

**NEW MATERIALS  
AND IT TECHNOLOGIES  
IN PRODUCTION ENGINEERING**





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**LUBLIN 2011**

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**Wydanie publikacji dofinansowane przez Ministra Nauki i Szkolnictwa Wyższego**

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Lublin 2011**

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**ISBN 978-83-62-025-14-5**

**WYDAWCA:** Lubelskie Towarzystwo Naukowe  
Plac Litewski 2, 20-080 Lublin

**DRUK:** Wydawnictwo-Drukarnia „Liber-Duo”  
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# **The Effectiveness of the Single Screw Extrusion of Selected Thermoplastic Polymers**

## **Introduction**

The process of polymer extrusion is well-known. In literature one can find publications on the extrusion of many polymers in various technological parameters [1, 2, 7] and by means of various extruders [4, 6, 8]. The analysis of the effectiveness of the extrusion of various polymers on the basis of these data is difficult because the publications concern the same polymers but extruded on the extruders of different sizes [5, 11, 13] or different polymers extruded on the extruders of the same size but differing in the structure of the plasticizing system [3, 9, 12]. When doing analysis of this kind it is also advisable to take into account the type of the driving motor, the usage of the reduction gear as well as the technological parameters of the extrusion process [5, 10, 13]. In spite of a relatively big number of publications on the extrusion, there is still a lack of information on the comparison of this process during the extrusion of various polymers with a geometrically unchangeable extruder and the same initial value of technological parameters.

## **1. Research aim**

The aim of the research is to determine the dependences of selected parameters of the extrusion process such as polymer pressure in the melt zone, torque of the extruder screw, polymer mass flow rate in the flow channels and extruder head die, power conducted to the extruder and energy consumption per unit mass on the rotational screw speed.

## **2. Research subject**

The subject of the research is low density polyethylene Malen E FABS 23 D022 by Bassel Orlen Polyolefins, characterized by density  $\rho = 919 \div 923 \text{ kg/m}^3$ , mass flow rate index  $\text{MFR}_{(190^\circ\text{C}/2.16\text{kg})}$  equalling  $1.6 \div 2.5 \text{ g/10 min}$ , breaking stress 11MPa and Vicat softening point  $90^\circ\text{C}$ , according to the producer's data.

The subject of the research is also plasticized polyvinyl chloride of the trade name Alfavinyl and symbol GFM/4-31-TR, by Alfa PVC, LLC. The polymer contains 31 % of plastificator, which is dioctyl phthalate and lime-zinc stabilizer,

is characterized by density  $\rho = 1230 \div 1400 \text{ kg/m}^3$ , mass flow rate index  $\text{MFR}_{(150^\circ\text{C}/10.29\text{kg})}$  equalling  $4.3 \div 4.6 \text{ g/10 min}$ , elongation at break 300%, tensile strength at break 21MPa and Shore hardness A equalling 80. The processing temperature of this polymer should be from 120 to 190°C.

The third polymer used for research is new polypropylene polymer of the trade name Higran RS1684 by Bassel Orlen Polyolefins, LLC. The mass flow rate index  $\text{MFR}_{(230^\circ\text{C}/5\text{kg})}$  of this polymer equals  $3.0 \text{ g/10 min}$ , Izod notched impact strength in temperature 23°C equals  $6\text{kJ/m}^2$ , according to the producer, while in temperature 0°C it equals  $4 \text{ kJ/m}^2$ . Vicat softening point equals 149°C, modulus of elasticity is 1700MPa.

### 3. Studies of extrusion process

Studies of the extrusion process include the determination of directly and indirectly studied parameters, constant and variable parameters, as well as the description of the course of studies, research workstation and research methodology.

#### 3. 1. Studied parameters

Taking into account the aim of the research and general methodological rules of conducting experimental studies, a collection of major studied parameters characterizing the studied extrusion process was developed.

Directly studied parameters were as follows: polymer pressure in the melt zone  $p$ , MPa; torque of the extruder screw  $M$ , Nm; time for 10 full turns of plate of electric meter  $T_{\text{rot}}$ , s, extrudate mass  $m_w$ , kg. Indirectly studied (result) parameters were as follows: polymer mass flow rate (mass output of the extrusion process)  $\dot{G}$  kg/h; power conducted to the extruder  $Q_c$ , W; energy consumption per unit mass  $E_j$ , kJ/kg.

A variable parameters is the rotational screw speed of the extruder  $v$  equalling respectively 1.0; 2.0; 3.0; 4.0 and  $5.0 \text{ s}^{-1}$ .

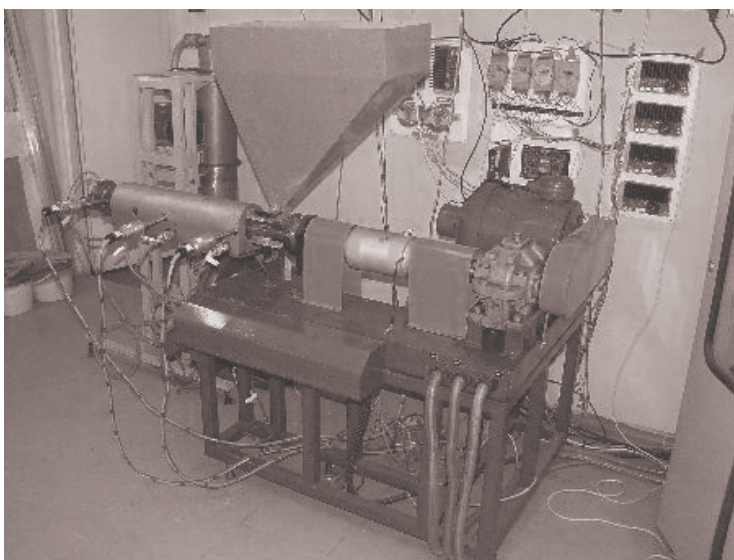
Constant parameters were first of all: studied polymer – polyethylene Malen E FABS 23 D022, Polyvinyl chloride Alfavinył GFM/4-31-TR and polypropylene Higran RS1684; temperature set in the respective functional zones of the plasticizing system 150°C, 160°C, 170°C and on the extruder head 160°C; consumption of energy conducted to the extruder  $E$ , J; time of cutting off extrudate measuring lengths – 30s; the number of full turns of plate of electric meter 10.

Disturbing factors were first of all: changes of the surrounding temperature –  $20 \pm 2^\circ\text{C}$  and air relative humidity –  $50 \pm 5\%$ .



### 3. 2. Description of the course of studies

Measurements were conducted on the laboratory extruder W-25D (fig.1) manufactured in the Institute for Engineering of Polymer Materials and Dyes in Toruń. The diameter  $D$  of the screw equals 25mm while  $L/D$  ratio = 23. The maximum value of the rotational screw speed during operation without the polymer load equals  $5.35\text{ s}^{-1}$  while power rating of the extruder motor equals 3.57 kW. The extruder was equipped with the extruder head with an exchangeable forming element – extruder head. During the research an element with a die of the circular cross section and diameter 3 mm was used. Between the screw shaft and drive shaft of the extruder gear transmission there is an inductive torque meter Mi200 for measuring the torque and the real spot rotational screw speed. Combined pressure and temperature sensors were placed in two zones of the plasticizing system and in the extruder head. The measurement station was complete with the IB MPC computer, whose software PCLS-920 GENIE enabled archiving, processing and visualization of data on the screen in real time.



**Fig. 1. General view of the research workstation**

Measurements of all directly studied parameters were made three or five times at various rotational screw speeds. On the basis of preliminary studies it was stated that the stabilization of the extrusion process, after the change of the rotational screw speed, takes place after about 20 minutes. During the research, measurements of directly studied parameters were always made after 20 minutes from the rotational screw speed change. Values of the studied parameters were read out from the respective slots of the computer screen.

During the extrusion, extrudate samples were taken in order to determine polymer mass flow rate and it was assumed that extrudate length extrusion time equaled 30 seconds. The samples were weighed by means of the laboratory scales TP-3/1 with the precision 0.1g and range 3000g. The value studied indirectly in order to determine energy consumption per unit mass was the time of 10 full turns of plate of electric meter. All necessary time measurements were made by means of Chronograph JS-306 with the precision 0.01s.

#### 4. Research results

As a result of the conducted research we determined the influence of the rotational screw speed change on the value of polymer pressure in the melt zone of the plasticizing system, mass flow rate of the processed polymer, power conducted to the extruder and energy consumption per unit mass.

Results of polymer pressure measurements in the melt zone are shown in table 1. With the increase of the screw speed there is an initial decrease of polyethylene pressure by 2.7 MPa (21.8%) and then its continuous increase in the range of screw speeds from 2 to 5  $\text{s}^{-1}$  by 5.3 MPa (54.6% in relation to polymer pressure at the rotational screw speed 2  $\text{s}^{-1}$ ). The observed decrease of the processed polymer pressure value can result from both the decrease of flow resistances together with polymer temperature increase and the insufficient granulate feeding into the plasticizing system, which is proven by significant differences in the received spot values of polymer pressure in the feed zone at the same value of the rotational screw speed. The dependence of polyvinyl chloride pressure in the function of the rotational screw speed has a slightly different course; however the general character of the curve is similar. At the lower values of the screw speed, PVC pressure has higher values and with the increase of screw speed  $v$  the PVC pressure decreases from 24.2 to about 20.5 MPa at  $v = 3 \div 4 \text{ s}^{-1}$ , and afterwards it increases to 30.0 MPa at the highest rotational screw speed within the studied range. At the lower values of screw speeds  $v$ , there are resistances connected with the flow of plasticized polymer of

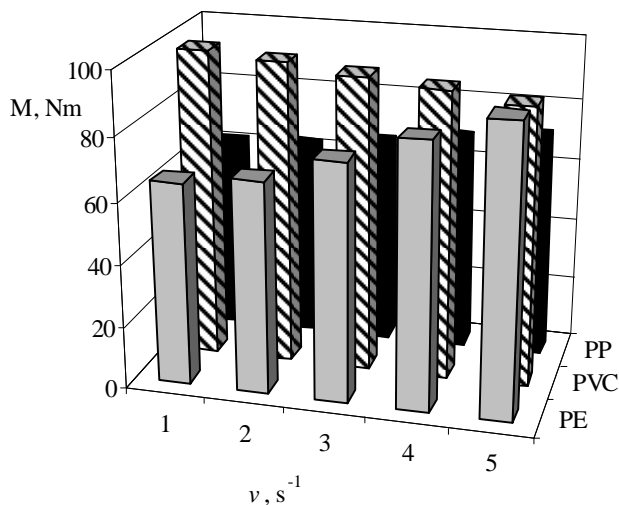
**TABLE 1. Pressure of the processed polymer in the melt zone in the function of the rotational screw speed of the extruder**

Rotational screw speed $v, \text{s}^{-1}$	Values of polymer pressure in the melt zone, MPa		
	PE Malen E FABS 23 D022	PVC Alfavinył GFM/4-31-TR	PP Higran RS1684
1,0	12,4	24,2	27,3
2,0	9,7	21,8	24,2
3,0	10,3	20,4	25,0
4,0	12,7	20,5	27,2
5,0	15,0	22,5	30,0

low temperature, and therefore of high viscosity, while at higher values (from  $v = 2 \text{ s}^{-1}$ ), the polymer pressure increase can result from increasing polymer flow resistances at the channels and extruder head die entries. The dependence of polymer pressure on the screw speed during polypropylene extrusion has a similar course to the one received for polyethylene, but values of the studied parameter are generally over twice as high. With the increase of the screw speed, there is an initial decrease of the studied parameter value by 3.1 MPa (11.3%), and then its increase within the screw speed range from 2 to  $5 \text{ s}^{-1}$  by 5.8 MPa, which is 24% in relation to polymer pressure received at the screw speed equaling  $2 \text{ s}^{-1}$ .

The course of torque changes with the increase of the rotational screw speed of the extruder in each of the studied cases is slightly different (fig.2). The highest torque values were observed during the extrusion of polyvinyl chloride, while the lowest during the extrusion of polypropylene.

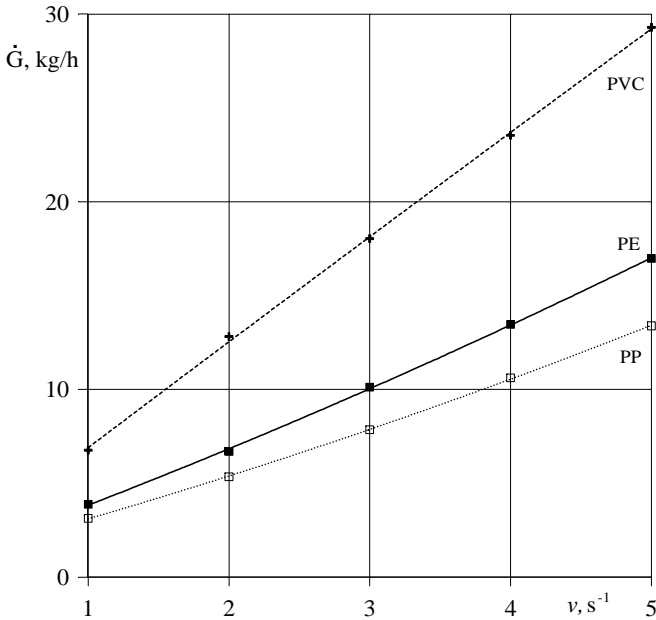
While extruding polyethylene, within the whole variability range of screw speed values, the torque value increases at average values by 27.3Nm, which corresponds to about 42.13% in relation to the initial value. A big variability range of spot values of the screw torque received at the same value of the rotational screw speed can constitute a kind of proof for the insufficient or discontinuous feeding of polyethylene granulate into the plasticizing system. The screw torque in the screw speed range from 1 to  $4 \text{ s}^{-1}$  during PE extrusion is always smaller than the screw torque during PVC extrusion, and only at the speed  $5 \text{ s}^{-1}$ , the torque is slightly bigger. In the case of polyvinyl chloride extrusion, the course  $M = f(v)$  is definitely different. The extrusion begins with a big torque equaling 98.5 Nm. With the increase of the rotational screw speed the



**Fig. 2. Screw torque of the extruder in the function of its rotational speed during the extrusion of studied polymers**

torque value undergoes a relatively small decrease to 88.9Nm at the highest value  $\nu$  (9.7%). Such a course of the dependence  $M = f(\nu)$  can be explained by the decreasing viscosity of extruded polyvinyl chloride occurring with the increase of the screw speed which directly corresponds to polymer flow resistances. However, when extruding polypropylene, the course of the torque in the function of the screw speed has a similar character to the course received during the extrusion of polyethylene but the torque has considerably lower numerical values. That is, after the period of relative stabilization at the level 62Nm within the screw speed range  $\nu = 1 \div 2 \text{ s}^{-1}$ , the torque begins to increase and reaches the peak at the highest screw speed equaling  $5 \text{ s}^{-1}$ . The increase of torque values equals 9.9 Nm, which constitutes 16.1% of the value at the screw speed equaling  $1 \text{ s}^{-1}$ .

Figure 3 presents the results of calculations of mass flow rate of studied polymers. With the increase of the value of the changeable factor the output of the polyethylene extrusion process increases – within the studied range of screw speeds the output increases over three times (337%). The increase of the crew speed, by a unit at a time, contributes to the increase of polyethylene mass flow rate by 2.81 kg/h (72.24%), 3.42 kg/h (51.04%), 3.34 kg/h (33.00%) and 3.53 kg/h (26.22%). During polyvinyl chloride extrusion the polymer mass flow rate was almost two times bigger in comparison with polyethylene and increased from 6.77kg/h to 29.3 kg/h, which corresponds to the increase by 333% which is comparable to the increase of the output during polyethylene extrusion.



**Fig. 3. Polymer mass flow rate in the function of rotational screw speed during the extrusion of studied polymers**

However, during the screw speed increase from 1 to  $2\text{s}^{-1}$  the output of polyethylene increased by  $2.81\text{kg/h}$  (72.24%), while of polyethylene by  $6.05\text{kg/h}$  (89.36%). Further increases are not as spectacular and nominally they are similar; they equal respectively  $5.22\text{kg/h}$  (40.72%),  $5.5\text{kg/h}$  (30.49) and  $5.76\text{kg/h}$  (24.47%) of the proceeding value. During polypropylene extrusion the lowest values of the flow rate for each of the screw speeds were observed. The increase of polypropylene flow rate equals  $10.26\text{kg/h}$ , that is 427.8%, which by percentage is the highest increase in the flow rate of studied polymers. During subsequent increases of the screw speed, the polypropylene flow rate increases respectively by  $2.22\text{kg/h}$  (70.93%),  $2.5\text{kg/h}$  (46.73%),  $2.77\text{kg/h}$  (35.29%),  $2.77\text{kg/h}$  (26.08%).

Differences in the increase intensity of PVC and PE mass flow rate result from a different character of polymer flow resistances in the plasticizing system and extruder head channels and die, which is visible on the charts showing the changes of extruder screw torque while increasing the rotational screw speed which, after an initial increase, decreases in the case of PVC and increases in the case of PE. The results correlate with the ones received earlier for polymer temperature and pressure distribution along the plasticizing system and extruder head. The received dependences also result from the differences in the density of studied polymers, which is bigger for PVC.

The power conducted to the extruder and the energy consumption per unit mass during the extrusion of polyethylene, polyvinyl chloride and polypropylene in the function of the rotational screw speed are shown in figures 4 and 5.

In each case there is a clear increase of the power conducted to the extruder with the increase of the screw speed. For polyethylene it equals  $2857.1\text{ W}$ , for polyvinyl chloride  $2869\text{ W}$  and for polypropylene  $2162\text{ W}$ , which corresponds respectively to 163.7%, 171.2% and 124.7% of the initial value.

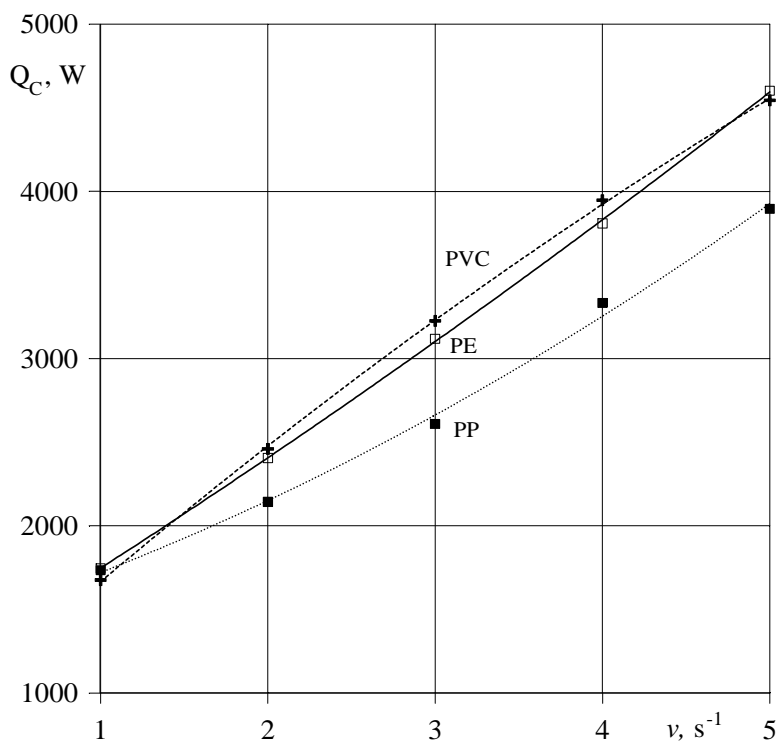
In the case of polyethylene and polyvinyl chloride extrusion, for each of the studied screw speeds, the power conducted to the extruder is almost the same or the difference equals merely over  $100\text{W}$ . However, the energy consumption per unit mass during polyethylene extrusion at the lowest screw speed is lower by 81.27% than during PVC extrusion at the analogical speed. The extrusion of these polymers at the speed  $2\text{s}^{-1}$  even makes this difference bigger – up to 87.28%. At subsequent studied rotational screw speeds the difference in the energy consumption per unit mass equals 72.39%, 68.75% and 74.61%.

The biggest energy consumption per unit mass occurs during polypropylene extrusion, independently from the rotational screw speed.

During polyethylene extrusion, the increase in the power conducted to the extruder together with the increase of the screw speed correlates with the course of the dependence of the screw torque and mass flow rate of this polymer on the screw speed. Simultaneously, the observed decrease of the energy consumption per unit mass proves the increase in the participation of the heat flux generated because of polymer friction in the heat flux necessary for polymer plasticization,

since the power conducted to the extruder does not increase as intensively as it would appear from the polymer mass flow rate increase.

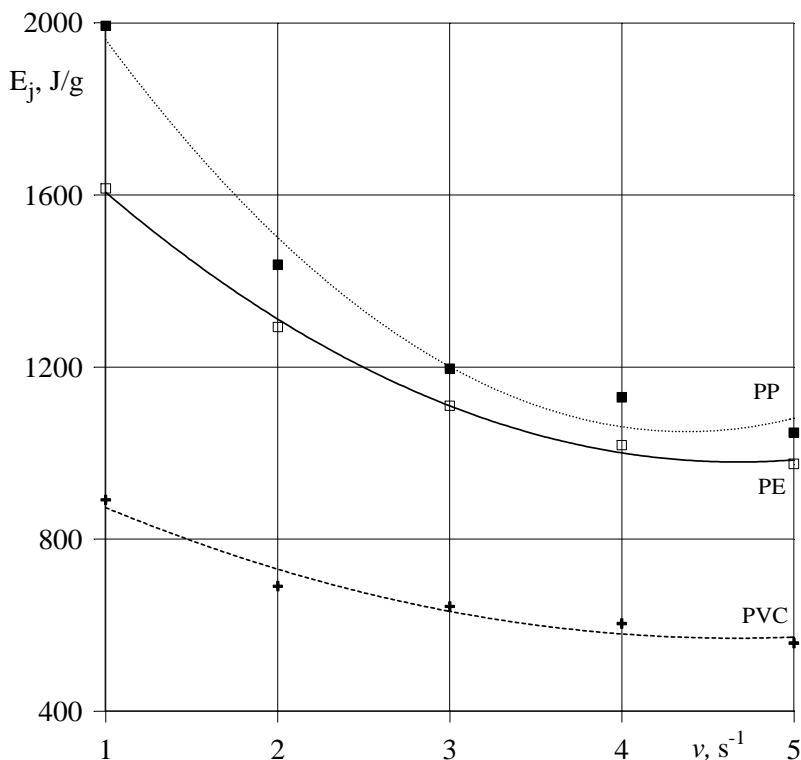
Nethertheless, during polyvinyl chloride extrusion, the initial increase in the screw torque is caused by the increase in the power conducted to the extruder resulting from the increase in polymer mass flow rate. The following decrease in the screw torque, despite the increase in the power conducted to the extruder and polymer mass flow rate, can be explained by too high an increase in the heat flux generated because of polymer friction which causes the increase in polymer temperature and decrease in viscosity, which in turn causes the decrease in polymer flow resistances. Certainly, a resulting thermal degradation of the processed polymer also matters and it causes the decrease of polymer viscous properties and decrease of polymer flow resistances in the plasticizing system.



**Fig. 4. Power conducted to the extruder  $Q_c$  in the function of the rotational screw speed  $v$  during the extrusion of studied polymers**

The observed changes of screw torque, polymer mass flow rate, power conducted to the extruder and energy consumption per unit mass depending on the extruder screw speed during polypropylene extrusion can be explained by analogical phenomena occurring during the extrusion of low density polyethylene.

With the increase of the rotational screw speed, the values of polymer mass flow rate and polymer temperature increase because of the increasing participation of friction heat which causes the increase of enthalpy flux of extruded polymers and the decrease of the energy consumption per unit mass.



**Fig. 5.** Energy consumption per unit mass  $E_j$  in the function of the rotational screw speed  $v$  during the extrusion of studied polymers

Differences in the received values of the energy consumption per unit mass result from different values of specific heat of studied polymers. This value is over two times lower in the case of PVC. The energy consumption per unit mass decreases with the increase of the screw speed and the change in value equals 39.65% during PE extrusion and 37.34% during PVC extrusion.

#### 4. Conclusion

During PE and PP extrusion, with the increase of the rotational screw speed, the torque value of the extruder screw also increases but it decreases during PVC extrusion. Independently from the type of the extruded polymer, the dependence of polymer mass flow rate on the screw speed is identical, that is polymer mass

flow rate increases with the increase of the screw speed, most intensively in the case of PVC.

The dependence of the power conducted to the extruder has a very similar course and the intensity of power increase is almost identical for each extruded polymer. However, the energy consumption per unit mass decreases with the increase of the screw speed, independently from the type of the extruded polymer - most intensively in the case of PP and least intensively in the case of PVC.

On the basis of the conducted comparative studies on the effectiveness of the single screw extrusion process of selected thermoplastic polymers (polyethylene, polypropylene and polyvinyl chloride) it turns out that it is polyvinyl chloride that can be most effectively extruded by means of W-25 extruder.

## **The Effectiveness of the single screw extrusion of selected thermoplastic polymers**

### **Summary**

The paper presents comparative studies on the effectiveness of the single screw extrusion process of selected thermoplastic polymers (polyethylene, polypropylene and polyvinyl chloride). The following dependences were determined: polymer pressure in the melt zone, extruder screw torque, polymer mass flow rate in the extruder head flow channels and die, power conducted to the extruder and energy consumption per unit mass on the rotational screw speed and type of extruded polymer.

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#### Acknowledgments

The research was financed from the science fund in the year 2010 ÷ 2012 as a research project no N 508 483838.

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## **The Effectiveness of the Single Screw Extrusion of Selected Thermoplastic Polymers**

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## **Issues of poly(vinyl chloride) extrusion process modified by blowing agent**

### **Introduction**

Until now many different kinds of elements from plastic materials was produced with using well-known methods [31]. This products was made mostly from cellular polyethylene [30, 32]. Currently produced polymer shapes, pipes, cables and plates are made from different types of polymer materials, depending on application [28, 29]. The most frequently low density polyethylene (PE-LD), high density polyethylene (PE-HD) and poly(vinyl chloride) (PVC) are used. This products are characterised by a solid structure across the whole section. However, because of new application possibilities, needs of changes and improvement specific properties and requirements it is essential to modify polymer material. In extrusion process polymer modification can be done by changes of technological conditions, construction of plasticizing systems and processing tools or by using special agents, which extensively affect polymer materials.

It is possible however, to change the polymer structure from solid into microcellular, which effects in obtaining new physical and functional properties of the product. In such a case, extrusion process must be replaced with the microcellular extrusion process.

### **Characteristic of process**

Microcellular extrusion process rest on inserting into the input plastic the blowing agent (porophor), i.e. a substance which in the transformation process boils or decomposes under increased temperature, emitting gas products which cause changes in the microstructure of the plastic, from solid into microcellular. This usually occurs within the melt-pumping zone for plasticizing system. However, some blowing agents, being liquids or solid bodies, are inserted into the plastic during the final phase of its manufacture [15, 18, 21, 23, 25]. Extruder product obtained in the microcellular extrusion process may be microcellular along the whole section, or have a solid topcoat and a microcellular core.

In microcellular extrusion of plastic materials with application of blowing agents, the extrusion product is obtained with new, modified physical and technological properties i.e. reduced mass of the product and reduced wear, improved dampening properties (heat, noise) and reduced processing contraction

[9, 13, 16]. Also the size, quantity and geometrical characteristic of micropores formed in the microcellular extrusion process have some influence on the properties of the final product of microcellular extrusion. Change in the degree of porosity of the shapes and coatings is made by decreasing or increasing the amount of the blowing agent and by gradually regulating the screw's rotational speed and the system receiving the extruded product [8, 14, 20, 24].

In the microcellular extrusion process it is very important to select the input plastic and the type of blowing agent properly. It has an influence on process conditions, specially on temperature of plasticizing system zones and extruder heads zones. Blowing agents used should expand at the end of melt-pumping zone of plasticizing system or in extruder head [7, 10, 22].

As far as blowing agents are concerned, the type and quantity of inserted porophors play significant role, inasmuch as they exert influence on the final density of microcellular plastic and determine the choice of microcellular method [10, 21]. During the selection the method of its proportioning, type of input plastic, temperature of its decomposition and construction of plasticizing system should be taken into consideration.

## **Methods of microcellular extrusion process**

Extruder product obtained in the microcellular extrusion process may have different structure types: microcellular in whole sections or with solid topcoat and microcellular core. In every type of presented structure can exist three kinds of micropores: closed, open and half – open. Depending on the structure of the obtained extruder product, the following methods can be applied [10, 21, 25]:

- free cellular method – plasticized material is subject to free extrusion; then porous structure is created along the whole section, whose extension is limited by means of cooling the shape,
- inside cellular method, called Celluka method – cooling of extruder product is done on the whole surface of the shape directly after leaving the extruder die, in order to avoid generation of porous structure on the surface of the profile. This method allows to obtain cellular extruder products with a solid topcoat,
- partial cellular method – extrusion of shapes with a partially solid topcoat. In this case, the cooling intensity of the extruder product is done only to the determined part, whereas the remaining part undergoes cellular extrusion in the free way,
- co-extrusion method – the plastic being provided through the internal channel from one plasticizing system, whereas outer channel of the extruder head provides solid plastic to the second plasticizing system.

Technological requirements for extrusion of microcellular shapes and over extruder products impose specific technology of constructing extruder heads.

While designing this type of extrusion heads, one must remember to meet two basic requirements: cross-sections of extruder head channels should be relatively large in order that there was no significant pressure drop, and extruder die cross-section has to be considerably reduced in relation to the cross-section of cellular extrusion product [7, 17].

The following extruder heads are used in microcellular extrusion process [10, 25]:

- straight line extruder heads – for the extrusion of shapes with thin walls and small cross-sectional areas,
- mandrel straight line extruder heads – equipped with a conical core enabling generation of necessary pressure, used for shapes obtained by means of changing the moulding ring,
- extruder heads with screening grid – enable regulation of plastic flow resistance and allow to generate higher material pressure, at possibly smallest reduction of plastic flux cross-sectional areas,
- extruder heads with rotary core – equipped with a screw tip performing the function of a core takes the form of a mandrel,
- extrusion heads of Celluka – plastic is extruded with significant resistance of flow.

In microcellular extrusion process of different types of profiles and coatings, shape and dimensions of extruder product cross – section are preliminary done by extruder head. It is important to take into consideration Barus effect and processing shrinkage during this process. However, this system is not stable yet. To obtain microcellular extruder product with homogenous topcoat without micropores and with suitable dimensions and shape is very important to fixed the topcoat by quick cooling and solidification in calibration process. Calibration machines used in microcellular extrusion technological lines have to cool down the extruder product to temperature, which guarantee stability of shape and dimensions [15].

### **Blowing agents**

Decomposition temperature of blowing agent used in the form of liquid or solid body should be higher than melting temperature of the plastic but lower than its processing temperature. Microcellular plastic which is in liquid state is not stable system, because of diffusion and contact potential difference between plastic/gas interface. It caused decreasing amount of micropores and increasing its dimensions in plastic material. Micropores grow until state of equilibrium between gas pressure and contact potential difference. The best microcellular structure of extruder product is made by the most quickly cooling and solidification of plastic material [11, 12].

Blowing agents used in microcellular extrusion process are subject to the same processes as input plastic i.e. heating, homogenisation, transportation and compressing.

Porophors divides to physical and chemical [15, 19]. Physical blowing agents are substances which only changes its state of aggregation during the process. That change ensure under the pressure and in higher temperature, which caused porophor dissolvation in plastic material. Chemical blowing agents act in the same way like physical porophors, but gas products became during its decomposition in microcellular process of plastic material.

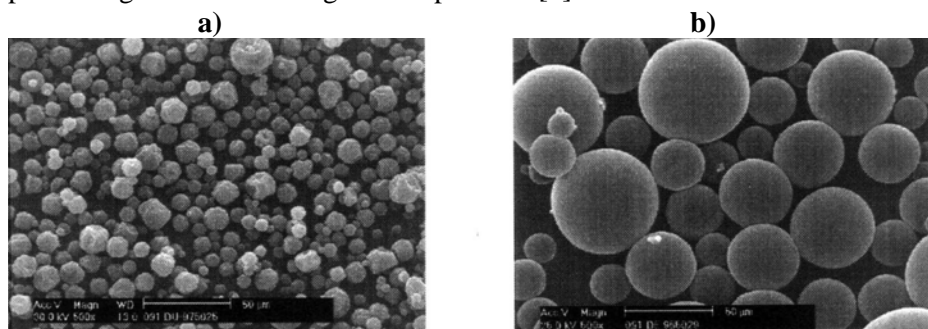
The next divide of blowing agents is to exothermic and endothermic. Decomposition of exothermic porophors proceeds self-acting, even after cutting off the heating. Because of that products modified by this kind of blowing agents should be long and intensively cooled to prevent deformations. Blowing agents having endothermic decomposition draw heat to expand of micropores. Microcellular process ends rapidly after cutting off the heating. This kind of porophors significantly reduce cooling process of extruder products.

Recently [3, 5, 25] was introduced to the market new blowing agent in the form of polymeric capsules called microspheres. This microspheres are filled gas form the group of hydrocarbons like isooktane, izobutan or isopentan. Microspheres take thermal energy to plastify the capsule and to change state of aggregation of hydrocarbon form liquid to gas. Under the influence of determined temperature microspheres increase its volume about 50 times (fig. 1). Next the microcellular structure is formed and ensure density decreasing of extruder product with retaining microscopic pores, which are closed and have homogenous size.

Microspheres, because of mass reduction of product give measurable economic benefits and also modify others properties, i.e. susceptibility to compression, ability to recovery of primary product shape, vibrations absorption and profitable electro- and heat-insulating properties [1].

Spherical shape of microspheres is one of the unique features, which distinguish this type of blowing agent from others [6]. During expansion microspheres retain its barrier properties, what prevent gas releasing and connecting particular capsules.

There are few types of microspheres, which should be selected depending on processing method and range of temperature [2].



**Rys. 1. Microscopic view of microspheres Expancel: a) before expansion, b) after expansion [1, 2]**

Microspheres are already used, specially in paints production [4]. This kind of blowing agents are just introduced to polymer processing, because of deficiency in appropriate information connected with change of processing conditions during its using in particular processes. There is also no information about connection between size and distribution of micropores and selected properties of the product. Microspheres influence on course, efficiency and effectiveness of microcellular extrusion process and also on properties of obtained extruder product was no supported by any research results until now.

## Experimental

Microcellular extrusion process of PVC developed by the Department of Polymer Processing at Lublin University of Technology involves selection of the input plastic and the blowing agent, determination of temperature for particular plasticizing system zones and extruder head zones, and also introduction of design changes in particular elements of processing machines and tools comprising technological lines.

Input plastic in cellular extrusion process was plasticized, transparent poly(vinyl chloride) PVC with a trade name Alfavinyl GFM/4-31-TR. The basic properties of PVC used in process were placed in table I.

The plastic was modified with a special blowing agent called microspheres Expancel. Microspheres are physical porophor in the form of granulated product having endothermic decomposition characteristic, which was inserted into the plasticizing system along with the plastic. The proportion of the blowing agent ranged from 0 to 2.5% of the mass in relation to the mass of the input plastic.

**TABLE I. Basic properties of PVC Alfavinyl GFM/4-31-TR according to producer's data**

Property	Value
Density, kg/m <sup>3</sup>	1230
Modulus of elasticity, MPa	2600
Tensile strength, MPa	21
Ultimate elongation, %	300
Hardness Shore A, °Sh	80

In the microcellular extrusion process of PVC, a single-screw extruder with screw diameter 32 mm and an extruder head with die diameter 4.1 mm were used. Modernised technological line included also complementary machines i.e. water cooling machine and collecting machine. Section of a technological line is shown in fig. 2.



**Fig. 2. View of microcellular extrusion technological line**

Microcellular extrusion process of modified PVC was conducted in the different conditions, which was selected in tentative research of the process. Main conditions of microcellular extrusion process are presented in table II.

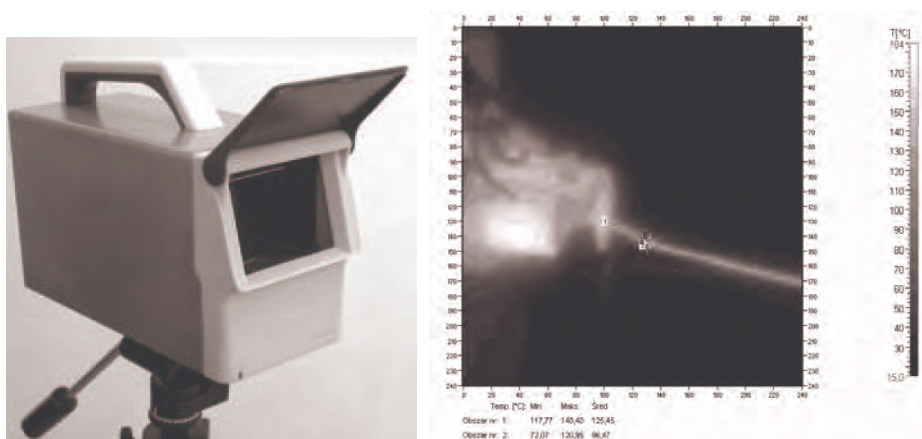
**TABLE II. Conditions of microcellular extrusion process of modified PVC**

Process conditions	Value			
Temperature in plasticizing system, °C	Heating zones			
	I	II	III	IV
	100	110	120	130
Temperature in extruder head, °C	140			
Temperature of cooling agent (water), °C	18			
Screw rotational speed, s <sup>-1</sup>	0.75 – 1.85			

## Results

During microcellular extrusion process of poly(vinyl chloride) research of process course was made. The research contain measurements of mass and volume intensity of discharge of microcellular extruder product, Barus effect and temperature of microcellular extruder product.

Thermovision measurements was done during microcellular extrusion process with the usage of thermovision camera V-20. Measurements were made in 29 measurement points, which let to prepare visualizations in the form of thermal pictures - thermographs (fig. 3).



**Fig. 3. View of thermovision camera and selected thermograph picture**

Volume intensity of discharge of microcellular extruder product essentially increase in whole range of content of microspheres. It is directly proportional to screw rotational speed in certain ranges (table III).

**TABLE III. Research results of volume intensity of discharge of microcellular extruder product for each content of microspheres and screw rotational speed**

Content of microspheres, %	Volume intensity of discharge of microcellular extruder product, $10^{-6} \text{ m}^3/\text{s}$		
	Screw rotational speed $v_1=0.75 \text{ s}^{-1}$	Screw rotational speed $v_2=1.30 \text{ s}^{-1}$	Screw rotational speed $v_3=1.85 \text{ s}^{-1}$
<b>0</b>	100.5	173.3	245.1
<b>0.5</b>	114.2	208.6	311.2
<b>1.0</b>	130.9	256.7	407.6
<b>1.5</b>	162.6	301.7	421.6
<b>2.0</b>	185.6	331.6	491.6
<b>2.5</b>	219.6	393.3	520.0

Barus effect is a process of enlarge of extruder product during extrusion process. It take place in the output of extruder head. Barus effect measurements show that it directly proportional increased with increasing screw rotational speed, without reference to content of microspheres (table IV). Value of this effect gradually and steadily increase up to 1.5% content of blowing agent. After exceeding this value Barus effect decreasing is observed. I could be caused by to much value of content of microspheres in PVC and worsen microspheres growing.



