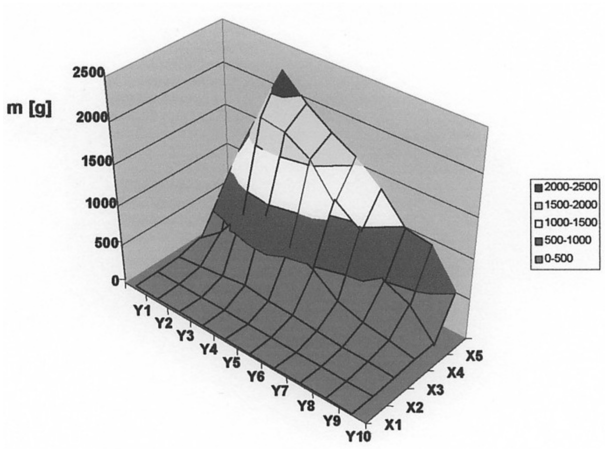

Fig. 6. Distribution of the grain mass m under the cylindrical sieve inclined at an angle α=10^0 "simulation of the movement along the contours ", X1 – X5 sections of the cylindrical sieve, Y1– Y10 measurement zones

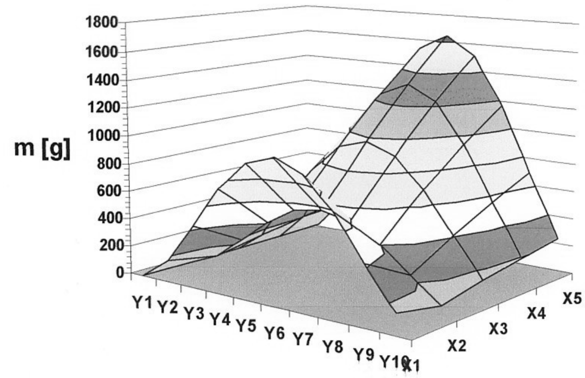

Fig. 7. Distribution of the grain mass m under the canopy sieve inclined at an angle α=10^0; inclination angle of the section canopies γ = 10^0, X1 - X5 – sections of the canopy sieve, Y1-Y10 – measurement zones

Except for the experiments at the stand, there were field experiments carried out simultaneously. They pointed out the direction for further activities that should be focused on limiting the unfavourable effect of sieve inclination on the separation. In particular, the impact of inclination for the separator (combine-harvester) moving up the hill must be reduced. When the sieve is inclined at an angle β = 10^0 to simulate the longitudinal inclination (movement "up the hill"), there is a strong tendency that the grain on the standard one-plane sieve is screened mainly at the sieve edge (Y14). Then, during the continuous operation of the sieve, the losses may reach up to 33%. The application of two-plane sieve and increasing the inclination angle of the half-open section δ to 25^0 resulted in shifting the extreme of the screened masses into the middle part of the Y8 zone (Fig. 8). It means that the effectiveness of grain separation increases while the combine-harvester is going up the hill and with reducing the speed of the cleaned mass on the sieve, grain losses became almost totally reduced.

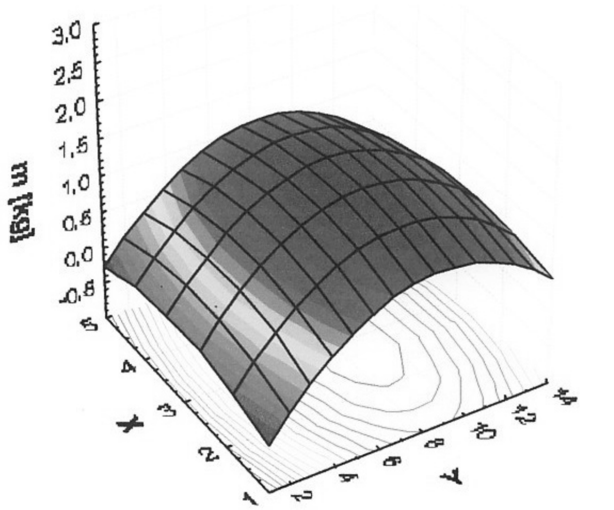

Fig. 8. Distribution of the grain mass m under the two-plane sieve at the main plane inclined at an angle β = -10⁰ „simulation of the up hill movement" for α = 0⁰ and inclination angle of the half-open section δ = 25⁰, X1 - X5 – sections of the two-plane sieve, Y1-Y14 – measurement zones

4. Conclusions

The analysis of grain mass distributions under the geometrically-shaped section sieves made it possible to formulate the following conclusions:

1. All of the sieves of changed geometry were found to improve the effectiveness of grain mass separation when the sieve basket is inclined up to 15^0.
2. The effects of properly-operated sieve models indicated that they could be applied in traditional combine-harvesters and thus, grain mass losses would be reduced on the hilly lands. Particularly good effects were achieved for the two-plane sieve with the automatic regulation of the inclination angle of the half-open section.

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Jerzy LEWITOWICZ

ZARZĄDZANIE I STEROWANIE POTENCJAŁEM EKSPLOATACYJNYM FLOTY STATKÓW POWIETRZNYCH

MANAGEMENT AND CONTROL OF THE POTENTIAL EXPLOITATION OF FLEET AIRCRAFTS

Każdy system wykorzystywany może być efektywnie, co oznacza uzyskiwanie maksymalnej skuteczności przy minimalnych kosztach. Jest to możliwe odpowiednio wykorzystując skuteczne strategie zarządzania, sterowania i kierowania tym systemem. Strategie te oparte powinny być na ciągłym śledzeniu zmian odpowiednich wskaźników niezawodnościowych, bezpieczeństwa i efektywności eksploatacji systemu z uwzględnieniem ryzyka wykonywania misji (zadań eksploatacyjnych). Takie podejście podatne jest na modelowanie. Rozważono model decyzyjny dotyczących zarządzania, sterowania i kierowania systemem i procesem eksploatacji flotą statków powietrznych.

***Słowa kluczowe*: lotnictwo, eksploatacja, zarządzanie, statki powietrzne**

Any system can be used effectively, which means maximum effectiveness is reached at a minimum cost. It is feasible if effective strategies of managing, control and administrating the system are suitably applied. The strategies should be based on continuous observation of changes in appropriate reliability and safety rates and those of effectiveness of the system operation, with account taken of the risk of performing a mission (operational task). Such approach is liable to the modelling. Consideration has been given to a decision-making model referring to the management, control and administration of the operational system and process, and to the functioning of the system.

Keywords: *aviation, exploitation, management, aircrafts*

1. Introduction

By definition, operation is a set of conscious activities that lead to a desired result. Therefore, scientific research should provide fundamentals for efficiency of such activities. Content of such approach is finalized in continuous progress of ideas, concepts, methods, procedures and tools as well as diagnoses and predictions. Though, the progress, similar to any other area of human activities, encounters a number of obstacles. Despite the fact that technical progress, including progress in operation and maintenance techniques, is virtually unlimited, rates of such progress subject to variations and have their upper limits, although still unknown. Various factors that restrict rates of technical progress are identified, not to mention the following:

- human factors with restricted ability to perceive and adopt new ideas,
- research methods that are considered as adaptable to the areas of operation knowledge and maintenance practice,
- affordability of offered solutions limited by economic incapability of structures and organizations that deal with operation of OT.

Knowledge related to technical operation is generally dedicated to performance of typical assignments that are referred to as operation tasks.

Operation task is a set of activities with a defined objective or a set of objectives. The task is performed in a defined space and time (space-time continuum of operations).

Operation tasks are subdivided into classes, series, groups, etc. Subdivision criterion results from specific features of the OT and its scope of dedication (assignment). Knowledge of operation and maintenance processes assists in successful completion of assigned tasks. It serves as the basis to set up the system of methods – procedures – tools (MPT) for execution of operation tasks. The tasks represent sequences of sophisticated actions that make up together operation events with complex time-related interconnections. Thus, the MPT is the base to define scope of operations within a single operation task.

Service and replenishment operations represent simple actions with only a limited set of MPT's. Diagnostic and maintenance actions and more complex, hence they are supported by relevant text and graphic documents (usually computer-aided documentation systems).

Each task should have strictly defined criteria for its correct execution with particular stress to crucial phases and components. Such an approach makes it possible to take maximum possible advantage of potential benefits inherent to any piece of technical equipment. e.g. an aircraft (SP), including its operation potential and operation energy [4].

2. Operation potential and operation energy of aircrafts

Operation potential (*Pe*) shall be understood as the enabling resource of an aircraft to carry out a defined number of flights. The potential is attributable to every aircraft and is released during performance of flights (operation).[1]

[1] Such a definition of *Pe* complies with the meaning of the word "potential" as it is common in the referenced literature. Potential is: a) "an overall resource of power, production capability [or operation ability, as here used – *J.L.*] that is inherent to something", b) a field represented by a function (a scalar of a vector one). That field is defined by differentiation, hence the potential [is – *J.L.*] determined only by a defined accuracy [4] c) e.g. "thermodynamic potential that make it possible to determine the work that is performed by the system during a specific process". The cited content

Operation energy (*Ee*) shall be meant as "something" that can be obtained from an aircraft during its operation. The energy has been accumulated during the manufacturing process and can be replenished (refilled) in various refurbishment and revamping processes.[2]

Every aircraft undergoes various phases and operation states during its operation lifetime (Table 1).

The term of aircraft status has several meanings. The system of aircraft operation has its initial status ($S_{puż}$), associated with the initial value of operation potential (Pe_p) and final status ($S_{kuż}$) characterized by its final operation potential (Pe_k). The difference of operation potentials equals to the useful value of operation energy:

$$Ee = \left(Pe_p - Pe_k\right) \cdot \beta \tag{1}$$

where: β – numerical parameter that stands for the unit value of energy *Ee* per a unit of potential *Pe*.

The obtained value of operation energy (*Ee*) can be defined for a single flight (single operation cycle of an aircraft) or for multiple flights of for the entire lifetime (all the flights) of an aircraft.

The term of operation energy is transformed into the term of achieved economic benefit in accordance to the formula:

$$K_w = \alpha \cdot Ee \tag{2}$$

where: K_w–unconditional economic benefit that is used for civil aviation or relative economic benefit used for military aviations, *Ee* – operation energy that can be released during the aircraft lifetime, α – coefficient that stands for the rate of economic benefit per a single unit of operation energy.

For operation of aircrafts that make up the entire fleet of an avionic transport system (LST) that consists of *N* types of aircrafts and each type comprises *M* units can be expressed by the total operation energy Ee_f inherent to the system:

$$E_{ef} = \sum_{i=1}^{N} \sum_{j=1}^{M} Ee_{ij} \tag{3}$$

Formal characteristics of the system operating condition can be noted with use of: the value of operation potential *Pe*, the value of operation potential variation rate φ, where:

$$\varphi = -\frac{dPe}{dt} \tag{4}$$

The values of *Pe* and φ can be positive, negative or zero.

Table 2 presents an example for classification of selected operation states in various operation phases. In accordance to the foregoing rule, the terms of maintenance, overhaul or revamping, etc. potentials can be introduced.

3. Administration and control of an aircraft fleet

Control, management and administration[3] of an operation system (SE) refers to the organizational structure of the system as the anthropotechnical system, while in other aspect as the technique of application of this system (its operation and

Tab. 1. Functional phases and subsystems, operation statuses of aircrafts

Phase name	Phase symbol	Aircraft	Subsystem name SE	Symbol
Aircraft operation	Uż	Initial status $S_{puż}$ Final status $S_{kuż}$	Aircraft operation	PEUż
Aircraft maintenance	Ut	Initial status S_{put} Final status S_{kut}	Maintenance of aircraft operability status (the aircraft is permanently ready to perform its tasks)	PEUt

Tab. 2. Example for description of operation statuses

Pe / φ	Situation 1		Situation 2		Situation 3	
	Pe = 0	Value Ee ↗	Pe	Value Ee ↘	Pe	Value Ee
φ= 0	downtime waiting	Ee = 0	-	-	-	-
φ > 0	-	-	overhaul, resource extension	Ee = 0	-	-
φ < 0	-	-	-	-	flight	Ee > 0

that is assigned to the term "potential" exhibits and reflects, to the best possible extent, the phenomena that occur during the operation process. Useful value can be obtained from an aircraft, that value can be defined as the operation energy. It is portent to pay attention to the phrase "with a defined accuracy" that is achievable for description of the field of operation potential, and, consequently, resulting effects of that potential, such as reliability, safety and readiness. Measures and values that describe these phenomena can be deterministic figures solely for the first approximation thereof. Actually, we have to deal with probabilistic and undeterminable processes and the measured value can be defined only with the maximum achievable accuracy.

