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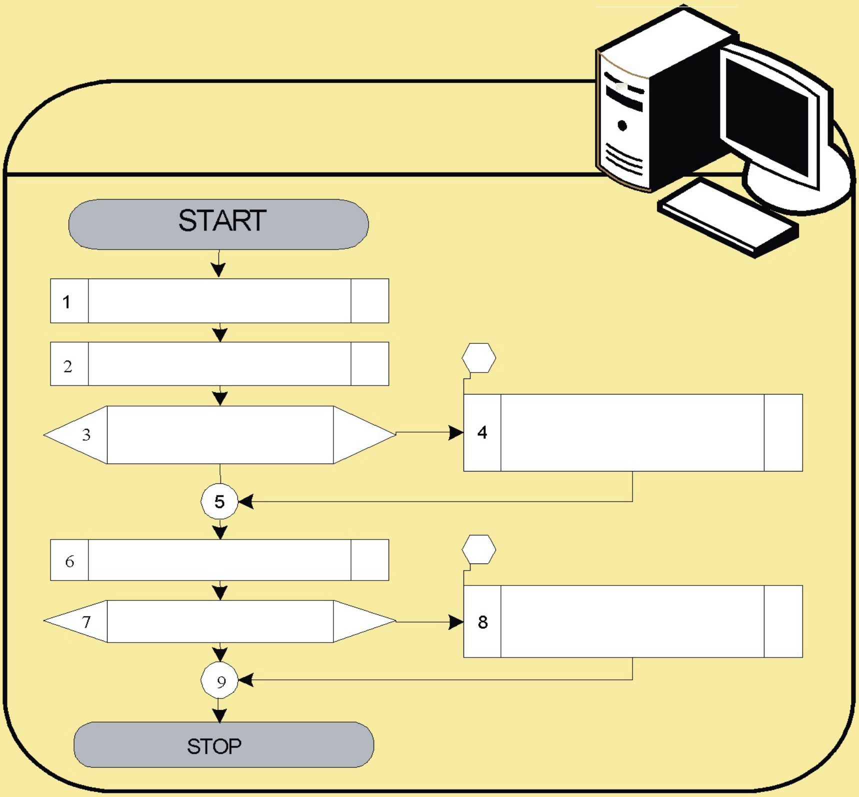

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tapered roller bearing, dynamic simulation, axial load force

Róbert KOHÁR, Frantisek BRUMERČÍK**, Michal LUKÁČ***, Aleksander NIEOCZYM*****

NUMERICAL ANALYSIS OF ROLLER BEARING

Abstract

The aim of this paper is to detail the creation of a large tapered roller bearing model with flexible body cages in the Adams program suite for subsequent dynamic analysis and to obtain information about kinematic and dynamic relationships of steel and plastic cages under various operating conditions. The bearing model was made to closely resemble its real-life counterpart, which allows us to estimate load conditions, dynamic conditions of individual bearing parts and interactions between them.

1. INTRODUCTION

Tapered roller bearings are used in shafts which sustain large axial and radial forces. To achieve high operational reliability and long lifetimes, tapered bearings have to be set with preload at the time of assembly. Preload allows to achieve required contact stress between the inner surfaces of the raceway and the rolling elements. The authors of [1] studied the effect of bearing assembly on bearing life. As input data they used bearing preload and shaft deflection angle. Simulation results were expressed in terms of bearing stiffness and distribution of contact stresses. In addition, modifications were introduced in the shape of the edge at the base of the cone [2, 3] report the results

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of modeling of the impact of operational factors such as angular displacements of bearing races, shaft deflection, and errors during mounting of ball bearing assemblies, on service life of a tapered roller bearing. The loadings used were radial and axial forces at varying rotational speeds. These factors were shown to effect changes in contact loads and contact stresses between the rolling element and the races, which led to reduced bearing life. Additionally, an analysis was conducted of the impact of geometric errors in internal surfaces of tapered roller bearings [3] on the value of contact forces. Describes the procedures of FEM modeling of tapered roller bearings which allow to obtain contact stresses [4, 5]. That study presents models of contact stresses and methods of modeling contact discontinuities on roller and race surfaces.

Tapered roller bearings are also investigated in terms of their material properties Describes the influence of contact stresses on fatigue spalling of bearing races, in particular pitting and flaking away of bearing material [6]. It presents the results of FEM modeling based on generating nonlinear material models, which allows to determine contact stresses. Analyzes the impact of the internal geometry and micro-geometry of the functional surfaces of raceways at the contact with the roller and their impact on internal resistance-friction of the bearing [7].

The above-mentioned studies do not take into account the impact of the bearing retainer on load bearing capacity and service life of bearings. The literature also offers no reports on interactions between the retainer and rolling elements. A bearing retainer moves in rotary motion, and errors in its manufacture affect the life of rolling elements. Another variable that could be investigated is the type of material the retainer is made of and its impact on the value of stresses on the surfaces of the rolling elements.

2. TAPERED ROLLER BEARING MODEL

Dynamic simulations of the tapered roller bearing were performed in the MSC.Adams system. A precise geometrical model of the bearing was necessary in order to perform the said simulations. The 3D model has been created based on available drawing documentation and incorporates various methods with regards to the overall model complexity. Model design was performed in Pro/Engineer Wildfire 5 (Fig. 1), which, when compared to the MSC.Adams environment, allows simpler model creation and subsequently easier bearing geometry modifications. The bearing model assembly was transformed from Pro/Engineer into Adams environment using the Parasolid file format and was further processed based on analysis requirements. The first step included material definition for individual bearing components. The bearing consisted of inner and outer ring, cage and rollers. Table 1 lists values assigned to individual parts.

Tab. 1. Material properties of individual bearing parts [source: own study]

	Density [kg.m^{-3}]	Young modulus [MPa]	Poisson constant[-]
Inner ring	7850	202000	0.29
Outer ring	7850	202000	0.29
Roller	7850	202000	0.29
Steel cage	7850	202000	0.29
Plastic cage	1100	3000	0.42

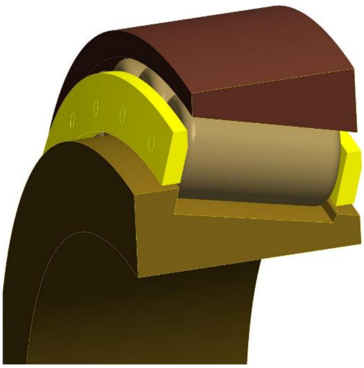

Fig. 1. Tapered roller bearing model in Pro/Engineer [source: own study]

In the next step we defined the contacts between individual bearing components. Contact type „solid to solid" was chosen for the afore mentioned operation, defining two objects coming into contact. This was due to the geometrical complexity of the model and inability to determine all bearing parts that come into contact [8, 9]. This contact type requires the definition of the following parameters: Stiffness, Exponent, Max Damping and Penetration Distance. Contact pairs were formed between inner ring and rollers, outer ring and rollers and between ring and rollers. Parameter values for contacts of rollers with outer and inner ring have been defined based on the Hertz theory of contact pressure. We also considered a friction model based on Coulomb friction force calculation. Values of static and dynamic friction coefficient have been set according to and values of transmission velocity.

Next we defined the geometric and kinematic constraint conditions and load force. Axial load force of the outer ring was associated with „Fixed joint" constraint, which resulted in removal of all degrees of freedom. Inner ring was associated with „Cylindrical Joint" constraint condition, which allowed rotation and translation along the x axis. „Rotational Joint Motion" of type „Velocity" has been assigned to the „Cylindrical Joint" constraint, allowing rotational movement.

This movement has been defined via the STEP function and corresponds to bearing rotational speed n = 15.5min^{-1} and n = 250min^{-1}. Loading force was defined via gravitation acceleration „Gravity“ and „Axial Force“ of magnitude 518000 N in x axis direction, influencing the inner ring. Figure 2 shows a model with axial load force with defined geometrical and kinematic constraint conditions.

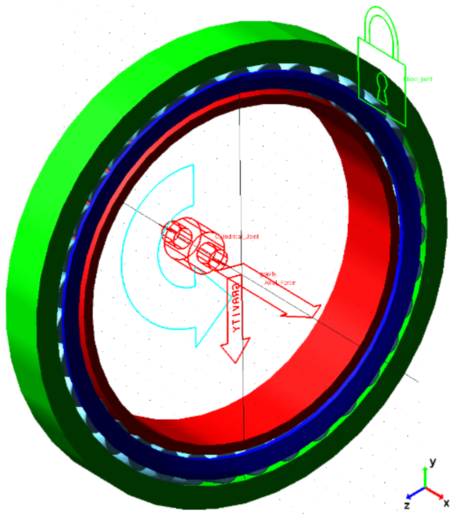

Fig. 2. Geometric and kinematic constraint conditions – axial load force [source: own study]

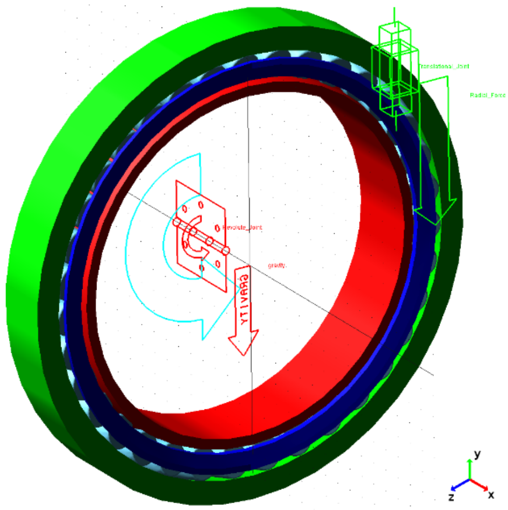

Fig. 3. Geometric and kinematic constraint conditions – radial load force [source: own study]

Constraint conditions for dynamic analysis with radial load force have been defined as following: „Revolute Joint“ has been assigned to the inner ring and allowed inner ring rotation around the x axis. „Translational Joint“ has been assigned to the outer ring, allowing movement in direction of the y axis. „Rotational Joint Motion“ of type „Velocity“ has been assigned the aforementioned constraint, allowing rotational movement. This movement has been defined in a similar fashion as described above using the STEP function. Load force was defined via gravitation acceleration „Gravity“ and „Radial Force“ of magnitude 4500000N has been applied in y axis direction, influencing the outer ring. Figure 3 shows the model under radial load force with defined geometric and kinematic constraint conditions.