**TABLE IV. Research results of Barus effect of microcellular extruder product for each content of microspheres and screw rotational speed**

Content of microspheres %	Barus effect %		
	Screw rotational speed $v_1=0.75 \text{ s}^{-1}$	Screw rotational speed $v_2=1.30 \text{ s}^{-1}$	Screw rotational speed $v_3=1.85 \text{ s}^{-1}$
<b>0</b>	108.8	112.3	117.4
<b>0.5</b>	115.7	121.3	126.4
<b>1.0</b>	124.9	131.2	136.5
<b>1.5</b>	128.9	137.6	142.3
<b>2.0</b>	129.5	134.0	143.1
<b>2.5</b>	133.8	140.6	145.4

Extruder product obtained as a result of PVC microcellular extrusion process was examined in terms of selected physical, mechanical and functional properties (table V).

In the conducted process, degree of porosity of the shape ranged from 0% to 52% was obtained. This value define percentage of microcellular surface in relation to the total surface of the tested extruder product. In the case of tensile strength, adding a blowing agent to plastic compound affects its value.

**TABLE V. Research results of microcellular PVC selected properties, for screw rotational speed  $v_1 = 0.75 \text{ s}^{-1}$**

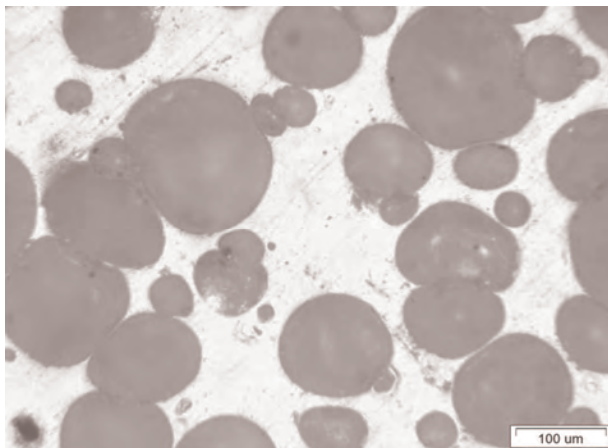
Property	Content of microspheres %					
	<b>0</b>	<b>0,5</b>	<b>1,0</b>	<b>1,5</b>	<b>2,0</b>	<b>2,5</b>
<b>Density, kg/m<sup>3</sup></b>	1209.2	883.4	781.9	689.5	639.6	581.6
<b>Degree of porosity, %</b>	0.0	26.8	35.2	42.9	47.1	51.8
<b>Hardness, ° Sh</b>	35.7	27.9	23.8	21.5	19.0	16.3
<b>Tensile strength, MPa</b>	no break	8.4	6.6	5.6	4.5	3.6

Both density and hardness of microcellular extruder product decreased depending on content of microspheres. Values of this properties are independent on screw rotational speed. The largest decrease of hardness is in 0.5% content of blowing agent. The obtained tensile strength also mostly depends on content of microspheres. Blowing agent influence caused weakness of extruder product just in the lowest content of porophor.

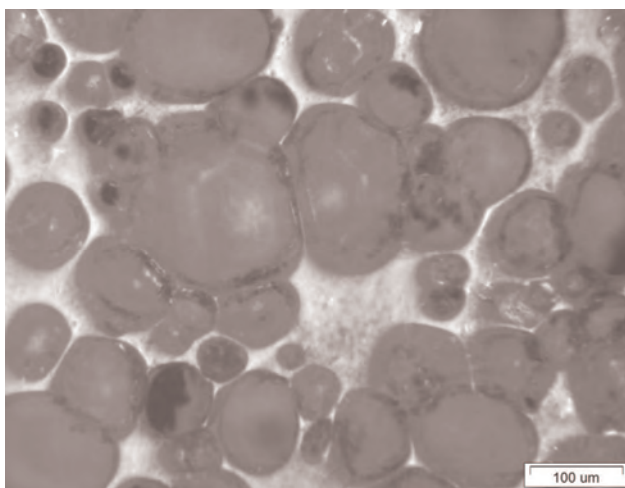
Research of poly(vinyl chloride) microcellular extrusion process contain also studies of microcellular physical structure of extruder product by computer image analysis [26, 27]. Structure research includes measurements of size, amount, distribution, surface fraction and unit surface of expanded micropores.

In the effect of microcellular extrusion process different types of extruder product physical structure was obtained. Selected structure of PVC extruder product containing 0.5% and 2.5% of microspheres are presented on fig. 4.

a)



b)



**Fig. 4. Physical structure of microcellular extruder product with content of microspheres: a) 0.5%, b) 2.5%**

## Conclusions

Extruder products obtained in microcellular extrusion process characterizes regular, microcellular inside structure with closed pores and smooth and hard. PVC modification by used microspheres Expancel caused significant changes in microcellular extrusion process course, selected physical properties and structure of microcellular extruder product.

Changes of mass and volume intensity of discharge of microcellular extruder product and Barus effect are caused by significant decrease of PVC density and physical structure change of extruder product.

Increasing of content of blowing agent used in poly(vinyl chloride) have an influence on temperature decrease of microcellular extruder product during microcellular extrusion process. Its caused by heating absorption through microspheres during its expansion.

This kinds of elements with blowing agent have low density, water and oil absorptivity and higher flammability. As result of increasing degree of porosity extruder product density was reduced by 52% in relation to solid plastic density. Blowing agent content does not cause deterioration of topcoat properties of the extruder product, owing to which it is characterized by low thermal conduction, good insulating power and high resistance to weather conditions.

The microspheres used in the microcellular extrusion process give a possibility of creating products with new, modified properties. Adding the blowing agent to the input plastic causes little processing shrinkage, better damping and insulating, lower flammability and water and oil absorptivity.

The change in these properties offers new possibilities of applying this kind of products with simultaneous reduction in their production costs. The microcellular extrusion method can be used to produce different kinds of shapes, profiles and cable and conduit coatings which have a microcellular structure and whose physical, chemical and functional properties can be modified to meet the needs resulting from the conditions in which they will be utilized.

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## **Issues of poly(vinyl chloride) extrusion process modified by blowing agent**

### **Abstract**

Nowadays different types of pipes, cables, plates and profiles are manufactured from different plastics. The most often applied include low and high density polyethylene and polyvinyl chloride. Due to new areas of use, the need to alter or improve specific properties and requirements set for new products, it was necessary to introduce certain modifications.

In recent years, microcellular extrusion technology became one of the most rapidly developing method of polymer processing. It was designed to obtain microcellular profiles and coatings with lower density, having no sinks on the extruder product surface and showing minimum contraction, with simultaneous retaining of similar properties of products obtained in conventional extrusion.

An extruder product obtained in the microcellular process has a regular microcellular internal structure with closed pores and a smooth, hard topcoat. This type of product containing the blowing agent has low density, poor water absorptivity, poor corrosion and chemical resistance, and also low flammability. In this paper are presented characteristic of PVC microcellular extrusion process modified by special blowing agent and selected research results of course and effects of that process.

**Key words:** polymer processing, microcellular extrusion process, blowing agent, microspheres, poly(vinyl chloride)

## **Aspekty wytłaczania poli(chlorku winylu) modyfikowanego środkiem mikroporującym**

### **Streszczenie**

Obecnie różnego rodzaju rury, kable, przewody oraz kształtowniki są wytwarzane z różnych tworzyw polimerowych. Do najczęściej stosowanych zalicza się polietylen małej i dużej gęstości oraz poli(chlorek winylu). Ze względu jednak na coraz to nowsze kierunki zastosowań, potrzebę zmiany lub polepszenie określonych właściwości oraz wymagania, jakie stawiane są tego typu wytworom konieczna staje się modyfikacja tworzywa. Wytłaczanie mikroporujące tworzyw termoplastycznych jest w ostatnich latach jedną z szybciej rozwijających się metod przetwórstwa tych tworzyw. Ma ono na celu otrzymywanie głównie różnych kształtowników i powłok mikroporowatych

o zmniejszonej gęstości, pozbawionych zapadnięć na powierzchni wytłoczyny oraz wykazujących minimalny skurcz przetwórczy przy jednoczesnym zachowaniu zbliżonych właściwości wytworów wytłaczanych metodą konwencjonalną.

Wytłoczyna otrzymana metodą wytłaczania mikroporującego charakteryzuje się regularną mikroporowatą strukturą wewnętrzną o zamkniętych mikroporach oraz gładką i twardą warstwą wierzchnią.

Tego typu elementy zawierające środek mikroporujący mają obniżoną gęstość, zmniejszoną nasiąkliwość, odporność na korozję i czynniki chemiczne oraz zmniejszoną palność.

W artykule przedstawiono charakterystykę procesu wytłaczania mikroporującego PVC modyfikowanego specjalnym środkiem mikroporującym oraz zaprezentowano wybrane wyniki badań przebiegu i efektów tego procesu.

**Słowa kluczowe:** przetwórstwo tworzyw polimerowych, wytłaczanie mikroporujące, środek mikroporujący, mikrosfery, poli(chlorek winylu)

## **Issues of poly(vinyl chloride) extrusion process modified by blowing agent**

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## **Effect of Milling Parameters upon Burr Formation during AZ91 HP Magnesium Alloy Face Milling**

### **1. Introduction**

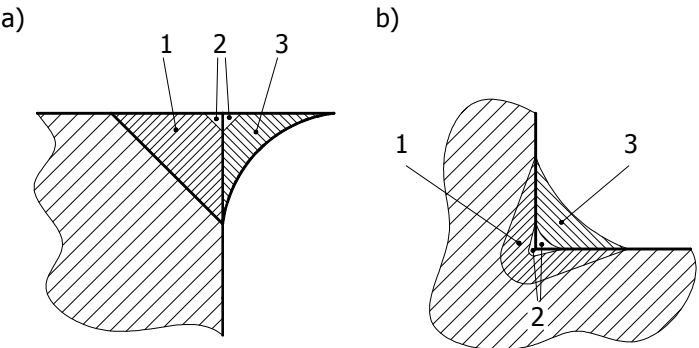
Machining process is one of the most frequently used from wide range of metalworking processes. Face milling, one of milling varieties, is a very important and often used industrial cutting process, especially because of its efficiency, productivity and possibility of manufacturing geometrical, complicated parts. Increasing demand for high accuracy, correlated with reasonable manufacturing costs, yield constant development of milling process.

Although burrs are created in most machining processes, there have not been sufficiently detailed studies of their formation and control in machining. In the lexicon a burr is described as a sharp overhand developed on the workpiece surface after machining or grinding operations. A more accurate definition is given by ISO standards. According to ISO 13715, a burr is a rough remainder of material outside the ideal geometrical shape of an external edge, residue of machining or forming process[12].

Parts created by designers in a computer systems have ideal shape without any deviation, nonetheless sometimes real parts created on the machine have large deviations from ideal geometrical shape and they are delivered without analysis of edge condition. Edges which are not well defined can create difficulties in assembly operations, where high accuracy is required. On the other hand, if burrs do not have to be removed from a workpiece for accuracy reasons, they can be very sharp and dangerous for workers and consumers due to injuries and scratches. Besides burr definition, ISO 13715 contains sharp edge, undercut and passing definitions, the graphical representations of external and internal edges are shown in Figure 1. The state of the edges of a part shall be indicated in the technical documentation by the basic graphical symbol shown in Figure 2, which is available in most CAD systems, such as Solid Edge, Unigraphics etc. If indication of permitted burr direction is necessary, the indication of size shall be given in particular area as shown in Figure 2b, which means that the burr direction is defined.

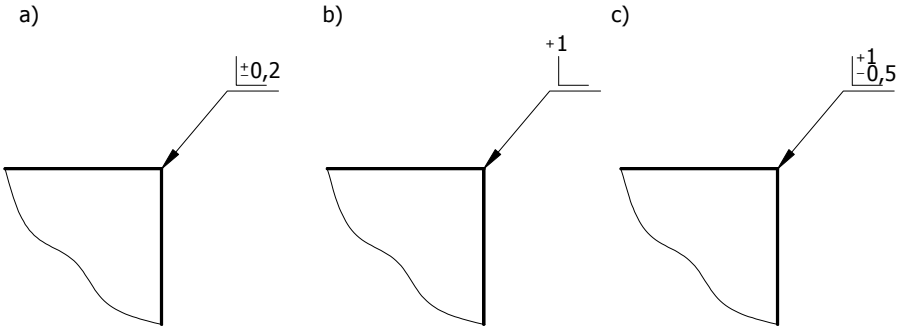
Cutting conditions and material properties are two significant variables influencing burr formation in face milling [10]. There are two main solutions for coping with burrs. First is deburring process, especially necessary in the manufacturing of small components and those requiring precision. Gillespie pointed out that total manufacturing costs can raise up to 30% due to deburring,

and even more when the parts are small [5]. In most cases deburring is a tedious manual task. Second solution is proper selection of cutting conditions which can lead to avoiding undesirable burrs or decrease time-consuming deburring operations. Other important factors are tool geometry and tool path in milling. Control in-plane exit angle in tool path planning, described by Chu and Dornfeld [4, 7], is one of the most efficient ways of avoiding burr formation.



**Fig. 1. States of: a) external edge, b) internal edge [12]**

Kumar and Dornfeld [8] demonstrated that orientation of cutting edge is significant in burr formation. These authors used three characteristic points to define the orientation of tool edges and analyzed six combinations of exit order sequence (EOS).



**Fig. 2. Basic symbol for edge condition**

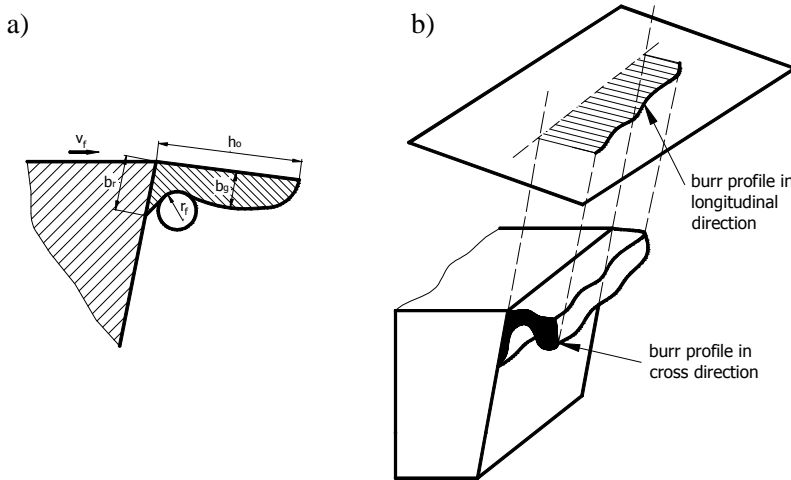
Magnesium alloys are commonly used in aerospace industry and many other branches of industry due to low density. AZ91 magnesium alloy with the lowest density of 1.81 g/cm<sup>3</sup> among the structural metallic materials (only two thirds that of aluminum) has excellent mechanical properties such as castability and machinability. These are major factors in the widespread use of magnesium alloys.



The purpose of this paper is to report the study results on burr formation mechanism during face milling of AZ91 HP magnesium alloy. The impact of different cutting conditions on exit side burr formation is shown.

## 2. Geometry and types of burrs

Burr geometry can be analyzed in cross-sectional and longitudinal profile (Figure 3). Cross-sectional profile gives important information about a burr. The most significant impact in relation to deburring process is exerted by burr root thickness  $b_r$ . The burr root thickness  $b_r$  is defined as the thickness of the burr root area measured in cross section. Another significant parameter is burr root radius  $r_f$ , determined by positioning a circle to the burr root. Burr height  $h_o$ , defined as distance between the ideal edge of the workpiece and the highest point in the cross-sectional area, depends strongly upon the radial depth of cut. The burr thickness  $b_g$  describes the thickness parallel to the burr root area at a distance of  $r_f$ , as measured in the cross-section. The longitudinal profile of the burr informs about the burr share in the total edge length and indirectly gives information concerning the time required for deburring the edge of a workpiece.



**Fig. 3. Burr geometry: a) cross sectional profile, b) longitudinal profile [1]**

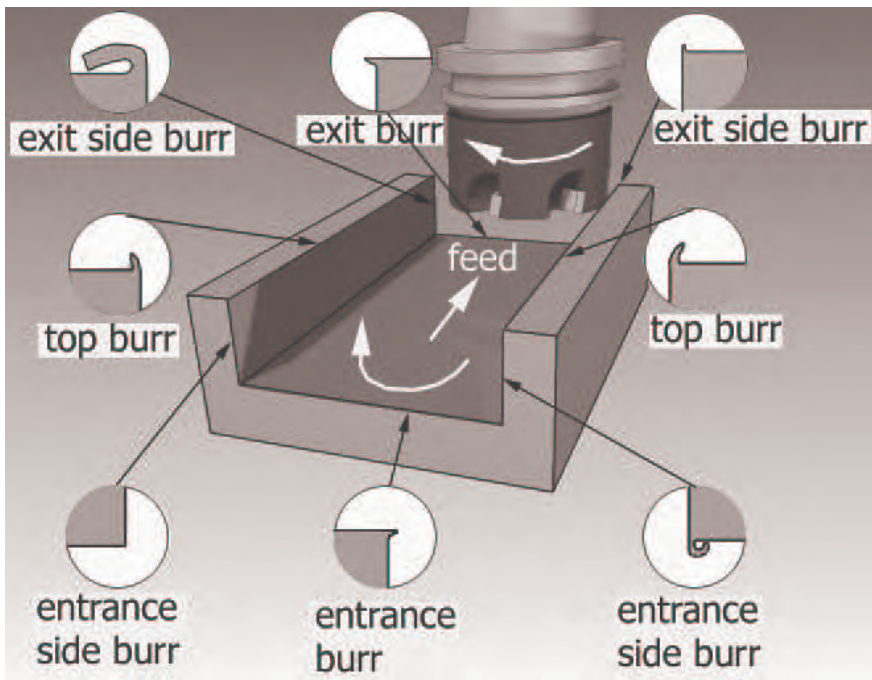
In order to numerically express the size and factor related to the deburring process, in accordance with the parameters mentioned above, burr value can be used:

$$g = \frac{4 \cdot b_r + 2 \cdot r_f + b_g + h_o}{8} \quad (1)$$

Weighting figures, besides burr root thickness  $b_r$  and burr root radius  $r_f$  result from the effect of these parameters on the deburring process [1].

One of the first works concerning burr formation was presented by Gillespie and Blotter [6]. The four basic types of burrs were characterized. First is the Poisson burr as a result of the tendency of material to bulge at the sides when it is compressed. The second type is rollover burr, generated mainly at the end of a cut. Another one is the tear burr, described as a result of material tearing loose from the workpiece rather than shearing. The cut-off burr, as a result of workpiece separation from the raw material before the separation cut is finished, is the fourth type of burr described by Gillespie and Blotter.

Chern [2] in his studies found out that in-plane exit angle has a significant influence on the type of burrs. Five burr types were observed during face milling of aluminum alloys: the knife-type burr, the wave-type burr, the curl-type burr, the edge breakout, and the secondary burr. The formation of knife-type, wave-type and curl-type burrs depends exclusively upon the particular values of in-plane exit angle even if other cutting parameters (cut depth, feed rate, cutting speed) are kept constant.



**Fig. 4. Types of burr in milling process**

As far as face milling process is concerned, burrs can be classified on the basis of their shape, position and mechanism of burr formation [8]. There are five geometrical combinations of workpiece surface intersections, where different types of burrs can occur (Figure 4). Entrance burr appears along the intersection of entrance surface and machined surface, whereas the intersection of entrance surface and transition surface leads to the formation of entrance side

burrs. Burrs formed on the intersection of top surface and transition surface are called top burrs. Similarly to the case of entrance surface, burrs can occur on the exit surface as the intersection of the exit and machined surface, as well as the intersection of exit and transition surface. These two types are called exit burrs and exit side burrs, respectively. If the radial depth of cut is the same as cutter diameter, then exit side burr, top burr and entrance side burr occur twice, due to the fact that transitional surface occurs twice. Due to the specific character of milling process, where on one side the insert exits the workpiece while, in the same time, on the other side the insert enters the workpiece, three types of burrs mentioned above have different shapes.

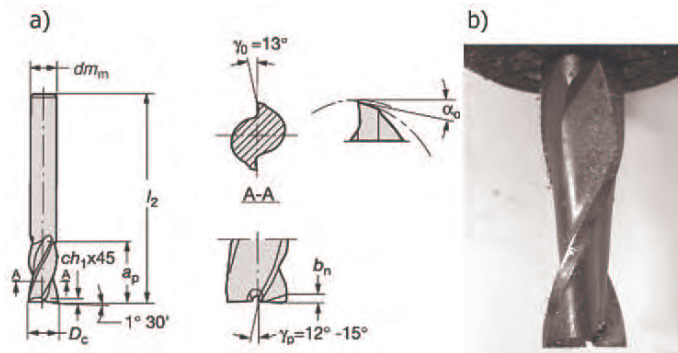
## 2. Experimental equipment end procedures

In this study AZ91 HP magnesium alloy was machined. The chemical composition of this material [11] is specified in table I.

**Table I. Chemical composition of AZ91HP alloy**

Elements	Al	Zn	Mn	Si	Fe	Cu	Ni	Mg
Content (wt. %)	9.0	0.78	0.21	0.08	0.01	0.001	0.001	Bal.

The solid carbide milling cutter was used in face milling tests. The photo and geometry of the tool are shown in Figure 5.



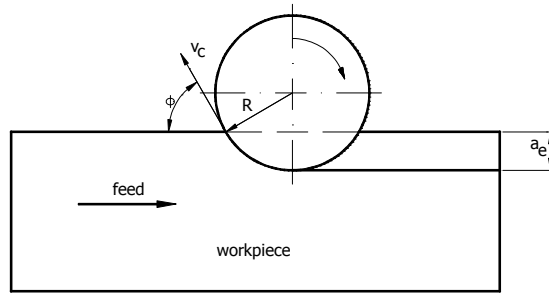
**Fig. 5. Geometry and photo of milling cutter**

Cutting parameters used during the experiment are presented in table II. The shape of burrs is highly dependent on in-plane exit angle which was constant in this study. Due to very good machinability of AZ91 HP magnesium alloy and high resistance to wear of the carbide tool, no significant tool wear was reported.

**Table II. Cutting conditions**

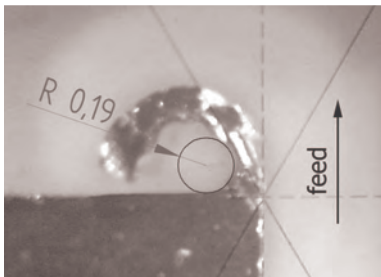
Parameter	Unit	Value
Cutting speed	[m/min]	75,3; 199; 282,7
Radial depth of cut	[mm]	1,5
Axial depth of cut	[mm]	15
Feed rate	[mm/tooth]	0,0093; 0,018; 0,035
In-plane exit angle	[°]	41,4

In-plane exit angle,  $\Theta$  is described as the angle between the cutting velocity vector  $v_c$  and the edge of machined workpiece in the machining plane. This

**Fig. 6. Definition of in-plane exit angle,  $\Phi$** 

definition is based on that presented in previous work [3]. In figure 6 graphical representation of in-plane exit angle is shown. The radial depth of cut is  $a_e$ .  $R$  is the radius of the milling tool. The value of in-plane exit angle can be obtained by equation

$$\Phi = a \cos\left(\frac{R - a_e}{R}\right) \quad (1)$$

**Fig. 7. Measuring method of burr root radius  $r_f$** 

The specific value of in-plane exit angle, during milling process, can be obtained by setting proper value of cut  $a_e$  radial depth. In-plane exit angle can change from  $0^\circ$  (for the minimum value of  $a_e$ ) to  $180^\circ$  when radial depth of cut equals the tool diameter.

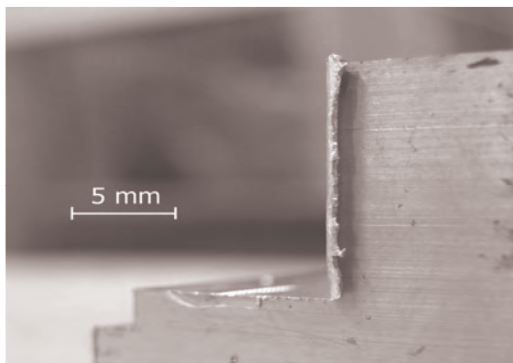
From the wide range of burr measurement methods, optical microscope was used to measure specific parameters of burr value. To determine the value of burr root

radius  $r_f$  the photos of particular burrs were imported to the draft module of

Solid Edge software. In this way the radius of inscribed circle of a burr contour drawn in Solid Edge approximated  $r_f$  parameter as shown in figure 7.

### 3. Results and discussion

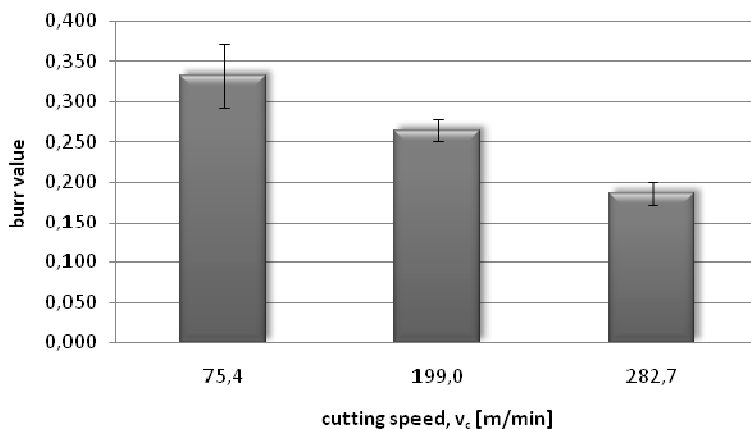
Typical exit side burr generated during the experiments is shown in Figure 8.



**Fig. 8.** Typical exit side burr generated during the experiments

For a range of established cutting parameters burrs were occurred on the full-length of edges as far as longitudinal profile is concerned. According to classification given by Chern [2] curl-type burrs were formed in all studies which is consistent with results presented by Chern for aluminum alloys. Curl-type burrs should be expected up to  $60^\circ$  of in-plane exit angle. In this study in-plane exit angle

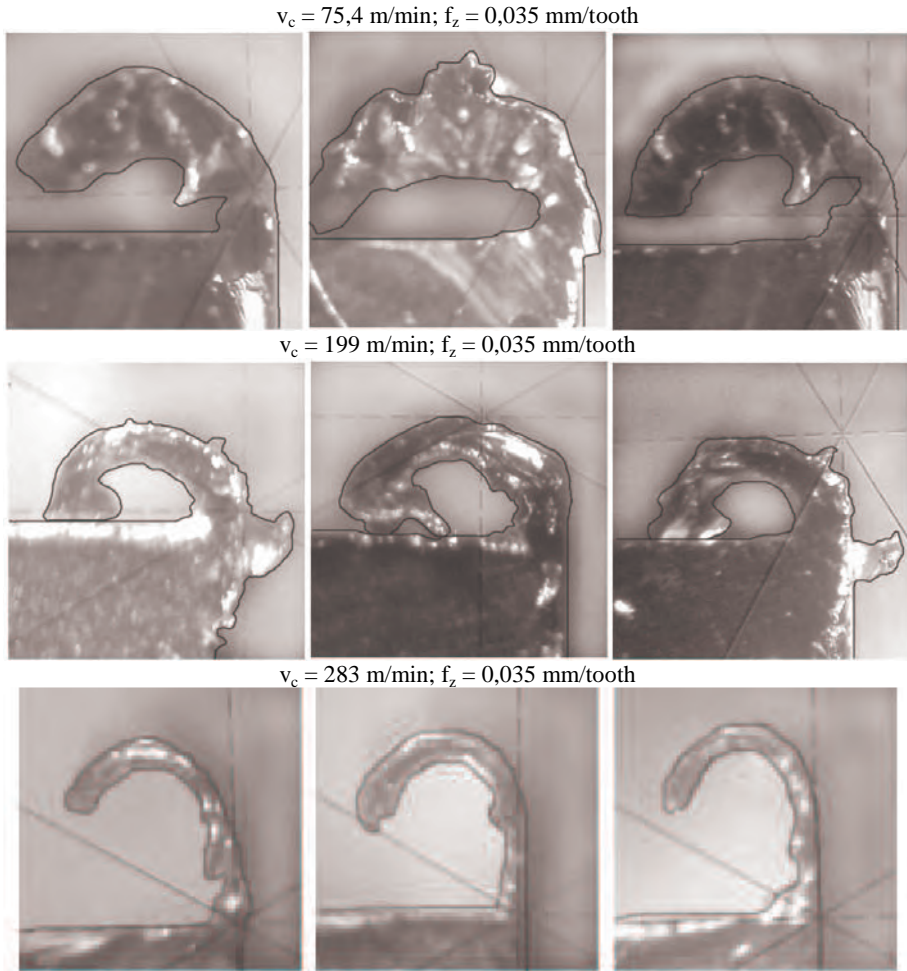
was kept constant on  $41,4^\circ$  (table 2). Table III presents variations of exit side burr shapes for different values of cutting speed, whereas variation of exit side burrs for different value of feed rate is presented in table IV.



**Fig. 9.** Variation of burr value vs. cutting speed

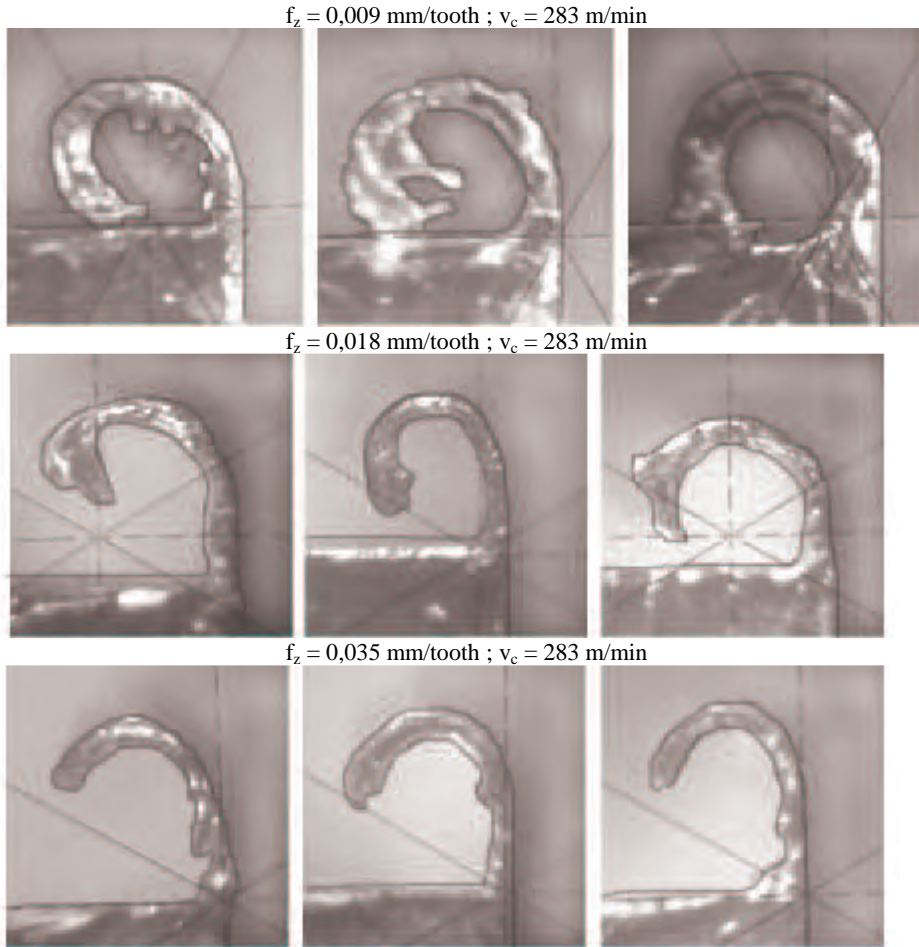
In machining, better stereometric parameters of surface could be obtained by cutting speed increase. Similar tendency is observed for magnesium alloys as well, which was presented in [9]. In accordance with the above, better chip separation from base material is probably obtained at higher cutting speed.

**Table III Variation of burr shape vs. cutting speed**



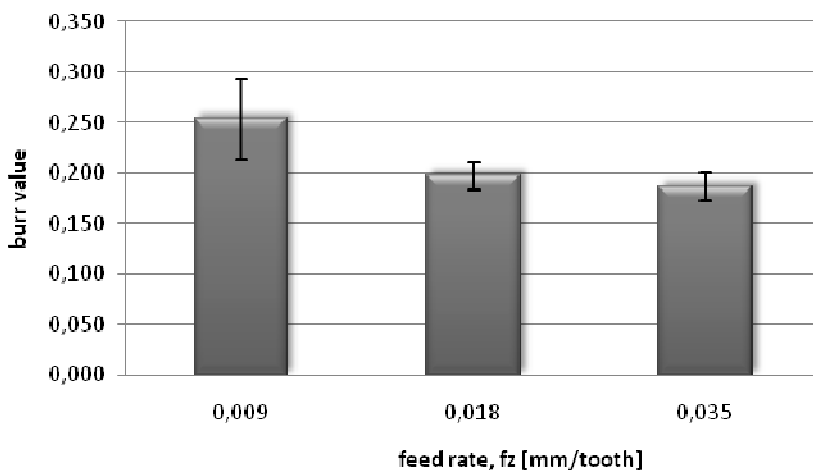
It is also correlated with burr formation mechanism. As shown in figure 9, for the cutting speed of  $v_c = 75,3 \text{ m/min}$  the burr value is the highest and it decreases as the cutting speed increases. When the cutting speed increased from  $75,3 \text{ m/min}$  to  $282,7 \text{ m/min}$ , burr value decreased by about 44%. This is direct information about decreasing inconvenience of deburring process. Table III shows that strong plastic deformation at low cutting speed negatively influences the most important burr parameters in terms of inconvenience of deburring, like burr root thickness  $b_r$  and burr root radius  $r_f$ . For higher cutting speed decreasing plastic deformation affects decrease of burr thickness  $b_g$  and burr root thickness  $b_r$ . These burrs can be easily removed from the workpiece.

**Table IV Variation of burr shape vs. feed rate**



Turning or milling conditions should be properly selected in order to avoid scratches and cracks on machined surface caused by chips. Cutting conditions, chip breakers and tool geometry bring required chip flow direction. Similar phenomena can be analyzed in relation to burr formation. For the feed rate of 0,009 mm/tooth bended tips of the burr can hit and stick into machined surface, as shown in table IV, which causes deterioration of the quality of parts. Moreover, another anchor point is developed, which can cause difficulties during the deburring process. This phenomenon was not observed at the feed rate of 0,018 and 0,035 mm/tooth and as maximum recommended feed rate for the tool used in this study was approached, burr root radius decreased (Figure 10).





**Fig. 10. Variation of burr value vs. feed rate**

#### **4. Conclusions**

In this study, burr formation in face milling of AZ91HP magnesium alloy was investigated. Consequently, exit side burrs were analyzed as a function of cutting parameters. In addition, detailed description of burrs was presented as the so-called burr value, giving information about the impact on the deburring process. The following conclusions summarize the results of face milling experiment for magnesium alloy:

- 1) The milling burrs can be classified according to their locations and shapes
- 2) For the cutting speed of 282,7 m/min, as the feed rate increased, the burr value decreased
- 3) For the feed rate of 0,035 mm/tooth, as the cutting speed increased, the burr value decreased

#### **Acknowledgment**

Financial support of Structural Funds in the Operational Programme - Innovative Economy (IE OP) financed from the European Regional Development Fund - Project "Modern material technologies in aerospace industry", Nr POIG.01.01.02-00-015/08-00 is gratefully acknowledged.



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## Effect of Milling Parameters upon Burr Formation during AZ91 HP Magnesium Alloy Face Milling

### Abstract

Due to great development of tools, milling can be the last operation in the technological process. Unfortunately when the tool leaves the part during machining operations burrs can form as a result of material plastic flow. Great demand of part quality leads to the study of the edge condition of the parts is still developed. Knowledge and understanding on the mechanism of burr formation is important in order to improve edge quality in machining. In this article the influence of milling conditions on burr formation process during face milling of AZ91 HP magnesium alloy were presented. The experiments were carried out using following cutting conditions. The cutting speeds selected in the experiment were 75,3, 199 and 282,7 m/min. The range of feed rates used in the experiment were 0,009, 0,018 and 0,035 mm/rev. The axial and radial depth of cut was kept constant respectively at 15 mm and 1,5 mm. Exit type of milling burrs were

showed. Burr descriptions and measurement parameters were defined in cross-sectional profile. Optical microscope was used to measure burr geometry.

**Keywords:** burrs, machining, magnesium alloys, burr value

## **Wpływ parametrów frezowania na formowanie się zadziorów podczas frezowania czołowego stopu magnezu AZ91 HP**

### **Streszczenie**

Dzięki znacznemu rozwojowi narzędzi, frezowanie może być ostatnią operacją procesu technologicznego. Niestety kiedy narzędzie opuszcza część podczas obróbki, w rezultacie plastycznego płynięcia materiału, mogą formować się zadziory. Wysokie wymagania co do jakości wyrobów prowadzą między innymi do ciągłego rozwoju badań nad stanem krawędzi wyrobów (części). Wiedza i zrozumienie mechanizmu formowania się zadzioru jest ważna z uwagi na podniesienie jakości krawędzi powstałych po obróbce. W artykule zaprezentowano wyniki badań wpływu warunków frezowania na proces formowania się zadziorów podczas czołowego frezowania stopu magnezu AZ91 HP. Badania prowadzono z następującymi parametrami skrawania. Wartości prędkości skrawania użyte w eksperymencie to 75,3; 199 oraz 282,7 m/min. Zakres zastosowanych posuwów wynosi 0,009; 0,018 oraz 0,035 mm/ostrze. Osiowa i promieniowa głębokość skrawania utrzymana była na stałym poziomie, odpowiednio 15 mm i 1,5 mm. Przedstawiono zadziory wyjściowe po frezowaniu. Opisano zadziory i zdefiniowano parametry mierzone w przekroju poprzecznym. Do pomiaru geometrii zadzioru wykorzystano mikroskop optyczny.