[2] The term *Ee* jest complies with the meaning of the word "energy" as it is common in referenced literature. [4]. Energy is) „penchant and ability to act in intense manner – the value that reflects the system ability to carry out a specific work", b) "the scalar physical parameter that conforms to the strict law of conservation and is used for quantitative description of various processes and types of interactions, c) "the universal physical value that us suitable for description of all the kinds of processes and interactions that occur in nature".

[3] Control – is understood as tracing the direction or evoking positive alterations, Management – is giving guidelines, instructions, directives or indications to be carried ot in order to achieve desired alterations, Administration – is the process of acting, chiefly in the sphere of personnel administration

maintenance). Control, management and administration is most frequently considered, i.e. described and modelled, in the categories of a process [1-8]. As result of such processes a desired effect is achieved, whose extent depends on the realization of the program, e.g. controlling as an extorting action.

Appropriate management of a fleet of aircrafts operated within a common system depends of efficient course of operation, exhausting and reliable information on operation and disastrous phenomena and events. Management refers to the spheres of technology, economy and social relations. By means of so called management engineering it solves problems that may arise along the borderlines of these zones [5].

The management process deals with events that happen in time moments and have defined duration (shorter or longer), therefore it is a process. As time passes, the information that serves for decision-making can become out of date at the moment when the actions caused by the specific decision are to be put in practice. This is connected with the term of operation time relativity [4].

Operation management of a single aircraft consists in organization of its use in accordance to the adopted operation strategy (by its resource, technical condition, age, reliability, etc.) until the aircraft lifetime is expired (flight hours or calendar age). Full (exact) records on the aircraft operation, its overhauls and revamps should be kept and retained.

Operation of aircrafts in accordance to conventional strategies (resource, technical condition and others) is well known and put in common practice. It is governed by relevant regulations and employs appropriate on-board and land-based diagnostic methods and tools for prediction of technical condition of the equipment. But a new strategy for operation management of aircrafts by age thereof has recently appeared [9]. The need to develop such a strategy has arisen due to premature so called calendar ageing. It refers to such aircrafts that have not completed their operation resource, counted as hours of flights, but have reached their calendar lifetime. This strategy, being more economical, needs to develop new methods, procedures and tools.

Efficient management of aircraft fleet should be based on optimal organization, well-defined interactions supervision of operation and assessment of results caused by various decisions in accordance to the adopted criterion of operational target.

The next component of efficient management is working out decisions of various nature and related to actions, operations and strategies.

By assumption, every decision should be correct, effective and preferably optimal one.

Among various decision-making models [2, 6] the probabilistic approach is the most popular. The model is described by the formula:

$$\mathbf{E}(y) = \int_{-\infty}^{\infty} F(x,a) f_a(a) \mathrm{d}a \qquad (5)$$

where: $\mathbf{E}(y)$ – expected value (EV) for the y variable, $f_a(a)$ – function of probability density of the for the a parameter

The expected value (2) should be minimized with respect to x and the result is the most advantageous in terms of the average value, i.e. for a specific number of working cycles it gives the lowest average value of y.

It is assumed that the operation system is controllable. Thus, it must be composed of a control unit and a controlled module. The controlled module transforms matter or energy. The control system is used for information processing.

Controling (management, administration) operation system is embedded into the cycle of planning and monitoring of activities by means of information circulation, which is nowadays achieved with aid of computer systems (Fig. 1).

The operation control process (for every operation system) represents a sequence of states and operation activities between the stated that make up a chain of events during the time when an aircraft is used in an avionic transport system (LST). It is the process that should guarantee:

- reasonable operation of aircrafts in accordance with the intended use thereof,
- maintaining aircrafts in full readiness to perform their functions and assigned tasks, to enable faultless operation thereof for the defined scope of operation tasks, with account of the existing resources, restrictions and disturbances under defined conditions and time.

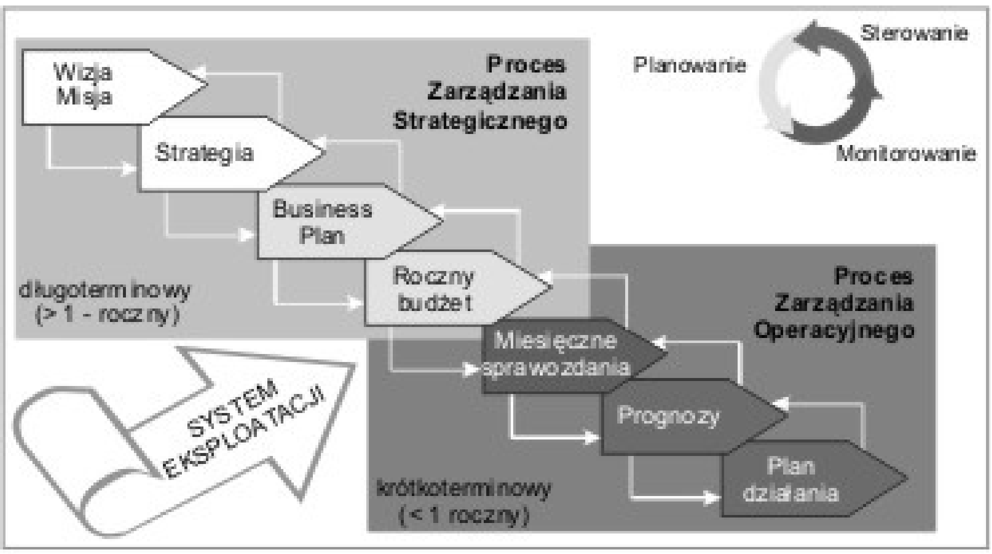

Fig. 1. Activities within the aircraft operation system

The set of control operations *DS* can be symbolically expressed in the following form:

$$DS = \{D, G, P, P_r, R_o, \mathrm{DZ}\} \tag{6}$$

The set incorporates the following components:

- diagnostic operations $D(t_i)$ as verification of a hypothesis that is moved at the moment of t_i about the system condition at the moment of t_i;
- genesis operations $G(t_i)$ as verification of a hypothesis that is moved at the moment of t_i about the system condition at the moment of t_{i-1};
- prediction $P(t_i)$ as verification of a hypothesis that is moved at the moment of t_i about the system condition at the moment of t_{i+1};
- prophylactics $P_r(t)$ as the activity that is carried out at the moment of t_i in order to prevent the system against the undesired predictable state at the moment of t_{i+1};
- revamping R_0 *(t)* as the activity that restores the state of the system as it was before the moment of t_i;
- replenishment activities *DZ*.

The most troublesome parts in the control process are the following: selection of a suitable model of the actual process and selection of diagnostic signals [3]. These problems must be solved individually, each time when detailed specification of the operated system is to be carried out.

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POŁOŻENIE BELKI POLOWEJ OPRYSKIWACZA A ROZKŁAD PRZESTRZENNY ROZPYLONEJ CIECZY I POKRYCIE OPRYSKIWANYCH POWIERZCHNI

IMPACT OF THE POSITION OF THE SPRAYER FIELD BEAM ON THE SPATIAL DISTRIBUTION OF THE SPRAYED LIQUID AND THE DEGREE OF COVERAGE OF THE TREATED SURFACES

W opracowaniu przedstawiono wyniki prac prowadzonych od kilku lat w Instytucie Inżynierii Rolniczej Uniwersytetu Przyrodniczego we Wrocławiu. Celem tych badań było określenie położenia belki polowej opryskiwacza przy zmianie parametrów i warunków pracy. Zmiana ustawienia belki polowej w płaszczyźnie pionowej powoduje zmianę wysokości rozpylania poszczególnych rozpylaczy umieszczonych na belce jak i ich asymetryczne ustawienia w stosunku do opryskiwanych powierzchni pionowych. W związku z tym w wynikach badań przedstawiono również ocenę rozkładu poprzecznego opadu rozpylanej cieczy oraz stopień pokrycia opryskiwanych powierzchni w zależności od ustawienia belki.
Wyniki badań wykazały, że każde wychylenie belki w płaszczyźnie pionowej powoduje zdecydowane pogorszenie jakości opryskiwania określanej przez wskaźnik zmienności rozkładu poprzecznego i stopień pokrycia.
Słowa kluczowe: *belka opryskiwacza, nierównomierność poprzeczna, stopień pokrycia, rozpylacz*

The paper presents the research findings from the studies carried out for a number of years at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences. The aim of the studies was to determine the position of the sprayer field beam when the working parameters and conditions vary. The change of the beam position in the vertical plane results in modifying the spraying height of the particular spray nozzles on the beam. This also leads to their asymmetrical arrangement in relation to the treated vertical surfaces. The research results also include the assessment of the transverse distribution of the sprayed liquid fall and the degree of coverage depending on the beam position.
The results proved that each beam deflection in the vertical plane significantly reduced the spraying quality, which is measured by the variability index of the transverse distribution and the degree of coverage.
Keywords**:** *sprayer beam, transverse roughness, degree of coverage, spray nozzle*

1. Introduction

Chemical plant protection is of particular importance in modern agricultural technologies as it not only helps maintain the yield but also guarantee the effectiveness of investments on the crops, seed material, fertilisation, etc. When this protection is carried out using the technical means such as the sprayers, the treatments must be both efficient and non-harmful to the environment and consumer health (they need to be applied in accordance with valid law regulations).

The quality of the sprayers' work is affected by many technical, technological and climatic factors. The most important are: equipment type, its technical condition, selection of the spray nozzle, suitable parameters of the treatment, temperature, humidity and keeping the recommendations of the pesticide producer. These are the level and uniformity of spreading and a proper degree of coverage that give evidence whether the sprayer works properly [2].

The major reasons for the abnormal distribution of the working liquid are: vibration and movement of the beam caused mainly by the irregularities of the surface. They depend, among other things, on construction solutions of the suspension system. The vertical beam deflection from the ground makes the particular spray nozzles work at different heights and thus the sprayed stream becomes asymmetrical to the plane perpendicular to the surface and parallel to the direction of the aggregate movement (Fig.1) [4, 5]. As a result, the treated surfaces are irregularly covered with the liquid.

The asymmetrical position of the spray nozzles causes that the vertical surfaces are treated as the internal and external in relation to the symmetry axis of the sprayed stream. This also deteriorates working conditions of the spray nozzles, and thus results in irregular coverage.

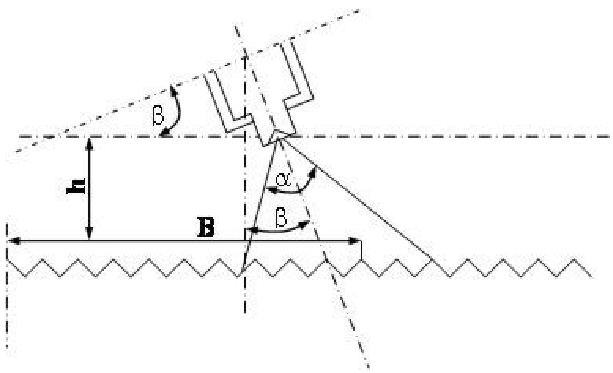

Fig. 1. Operation of the spray nozzle on the beam inclined at an angle β, h – height, B – spraying width, α – angle of the stream, β – asymmetry angle of the spraying

The user of a typical field sprayer cannot do much to affect the technical conditions that determine the beam position during the work as most often the equipment has a specified beam suspension system. However, it is possible to modify the working parameters and choose the working conditions of the sprayer to maintain the beam in the plane close to the horizontal one [3].