After defining all constraint conditions, boundary conditions and load force, we defined the analysis type and solver parameters as follows:
SIMULATE/DYNAMIC, END=30, STEPS=3000, Integrator GSTIFF, Formulation SI2, Corrector Modified, Error 1e-3, Executable External C++, Thread Count 8, Contacts Default_Library, Faceting Tolerance 1e.

3. DYNAMIC SIMULATION RESULTS – AXIAL LOAD FORCE WITH ROTATIONAL SPEED n = 15.5 rpm

Dynamic simulation results with axial load force and rotational speed n = 15.5 rpm represent force interactions between individual bearing parts, movement of bearing cage center of gravity and angular velocity thereof. Figure 4 shows forces between roller and cage, roller and inner ring and angular velocity of this roller. Maximum force between steel cage and rollers was observed during interaction of the cage with roller n. 26 and is equal to 268 N (Fig. 4 up, green line). Also shown is the force between inner ring and roller n. 26 (red line), which varied between 54297 N and 59103 N, a difference of 4.2% (minimal force) and 8.1% (maximal force) when compared to theoretical calculations. The blue line displays angular velocity of roller n. 26 and varies between 483°/s and 495°/s.

Maximum force between plastic cage and rollers was observed during interaction of the cage with roller n.2 and is equal to 251N (Fig. 4 down, green line). Also shown is the force between inner ring and roller n. 2 (red line), which varied between 54467 N and 58636 N and was lower when compared to the steel cage, representing a difference of 3.9% (minimal force) and 7.1% (maximal force) when compared to theoretical calculations. The blue line displays angular velocity of roller n. 2 and varies between 483°/s and 495°/s, similar to the velocity observed for the steel cage.

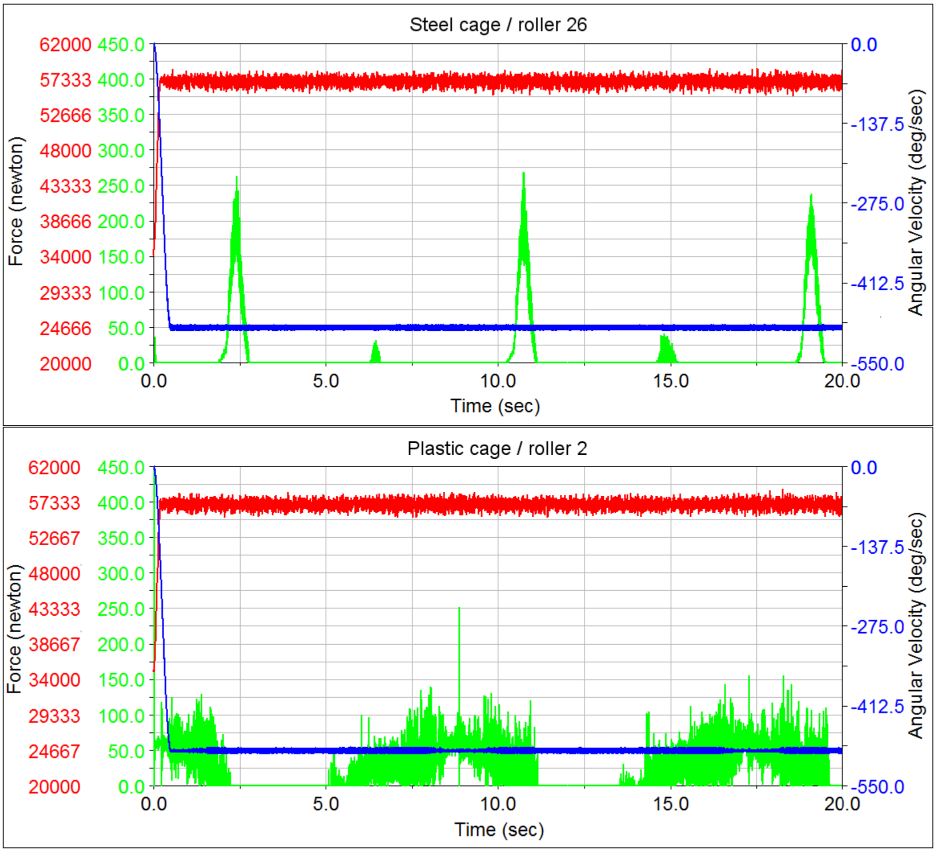

Fig. 4. Force interaction between inner ring and rollers (red lines), force interaction between cage and rollers (green lines) and angular velocity of rollers [source: own study]

Figure 5 shows the center of gravity location in the y-z plane of steel cage oriented as per Fig. 2. Figure 6 shows the center of gravity location in the y-z plane of plastic cage, fig. 7 shows force interaction between inner ring and rollers.

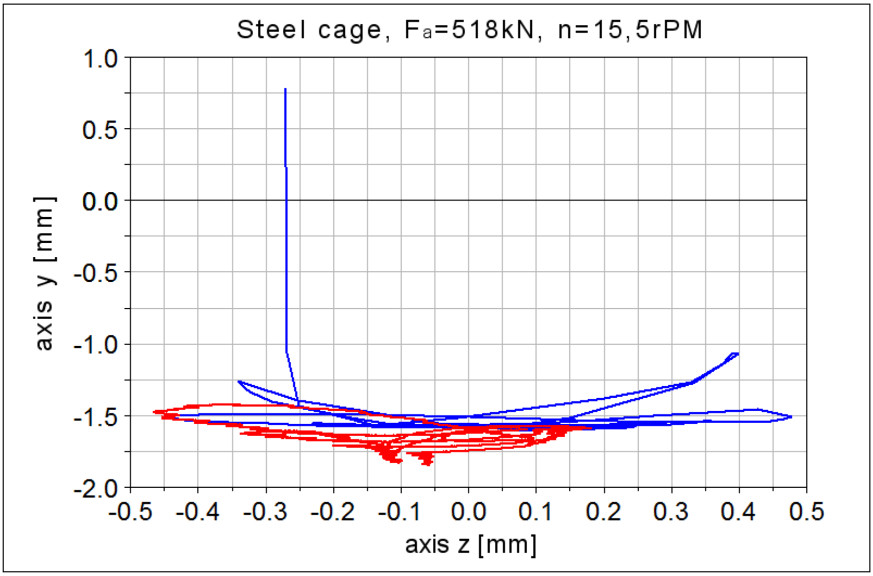

Fig. 5. Movement of center of gravity of steel cage in the y-z plane under axial load [source: own study]

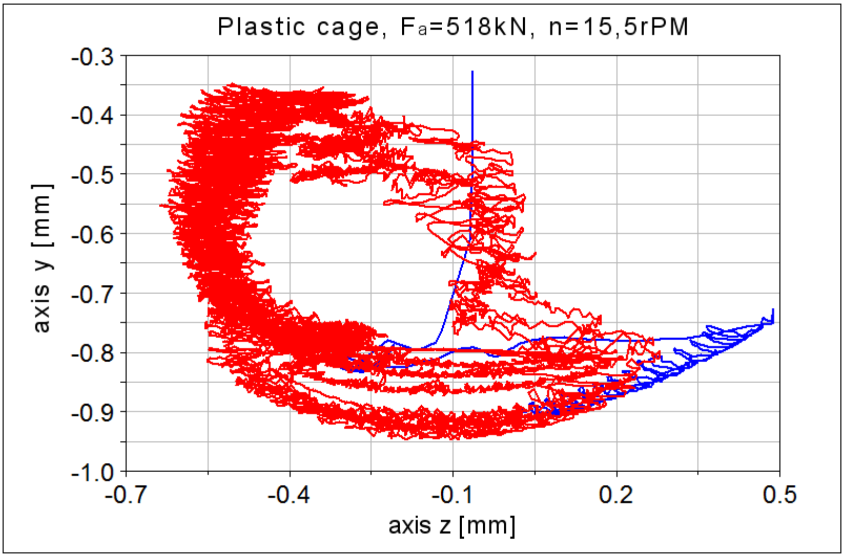

Fig. 6. Movement of center of gravity of plastic cage in the y-z plane under axial load [source: own study]