**Słowa kluczowe:** zadziory, skrawanie, stopy magnezu, wskaźnik zadzioru

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## **Application of arc weld surfacing for reclamation of knives used in recycling of waste tires**

### **Introduction**

One of the problems which mankind faces in the beginning of the 21-st century is the problem of waste disposal management. Development of motorization caused the accumulation of large quantity of rubber scrap including tire tubes, tires, linings, electric wire isolations and pipes. The major ecological problem are waste tires of passenger cars and trucks. It is estimated that nowadays in the EU countries about 600,000 tons of waste tires are disposed in landfills each year [3]. In Spain in 2006 about 80% of worn tires are placed in dumps, 3% of them which makes 7500 Mg are incinerated and just 1% is recycled. [2]. The problem is in large space occupied by waste tires and that the interior of the tire creates ideal conditions, in terms of temperature and humidity, for spreading mice, mosquitoes and rodents.

The fundamental function of the tire is to protect the wheels and car body from wear and vibrations. The entire mass of the car rests on tires which creates demand of adequate stiffness of the tire structure. During operation of the vehicles tires roll across surfaces of various quality. It makes demand of high wear resistance required to avoid damage by road surface. The tire must be able to produce traction to allow vehicle to drive. The value of friction coefficient must not be too high as it would cause excessive fuel consumption. In addition, tire material must be air-tight as to retain air cushion in the tube. The limit of elongation of tire material required to survive operation on uneven pavement is at least 200% [4]. The temperature developed at belt edge can be even 100<sup>0</sup> C.

The demand of the balance between rigidity and flexibility of tire material is fulfilled by the composite material which has soft rubber matrix reinforced with rigid fibres. Average composition of contemporary radial tire includes natural rubber 14%, synthetic rubber 27%, carbon black filler 27%, steel fibres 14-15% and fabric, fillers, activators, which makes the remaining 16-17% [1,10]. Young modulus of styrene-butadiene rubber is equal to 1.5 GPa. Conversely, steel fibers used to reinforce threads have Young modulus of 205 GPa. In Poland, typically the mass of truck tire equals 80 kg and tire is composed of 30% of steel fibres, 45% natural rubber and 25% synthetic rubber. The significant part of environmental problems is connected with the presence in tire material such constituents as vulcanization agents, vulcanization intensifiers, fillers,

plastificators and antiageing agents [9]. The period of time required for tire mineralization is estimated on 100 years.

The following methods of tire recycling are used:

- Retreading, in Poland only 2% of waste tires are reclaimed in this way [9],
- Incineration, the amount of energy obtained in the process is only one third of that needed to produce the tire [5]. Tires are used as an alternative fuel in cement industry to fire clinker kilns.
- Mechanical shredding, sometimes carried out at low temperatures which provides fine granulate [11].
- Pyrolysis and production of regenerate.
- Application of entire tires to construct facilities of playgrounds and retaining walls.

The attention of researchers is drawn by the possible application of rubber granulate and steel fibres in construction [2,12]. Scrap rubber is used as partial substitute of fine aggregates in concrete. Particle sizes used to rise attenuation of concrete are in the range 0.29-0.59 mm [3]. Rubber particles increase also energy absorption capacity which creates potential application as crash barriers. The great disadvantage is emission of gases in the event of fire. Steel fibres when added to concrete improve properties of the fragile matrix increasing impact resistance and post-cracking behavior.

### **Wear process of knives used in tire shredders.**

The process of tire shredding is usually carried out in a few stages depending on the required size of the end-products. The products include steel fibres, rubber pieces and granules. The machines used for this purpose are produced by a few producers, among them leading positions are occupied by Komei (Italy) and MeWa (Germany). The common experienced problem is intense wear of knives and blades. In order to increase service lives these elements are often hardfaced by means of welding methods, unfortunately information regarding hardfacing technology are usually classified. Replacement of used components takes long time and, therefore, the choice of adequate material and reclamation technology is vital to the user. The offer of commercial materials which can be applied in hardfacing is not huge [6,8]. Working conditions of knives are very difficult and include simultaneously operating two body wear (during cutting of steel fibres), abrasion by mineral particles, corrosion due to humidity. Tribochemical reactions which modify properties of superficial layer can be also mentioned. The damaging effect have impact loadings of knife twich cause spalling of hardfacing and even breakage of teeth.

The machine used in Novo Recycling for tire shredding comprises two shredders, a granulator and magnetic separator. In the primary shredding process tire shreds are produced. Secondary shredding results in the production of nearly

equidimensional chips. The machine components are presented in fig. 1-3. The machine was constructed and built by the founder of the firm basing sometimes on trial-and-error approach, hardfacing of knives was applied with mild success which was strong motivation to conduct this study.



**Fig. 1. First stage shredder**



**Fig. 2. Second stage shredder knives**

The first stage shredder is driven by the 90 kW electric motor through a worm gear. The rotational speed of the rotor equals 9 rev./min. The produced shreds are about 350 mm long. The capacity of the machine is 12 Mg/h.

The second stage shredder produces chips having approximate dimensions 100×100 mm, the capacity of this machine is 8 Mg/h. The machine is driven by the twin electric motors 75 kW each.

The capacity of granulator depends on the sieve mesh applied and for F35 mesh it equals 3.5 Mg/h. The produced rubber chips and steel fibres are presented in fig. 4 and 5.



**Fig. 3. View of granulator**

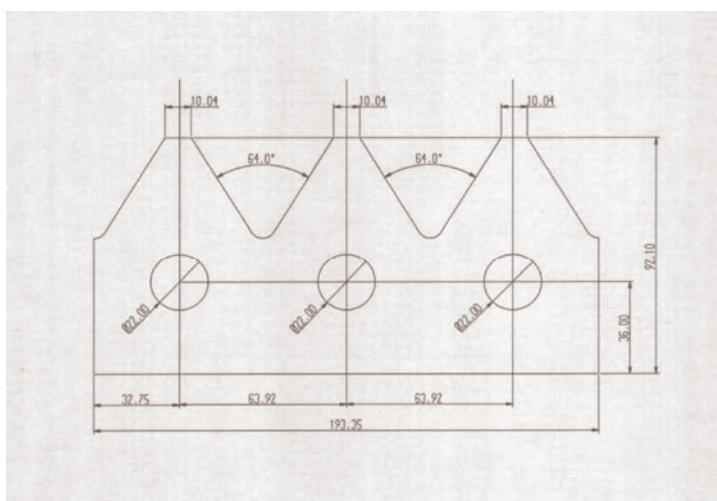


**Fig. 4. View of rubber chips**



**Fig. 5. View of steel fibres**

The granulator knife is fabricated from Brinar 500 abrasion resistant steel. The steel plates are delivered in the state water quenched and tempered. The nominal chemical composition of Brinar 500 is:  $C_{\max}=0.28\%$ ;  $Si=0.7\%$ ;  $Mn=1\%$ ;  $P_{\max}=0.02\%$ ;  $S_{\max}=0.005\%$ ;  $Cr=0.8\%$ ;  $Mo_{\max}=0.3\%$ ;  $Al\geq 0.015\%$ . The carbon equivalent is equal to 0.42 and thus steel is considered weldable. To avoid cold cracking in hardfacings deposited on thicker plates preheating prior to deposition is necessary. The granulator knives are produced from Brinar 500 steel plate by means of abrasive waterjet cutting. The drawing of granulator knife is shown in fig. 6.



**Fig. 6. Schematic diagram of granulator knife**

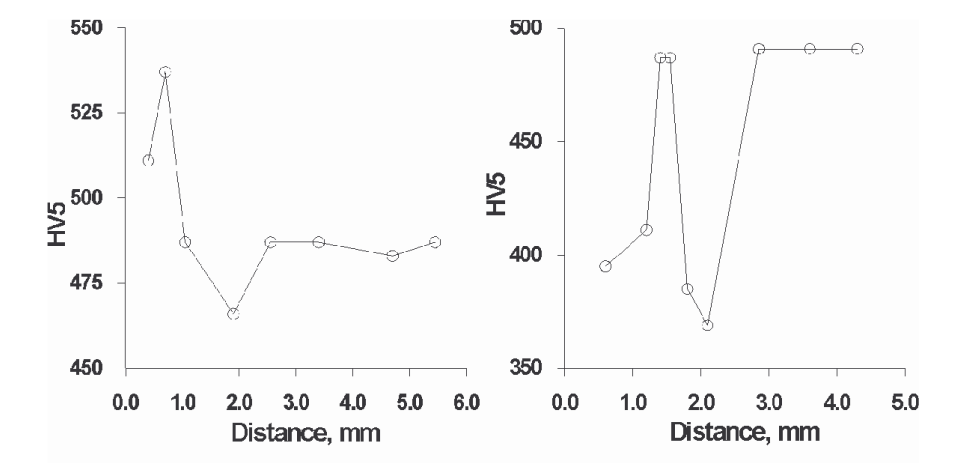
## **Hardfacing materials and technology**

Hardfacing was performed by arc welding, as the buffer served the Tigrod 12.64 layer deposited by means of TIG method. Prior to elding knife was preheated to 200<sup>0</sup> C and temperature was controlled by means of optical pyrometer. The interpass temperature did not exceed 300<sup>0</sup> C. The role of buffer layer is to relax welding stresses and to reduce the risk of cold cracking. Buffer was used in case of MMA hardfacing with shielded OK 83.65 and OK 85.65 electrodes. The OK 83.65 electrode is used for hardfacing of machine components applied in mining industry. The OK 85.65 electrode is applied for hardfacing metal cutting tools. The third type wear resistant coating was deposited by means of TIG method with Stellite grade 6. The microstructure of this material consist complex carbides in the alloy matrix. Stellite grade 6 is considered resistant to adhesive wear, seizure, galling and combines high wear restiance with good toughness. Hardfacings were deposited in welding grooves machined in the cutting edge of the knife. The dimensions of welding groove (depth×width) were 7×7 mm. After hardfacing the excess material was machined to retain the shape of the knife. The Brinar 500 plates were also used to make test plates, from which specimens for metallographic and abrasion resistance test were machined. The abrasion test was performed on the T07 type tester using crushed silica as the abrasive and C45 steel (180 HV) as the reference material. The abrasive used has the hardness of about 900 HV and contained grains with sharp edges. The abrasive can therefore model cutting caused by steel wires. Chemical compositions of welding material, the measured hardness data and results of abrasion tests are in table 1. Microhardness was measured by means of Hanemann's microhardness tester, the load applied was 45G.

Hardness values of MMA hardfacing were lower than expected, it was caused by low depth of welding groove which could accomodate only 1-2 layers of hard deposit. For comparison, Brinar 500 hardness was 468 HV5, microhardness 551-642HV (mean micorhardness 575 HV). Microhardness of buffor layer was in the range of 322-465 HV with the average value of 405 HV. The hardness profiles were measured on transverse sections of test plates, the results are depicted in fig. 7-9. The hardness is plotted against distance measured from the free surface. The effects of tempering in heat affected zone and dilution of hard material with buffer are seen.

**TABLE 1. Properties of hardfacing materials**

Material	Hardness HV5	Micro hardness	Chemical composition, %	Relative wear resistance
OK 85.58	580	757-915, average 820	C=0.35; Si=1; Mn=1; Cr=1.75; W=8; Co=2, Nb=0.8	4.7
OK 83.65	411	445-580 Average 475	C=0.75; Si=4; Mn=0.6; Cr=2	2.8
Stellite Grade 6	460	715-757, average 736	Cr=28; C=0.1.2; W=5; Si=1; Mn=1, Fe <sub>max</sub> =2.5; Ni <sub>max</sub> =3	3.3



**Fig. 7. Hardness profile, hardfacing 1      Fig. 8. Hardness profile, hardfacing 2**



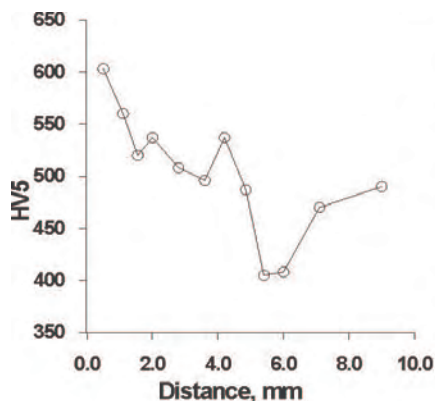
## Results of field trials

Hardfaced knives were mounted in the machine and tested for 6 days, 3 shift lasting exploitation. Wear of knives was accessed by the linear and weight methods. The results are given in table 2.

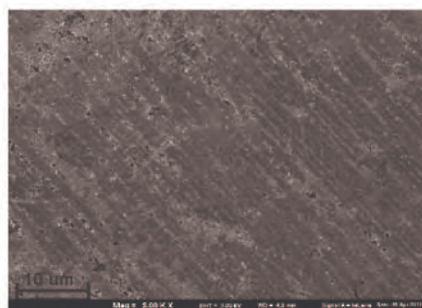
**TABLE 2. Results of field trials**

Knife number	Coating system	Original weight, g	Mass loss, g
1	Stellite grade 6	3530	130
2	Tigrod 12.64/OK	3470	165
	85.58		
3	Tigrod 12.64/OK	3470	125
	83.65		

Stellite grade 6 and OK 83.65 coating outperformed the deposit of OK 85.58 electrode. Macroscopic investigations of wear scars revealed voids placed in Stellite hardfacing parallel to groove edge these were undoubtedly produced during deposition. The wear mechanism was investigated by means of Zeiss Ultra Plus scanning electron microscope on specimens cut off the knife tip. Fig. 10-12 show appearances of wear scars.



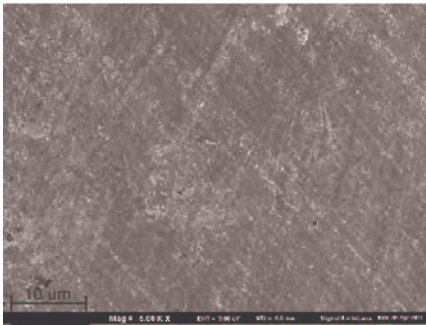
**Fig. 9. Hardness profile, hardfacing 3**



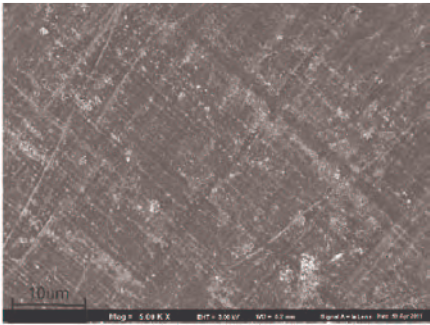
**Fig. 10. Wear scar, hardfacing 1**

In every case shallow scratches were found on knife surface. Scratching action of steel fibres and entrapped mineral grains was less effective than expected. The surface of knife No 2 contained dimples caused by welding imperfections, which served as wear starters, and recesses left probably by cracked and pulled out carbides. Topographies of teeth of used knives were

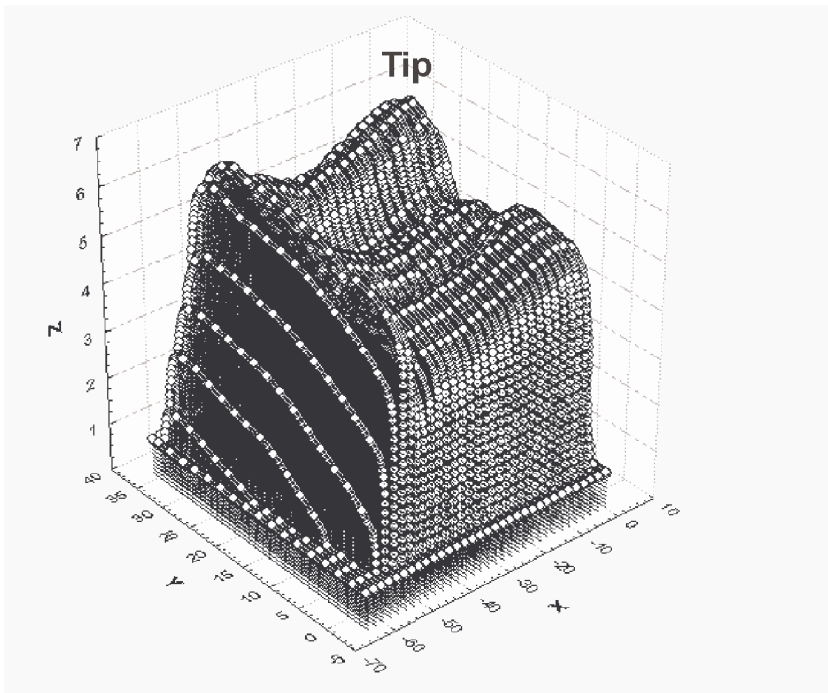
examined by means of the fixed bridge/moving table coordinate machine of Leitz type PMM 12107. Accuracy of measurements was  $(0.6+L/600)\mu\text{m}$ , the stylus was ended with the ruby ball of 1.5 mm diameter. Results of measurements taken for central teeth are depicted in Figures 13-15.



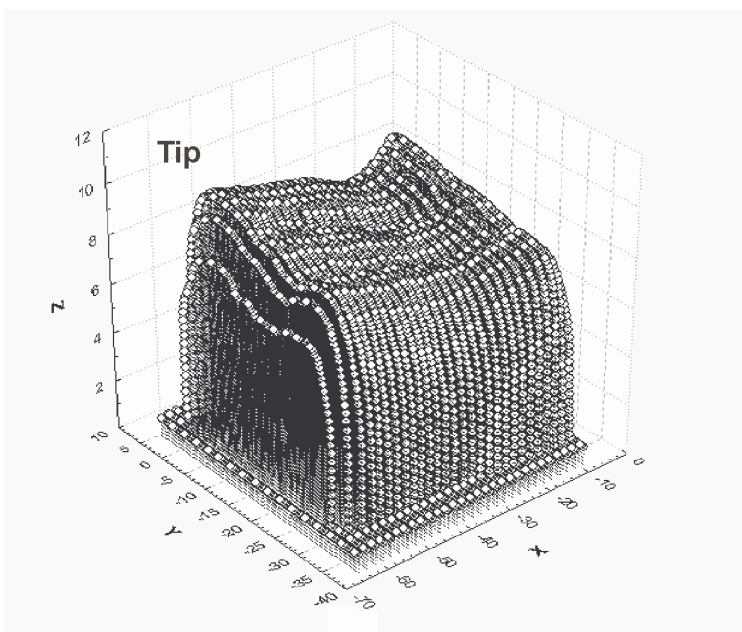
**Fig. 11. Wear scar, hardfacing 2**



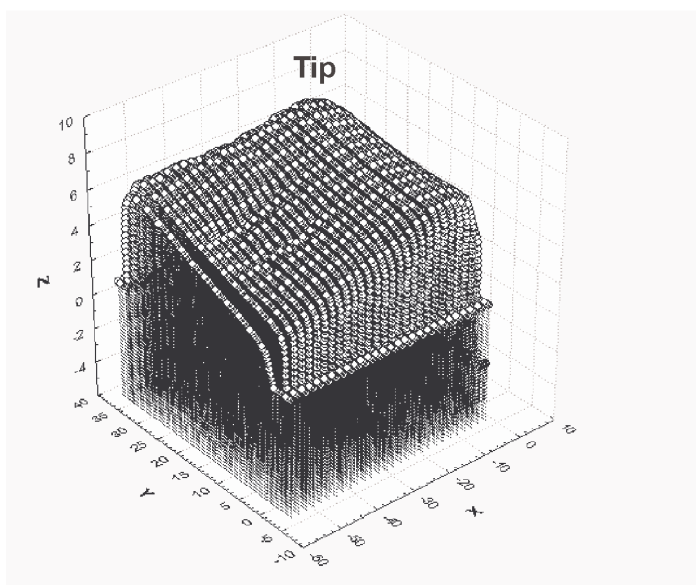
**Fig. 12. Wear scar, hardfacing 3**



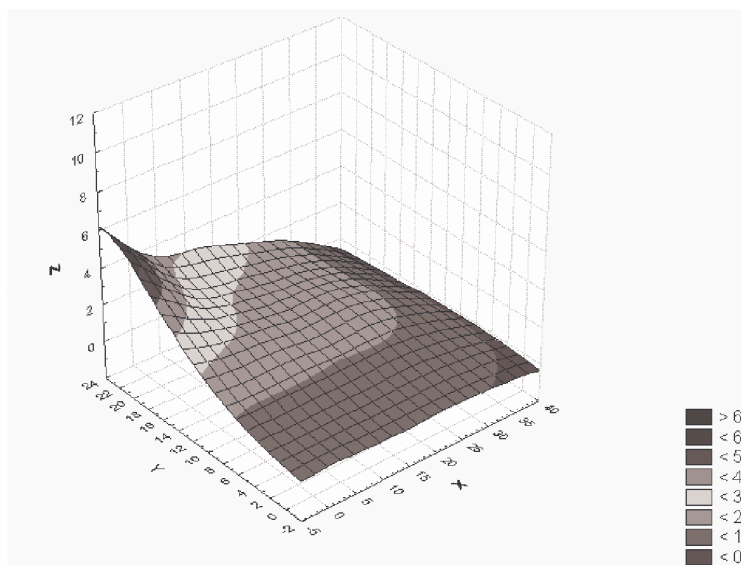
**Fig. 13. Topography of worn tooth, knife No 1**



**Fig. 14. Topography of worn tooth, knife No 2**



**Fig. 15. Topography of worn tooth, knife No 3**



**Fig. 16. Linear wear of tooth surface, knife No. 1**

The Y coordinate is measured perpendicularly to the the element surface, X coordinate- along the cutting edge, Z coordinate- perpendicularly to the tooth surface. The disadvantage of this measurement was that it was performed only once on specimens cut off worn knives. The remarkable differences are seen between topografies of particular knives. In knives hardfaced with shielded electrode wear process is seen intensified in buffer and heat affected zone. Hardfacing were found protruding above steel surface. At the rear side of the knife wear of hardfacing was low especially on knife tip. It is obvious that each knife can be used longer.

Because of the lack of former investigations, it is difficult to formulate wear criterion basing on linear and weight measurements. To check what was the state of granulator at the termination of field trials the quality of produced fibres and granules was evaluated on specimens sampled from recycled material. Before inclusion fibres were weighted and then included in the tin alloy to measure their microhardness and diameters. Microhardness of fine fibres was in the range 610-851 HV with the mean reading of 793 HV. Bead fibres has comparable average hardness of 774 HV. It can be deduced from hardness data that hardfacing No 2 could not withstand wear. The steel fibre length is in the range 5.93-98.9 mm with the average value of 52.8 mm. Wire diameters are in the range of 0.09-0.43 mm with the average value of 0.25 mm. It can be concluded that produced fibre length is comparable with that used as efficient reinforcement of concrete [2].

The pattern of corrugation running parallel to the direction of recycled material flow, clearly visible on knife No 3, can be produced only by bead wire which average cross section area was  $2.6 \text{ mm}^2$ . At present produced wires are not utilized as the steel fibre reinforced concrete did not achieve a commercial status and fibres are not accepted as charge materials in steelmaking. Bead wire length was in the range 38.2-190.2 mm with the mean value of 38.2 mm.

The produced chips have the average mass of 1.4 g and the equidimensional shape. The rubber fraction that passed sieve has the average mass of 26 mg. Due to the size, the produced rubber granules can be used as the substitute for fine aggregates in the asphalt in addition to current application for pavements of athletic stadiums [12].

Linear wear of teeth was evaluated by especially designed and performed device for non-destructive measurements, in this instance surface topographies were taken before and after service. Its idea is the subject of patent pending. The exemplary result is depicted in fig. 16, it is seen that wear loss of hardfacing at the rear side of the knife is much lower and the knife can be mounted again on the rotor and used for 2-3 days without any reclamation.

## **Summary**

Hardfacing with OK 83.65 shielded electrode and by means of TIG method with Stellite Grade 6 has doubled the service life of granulator knives. Further profits can be derived from heat treatment of pad welded layer which would rise the hardness in the tempered zone. Although the proposed hardfacing technologies were found effective the effort is needed to explore wear mechanism of knives and to reduce labor costs of reclamation. The circle of receivers of reclamation products can be widened.

## **Zastosowanie napawania łukowego do regeneracji noży używanych do recyklingu opon**

Napawanie łukowe elektrodą otuloną OK 83.65 oraz metodą TIG Stalitem Grade 6 zwiększyło dwukrotnie trwałość noży granulatora. Dalsze korzyści można uzyskać poprzez obróbkę cieplną napoiwy, która zwiększy twardość strefy odpuszczonej. Stwierdzono efektywność zaproponowanych technologii napawania ale są potrzebne dalsze prace w celu określenia mechanizmu zużywania noży oraz obniżenia kosztów robocizny. Jest możliwe rozszerzenie kręgu odbiorców produktów recyklingu.

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Novo Recykling

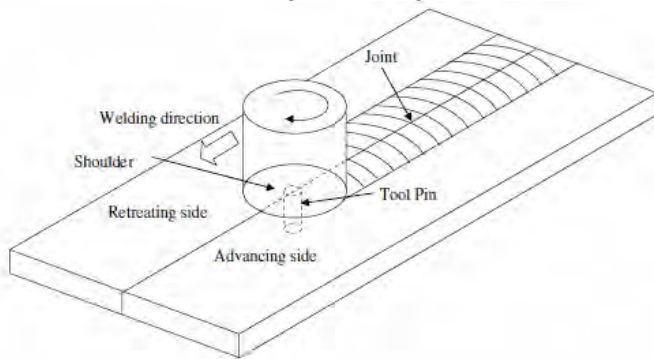
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# **THE EFFECT OF TOOL PRESS FORCE ON THE WELDABILITY OF IF STEEL BY FRICTION STIR WELDING**

## **1. INTRODUCTION**

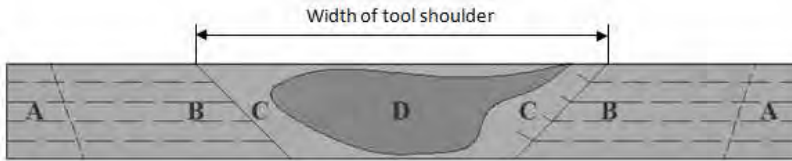
In the last ten years, aerospace and automotive industries have addressed large attention to a new welding technology based on a solid-state process, called friction stir welding (FSW) [1]. Although originally intended for aluminum alloys, reach of FSW has now extended to a variety of materials including steels and polymers [2]. In a typical FSW, a rotating tool with a shoulder and terminating in a threaded pin, moves along the butting surfaces of two rigidly clamped plates placed on a backing plate [3]. The shoulder makes firm contact with the top surface of the work-piece. Heat generated by friction at the shoulder and to a lesser extent at the pin surface, softens the material being welded. Severe plastic deformation and flow of this plasticized metal occurs as the tool is translated along the welding direction. Material is transported from the front of the tool to the trailing edge where it is forged into a joint. The schematic illustration of the FSW is given in Fig. 1 [3,4].



**Fig. 1. The schematic illustration of the FSW [3].**

The welding zones occurred in FSW has been given in Fig. 2. The base metal here is the zone which has not been affected by the heat and deformation forming in the welding zone. Stir zone (SZ) is the main area; which is affected most by the heat effect and plastic deformation; and where changes occur in the

mechanical properties and microstructure- due to the friction and stirring of the tool pin and shoulder. Thermo mechanical affected zone (TMAZ). In this region, the material has been plastically deformed by the friction stir welding tool and significant changes occur in the micro structure. Heat Affected Zone (HAZ) is the region which is affected only by heat, and no macro plastic deformation should be visible.



**Fig. 2. The welding zones forming in the jointed samples A: Base Metal (BM)  
B: Heat Affected Zone (HAZ) C: Thermo Mechanical Affected Zone (TMAZ)  
D: Stir Zone (SZ)**

The side of the weld where the local direction of the tool is the same as traversing direction is called the advancing side (AS). Similarly, the side where the directions are opposite, and the local movement of the shoulder is against the traversing direction, is called the retreating side (RS) [5, 6]. The parameters that affect joint quality in this welding method are tool advancing speed (welding speed), revolution speed of stirring, tool press force and penetrating pin geometry. Choosing the optimum for these parameters enhances welding quality and thus the mechanical properties of welding zone [7, 8].

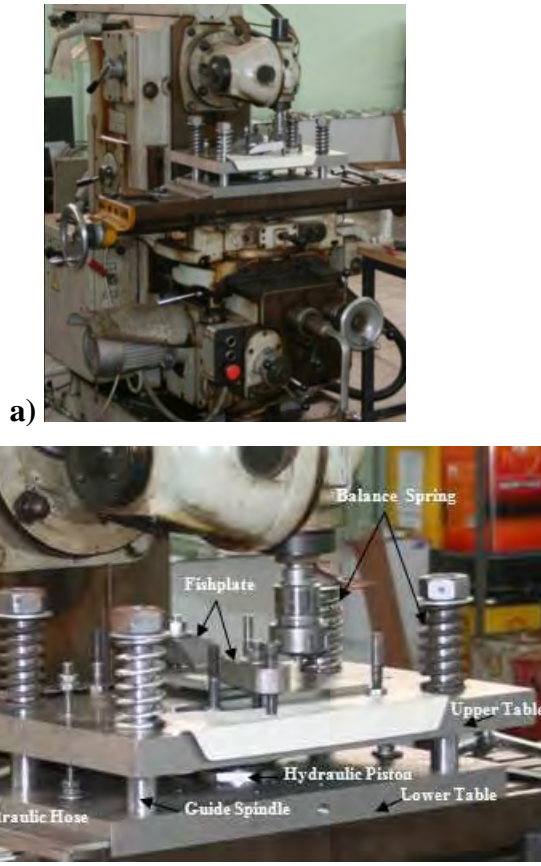
Interstitial Free (IF) steel has many applications in industry due to its property of high formability and deep drawing. IF steel, which is also widely used in automotive industry, require to be joined in some applications. One of the methods in which the mechanical properties of the welding zone are affected the least is the solid state welding method. In this study, the aim is to examine the weldability of IF steel by one of the solid state welding methods, FSW. For this aim, the effects of the tool press force used in the welding process on the mechanical and structural properties of the welded zone of joined work pieces are examined [9,10].

## **2. EXPERIMENTAL PROCEDURE**

IF steel, which is appropriate for extra deep drawing and used widely in automotive industry, has been used for the Friction Stir Welding process in this study. The material in question has been supplied from Ereğli Iron – Steel Plant in Turkey. This 7114 grade steel (DIN EN 10130- 1999) has got % 0.006 C, % 0.25 Mn, % 0.015 P, % 0.015 S and % 0.10 Ti. As for mechanical properties, it has got 295 MPa tensile strength, 185 MPa yield stress, % 40 elongation at break and 80 J energy at break.



As seen in Fig. 3, a universal vertical milling machine has been used for the mechanism. Thanks to a hydraulics table unit put in this bench, experiments have been carried out, by setting the tool press force in the determined and constant adjustments [11]. For the welding process, samples in 200x 60x 2 dimensions have been prepared. The butt welded surfaces of the samples are milled and cleaned with some dissolvent just before the experiment. The tool used for the FSW, is made from a WC (tungsten carbide) as a triangular pyramid which has a 16 mm shoulder dimension and 5 mm stir pin.



**Fig.3. FSW mechanism a) overall picture b) hydraulics table unit**

**In the light of information obtained from literature review and preliminary tests, experiments have been carried out by using the specified range of parameters in**

Table 1. With the thermocouples put between the joint faces of samples to be joined, the temperature ranks reached during the friction stir welding have been recorded.

**Table 1. Welding Parameter Table**

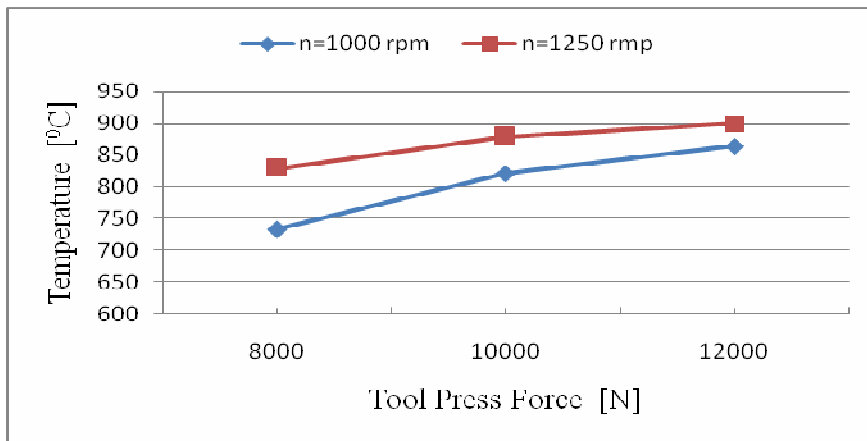
Sample No	Rotation Speed rpm	Welding Speed cpm	Tool Press Force N
1	1000	11.5	8000
2			10000
3			12000
4	1250		8000
5			10000
6			12000

A 30 mm part of the no homogeneous beginning and end zones of the each friction stir welded sample has been removed and left aside the evaluation procedure. The rest of the homogenous welding zone is prepared as the samples to be used in the examinations. %2 Nital has been used as a solution for the metallographic samples. The hardness profiles in the welding zones of the welds obtained have been determined by the micro hardness method. Tensile tests have been carried out in accordance with TS EN 876 and TS 282 EN 910 standards.

### 3. RESULTS AND DISCUSSION

#### 3.1. Temperature

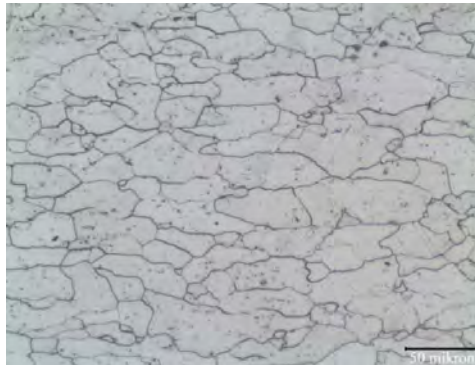
The measured temperature under the experiment conditions varies from 730<sup>0</sup>C to 900<sup>0</sup>C, as shown in Fig. 4. It is observed that the maximum temperature reached is proportional to the increasing tool press force and rotation speed.



**Fig. 4. The graphic of the change in temperature with the effect of tool press force**

### 3.2. The Properties of Macro and Microstructure

The micro structure of the material used in the experiments is somewhat oriented due to the rolling, single phased ferrite structure and its average grain size is 45  $\mu\text{m}$ . The welded surface appearances of the samples and the micro structure of the welding zones are shown in Fig. 6. and Fig. 6b respectively. No defects such as a fracture or void have been identified in the surface appearance of the welded samples. In the examination done in macro level, it is observed that the surface roughness of the weld nuggets is close to one another in all the samples. No visible voids have been detected in the microstructure of the welding zones of the joined samples.



**Fig. 5. Optical Microscope Picture Showing the Internal Structure of IF Steel**

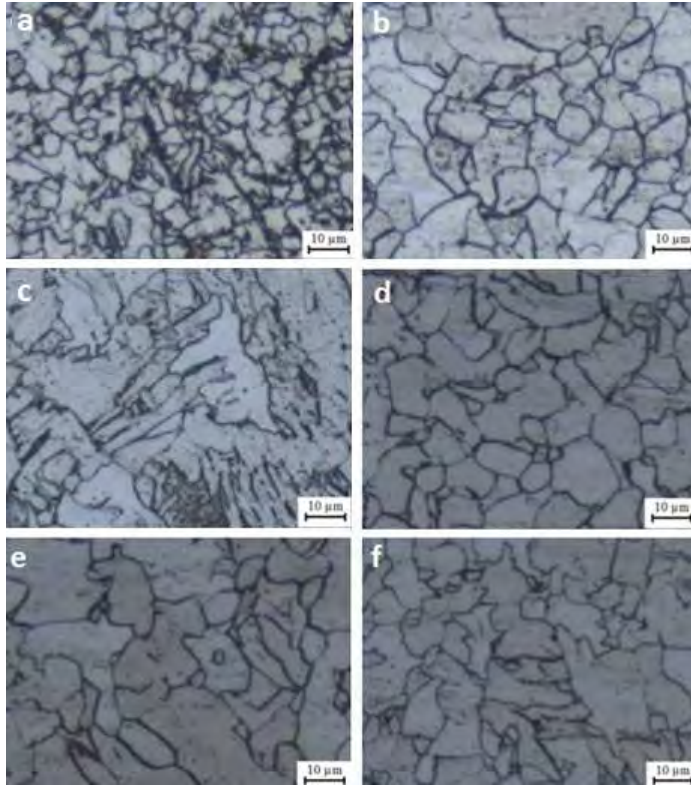




**Fig. 6. Joined Samples a) Surface Appearance b) Micro Internal Structure**

Fig. 7 shows the microstructures of various zones formed in the joining area of the joined material. The recrystallization temperature of the IF steel in question is 650 C and the temperatures reached at the stir zone (733-900<sup>0</sup>C) exceeds this temperature. In this region, we can talk about the recrystallization during the deformation forming in the course of welding. Thus, the stir zone is the region where dynamic recrystallization is observed. Due to the simultaneous excessive plastic deformation in this zone grain thinning occurs and as a result of exceeding recrystallization temperature grain growth occurs.

The effect of both mechanisms is seen in Fig. 7. Under the same tool press force with low rotation speed conditions fine grained microstructure, with high rotation speed coarse grained structure is observed. The thinnest grained structure has been measure as 6  $\mu\text{m}$  at the stir zone of the sample to which 1000 rpm and 8000 N tool press force is applied (Fig. 7a). The coarsest grained structure in the stir zone is measured as 18  $\mu\text{m}$  in the sample to which 12000 N tool press force is applied (Fig. 7c). In the test samples to which 10000 N tool press force is applied, the average grain size is 13  $\mu\text{m}$  (Fig. 7e). All the grain structures in the stir zones which are exposed to excessive plastic deformation have become remarkably thinner compared to the ones in the beginning. The increase in the tool press force causes the temperature to rise from 733<sup>0</sup>C to 900<sup>0</sup>C levels. This increase in the temperature has led to grain growth. The same situation has been observed in the microstructures of the samples welded in 1250 rpm rotation speed. Under the 1250 rpm rotation speed, in the samples to which 8000 N, 10000 N and 12000 N tool press forces are applied, the average grain sizes are respectively 14  $\mu\text{m}$ , 20  $\mu\text{m}$  and 24  $\mu\text{m}$ . (Fig 7b 7d 7f).