The studies on the impact of working parameters on the beam position during the sprayer movement have been conducted at the Institute of Agricultural Engineering of the Wroclaw University of Environmental and Life Sciences for many years. The effect of the spray nozzle position on the spray transverse distribution and the degree of coverage has been also analysed.

2. Aim of the work

The aim of the studies was to:

- assess the position of the sprayer field beam during the movement of the aggregate depending on the working conditions and parameters assumed in this study,
- determine the transverse distribution of the sprayed liquid and the degree of coverage when the spray nozzle, due to the beam deflection in the vertical plane, is asymmetrical to the vertical plane that is parallel to the aggregate movement.

3. Materials and methods

The first stage of the studies was focused on determining the impact of some working parameters of the suspended and attached field sprayers on the beam position during the movement of the aggregate. The effect of the below-mentioned working parameters was also investigated:

- height of the beam position,
- filling ratio of the sprayer tank,
- tractor tyre pressure for the tractor-suspended sprayers and the pressure in the tyres of the attached sprayers,
- working speed.

The suspended sprayers used for testing: PILMET 412 and PILMET 818 vary in the working width, tank capacity and the beam suspension system. The attached sprayers: PILMET 2518, PILMET 2-1018 and PILMET 1014 are mass-produced and they have different beam suspension system.

The measurement sector was marked on the agricultural land and described in the form of the profilogram for both wheels separately. The whole measurement cycle for all parameters took place on the same sector. The beam movements were recorded using a digital camera and its operation was then processed on computer in order to determine the beam inclination angle and the inclination time against the whole working time. To achieve a more general picture of the beam performance during the work, beam position indicator (WPB) was developed as the average inclination angle at which the sprayer is expected to pass through the measurement section. The beam position indicator (WPB) was calculated from the following relationship (1):

$$WPB = \sum_{i=1}^{n} \beta_i \mu_i \qquad (1)$$

where: β – beam inclination angle [deg], μ – part of the area treated at a given inclination angle, n – number of the angle values measured [-].

In order to assess the impact of the significance of the analysed parameters on the WPB, the results achieved were evaluated by multifactorial analysis of variance.

The second part of the studies was aimed at evaluating the effect of the height position and asymmetry angles of the sprayed stream on the transverse distribution and coverage with the spray for some spray nozzles. The spray nozzles were selected from among the main types of nozzles used by Polish farmers.

A constant pressure value of 0,3 MPa was applied for all spray nozzles and the variable parameters of the spray nozzle position were:

- asymmetry angle of the sprayed stream (0 - 4 degrees),
- spraying speed (1,4- 2,5 $m*s^{-1}$),
- height of the spray nozzle operation (0,4 - 0,8 m),
- spray nozzle type ,
- position of the samplers (vertical inner and outer position and horizontal position).

The studies on the variation index of the transverse distribution were run on a specially constructed stand where it was possible to place the beam and thus the spray nozzle at the desired asymmetry angle and spraying height. The surface to be sprayed was grooved with 50mm grooves. The falling liquid was collected in the graduated cylinders with graduation interval of 2ml. The variation index of the liquid fall was calculated according to the following relationship (2):

$$\eta = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(q_1 - q_{sr})^2}}{q_{sr}} 100[\%] \qquad (2)$$

where: n- number of the measuring grooves, q_1- liquid volume at the succeeding liquid volume from i-th measuring groove, $q_{śr}$- arithmetic mean of the liquid volume from n-th measuring grooves [1].

Water-sensitive test strips changing their colour under the influence of liquid drops falling down, were applied to evaluate the degree of spray coverage. The range of the colour change determined by a computer programme was treated as a coverage of a particular plant. The way of mounting the samplers to the construction that simulated an artificial plant is shown in Figure 2.

The working speed of the sprayer was simulated by changing the position of an artificial plant with the samplers towards the

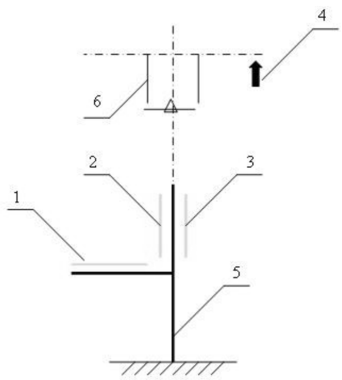

Fig. 2. The way of mounting water-sensitive test strips to the artificial plant: 1 – horizontal sampler, 2 – vertical inner sampler, 3 – vertical outer sampler, 4 – direction of beam inclination, 5 – artificial plant , 6 – spray nozzle under study

sprayer beam. The research results were statistically analysed using a multifactorial variation analysis.

4. Results

Due to the limited volume of the paper, only the most characteristic findings of the measurement results analysis were discussed.

The values of the beam position indicator depending on the studied movement speeds of the attached sprayers is presented in Figure 3 and Figure 4 shows the beam inclination for different air pressure in the tyres. From Figure 3, it appears that increasing the speed causes some deterioration of the beam working conditions by making it more inclined. The problem was more evident for the Pilmet 412 sprayer that has an oscillatory beam suspension system. When analysing the impact of the pressure in the tyres, as seen in Figure 4, the best working conditions for the beam operation were recorded at the pressure of 0,21 MPa and it was even more clear for the higher width. It proves that this parameter is quite important for the sprayer operation.

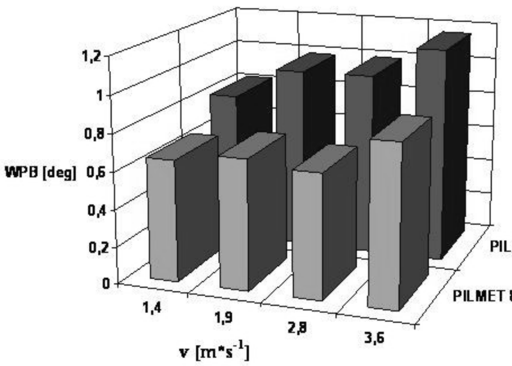

Fig. 3. Impact of the speed (v) on the beam position indicator value (WPB)

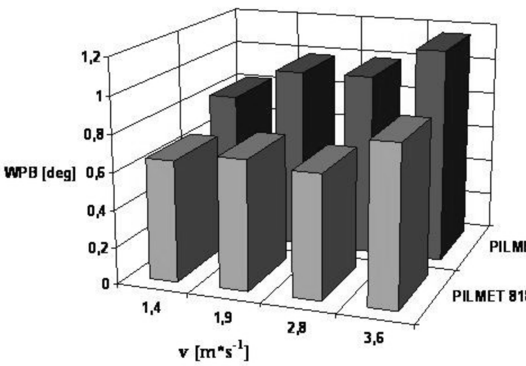

Fig. 4. The value of the beam position indicator at various pressure in the sprayer tyres

The multifactorial variation analysis of the impact of the tank filling ratio and the impact of the beam height on its deflections in the vertical plane turned to the conclusion that these factors are insignificant for the beam position during the work.

Figure 5 presents the average values of the irregularities of the transverse distribution depending on the spraying height at the 95% confidence level.

Using the variation analysis, it was found that the impact of the working height on the irregularities of the transverse distribution of the stream was significant for all tested spray nozzles. However, the effect of the asymmetry angle of the spraying on the spray irregularity tender to be insignificant for the majority of the spray nozzles tested.

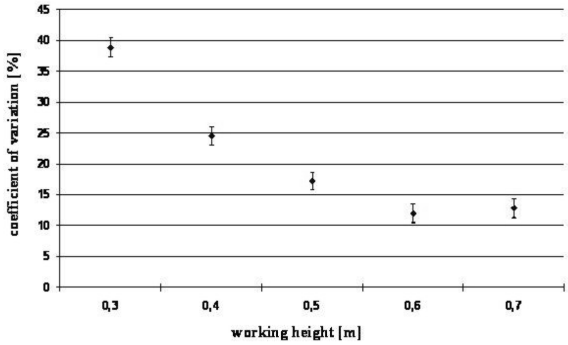

Fig. 5. Average values of the variation coefficient for the tested spraying heights

Figures 6, 7 and 8 show the impact of the height, asymmetry angle of the spraying, sampler speed and its position on the degree of spray coverage for the XR 11003 VK spray nozzle.

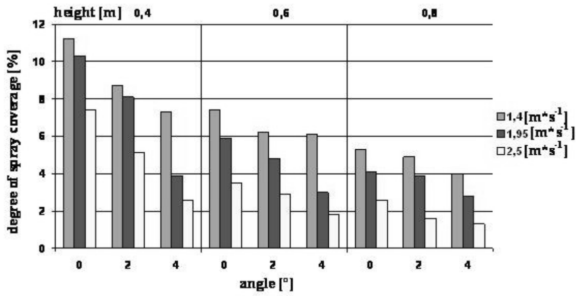

Fig. 6. Degree of spray coverage of the vertical inner sampler

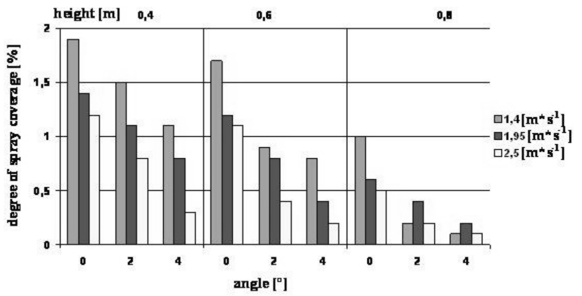

Fig. 7. Degree of spray coverage of the vertical outer sampler

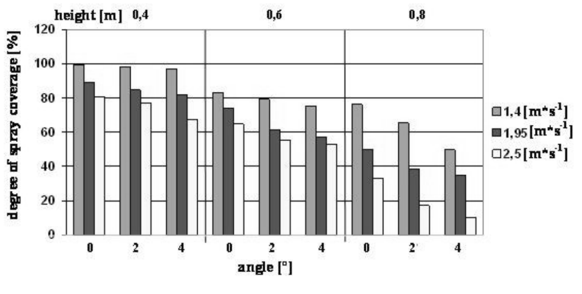

Fig. 8. Degree of spray coverage of the horizontal sampler

Multifactorial variation analysis of the results proved that there was a relation between tested working parameters and the degree of spray coverage of the samplers. The highest impact of the asymmetry angle of spraying on the coverage was noted for the vertical surfaces. Also, the sampler position itself (vertical inner and outer as well as horizontal) had the significant effect on the spray coverage. For the vertical samplers it was found that spray coverage between the inner and outer vertical surface significantly differed.

As indicated on the graphs, there is a considerable impact of the spraying speed on the degree of coverage. It is a logical consequence that at the higher speed and the same spraying pressure, different spraying rate were achieved. It is interesting that worse coverage was recorded for the spraying height of 0,4 m and for other heights: 0,6 and 0,8 m this was less clear. When the beam deflects from the horizontal line, the spraying height is other than recommended and thus the coverage of the treated surfaces seems to be automatically worse. As opposed to the indicator of variation, the impact of the asymmetry angle of spraying on the degree of coverage was clearly distinguished at each spraying height. The schemes show that with the increasing beam deflection, the degree of coverage decreases, and it particularly applies for the vertical surfaces, what in practice can mean the significant deterioration of the spray quality.

5. Conclusions

As regards working parameters of the chosen sprayers, the most significant impact on the field beam deflection was noted for the pressure in the tractor wheels for the suspended sprayers and the pressure in the tyres of the attached sprayers. The second most important factor affecting the beam movement was the aggregate speed but this parameter has a greater effect for the pendulum (for example Pilmet 412M sprayer) than trapeze (Pilmet 818) beam suspension.

The transverse irregularity of the fall was most greatly affected by the working height of the spray nozzles while the asymmetry of their positions tended to be of little significance within the range of asymmetry angles tested.