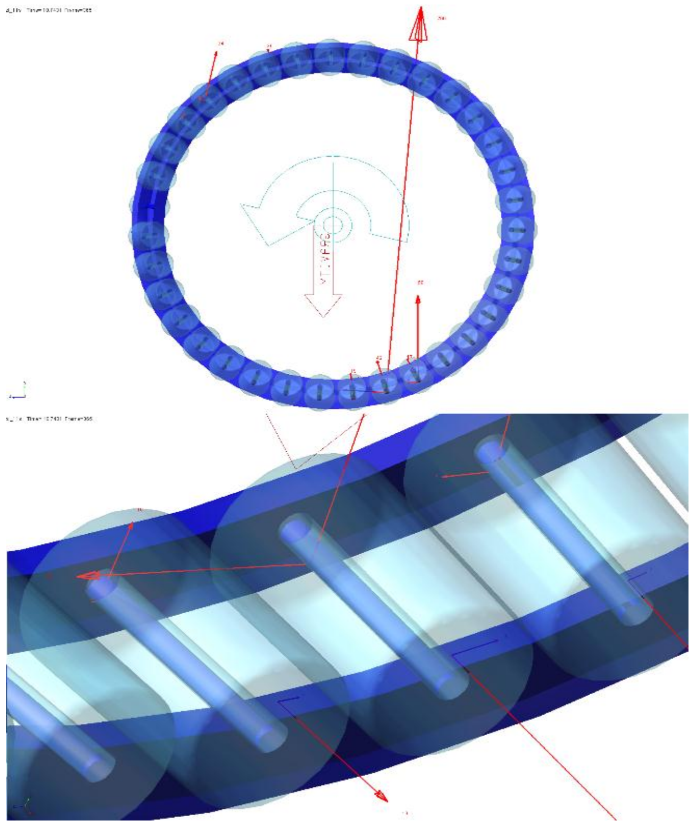

Fig. 7. Force interaction between inner ring and rollers [source: own study]

4. RADIAL LOAD FORCE WITH ROTATIONAL SPEED n = 15.5 min^{-1}

Similar to axial load force, we calculated force interactions between individual bearing parts, movement of bearing cage and angular velocity thereof when subjected to radial force. Figure 8 shows force between roller and cage, roller and inner ring and angular velocity of the roller. Also shown is the force between inner ring and roller n.13 (red line). Maximum force between steel cage and rollers was observed for roller n.13 and is equal to 706N (green line). The analysis also showed that highest load rates are present at rollers 10 to 14 during start-up time (2–5 seconds) and are equal to 700 N. During subsequent simulation time, the cage was in contact with rollers only when the rollers were off-loaded and maximum force value was equal to 250 N. Angular speed was constant (489°/s) under applied roller load and lowered under roller load in the 20000N to 70000N range, achieving a minimum value of 445°/s (blue curve).

Figure 8 down shows force between inner ring and roller n.10 (red line) for bearing with plastic cage. Maximum force between the plastic cage and rollers was observed for roller n.10 and is equal to 670N (green line). Similar to the steel cage, highest load rates were present at rollers 10 to 14 during start-up time (2–5 seconds) and are equal to 700 N. When compared to the steel cage, the rollers were in contact not only in the off-load phase (force equal to 100 N) but also during the load phase, with the force equal to 400 N. Angular speed was constant (489°/s) under applied roller load and, similar to the steel cage, lowered under roller load in the 20000N to 70000N range, achieving a minimum value of 167°/s (blue curve) and 320°/s under load.

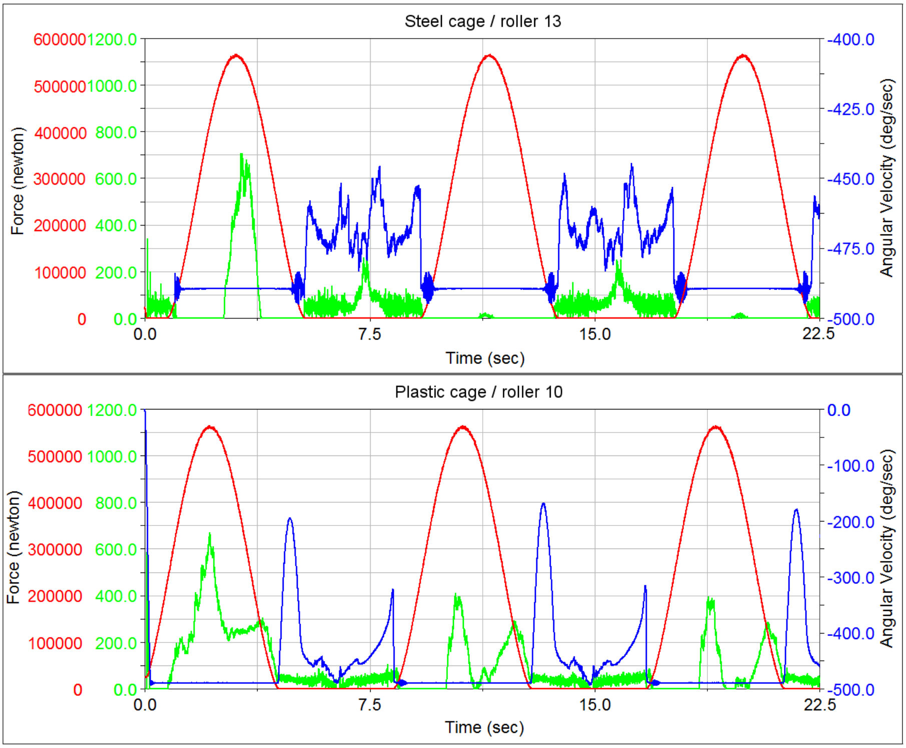

Fig. 8. Force interaction between inner ring and rollers (red lines), force interaction between cage and rollers (green lines), angular velocity of rollers (blue line) [source: own study]

Figure 9 shows the center of gravity location of the steel cage in the y-z plane, figure 10 shows the center of gravity location of the plastic cage in the y-z plane, and figure 11 shows force interaction between inner ring and rollers.

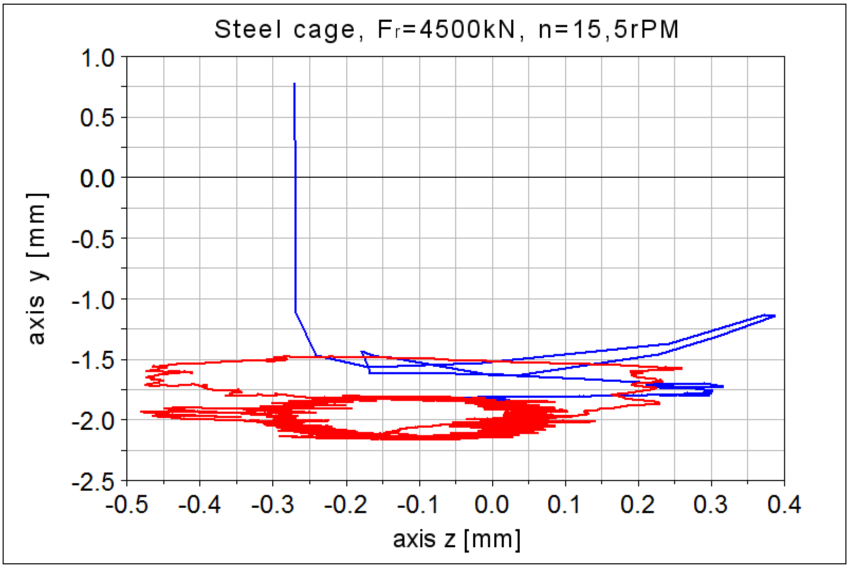

Fig. 9. Movement of center of gravity of steel cage in the y-z plane under radial load [source: own study]

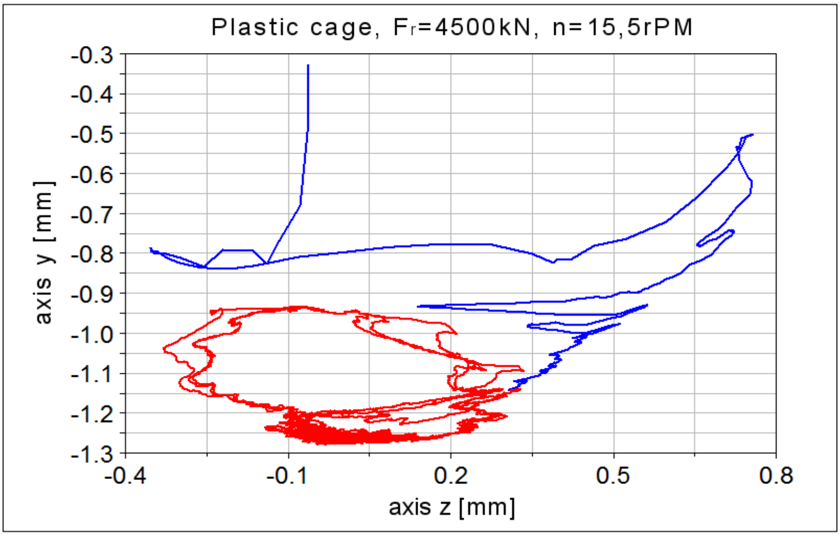

Fig. 10. Movement of center of gravity of plastic cage in the y-z plane under radial load [source: own study]