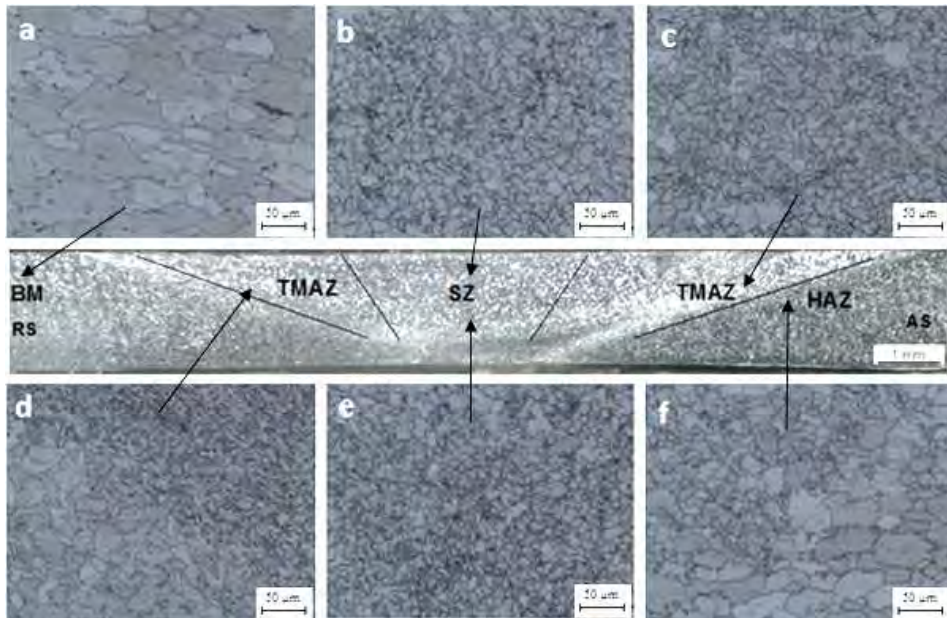
**Fig. 7 Microstructure Images of the Stir Zone**

- a)1000 rpm 8000 N (6 μm)      b)1000 rpm 10000 N (14μm)  
c) 1000 rpm 12000 N (18μm)  
d)1250 rpm 8000 N (20μm)      e)1250 rpm 10000 N (20μm)  
f)1250 rpm 12000 N (24μm)

In Fig. 7a and Fig. 7b, we can witness that welded samples have different grain sizes in the same tool press force under these two rotation speeds. When the rotation speed rises from 1000 rpm to 1250 rpm, it can be said that stir effect (revolution per mm) increases since welding speed remains the same. Another effect of the rise in stir effect is the increase in friction and this also caused an increase in temperature. Hence, the more the temperature increases, the more grain growth increases. It is determined that the micro structures and grain structures obtained at different tool press forces in 1250 rpm are similar to each other. The effect of rotation speed on the temperature level is more dominant than the effect of tool press force. Therefore, under high rotation speed, the effect of tool press force on the micro structure decreases. Since the effect of tool press force on the temperature increase under low rotation speed is a lot, it is much on the micro structure, as well. The mechanical properties obtained in the experiments under 1250 rpm rotation speed and 10000 N tool press force



have the closest values to the base metal. The internal structure of the welded zones done in these parameters is shown in detail in Fig. 8. In the upper part of the stir zone (Fig. 8b), the structure has been recrystallized and the grain size has turned into a finer grained structure compared to the one in the beginning. In the lower part of the stir zone (Fig. 8e), it is seen that the observed grain size has become thinner compared to the base metal and the upper part of the stir zone. It is considered that this situation is a result of its proximity to the shoulder where the temperature is produced, along with the pin's intense rolling. The average grain size measured in this zone is 12  $\mu\text{m}$ . Fig. 8d clearly shows the transition between the zone of which retreating side is thermomechanically affected (grain size is 8  $\mu\text{m}$ ) and heat affected zone. The average grain size (18  $\mu\text{m}$ ) of the thermomechanically affected structure that is on the advancing side (Fig. 8c) is more than the one on the retreating side. The transition between heat affected zone and thermomechanically affected zone is obvious in Fig. 8f. The average grain size of the heat affected zone reaches to the average grain size level of the base metal (45  $\mu\text{m}$ ).



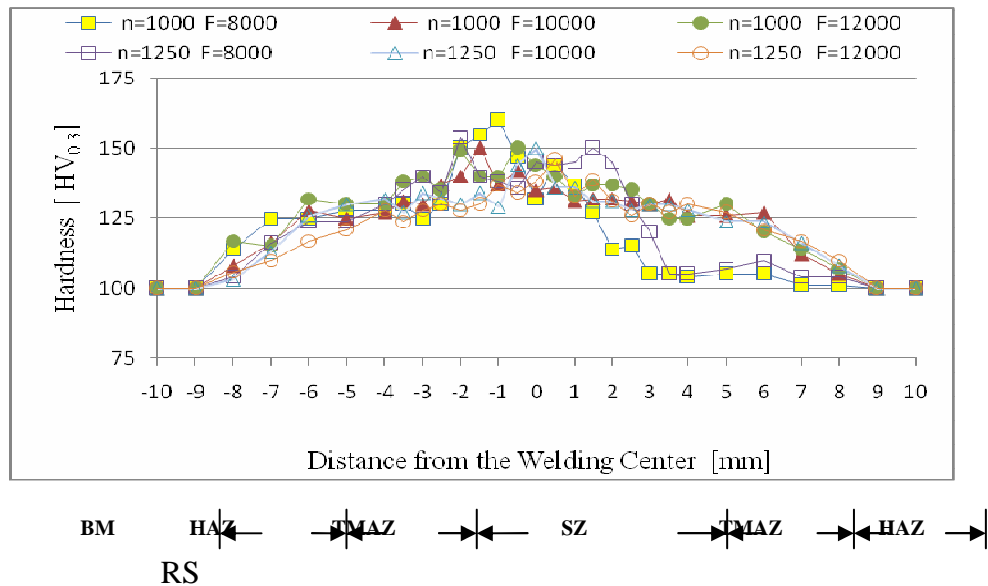
**Fig. 8. Optical Microscope Images of the joint zone of the sample welded in 1000 rpm rotation speed, 115 mm/min. welding speed and 10000 N tool press force.**  
a) Base metal, b) Stir zone close to shoulder, c) The zone, the advancing side of which is thermomechanically affected The zone, d) the retreating side of which is thermomechanically affected, e) Pin stirring f) Heat affected zone.

The thinnest grained structure in the stir zone has appeared on the retreating side where intense rolling takes place, that is, thermomechanically affected zone. The reason is that the rolling effect on the retreating side is more effective than the one on the advancing side [11]. As a result, in the samples joined by friction stir welding TEB and KB, the grain size of the micro structure has thinned considerably compared to the one in the beginning. No significant changes have occurred in the average grain size of ITAB and it is the same as the average grain size of TM

### 3.3. Mechanical Properties

In the joint zones of the samples obtained in the welding process, it is observed that the hardness profiles are similar to one another (Fig. 9 ). The hardness values measured in all the samples vary from 100 to 160 VSD. The hardness value of the base metal measured before the welding is 100 VSD on average and the hardness of the heat affected zone is between 100 and 125 VSD.

The hardness values of KB and TEB, which are plastically deformed, ranks from 130 VSD to 160 VSD.



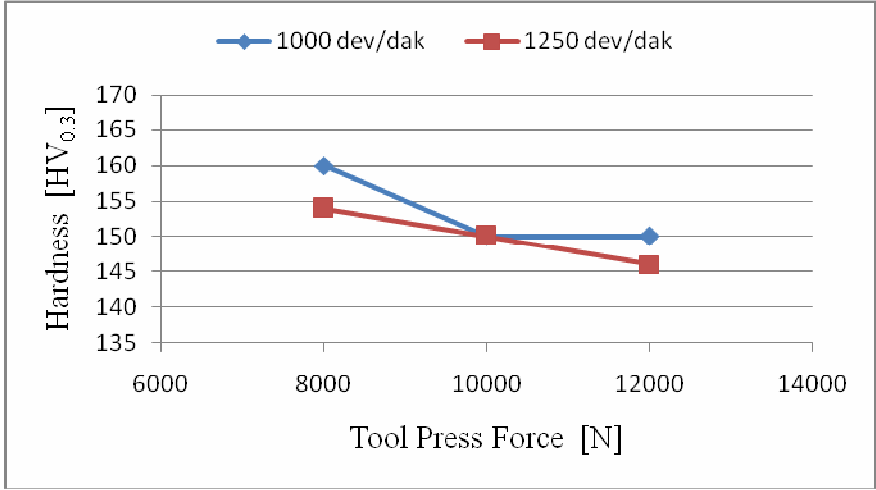
**Fig. 9. The hardness distribution of the welding zone in the experiments done in 1000 rpm and 1250 rpm rotation speeds.**

It is seen that the hardness values in the retreating side of the stir zone is higher than the ones in the advancing side. The reason is that the effect of rolling is more intense in the retreating side. In parallel with this, it is revealed in the

microstructure examinations that the average grain size in the retreating zone is thinner ( $8\text{ }\mu\text{m} \pm 1$ ). The change of the highest hardness values obtained in the stir zone with the tool press force is given in Fig. 10. In this graphic, it is seen that the measured hardness values decrease while the tool press force increases. This is due to the recrystallization effect of the temperature increase resulting from the friction force.

The average values of the results obtained from the flat tensile samples made of test samples are given in the Table 2. Three samples are used for each experiment condition. It is clearly seen in Fig. 11 that tensile samples are all taken from the TM part of the ITAB zone.

The highest tensile strength value is 299 MPa and obtained in the samples 2, 5 and 6. This value is approximately within the borders of dimensional tolerance of the base metal's tensile strength. The lowest tensile strength measured is 284 MPa and obtained in the sample 1. However, in all of the samples, the break has occurred in the zone of base metal.



**Fig. 10. The change of the highest hardness values in the stir zone with the tool press force**



**Table 2. Mechanical Properties Obtained from the Tensile Samples**

No	Rotati on Speed [rpm]	Weldi ng Speed [cpm]	Tool Pres s Forc e [N]	Tensil e Streng th [MPa]	Yiel d Point [MPa]	Elongati on at Break [%]	Energ y at Break [J]	Stir Effect [rpm m]	Peak Temperat ure [C]
1	1000	11.5	8000	284±3	180± 2	30±1	70	8,7	733
2	1000	11.5	1000 0	299±3	190± 2	28±1	59	8,7	821
3	1000	11.5	1200 0	294±3	189± 2	28±1	55	8,7	864
4	1250	11.5	8000	286±3	180± 2	27±1	60	10,9	829
5	1250	11.5	1000 0	299±3	188± 2	32±1	75	10,9	879
6	1250	11.5	1200 0	299±3	190± 2	25±1	57	10,9	900
B M				295±3	185± 2	40±1	80		



**Fig. 11. The image of the tensile strength samples**

It is seen in Fig. 12 that the tensile strength values obtained in both rotation speeds increase a bit with the increasing tool press force. The fracture energy values obtained from the tensile experiments of the test samples are seen in Fig. 13. In the case of an increase in the tool press force applied in 1000 rpm rotation speed, tensile strength increases and fracture energy decreases. In 1250 rpm rotation speed, it is determined that measured fracture energy has reached the highest value at 10000 N tool press force.

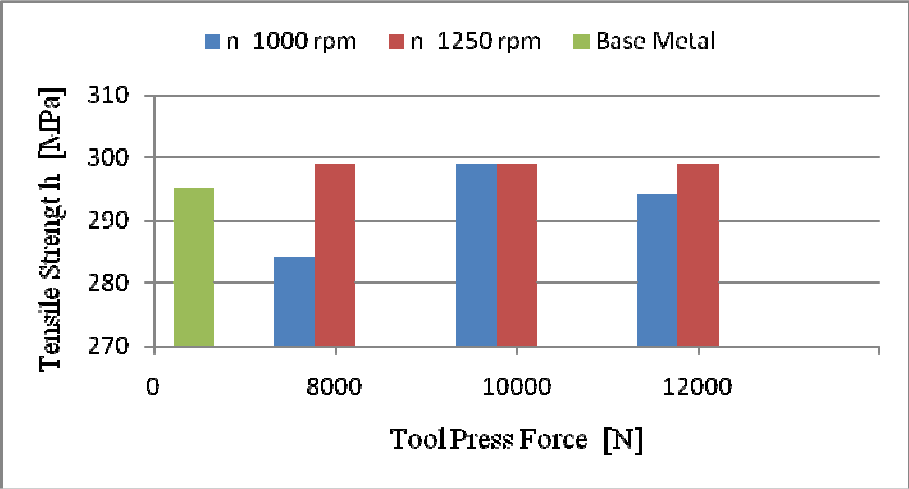


Fig.12. The graphic of the change in tensile strength with the effect of tool press force

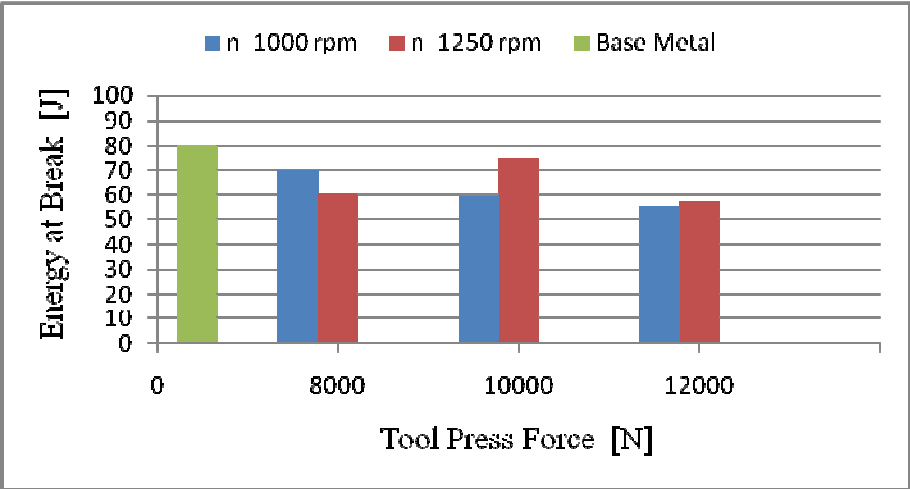
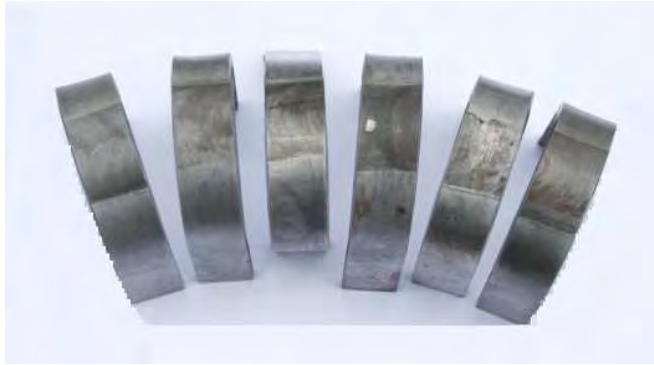


Fig. 13. The graphic of the change in energy at break with the effect of tool press force

180° bending test is applied to the samples obtained from the experiments by putting the root zone to the inner part. No symptoms of fracture are detected on the surfaces of the samples obtained from the tests, Fig.14.



**Fig. 14. Panorama of the bending test samples**

#### **4. CONCLUSIONS**

The results obtained from joining 7114 grade (DIN EN 10130- 1999) IF steel by using friction stir welding process under 1000- 1250 rpm rotation speed, 115 mm/min. welding speed and 8000 N- 12000 N tool press force conditions are as follows;

1. 7114 grade IF steel can be successfully joined by FSW process.
2. The increasing tool press force and the temperature level reached increase proportionally.
3. The effect of tool press force on the increase of the welding temperature decrease with the revolutions.
4. The increase in the tool press force reduces the hardness value of the joint zone.
5. The weakest zone in the welding process stays out of the joint zone.

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## ABSTRACT

Interstitial Free (IF) steel has many applications in industry due to its property of high formability and deep drawing. IF steel, which is also widely used in automotive industry, require to be joined in some applications. In this study, IF steel has been butt welded by using friction stir welding (FSW). In the experiments carried out, while tool angle and welding speed are kept constant, different tool press forces in different rotation speeds have been applied. The mechanic properties of welded samples have been identified by tensile, bending and hardness experiments. In this research, no significant changes have occurred in the strength of joint with the increasing tool press force. However, significant changes have been observed in the microstructure and the hardness of the welding zone.

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## **Research of dynamic properties of selected machining fixture structures**

### **Introduction**

The subject of the research are basic parameters influencing the dynamic rigidity of the chosen structures of machining fixtures. During analysis of vibrations of any machining fixtures [3] the method of fixture fixing is of an essential importance.

Two factors influencing the quality of the measurement results and connected with the fixing of the fixture should be considered in the research. This is caused by the fact that the connection between the fixture and the support plane has some impact on the system as the whole and can change the natural frequency and the amplitude and frequency characteristics [1]. The support plane has certain rigidity and its own dynamic characteristics. The fixing should be very rigid or very loose (for example unbounded suspension of the fixture on the threads). The last method of fixing reflects the conditions of free construction and it is often used in an experimental modal analysis because it does not significantly influence the measured natural frequency. The second important factor connected with the fixing of the structure is the influence of the method of fixing of elements and assemblies of fixture on the effect of vibration damping [4, 5].

Taking into account the above statements, during the experiment, the modular fixture was fixed to the rigid plate of 550x700x70 [mm], placed on the rigid support to eliminate the flexibility of fixing. The most characteristic structure of modular fixture is the column connected to the plate with fixing bolt. The analysis was carried out for the set of modular fixtures TGL(HWN)-48. The fixing force of  $Q=1,34 \cdot 10^4$  N was selected as a standard value [2].

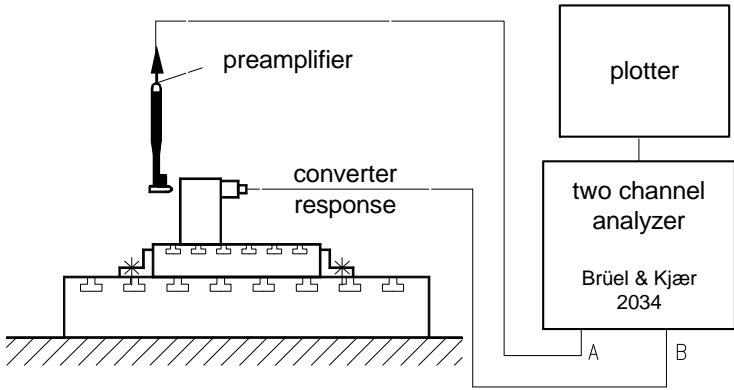
### **THE EXAMINATION OF VIBRATIONS OF MODULAR FIXTURES**

The analysis of vibrations of the selected structures of modular fixtures such as base plate-housing were carried out. The housing consisted of one or more blocks. The piezoelectric converter was used to measure the vibrations of elements of fixture. Its advantage is the wide range of measured frequency [4]. The measurement circuit is shown on Fig. 1.

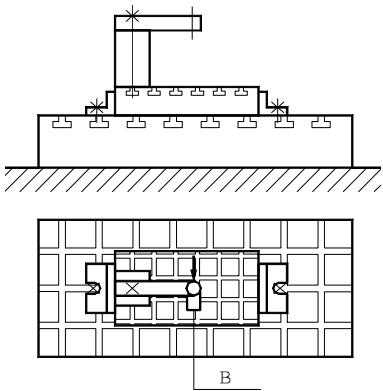
The vibrations of modular fixture were generated by pulse hammer Brüel & Kjær 8202, while the response of the system was measured in the selected place on the column of the fixture. The signal coming from the pulse hammer was directed through the preamplifier to the input A of the two channel analyzer

Brüel & Kjær 2034, while the signal from the piezoelectric converter Brüel & Kjær 4384 was directed to the preamplifier type 2644 and next to the input B of the analyzer. The channel A was calibrated using the given sensitivity of the hammer and preamplifier with connecting cable. The channel B was calibrated by the measurement of the deflection of standard steel beam. The selectivity of the hammer was 0,96 mV/N. The two channel analyzer Brüel & Kjær 2034 was used for analyses.

First, the amplitude and frequency characteristics for selected modular fixtures such as: the standard base plate- column with the height of 48 [mm] and 96 [mm] were determined. The fixtures using the special plate with modified design were also analyzed [2].



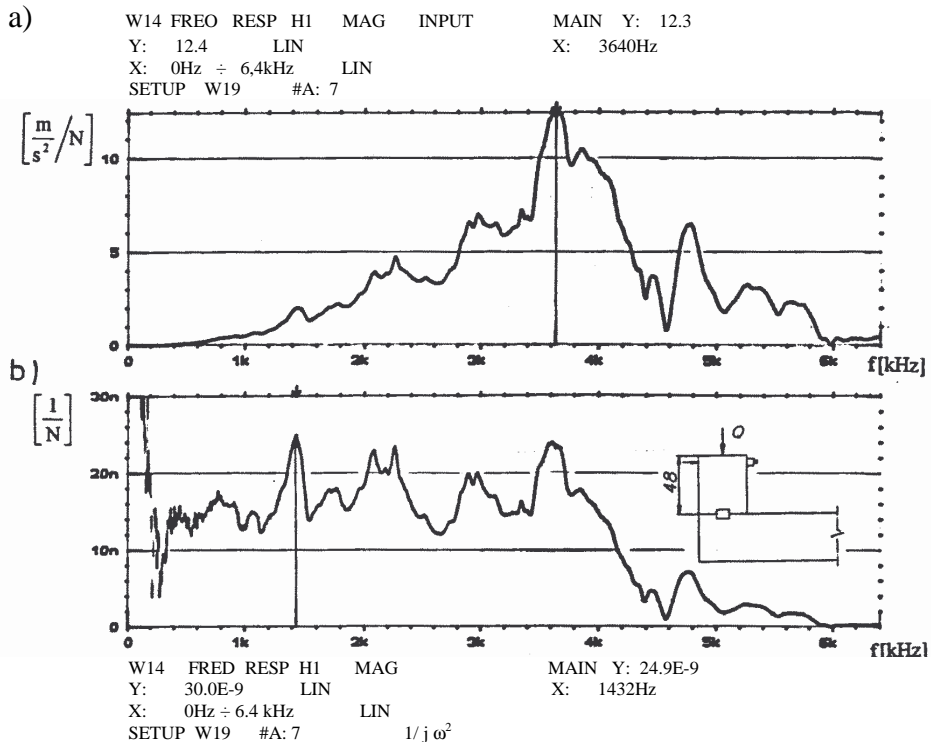
**Fig. 1. Measurement circuit used for determination of natural frequency and modal coefficient of loss of modular fixtures**



**Fig. 2. The structure of the drilling modular fixture and the point of applying of the impulse of the force (marked by arrow) and the accelerometer (B)**

The received amplitude and frequency characteristics are presented on fig. 3÷8. The upper part shows the acceleration spectrum and the bottom the displacement spectrum. All of the presented characteristics are the average of the responses received from the system. For characteristics presented on fig. 4 were calculated using 14 samples.

Fig. 3 presents the amplitude and frequency characteristics for one-block system. First two-resonance frequency are as follows: 1432 Hz, 3640 Hz.

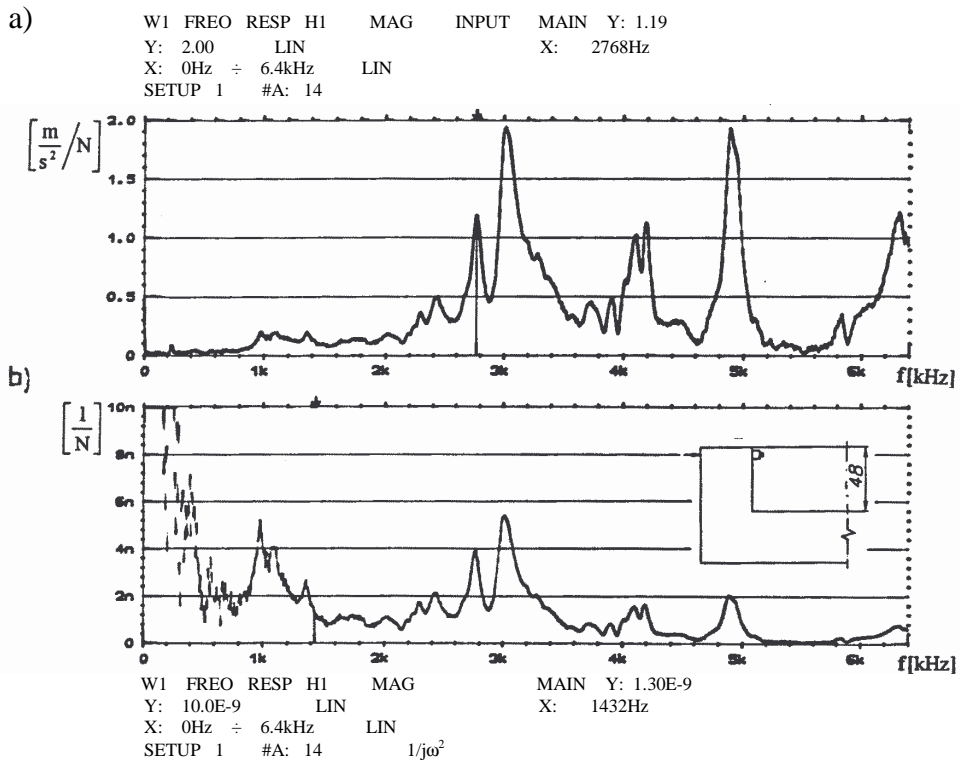


**Fig. 3. Amplitude and frequency characteristics a) acceleration, b) displacement**

Fig. 4 presents the amplitude and frequency characteristics for modular fixture using modified plate. In this case, the resonance frequency have the following values: 2778Hz, 3008 Hz, 4096 Hz, 4192 Hz, 4888 Hz, 6320 Hz.

Based on the comparison of the amplitude and frequency characteristics for the one-block fixtures having similar height of 48 [mm] with standard plate (fig.3) and modified plate (fig.4) it can be noted that, despite the same values of pulse forces, the displacement amplitudes for modified plate are 5 times less.

Fig. 5 shows the amplitude and frequency characteristics for two-block fixtures. The height of the one block is  $h=48$  mm. The increase in the column height lowers the system rigidity and resonance frequency, which takes the following values: 1015 Hz and 1168 Hz.



**Fig. 4. Amplitude and frequency characteristics a) acceleration, b) displacement**

Fig. 6 presents the amplitude and frequency characteristics for one-block system of the height  $h = 96$  mm. The increase of the height of the column causes the lowering of the rigidity of the system and resonance frequency, which receive the following values: 936 Hz, 1152 Hz, 3200 Hz, 4416 Hz.

The comparison was made for one-block system with the height of the column of the fixture  $h = 96$  mm; the block of the height  $h = 48$  mm is fixed with modified plate. The resonance frequencies were as follows: 1272 Hz, 2152 Hz.

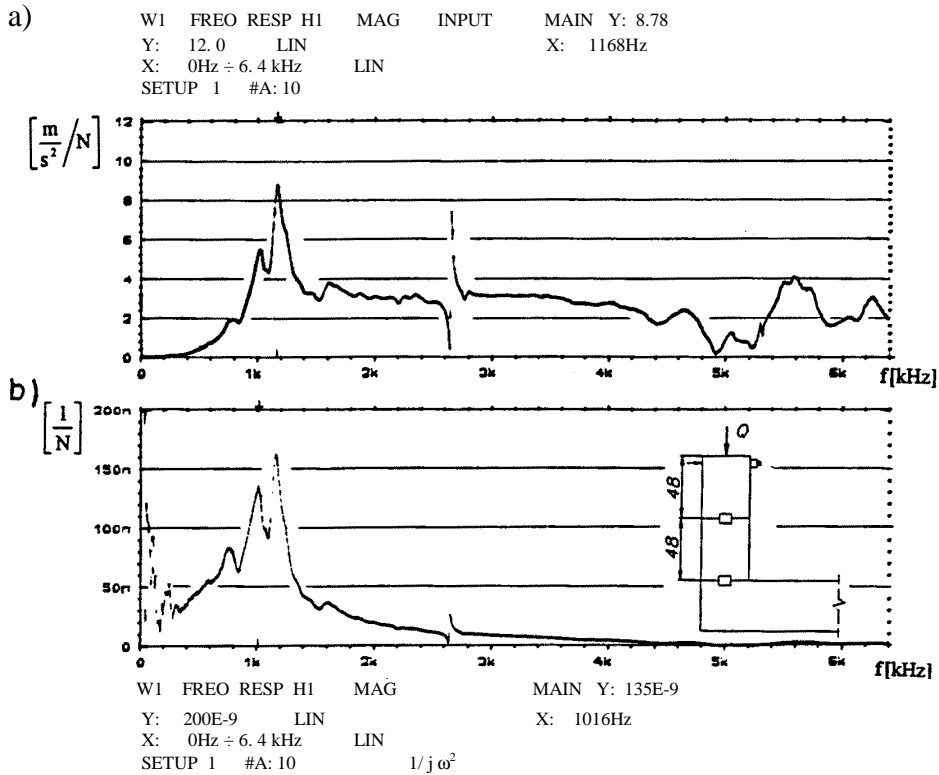
Table I contains the results based on the amplitude and frequency characteristics for analyzed modular fixtures. It shows the influence of the plate on the dynamic properties of fixtures.

In the second series of the research, the amplitude and frequency characteristics for the selected structures of drilling fixtures were determined. The point of applying of the impulse of the force and fixing of the accelerometer in the drilling fixture is presented on fig. 2.

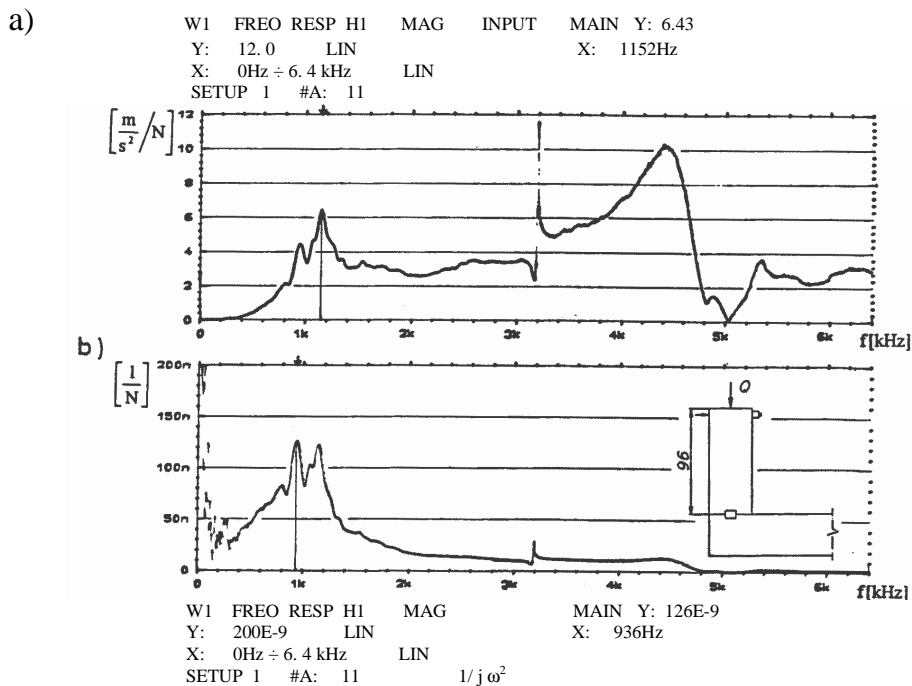


**TABLE I. The results of the amplitude and frequency characteristics for the modular fixtures**

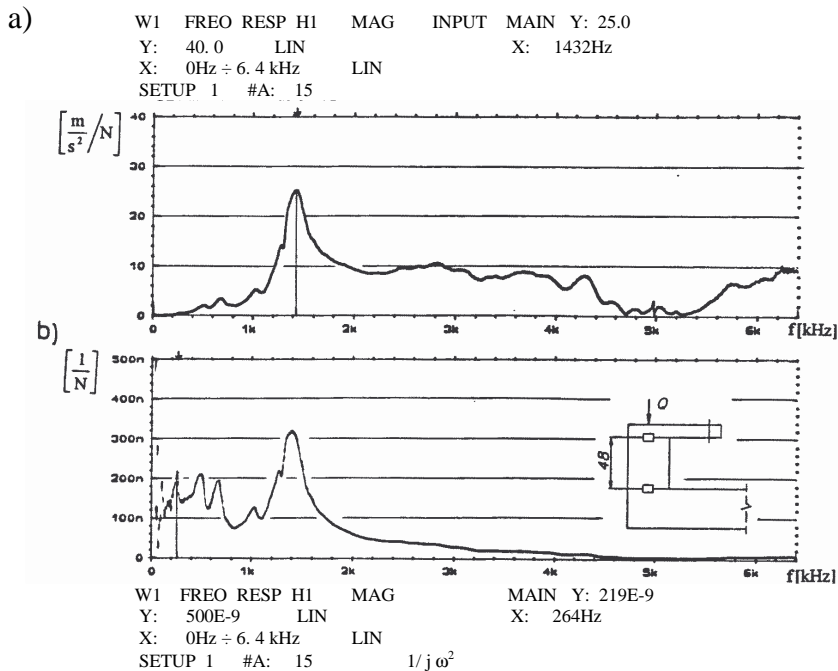
The structure of fixtures with the height of the column	Max. Displacement	Resonance frequency for max. Amplitude of
h = 48 mm		
One – block set, standard plate	$25 \cdot 10^{-9}$ m	1432 Hz
One – block set modified plate	$5 \cdot 10^{-9}$ m	3000 Hz
h = 96 mm		
Two – block set standard plate	$165 \cdot 10^{-9}$ m	1168 Hz
One – block set, standard plate	$125 \cdot 10^{-9}$ m	936 Hz
One – block set modified plate	$46 \cdot 10^{-9}$ m	1272 Hz



**Fig. 5. Amplitude and frequency characteristics a) acceleration, b) displacement**



**Fig. 6. Amplitude and frequency characteristics a) acceleration, b) displacement**



**Fig. 7. Amplitude and frequency characteristics a) acceleration, b) displacement**

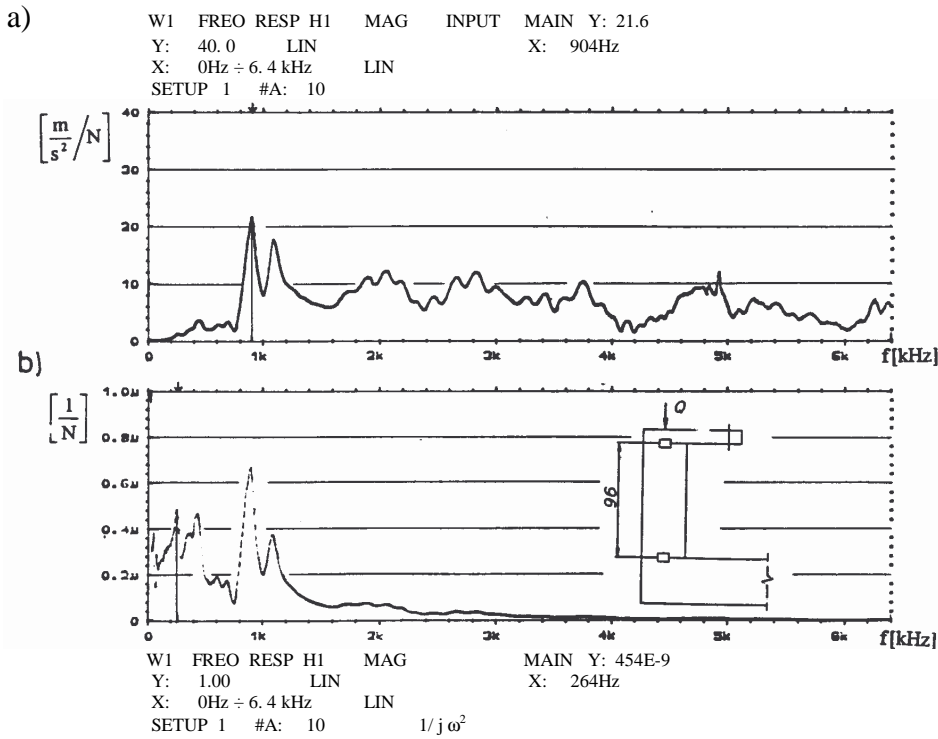
The fig. 7 presents the amplitude and frequency characteristics for the drilling fixture of the height of the column  $h=48$  mm under the maximum reach of the drilling sleeve, type 11281 11010. The resonance frequencies have the following values: 264 Hz, 1432 Hz.

The fig. 8 presents the amplitude and frequency characteristics for the drilling modular fixture of the height of the column  $h=96$  mm under the maximum reach of the drilling sleeve, type 11281 11010. Resonance frequencies have the following values: 264 Hz, 904 Hz.

The results concerning the amplitude and frequency characteristics for the selected structures of the drilling modular fixtures are given in the tab. 2.

**TABLE II. Amplitude and frequency characteristics for the selected modular fixtures**

No	The structure of drilling fixtures with the height of the column	Resonance frequency for max. Amplitude of displacement	Resonance frequency for max. Amplitude of displacement
1	48mm	$320 \cdot 10^{-9}$ m	1432 Hz
2	96mm	$700 \cdot 10^{-9}$ m	904 Hz



**Fig. 8. Amplitude and frequency characteristics a) acceleration, b) displacement**

The research shows that the values of the natural frequencies are higher in comparison to the frequencies resulting from the rotary speed of the tool, particularly for the fixtures with the height of the column 48mm.

## CONCLUSIONS

Based on the analysis it can be stated, that the natural frequencies of modular fixtures are higher than frequencies generated by the typical, rotational tools, and this especially true in the case of fixtures with the column height of 48 mm.

The dynamic rigidity of fixtures significantly depends on the design of resistance components and because of this, the use of modified base plates (with increased resistance height) is recommended.

Based on the comparison of the amplitude and frequency characteristics for the structures of drilling modular fixtures of the height of the column 48 mm and 96 mm it can be stated that for the column of the height of 96 mm the natural frequency was lower and the amplitude was near two times greater.

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## Badania właściwości dynamicznych wybranych struktur uchwytów składanych

### Streszczenie

Przedmiotem badań są podstawowe parametry kształtujące sztywność dynamiczną wybranych struktur uchwytów składanych. Analiza charakterystyk amplitudowo-częstotliwościowych oraz przebiegów czasowych odpowiedzi impulsowej dla typowych struktur uchwytów obróbkowych montowanych z systemu elementów uchwytów składanych umożliwia wyznaczenie

częstotliwości własnych drgań. Zagadnienia te stają się coraz bardziej istotne z uwagi na zwiększanie prędkości obrotowych narzędzi skrawających.

**Słowa kluczowe:** uchwyty składane, sztywność dynamiczna, częstotliwość rezonansowa

## **Research of dynamic properties of selected machining fixture structures**

### **Abstract**

The subject of the research are the basic parameters influencing the dynamic rigidity of selected modular fixtures. The analysis of amplitude-frequency characteristics and time variations impulse response for typical structures of machining fixtures build of modular elements allows to determine the natural frequency. This tasks become continuously more important because of het tendency to increase het rotational of het cutting tools.