Sampler position towards the axis of the sprayed stream had a significant impact ($\alpha= 0{,}01$) on the spray coverage degree. For the vertical surfaces it was found that there is a considerable difference in the coverage between the inner and outer vertical surfaces.

Speed of the sampler and the spraying height tended to have the highest impact on the degree of spray coverage for all studied working parameters of the spray nozzles.

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WARUNKI TECHNICZNE POJAZDU A EMISJA SPALIN

VEHICLE'S TECHNICAL CONDITION AND EMISSION

Artykuł prezentuje wyniki badań mających na celu znalezienie różnic w emisji spalin dwóch silników o zapłonie iskrowym pojazdów osobowych o różnym roku produkcji. Porównania dokonano podczas poziomego ruchu pojazdów ze stałą prędkością. Podczas prowadzonych badań silnik samochodu pokonywał tylko następujące opory: układu napędowego, toczenia oraz powietrza. Do badań wybrano samochody o porównywalnych masach i powierzchni czołowej. Były to Škoda 105 L wyprodukowana w 1983 roku oraz Toyota Yaris 1,0 VVTi z roku 2003.

***Słowa kluczowe**: zużycie paliwa, opory powietrza, opory toczenia*

The article presents the research results aimed to get true differences of pollution production between two cars with spark ignition engine depending on the car's age. A car movement by constant speed on horizontal plane was realised for comparison. The vehicle engine must overcome only mechanical transmission losses, air resistance and rolling resistance, too. The air resistance size depends on the speed, the vehicle frontal area and the air resistance coefficient. It was chosen vehicles with approximated equal weight and approximated equal vehicle frontal area for comparison. These conditions fulfil vehicles Škoda 105 L, made in 1983, and Toyota Yaris 10,0 VVTi, made in 2003.

***Keywords**: fuel consumption, emissions, air resistance, rolling resistance*

1. Introduction

Transport became a fix part of modern people's life. We exploit it for travelling, movement of goods, sometime for relaxation. The vehicle consumes some fuel quantity for each distance. It produces some quantity of pollution into the air therefore it drives. It is matter of common knowledge that low age of the vehicle leads to the lower fuel consumption. We tried to find out real consumption of difference cars with different year of produce by the exact determined conditions.

2. Method of research

We determined car movement by constant speed on horizontal plane for comparison. The vehicle engine must overcome only mechanical transmission losses, air resistance and rolling resistance, too [3÷5]. The mechanical transmission losses depend on construction level.

The rolling resistance loss size depends on vehicle weight. We can calculate it by the help of formula:

$$O_f = f \cdot G \tag{1}$$

where: f - rolling resistance coefficient [-], G - vehicle weight [N].

We can calculate the air resistance by the help of formula:

$$O_V = 0{,}05 \cdot c_x \cdot S \cdot V^2 \tag{2}$$

where: c_x - air resistance coefficient [-], S - vehicle frontal area [m^2], V - car speed [km.h^{-1}].

The air resistance size depends on the speed, the vehicle frontal area and the air resistance coefficient. The air resistance coefficient reflects the level of construction. We chose vehicles with approximated equal weight and approximated equal vehicle frontal area for comparison. It ensures comparability of the cars and only their technical level. These conditions fulfil vehicles Škoda 105 L, made in 1983, and Toyota Yaris 10,0 VVTi, made in 2003. Parameters of both vehicles are listed in Table 1.

We made comparison at speed 40, 50, 60, 70, 80, 90, 100 km·h^{-1}. It was evaluated air resistance size for those speeds. This value was adjusted in measure time of concrete vehicle [1,2]. Value of air resistance calculated for particular vehicle is listed in Table 2.

Fuel consumption for Toyota Yaris was found by using information of on-board computer. On-board computer is able to inform about instant fuel consumption as well as about average fuel consumption. Accuracy of it was tested, by comparison of

Tab. 1. Basic parameter of compared vehicles

	Toyota Yaris 1,0 VVTi	Škoda 105 L
Car width [mm]	1660	1595
Car highness [mm]	1500	1400
Vehicle frontal area [m^2]	1,992	1,786
Air resistance coefficient [-]	0,30	0,35
Car basis weight [kg]	840	890
Car total weight [kg]	1320	1290
Useful weight [kg]	480	400
Tire size	155/80 R 13	165 SR 13
Maximum speed [km.h^{-1}]	156	130
Fuel consumption extramural [l/100 km]	5,1	6,4
Fuel consumption in the town [l/100 km]	6,9	8,4
Engine cubature [cm^3]	998	1 046
Compression ratio	10,0 : 1	8,5 : 1
Maximum power/at engine speed [kW.min^{-1}]	50/6000	33,9/4800
Maximum torque/at engine speed [N.m.min^{-1}]	90/4100	74,5/3000
Mixture preparation	Injection	Carburettor

Tab. 2. Value of calculated air resistance [N]

Speed [km.h^{-1}]	Toyota Yaris 1.0 VVTi	Škoda 105 L
40	48	50
50	75	78
60	108	113
70	146	153
80	191	200
90	242	253
100	299	313

indicated fuel consumption with calculated fuel consumption. We divided the litters tanked into fuel tank by covered distance for calculation. Covered distance was 10 000 kilometres. The on-board computer indicated 0,05 l per 100 km below the calculated consumption. Average fuel consumption was 5,8 litres per 100 kilometres.

We had to install fluid meter Pierburg into fuel system therefore vehicle Škoda 105 L is not equipped by the on-board computer. Fluid meter was installed into extrusion branch behind fuel pump. Computer Correvit calculated fuel consumption with accuracy ± 1%.

It is necessary ensure permanent changeless resistance on the vehicle wheels for comparability of the results. The cylinder power test stand MAHA LPS 2000 fulfils this request. It is possible to set constant resistance in N on the vehicle wheels on that stand. Display of the stand shows value of resistance in N and speed in kilometres per hour. It works with accuracy ± 2 % of measured parameter.

The driver had to warm up tyres to the working temperature by driving and by the arbitrary speed. He had to achieve required speed then for required gear. He was obliged to keep the speed on that value for 1 minute. It was necessary to start new measurement if the speed was higher or lower more than 2 kilometres per hour in that interval 1 minute.

The vehicle engine produces pollutions which are released into the environment by the vehicle exhaust system. Toyota Yaris exhaust system was equipped by the catalytic converter and Škoda exhaust system was without it. Difference in the pollution production was tested by SUN MEA 1500 SL equipment.

3. Received results

The quantity of CO_2 production depends directly on quantity of fuel consumption. Fuel consumption comparison of both vehicles we can see on Fig. 1, 2, 3.

Figure 1 compares fuel consumption if both cars use II. gear for driving. Engine of the vehicle Škoda with mixture preparation by the carburettor indicate more steepness growth of the fuel consumption in opposite to the Toyota Yaris vehicle whose mixture preparation is administrated in accordance to the λ sound signals. Škoda vehicle fuel consumption goes up on 129,33 % and Toyota Yaris consumption go up only to 118,37 % when speed increases from 40 to 60 kilometres pre hour. The Škoda vehicle fuel consumption is 53 % higher than the Toyota Yaris consumption in speed 40 kilometres pre hour.

Figure 2 compares fuel consumption if both cars use III. gear for driving. Fuel consumption goes up to the 172,72 % for vehicle Škoda and to 140,54 % for Toyota Yaris if speed was changed from 40 to 8O kilometres per hour. Curved line of fuel consumption for Toyota Yaris indicates constant growth. Curved line for vehicle Škoda indicates different slope. The reason of it is quality of preparation mixture in the carburettor. Vehicle Škoda fuel consumption is higher about 48 % at speed 40 kilo-

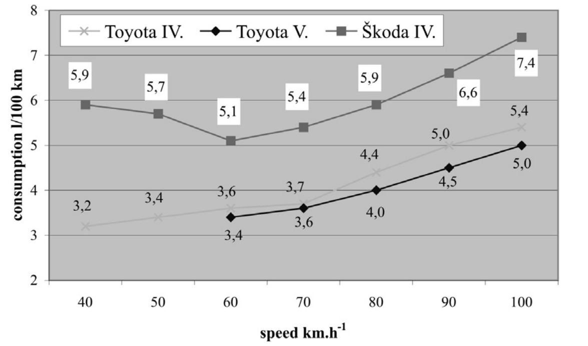

Fig. 1. Vehicle Škoda 105 L and Toyota Yaris 1,0 VVTi fuel consumption by using II. gear

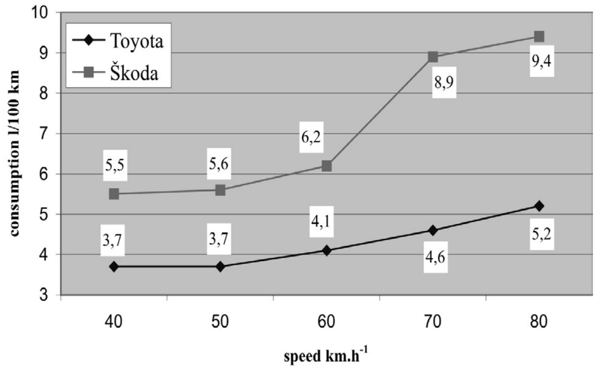

Fig. 2. Vehicle Škoda 105 L and Toyota Yaris 1,0 VVTi fuel consumption by using III. gear

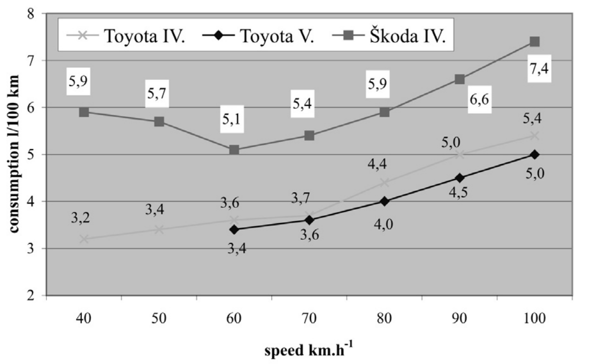

Fig. 3. Vehicle Škoda 105 L and Toyota Yaris 1,0 VVTi consumption by using the highest suitable gear

metres pre hour and difference increase to 80,77 % at speed 80 kilometres per hour.

The vehicles engines work with partial load if they use II. and III. gear. The Fig. 3 indicates fuel consumption if vehicles use the highest possible gear. It manifests in higher load of engine and it starts to work in optimal mode. Vehicle Toyota engine keeps still constant inclination of the consumption, but vehicle Škoda engine change inclination. For speed from 40 to 60 kilometres pre hour it decrease and from 60 to 100 kilometres pre hour it starts to increase.

4. Conclusions

Vehicle Škoda consumption is equal to 184 % of consumption of Toyota at speed 40 kilometres per hour and it decrease to 148 % at speed 100 kilometres per hour.