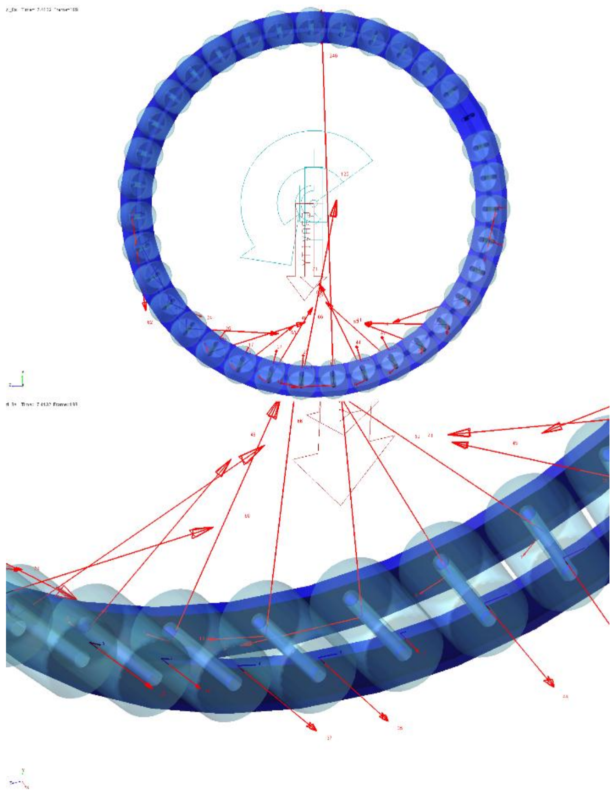

Fig. 11. Force interaction between inner ring and rollers [source: own study]

5. CONCLUSION

Based on obtained results, we can conclude that the steel cage is more appropriate for axial force load due to lower interaction force between the cage and rollers. Also reduced are bearing oscillations in both the rotation axis and in the plane normal to the said axis. Forces between rollers and bearing rings are minimally influenced by the cage type. This is also true for the angular velocity of the rollers. Radial force load results in reduced load of steel cage at lower speed, however at higher speed the plastic cage is more appropriate. At lower speed, the angular velocities of bearing rollers with steel cage are randomly changing during the offload phase and could result in undesirable behavior of the bearing. Angular velocities of plastic cage rollers exhibit a smoother behavior when compared to steel cage. Additionally, oscillations in the plane normal to the rotational axis are also lowered.

Based on the afore-mentioned results, we can conclude that the use of plastic cage is more appropriate for radial load force scenarios.

REFERENCES

[1] VAN-CANH T., HONG S.: *Characteristics of tapered roller bearings in relation to roller profiles*. Journal of Mechanical Science and Technology, 29 (7), 2015, p. 2913–2919.

[2] VAN-CANH T., HONG S.: *Fatigue life of tapered roller bearing subject to angular misalignment*. Proceedings of the Institution of mechanical engineers. Part C – Journal of Mechanical Engineering Science, 230 (2), 2016, p. 147–158.

[3] VAN-CANH T., HONG S.: *Characteristics of Tapered Roller Bearing with Geometric Error.* International Journal of Precision Engineering and Manufacturing, 16 (13), 2015, p. 2709–2716.

[4] YANG X., HUANG Q., YAN C.: *Analyzing the load distribution of four-row tapered roller bearing with Boundary Element Method*. Engineering Analysis with Boundary Elements, 56, 2015, p: 20–29.

[5] KOHÁR R., MEDVECKÝ Š., HRČEK S.: *Usage of dynamic analysis to determine force interactions between components of rolling bearings with different rotation speed*. In: Machine Design, 4 (3), 2012, p. 145–150.

[6] LOSTADO R., FERNANDEZ M., MAC DONALD B.: *Determination of the contact stresses in double-row tapered roller bearings using the finite element method, experimental analysis and analytical models.* Journal of Mechanical Science and Technology, 29 (11), 2015, p. 4645–4656.

[7] JURKO J., PANDA A., VALICEK J.: *Study on cone roller bearing surface roughness improvement and the effect of surface roughness on tapered roller bearing service life* International Journal of Advanced Manufacturing Technology, 82 (5-8), 2016, p. 1099–1106.

[8] HARRIS T. A., KOTZALAS M. N.: *Essential Concepts of Bearing Technology*. 5. edition. 2007.

[9] GLOWACZ A.: *Diagnostics of DC and Induction Motors Based on the Analysis of Acoustic Signals*. Measurement Science Review, 14 (5), 2015, p. 257–262.

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biomechanical analysis of motorsports drivers,
modern 3D technologies in motorsports, balance analysis, long jump analysis

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Jakub SMOŁKA[***]*, MarcinKWIATKOWSKI*[****]

MODERN 3D TECHNOLOGY USED FOR THE EVALUATION OF MOTORSPORTS DRIVERS

Abstract

The article presents selected modern 3D technologies (a motion capture system, forceplates) that can be used to examine the biomechanics of motorsports drivers. The aim of this paper is to prove the following thesis:"modern 3D technologies allow for precise and objective biomechanical analysis of motorsports drivers as a complement to psychomotor tests" based on the preliminary research. Three motorsports drivers participated in this study.

1. INTRODUCTION

Today 3D technologies are exhibiting very fast growth and development. Modern systems offer new ways for analyzing biomechanical parameters. These systems often combine different types of equipment (both hardware and software)

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for capturing motion and so-called “analogs” for further analysis. All data streams (motion and “analog”) are synchronized. This allows for the correlation analysis of data streams. An example of such a system is presented in this paper. It combines three components: an optical motion capture system for recording 3D movements, an electromyographysystem(EMG) for capturing electrical muscle activity and two force plates used for measuring ground reaction forces (GRF).The system is accurate and non-invasive. It is located at the Lublin University of Technology.

Modern 3D technologies enable many research projects concerning car driving ability and vehicle parameters. Due to the fact that optical motion capture systems are static (the cameras are in fixed positions on tri-pods or wall mounts),frequently a car simulator has to be used instead of a real car. The motion capture system can record human movement during various activities. The task of driving on a simulator is studied in several aspects. The hand grip force is examined in [1] and the pattern of hand positioning is analyzed in [2]. The electrical muscle activity and its relationship with forces applied on a steering wheel are described in [3, 4]. The analysis of the force wrench of individual hands is examined. A specific calibration process which compensates for the effects of both static weight and inertia is proposed. The instrumented steering wheel allows one to measure all the forces and torques. The research shows that the driver does not steer the wheel with symmetrical hand actions. The steering effort of each individual hand shows rapidly changing actions that are well coordinated to produce a smooth combined action on the steering wheel [5]. Another motion capture application concerns the measurements of the kinematic of the driver’s upper limbs and torso [6]. The research is conducted using a platform built out of a Peugeot 206 vehicle. Steering movements are analyzed.

Vehicle egress and ingress are analyzed in several papers [7, 8]. The first exampleis a study concerning cervical spine motion examined during extrication from the vehicle [7]. A motion capture system is used to record head movement relative to that of the torso. Various extrication techniques are examined. The second research is about the egress of the younger and older persons [8]. Collected data is used to simulate movement using a Digital Human Model. An occupant’s posture and its effect upon the overall risk of injury in frontal collisions are studied in [9, 10]. A motion capture system is used to determine the range of motion of the following parts of the body: neck, corpus, right hip and right knee.

There is a lot of psychomotor research conducted on motorsports drivers without investigating their movements. Reaction time to sound and light stimuli, hand-eye coordination, depth perception and results of the Poppelreuter test are studied [11]. The studies use monitoring tools for measuring the above-mentioned parameters. The tools include: reaction time meter, hand-eye coordination testing device, tremometer, computer software for the assessment of concentration and divided attention. The studies also use normalized diagnostic tests such as: Automated Neuropsychological Assessment Metrics-4 (ANAM-4), the Cambridge Neuropsychological Test Automated Battery (Cantab) and the Vienna Test System (VTS). The tests are carried out using purposely built devices; however, their disadvantage is low precision and measurement accuracy [12].

The drivers' abilities, both cognitive and psychomotor together with driving performance, are examined in [13]. The research is performed with the participation of professional (licensed) drivers (over and under 40 years old). The study is performed using simulated driving.

This paper presents the idea of combining a motion capture system together with psychomotor tests for the purpose of a motorsports drivers' examination. This kind of interdisciplinary research may bring many benefits for improving drivers' performance. The results, both obtained from motion capture system and psychomotor tests, may create a precise and objective tool for drivers' examinations.

2. MODERN 3D TECHNOLOGIES

Modern technologies are more and more available, thus making possible interdisciplinary research. This paper describes the use of a motion capture laboratory for motorsports drivers' examination. It is part of the Laboratory of Motion Analysis and Interface Ergonomics located at Lublin University of Technology in Poland.

The motion capture laboratory consists of three connected systems which provide time-synchronized data streams. The three systems are: an optical motion capture system, an EMG system and two force plates. They are often used together during recordings: in this this way the recorded material can be analyzed in many aspects.

2.1. The motion capture system

The motion capture system used for the research presented below consists of 8 T40S infrared cameras, two Bonita reference video cameras, a Giganet hub, a PC with 8 GB of RAM and other accessories (e.g. markers, double-sided tape, a calibration wand). The T40S cameras are mounted using wall-mounts, two cameras on each wall. Their positions determine the visible area where the motion may be recorded. All the relevant movement should fit into this area. Infrared cameras allow framerates up to 512 per second at full frame resolution (4 Megapixels). These cameras record the position of each marker in 2D. If a marker is seen by at least two cameras, the PC software is able to reconstruct its position in the 3D space of the laboratory (this is possible because of a calibration step performed prior to the motion capture session).

The Giganet hub ensures that the data received from the cameras is synchronized and transferred to a PC. Two Bonita reference cameras record video. This is frequently useful during the post-processing step (for indicating the right marker) and for creating a video with an overlay (video combined with the biomechanical model outputs).