**Key words:** buid-up fixtures, dynamic rigidity, frequency of vibrations

## **Badania właściwości dynamicznych wybranych struktur uchwytów składanych**

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# **Method of Representation and Saving Casing-Class Parts' Constructional Knowledge Using MS Access System**

## **Introduction**

More and more complex problems connected with designing of manufacturing processes of machined parts or designing modern and future production systems force designers to reach for formalized, computer aided tools which helps to solve such types of problems [1,2,3,4]. In order to be possible fast and effective analyze data necessary for solving defined problem, these data must be input into the computer system in structuralized way and simultaneously represent real character of information about an object.

One of the problems of methodological character is a question of representation and saving data of constructional character using database systems in such way to their application into solving specified design problems could be possible. An example of such type of task is computer aided machine tools subsystem selection for casing-class flexible manufacturing system. The problem was particularly presented i.a. into publications [5,6,7,8,9].

In this paper the conception of method of representation and saving constructional knowledge about casing-class parts using the MS Access system was shown. This solution can be implemented into presented above problem of machine tools selection or different similar to that problems.

## **1. Method of representation of constructional knowledge about casing-class parts**

In this work the concept of '*construction*' word is understood in accordance with definition presented by J. Dietrych into [10]. Following to this definition, '*construction is configuration of structures and different states of a part*'. Determination of construction depends on assigning of part's states. Construction is determined by defined constructional features. Identification of constructional feature depends on selection of constructional structure and configuration of dimensions what can be presented as below:

$$C = f(\Pi; Y), \quad (1)$$

where:

- C – constructional feature ,
- $\Pi$  – constructional shape of part,
- Y – configuration of dimensions.

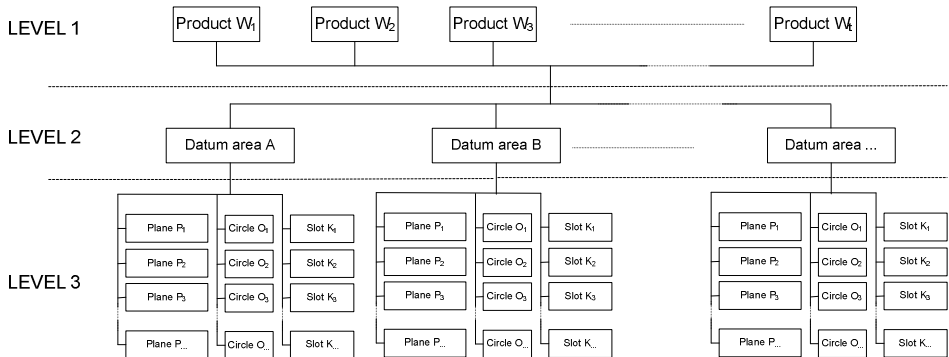
According to J. Dietrych's definition, constructional shape of part is quality constructional property while configuration of dimensions is a way of identification constructional features. Simultaneously, only construction determines permissible decomposition identified using a configuration of dimensions. Formal representation of W dimension as a element of configuration of dimensions can be submitted as below:

$$W = N + T, \quad (2)$$

where:

- N – rated dimension,
- T – tolerance of dimension.

After analyzing traditional constructional and technological documentation of casing-class parts and also available in literature solutions concerning with designing of technological data base and data management [11,12,13,14], when taking into account specificity of problem of machine tools selection, the method of representation and saving constructional data was developed. This method was based on three-levels data base what was shown in fig. 1.



**Fig. 1. Structure of database for saving data on casing-class products to be machined in a FMS**

From Level 1 the user can input data of informative character, defining the product to be machined in the FMS being designed. In particular, the input data will include such items as:

- the name of the product,
- product symbol,
- overall dimensions of the semi-finished product (including distances required for fixing the product on a machining palette or in a fixture),
- weight of the semi-finished product,
- assumed annual production program for the part.

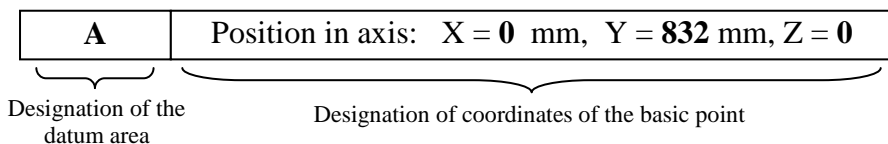
Level 2 is used to define the datum areas for the machining of the part. The datum area is taken to mean an actual or a virtual plane within the machining space, defined in terms of position, permitting precise parameterization of coordinates of features involved in the machining of a specific product. A uniform system of classification of machining datum has been developed for the purposes of description of datum areas in machining of parts.

Level 3 of the database is used to define the consecutive features to be machined, with relation to specific products from the casing class. In particular, there is a possibility of defining three basic types of machined features – planes, circles, or slots.

### 1.1. Classification of the basic datum areas for the machining of the casing-class part

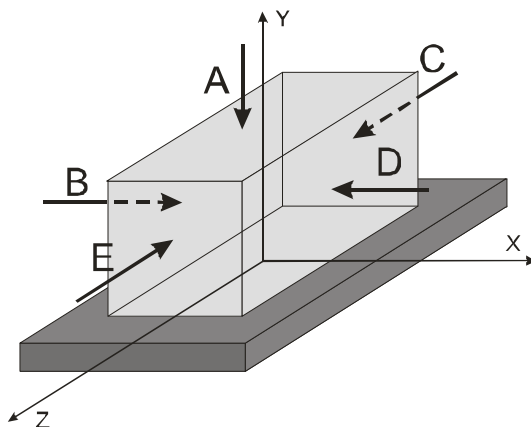
To be possible automatic verification of possibility of machining specified part on specified machine tool it is necessary to simultaneously define both the position of the part and position of all objects to be machined in the machining space of machine tool. But what is also important it must be defined not only position but also side from with the machining process will be realized.

Casing-class parts are objects which have three-dimensional character, and machining process for these parts can be realized in flexible manufacturing system after fixing them on the technological (or machining) pallet [15]. In order to realize proper description of basic datum areas for the machining of the part the literal-numerical system was taken. This system allows for determination of datum area and coordinates of basic point which is characteristic for the position of basic datum area for the machining (fig. 2).



**Fig. 2. An example of designation of basic datum area for the machining**





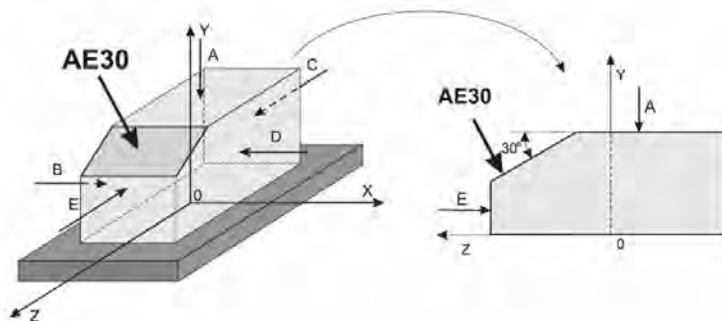
**Fig. 3. Literal denotation of basic datum area for machining**

The system of classification of datum area for the machining was based on five basic datum areas for machining designated with using the symbols as below (fig. 3):

- A – basic datum area for machining (cutting plane) parallel to the surface of technological pallet,
- B – basic datum area for machining (cutting plane) perpendicular to the surface and parallel to one of the longer edge of technological pallet
- C,D,E – basic datum area for machining (cutting plane) perpendicular to the surface of technological pallet turned in accordance with the direction of clock-hand moving adequately for an angle  $90^\circ$ ,  $180^\circ$  and  $270^\circ$  in relation to defined basic datum area for machining B.

In case of existing additional datum areas for machining placed into specified angle in accordance with the location of basic datum area for machining the destination has the literal-numerical character, where letters indicate basic datum areas which are the basis for determination of placement and number which determines the angle of cutting-plane location in accordance with basic planes (for example: designation AE  $30^\circ$  determines basic datum area placed between cutting planes A and E slanting into angle  $30^\circ$  in according to basic datum area for machining A – fig. 4).

In order to define in an unequivocal way the basic datum area for machining in machine-tool's machining space it is needed to define coordinates of location any basic point on the plane in according to co-ordinate system with origin of coordinates in the middle of front plane of technological pallet on which the object to be machined is fixed (see fig. 5).



**Fig. 4. An example of indicating the basic datum area for machining located with the angle  $30^\circ$  in relation with basic datum area for machining A and E**

## 1.2. Saving constructional knowledge about parts to be machined

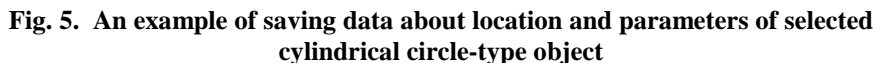
Defining the basic datum area for machining according to classification presented in point 1.1 gives possibility to define datum area for machining in machine tool's machining space and determines the cutting plane of reference for each of object intended to be machined in specified part. Analysis of features of casing class parts presented in work [16] allow for specification three elementary objects which are machined in this type of parts:

- Planes,
- Circles,
- Slots.

Planes are the most often machined to obtain imposed by the constructor surface roughness or flatness. It is possible to distinguish two types of planes: internal (grooves) or external (shelves), for which are defined: coordinates of machining range in X and Y axis (in local co-ordinate system on the basic datum area for machining in relation to placement of basic point), value of withdrawal from basic datum area for machining, roughness of butting and/or lateral face (for grooves) and also different information concerning with the machined surface (for example: flatness deviation).

Circles can be divided in cylindrical circle (straight forward) and conical (convergent). In case of circles defined parameters are: coordinates of circle centre, its dimensions (diameter or diameters, angle of inclination), roughness parameters, deviations of position and dimension, information about its arterality, thread, machining depth and others.

All of presented above objects are defined individually and independently apart from each other and each of these is identified using the unrepeatable symbol given by the user in moment of input the object into database. In case of complex circles (with cylindrical or conical spot facing) they are decomposed into elementary elements (cylindrical or conical circle) where each of these is defined separately.



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The database where parameters about parts intended to be machined in FMS are gathered was developed in Polish language in MS Access system and in this article was presented as a part of the system <<OPTSELECT>> which allows for computer aided machine tools selection for casing-class flexible manufacturing system. Its starting, which allows to input constructional data is realized from the main form of program by trusting the bottom “Wprowadzanie danych o przedmiotach” – fig. 6.

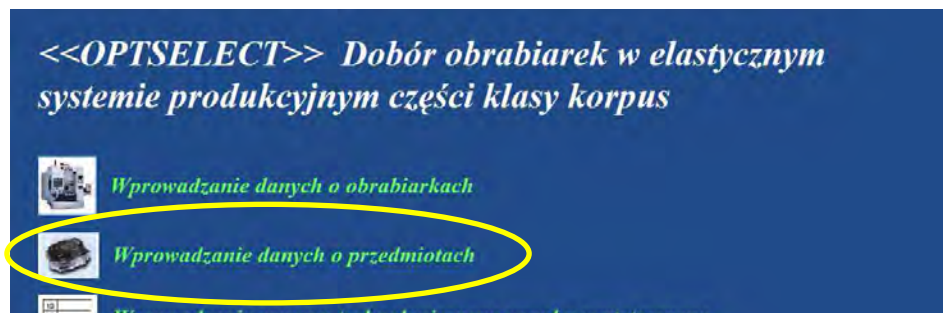


Fig. 6. Starting data base about parts to be machined in FMS

Data base where the saving process of constructional knowledge of parts to be machined in flexible manufacturing system has three-levels structure according to brief foredesign presented in point 1 (fig. 1). Starting the database causes opening the main form of data base, which gives possibility to input data of informational sense which define the part to be machined in FMS – fig. 7.

Fig. 7. Main form to input data about parts to be machined in FMS (fragment)

Using the form presented above, the user has also possibility to define all necessary basic datum areas for machining in case of consecutive parts move into system – fig. 8

**Fig. 8. The form of defining datum areas for machining**

Defining individual objects intended to be machined into part is possible after opening the datum area for machining form (button “Przejdź do formularza strony obróbki”) and pressing the button “Wprowadź nowy obiekt obróbki” – fig. 9.

**Fig. 9. The form „Datum area for machining” in data base about parts to be machined in FMS**

After choosing in successive steps the defined object (fig. 10) the user takes advantage of proper appearing form (which is characteristic for particular

object) input parameters connected with defined object. The fragment of an example cylindrical-circle's object was presented in fig. 11.

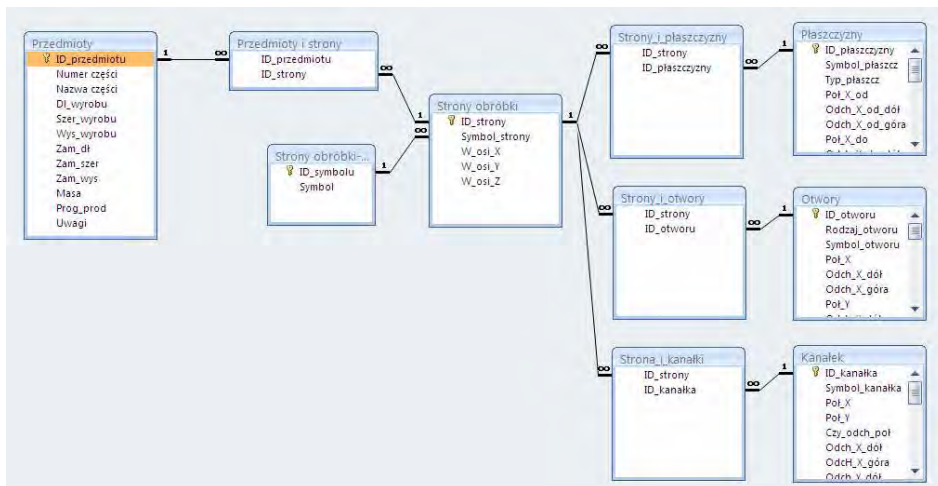


**Fig. 10.** Following steps in process of defining the object to be machined in <<OPTSELECT>> program

**Fig. 11.** The form of saving data about cylindrical circle object (fragment)

Information about loaded parts, basic datum areas for machining and objects can be chosen both from the level of form and the table, where the data are saved. Passing between separate forms is possible thanks to navigational buttons located on each of the form. From the level of particular form it is possible to check each time all connected objects (for example: part and defined basic datum areas, or the basic datum area for machining and connected objects).

All constructional data about parts to be machined are saved in 10 connected tables, which detailed specification and relation between them were presented in fig. 12.



**Fig. 12. Tables and relations between tables in data base about parts to be machined in FMS**

## Summary

One of the fundamental tasks when design and develop software which helps the human to realize any activity is to guarantee possibility of simple and fast input appropriate data and in such way that it would be possible to select, look over and verify them. In order to make it possible one often has to develop the conception of gathering information in structuralized way, that gives further possibility to fast access to their source and fast their processing.

This kind of problem is possibility of saving technical knowledge (constructional and technological) about parts to be machined in manufacturing system in such way to be possible optimal selection of machine tools used for their processing. In this article the method of representation and saving constructional data about casing-class parts was presented. This method was submitted in context of problem of machine tools selection in flexible manufacturing system. The presented method allows for relatively fast

and simple “transfer” data recorded as traditional constructional and technological documentation to computer software which helps the designer to select the FMS machine tools subsystem.

The presented method was based on three-levels data base which allows for saving constructional parameters and in different module – technological knowledge. This conception was implemented in the area of MS Access database software and is an integral module of <<OPTSELECT>> program which is dedicated for casing-class flexible manufacturing system machine tool subsystem selection. The method can be moreover used in an independent way both for different task where the computer saving and registering technical documentation is necessary and also in different user applications.

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## **Method of Representation and Saving Casing-Class Parts' Constructional Knowledge Using MS Access System**

### **Abstract**

One of the elementary problem to develop tools which helps in process of manufacturing systems design or technological process design is possibility of computer saving data about parts to be machined in the system in such way to be possible their simple, fast and effective processing. In the article the method of saving technical knowledge about casing-class parts was shown. The method was practically implemented in the MS Access database software.

**Keywords :** construction al knowledge, saving of technical knowledge, casing-class part, MS Access database software

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## **Manufacturing-oriented language for communication with part database**

### **1. Introduction**

Manufacturing features are commonly accepted as the mans for CAD/CAPP (Computer Aided Process Planning)/CAM (Computer Aided Manufacturing) integration. The feature technology is the subject of many research works, both abroad [1, 5, 9], as well as in Poland [3, 4, 6, 7, 8]. Especially high number of works deals with the algorithms for the feature recognition and the feature representations. These works does not cover the problem of the communication with the database used for the storage of feature-oriented part model, although it is essential factor for the successful use of such database.

The selected communication method must fulfill two basic criteria:

- Possibility to communicate in an interactive mode, in which the decisions are taken by manufacturing engineer, as well as in automated process planning mode, when the data are exchanged without the humans,
- fulfillment of all requirements imposed by the up-to-date computer aided process planning systems [4].

In relation to this second requirement, apart from delivering the required information about the part, there must be also possibility to execute other tasks. The communication method must also allow to modify the part model to reflect the changes in its characteristics during manufacturing process planning. For example, when using the three-stage algorithm for manufacturing process planning [4], the communication language must be able to transform the part with backward method, from the final part to stock, and with standard method, from stock to the final part. During manufacturing process planning, not only geometry characteristics are changed but also mechanical properties. The communication language must be able to order the change of such properties for selected manufacturing features, for example to change the surface roughness and hardness. The algorithms of nowadays CAPP systems are using intermediate states of the part in the reasoning process. Because of this, language must also allow to read and store the intermediate states. To increase the user comfort, especially when working in an interactive mode of process planning, the communication language must also include some commands for the visualization.

The communication language, fulfilling the above mentioned requirements is presented in this paper. The following points discuss the part modeling system architecture, feature-oriented part model used for the development of the part database and the database. This database includes internal level, logic level and external level. The external level, responsible for the communication, is presented in details. The language, based on Backus-Naure notation (BNF), similar to SQL language commonly implemented in database systems, is used for the communication.

## **2. System architecture**

The object- oriented database of manufacturing features is the central element of the system for part modeling in the manufacturing process planning environment (Fig. 1). The main elements of this system are as follows:

### **Commercial CAD system**

The commercial CAD system SolidEdge is used for the modeling of part geometry. It is the system oriented on design feature and additionally it exposes the full B-Rep representation through the API interface. This system is also used for the modeling of some non-geometry information.

### **Application for the modeling of non-geometry information**

This applications runs in the commercial CAD system environment. It is intended to model the non-geometry information in a manner making possible the automatic processing of this information. It appends the blocks of non-geometric information to the basic geometric elements.

### **Transformation module**

This module creates the manufacturing features- oriented part model using the geometric and non-geometric information modeled in the CAD system. The received model is stored in the object-oriented part database.

### **Communication bus**

The communication bus receives the messages sent by CAx applications using the object-oriented database of manufacturing features and sends the answers to them. The messages form the process planning oriented method of information exchange.

### **Manufacturing feature oriented part model**

The object database uses the manufacturing feature oriented part model. This model is the set of intermediate shapes:

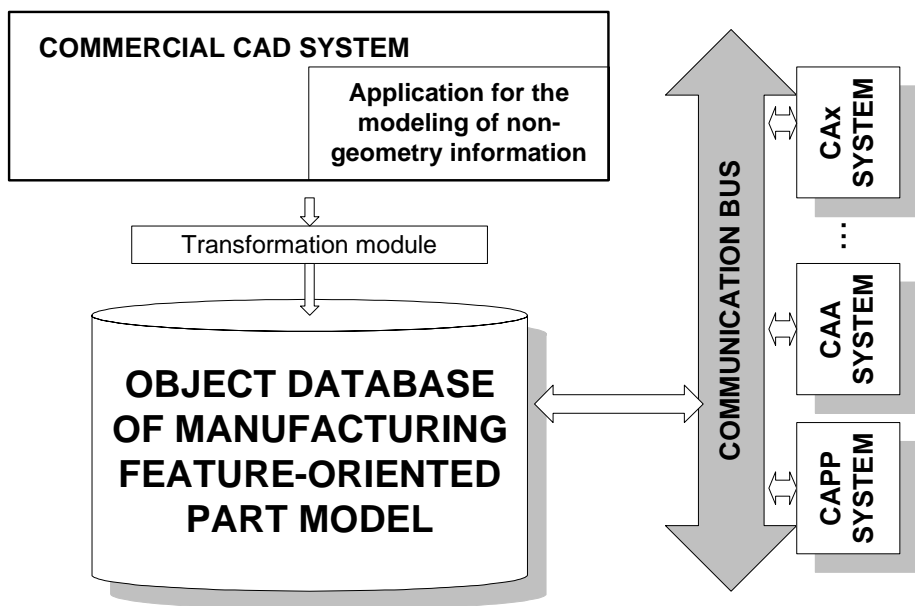


Fig. 1. The simplified architecture of part modeling system

$$P=\{PO_1, PO_2, \dots PO_k\} \quad (1)$$

where:

P Part model

$PO_i$  Intermediate state of the part,  $i=1\dots k$ , for  $i=1$  the intermediate state  $PO_1$  represents the finished part, while for  $i=k$  the intermediate shape  $PO_k$  represents the stock.

Each intermediate state  $PO_i$  can be described by:

$$PO_i=(G_i, T_i) \quad (2)$$

where:

$G_i$  graph of the structure of the intermediate state

$$G_i=<C_i, W_i> \quad (3)$$

where:

$C_i$  the set of nodes representing the simple and complex manufacturing features occurring in the intermediate state  $i$

$W_i$  the set of constraints in the intermediate state  $PO_i$

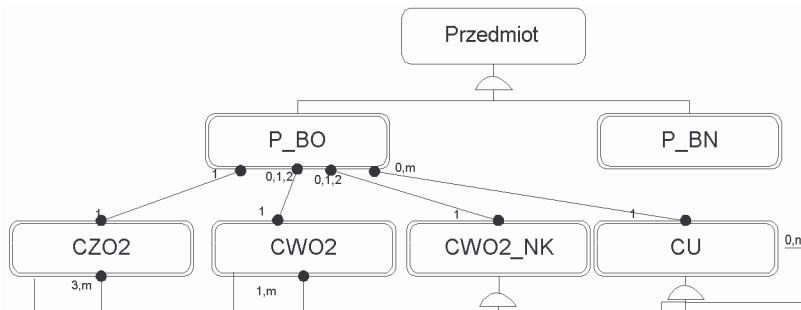
### 3. Object-oriented database

In the object-oriented database, similarly like in the other types of database, three layers can be distinguished [2], described in the following points (except the internal layer which is realized by the operation system and not discussed in this paper):

- **internal layer** (also called the physical layer),
- **external layer** (also called the user layer),
- **logic layer** (also called the conceptual layer).

**Logic level** is responsible for the representation of the database scheme. The database scheme is defined according to the selected data model. In the developed approach, object model is selected, in which the database structure is described by the classes represented by the objects.

Fig. 3 presents the fragment of the object structure on this level. Class P\_BO represents the rotational part. It is connected to class CZO2 (external contour), CWO2 (internal contour), CWO2\_NK (centre holes) and CU (auxiliary features, like for example grooves). According to the structure presented on this figure, the part must have one external contour, and can have 0, 1 or 2 internal contours. The part can also have 0, 1 or 2 centre holes and 0 or m auxiliary features.



**Fig. 3 Fragment of object structure**

**External layer** is used by the user (or other computer system) for the communication with the database. It separates the user from the detailed technical solutions implemented in the database system by offering the high-level languages for the definition and accessing the data, without the detailed knowledge of the internal representations.

To assure the required functionality of the database, the object-oriented database of manufacturing features must support the following commands:

- queries,
- commands for the data modification,
- commands for the management of the intermediate states and for visualizations.

The language similar to the SQL is used for the communication. The following point covers the detailed presentation of this level.

#### 4. The language for the communication with part database

First the notation of the developed language used for the communication on the external level is presented. Next the syntax of queries, and the commands for the data modification and management of the intermediate states are presented.

## 4.1 Language notation

The language is based on Backus-Naur (BNF) notation.

- Key words are written in *italic*,
- optional parts of the instruction are placed in square brackets [],
- vertical line separates the optional parts of the instruction,
- comma and dots (,...) informs, that the previous part of the instruction can be repeated any number of times, singular occurrences shall be separated by comma, and without comma after the last occurrence.

## 4.2 Queries

The queries are indemnified by the key word *Select*. The syntax for queries is as follows:

```
Select Attribute ,,... | *  
      from name | ID  
      [where predicate]
```

where:

Attribute Feature attribute

Name Name of feature or constraint

Predicate Predicate in the form of logical expression

*Select* instruction is simply a query directed to the database. The result of the query is the list of features or constraints fulfilling the criteria specified in the query. The list forms so called resultant set. The query syntax is similar to SQL (Structured Query Language). The queries can ask only the data included in the part database.

Three parts can be distinguished in *select* instruction. The first part are attributes placed after the key word *select*. Each feature/constraint is characterized by several attributes, and the number of the attributes is sometimes very high. Nevertheless, the resultant set constraints only the attributes of features/constraints specified in the query. This allow to reduce the transfer of data not necessary for the given manufacturing process planning task. When asterisk (\*) is given instead of attribute (-es), all attributes are returned.

In the second part, after keyword *from*, the name of feature/constraint shall be given. The name identifies the type of object. If the part contains more than one feature/constraint of the given type, for example it contains several cylindrical surface features, or external grooves, all such features are returned.

The identifier can be given to specify the particular feature. If the identifier of the feature is given instead of the name, the particular feature is returned.

Examples:

- *Select L, DMax from CZO2*  
The instruction returns L and DMax (length and maximum diameter) for the feature representing external contour (CZO2).
- *Select ID, L, D, Ra, IT from CWO2\_OP*  
The instruction returns ID (identifier), L (length), D (Diameter), Ra (surface roughness Ra) and IT (tolerance class) of the features representing through holes (ZWO2\_OP). If the part has more than one through hole feature, these parameters are returned for all such features.
- *Select \* from #0016*  
If the previous *Select* instruction returned through hole with identifier #0016, this instruction return all attributes for this hole.  
The third part of the *select* instruction, after the keyword *where* is optional. This predicate is the expression using feature/constraint attributes and must have the logical value TRUE to return the attributes of the feature.

The predicate after the keyword *where* can use the following operators:

Equal ('='),  
Not equal ('!='),  
Greater ('>'),  
Less ('<'),  
Greater or equal ('>='),  
Less or equal ('<='),

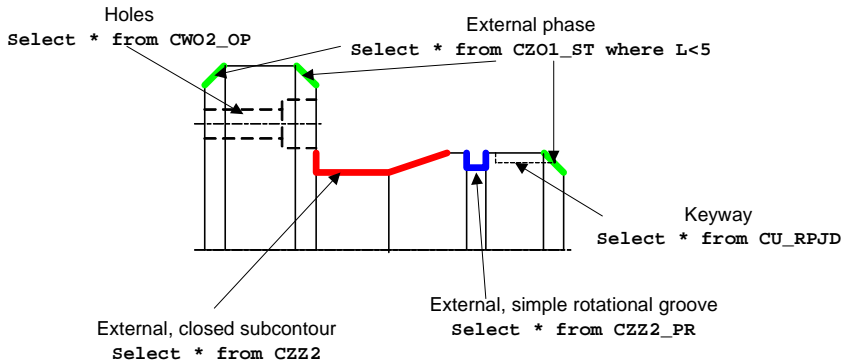
The search criteria can use test more than one attribute, as in the instruction *select ID from CWO2\_OP where D<22 and IT<7*, returning all holes with the diameter (D) less than 22 mm and tolerance class (IT) less then 7.

The resultant set is stored as the table of relational database and can be further processed using normal SQL commands, executed from the manufacturing process planning system environment. The use of select instruction operating on the resultant set allows to receive the subset of the returned features. This allows the nesting of the queries and the exclusion of the elements from the resultant set using the criteria specified in the subsequent queries.

Instruction *select* can be also used to check the occurrence of the contour features (so called refinement features [8]). The execution of the *select* instruction may also require to calculate the value of some attributes.

Fig. 4 presents the examples of usage of *select* instruction.





**Fig. 4 The use of *Select* instruction**

### 4.3 Command for the data modification

The following command for the data change in the part database can be distinguished:

- command for the backward transformation (from finished part to stock [4]):  
*RewTransform*,
- command for the forward transformation (from stock to finished part:  
*Transform*),
- command for the modification of the object attributes: *Change*.

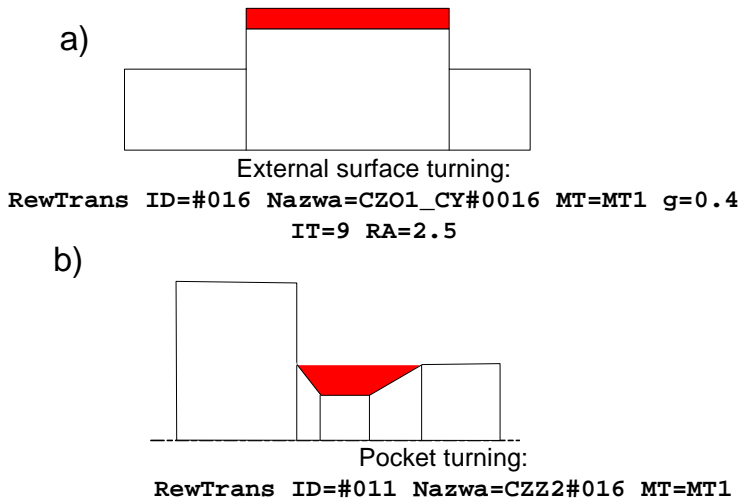
The command for the backward transformation has the following syntax:

```
RewTransform ID, Name, TM
    [, TParam=value,...]
    [, Attribute=value,... ]
```

where:

ID	Feature identifier
Name	Transformation name
TM	Transformation model
TParam	Parameters of the transformation for the given transformation model
Attribute	Feature attribute
Value	Values (parameters of the transformation model or feature attribute)

Transformed feature identifier, name for the storage of the new transformation (this name is specified by manufacturing process planning system), transformation model, transformation parameters for the selected transformation model and the examples of *RewTrans* command are given on Fig. 5.



**Fig. 5 The example of use of *RewTransform* instruction**

*Transform* command is for the standard transformation (from stock to finished part). This command is used on the III stage of the manufacturing process plan generation [4] using the intermediate states and the transformations generated on earlier II stage.

The syntax is as follows:

*Transform* Name

where:

Name Transformation name

The operation of *Transform* command is similar to *RewTransform* command. The features attributes after transformation are retrieved from the previous *RewTransform* transformation.

*Change* command is used for the modification of the feature or constraint attributes. It can be used for example to change to manufacturing properties (as surface roughness), automatically retrieved from drawing database of CAD system or to change the position of the global coordinate system.

The syntax is as follows:

*Change* ID [ , Attribute=value,... ]

where:

ID Object identifier,  
 Attribute Feature attribute,

Value     Value of parameter of the transformation model or feature attribute.

#### 4.4 Commands for the management of the intermediate states and visualization

These commands for the management of intermediate states allows to store (Save) or read (Read) the intermediate states. The syntax of both commands is similar.

*Save* Type Name

*Read* Type Name

where:

Type	Type of write/read operation
SSP	Write/read the intermediate state structures [8]
SP	Write/read the intermediate state
Name	Name of the data file

The syntax of the command for the visualization is as follows:

*Display* ID

where:

ID	Identifier of the feature to be shown on the screen
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#### 5. Conclusions

The proposed manufacturing-oriented language fulfills the requirements imposed by the computer aided process planning systems (CAPP) and can be used both in the interactive as well as automated operation mode. The presented idea of the communication with the part database has the following characteristics:

- the communication in the manufacturing-oriented planning systems allows to formulate the queries using the logical elements of the part structure (so it is not necessary to deal with the basic geometric elements like vertexes, edges or surfaces),
- it allows to use the part database without the detailed knowledge of its logical structure,
- easy integration with relational database due to the format of the resultant set and similarity to SQL language,
- possible integration with the object database, because it allows to reference the objects and their parameters.

The proposed solution is the fragment of the part modeling subsystem [8].

This subsystem is one of the elements of the manufacturing process planning system [4]. The testing of this system proved the presented concept.

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## **Technologicznie zorientowany język do komunikacji z bazą danych przedmiotów**

### **Streszczenie**

W referacie przedstawiono technologicznie zorientowany język do komunikacji z bazą danych przedmiotów obrabianych. Język ten służy do komunikacji z obiektową bazą danych przedmiotu reprezentowanego za pomocą cech technologicznych. Pozwala efektywnie wyszukiwać i modyfikować dane, niezbędne do komputerowo wspomagane projektowania procesów technologicznych (CAPP), bez konieczności szczegółowej znajomości poziomu logicznego (struktury logicznej) tej bazy. Proponowane podejście zostało z pozytywnym wynikiem zweryfikowane w prototypowym systemie do projektowania procesów technologicznych.

**Słowa Kluczowe:** cechy technologiczne, CAPP, SQL, wyszukiwanie danych

## **Manufacturing-oriented language for communication with part database**

### **Abstract**

The paper presents the manufacturing-oriented language for the communication with the part database. This language is used for the communication with the part object database developed based on the concept of manufacturing features. It allows for the effective data retrieval and modification, necessary for the computer aided process planning, with no necessity to have the detailed knowledge about the logical level (logical structure) of this database. The proposed approach was successfully verified in the prototype system for manufacturing process planning.

**Key words:** manufacturing features, CAPP, SQL, data retrieval

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## **An example of using the VBA language in accounting**

### **Introduction**

A problem for many organizations is accounting in its broad sense, which as a rule requires processing of large data sets (ranging from a few megabytes to several dozens terabytes in size, in the case of large enterprises using integrated Material Requirements Planning (MRP) systems), also for management purposes. Also important is that a needed piece of information be quickly retrieved from possessed and appropriately processed data. For this purpose, large companies generally use specialized database systems (Oracle [4], MS SQL Server [5]), while smaller firms, of-the-shelf database and spreadsheet programs. In many companies, Access [6] and Excel [8] (powerful applications, anyway) are dominating, which are elements of the popular package Microsoft Office for the Windows environment (many a time, this software is already preinstalled on a new computer). This is an inexpensive solution and, in many instances, sufficient. This is particularly true when the user is able to make use of the system's latent capabilities, such as the possibility of creating macros or add-ins created in Excel using the VBA (Visual Basic for Applications) language. The article provides an example of an add-in (macro command) developed in Excel in the VBA language for the accounting purposes of an industrial plant. Add-ins are mechanisms that enrich spreadsheets with new functionalities. For example, the *Analysis ToolPak* package (which comes with Excel) offers the capability to perform statistic and analytic computations, which are absent in Excel, as standard [7].

### **Visual Basic for Application**

Visual Basic was created based on Basic, a language very popular in the 80s of the 21<sup>st</sup> century. Basic was a high-level language dedicated to all then 8-bit computers, and was even present in the ROM (Read Only Memory) of early IBM PC series computers. Basic was an interpreted language, which means that its code in a source form was processed by a special application (processor) only at the moment of running. As a consequence, the application operated very slow. There were no integrated programming environments, like e.g. RAD. An application was created in a text processor which had no capability to check the

code during writing. Any errors were “captured” at the moment of running. The language was considered amateur, simple and easy to be mastered by an inexperienced user (which was its great advantage).

Apart from the C++ language, Visual Basic is an element of an advanced programming tool which is Microsoft Visual Studio 2010 (also for the .NET environment [2]). .NET is a new generation program platform by Microsoft featuring the CLR (Common Language Runtime) facility that allows creation of RAD (Rapid Application Development) type applications, and in which all languages are equal (for example, VB.NET can do anything that C#) [3, 4, 9]. VB.NET is a fully object-oriented modern high-level programming language. Its very interesting variation is Bascom which is used for programming controllers [1, 3] (aside from Pascal, C++ and Assembler). Presently, the Visual Basic language has its own unique object model, however, it lacks inheritance and polymorphism and it is compiled (we get files with the .exe extension). Its specialized variation is Visual Basic for Applications. It provides no possibility of code compilation. The program is run by a special interpreter in-built in the Microsoft Office package applications (and also AutoDesk AutoCad or Word Perfect) and is included in common documents with the \*.doc or \*.xls extensions. The only exception is Microsoft Access, for which the Microsoft Office Developer package is offered for additional charge. The Microsoft Office package features a specialized Visual Basic editor that checks a code as it is created.

### **Data formatting and processing**

The globalization of economy has contributed to setting up huge international corporations having their divisions in many countries in various continents. The headquarters is in the parent country, while documents are distributed throughout the world and get to particular affiliates. There, different, country-specific tax regulations are applicable and different accounting principles are valid. More importantly, different languages and regional settings are used. This is of key importance in the case of numbers (a dot instead of a comma in the decimal notation) or dates (the notation of months and the year) and, as a consequence, poses very serious problems when importing data for localized versions of accounting programs. In spite of the versatility of the Microsoft Office package which is able to change the codepage “on the run”, errors do happen, especially during loading files written as plain text. The applications included in the package do not satisfactorily manage the interpretation of special characters (spaces, tabs, hard returns, etc.). The result is a completely illegible document.

	A	B	C	D	E	F	G	H
1	Journal	IDateEcr	ICount	ICoog	INoFact	ITiers	ILabelC1	IAdrst
2	6C	20110107	11090037	44566001	9/01/2011	000286	CEZARKNA	
3	6C	20110104	11090042	44566001	102964-011	000104	TELEKOMUNIKACJA POLS	UL Mokrs 23
4	6C	20110113	11090014	44566001	08319494/1	000104	MINISTERSTWO P	UL KRÓTKA 23
5	6C	20110113	11090014	44566000	08319494/1	000104	ZAKŁAD TRANS	UL CICHY 1
6	6C	20110104	11090013	44566000	P35045399	000118	GASPROM	JANA MATEJKI 23
7	6C	20110104	11090032	44566001	11FV/S/15	000984	TROJANOWSKI	UL MYSIA
8	6C	20110110	11090011	44566001	4/11	000125	KANCELARIA PRAWNA	MOKRA 1
9	6C	20110113	11090026	44566001	137/2011	000157	FA-METALI K	UL KATOWICKA 34
10	6C	20110104	11090017	44566000	39/2011	000159	POLONEZ SJ	MATEJKO 4

**Fig. 1. A fragment of an input data file table**

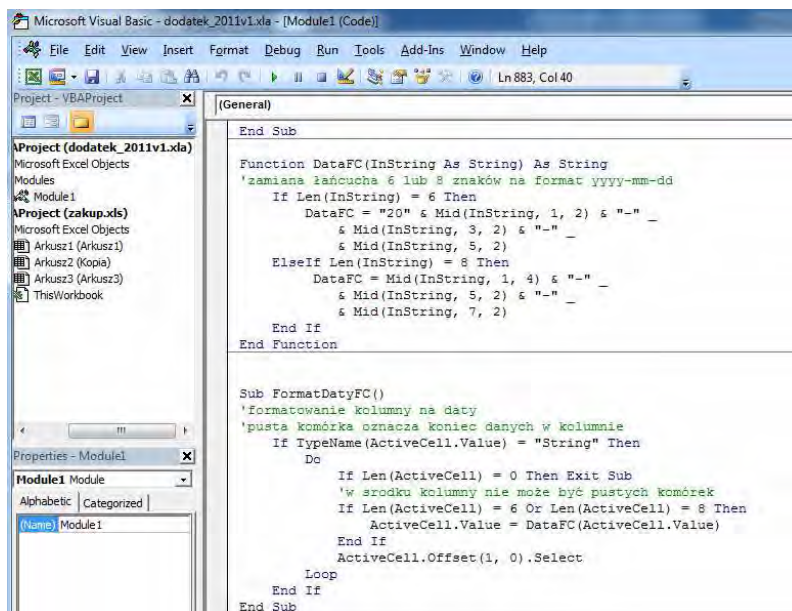
In the case under consideration, a Polish branch receives systematically files to be processed from the headquarters based in another country, or, for their purposes is required to prepare and process its own data (in accordance with standards applicable in the country of destination). Each package consists of two large files. One of them includes purchases documents, and the other, sales documents.