Tab. 3. Composition of the exhaust fumes

Speed [km.h⁻¹]	Gear	Vehicle	CO [%]	HC [ppm] (parts per million)	λ	CO_2 [%]
40	II.	Toyota	0,00	11	1,017	14,04
		Škoda	1,53	154	1,001	12,76
40	III.	Toyota	0,03	11	1,017	14,02
		Škoda	2,76	228	0,970	11,83
40	IV.	Toyota	0,00	11	1,017	14,04
		Škoda	6,72	317	0,852	9,06
50	II.	Toyota	0,00	11	1,018	14,07
		Škoda	1,50	192	1,040	12,46
50	III.	Toyota	0,03	11	1,016	13,92
		Škoda	1,72	192	1,308	12,26
50	IV.	Toyota	0,02	11	1,017	13,97
		Škoda	2,40	214	1,486	11,83
60	II.	Toyota	0,03	12	1,017	14,05
		Škoda	0,57	72	1,007	13,51
60	III.	Toyota	0,06	11	1,017	14,00
		Škoda	1,28	151	0,986	13,36
60	IV.	Toyota	0,04	12	1,017	13,88
		Škoda	1,53	206	0,990	13,19
60	V.	Toyota	0,03	12	1,017	13,96
70	III.	Toyota	0,0	12	1,016	14,02
		Škoda	1,13	175	0,990	13,40
70	IV.	Toyota	0,04	12	1,017	13,94
		Škoda	1,30	210	0,980	13,22
70	V.	Toyota	0,07	12	1,016	13,91
80	III.	Toyota	0,03	12	1,016	13,91
		Škoda	0,81	149	1,003	13,51
80	IV.	Toyota	0,02	12	1,012	13,93
		Škoda	0,28	211	1,141	12,04
80	V.	Toyota	0,03	13	1,017	13,88
90	IV.	Toyota	0,01	12	1,017	13,94
		Škoda	1,35	182	1,05	13,20
90	V.	Toyota	0,02	12	1,016	13,98
100	IV.	Toyota	0,06	13	1,015	13,83
		Škoda	1,36	180	0,975	13,18
100	V.	Toyota	0,06	14	1,021	13,75

The production of CO_2 depends directly on vehicles consumption. We can draw conclusion that vehicle Škoda had higher fuel consumption in all measured area and so it produced higher quantity of CO_2 in whole measured area, too. Exhaust fumes contains more kind of pollutions, not only CO_2. Composition of the exhaust fumes is indicates in Table 3.

Mixture preparation in carburettor reflects in higher percentage of CO and HC. Carburettor works only on base of underpresure in the intake system. It leads to the worse composition of the mixture.

Toyota engine prepares mixture on base of λ sound signal and its composition is always the best. Redundance of the oxygen in exhaust fume is very closely to the one. The exhaust system of vehicle Toyota includes catalytic conventer. This both reasons lead to the lower contents of the CO and HC in the exhaust fume.

5. References

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ZMIANA ZŁOŻONYCH WSKAŹNIKÓW GOSPODARCZYCH ZUŻYCIA OSOBOWEGO TABORU KOLEJOWEGO

A CHANGE OF COMPLEX ECONOMIC INDICATORS OF PASSENGER ROLLING STOCK DETERIORATION

Szereg kryteriów opisujących stan lokomotywy z różnych perspektyw może być używanych do oszacowania ich stanu. Kilka złożonych albo zintegrowanych kryteriów obrazujących stan ogólny lokomotyw Diesla może też być alternatywnie używanych w takim przypadku. Zintegrowany wskaźnik wyników charakteryzujący stan lokomotyw może być wyrażony przez opisane funkcjonalne zależności. Analiza dostępnych metod dla złożonej oceny stanu taboru kolejowego pokazała, że wydajność całkowita lokomotywy może być opisana przez bezwymiarowy wskaźnik.

***Słowa kluczowe**: lokomotywa, lokomotywy z napędem Diesla , kryteria zintegrowane, dieslowski skład pociagu, paliwo, olej napędowy, naprawa.*

Various criteria describing the state of a locomotive from various perspectives can be used to assess its performance. Some complex or integrated criteria reflecting a general state of Diesel locomotives can also be used. an integrated performance indicator characterizing the locomotive performance is expressed by the following functional relationship. The analysis of the available methods for complex evaluation of the locomotive condition has shown that overall performance of the locomotive can be described by a dimensionless indicator.

***Keywords**: locomotive, diesel locomotives, integrated criteria, diesel trainset, fuel, diesel oil, repairs.*

1. Introduction

One of the main economic indicators (criteria) of rolling stock deterioration is the increase of maintenance expenses when it is aging. The present research is aimed at developing and comparing the criteria of passenger rolling stock deterioration, which would take into account expenses on fuel, diesel oil and repairs. The analysis of fuel, oil and repair costs as well as their variation in time will enable the development of complex economic criteria, describing fuel, diesel oil and repair costs and their comparison [1,4].

2. The analysis of maintenance costs

The statistical data obtained from Vilnius locomotive depot show that fuel costs of passenger locomotives make 20.6-22.3 EUR/10000 tkm, oil costs make 0.6-0.7 EUR/10000 tkm, and repair costs – 0.3-0.4 EUR/10000 tkm. These costs vary when the locomotives are aging. Percentage distribution of expenses also varies in time. Percentage distribution of costs for passenger locomotive is shown in Fig. 1.

The analysis of histograms in Fig. 1 shows that fuel costs make the largest component of costs for passenger locomotives.

For diesel trainsets fuel costs make 25.6-26.2 Eur/10000 tkm, diesel oil costs make about 0.5 Eur/10000 tkm, and repair costs – 1.2-3.1 Eur/10000 tkm. Their percentage cost distribution slightly differs from that of passenger locomotives (Fig. 2).

The analysis of data presented in Figs 1 and 2 shows that the percentage of repair costs is increasing most rapidly both for diesel trainsets and passenger locomotives (due to this increase the percentage of fuel costs is decreasing). For passenger locomotives the increase considered makes about 10 % per year,

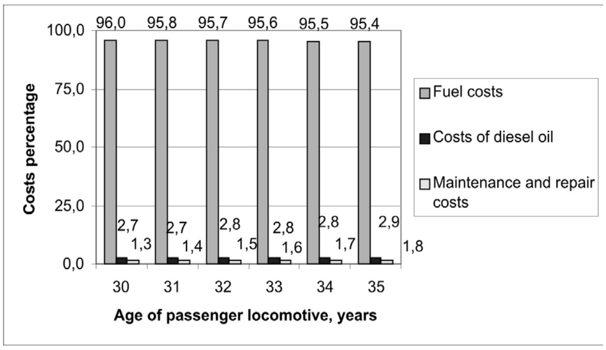

Fig. 1. Percentage distribution of costs for passenger locomotive

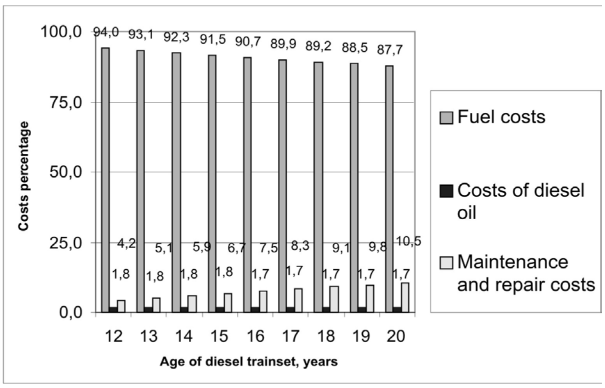

Fig. 2. Percentage distribution of costs for diesel trainset

while for diesel trainsets it is about 70 % per year. Since about 40 % of traction rolling stock failures are engine failures [5], it can be assumed that engine condition in diesel trainsets is worse, since their operating conditions are more difficult because of heavier loads.

The research has shown that, when renewing traction rolling stock (by purchasing new locomotives), special attention should be devoted to fuel costs. Engine design and transmission should be chosen particularly carefully. For example, the efficiency of thermal engines (a part of thermal energy converted to work) usually ranges from 15 to 35 % [2,3,6], depending on their design. Fuel costs are directly related to efficiency.

It should be stated that oil costs are growing considerably with the increase of diesel trainset age. However, this is accounted for by the peculiarities of their engine design.

3. Developing a complex criterion for assessing traction rolling stock performance

A complex criterion for assessing traction rolling stock performance should take into account costs of fuel, oil and unscheduled repairs. It can be expressed as follows:

$$K = d \cdot I_d + a \cdot I_a + p \cdot I_p \quad (1)$$

where: K is a complex criterion of traction rolling stock performance, EUR/10 000 tkm; d - means relative fuel consumption, kg/10 000 tkm; a - denotes relative oil consumption, kg/10 000 tkm; p - denotes relative costs of unscheduled repairs, h/10 000 tkm; I_d - denotes relative costs per unit of fuel, EUR/kg; I_a - denotes relative costs per unit of oil, EUR/kg; I_p - means costs per arbitrary unit of unscheduled repairs, EUR/h.

Based on the data of the earlier research [3], it can be stated that a complex criterion K for passenger locomotives will be of the form:

$$K_{Kel} = (0{,}687 \cdot x + 21{,}46) \cdot I_d + (0{,}069 \cdot x + 0{,}238) \cdot I_a + +(0{,}0035 \cdot x - 0{,}0672) \cdot I_p \quad (2)$$

The criterion K for diesel trainsets will be respectively of the form:

$$K_{DT} = (0{,}005 \cdot x^2 - 0{,}025 \cdot x + 51{,}92) \cdot I_d + (0{,}0147 \cdot x + 1{,}745) \cdot I_a + +(0{,}00329 \cdot x + 0{,}243) \cdot I_p \quad (3)$$

where x is the age of traction rolling stock, years.

4. The relationship between complex economic criterion of rolling stock and its age

Since not all road vehicles of Vilnius depot are used uniformly, it is more rational to express complex criteria in terms of their mileage, rather than age (as in formulas (2) and (3)). Based on the formulas (2) and (3) and the current price of fuel, diesel oil and repair in Lithuania (which is 0.483 EUR/kg, 0.248 EUR/kg and 0.095 EUR/h, respectively), it is possible to calculate the values of complex rolling stock performance criteria, depending on its age. By multiplying the age of a rail vehicle by its mean annual mileage (run), it is possible to calculate the mileage of a road vehicle of a particular age and, then, to obtain the dependence of complex criteria on mileage (according to the data provided by Vilnius locomotive depot, the average annual mileage of passenger locomotives is 68.4 thous. km, while for diesel trainsets it makes 104.4 thous. km.). The relationships between complex economic criteria of passenger locomotives and diesel trainsets and their mileage (run) are presented in Figs 3 and 4, respectively.

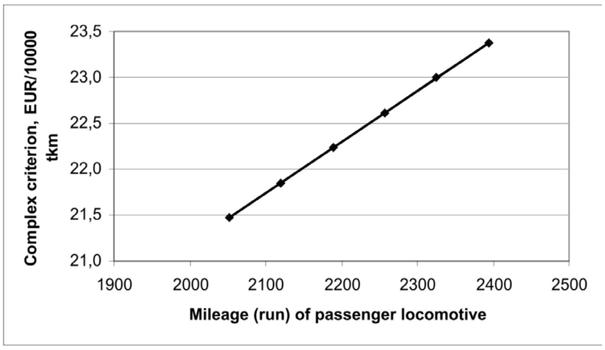

Fig. 3. The relationships between complex economic criterion of passenger locomotives and their mileage (run)

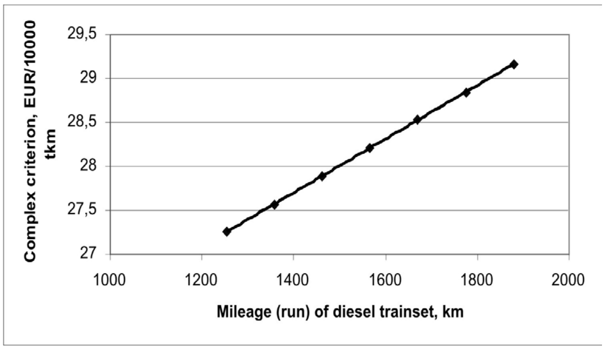

Fig. 4.The relationship between complex economic criterion of diesel trainset and mileage (run)

The relationship given in Fig. 3 is expressed by the equation:

$$K_{Kel} = 0{,}0056 \cdot r_{kl} + 10{,}06 \quad (4)$$

where: r_{kl} is the mileage (run) of passenger locomotive, thous. km.

The relationship given in Fig. 4 is expressed by the equation:

$$K_{DT} = 9 \cdot 10^{-19} \cdot r_{dt}^{\,2} + 0{,}0031 \cdot r_{dt} + 23{,}43 \quad (5)$$

where: r_{dt} is the mileage (run) of diesel trainset, thous. km.

The comparison of equations 4 and 5 shows that both Complex economic criteria of passenger locomotives have linear dependence on their mileage (run), while the coefficients of direction are 0.0056. Complex economic criteria of diesel trainsets have dependence.