The system tracks retro-reflective markers attached to the recorded object. When recording human motion, the markers may be placed directly on the skin or on a special motion capture suit. The markers are placed on the body according to a selected schema called a biomechanical model. The type of model should be adapted to the particular sport being investigated.

2.2. Force plates

Two AMTI force plates are often used for the motorsports drivers' examination. They are built into the laboratory floor and are at the same level as the floor, thus ensuring that the patient's movement is not disturbed (there is no step up or down of any kind). Two platforms are installed next to one another, in one line as shown in fig.3. There can be no contact between the platforms and the floor tiles. The force platforms measure ground reaction forces (three orthogonal force vectors and moment components along X, Y and Z axes). They are highly sensitive, hence they are often used in interdisciplinary research, such as for motorsports drivers' evaluations. The platforms are presented in fig. 1.

Fig. 1. Arrangements of two force plates [source: own study]

3. THE EXAMPLE ANALYSIS OF BIOMECHANICS MOTORSPORTS DRIVERS

Body balance is essential in most sport disciplines. Operation of the body control system is something which can be improved through sports training [14]. Measurement of balance is conducted by a technique that belongs to one of two groups: tests of balance and instrumental techniques. The former is a simple and good tool for a coach. The tests include: Eurofit, rotary test and Starosta test. They all are very inaccurate [15]. The solution using 3D technology proposed in this article is a technique of the latter type. The analysis of three motorsports drivers is presented in this paper. They are among the top Polish professional racing drivers. Their ages are between 12 and 17 years. The values, presented in this analysis, were computed by a custom piece of software written by the authors in C++ language.

4.1. The long jump test

The long jump is analyzed in two aspects: its length and ground reaction forces (GRF). The examined person makes a jump from the two force plates (with one leg on each force plate). The 39 retro-reflective markers are attached directly to the skin. 3D motion is captured using a motion capture system while AMTI platforms record GRF vectors (in 3D) and the center of pressure (CP). The “analog data” (from the force plates) is recorded together with motion data using one piece of software (Vicon Nexus).

The length of the jump is computed using 3D marker position data. At the beginning of the jump one marker (the toe marker from the either right or left foot) is used to find the start position of the farthest marker. At the end of the jump the final position of the closest (to the initial position) heel marker is taken. These two positions are used to compute the jump length along one axis (X).

The maximum GRF is computed in two steps. First, the GRF for the right (F^r)leg is computed using formula 1. The GRF for the left leg (F^l) is calculated analogously.

$$F^r(t) = \sqrt{\left(F_x^r(t)\right)^2 + \left(F_y^r(t)\right)^2 + \left(F_z^r(t)\right)^2} \tag{1}$$

Second, force (F) is defined as the maximum GRF average for both legs as specified by formula 2.

$$F = \max \frac{F^r(t) + F^l(t)}{2} \tag{2}$$

The values of jump length and GRF computed for three drivers are presented in table 1. Additionally, jump length was compared with the International Physical Fitness Test (IPFT). The results were obtained with the norms included in IPFT.

Tab. 1. Analysis of jump length based on 3D data and force F [source: own study]

No.	*Jump length [mm]*	*F [N]*	*IPFT/maxIPFT(age) [point]*
1.	2275	716,2	53/100 (17)
2.	1638	461,6	49/100 (12)
3.	2009	637,8	45/100 (16)

Three graphs of GRF vector components obtained from Polygon software for one of the drivers are presented in figures 2 to 4.

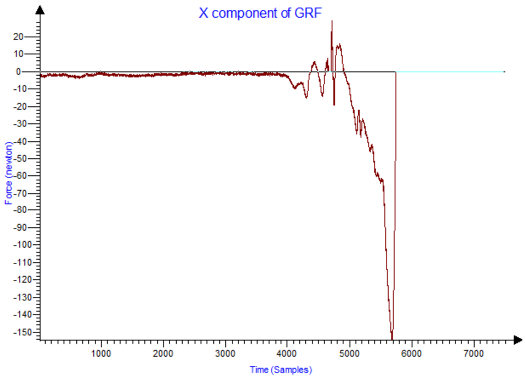

Fig. 2.The X-axis GRF component [source: own study]

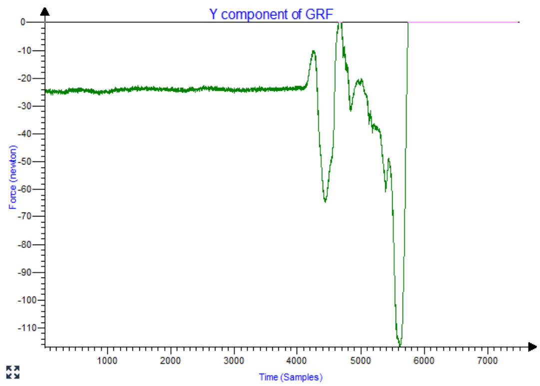

Fig. 3. The Y-axis GRF component [source: own study]

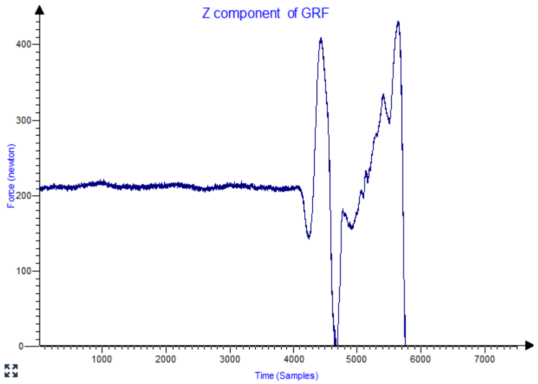

Fig. 4. The Z-axis GRF component [source: own study]

4.2. Balance analysis

The balance test is performed using two force plates. The driver stands with one leg on a single platform. The test consists of four exercises: 1) standing on the left leg with eyes open, 2) standing on the right leg with eyes open, 3) standing on the left leg with eyes closed, 4) standing on the right leg with eyes closed. The driver has to raise and bend one leg so that the angle between the thigh and calf is about 90° degrees. He/she has to keep the one position for at least 10 seconds. During the test arms should be kept along the body.

The balance coefficient (B_c) was computed based on the GRF obtained from force plates using formula 3.

$$B_c = \left(F_{\max}^{x} - F_{\min}^{x}\right) + \left(F_{\max}^{y} - F_{\min}^{y}\right) \tag{3}$$

The maximum and minimum X and Y components of forces from two platforms are computed. Then the difference between the maximum and minimum values for each component is calculated. The balance coefficient is the sum of those differences.

A screenshot of the post-processed subject during balance test is shown in fig. 5.

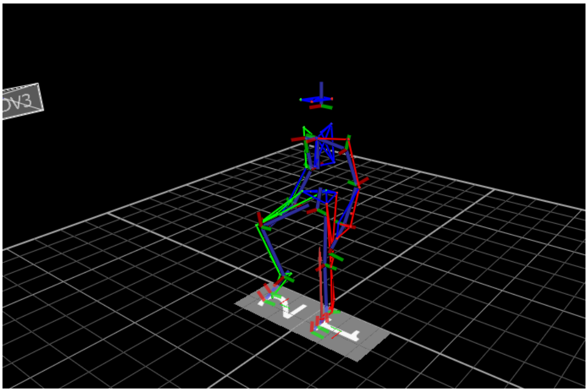

Fig. 5. The balance test on the left leg with eyes open [source: own study]

The results of the balance test analysis are presented in tables 2 and 3. The first table contains the balance coefficients computed for the left and right legs in the open and closed eyes tests. Additionally, the differences between the coefficient values from the open and closed eyes tests are shown. The differrences between values computed for the right and the left leg are shown in table 3.

Tab. 2. Analysis of the balance test based on GRF data [source: own study]

No.	***GRF for left leg [N]***			***GRF for right leg [N]***		
	open eyes	***closed eyes***	***difference***	***open eyes***	***closed eyes***	***difference***
1.	37,0	164,6	127,6	84,4	66,1	18,4
2.	58,9	157,8	99,0	44,4	174,5	130,1
3.	19,9	40,3	20,4	31,6	63,7	32,2

Tab. 3. Analysis of balance test – the difference between legs [source: own study]

No.	***Difference between legs [N]***	
	open eyes	***closed eyes***
1.	47,4	98,6
2.	14,5	16,7
3.	11,6	23,4

Differences in the results with open and closed eyes were obtained for each person. Two of them are very significant. This indicates that general training should pay attention to training on both sides in order to minimize the difference between the left and right sides of the body. In improving the ability to maintain body balance, the following group exercises can be used: exercises isometric, exercises perfecting balance in place and in motion, central stabilization exercises, exercises using unusual starting positions, exercises shaping the ability to perform high-speed rotations and others.

Assessment of the ability to maintain body balance is useful for athletes. Research carried out periodically in the long term will help to determine individual progress in a range of functions and in training methods' effectiveness. It will allow for the development of classification standards in this field.

4. CONCLUSIONS

3D modern technologies offer new ways for the biomechanical analysis of motorsports drivers. Comprehensive training planning is one of the basic conditions determining success in sports. Selected motion parameters obtained using 3D technology provide a coach with valuable information that he/she can use in planning appropriate training. Accuracy of the measurements is an advantage of the tests utilizing 3D technology. They complement the psychomotor tests already used on a large scale. Properly selected tests, at all training levels, are a source of information about the athlete. They can be excellent indicators of the effectiveness of training methods.

REFERENCES

[1] EKSIOGLU M., KIZILASLAN K.: *Steering-wheel grip force charcteristics of drivers as a function of gender, speed, and road conditio*. Int J and Ergonom, 38, 2008, p. 354–361.