	D	E	F	K	L	M	N	O	P	Q
	ICoog	INoFact	ITiers	ILabelC1	IAdrst	ICount	ICoog	INoFact	ITiers	ILabelC1
3	6C	2011-01-04	11090042	44566001	102964-011	104	989-020-44-99	1	267.85	267.85
4	6C	2011-01-13	11090014	44566001	08319494/1	104	989-020-44-99	1	268.7	1390.00
5	6C	2011-01-13	11090014	44566001	08319494/1	104	989-020-44-99	1	63.71	2389.84
6	6C	2011-01-04	11090013	44566000	P35045399	118	989-020-44-99	1	352.86	1738.34
7	6C	2011-01-04	11090032	44566001	11FV/S/15	984	989-020-44-99	1	7.82	24.00
8	6C	2011-01-10	11090011	44566001	4/11	125	989-020-44-99	1	276	1230.00
9	6C	2011-01-13	11090026	44566001	137/2011	137	989-020-44-99	1	139.71	477.00
10	6C	2011-01-04	11090017	44566000	39/2011	139	989-020-44-99	1	490.90	2478.90

**Fig. 2. A fragment of an input data file table with formatted data and the extended Excel program menu**

Data files, in the form of tables in the Excel (.xls extension) format, each of a size of several hundred rows by 20 columns, contain text data, numbers and dates - Fig. 1. The task is, above all, to properly format the data (without doing this they cannot be further processed and used), to check them and correct any errors, and to divide them into respective tables. Prior to developing the program, this task would take one person about 2 weeks, 8 hours per day.





**Fig. 3. An example of procedures in the VBA language**

First, incorrectly formatted dates are interpreted by the program as numbers stored as text (the triangle in the upper left-hand corner of the cell indicates an error), while numbers preceded by a space are interpreted as text. The same columns contains data interpreted as numbers, text, or numbers interpreted as text. These are, however, errors easy to correct – Fig. 2. Whereas, factual errors (incorrect data values, a number or text written in the date column, or vice versa, or data confusion, mistakes in contractors' addresses or names) cannot be corrected by software - there is no possibility of creating a suitable algorithm and, as a consequence, the user has to capture them on his/her own. As a rule, such mistakes are few and, upon correct data formatting, they are clearly visible. Add-ins (macro commands) written in VB are convenient for the program's user, as they are displayed in the form of an option (herein, the name Add-in has been adopted) in the top menu bar - Fig. 2. The *Developer* menu option (Fig. 2; or Alt+F11) enables the user to run a Visual Basic editor – Fig. 3, in which the source code of the add-in program is written.

For example, the data column, which contains 6 or 8 characters, is filtered from the top until an empty cell appears, and in subsequent cells (from the first to the empty one) dates are written in the format *yyyy-mm-dd* – Fig. 3, Fig. 4 – column C). This means that no empty cell may be in the date column (as an empty cell means the end of data). And, more importantly, dates written in the format required by Excel can be further used for making computations (e.g. using system functions available in the *Functions / Date and time* menu).

	A	B	C	D	E	F	G	H	I	Q	R
1	Lp	data wplywu	data faktury	nr faktury	nr rej.	kontrahent	NIP	VAT 23%	netto 23%	suma VAT	suma brutto
2	1	2011-01-19	2011-01-14	5/2011	11110001	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	410.38	1 865.38	410.38	2 275.76
3	2	2011-01-26	2011-01-12	2420488	11110002	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	77.99	886.60	77.99	964.59
4	3	2011-01-26	2011-01-25	KOR6/2011	11110003	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	522.28	2 373.99	522.28	2 896.27
5	4	2011-01-26	2011-01-25	KOR7/2011	11110004	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	43.75	198.88	43.75	242.61
6	5	2011-01-26	2011-01-25	KOR8/2011	11110005	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	92.19	419.04	92.19	511.23
7	6	2011-01-26	2011-01-25	KOR9/2011	11110006	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	204.09	927.67	204.09	1 131.76
8	7	2011-01-26	2011-01-25	KOR10/2011	11110007	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	104.07	473.06	104.07	577.13
9	8	2011-01-26	2011-01-25	KOR11/2011	11110008	CENTRUM EXPORT-IMPORT MOKRA 17 54 322 KINOLE	555-022-55-55	111.99	509.04	111.99	621.03
10								1 566.74	7 653.64	1 566.74	9 220.38

**Fig. 4. A fragment of one of the end data tables**

For moving relative to an active cell (the *ActiveCell* property of the *Application* object), the *Offset* property is used, with arguments defining displacement by a specific number of rows (1 – moving to the next row) and columns (0 – with no column change). The *Select* method selects an object (cell) and, as a result, in a loop, provides the capability to move down the column. In addition to the standard syntax characteristic of a high-level language (variables, procedures, objects, keywords), the VBA language allows also the use of functions offered by the Excel program. For example, in the procedure under discussion, the *Mid* function (an internal Excel function) is called up, which returns a specific number of characters from the chain (the arguments of this function define, in turn, the chain, the position of the first character taken, and the number of subsequent characters) - Fig. 3. The default procedures on the developed program are public (the keyword of the *Public* extent declaration is optional) and can be called up by other spreadsheet procedures and functions. An argument for the procedure can be transferred by reference (by default) or through the value. The procedure declaration with a pair of empty brackets following the name indicates that the procedure does not accept any arguments (*Sub FormatDatyFC()* - Fig. 3). The transfer of an argument by reference consists in sending the variable's memory address to the procedure, while the argument transfer through the value involves sending a copy the original variable (the variable itself does not change). The procedure enables defining of the data type in the argument list. While the *Sub* procedure can be regarded as a command by the user or another procedure, the *Function* procedure returns a single value or a table (similarly as other Excel functions and embedded VBA functions) – Fig. 3.

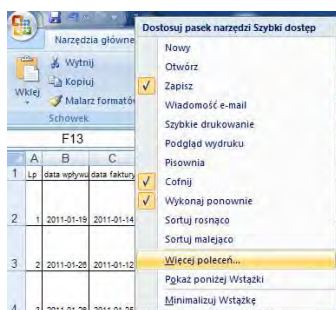
After being formatted, the data are divided into a number of tables according to the user's suggestion - Fig. 4. The data are filtered in rows and columns according to preset selection criteria (by dates, code in the columns, and column descriptions).

```
Sub ArkuszF_K6abcdedata()  
    Dim SheetCount As Integer  
    Worksheets.Add  
    SheetCount = 3  
    'arkusz 6abc  
    Call Kabcdedata(SheetCount, "6abc", "Kabc")  
    Call SortujFC(SheetCount, "Kabc", "E1")  
    Call PrzesunUsunF(SheetCount, "Kabc")  
    Call NumerujFC("Kabc")  
    Worksheets.Add  
    .  
    .  
    .  
    'arkusz data  
    Call Kabcdedata(SheetCount, "data", "Kdata")  
    Call SortujFC(SheetCount, "Kdata", "E1")  
    Call PrzesunUsunF(SheetCount, "Kdata")  
    Call NumerujFC("Kdata")  
End Sub
```

**Fig. 5. Procedure of formatting table sheets**

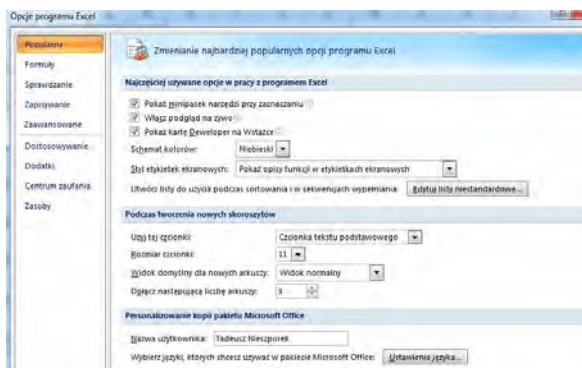
Finally, data printout sheets are formatted, taking into account headings, dates, page numbering and with a properly chosen column width and typeface size (the summing of data in rows or columns is also done, as necessary).

The entire program is built from many short procedures and functions (in total, it includes 800 rows – Fig. 3) which are called up repeatedly – Fig. 5 (in this procedure, sorting, column relocation and row numbering procedures are called up for successive sheets). Many on them are universal in nature and can be utilized also in other similar programs (macro commands).



**Fig. 6. Selecting the option of entering additional Excel menus**

VBA makes use of the hierarchical Excel object model. At the top is the *Application* object, which is *Excel* itself (other MS Office package applications are also objects and can be communicated with). The *Application* object includes other objects. In order to refer to an object using the VBA instruction, the object must be identified by connecting the dots and object names with the operator (a qualified name must be used). Each object has properties, and the method is an operation performed on the object. Programming in the VBA language has thus the features of object-oriented programming. With the use of the VB editor, nonstandard dialog boxes can be created in Excel (by introducing controls available in the *Toolbox* window and procedures of their operation) using the UserForm form [10] (like in Microsoft Visual Studio 2010 or Embarcadero RAD Studio 2010 [1]). Similarly, the user's own menu options and popup menu can be created to facilitate the operation of the program.



**Fig. 7. Adding the *Developer* option to the Excel main menu**

To run the add-in, select the *Więcej poleceń* (*More commands*) option from the *Dostosuj pasek narzędzi i szybki dostęp* (*Adjust Toolbar and Quick Access*) dropdown menu at the very top of the screen – Fig. 6. Then, after making selection in Excel's Option screen, select *Popularne* (*Popular*) and tick *Pokaż kartę Developer na wstążce* (*Show Developer sheet on the bar*) (the *Developer* option will show up with the possibility of calling up VBA; after completion of the add-in, this option can be disabled) - Fig. 7. Next, in the same screen, select the *Dodatki* (*Add-ins*) option from the left-hand side and the option *Przejdź...* (*Go to...*) from the bottom of the screen – Fig. 8. After that, in the *Dodatki* (*Add-ins*) window select the *Przeglądaj...* (*View...*) option and, in the open window, select the access path and indicate the add-in file - Fig. 9.

The majority of operations in the developed program are connected with the cells and ranges of sheets. The *Range* object, consisting of a single cell or a range of cells, is included in the *Worksheet* object and can be called up using the *Range*, *Cells* or *Offset* properties with arguments indicating the cell range being selected. The *Range* property has been used, for example, for titling

column headings – Fig. 10. Another important issue utilized in the program is the use of the *Variant* default data type serving to store different types of data (digital characters were treated as either numbers or texts, as needed).

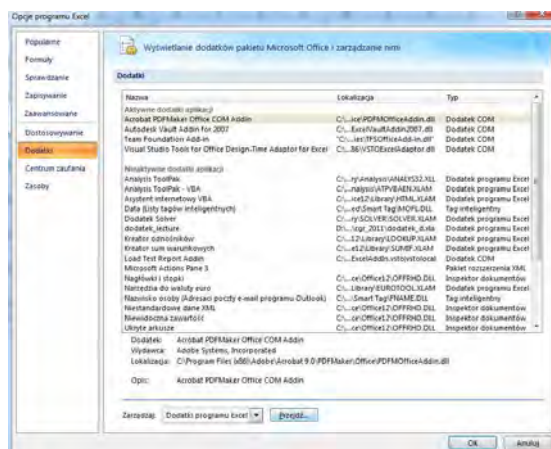


Fig. 8. Selection of the add-in entering option

In addition, attention should be given to the *Option Explicit* instruction at the beginning of the program, which forces the declaration (*Dim* – Fig. 5) of variables to be used in the program, which enhances the legibility of the code (following the example of the Pascal language). As a rule, this step is skipped by a majority of programmers (similarly as in the C language, variables can be entered anywhere in the program, without prior declaring them). However, as practice has shown, detailed commenting makes improving of the source code easier and allows it to be easily modified even after several years after writing it (which has been utilized in this case).

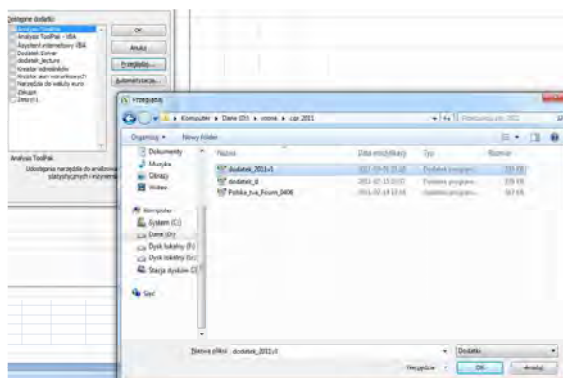


Fig. 9. Indicating the add-in file

```

Sub NaglKolumnC(ArkName2 As String)
    With Worksheets(ArkName2)
        .Range("A1:Z1").Font.Size = 7
        .Range("A1").Value = "Lp"
        .Range("B1").Value = "data faktury"
        .Range("C1").Value = "data sprzedaży"
        .
        .
        .
        .Range("M1").Value = "Vat 5%"
        .Range("N1").Value = "netto 5%"
        .Range("O1").Value = "Vat 0%"
        .Range("P1").Value = "netto 0%"
        .Range("Q1").Value = "zw. netto"
        .Range("R1").Value = "nieopod. netto"
        .Range("S1").Value = "suma brutto"
    End With
End Sub

```

**Fig. 10. A fragment of the procedure of defining column headings**

## Summary

Universal or even specialized software is not often flexible enough and really versatile to be able to meet all the needs of the user. At the same time, the learning and operation of a very extensive program offering many functionalities that are not always needed by the user, can be very hard. In the case of the Microsoft Excel program, the possibility of using macros and add-ins programmed in the VBA language considerably extends the program's capabilities. The advantages are the greater, the larger data sets are processed. The new add-ins (macro commands) to the program well integrate with its original interface (menu) and appear to an ordinary user to be part of the program (this is co called transparent integration [7]). At the same time, the add-ins restrict the access to the code and sheets, thus reducing the likelihood of making a mistake. This is so, because upon protecting the program with a password, the user will not be able to modify the add-in program code. The add-in is stored in a file with the extension \*.xla (but this extension can be changed). In the case under consideration, formatting and processing of data in the traditional manner in Excel would require one worker to be engaged for two weeks, one shift a day (this being repeated every month). Now, the entire process takes about two minutes (with a 2.4 GHz processor, 4GB RAM). Moreover, the developed program can be easily modified (after 5 years of using, the program had to be modified because of the change in VAT rates) and expanded, depending on the user's needs (currently, comments in the Applications code are particularly useful after a prolonged break). So, VBA language has met its purpose. Despite its theoretical simplicity and lack of full object-orientation, it has enabled the creation of an application extending the

capabilities of the Excel program and tailoring it to the specific requirements of the user. While the possibility of creating the user's own forms, adding new options to the program's main menu, or an easily accessible popup menu, facilitates the communication of the user's program with the main program and considerably enhances its functionality. This provides the capability to ultimately build professional applications being able to execute even complex tasks based on simple and easily accessible tools (Excel, VBA). Excel is readily used in accounting and management owing also to its wide range of graphical functions and a rich library of in-built financial functions.

The latest VBA versions allow the use of the client-server model in cooperation with the Microsoft SQL Server database, which will be utilized in a new version of the program, in the case of very large data files that would not be able to be processed by Excel. The solution is to record imported data in a database (the size of the file has practically no importance in this case) and process them by a database processor. The results will be sent to Excel and displayed in the form of a segregated sheet. The whole operation will be "transparent" to the operator.

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## Przykład wykorzystania języka VBA w rachunkowości

Problemem wielu zakładów jest szeroko rozumiana księgowość, która z reguły wymaga przetwarzania dużych zbiorów danych, również dla potrzeb zarządzania. Istotne jest także szybkie wyszukiwanie potrzebnej informacji z posiadanych i odpowiednio przetworzonych danych. W wielu firmach dominują Access i Excel, które są elementem popularnego pakietu Microsoft Office dla środowiska Windows. Jest to rozwiązanie tanie i w wielu przypadkach wystarczające. W artykule podano przykład opracowania dodatku w języku VB w programie Excel dla potrzeb księgowości zakładu przemysłowego. Dodatki są mechanizmami, które wzbogacają arkusze kalkulacyjne o nowe właściwości funkcjonalne. Na przykład pakiet *Analysis ToolPak* umożliwia wykonywanie obliczeń statystycznych oraz analitycznych, których standardowo nie ma w Excelu.

## An example of using the VBA language in accounting

A problem for many organizations is accounting in its broad sense, which as a rule requires processing of large data sets, also for management purposes. Also important is that a needed piece of information be quickly retrieved from possessed and appropriately processed data. In many companies, Access and Excel are dominating, which are elements of the popular package Microsoft Office for the Windows environment. This is an inexpensive solution and, in many instances, sufficient. The article provides an example of an add-in (macro command) developed in Excel in the VBA language for the accounting purposes of an industrial plant. Add-ins are mechanisms that enrich spreadsheets with new functionalities. For example, the *Analysis ToolPak* package (which comes with Excel) offers the capability to perform statistic and analytic computations, which are absent in Excel, as standard.



# **An example of using the VBA language in accounting**

## **Przykład wykorzystania języka VBA w rachunkowości**

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# **The BPMN and WebML solution for web app-aided flow of documents**

## **1. Introduction**

Nowadays application development concentrates on the web. The growing need for the new web based applications, including aiding flow of documents, causes a demand for the methods of rapid web-app development and for the professionals knowing how to implement them. Consumers and developers expect the fast realization of their requests while keeping in mind application's security, scalability, usability and efficiency.

While serving many different purposes, those applications are quite similar inside and follow some basic rules of the web-app design. One of the most frequently used patterns is MVC (Model View Controller). The Model provides data access, the View takes care of data presentation and user interface and the Controller contains business logic connecting first two ones. WebRatio, providing implementation of WebML and BPMN models, follows MVC rules, which are utilized in process of generation of web application pages.

Moreover WebRatio represents model driven approach to the application development, thus not only qualified specialists can create their applications. It simplifies development process by introducing special models being a connection of the predefined chunks (units). These models are also up-to-date documentation expressing the exact state and structure of the application. On the other hand there is only a small number of the predefined chunks available by default, limiting the freedom of non-standard application development. Creation of specialized units causes a return to the programmer approach [1].

The purpose of this article is to show how to use the introduced tools to easily develop web application aiding flow of documents. Exemplary application is intended to facilitate process of submission and acceptance of conference papers. It also shows, that it is enough to have generic knowledge of BPMN and WebML notations to create fully functional solutions.

## **2. WebML models**

WebML is described by its authors as “a visual notation for specifying the content, composition, and navigation features of hypertext applications, building on ER and UML” [1]. It can be seen as a high level visual description of a MVC organized web application.

WebML consists of three models:

1. Data Model,
2. Hypertext Model,
3. Presentation Model.

Data model describes application data design and is similar to a standard ERD model used in conceptual database design [1]. It utilizes entities with attributes connected with binary relationships – many-to-many relationships are permitted. It allows single inheritance in entity hierarchies, that are mapped vertically.

Hypertext model concentrates on a composition and navigation of the web-application. It arranges application into views containing areas and pages. Pages contain units responsible for the data presentation. The business logic is projected by the operation units placed either within or outside the pages. The set of units representing the commonly used operations is made available. Non-standard operation can be introduced by defining the custom units. Pages and units are connected by the links representing information flow between them. Links can carry the activation and be rendered on the page, or be in so called “transport” mode, representing the inner data flows inside application. The hypertext model is independent from the data model, however it uses the names of the entities and attributes described by it [1].

The third layer is the presentation model describing the layout of the data presentation units on the pages, the pages layout and the layout of the whole application. It imports the standard DOM/CSS design and is partially left for the developers consideration making it a bit fuzzy, on the other hand leaving the freedom to use the presentation technique of developers choice [1]

## **3. BPMN models**

Notions related to the BPMN models are: Business Process Modeling, business process and Business Process Modeling Notation.

“Business process modeling (BPM) in systems engineering and software engineering is the activity of representing processes of an enterprise, so that the current process may be analyzed and improved.” [3]. BPM is usually performed by business analysts or managers whose goal is improving process efficiency and quality. Very often processes are identified in purpose of creating IT systems which facilitates management of information, flow of documents or speeds-up some procedures in a company. Another purpose is to aid people

involved in such procedures and improve their communication with other workers [4].

Business process can be defined as a collection of related, structured activities or tasks that produce a specific service or product. It is also often visualized as a flowchart which is transformed into working system by IT engineers and programmers [4].

The last notion is Business Process Modeling Notation (BPMN) – graphical notation for specifying business processes in a workflow. Its objective is to support business process management by providing a notation that can be understood by business users (like business analysts and managers) and sufficient for representing complex process semantics. Thus BPMN serves as a bridge between business process design and implementation [4].

BPMN provides simple diagrams with small set of elements divided into four basic categories [4]:

1. Flow objects – the main describing elements within BPMN, consist of three core elements: Events, Activities and Gateways.  
Events denote something that happens, rather than Activities which are something that is done. It can be divided into i.e.: Start events (trigger for the process), End events (represent the result of a process), Intermediate events (represent something that happens between the start and end events).  
Activities describe the kind of work which has to be done. It can be divided into i.e.: Tasks (represent a single unit of work), Sub-processes (enclose additional levels of business process detail), Transactions (sub-processes enclosing activities that has to be treated as a whole, failure of any task undo performed activities).  
Gateways determine forking and merging of paths depending on defined conditions.
2. Connecting objects – describe flows of execution and documents, consist of following elements: Sequence Flow (determines the order of activities to perform), Message Flow (represents the flow of messages across organizational boundaries e.g. between pools), Association (associates an Artifact or text to a Flow Object, directionality of arrows indicates result or input).
3. Swim lanes – organize and categorize activities, consist of following elements: Pool and Lane. Pool represents major participants (usually different organizations) in a process. It is characterized by a set of parameters (hold information managed by the process) of following types: simple parameters (hold values of simple types) and business objects (complex objects enclosing set properties of simple types). Pool contains one or more lanes which are used to organize activities within a pool according to function or role. Lane can contain objects of following categories: Flow Objects, Connecting Objects and Artifacts

4. Artifacts – introduce more information into the model, consist of following elements: Data Objects (indicates data produced or required by activity), Groups (group activities without affecting the flow in the diagram), Annotations (comments describing a model).

These four categories of elements are enough to build a simple business process diagram (BPD).

#### 4. WebRatio Interface and capabilities

WebRatio IDE out of the box provides: designer tool, Apache Derby Database and Apache Tomcat (application server). It transfers WebML and BPM concepts to the real web application development and enables automatic application generation basing on the WebML model aided by a few own refinements. Resulting application is output in a JSP code and follows Apache Struts MVC pattern [1].

WebRatio handles the construction of WebML Data model as well as the connection and creation of the corresponding database via Hibernate. It also allows to import an existing database into the model. Hypertext and Presentation models are unified into the Site or the Service view. Both of these allow to visually construct a site Hypertext model starting from views, through areas and pages, ending with units, their attributes and connections. Presentation model is handled by layout definitions of pages, as well as single units.

WebRatio also supports user identification and access control. It is organized in a strict pattern: User – Group – Module, where User belongs to a group (or groups) which has access to a module (or modules). Module is understood as any part of the hypertext model (including single units) marked as protected.

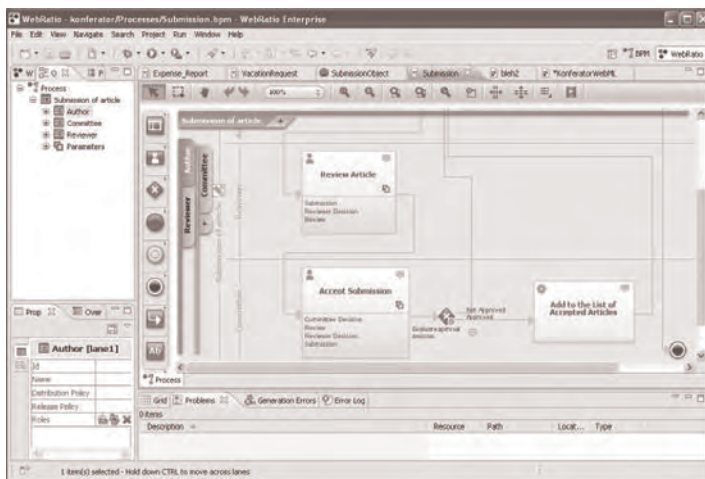


Fig 1. Webratio BPM perspective

WebRatio provides special perspectives designed for BPM and WebML models creation e.g. BPM perspective is organized into 4 main areas:

1. BPM Explorer (right upper area) – contains all the BPM Projects created in chosen workspace.
2. Editor Area (central part of the perspective) – allows drawing models of processes. Its left area is palette containing elements of the BPMN notation that can be used in models.
3. Properties View (bottom left area) – presents properties of selected element.
4. Utility Views (bottom right area) – set of views for checking logs, errors and using documentation.

## **5. Exemplary application aiding flow of documents**

### **5.1. Roles**

Exemplary application is accessed by three groups of users:

1. Authors – writes and submits articles, related to the Author lane in “Submission of article” process model.
2. Reviewers – reviews submitted articles, related to the Reviewer lane in “Submission of article” process model.
3. Committee members – decides if articles are accepted, related to the Committee lane in “Submission of article” process model.

The first step is creation of new BPM Project. Project tree contains four nodes (directories):

1. Processes – contains processes data.
2. Business Objects – contains business objects.
3. Signals – contains signals data.
4. Roles – contains roles data.

New business process can be created by right-clicking on Processes node in BPM Explorer and choosing *New -> Process*. The list of lanes in pool should be extended to the number of user groups. Each process lane contains activities performed by particular group of users.

Group of users in IT system can be also described as role, because of performing constant type of activities. Single role might correspond to more than one lane in the same process or in different processes. Thus a user belonging to the Committee or Reviewer role might act as Author in the Submission of article process. The Roles are defined within a WebRatio BPM Project and shared among all business processes in the project.

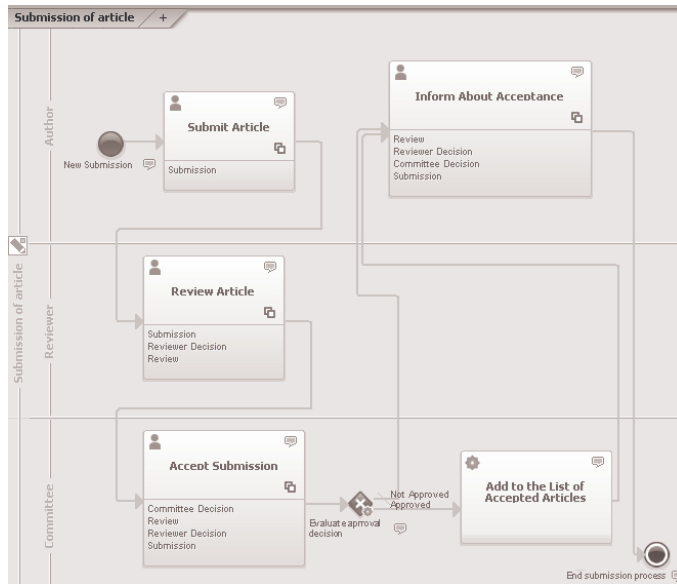
Addition of the roles to the business process model can be made in the BPM Explorer by double-clicking Roles node of the project. Displayed window allows easily adding new roles and its participants (by providing username, password and e-mail). It is mechanism for creating initial users of developed solution.

Necessary data will be put into the database tables and used for logging. The last step is assigning roles to the lanes. It can be made by setting Roles property of particular lane. To the Author lane all roles are assigned.

## **5.2. Business process**

Next step is definition of business process, which contains following elements:

1. New Submission –starts process of submission of article. Article is added as attachment to the submission request and can be seen by users taking part into the flow of this document.
2. Submit Article – user task, allows submission of the article by its author.
3. Review Article – user task, allows accessing the file with the article by reviewer. He can choose whether he approves or rejects submitted article and inform author about his objections by writing a review.
4. Inform About Acceptance – user task, informs author about reasons of rejection of his article. Author can read review written by the reviewer.
5. Accept Submission – user task, allows deciding whether article is accepted and can be presented during the conference. Committee member can write some cautions that will be seen by the author.
6. Evaluate approval decision – exclusive gateway, when article is approved by a committee member invokes Add to the List of Accepted Articles task, otherwise invokes Inform About Acceptance task.
7. Add to the List of Accepted Articles – service task, saves into IT system articles that get positive reviews and were accepted by the committee member.
8. End Submission Process – ending point, ends process of article submission initiated by the author of the article.



**Fig 2. Business process model**

### 5.3. Business process parameters

Business object called Submission is an object that contains submission data like names of authors, title of article, abstract, affiliation of authors etc. It can be created by right-clicking on Business Objects node in BPM Explorer and choosing *New -> Business Object*. It is processed during the execution of the process.

During the process some other attributes/parameters are necessary e.g. for representing the reviewer and committee member decisions. Assigning business objects and defining simple parameters of the process can be done in Process Parameters window opened by “Edit Process Parameters” option of the pool.

Moreover one can indicate which objects and parameters are computed by particular tasks. Besides that developer can indicate whether object or parameter is editable, visible or required. Simple parameters and components of the business object can have following types: boolean, date, decimal, file, integer, password, string, text, time, timestamp or url, which are typical types used in WebML data and hypertext model.

Besides Submission objects exemplary application uses following properties:

1. Committee Decision – holds Approve and Not Approve string values. Allows defining whether article is accepted for the conference.
2. Review – holds text of the review which can be written by the reviewer.
3. Reviewer Decision – holds Accept and Reject string values. Allows defining whether article review is positive or not.



Objects and properties are assigned to the tasks in the following way:

1. Submit Article – operates on Submission business object.
2. Review Article – operates on Submission business object and Reviewer Decision and Review parameters.
3. Accept Submission - operates on Submission business object and Reviewer Decision, Review and Committee Decision parameters.
4. Inform About Approval – operates on Submission business object and Review Decision and Review parameters.

#### **5.4. Business rules**

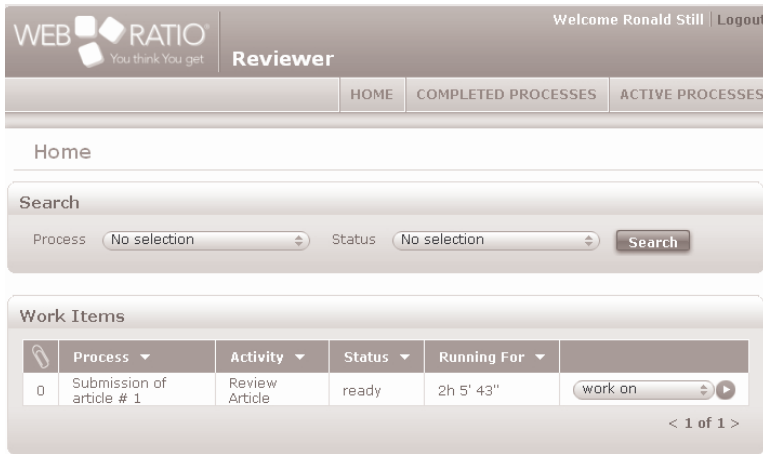
The last step is defining business rules which determines the behavior of the process' gateways by defining the conditions for the proceeding of the process. Exemplary application model contains one exclusive gateway called “Evaluate approval decision”. Depending on behavior configured in Condition Values property of the gateway, different tasks will be invoked.

Model presented in the figure 2 works as follows:

1. Author submits his article. He provides title of the article, its authors and their affiliation, invoice data, abstract and indicates file with the article within the filesystem of his computer. After confirming submission “Review Article” task is invoked – author waits for the reviews and acceptance notification.
2. Reviewer after logging into the system sees active submission processes and chooses submission to work on it. Displayed form presents submission data (including article file, which can be downloaded) and allows accepting or rejecting submitted article (Reviewer Decision parameter) and writing review (Review parameter). Current status of the form can be saved at any moment. After finishing the process of reviewing the article, Accept Submission task is invoked. Author can monitor the status of submission process.
3. Committee member after logging to the system, sees active processes and chooses one to work on it. Presented form contains submission data provided by the author (Submission object), text of review (Review parameter) and recommendation (Reviewer Decision parameter) of the reviewer (accepted or rejected). Basing on that data committee member decides whether the article will be accepted or not (Committee Decision parameter). Article accepted by him is put into agenda, information about reviewer and committee opinion is passed to the “Inform About Acceptance” task. In case of rejection, proper data is passed to the same task.
4. The final step is execution of Inform About Acceptance task by the author. He can see review of the article and decision of the committee member.

## 5.5. Publishing the process

Business process model can be transformed into working solution. WebRatio translates model into JSP pages that can be hosted by commonly used web servers. The database Utilized by default is Apache Derby although it can be changed to another solution.



**Fig 3. Generated application**

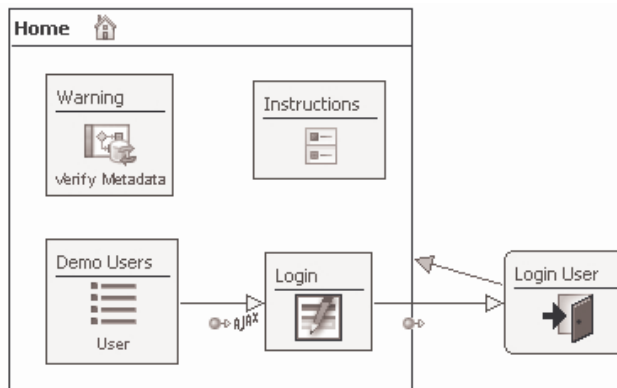
Generated application can be run on developer's computer using Apache Tomcat and Apache Derby, which are attached to WebRatio. Moreover application running on such computer is accessible from other computers in network.

## 5.6. Modification of the application behaviour

Generated and run web application has some disadvantages which should be removed before deployment in a production environment i.e.:

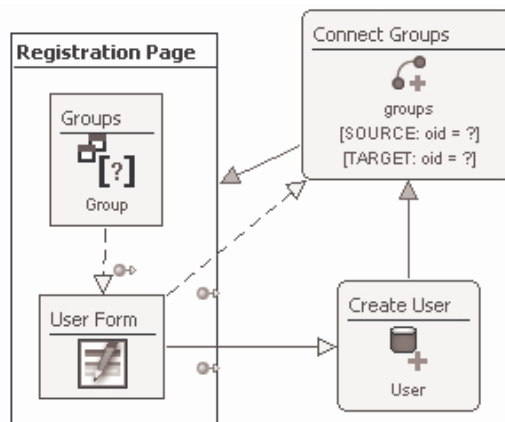
1. Demo users are presented on the home page so restricted areas of application can be accessed by anyone.
2. It would be better to put the title of article as the label of the process instance (instead of e.g. "Submission of article # 1").
3. Notifications after finishing particular tasks are not sent via e-mail to involved users.
4. Users cannot register to the system, registration form and extended user management capabilities are needed.

Mentioned disadvantages can be repaired and behavior of application changed by modifying WebML models hidden beneath the business process model. Home page of the application generated from the process model is presented in the figure 4 as a piece of WebML hypertext model.



**Fig 4. Automatically generated WebML model of the homepage**

In purpose of adding registration form to the generated application one should build hypertext model presented in the figure 5. User puts his data into the “User Form” and chooses groups to which he would like to belong. Groups are provided from the Group table to the multichoice list by the “Groups” selector unit. After clicking create user link, “Create User” unit adds record to the proper database table. “Connect Groups” unit connects users with chosen groups by putting records into intermediary table being the result of many-to-many relationship between User and Group entities in the data model.



**Fig 5. WebML model of the registration page added by the designer**

## 6. Summary

The BPMN and WebML tandem presents an easy and rapid method of creating web-placed, solution of a business problem, thus giving a tool which can be used even by non web-design experts.

Usage of the BPMN as the top model is well suited for business specialist, as they are familiarized with that notation. Entire process of creation lanes, roles and its participants, and assigning them to lanes is graphical, and user friendly. Also each user can see the progress of the process and track the dates and users that took part into initiated process. Further components of process can be easily added by clicking on the set of available components connected with highlighted one. Also developer can add some comments describing the role of particular components of the business process model. It can be clearly seen that set of BPMN elements is not overwhelming, which improves readability of models, thus even not specialists can create and read business process models.

WebML as the second layer gives the way to fine-tune the solution (within some limits), without the need to dive into source code.

WebRatio enables and somehow forces the reproduction of creation patterns, suitable for a groups of business problems.

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## The BPMN and WebML solution for web app-aided flow of documents

### Abstract

The article shows a Model Driven approach to creation of web-based solutions to business problems. The duet of BPMN and WebML technologies is used for rapid development of a web-based application, starting (and in most cases finishing) from definition of a business process –solution description of that problem. It is then automatically transformed to WebML model of a web application and finally to the code of a working JSP webservice.

Presented example of application aiding the process of submission and acceptance of conference papers shows the friendliness to non IT specialists of a design tool WebRatio when following the BPMN-WebML solution pattern.

### Keywords:

BPMN, BPM, MDSD, WebML, WebRatio, aided flow of documents

# Wspomaganie przepływu dokumentów z wykorzystaniem technologii BPMN i WebML

## Streszczenie

Artykuł przedstawia podejście Model Driven do tworzenia internetowych rozwiązań problemów biznesowych. Połączenie technologii BPMN i WebML jest wykorzystane do szybkiego tworzenia aplikacji internetowej, rozpoczynając (i z reguły kończąc) na zdefiniowaniu procesu biznesowego będącego rozwiązaniem analizowanego problemu. Model ten jest następnie automatycznie przekształcany w model WebML i ostatecznie w kod JSP działającej aplikacji. Zaprezentowany przykład aplikacji wspomagającej proces zgłaszania artykułów na konferencję ukazuje przyjazność środowiska dla osób nie koniecznie będących specjalistami IT.