These values show that the variation rate of the complex economic criterion of diesel trainsets in time is by 1.8 lower than that of passenger locomotives. This can be accounted for by lower deterioration rate of diesel trainsets.

Further research of these problems should involve the determining of the above complex criterion for the condition when the maintenance costs of traction rolling stock are higher than the income obtained in the respective period of time, i.e. the use of rolling stock is not rational, taking into account the required expenses on fuel, oil, maintenance and repairs. The criterion should be a non-dimensional value and take into account the variation of a complex criterion in operation.

5. Conclusions

- Complex economic criteria for assessing the process of rolling stock aging based on fuel, diesel oil and repair costs were developed.
- Complex economic criteria of passenger locomotives have linear dependence on their mileage (run), while the coefficients of direction are 0.0056.
- Complex economic criteria of diesel trainsets have dependence.
- The growth of the complex economic criterion value for diesel trainsets is by 1.8 times slower than that for passenger locomotives because of less heavier deterioration of these trainsets.

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MODELOWANIE PROFILAKTYCZNEGO OBSŁUGIWANIA PARKU SAMOCHODÓW

MODELLING PREVENTIVE MAINTENANCE FOR A VEHICLE FLEET

W referacie przedstawiono metodę utrzymania wymaganej niezawodności parku pojazdów. Założony efekt uzyskano poprzez użycie diagnozowania statystycznego do wskazywania zakresu wymian profilaktycznych. Kryterium wyboru był akceptowalny poziom prawdopodobieństwa uszkodzenia pojazdów podczas realizowania zadań transportowych. Opracowano algorytm wyboru wymienianych składników floty pojazdów. Wykazano, że na poziom niezawodności parku pojazdów można oddziaływać nie tylko poprzez zmianę rzędu kwantyla, ale także poprzez dodawanie odpowiedniej liczby nadmiarowych pojazdów. Dla potwierdzenia wyprowadzonych zależności zastosowano model symulacyjny wymian profilaktycznych.

***Słowa kluczowe**: obsługiwanie, wymiana profilaktyczna, diagnoza statystyczna*

The paper presents a method of means of transport maintenance with a required reliability. Such results are achieved by using statistical diagnosing as a base of preventive replacement of objects in a fleet. The acceptable level of a failure risk while executing transportation tasks has been taken as a criterion. An algorithm for selecting elements for preventive replacement has been developed. It was shown that a level of a fleet reliability can be controlled not only by changing an order of a quantile function but also by adding a number of redundant objects to the fleet. A computer simulation model was used to explicate derived dependencies between a redundancy and a quantile order.

***Keywords**: maintenance, preventive replacement, statistical diagnosis*

1. Introduction

Preventive replacements are used to maintain demanded reliability of vehicles in a transport firm. They enable avoiding failures of individual vehicles in a fleet. However a need for high reliability of fleet of vehicles being used can effects in great amount of elements replaced during preventive actions.

High reliability is achieved in practice by services when specific elements are replaced by new ones. A criterion of selecting elements depends on level of reliability that is expected. In a case of a homogeneous set of vehicles, a range of prophylactic activities depends on a reliability level of the whole fleet and on its reliability structure.

This takes in account redundancy, that enables first off all to replace failed objects enabling of transportation tasks fulfilling. A number of redundant objects depend on the acceptable probability of failure during the task implementation period. In order to minimize the size of redundancy one should, on the one hand, be using objects of high reliability, and also keep their reliability in the operating process at possibly high level, on the other hand.

Instead of known from the literature method of replacing object in a given rate [6], the method of replacing of chosen elements that enables achieving demanded level of the fleet reliability is proposed. This method uses statistical characteristics of the vehicles instead of applying measurable parameters of its elements.

The ability of the object of fulfilling given tasks with demanded probability could be statistically measured by quantile of given order. For this measure, a method of statistical diagnosis was developed. It points out at given moment to a set of elements that should be replaced by new ones to achieve demanded reliability of the whole fleet of vehicles.

2. Preventive replacements

A method that is known from literature and used for defining of a scope and deadlines of preventive replacements is to include the costs of attentive replacements and the costs generated by the occurring failures [1, 5]. As a result of its application, minimum average costs per unit of time related to maintenance of objects in a proper reliability status are achievable. However, in order to benefit from that effect there is a need to replace individual elements in various time intervals, usually uncoordinated with the performance of tasks, which may wipe out advantages effecting from the implemented optimisation. Therefore, a possibility should be considered to make preventive replacements of objects in the assumed time intervals whose scope is defined on the basis of assessment of reliability of the objects and the assumed reliability level of the entire fleet [3]. The fleet maintained in such a way preserves its ability to realise transportation tasks with a given probability.

In case of complex systems, a failure appears whenever an object, which constitutes a series reliability structure with the others, has failed. A repair usually involves a replacement of this object for a brand new one.

Dynamic determination of a scope of preventive replacements could be based on a statistical assessment of present status of objects. The statistical diagnosis is a maintenance methodology in the area of maintaining objects with non-exponential lifetime distribution [3, 4]. It identifies preventive maintenance tasks to realise the inherent reliability of equipment at a minimum expenditure of resources. In order to do that, data is required about a distribution of time to failure and its parameters as well as about its operational use so far (since being new or from the moment of its replacement). The statistical diagnosis uses data gathered during normal utilization of objects. They concern failures, repairs and replacements of objects. Next, the distribution of time or mileage to failure for each of these elements is determined. It can be done either with the use of data collected in the past or by relying upon experts' opinions at the start.

Statistical inspection can be performed at any moment because it retrieves data gathered in the informational area of the means-of-transport maintenance management system. It could be done either in a constant period of time or during planned service or during current repair. The distribution parameters are modified when either repair or replacement of the element has been done. The actual technical condition of the object is not taken into consideration here as that would require for the object to be excluded from its operational use. Having data, reliability characteristics of elements, updated working time of individual elements, a period for execution of the transportation task, it is possible to define objects that require preventive replacement in order for the project implementation probability not to decline below its assumed value. It can be applied as well to elements as to complex objects.

The procedure statistically predicts failures at part level by calculating a quantile function of residual lifetime instead of the mean residual lifetime to failure. This measure directly relates to predicted work period and the reliability of the system. For any moment **t** the following condition has to be met:

$$q_p(t) \geq d \tag{1}$$

where: d – tasks implementation period, $q_p(t)$ – quantile of residual lifetime function, order p.

Function $q_p(t)$ shall be defined as follows [2]:

$$q_p(t) = F_t^{-1}(p) = \inf\{x : F_t(x) \geq p\} \tag{2}$$

where: $F_t(x)$ – cumulative distribution function of the residual lifetime, $R_t(x)$ – conditional reliability function, and

$$1 - F_t(x) = R_t(x) = \frac{R(t+x)}{R(t)}, \quad x,t \geq 0 \tag{3}$$

A fleet of vehicles in a transport firm could be characterized by reliability and as well as by a reliability structure. Probability of a failure occurring during a task period can be determined in both cases, that is, when the replacements either have or have not been made. Additionally, the assessment may refer to the entire fleet of objects that have been assigned for execution of the transportation tasks.

A preventive replacement of objects is made if the value of function (2), which has been calculated for the entire set of objects, is lower than the duration of the scheduled task planned for that set of objects. In order to select a set of objects to be replaced at given moment, an updated value of the reliability function is calculated including operational time of each and every one of them. Then they are put in order according to the growing value of the quantile of a given order for a distribution of the residual lifetime.

Subsequent objects are assigned for replacement, starting from an object of the lowest quantile value until the quantile of the entire fleet of objects – calculated by having included the replacement of assigned elements for brand new ones – is not less than the duration of the scheduled task (algorithm in Fig. 1). The replacement of objects that have been assigned in this way ensures the assumed probability that the fleet of objects will not fail during implementation of the transport task.

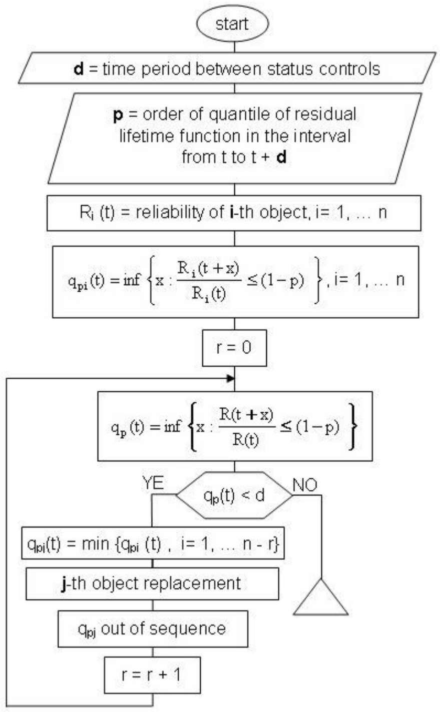

Fig.1. Algorithm for selecting objects for preventive replacement

3. Redundancies in a fleet of objects

Sustaining a high reliability level of technical objects in their operational use process – served by preventive replacements of components being threatened by a failure – can be accompanied by adding redundant objects to the fleet.

If the entire fleet consists of n objects and n objects are essentially required for carrying out transportation tasks, then an assumption can be made that reliability structure of the fleet is in series. This imposes large requirements on reliability of each object, which is often not achievable. Then, in order to keep reliability of the fleet at its required level, redundant objects can be introduced into the fleet. After adding k redundant objects to the fleet its reliability structure can be seen as a threshold structure, in this case "*n out of n+k*".

The fleet reliability model also depends on the way the redundant objects are operating in. Redundant objects may play a role of the cold (unloaded) reserve, that is, they passively wait for one of the objects to fail, or the hot (loaded) reserve, thus increasing the entire fleet capacity until one of the objects has failed.

In case of the structure "*n out of n+k*" for $k>1$ in the cold reserve, the analytical description becomes very complex, as there are more reserve objects than in the structure "*n out of n+1*". This is because that in the fleet, established at the moment τ and consisting of (n-1) objects aged τ and one new object, one of the objects may fail and be replaced by the second reserve object before the moment t.

In case of the fleet with structure of "*n out of n+k*" with the hot reserve, we may use the simpler relation for homogenous objects:

$$R_{(n,n+k)} = \sum_{i=n}^{n+k} \binom{n+k}{i} R^i (1-R)^{n+k-i} \tag{4}$$

Complexity of the analytical description, regardless of simplifying assumptions that have been made (i.e. identical objects, omission of the reliability structure of objects alone), indicates that there is a need for using a computer simulation for issues being considered here.

If k vehicles works as the hot reserve, the system can be treated as "*n out of n+k*" structure and the order p represents demanded level of reliability of the whole fleet. However, in the case of k redundant vehicles working as the cold reserve with n objects presenting a series reliability structure, there is a possibility for calculations new value for the level of reliability, which decreases the reliability demands. The formula is as follows:

$$1-\alpha_k = \frac{1-p}{(1-R)^k\left[\binom{n+k}{n}+\sum_{i=1}^{k}\binom{n+k}{n+i}\left(\frac{R}{1-R}\right)^i\right]} \quad (5)$$

where: α_k –probability of failure one of n vehicles ($\alpha_0 = p$), p – acceptable probability of system failure, R – reliability of a single vehicle, n – number of vehicles needed for transportation tasks execution, k – number of redundant vehicles.

This new order is greater then that assumed for the whole fleet without redundancy. The relation between orders (p, α_k) is shown in Fig. 2.