[2] WALTON D., THOMAS J.: *Naturalistic observations of drivers hand positions*. Transport Res Part F: Traffic Psychol Behav, 8, 2005, p. 229–238.

[3] PICK A. COLE D.: *Measurement of driver steering torque using electromyography*. ASME J DynamSyst, Measue Control, 128 (4), 2006, p. 960–968.

[4] HOULT W., COLE D.: *A neuromuscular model featuring co-activation for driver simulation*. In: Proc. 20th IAVSD symposium on the dynamics of vehicles on roads and tracks, Berkley, USA, 2007.

[5] GABRIELLI F., PUDLO P., DJEMAN M.: *Instrumented steering wheel for biomechanical measurements*. Mechatronics 22, 2012, p. 639–650.

[6] GABRIELLI F., PAGANELLI S., SCHIRO J., PUDLO P., DJEMAI M.: *Driving simulation protocol to determine steering strategies*. International Journal of Industrial Ergonomics, 42, 2012, p. 469–477.

[7] ENGSBERG J. R., STANDEVEN J. W., SHURTLEFF T. L., EGGARS J. L.: *Cervical spine motion during extrication*. The Journal of Emergency Medicine, 44 (1), 2013, p. 122–127.

[8] CHATEAUROUX E., WANG X.: *Car egress analysis of younger and older drivers for motion simulation*. Applied Ergonomics 42, 2010, p. 169–177.

[9] BEHR M., POUMARAT G., SERRE T., ARNOUX P.J., THOLLON L., BRUNET C.: *Posture and muscular behaviour in emergency braking: an experimental approach*. Accident Analysis and Prevention 42, 2010, p. 797–801.

[10] BOSE D., CRANDALL J.R., UNTAROIU C.D., MASLEN E.H.: *Influence of precollision occupant parameters on injury outcome in a frontal collision*, Accident Analysis and Prevention 42, 2010, p. 1398–1407.

[11] ANDO S., KIDA N., ODA S.: *Proctide effects on reaction time for peripheral and central visual fields*. Perceptual and Motor Skills 95(3), 2002, pp. 747–752.

[12] KWIATKOWSKI M.: *The relationships of select psychological and psychomotoric variables to skill level*. Medycyna Sportowa. Medsportpress, 235(6), 2007, p. 271–278.
[13] SHANMUGARATNAM S., KASS S. J., ARRUDA J. E.: *Age differences in cognitive and psychomotor abilities and simulated driving*. Accident Analysis and Prevention 42, 2010, p. 802–808.
[14] KALINA M.R.: Sporty walki w edukacji dzieci i młodzieży – perspektywa metodyczna, Wydawnictwo Naukowe Novum, Płock, 2002.
[15] PYSKIR M., PUJSZO R., BOSEK M., GRZEGORZEWSKI B., BŁACH W.: *Influence of chosen physical exercises of human posture control system*, Medycyna Sportowa, 20(5), 2004, p. 247–253.

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CATIA, construction design, stress analysis, optimization

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STRESS ANALYSIS AND DESIGN OPTIMIZATION WITH CATIA

Abstract

Stress analysis obtained from CAE methods is one of the most important parameter of designing parts, assemblies and constructions. Loads and stress limits applied on the model should be known also for better design procedure. Evaluation of all parameters is known as optimization. Designed model should contain the optimum values of each parameters such as loads, stresses and weight. Designer creates the model using optimized values for better products. In this paper, Computer Aided Engineering Design Optimization process is studied experimentally with CATIA Product Engineering Optimizer module and optimization algorithms within limitations are used. Benefits of the optimization procedure is also evaluated. Optimization process and benefits are presented in an example of I profile cantilever beam with a length of 2000 mm.

1. INTRODUCTION

The concept of optimization may be expressed simply as making something better. For a system working properly or a design manufactured with a convenient safety factor does not mean that it is designed in the best way. Optimization techniques are used to suggest the best solution for the work on the progress or has already been completed. The solution obtained by use of these techniques is called as the optimum solution.

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In order to compare if one design is better than the other, a criteria is required. This criteria is called as the fitness function. The fitness function is predefined depending on the design parameters in the aim of obtaining the optimum solution. In this study, minimum weight is investigated for specific boundary conditions.

All systems are designed so as to satisfy some constraints such as resources, strength of material, response of the system and geometrical properties of the system components. These constraints are defined depending on the design parameters. If a design satisfies the whole constraints, then the system is compatible and ready to work, otherwise it is not. In addition, it is possible to have various designs satisfyingthe same goal. In this case, one of the conveniet design can be chosen.

Modern CAD systems contain some factors decreasing the operation time of user against complex functions of complicated mechanical structures and manufacturing necessitiesOptimization process is the most important factor among these. The model used in this study is developed by use of Catia V5 Product Engineering Optimizer and Generative Structural Analysis modules. For the best design, an initial design is built up geometrically and geometrical properties,varying through specific limits, are defined as design parameters [1, 2].

Firstly, the weight of construction affects the cost depending on the amount of material. Mountability and transportability are also important. In the design of a product that would be manufactured for thousands and millions in a mass production, it should be appreciated that all parameters must be taken into account carefully. Besides, an optimization will be necessary for the new system [3].

In this study, rather than optimization of a system, the implementation and advantages of optimization are emphasized. The implementation of optimization is carried out by Catia Optimization Module which has wide application fields in CAE especially in automotive industry [4].

2. OPTIMIZATION PROCESS WITH CATIA

In Figure 1, the cross-section of an I profile beam, used in the optimization problem is presented. The profile has almost the same dimensions with a standart NPI-200 profile.

The profile has a length of 2000 mm, clamped at one edge and loaded with 10 kN on the other edge. During the stress analysis, global sensors of Mass and Von Mises have been created before mesh arrangements. By use of these sensors, the stress and weight of the design are observed continuously (Figure 2) [5].

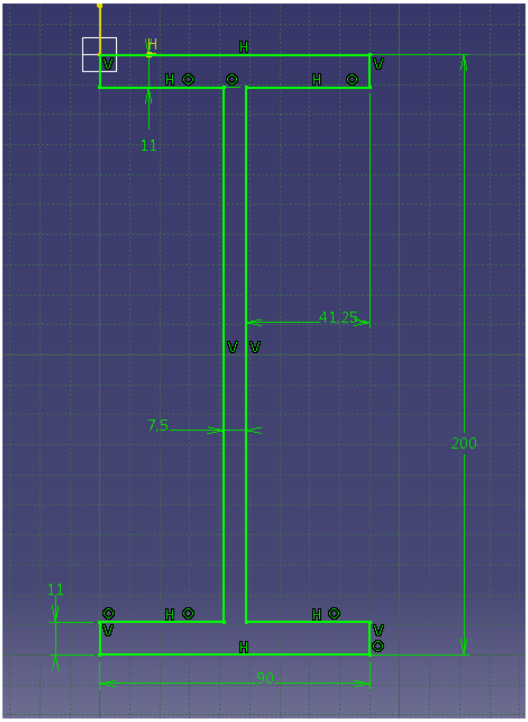

Fig. 1. Cross-section of I profile beam [source: own study]

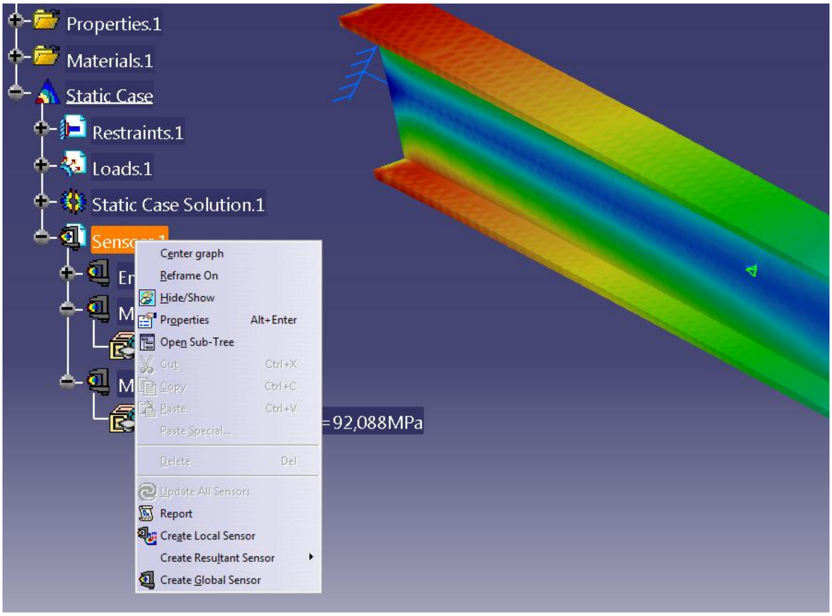

Fig. 2. Sensor definition of I profile beam in a stress analysis [source: own study]

In the stress analysis with CAD programmes, the most important parameter for user is to choose the mesh size. Since each CAD programme has its own technicality and properties, the experience of user in these programmes is very important.

All of the colors representing the stresses on profile must be shown in the final design. I profile beam has a simple geometrical shape. Meshing is not appropriate for the analysis if 99% of blue and red dots and no average colors are obtained in the stress scale at the end of analysis. Besides, the reports of analysis also offer an insight into the reliability of stress analysis.