## Słowa kluczowe:

BPMN, BPM, MDSD, WebML, WebRatio, wspomaganie przepływu dokumentów

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## Web accessibility for the visually impaired

### Introduction

Rapid development of web services and their ubiquity, instant communication, easy access to information published online, new methods of knowledge gathering and sharing, etc. – all those factors contribute to the fact that the Internet has become the most rapidly developing medium in human history. A society-shaping medium with significant impact on almost every aspect of our everyday life. The World Wide Web not only influences single people, but also wider social groups – even at the national or multinational level, as it has been recently proven by the events in North Africa.

But one question arises: is the virtual world better than the real one? Does it eliminate the limits and obstacles for e.g. impaired people?

Tim Berners-Lee, one of the Internet founding fathers, mentions that universality of the Web is one of its foundation stones and free access to data published online is one of the most important aspects of it [7]. These words can be taken as an indication, that each website should be designed in a way allowing its every user to access its service and functionality equally, regardless of any criteria [9] (e.g. any kind of disability, software and hardware used, etc.). Thus, the notion of accessibility, or – to be more precise – web accessibility needs to be considered while building a webpage or web service.

### Web Accessibility Initiative

Web Accessibility Initiative, usually abbreviated as WAI is one of the projects realized by W3C (World Wide Web Consortium), which is focused on improving the accessibility of the Internet (also called web accessibility) for people with disabilities.

WAI is based on the following assumptions [7]:

- ensuring accessibility support for main Internet technologies
- providing accessibility guidelines for web browsers, web development tools and even webpage content
- facilitating the development of tools used for validating accessibility
- educating the web society in the field of accessibility
- coordinating the research on web accessibility

In 1999 WAI published the Web Content Accessibility Guidelines WCAG 1.0. In recent years, these have been widely accepted as the definitive guidelines on how to create accessible websites. In December 2008 WAI released the WCAG 2.0, which aims to be up to date and more technology neutral as a Recommendation [7].

### ***Accessible Rich Internet Applications***

Creating an accessible website or web service requires not only good design (e.g. creating an accessible layout) but also writing the code (e.g. using programming language semantics) in a way allowing assistive technology to understand and process the content of the website in order to adapt it for the user [1].

Standard HTML elements (like tags and attributes) become inadequate in providing semantic reliability in case of growing complexity of webpage content [1]. Nowadays more and more web pages and applications control the functionality of the whole site or its particular elements by using different kinds of scripts, although it has to be noticed that those solutions are not able to provide semantic information to the browser.

WAI-ARIA (Web Accessibility Initiative - Accessible Rich Internet Applications) is a specification [1] developed by the World Wide Web Consortium on increasing the accessibility of dynamic content and user interface components developed with dynamic technologies (e.g. Ajax or JavaScript). ARIA enables accessibility as the webmaster is able to provide all semantic information to fully describe its supported behavior [1]. Furthermore, it allows each element to expose its current state, properties and relationship to other elements. Described specification also corrects accessibility problems with the focus and tab index.

### **People with disabilities and the Internet – short problem analysis**

Due to their impairment, people with different disabilities may rely more on the services provided on-line, e.g. it may be easier for people with motor impairment to perform certain actions online – from shopping to maintaining social contacts, as they are able to do it without leaving their homes.

The disabilities can be divided into four groups [8]:

- visual, including blindness, various types of low vision and poor eyesight, various types of colorblindness, etc.
- motor, e.g. difficulty or inability to use limbs, tremors, muscle slowness, loss of fine muscle control, etc.,
- auditory, e.g. deafness or hearing impairments
- cognitive, e.g. developmental disabilities, learning disabilities (dyslexia, dyscalculia, etc.), and other cognitive disabilities (affecting memory, attention, logic skills, etc.)

Considering this division, both users with motor and auditory impairment can be treated as ‘normal’ users, as their disabilities should not prevent them from seeing and interpreting the majority of information published online [8], as it is usually published in a text form, although aurally impaired people may have difficulties with multimedia, as at least part of the content is presented in audio form. Moreover, many multimedia websites provide a least partial alternative to their audio content (e.g. subtitles for movies). This is caused not only by care about people with auditory impairment, but also by the fact that many people work online with their speakers turned off (e.g. while in office).

Users with cognitive disabilities should also be eliminated from further consideration, as on the one hand they may be not fully responsible for their actions due to their impairment (e.g. mentally retarded people), but on the other hand some of the disabilities – like dyslexia or dyscalculia should not interfere with user’s performance online (at least if understanding the information published online is considered) [8].

Visually impaired users have a priori difficulties with seeing any message published online. But this particular group of users should be divided into at least two subgroups – the blind (or legally blind) users and the sighted (but with impaired vision – e.g. colorblind or people with various vision sharpness disabilities). The latter group will be discussed further – as those users can actually see, although their vision can be significantly different from ‘normal’, thus resulting in difficulties with noticing and interpreting the message properly.

### **General issues with visual impairment and the World Wide Web**

According to the data published by WHO, currently about 0,7% of the whole human population is blind. Moreover, the number of people affected with various vision disorders is much higher (e.g. about 10% of total human population has color vision disorders [8]).

It should be noticed, that there are various scales developed to describe the extent of vision loss and define blindness. For example, 10<sup>th</sup> Revision of the WHO International Statistical Classification of Diseases, Injuries and Causes of Death defines *low vision* as visual acuity of less than 20/60 (6/18), but equal to or better than 20/200 (6/60), or corresponding visual field loss to less than 20 degrees, in the better eye with best possible correction. *Blindness* is defined as visual acuity of less than 20/400 (6/120), or corresponding visual field loss to less than 10 degrees, in the better eye with best possible correction [6, 13]. 20/60 (6/18) means that a person would have to stand 20 feet (about 6 m) from an object to see it—with corrective lenses—with the same degree of clarity as a normally sighted person could from 60 feet (about 18m) [10].

Approximately 10% of legally blind (recognized as blind by law) have no vision by any measure [10]. The rest have some vision, from light perception alone to relatively good acuity.



Colorblindness is the inability to perceive differences between some of the colors that other people can distinguish. In most cases it is of genetic nature (but it may also occur because of eye, nerve or brain damage or exposure to certain chemicals), inherited recessively in feedback with the X chromosome – effects more men than women [12]. There are several types of color vision deficiencies, which can be divided into three different groups: monochromacy, dichromacy and anomalous trichromacy [12].

Monochromacy is an inability to distinguish any color (this impairment is often referred to as full colorblindness) [12]. Dichromacy is a color vision defect occurring when one of three cone pigments is missing and color vision is reduced to two dimensions [8]. Anomalous trichromacy occurs when one of the three cone pigments is altered in its spectral sensitivity, resulting in an impairment, rather than loss, of normal three-dimensional color vision [12].

It should be mentioned, that nowadays the computer with an Internet connection is an important source of information about the world for the visually impaired user. Moreover, it often improves the quality of communication – words are more important during an online conversation than nonverbal communication (e.g. body language) as usually both sides do not see each other. Of course other aspects of web usage, such as independent access to information, using educational courses for the disabled or teleworking should also be considered.

### ***Economical aspects of web accessibility***

There are several different reasons for creating a website or a web service, which is accessible for the visually impaired. For example if the interface of an online shop or a website is not adjusted to meet the needs of visually impaired users, it may prevent them from using it (e.g. from making purchases).

Moreover, considering the problem in aspect of online advertising, if the user is not able to see (or understand) the advertisement due to color vision defect, this commercial is not effective. Usually online advertisers pay whether for exposure of their message (so called Cost-Per-View method [8]) or (more recently [8]) for each time user clicks on their banner or listing (Pay-Per-Click method).

In both cases the situation, when user is not able to see (or interpret) the advertisement, means financial loss – either to the advertiser or to the website displaying the message. It was estimated [8] that - in some cases – those losses can reach even hundreds of thousands of U.S. dollars per year!

But the problem of web accessibility economy should also be analyzed from the other point of view – not the one of user but the one of the owner. Research proves that creating and maintaining an accessible website costs less than a non-accessible one. This is due to few different reasons: an accessible website has usually better-written code, which enables accessing the site from different platforms and systems, thus widening the audience. Moreover, the better

the code is written, the less errors it has – this eliminates the necessity for frequent code fixes, resulting in lower development costs. The content of an accessible website is usually separated from presentation (e.g. HTML code (content) is separated from CSS code (presentation)), resulting in reducing the size of the website, thus reducing loading time and amount of data transferred. All of these factors contribute to lowering the cost of website maintenance, as many hosting companies introduced limits on data transfer – each byte over the set limit means additional cost.

There is one more advantage on improving web accessibility. It was proven that search engine bots can 'see' (thus analyze and index) only the same information which is 'seen' by a blind person using e.g. a screen reader [2]. This means that web accessibility improvement translates to better site indexation by search engines, potentially resulting in better search engine results (search engine optimization) without using any SEO tricks.

### **Legal aspects of web accessibility**

Adjusting the website in order to meet the needs of disabled people is not only important due to economic causes. It may also be an important legal matter - in number of countries all around the world, legislation focused on providing universal access to the information published on-line to all of their citizens have been introduced [4].

Those legislative measures to some extent force webmasters to take impaired users into consideration while creating a website. For example, in European Union the right of disabled people to access information published online is regulated by directive eEurope 2002 [8].

By its virtue, all of the organizational units of member countries are obliged to grant access to all of their services to their users [12]. Moreover, a number of EU member countries have introduced more detailed bills or acts addressing their citizens equality in accessing information published on-line, regardless of any criteria.

For example, in Poland there are four different bills addressing this matter (according to [8]):

- Constitution of Republic of Poland (especially sections 32 and 69),
- Public Information Access Bill,
- Computerization of Public Services Bill,
- Charter of Rights of Disabled People.

Legal solution similar to eEurope 2002 directive is used by American legislation (Rehabilitation Act of 1973, especially Section 508) [8].

Some countries have much more restrictive legislation - e.g. the Disability Discrimination Act, introduced in 1995 in the United Kingdom and applying to anyone providing a service either public, private or voluntary, makes any kind of discrimination of disabled people illegal [12]. Although it should be noticed that the Code of Practice: Rights of Access - Goods, Facilities, Services and

Premises document [5] published by the government's Disability Rights Commission to accompany the Act does refer explicitly to websites as one of the "services to the public" which should be considered covered by the Act.

It should be mentioned, that there is also another important trend in legislative systems of many countries – as many countries have introduced guidelines for webmasters, which should be met, although are not mandatory. For example: Canada has the Common Look and Feel Standards requiring federal government internet websites to meet Web Content Accessibility Guidelines (WCAG) since 2000. In Sweden, Verva, the Swedish Administrative Development Agency is responsible for a set of guidelines for Swedish public sector web sites. In Spain, UNE 139803 is the norm entrusted to regulate web accessibility [4]. In Ireland, the Disability Act 2005 was supplemented with the National Disability Authority's Code of Practice on Accessible Public Services in July 2006. It is a practical guide to help all Government Departments and nearly 500 public bodies to comply with their obligations under the Disability Act 2005 [4].

Legal regulations give also the disabled people the basis for suing companies or organizations, which do not comply with customary accessibility rules. For example in 2000, Bruce Maguire, an Australian blind man won a court case against the Sydney Organizing Committee of the Olympic Games because SOCOG had failed to make their official website, Sydney Olympic Games, adequately accessible to blind users. The plaintiff was awarded \$20000 [3, 8]. This was the first successful case under Disability Discrimination Act 1992 [3,8]. The Human Rights and Equal Opportunity Commission (HREOC) also published World Wide Web Access: Disability Discrimination Act Advisory Notes. All Governments in Australia also have policies and guidelines that require accessible public websites; Vision Australia maintain a complete list of Australian web accessibility policies [3]

### **Social aspects of web accessibility**

Research conducted in 2007 among the visually impaired showed that little accessibility of websites is the main limitation for using the World Wide Web for almost 48% of them [14].

Another research, conducted in 2008, showed that time consumed on looking for specific information on a webpage can be significantly reduced by improving the accessibility of that website. The same results were obtained for both user groups: ones with normal vision and the visually impaired [11]. This fact proves that web accessibility improvement translates positively on user experience whether he is impaired in any way or not.

Usability issues should also be taken into consideration. Improving web accessibility is often connected with simplification of some of the user actions in order to make them more accessible (and understandable) for the disabled.

Those facilitations affects all of webpage or web service users resulting in user experience betterment.

Web accessibility improvement affects also the field of public relations (PR). Companies which websites or web services meet the needs of impaired users (especially those impaired ones) are usually seen as responsible and more professional. Compliance with web accessibility standards can be confirmed by those companies itself e.g. by placing W3C logo in the footer of the website. However, there are several NGOs which perform own web accessibility audits and mark out accessible websites. For example Polish foundation *Fundacja Widzialni* confers the title of 'Blind-friendly website' to those websites which meet the accessibility requirements defined by W3C and are audited positively by the foundation employees.

### **Summary**

This article is a cross-sectional attempt to analyze the most important issues connected with the notion of web accessibility.

Improving the web accessibility is a complex and staggered process which should be implemented as an important part of website or web service development. It should not be treated as a one time action performed only because it is forced by legal regulations.

As it was mentioned above, web accessibility improvement results in twofold profits: economical (as both long-time web development and maintenance costs are reduced and user profits are usually higher) and social (e.g. PR improvement). Furthermore, some of the improving actions affect positively issues usually not connected with the subject – e.g. search engine optimization.

All those factors prove, that web accessibility issues affect not only the disabled, but the whole web society – both website or web service users and creators.

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## ***Web accessibility for the visually impaired***

### ***Abstract***

The following article is a cross-sectional attempt to analyze the most important issues connected with the notion of web accessibility. During last decade, the Internet has become the most rapidly developing medium in human history. A society-shaping medium, which has significant impact on almost every aspect of everyday life, especially in developed countries.

Author analyzes different aspects of web accessibility: social, legal and economical and their impact on the website and web application developing and managing process.

**Keywords:** web accessibility, WAI, usability, vision disorders, visually impaired

## ***Web accessibility dla osób z zaburzeniami widzenia***

### ***Streszczenie***

Powyższy artykuł jest próbą przekrojowej analizy najważniejszych zagadnień powiązanych z pojęciem dostępności w Internecie. W trakcie ostatniej dekady Internet stał się najszybciej rozwijającym się medium w historii ludzkości. Medium, które kształtuje społeczeństwo i ma znaczący wpływ na praktycznie każdy aspekt codziennego życia, zwłaszcza w krajach rozwiniętych.

Autor analizuje różne aspekty dostępności w Internecie: socjalne, prawne oraz ekonomiczne, a także ich wpływ na proces projektowania i zarządzania witryną i aplikacją internetową.

**Słowa kluczowe:** web accessibility, WAI, usability, zaburzenia widzenia, osoby niepełnosprawne

## **Web accessibility for the visually impaired**

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## **Modernity of the company operating on the Internet - study and evaluation**

### **Introduction**

The development of Internet technology has contributed to a significant increase in the number of companies whose activities are carried out exclusively on the Internet. These companies are often on their own Web sites publish information about their modernity and novelty of their activities. Website is a form of advertising and promotion company and not always represent reality. The object of this paper is to answer the question whether the company is presenting himself as a modern and innovative is that in reality, or the information contained on its web site are only a form of advertising and promotion? This paper presents a method to study of modernity of the company operating on the Internet, which can be used in certain specific cases and may help in the assessment of similar businesses that operate on the Internet.

### **1. The concept of *modernity* in the management**

The concept of modernity is not defined in the theory of organization and management. There is not this concept in the *Encyclopaedia of organisation and management*, or in a *Small Encyclopaedia of praxeology and organization theory*, or in *Lexicon management*, or in the *Lexicon of the entrepreneur*. In the literature on the subject there are, however, the concept of correlated with the modern, such as: novelty and innovation.

The concept of novelty shall be construed "feature object that has been created, and which never before and never was. (...) Novelty is a feature of the products disseminated in the innovation process"<sup>1</sup>.

The concept of innovation is defined in multiple sources as: "the process of placing the production of a new invention, with a view to changing its techno-economic characteristics. The new invention to be

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<sup>1</sup> T. Pszczołowski, *Mała encyklopedia prakseologii i teorii organizacji*. Zakład Narodowy im Ossolińskich, Wrocław Warszawa Kraków Gdańsk 1978, p.138.

understood as an invention which has not been previously used in the production”<sup>2</sup>.

In another way innovation is defined as “change intentionally introduced by humans, which consists of replacing the existing states of affairs other evaluated positively in the light of certain criteria and make up the progress. Innovation is a process that involves all activities associated with creating the idea, invention, creation, implementation of a new product (process, service)”<sup>3</sup>. In the field of business *innovation* should be regarded as “intermittent manufacturing enterprise of new combinations of factors relating to the introduction of a new product, new production methods, opening new markets, gain new sources of raw materials or semi-finished and a new organization to carry out a new organization of business processes”<sup>4</sup>.

The lack of definition of the concept of modernity in the theory of organization and management concept means that it is understood intuitively, and that this means that either something modern, or is not. This paper presents the study of modernity company whose business is conducted on the Internet using the form questionnaire, which was supplemented an interview.

## **2. The research of modernity of enterprise**

In the literature, there is no research of modernity of enterprise. However, there are studies of innovation.

The paper [2] summarizes the innovation of enterprises in the 90s of last century, according to their size and sectoral affiliation. It presents the percentage of firms that have adopted and intend to introduce innovations in different years.

The paper [3] states that the use of modern technologies in Polish enterprises is much lower than in Western European companies. Only 11.3% of Polish companies use ERP management systems (6.6% small, 22% medium and 57.9% larger), less than two thirds have a basic Web site, although “just 7% of those pages is more than display window and allows for example to order the product”<sup>5</sup>. However, it is a chance for some companies introduce new low-cost solutions based on software provided by the Internet.

Paper [1] presents studies of innovation of enterprises from one region. The results show that companies from Lubuskie are not innovative, “only 2.9% have R & D department and 1.7% have separate funds earmarked exclusively for

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<sup>2</sup> *Encyklopedia organizacji i zarządzania*. PWN, Warszawa 1981, p. 166.

<sup>3</sup> *Leksykon zarządzania*. Wydawnictwo Difin, Warszawa 2004, p. 168.

<sup>4</sup> Op. cit, p.168.

<sup>5</sup> Boguszewicz, T., *Firmy boją się nowych technologii*, [www.rp.pl/arttykul/578508.html](http://www.rp.pl/arttykul/578508.html), [15.03.2011].



innovation, research and development”<sup>6</sup>. Just over a quarter of the companies surveyed in the past three years has introduced innovations, and these were mostly product innovation. The most innovative are large companies, employing over 250 employees, operating in European or world market.

Article [12] contains a discussion of the ranking of the Rzeczpospolita of 50 innovative companies. It shows that “in innovations are investing, not only those companies for whom modernity, research and development is a matter of survival”<sup>7</sup>. However, there is a gap between the narrow elite of companies - the innovators and other companies from the present ranking

The paper [8] was presented study innovativeness of Polish firms in the SME sector. “Generally, manufacturing companies have higher levels of innovation. (...) Small and medium-sized enterprises in the vast majority do not market a radical product innovation and service - most are copying innovations. The reason for this is a very poor co-operation between the company and a research center for the commercialization of innovative projects”<sup>8</sup>.

### 3. Research problem and methodology

The research problem was to find answers to the question if it is possible objective assessment of modernity of company operating on the Internet? The subject of this study was a company that is dedicated to providing advanced technologies and innovative solutions that enable customers to achieve a competitive advantage and support of customers and business partners to improve their effectiveness through consulting and outsourcing. The company employs full-time employees and a large group of people working on contract-order work. The study assumes that new technologies and innovative solutions are developed and implemented by permanent staff, carrying out their tasks “in place” in the office. Workers employed in the system of remote work are only of contractors, who no impact on decision-making process within the company. If the company has be seen as modern, full-time staff should use fully new technologies and innovative solutions at work, and workers employed on contract-order, as a contractor, have no impact on the concept of created innovative products and services.

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<sup>6</sup> *Badanie innowacyjności przedsiębiorstw z województwa lubuskiego*, [www.analizygospodarcze.org.pl/lubuskie/index.php?strona=BADANIA&dzial=14&nazwa=Wyniki%20bada%26%23324%3B](http://www.analizygospodarcze.org.pl/lubuskie/index.php?strona=BADANIA&dzial=14&nazwa=Wyniki%20bada%26%23324%3B), [15.03.2011].

<sup>7</sup> *Nowoczesność w krajowy wydaniu*, [dlafirmy.info.pl/2060\\_nowoczesnosc\\_w\\_krajowym\\_wydaniu.htm](http://dlafirmy.info.pl/2060_nowoczesnosc_w_krajowym_wydaniu.htm), [15.03.2011].

<sup>8</sup> Kowalczyk, D., *Jaki jest poziom innowacyjności polskich firm z sektora MSP*, [www.damiankowalczyk.pl/2009/12/jaki-jest-poziom-innowacyjnosci.html](http://www.damiankowalczyk.pl/2009/12/jaki-jest-poziom-innowacyjnosci.html), [15.03.2011].

In order to verification of the assumptions has been made questionnaire survey among the two groups of employees: employees “in place” with a contract of employment, and among the contract-order workers. The study was supplemented with an interview with a representative of the management.

#### **4. The results of research, evaluation and conclusions**

The company employs 11 employees who work in the office and are full-time employee, and cooperates with 60 partners who are working on contract-order. Any new technology are introduced to the company as often as it is necessary. If there are new opportunities the management of the company analyzes it, and possibly implement new technology temporarily. They remain permanently, if they prove successful.

According to the management of this company this is an innovative enterprise that introduces constantly innovative and modern technologies. They consider implementing of server virtualization and run Terminal Services (virtualized workstations). With these modern solutions will be possible to reduce the number of simultaneously running virtual environments, allowing to run from a few to several hundred independent systems on one server. The company does not use the tools that are economically unreasonable, useless, unreliable, dangerous and illegal. In the company there is a sense of uniqueness, all employees feel their the company is always a step ahead of others. Usually the company as first tests and implements innovations. Company ahead of the competition and draws on the financial profits. Drawbacks are the problems with the acquisition of modern technology, without additional financial contribution, and obtaining professional staff for a period of testing new technology, which is a very laborious process. However, there are advantages if the technology proves to be useful for business direction implement it permanently to their offerings.

Presented evaluation is the opinion of the management of your company. Survey research was conducted in order to analyze and evaluate the company's activities related to the functioning of modern enterprise systems, platforms and technologies. Empirical studies were designed to illustrate the functioning of the company, which mainly focuses on the modernization and expansion of modern tools at work. Survey gave the opportunity to obtain answers to questions about the most frequently used technologies in your organization and determine whether the information contained in the Internet website reflect reality.

The studies included all full-time employees who work in the office, and 30 contract staff working in remote work system. The sample was 41 persons. Position occupied by employees participating in the study are given the table below.

**TABLE 1. Structure of employees participating in the study**

	<b>Position</b>	<b>Number of employees</b>	<b>Share in the company's employment structure [%]</b>
Permanent staff	Director/Manager	2	2.8
	Designer	2	2.8
	Computer graphics	2	2.8
	Specialist of deployments	1	1.5
	Employee administration	2	2.8
	Commercial agent	2	2.8
	<b>TOTAL</b>	<b>11</b>	<b>15.5</b>
Workers employed in the system of remote work	Director/Manager	2	2.8
	Designer	10	14.1
	Computer graphics	10	14.1
	Specialist of deployments	8	11.2
	<b>TOTAL</b>	<b>30</b>	<b>42.2</b>
	The size of the research sample	41	57.7

Source: Elaborated on the basis of studies (participation in the company's employment structure has been calculated based on the number of 71 employees of the company)

Knowledge of the system areas of e-Commerce among company employees is presented in the following table, and in the next table contains the results of studies regarding the use of modern technology by employees.

**TABLE 2. Knowledge of the system areas of e-Commerce**

<b>System areas of e-Commerce</b>	<b>Permanent staff</b>	<b>Remote workers</b>	<b>TOTAL</b>
	Responses, %		
B2B	91	67	73
B2C	91	67	73
B2PA	18	17	17
No answer	9	33	27

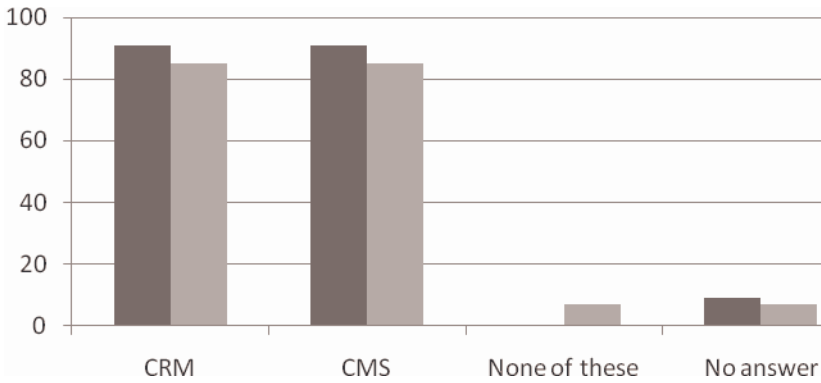
Source: Elaborated on the basis of studies (these responses do not add up to 100% due to the choice of more than one answer)

**TABLE 3. Utilization of advanced technology by employees**

Categories of responses	Permanent staff				Remote workers				TOTAL			
	Responses, %											
Types of used tools	CRM	CMS	Lack of tools	No answer	CRM	CMS	Lack of tools	No answer	CRM	CMS	Lack of tools	No answer
	91	91	0	9	87	87	6,5	6,5	88	88	5	7
Types of used technologies	EDI	ASP	VoIP	VPN	EDI	ASP	VoIP	VPN	EDI	ASP	VoIP	VPN
	45	0	100	9	33	3	100	50	37	2	100	39
Are all the tools are used	Y	N	Not all		Y	N	Not all		Y	N	Not all	
	73	0	27		57	10	33		61	7	32	
Can be used outside firms	Y	N	Occasionally		Y	N	Occasionally		Y	N	Occasionally	
	64	18	18		7	83	10		22	66	12	

Source: Elaborated on the basis of studies (Y – yes, N – no; the first two categories in the table do not add up to 100% due to the choice of more than one answer)

Table 3 shows that workers performing duties in the office, employed on a contract of employment, full use of modern tools and innovative solutions while working. The company most frequently used tools such as CRM and CMS, which is presented the next figure.

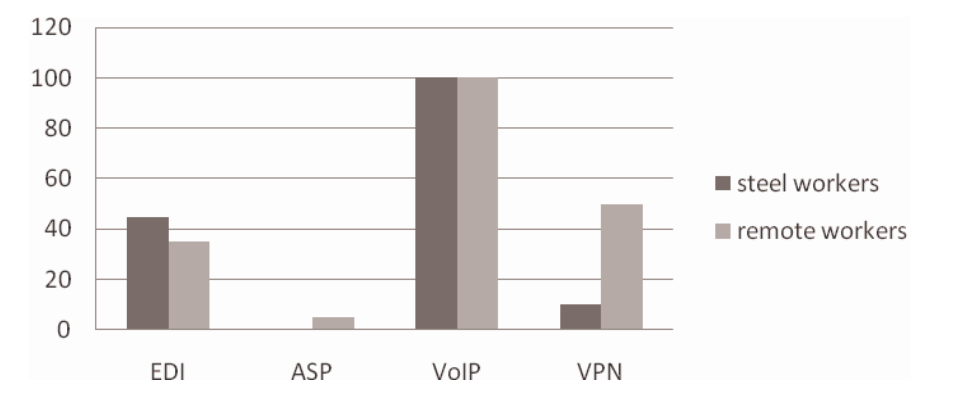


**Fig. 1. Types of tools used by employees**

Source: Elaborated on the basis of studies (these responses do not add up to 100% due to the choice of more than one answer)

Steel workers who are employed on a contract of employment, greater use of available tools than contract staff. Is striking, however, the percentage of persons who did not respond to the question about the types of tools used, which in the company is 7%. This may prove that there are a disturbance in the communication between company’s management and employees, particularly employees working in the remotely system.

The next figure shows the types of used technologies, and it shows that it is mainly used the VoIP in the company.

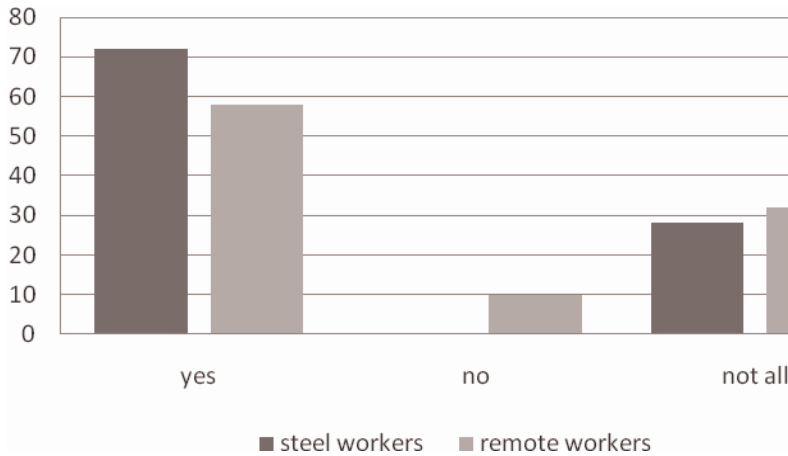


**Fig. 2. Types of technologies used by employees, %**

Source: Elaborated on the basis of studies (these responses do not add up to 100% due to the choice of more than one answer)

The graph above shows an interesting phenomenon that workers on full contract make greater use of electronic data interchange systems, and to a lesser extent, private network VPN, that non-contract staff. This is due to the specificity of remote working, where the VPN is faster and cheaper way of communication.

The degree of use of all tools available job in the company presents the following chart.



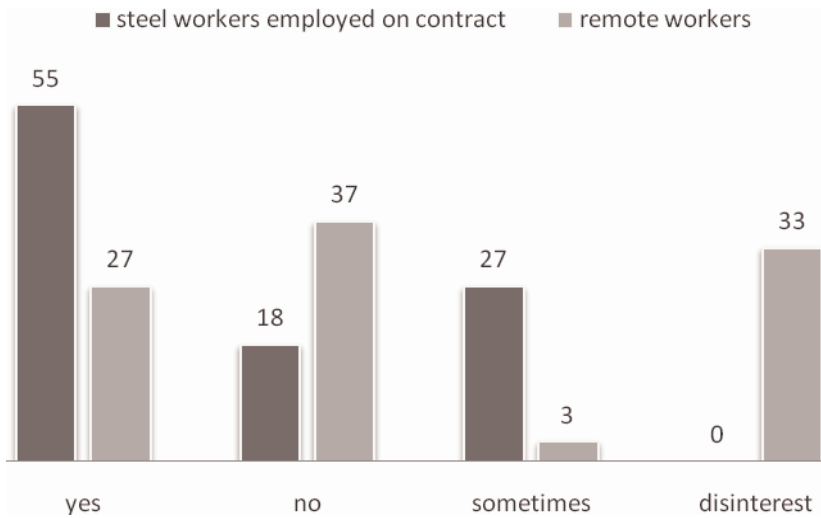
**Fig. 3. Use all available tools at work, %**

Source: Elaborated on the basis of studies

It shows that workers on full contract make greater use of all available tools rather than contract staff.

With this in mind, it should be noted that workers performing tasks in the office, employed on a contract of employment, use a fully modern technologies and innovative solutions at work, which is a confirmation of accepted assumptions. It can therefore be concluded that the analyzed company is modern.

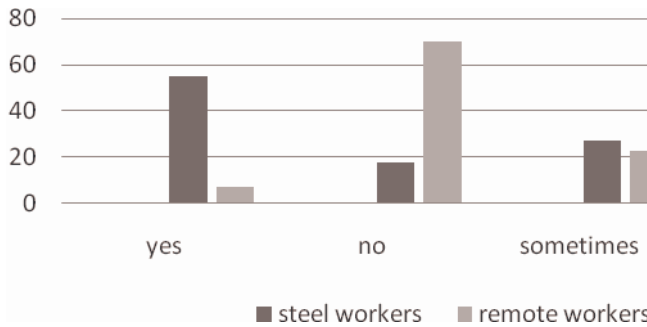
The next questions in the survey yielded a response to the question about those responsible for the creation of new technologies in the company. Workers employed in the system of remote working, as the only direct contractors jobs within the company, have no impact on the concept created innovative products and services. This trend is visible if you examine the data on the reporting of new solutions and technologies among employees, which is presented the next figure.



**Fig. 4. Notification of new solutions and technologies, %**

Source: Elaborated on the basis of studies

In the above figure it is apparent that contract staff are employed in the system of remote working, they do not have new ideas as much as the steel workers, and even a third of them shows a lack of interest in this field. Contract workers also do not participate as actively in the creation of new technologies, like their colleagues working in the office.



**Fig. 5. Active participation in the development of new technologies, %**

Source: Elaborated on the basis of studies

The above chart shows that the contract staff, do not have a influence on the submission of innovative ideas, do not have the motivation to actively participate in the creating of new technologies. 70% of them do not participate in the creative process, 23% sometimes participates in the development of new

technologies, and only 7% actively participate in the creating. This follows from the model of corporate governance, which boils down to the authoritarian government. Given the it is concluded that the workers employed in the system of remote work as a direct contractors within the company, have no impact on the concept created innovative products and services.

As a result, the study found the answer to the presented research problem, which was based on finding the answer to the question whether it is possible as the objective assessment of modernity, a company operating on the Internet. This assessment was carried out and achieved. Modern technologies and innovative solutions are developed and implemented by permanent staff employed under a contract of employment, carrying out their tasks “in place” in the office. Workers employed in the system of remote working are only of contractors, with no impact on decision-making process within the company.

The aim of this study was to analyze and evaluate the use of modern technology in the business activity of which focuses on developing and implementing new technologies and innovative solutions. Empirical studies were intended to bring the functioning of the enterprise, which mainly focuses on the modernization and development of modern tools. An important issue was that the answer to the question whether a company uses available IT technology in an efficient way and that this affects the success of the entire enterprise. Empirical studies have been carried out in order to analyze, and then evaluate the use of modern tools and innovative solutions by company employees. The main problems raised in the survey included questions related to the conduct of electronic business and activities relating to the implementation and use of modern technology in the activities of this company.

The studies gave the opportunity to obtain answers to questions about the most commonly used technologies, online tools by employees of the company and to determine whether the information contained in the website company reflect reality, and not only a few wrestling holds marketing.

The company extends its spectrum and focuses mainly on information technology offer for large enterprises and public administrations. Any change in the technology-this is a change within the company, whose external manifestation of the changes in appearance and functionality of the corporate website, and an internal symptom is modernization of the company, the use of modern tools of work based on IT technology.

System of employment in the company is innovative, it is based mainly on contract workers, employed in remote working, but the core of decision-making belongs to the workers employed on a contract of employment.

Studies have shown that the system of remote work, although innovative and bringing the company a financial advantage it is not used as effectively as it might seem. In fact, the greatest burden lies with the employees working under an employment contract when it comes to creating new technologies and innovative solutions, while remote workers are only contractors of concepts



developed by the management. In fact, the steel workers, who are employed on a contract of employment are the most penalized, as far as the creation of modern technology and innovative solutions. However, contractors are only contractors concepts developed by the management.

Particular attention should be paid to the contract workers, employed in the system of. remote working, who according to their relationship does not participate in the process of the formation of modern technology, which is an error management in the management of the company.

The greatest wealth for the company is human capital which accurately targeted and motivated can bring the company great benefits. Management resigns in large part to the knowledge and experience of nearly sixty of contract staff, that still, in spite of more than twenty years of existence, this is a small company with limited capabilities.

Information on the website of the company is only marketing tricks, not the company image, and even the best innovations in the absence of effective governance cannot make the company will succeed. Technology and innovations do not bring the company success, if not skilfully used. That managers are an efficient use of technological solutions, they know the market and the laws that govern it. The company does not have such manager. Innovations used in the company are aimed mainly at cutting costs, a lack of knowledge by employees of the strategy the company will not contribute to its development, but will give it only to survive.

## **Conclusions**

In the presented research shows the method of testing of the modernity a company, whose activities are on the Internet. Companies with a similar profile of activity on their Web sites publish information about its modernity and innovation. Often, evaluation of modern business is done in an intuitive way, so - no. Its means that the company is either a modern or is not. This paper presents a quantitative method for assessing the company's modernity.

The presented method is not a universal method and cannot refer to all companies operating in such an environment. However, it may be used as a tool to assess, in many cases, when the scope of the company, which would be assessed, is similar to the one given. The number of companies with a similar profile of activity is continuously growing, because of changing market conditions. Companies are constantly modernizing, trying to follow the trends of the new economy. Many companies state prior to the selection of suppliers of advanced technology. This method of assessment of a firm operating in Internet can help companies seeking a supplier of advanced technologies in the evaluation of potential suppliers and appropriate selection of the best of them. From the proper selection to a large extent may depend the further activity the company on the market of the new economy and its market success.

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## Modernity of the company operating on the Internet - study and evaluation

### Streszczenie

W artykule przedstawiono metodę badania nowoczesności firmy, której działalność odbywa się wyłącznie w Internecie. Często ocena nowoczesności firmy odbywa się w sposób intuicyjny, zero – jedynkowy. Oznacza to, że firma albo jest nowoczesna, albo taka nie jest. W niniejszym opracowaniu zaprezentowano ilościową metodę oceny nowoczesności firmy.

Prezentowana metoda nie jest metodą uniwersalną i nie może odnieść się do wszystkich firm działających w takim środowisku. Jednakże może być użyta jako narzędzie oceny w wielu przypadkach, gdy zakres działania firmy, która miałaby być oceniana, jest podobny do zaprezentowanej. Liczba firm o podobnym profilu działalności stale wzrasta, ponieważ zmieniają się warunki rynkowe. Firmy modernizują się, chcąc podążać za trendami nowej gospodarki. Wiele firm stanie przed wyborem dostawcy nowoczesnych technologii. Zaprezentowana metoda oceny nowoczesności firmy działającej w Internecie może pomóc firmom poszukującym dostawcy nowoczesnych technologii w ocenie potencjalnych dostawców i wyborze najlepszego z nich. Od właściwego wyboru dostawcy w dużym stopniu może zależeć utrzymanie się przedsiębiorstwa na rynku nowej gospodarki i jego sukces rynkowy.

**Słowa Kluczowe:** nowoczesność firmy, Internet

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## **Web Analytics. Analytical tools and their practical utilization in e-commerce environment – an e-store case study**

### **Introduction – web analytics**

Web analytics is a relatively new discipline. Although its existence can be traced back to the mid 90s, its universal definition was formed only in 2006 by Web Analytics Association. The definition goes as follows:

*Web Analytics is the measurement, collection, analysis and reporting of Internet data for the purposes of understanding and optimizing Web usage.*[3]

In the initial stages of Web Analytics development, only server logs were used as an optimal source of information about errors and visits on the server. In 1995 dr Stephen Turner wrote the first application specifically designed for web data analysis called *Analog*. This and other derivative software created later allowed for the better understanding of accumulated data to the professionals not affiliated with the computer departments of companies.