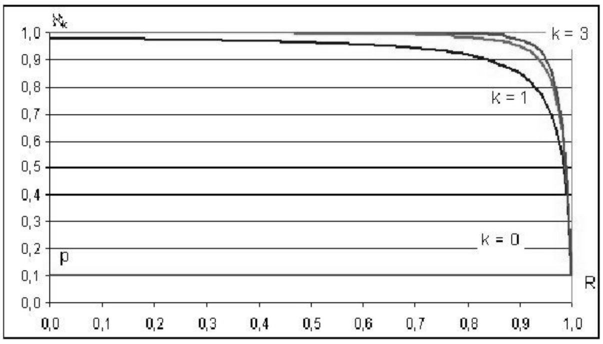

Fig.2. Relation between α_k and R for the given n, k and p

4. Simulation experiments

The above consideration was confirmed with use of a computer simulation. In the model, objects were applied, that were fully replaced at steady intervals of mileage, according to results of statistical diagnosis. The planned process of replacements was combined with random process of failures and repairs. A graph of model states is presented in Fig. 3. The meanings of model states are as follows: *work* – object is working, *statistical diagnosing* – set of objects is selected, *preventive replacement* – selected objects are replaced by new ones, *repair* – failed object is replaced by a new one)

The fleet of n objects was used for execution of tasks in the model. The mileage to failure of a single object was assumed as the Weibull distribution. The acceptable probability of the fleet unavailability was p. The required reliability was maintained by preventive replacements of objects. Statistical diagnosing was done with the period of length d. Three options of the model were applied. In the first n objects was used, that means the fleet without redundancy. Next, n+1 objects was used, with one redundant object, and then n+2 objects, with two redundant objects.

Parameters of the model were as follows: $n = 50$, $p = 0.1$, $d = 3$, and $a = 2.5$, $b = 50$ as the Weibull distribution parameters.

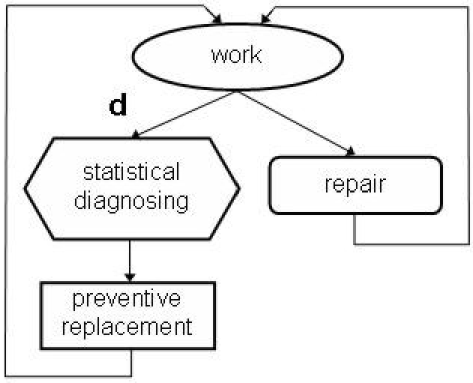

Fig.3. Graph of model states

The range of simulation was $T = 1000$, and experiments were repeated 10 times. As a result of simulation, numbers of replacements and failures of objects and unavailability of the whole fleet were estimated.

In the first step, the number of failures in the system "*n out of n*" without any prophylaxis and then with statistical diagnosing was estimated (Tab.1).

Tab.1. Simulation experiments results for system "n out of n"

Number of:	***Without preventive replacements***	***With preventive replacements d = 3 p = 0.10***
- preventive replacements	*-*	*10322*
- fleet unavailability	*1102*	*34*
- object failures	*1102*	*34*

The results show that it is possible to achieve demanded reliability with significant decreasing the number of random brakes in work but with a very big number of preventive replacements, as the object reliability was rather low

The reliability of the fleet can be also enlarged by adding redundancy to the system. This decreases the number of preventive replacements in system "*n out of n+k*" as – according to formula (5) – the result is analogical to appropriate increasing the quantile order of the system "*n out of n*". Such modification of the quantile order can be designated graphically as it is shown in Fig. 4.

The modified orders of quantile calculated with use of formula (5) for systems with n+1 and n+2 objects are as follows: $\alpha_1 = 0.41$, $\alpha_2 = 0.66$ (Fig.4). But this result would be valid only for a new system or for a perfect repair after every statistical diagnosing, i.e. whole fleet is replaced by the new one. This condition could be fulfilled if the interval of statistical inspections where long enough. However, such a long interval is useless and practically should be lower than quantile of given order at $t = 0$.

After a number of preventive replacements of objects the fleet consists of objects of different age. This means that an average object is improved by the statistical diagnosing. So the probability of tasks fulfilling by a single vehicle should be calculated for systems "*n out of n+1*" and "*n out of n+2*" separately on the base of experimental data (Tab. 2). Then the modified orders α_k for appropriate systems "n out of n" can be calculated with use of formula (5). The empirical values are as follows: $\alpha_1 = 0.40$, $\alpha_2 = 0.64$. The procedure is presented in Fig. 5.

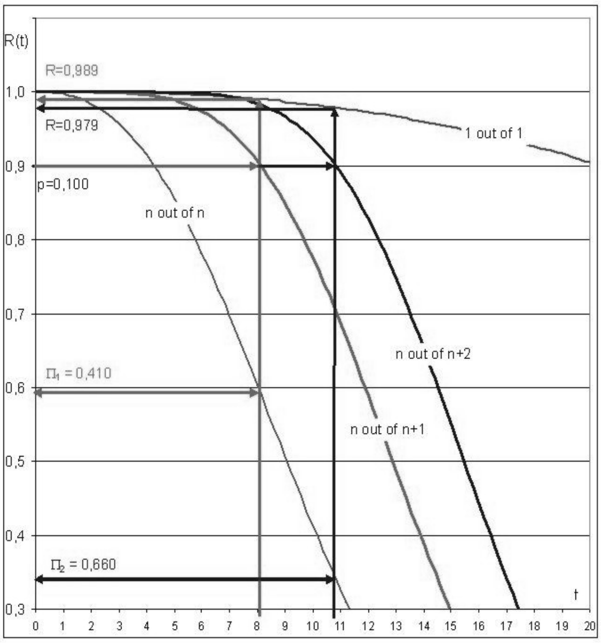

Fig. 4. Graphical interpretation of calculating new quantile orders at t = 0

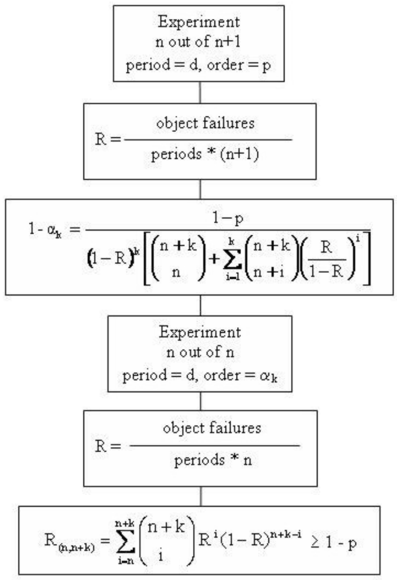

Fig.5. The procedure of applying new quantile order to the fleet of vehicles

Tab.2. Simulation experiments results (d = 3)

	Model			
	n out of n+1	***n out of n***	***n out of n+2***	***n out of n***
Number of:	***p=0.10***	***α_1=0.40***	***p=0.10***	***α_2=0. 64***
- preventive replacements	***3216***	***3170***	***1850***	***1814***
- fleet unavailability	***56***	***167***	***87***	***326***
- objects failures	***172***	***167***	***353***	***326***
Empirical reliability of a vehicle	***0.990***	***0.990***	***0.980***	***0.979***
Empirical fleet unavailability	***0.09***	***0.39***	***0.09***	***0.61***

Simulation results in Tab. 2 show that the numbers of replaced elements in systems "*n out of n*" with $p = \alpha_1$ and "*n out of n+1*" with $p = 0.1$ are similar, as well as in systems "*n out of n*" with $p = \alpha_2$ and "*n out of n+2*" with $p = 0.1$. In both cases the fleet unavailability – calculated as $1\text{-}R_{(n,n+k)}$ with use of formula (4) – is less than assumed p.

5. Conclusion

The application of the statistical control results in a considerable reduction in a number of incidental failures of vehicles, compared to a use without any prophylaxis. However, maintaining a high reliability of a fleet of vehicles is accompanied by a great amount of preventive replacements of vehicles. This means that there would be many more preventive replacements than random repairs of objects according to relatively low reliability of a single object.

Thus, it would be easier to achieve the required fleet availability by adding redundant vehicles which replace damaged one than to maintain a high reliability of the fleet of vehicles without redundancy. By adding a redundant object, more failures of vehicles can be accepted as well as a number of preventive replacements is reduced. Thus it would be useful to combine redundancy and preventive replacement based on statistical diagnosing.

Required level of fleet reliability could be achieved by adding surplus vehicles and properly matching them with the quantile order applied to the main part of the fleet. By those two measures, random failures of the vehicles fleet are significantly reduced in number of replaced elements being much lower than those without redundancy.

The hereto presented method for setting a scope of preventive replacements, based on reliability properties of individual objects being used, allows for matching the parameters of replacements for applied reliability parameters of the objects.

Reliability analysis with respect to preventive replacements can be also performed with reference to objects' elements being of critical importance for tasks that are executed. This analysis can be carried out for any set of compound objects that will jointly be used for execution of the tasks.

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WPŁYW ORGANIZACJI PRACY SAMOCHODU NA WARUNKI ROZRUCHU SILNIKA SPALINOWEGO

THE INFLUENCE OF THE VEHICLE WORK ORGANIZATION CONDITIONS ON THE ENGINE START-UP PARAMETERS

Podczas etapu planowania przewozu określonego rodzaju ładunku, bierze się pod uwagę: uwarunkowania techniczne posiadanych środków transportu, odległości pomiędzy założonymi punktami dowozu, czas i koszt przewozu, a także czasy załadunku i wyładunku. Inne czynniki, związane z warunkami pracy danego środka transportu oraz jego wpływem na otoczenie, najczęściej nie są brane pod uwagę podczas procesu projektowania tras przejazdu.
Wydaje się, że znajomość wpływu warunków organizacji pracy samochodu oraz rozruchu silnika spalinowego na środowisko naturalne ma także istotne znaczenie przy planowaniu organizacji przewozu. Niniejszy artykuł prezentuje omówienie przeprowadzonych analiz statystycznych wyników eksploatacyjnych badań samochodu dostawczego LUBLIN i jego silnika spalinowego 4CT90. Przeprowadzone analizy miały na celu określenie związków pomiędzy organizacją pracy samochodu a warunkami w jakich następują rozruchy jego silnika spalinowego.

Słowa kluczowe: *organizacja pracy pojazdu, warunki rozruchu silnika*

The technical parameters of the means of transport, the distance between particular points of carriage, the time of loading and unloading the cargo, the time and the cost of the transport are taken into consideration during the planning of the transport specified shipment.
Another factors, which are connected with the influence of the working conditions of the means of transport on the natural environment, are not taken into account during the planning of their routes. Nowadays it seems, during the planning of the organization of the transport service, that the knowledge of the influences of the vehicle and its combustion engine work conditions on the natural environment is significant. This paper presents the results of the statistical analysis of the maintenance research of the LUBLIN delivery truck and its engine 4CT90. The conducted analysis aimed at the estimation of the relations between the vehicle work organization conditions and the parameters of the engine start-up.

Keywords*: vehicle work organization, engine start-up parameters*

1. Introduction

The technical parameters of the means of transport, the distance between particular points of carriage, the time of loading and unloading the cargo, the time and the cost of the transport are taken into consideration during the planning of the transport specified shipment. Another factors, which are connected with the working conditions of the means of transport, are not taken into account during the planning of their routes [4,5,6].

Nowadays the transport systems are mainly based on the use of the vehicles which are driven by the combustion engines. The work of the vehicle assemblies generates the noise and the vibration of the surrounding elements. Additionally, although the development, the combustion engines are characterized by the emission of toxic compounds of exhaust gases [1,7]. For these reasons, it's necessary to take into account the influences of the vehicle and its combustion engine on the natural environment during the planning of the organization of the transport service.

The engine start-up and the work of non-warm engine seem to be the most important functional states. Due to unfavourable physical processes that take place during these states there is an increased emission of toxic compounds of exhaust gas and the wear of selected tribological engine units. We can also observe the high noise level and the overloads in the vehicle electric power system. The extent of such negative processes depends on engine start-up parameters: the temperature and the time of the engine start-up, the value of current consumed by a starter etc [3]. The working conditions of the vehicle, which depend on the organization of its driving, influence on the engine start-up parameters

Thus, the knowledge of the influence of the vehicle work organization conditions on the engine start-up parameters has theoretical and practical meaning. The paper presents the results of the statistical analysis of the maintenance research of the LUBLIN delivery truck and its engine 4CT90. The conducted analysis aimed at the estimation of the relations between the vehicle work organization conditions and the parameters of the engine start-up.