Stress analysis results by CATIA has an accuracy of 98%. It is very important to choose an appropriate mesh in order to have the correct results. In stress analysis, CATIA specifies a mesh size depending on the geometrical structure and volume of the profile. For instance, it specified a mesh of 125 mm size and 12 mm (at right) for I profile beam. For given mesh size, the criteria of stretch and aspect ratio is about 6%.

For the values of stretch and aspect ratio for I profile, it is appropriate to choose the stretch ratio as 80–100% and 80–90% for aspect ratio. If the mesh size is chosen so as to satisfy the aspect ratio as 100%, Von Mises stress value will be in the form of cluster and greater than the true stress value.

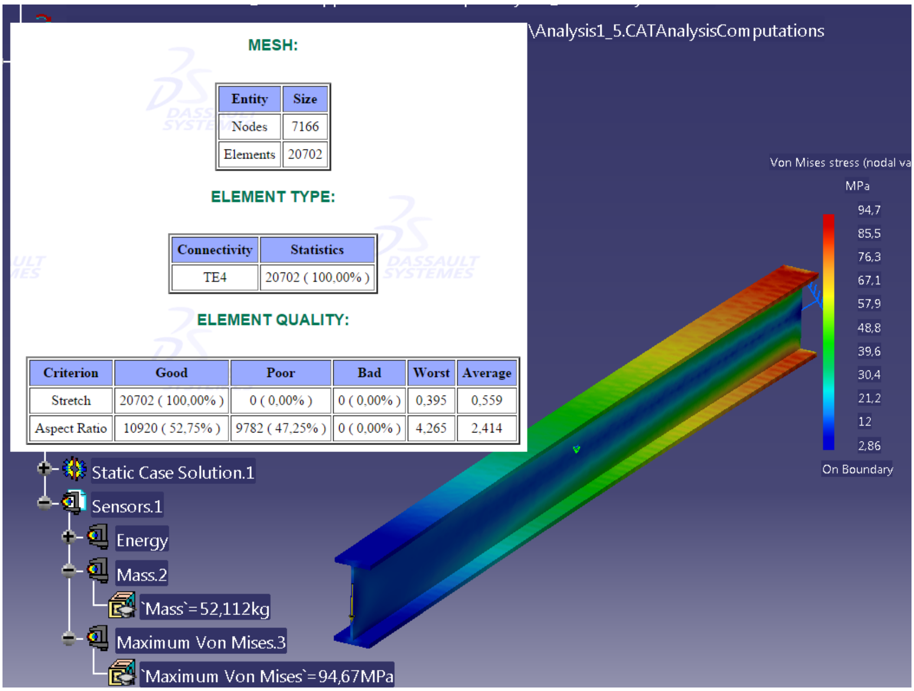

Fig. 3. Stress analysis of I profile beam for an aspect ratio of 52% [source: own study]

In the stress analysis of I profile beam, it is possible to see that the selection of mesh size is relevant not only the volume but also the geometrical structure. For two beams with I profile and different mesh structures, only 2,1 MPa of difference is occured for an aspect ratio between 52% and 91% for good case. In Figure 3 and Figure 4, stress analysis of I profile beam for an aspect ratio of 52% (94.7 MPa) and 91% (96.8 MPa) are given respectively.

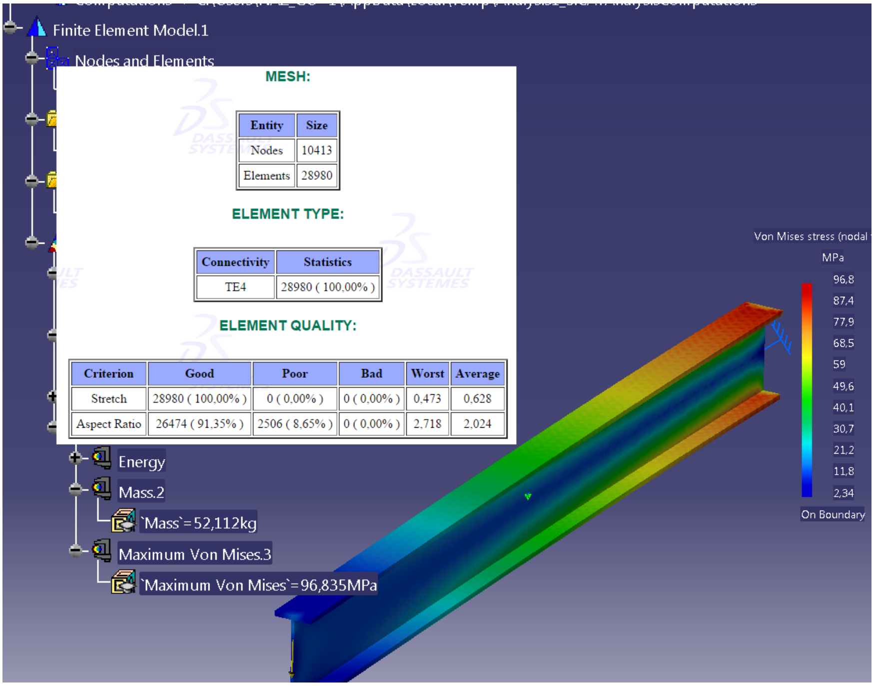

Fig. 4. Stress analysis of I profile beam for an aspect ratio of 91% [source: own study]

In Figure 5, an aspect ratio of 91% in I profile beam is presented. Because of a simple structure, the mesh size is the same through all structure.

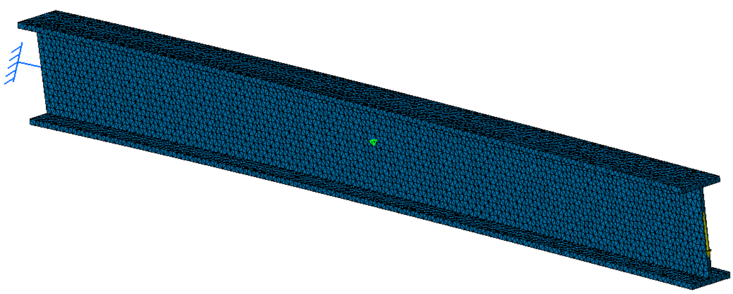

Fig. 5. Mesh structure of an I profile beam [source: own study]

When the stress distribution of an I profile beam is examined, major differences can be seen in through the structure. 90 MPa of stress for 10% and 10 MPa of stress for 40% of the beam is acceptable for loading. Additionally, more than 60% of the profile will be exposed to small amount of stresses. Therefore, it can be mentioned that the beam has more weight than it can carry or better geometry can be chosen. For the first case, the I profile beam with a length of 2 m is 52,112 kg.

When the stress distribution of an I profile cantilever beam is examined, the minimum stress is obtained at the free edge of the beam. It would be wise to minimize the weight of the beam starting fom this point. Moreover, the blue region in lateral axis of the beam (Figure 6) is also convenient for minimizing. For this reason, initially, the optimization of cantilever beam with triangle and circular holes is performed.

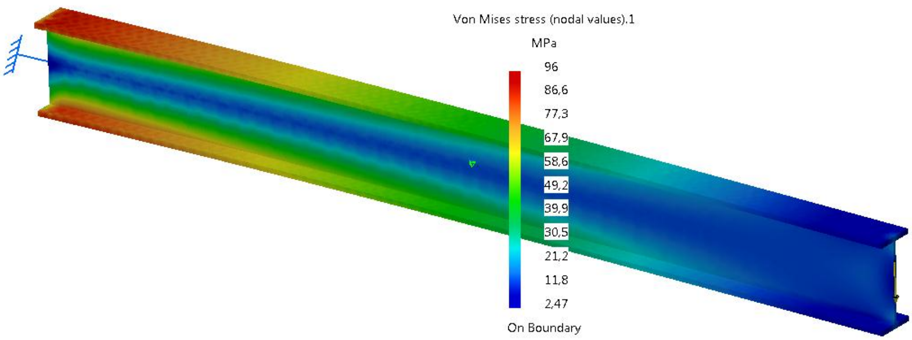

Fig. 6. Stress distribution of an I profile beam [source: own study]

Optimization process is carried out in order to minimize the blue region and the excessive stress values. So, it can be called as the minimum weight optimization problem for a significant geometry and maximum stress value.

2.1. Optimization-1: Triangular I Profile Cantilever Beam

The left and right measurements of plate with a thickness of 7,5 mm, are defined as parameters by not exceeding the height of I profile beam of 200 mm and considering the top and bottom regions as constant (90 mm x 11 mm). In Figure 7, the bottom and top limits and step values of parameters are illustrated. In Figure 8, the mass sensor of the beam is defined.