From 1995 to 1996 web statistics had become more prominent owing to the widespread use of visit counters, which informed the owners about the number of users their site received.

Around the year 2000, it became apparent that in the face of increasing traffic and the eve of new, more user oriented technologies, server logs may have lost much of their credibility. At that point so called Javascript markers became a new standard of web-traffic monitoring, largely due to their simplicity in use. Currently, this method is a standard. It is so popular, in fact, that some service provides no longer supply their clients with tools for server log analysis.[2]

The massive surge of interest in web analytics, and correspondingly the period of its greatest development took place in 2006 when Google corporation made their new tool, called *Google Analytics*, available. With this step Google secured the position of the leader in the market – their tool was very complex, functional and free. Currently in the USA *Google Analytics* is dominates over 70% of Web Analytics market, while in the UK the figures indicate 80%.

The idea of web analytics reached Poland around at the start of 20<sup>th</sup> century. Year by year we can observe a substantial boost of interest in this in this

country. Sadly, however, its importance is still largely overlooked, which may be seen in the fact that over all that time no equivalent for the phrase *Web Analytics* have appeared in Polish language.

Web Analytics is not merely a tool for evaluating user traffic on the website. It has much more important uses than that. Specifically, it is perfect for marketing research. Analytic software enable their users to evaluate effectiveness of Internet services as well as traditional advertising campaigns. Moreover, they can estimate traffic change, after particular news or advertisement is published.

We can distinguish between two basic forms of web analytics: *on-site* and *off-site*. The former stands for analytical results gathered in consequence of the website visitor's actions. The latter refers to the measurement of the outside factors associated with the site such as brand recognition, the general user awareness of site existence etc. These two techniques should not be used separately. Rather, they should be taken advantage of to complement each other's results.

The large quantity and complexity of the data gathered by analytical software may result in drawing bad conclusions from them. Such errors usually stem from the lack of clearly defined goals or their misinterpretation. For that reason, prior to commencing any kind of research setting viable objectives and key indicators ought to be an imperative. One must have the plan: what factors are to be accounted for and how they can be used. Without that knowledge, all resulting data are at risk of proving useless.

The most common errors made while analysing output data:

2. Analysis is based on unrealistic size of the sample. The Web Analysis ought to be treated similarly to a scientific experiment. Hence, any hasty decision based on preliminary results should be avoided. One must amass appropriate amount of data before making the final judgement. In case of commercial advertising campaigns all estimations ought to be done after some time has passed so that the collected data will reflect the actual work of the service. For instance, it would be downright wrong to presume that a few clicks on a word which brought about the conversion ought to make the word the key phrase of the campaign. Once some time has passed the conditions and results may change drastically.

3. Neglecting the implementation of IP address filters. Web designers and analysts responsible for the maintenance of the service are their very frequent guests. By default the web analytics register their visit normally, as though they were ordinary users, which may lead to inflating the data. In order to prevent this an IP address filter should be implemented and activated in the software which would make the site ignore their creators in statistical computations.

4. Wrong settings in goal Conversion Rate. In order to receive reliable analytical results one must first specify appropriate type of pathway to the goal.

Although the matter seems trivial, many mistakes can occur. First and foremost, one should remember about the importance of URL Destination goal. It is always set at the beginning of system's implementation. Therefore, it must not be added again during organisation of goal pathways since it will duplicate and influence the final results.[1]

## The e-store case study

The subject of this study is *Lovely home* e-store established under [www.lovely-home.pl](http://www.lovely-home.pl) domain address. The store has been running since march 2009. The service deals with selling unique household articles imported from western Europe, primarily Great Britain. The main target group are middle and higher-class citizens of Poland between the ages of 20 and 50 years old, predominantly women, as they are believed to more often take the burden of household purchases on themselves.

The store operates throughout Poland. The users' visits spread evenly all over the country's territory. The store receives the highest ratio of visitors from large and developing cities i.e. Warsaw, Krakow, Poznań, Katowice and Wrocław. Correspondingly, the highest number of orders comes from these agglomerations.

The web site of the store distinguishes itself with an original and exquisite layout (see Fig. 1), exhibiting characteristic house which constitutes the frame for whole service. There are links to four main shopping categories on the main site. These take the form of windows to three main rooms in every house: kitchen, bathroom, living-room and children's room. A screenshot of the site

**Fig. 1. The “Lovely home” home page**



is available below.

The service's structure boasts several unorthodox solutions that one could scarcely find in any other e-store. For instance, the main page lacks standard store menu. In consequence the user can focus on the offer instead of reading redundant descriptions and positions in the menu. The apparent intention by the project's authors was to create warm and cosy ambience, reflecting the intimate atmosphere in one's own home. However, there are also more ordinary solutions present. Once a customer decides on buying a particular item they will not be surprised by non-standard controls or unintuitive layout of the cash-desk window as it may discourage them from shopping.

The image above (see Fig. 2) shows the product's card. It comprises elements which a customer can find in any other store i.e. a thorough description of an item, photographs, price an 'Add to cart' button etc. Apart from that the customer is enabled to write their opinion about the product, send an information about it to an acquaintance via email or still growing much in popularity Facebook social networking portal.

**Fig. 2. The product card in Lovely home e-store**



### Utilised research tools

As mentioned before, there is a varied choice of means of collecting web related data. From server log analysis, through one-pixel files, and Javascript markers to packet sniffing etc., each of these methods has as many proponents as detractors.[7]

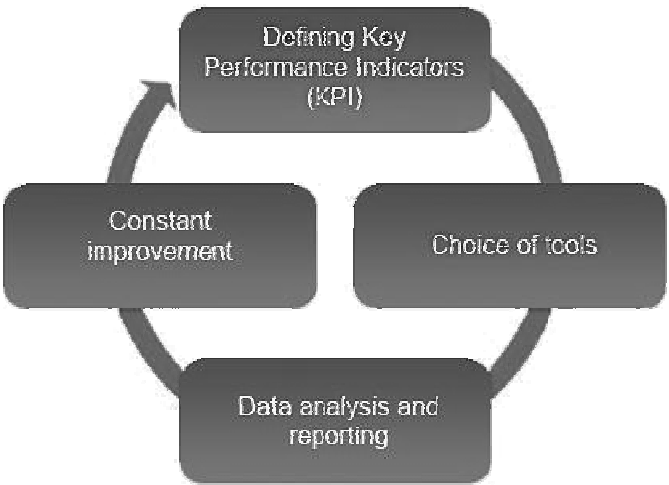
In this research, however, it was resolved to utilise server logs and Javascript markers. This choice is justified by the popularity of both procedures as well as the high ratio of their analytical reliability. In the selection of the analytical tool the team took mainly two criteria into consideration: the price and the quality.

Google is the most prominent company working exclusively in the field of e-business and e-commerce through advertising, software distribution and services. All of these activities must be measurable. Thus, Google constantly scrutinises all the indicators of their popularity on the market. The direct consequence of their experience is *Google Analytics* software – the tools for Web Analysis.

*Google Analytics* is by far the one of the best analytical software available on Polish market. Its interface is intuitive and user-friendly. The application is easy in use and straightforward in integration with other tool-sets published by Google e.g. *Google Adwords* online advertising system.[5]

### Research – the progress

The entire process of accurate, reliable web analysis should consist of four stages illustrated by image below (see Fig. 3).



**Fig. 3. The stages of research with the use of Web Analytics**



The analysis in question was based upon a set of pre-defined Key Performance Indicators (KPI). It was researched if the target values were achieved in the period of five months. Some months before KPI were set (the period from October to December 2009) the values were to be compared with the results from the months dedicated for conducting a marketing campaign (July-September). The purpose of this comparison was to determine the reference point so that the users without any significant experience in analytics could evaluate the company's development themselves.

### Defining Key Performance Indicators

Key performance Indicators serve companies to measure and assess their progress in reaching set strategical targets. Once the company's mission statement has been defined together with operational and strategic objectives a method is necessary for measuring progress in reaching next successive milestones. Key Performance Indicators aid in that process.

**TABLE. 1. Defining Key Performance Indicators.**

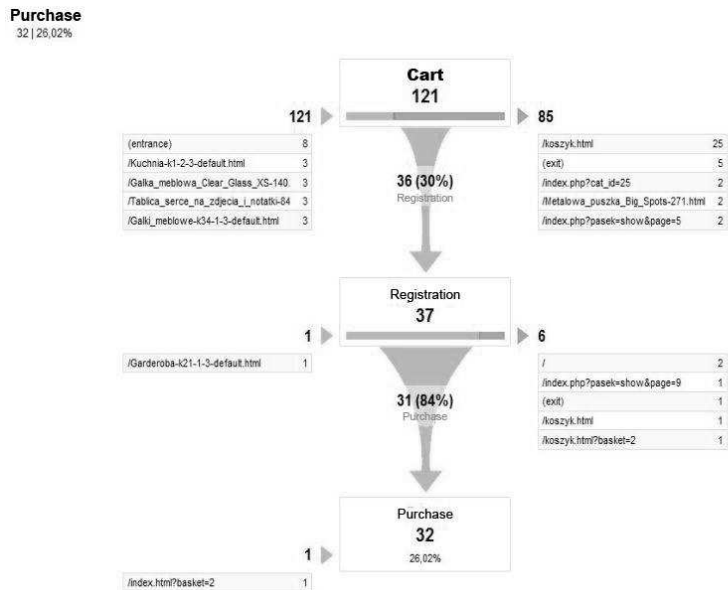
Strategic objectives	Operational objectives	KPI (Key Performance Indicators)	Target values
<b>High profits</b>	Getting users interested in the merchandise	Average total value of a single order	150.00 PLN
	Building brand loyalty	Conversion rate	1.50%
	Increasing sales	Monthly revenue	7 200.00 PLN
<b>High e-store recognition</b>	General increase in the number of visits	Number of visits per month	3000
	Improving brand recognition on blogs, forum and social networking services.	The ratio of hits from third-party sites	30.00%
<b>The first ranking in Google search-engine results</b>	The full optimization of the site for Google search-engine.	the percentage ratio of visits from the search-engine.	48.00%
		The level of Web-site indexing.	90.00%

Source: Own research

### Research results

Conversion Ratio (CR). The main objective for most of e-stores is accepting visitor's order. The conversion takes place when a visitor accomplishes that goal i.e. successfully places an order with the store (see Fig. 5).

The Conversion Ratio was measured by *Google Analytics* for all the valid visits i.e. those lasting longer than five seconds (t). In the table (see Table. 2, below) one can observe that the valid visits constitute 77-78% of all the



visits. All the visits that take less than five seconds are considered

**Fig. 4.** The image shows the visualisation of pathways leading to the objective which is the successful placement of an order

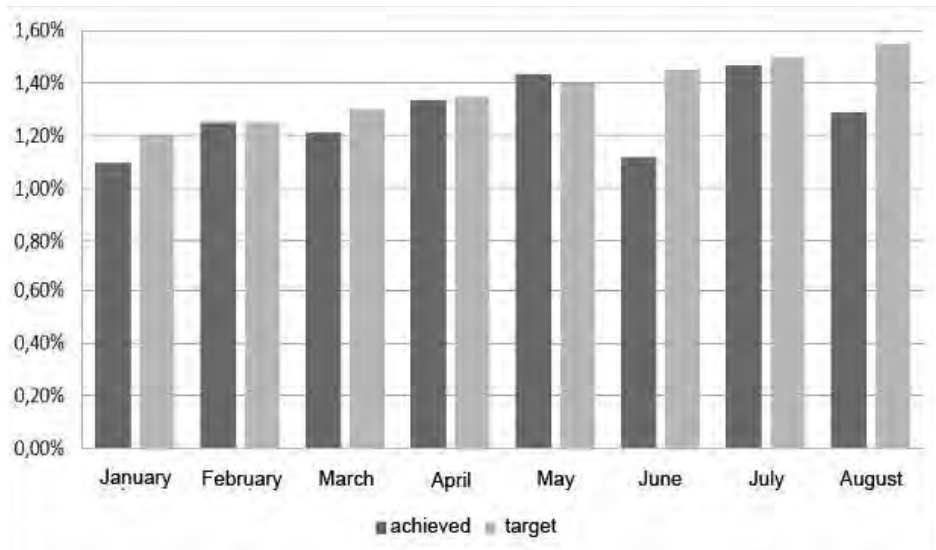
accidental – they usually take place without a user's volition and their short span cannot be indicative of the failure to address customer's demands.

**TABLE 2.** Changes in conversion rate in the analysed months

Month	Visits	Valid visits t> 5 s	%	Number of orders placed	Revenue	Conversion Rate
Oct-09	2250	1737	77%	17	2 199 PLN	0.98%
Nov-09	2886	2323	80%	18	3 342 PLN	0.77%
Dec-09	2307	1666	72%	25	2 038 PLN	1.50%
<b>Total</b>	<b>7443</b>	<b>5726</b>	<b>77%</b>	<b>60</b>	<b>7 580 PLN</b>	<b>1.05%</b>
June-10	2698	2145	80%	24	6 021 PLN	1.12%
July-10	4169	3200	77%	47	7 023 PLN	1.47%
Aug-10	3903	3021	77%	39	7 142 PLN	1.29%
<b>Total</b>	<b>10770</b>	<b>8366</b>	<b>78%</b>	<b>110</b>	<b>20 187 PLN</b>	<b>1.31%</b>

Source: Own research

As can be inferred from the graph below (see Fig. 5) the target values were set from 1.20% with the gradual aggregation of 0.05% each month. This kind of leaps inevitably leads to the substantial increase in Conversion Rate of 46% by the end of the year. In December the target value totals 1.75%. This is of particular significance if one takes into consideration the fact that the target sales will rise accordingly by the same amount. Moreover, the extra revenue attained as a result, will turn into gross profit. Most of the expenses (e.g. the cost of server, marketing,



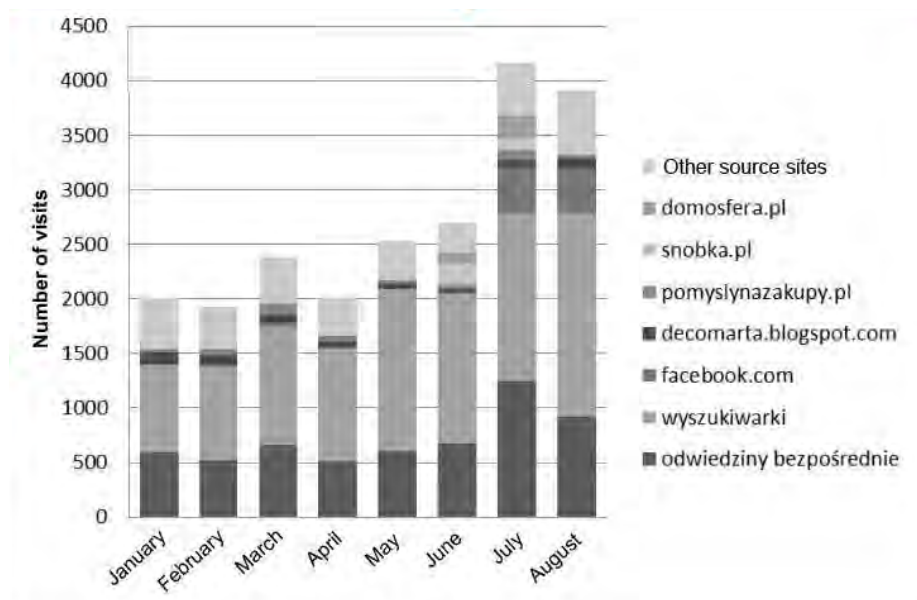
**Fig. 5. The comparison between the desired and achieved Conversion Rates (CR)**

running a business venture etc.) incurred over this period are steady, irrespective of the boost of conversion ratio.

**The number of visits**

The overall number of visits may be indicative of site's popularity. When complemented with the Conversion Ratio, the value proves the rise in the store's revenue. However, in order for the website to perform its role, the target audience must be informed about their existence. While the number of visits can be measured easily, a reliable analysis of the visits originated from other sites associated with the web-portal is still a difficult task. Nevertheless, *Google Analytics* somehow addresses the issue, as it allows for accurate measurements in various configurations.

The graph below (see Fig. 6) shows the share of the affiliated portals in the total number of hits the e-store received.



**Fig. 6. The distribution of the most popular sources of visits to the e-store and their share in the total of all visits**

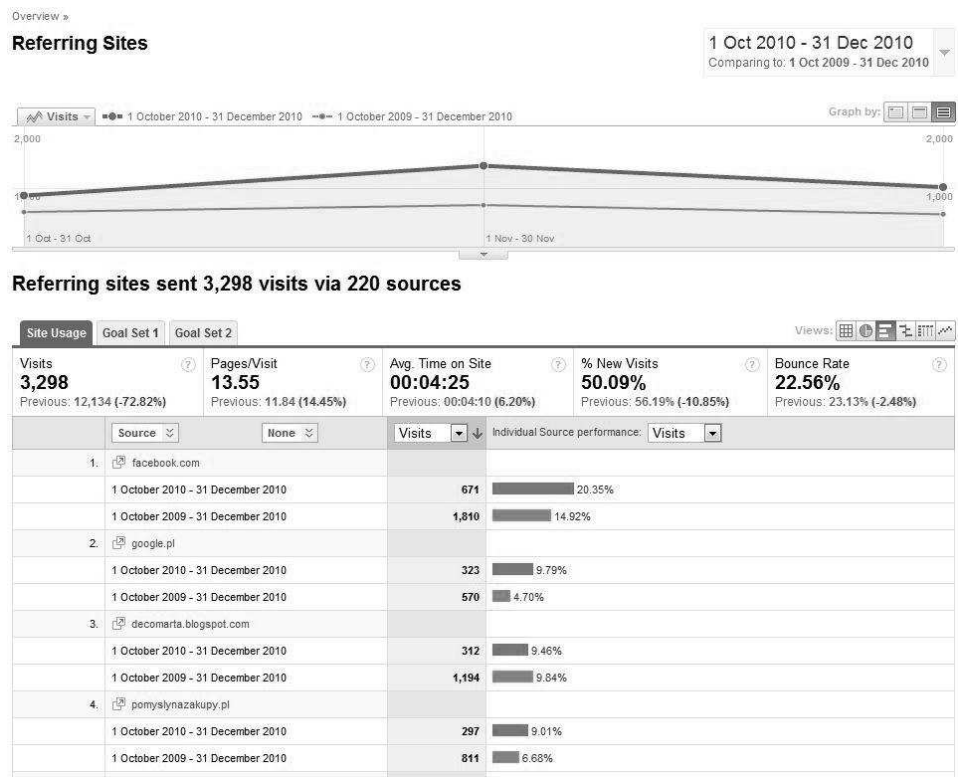
Source/medium	Visits	Pages/visit ratio	Weight sort		
			Average time spent on the site	% of new visits	Rejection ratio
domosfera.pl / referral	312	9,89	00:03:14	54,49%	43,27%
fotoforum.gazeta.pl / referral	69	5,78	00:01:31	85,51%	57,97%
magiakobiet.pl / referral	40	7,10	00:02:46	22,50%	57,50%
forum.gazeta.pl / referral	13	1,15	00:00:03	92,31%	92,31%
housik.pl / referral	184	11,29	00:02:56	52,72%	30,98%
madlinka1989.blogspot.com / referral	21	3,90	00:00:45	47,62%	61,90%
webepartners.pl / referral	10	1,00	00:00:00	100,00%	100,00%
google.pl / referral	190	11,16	00:05:16	72,11%	29,47%
yahoo / organic	23	8,52	00:02:15	73,91%	47,83%
allegro.pl / referral	67	12,81	00:03:51	67,16%	31,34%

1 - 10 of 168

**Fig. 7. The analysis of 10 most significant sources of hits with the lowest rejection ratio**

Thanks to *Weight Sort* function in *Google Analytics* it is possible to determine which sources of web-traffic have the largest rejection ratio, and relatively high number of visits. In this way the store's administrator can discard the sources of little affect on the sales as well as localise those whose high rejection ratio is disturbing (which may hint at e.g. particular advertisement being ineffective or targeted at wrong audience etc).

The analysis above (Fig. 7) hints that, for instance, the hits from *fotoforum.gazeta.pl* service make little contribution to the profits as they are characterised by large rejection ratio: almost 58%. It can be surmised that that ongoing advertising in the service will be counterproductive – almost 58% of visitors from the site left the store practically immediately after load, especially in the face of the fact that all the other services boast much smaller number of rejections. The advert should be withdrawn or changed to a more effective one.



**Fig. 8.** The report showcasing the distribution in the number of visits in comparable periods: October to December 2009 and 2010

Report (see above, Fig. 8) presents the distribution of incoming visits from the sites with formerly large rejection ratio. The results from two time-spans are compared: October - December 2009 and October-December 2010. The rise in the number of visits is clearly observable. Additionally, from all 10 most popular web-sites in the ranking, only one service – the *Decomart* blog – showed a decrease in number of hits. This is likely due to the difference between the time of initial marketing campaign and the advertisement being 'burned out' by the time the survey was taken.

Furthermore, many more reports were prepared over the whole period of the research such as: the distribution of visits between different web-browsers, the level of site's indexing etc.

## **Conclusions**

The article touched upon the issue of web analytics. The complementary research was based on the case study of a business entity in the process of entering the market. Therefore, the efficiency of the analytical methods was of utmost importance. For the research purposes Google Analytics software was used.

In the research the process of data analysis was divided into four stages: the defining of Key Performance Indicators (KPI), the selection of tools, data analysis and reporting, and the process of constant improvement. Although over the period of the research all those stages were completed, it is by no means the end of the process this study initiated. After the last step is finalised the whole process ought to start anew with new objectives to achieve, planned in response to the data collected so far. One should account for previous analyses in order to eliminate the errors recurring due to improper planning of the experiment. Thus, it may be concluded that Web Analytics comprise all methods and stages of monitoring an e-business venture from its establishment, through the entire course of its operation.

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## **Web Analytics. Analytical tools and their practical utilization in e-commerce environment – an e-store case study**

### **Abstract**

The article deals with the issue of Web Analytics. E-business has become an activity prone to all kinds of fluctuations and seemingly random factors prompted by individual and business users. For that reason, the establishment of new tools permitting one to study the phenomena resulting from the use of portals, e-stores and other web-venture has become a crucial concern. The article presents a case study conducted on [www.lovely-home.pl](http://www.lovely-home.pl) e-store in the period from January until December 2010. In carrying out the analyses the authors used Google Analytics software.

**Key words and phrases:** e-business, e-commerce, web analytics, Google Analytics, web analytics tools, e-store.

## **Analitka sieciowa. Narzędzia analityczne stosowane w e-biznesie na przykładzie sklepu internetowego**

### **Streszczenie**

W artykule przedstawiono zagadnienie analityki internetowej. E-biznes jest w dużej mierze wystawiony na publiczne dość przypadkowe działania użytkowników indywidualnych lub biznesowych. Stąd też, istotnym zagadnieniem jest tworzenie narzędzi pozwalających badać zjawiska związane z wykorzystaniem portali, sklepów lub innych wirtualnych miejsc znajdujących się w Internecie. W artykule przedstawiono badania przeprowadzone w miesiącach styczeń – grudzień 2010 na sklepie internetowym

www.lovely-home.pl. Autorzy przeprowadzili szereg analiz z zastosowaniem narzędzi Google Analytics.

**Słowa kluczowe:** e-biznes, e-commerce, analityka internetowa, Google Analytics, narzędzia analityki internetowej, sklep internetowy

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## **Computer system assistance of business decisions – example of customer relationship management**

### **Introduction**

Nowadays easier and more effective making business decisions is very important. Companies have many competitors on the market. Good decisions always depend on effective data. Managers can obtain information and data by useful computer tools. This paper concerns about computer system assistance of business decision. Many of decisions made in companies are connected with customer behavior. Author of this paper has used example of customer relationship management (CRM) systems to show how useful these systems can be for business.

### **Importance of making decisions in e-business**

**Electronic business** (called e-business) – according to common definition, is model of business conducting based on widely understood **ICT** (information and communication technologies) solutions, particularly Internet applications [3]. Information and communication technologies can be useful to achieve success by modern organizations. Effectiveness of making decisions in e-business is very important for success achieving. These decisions should be quick and right. Managers should have accurate data for making decision process. These data came from new ICT tools. There are many examples of ICT solutions [9]:

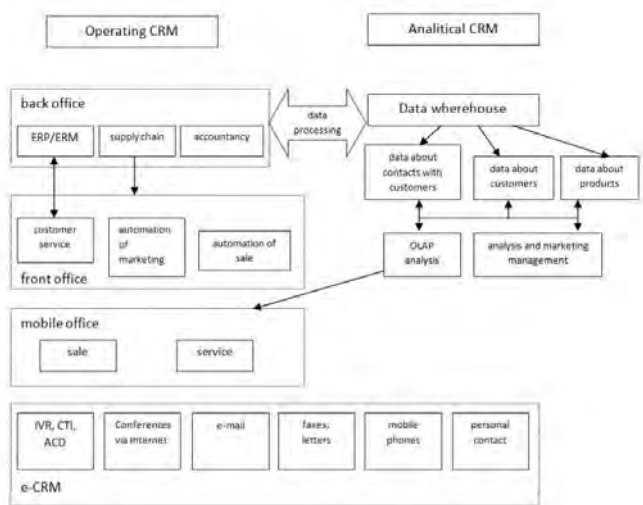
- hardware support,
- on-site training,
- networking solutions,
- service,
- managed services,
- communications and telecoms,
- web/intranet design solutions,
- maintenance,
- consultancy etc.

Managers use ICT tools for solving various complicated problems. There are tools for enterprise resource planning (ERP), material requirements planning (MRP), marketing, accountancy and also for customer relationship management (CRM). The decision making process is very complicated and depends on many factors. When manager carry this process personally, without any ICT supporting, sometimes it could bring higher costs and waste of time. Nowadays

is very difficult to function on market without ICT supporting. An example of use of ICT supporting in companies is developing idea of customer relationship management (CRM). It is said that CRM strategies take full advantage of technology innovations with their ability to collect and analyze data on customer patterns, interpret customer behavior, develop predictive models, respond with timely and effective customized communications, and deliver product and service value to individual customers [7]. This is an excellent field to show how ICT can be useful for company.

**Customer relationship management in e-bussines**

Customer relationship management is very important for all modern organizations because present-day customer has wide access to goods and services. Some managers see **CRM** as the strategic use of information, processes, technology, and people to manage the customer’s relationship with company (Marketing, Sales, Services, and Support) across the whole customer life cycle [11]. Many managers say that now is a customer era [13]. Customers need more attention and they wish to have individual service. These could be achieved by using modern CRM solutions such as Microsoft Dynamics CRM. CRM systems could consist of many different modules. It depends on producer and needs. On figure 1 was shown how could be CRM system build. There could be operating and analytical CRM modules in CRM system. These modules cooperate by data processing. The first one occurs in company processes. It is connected with back and front office work. By using ICT tools CRM could be supported on all operating fields. For example mobile offices or e-CRM could use some tools by mobile phone and through Internet. Analytical CRM is based on Data Warehouse.

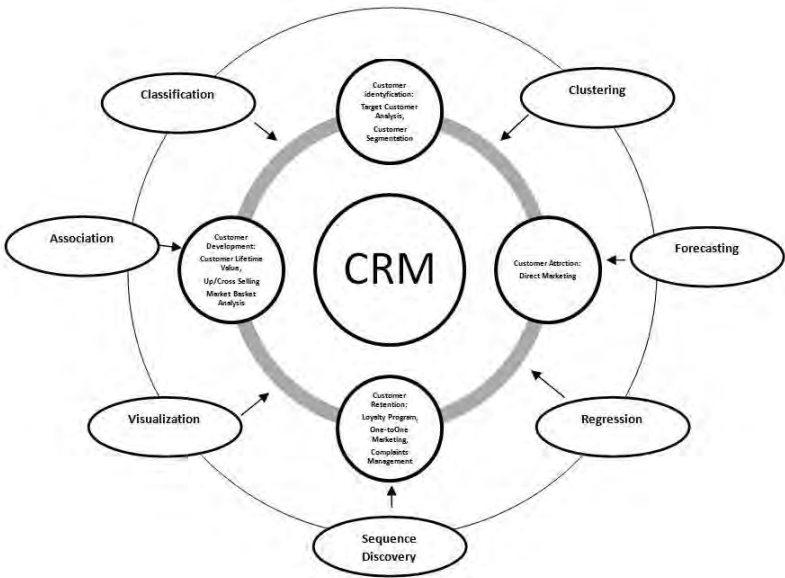


**Fig. 1. Example of CRM system structure** [own work based on 2]

The term **data warehouse** was coined by Inmon in 1990, which he defined in the following way: "A warehouse is a subject-oriented, integrated, time-variant and non-volatile collection of data in support of management's decision making process". He had noticed a few important factors about data in data warehouse:

- Data that gives information about a particular subject instead of about a company's ongoing operations.
- Data that is gathered into the data warehouse from a variety of sources and merged into a coherent whole.
- All data in the data warehouse is identified with a particular time period [10].

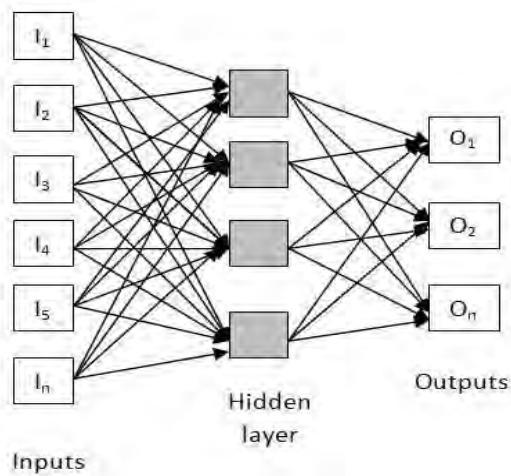
Data warehouse is indispensable in CRM system because it is “a place” to collect data and it makes easier to find and analyze data. One of possibilities is using OLAP (Online Analytical Processing) analysis for mobile office. **OLAP** provides a historical view of data, although useful when used by itself, OLAP analysis becomes truly powerful when combined with predictive analysis from data mining [6]. **Data mining** is defined as a sophisticated data search capability that uses statistical algorithms to discover patterns and correlations in data [15]. CRM can be supported by different data mining models, which generally include association, classification, clustering, forecasting, regression, sequence discovery and visualization [16]. In figure 3 it is shown how useful this model can be and where.



**Fig. 2. Classification framework for data mining techniques in CRM [16]**

Forecasting, for example, is very important in planning and developing marketing strategies and in customer behavior prediction. Sequence discovery which is used in market basket analysis (identifying customers purchasing habits). Clustering helps in market segmentation. When managers know features of part of the market they can effectively plan some actions and some campaigns. There are various data mining tools connected with data mining models, for example companies can use CHAID or neural network. **CHAID** (Chi-squared Automatic Interaction Detector) is one of the oldest tree classification methods originally proposed by Kass (1980). It can "build" non-binary trees (i.e., trees where more than two branches can attach to a single root or node), based on a relatively simple algorithm that is particularly well suited for the analysis of larger datasets [5]. CHAID can be used to create data for boosted trees analyses. This can allow to omit mistakes in system.

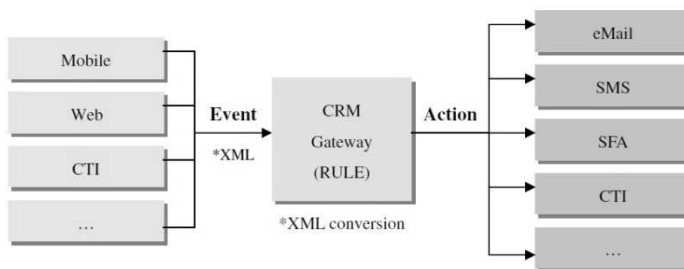
Whereas an artificial **neural network** is a collection of simple artificial neurons connected by directed weighted connections. When the system is set running, the activation levels of the input units is clamped to desired values. After this the activation is propagated, at each time step, along the directed weighted connections to other units. The activations of non-input neurons are computed using each neuron's activation function. The system might either settle into a stable state after a number of time steps, or in the case of a feedforward network, the activation might flow through to output units [19]. The idea of neural network was shown on figure 3.



**Fig. 3. The idea of neural network** [own work based on 18]

The hidden layer is the hearth of neural network. There can be many hidden layers in neural networks, it depends on kind of network. Hidden layer helps to process data from input to data on output. It can participate in the neural network learning process. This process can be successfully use in CRM. For example some customer behavior can teach neural network how to react in such case in the future. This can allow to omit fallible employee in this process. Neural network can process significant amount of data in short period of time. This can help to improve effectiveness of all company, starting from customer relationship management, marketing and front office divisions. Neural network can be use in CRM gateways.

CRM system needs information but the flow of information is the most important thing in this system. Data mining tools can be use in CRM gateways. The CRM gateway analyzes such event information (figure 4) expressed in XML by means of an analytical engine, and takes it into the account of an internal system [20].



**Fig. 4. Flow of system on the basis of event [20]**

The analytical results are useful for making business decisions for example in area of Sales Force Automation (SFA) or Computer Telephony Integration (CTI). CRM philosophy says that companies should find as many channels to contact customers as they can. So CRM Gateway makes it possible.

### **Examples of use CRM system based on ICT**

Implementation of CRM system relies on introduction of CRM philosophy, tools and software. This software is based on ICT technology and cooperates with CRM tools and philosophy. There is a lot of CRM software on the global market. Every organization has various choice and can fit software to own goals. Choice of CRM software depends on its functions, price, availability, company needs, offered by software provider support and training, ect.

Functionality of CRM software can improve information management in company by [14]:

- Service Scheduling - manage field service appointments, facilities, and resources with the powerful unified service scheduling feature.

- Purchase History – track product purchasing history, contracts, and key renewal dates so agents can take proactive action and offer relevant services or products.
- Insightful Service Analytics – deepen insight with out-of-the box or configurable dashboards, drill-down analysis, and inline data visualization capabilities.
- Service Queue Management – build queues against any entity, user, or team and streamline work state management for improved efficiency.
- Service Record Auditing – improve visibility into service and support activities and effectively meet service level agreements (SLAs) with system-wide auditing.
- Guided Service Processes – streamline case resolution and escalations with guided dialogs, automated processes, and conditional formatting rules.
- Service Goal Management – instantly track service goals, such as first call resolution, average call time, and more with comprehensive goal management capabilities.

One example of CRM implementation in Dagbladet Børsen, largest publisher of business-related materials in Scandinavia, shows what is important in CRM ICT solution. In order to monitor customer loyalty, the following three components were used in the CRM software:

- the customer retention rate, which expresses a company's ability to retain its customers over a year;
- the share of a customer's account or, as it is also known as, the share of a customer's wallet;
- the ambassador degree, which means the extent to which the present customers will recommend the company to potential customers [12].

These three components are good field for ICT solutions. All of them are problem which could be solve by data mining. Data mining tools take data and construct a representation of reality in the form of a model. The resulting model describes patterns and relationships present in the data [17].

Examples of use of these solutions in companies can be shown by following examples of CRM implementation. Another example could be Mitsubishi Caterpillar Forklift Europe (MCFE) - company manufacturing, selling, and distributing 18 000 forklifts and related spare parts each year. MCFE began looking at CRM systems to meet its business needs. They decided to implement Microsoft Dynamics CRM, which is built on the xRM application platform [4]. xRM is a leading provider of strategic and value-added software services. One of the key business goals for Mitsubishi Caterpillar Forklift Europe was to speed its order processing time. After implementation of Microsoft Dynamics CRM time of this process has been reduced from 5 minutes to 90 seconds. Customers of this enterprise are loyal and profitable now.

Another example of CRM implementation with use of ICT technology can be Bank Austria Creditanstalt. In this bank innovative data mining tools are now helping turn targeted marketing into a fine art. They have decided to implement KXEN's Extreme Data Mining technology. This software includes modules of prediction of propensity-to-buy, customer segmentation (cluster analysis) and retention analysis. The bank had a problem with prediction of customer behavior. Now if a customer displays certain behavioral patterns – such as termination of products or a decrease in volume - staff can spot it in time and take appropriate action [1]. Sometimes it is difficult to measure effects of implementation but there are some unmetered results also.

Very representative of CRM development is case of Toyota Motor Corporation. The heart of Toyota's Lean CRM is "Customer DNA." Just as real DNA influences how each individual develops, looks and responds to his or her environment [8]. This is connection between technology and biological approach to this problem which can come closer to neural network.

There are many companies which have a successful CRM based on ICT implementation, including:

- Bank of Montreal (KXEN),
- DaimlerChrysler (Great Plains SIEBEL Front Office),
- British Airways (Teradata's customer relationship management),
- Lloyds TSB (KXEN),
- Bank BPH Poland (Comarch CRM Sales Management),
- The Linc Group (Microsoft Dynamics CRM),
- Polpharma SA (Microsoft Dynamics CRM),
- Vistula & Wólczanka (Microsoft Dynamics CRM),
- Centel (Isof CRM).

Many companies where CRM system was introduced are now more profitable, effective and flow of information inside of them is better. Managers of this organizations have more information to make effective business decisions. This information comes from ICT tools using data mining solutions.

Examples of CRM implementation shows that software is very important in CRM system. Some managers could even say that software is heart of these systems. In CRM system many decisions need to be made quickly because customers can't wait. If they don't have company decision, for example about a new offer or granting of credit, they can go to competition. Customer data are collected in data warehouses. Data mining methods can help to process data in data warehouse. Much of CRM software uses data mining tools like CHAID or neural network. Knowledge about customers is getting wider and a number of data is enormous. So people need computer technology tools to cope with this.

## Summary

Huge need of decisions process supporting require from managers using ICT solutions. This solutions can be based on data mining tools like CHAID, OLAP or neural network. It is common to use these tools to data warehouse management for example in CRM software. It brings many profits and enable function of whole CRM system. Many companies on the world are profiting from CRM software. Managers can make decisions based on data from this software and quality of this data determines quality of decisions. So computers systems helps to make decisions in nowadays business.

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## **Computer system assistance of business decisions – example of customer relationship management**

### **Abstract**

In this paper author presented an idea of computer system supporting of making decisions in business. Author focused on ICT tools which transforms business to e-business. ICT tools can be used on many fields of organization activity. In this paper was shown how useful it can be on customer relationship management (CRM) field. Author stressed use of data mining in CRM software by using neural network, OLAP or CHAID. It was shown were this tools can be useful in CRM system and how it can help managers to make good decisions. In further part of this paper some examples of CRM software implementation and effects of it were shown.

**Key words:** e-business, computer system, IT, decisions making, CRM, e-CRM, OLAP, data mining, neural networks, CHAID

## **Computer system assistance of business decisions – example of customer relationship management**

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