2. Operational research

The operational research was carried out using LUBLIN III delivery truck (maximum authorized total weight < 3,5 t) used by Polish Postal Service in Lublin. This truck has the 4CT90 diesel engine produced by a Diesel Engines Factory „ANDORIA S.A." in Andrychów. The engine was characterized by the following general data: the cubic capacity: 2,417 dm^3, max. power 63,5 kW at 4100 rpm and develops maximum moment 195 Nm at 2500 rpm. The engine was fitted with an in-line fuel injection pump.

The investigated truck was one of the several ones being currently at the disposal of the Lublin Branch of Polish Mail. A special recorder constructed to register the selected parameters of LUBLIN III operation and activity of the 4CT90 engine was mounted [2]. Basing on the results of the researches of selected parameters of the 4CT90 engine start-up and its operation as well as activity of the LUBLIN III vehicle the followed variables were obtained:

1. t_{pause} – the time of the pause in the vehicle operation with the engine switched off before the start-up [min],

2. t_{work} – the time of the engine operation before its next start-up [min],
3. t_{oper} – the time of the vehicle operation before the next engine start-up [min],
4. l_{veh} – the distance covered by the vehicle before the engine start-up [km],
5. l_{pis} – the distance covered by the piston before the engine start-up [km],
6. T_{agent} – engine (cooling agent) temperature at the engine start-up [°C],
7. I_{ave} – the average value of the current consumed by the starter during the engine start-up [A],
8. t_{start} – the work time of the starter during the engine start-up [s].

The first five parameters are connected with the organization of the LUBLIN III delivery truck work conditions. Next three ones concern the parameters of the engine start-up.

3. The analysis of the results of the researches

3.1. The correlation analysis

The obtained results of the maintenance researches were analysed by a computer programme STATISTICA. The correlation analysis was first carried out. The results of the data analysis are presented in the matrix ***r*** of the line correlation coefficients between specified random variables:

$$r = \left| \begin{array}{ccccccccc} & t_{pause} & t_{work} & t_{oper} & l_{veh} & l_{pis} & T_{agent} & I_{ave} & t_{start} \\ t_{pause} & 1.00 & 0.01 & -0.02 & -0.03 & 0.02 & -0.55 & -0.42 & 0.61 \\ t_{work} & 0.01 & 1.00 & 1.00 & 0.97 & 0.92 & 0.18 & 0.13 & -0.16 \\ t_{oper} & -0.02 & 1.00 & 1.00 & 0.98 & 0.92 & 0.20 & 0.15 & -0.18 \\ l_{veh} & -0.03 & 0.97 & 0.98 & 1.00 & 0.93 & 0.16 & 0.15 & -0.17 \\ l_{pis} & -0.02 & 0.92 & 0.92 & 0.93 & 1.00 & 0.17 & 0.12 & -0.01 \\ T_{agent} & -0.55 & 0.18 & 0.20 & 0.16 & 0.17 & 1.00 & 0.43 & -0.71 \\ I_{ave} & -0.42 & 0.13 & 0.15 & 0.15 & 0.12 & 0.43 & 1.00 & -0.63 \\ t_{start} & 0.61 & -0.16 & -0.18 & -0.17 & -0.01 & -0.71 & -0.63 & 1.00 \end{array} \right| \quad (1)$$

Basing on the values of the correlation coefficients we can see the correlation between the time of the pause in the vehicle operation with the engine switched off before the start-up and the engine start-up parameters. When this time increases the value of the engine temperature at the engine start-up and the average value of the current consumed by the starter during the engine start-up are reduced. But the work time of the starter (this time can be identified with the time of the engine start-up) increases. Another parameters which describe the vehicle work organization conditions haven't the essential influence on the engine start-up parameters. The values of the correlation coefficients show some relations among the parameters connected with the organization conditions. The values of the distance covered by the vehicle and the distance covered by the vehicle before the engine start-up are directly proportional to the time of the engine operation and the time of the vehicle operation before the next engine start-up.

3.2. The canonical analysis

The carried out analysis between two distinguished set of the parameters was the canonical one. We can state that the group of the parameters which describe the vehicle LUBLIN III work organization conditions explains only 31% of the total variance occurring inside this group. The set of the 4CT90 engine start-up parameters interprets 100% variability appearance inside this set. The group of the parameters connected with the vehicle work organization conditions explains about 35% variability inside the set of engine start-up parameters. The set of the engine start-up parameters determines only 11% of the variance occurring inside the organization parameters group. It certifies that some factors which cause the variability inside the groups of the vehicle work organization and the engine start-up parameters exist. They weren't taken into the analysis.

Basing on the calculations we can separate three canonical roots. The value of the canonical correlation coefficient of the first canonical root equals R_{k1}=0.6838. The value of the statistics χ^2 is equal 3990.7 and the probability level p=0.00. The characteristic value of this canonical root is equal 0.4677. The value of canonical correlation coefficient of the second canonical root is considerably small and equal R_{k2}=0.2349 (χ^2=21.1621 with p= 0.006). The characteristic value of the second canonical root is only 0.0551. The value of the canonical correlation coefficient of the third canonical root is equal only R_{k3}=0.133 (χ^2=5.066 and p= 0.166). This coefficient isn't statistically significant. Basing on these results we can state that only the value of the canonical correlation coefficient of the first canonical root is statistically essential. This coefficient will be presented in details.

The first separated canonical root explains 23% variance of the results in the first group of the parameters describing the vehicle work organization conditions. The same root separates more than 71% variability which occur inside the set of engine start-up parameters. In the first canonical root the set of engine start-up parameters explains only 10% variances in the group of the parameters describing the vehicle work organization conditions. The group of the parameters which describe the vehicle LUBLIN III work organization conditions explains only 33% variability inside the set of engine start-up parameters. The system of the canonical variables for the first canonical element assumes:

$$\begin{cases} U_1 = -0.898 \cdot \dot{t}_{pause} - 1.645 \cdot \dot{t}_{work} + 2.887 \cdot \dot{t}_{oper} - 0.803 \cdot \dot{l}_{veh} - 0.185 \cdot \dot{l}_{pis} \\ V_1 = 0.435 \cdot \dot{T}_{agent} + 0.149 \cdot \dot{I}_{ave} - 0.543 \cdot \dot{t}_{start} \end{cases}$$

where U_i – the canonical variable, which represents the parameters connected with the vehicle work organization conditions, V_i – the canonical variable, which represents the set of the engine start-up parameters, $\dot{X}_i$ – the standardized variable for the following analyzed parameters

Basing on the value of the coefficients at the particular standardized variables we can state that the parameter t_{oper} which describes the time of the vehicle operation before the next engine start-up has the greatest contribution to the U_1 canonical variable. The time of the engine operation and the time of the pause in the vehicle operation with the engine switched off before the start-up are in the next sequence. For the canonical variable V_1 the working time of the starter during the engine start-up has the greatest contribution. The engine temperature at the engine start-up is next.

In the first group of the parameters describing the vehicle work organization conditions the value of the canonical load for the time of the pause in the vehicle operation with the engine switched off is very high and equals –0.929. It shows the strong correlation between this parameter and the canonical variable U_1. The canonical loads for the next organization parameters don't exceed the value 0.3. In the set of engine start-up parameters the value of the canonical load for the working time of the starter during the engine start-up is equal –0.945. For the engine start-up temperature the value of the canonical load is high and equals 0.883. For the average value of the current consumed by the starter the value of the canonical load falls down and equals only 0.678.

Basing on the value of the canonical loads we can state that the time of the pause in the vehicle operation with the engine switched off has the most connection with the canonical variable which represents the parameters describing the LUBLIN vehicle work organization conditions. The canonical variable describing the 4CT90 engine start-up has the most connection with the working time of the starter and the engine start-up temperature.

3.3. The neural networks analysis

The next analysis, connected with searching of relationships between the set of engine start-up parameters and the group of the parameters describing the vehicle work organization conditions, was a neural networks analysis. Basing on the results of this analysis we can state that the MLP 5:5-11-3:3 neural network gives the best solution to the regression problems. This multilayer perception (characterized by the 5 neurons in input layer, 11 neurons in hidden layer and 3 neurons in output layer) is presented on Figure 1.

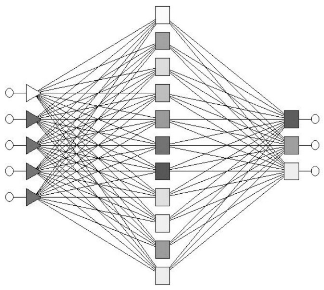

Fig. 1. The MLP 5:5-11-3:3 neural networks which give the best solution to the problem of the influence of the vehicle LUBLIN III work organization conditions on 4CT90 engine start-up parameters

The neural network MLP 5:5-11-3:3 takes into account all parameters connected with the vehicle work organization conditions. The time of the pause in the vehicle operation with the engine switched off has the top rank in this network. In the next order of the rank is: the distance covered by the vehicle, the time of the vehicle operation, the time of the engine operation. The distance covered by the piston has minimum rank. Unfortunately this neural network was characterized by the values of the errors for the following data sets: validation (error equal too 0.1301), training (error equal too 0.1353) and testing (error equal too 0.1538). The values of these errors exceed 95% level of confidence. It shows that this neural network does not give the satisfactory solution to the regression problem between the parameters describing the vehicle work organization conditions and the engine start-up parameters. It's caused by the dimensionality, interdependency and redundancy of the variables in the group of the parameters describing the vehicle work organization conditions.

4. Conclusions

Basing on the results of the statistical analysis of the operation research of the LUBIN III delivery truck and 4CT90 diesel engine we can state that the most important parameter (which is connected with the organization of the truck work conditions) influencing on the engine start-up condition is the time of the pause in the vehicle operation with the engine switched off. When this time increases the value of the engine temperature at the engine start-up is reduced and the work time of the starter during the engine start-up increases.

The results of the analysis show that the another analyzed parameters, connected with the organization of the LUBLIN III delivery truck work conditions (the time of the engine operation and the time of the vehicle operation before the next engine start-up, the distance covered by the vehicle and the distance covered by the piston before the engine start-up), have not crucial influence on the engine start-up parameters.

During the planning of the transport system we must aim at the minimizing of the time of loading and unloading the cargo in the particular points of carriage.

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AKTUALNOŚCI PNTTE

NOWE WŁADZE POLSKIEGO NAUKOWO-TECHNICZNEGO TOWARZYSTWA EKSPLOATACYJNEGO

Na zorganizowanym w październiku 2007 roku Walnym Zgromadzeniu Członków Polskiego Naukowo-Technicznego Towarzystwa Eksploatacyjnego we Wrocławiu wybrano nowe władze PNTTE. Prezesem Zarządu został ponownie prof. dr hab. inż. Andrzej Niewczas, profesor Politechniki Lubelskiej oraz Wyższej Szkoły Ekonomii i Innowacji w Lublinie. Jego zastępcami zostali dr hab. inż. Tomasz Nowakowski, profesor Politechniki Wrocławskiej oraz dr hab. inż. Jan Szybka, profesor Akademii Górniczo-Hutniczej w Krakowie. Sekretarzem został dr inż. Krzysztof Olejnik, pracownik naukowy Instytutu Transportu Samochodowego w Warszawie, natomiast Skarbnikiem został dr inż. Paweł Droździel, adiunkt Politechniki Lubelskiej. Pozostałymi Członkami Zarządu zostali: prof. dr hab. inż. Ryszard Michalski, profesor Uniwersytetu Warmińsko-Mazurskiego w Olsztnie, mgr inż. Jan Nikoniuk, dyrektor Centrum Logistyki Poczty Polskiej Oddział Regionalny w Łodzi, dr inż. Andrzej Wojciechowski, dyrektor Instytutu Transportu Samochodowego w Warszawie.