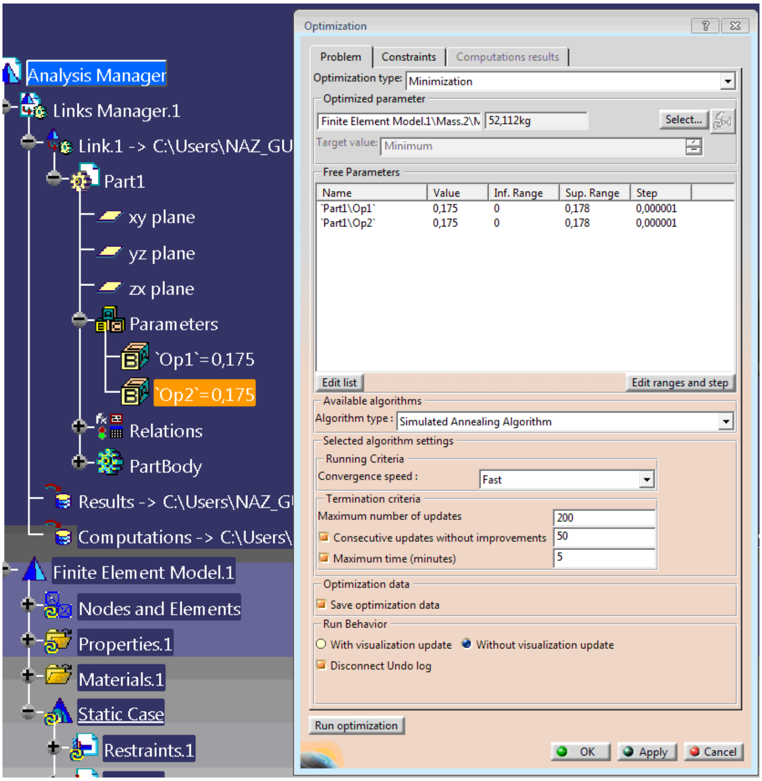

Fig. 7. Definition of the optimization parameters [source: own study]

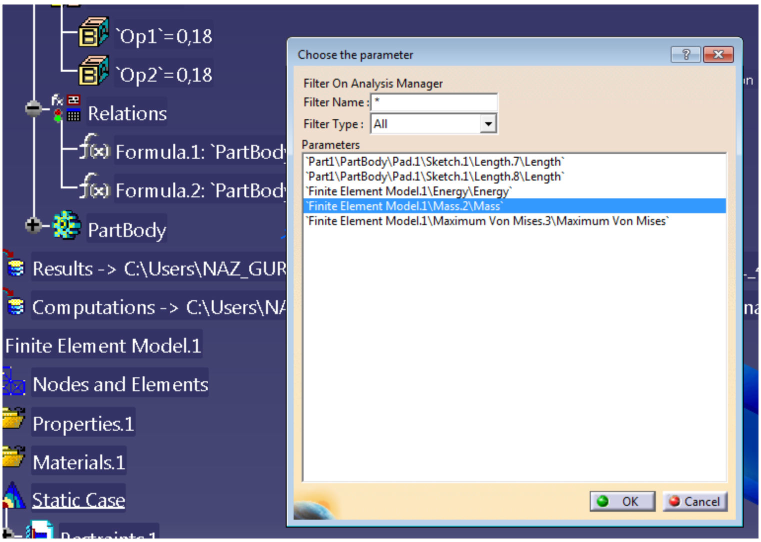

Fig. 8. Definition of the mass in Optimization-1 [source: own study]

For an I profile of 200 mm, the plate's height should not exceed 178 mm. The optimization process is achieved for a maximum stress value of 100 MPa (Figure 9). This solution of the analysis is listed as below (Figure 10). Appropriate ones are chosen and chosen parameters are applied to the model.

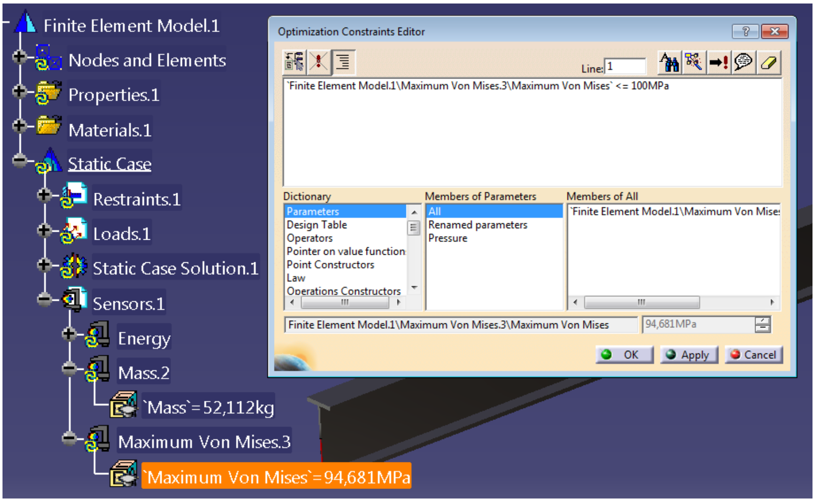

Fig. 9. Definition of the constraints in Optimization-1 [source: own study]

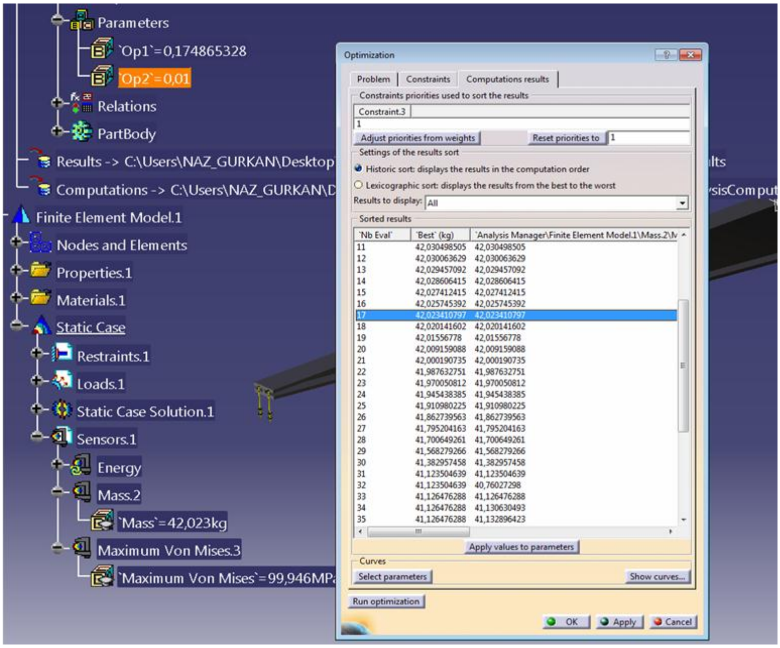

Fig. 10. Solution of Optimization-1 and the selection of appropriate solution [source: own study]

As a result of the optimization process, the triangular I profile beam chosen amongst the others has an allowable stress of 99,9 MPa. The mesh distribution is convenient and has a weight of 42,023 kg (Figure 11).

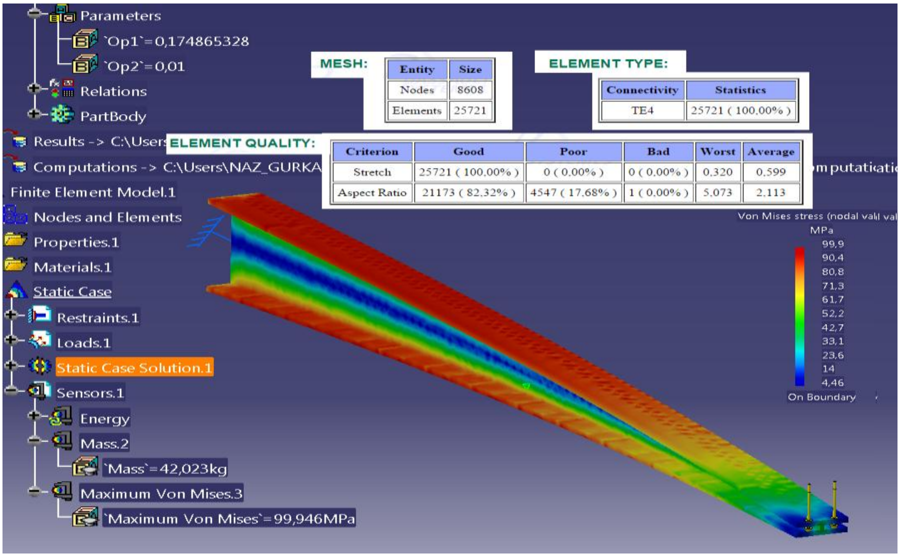

Fig. 11. Stress analysis of Optimization-1 for final geometry [source: own study]

2.2. Optimization-2: I Profile Cantilever Beam with Circular Holes

In the optimization process, nine circular holes with a distance of 200 mm to each other are defined on an I profile beam. In Figure 12, due to the optimization, the measurements of the circles in final profile are presented.

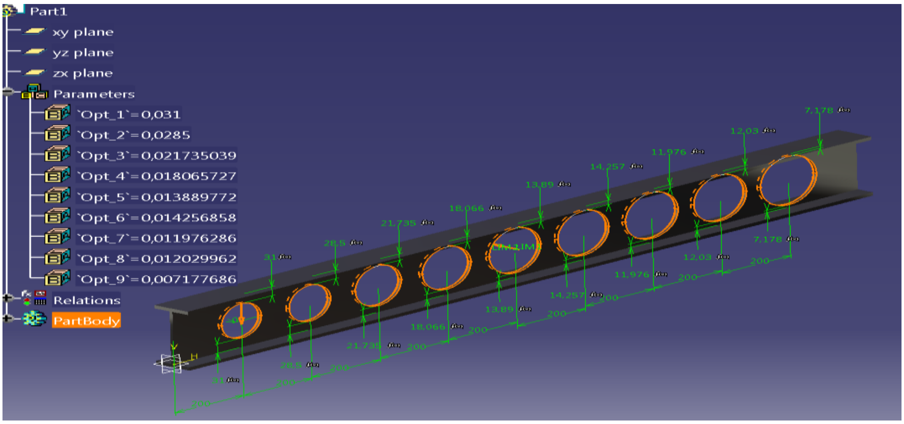

Fig. 12. The parameter values of Optimization-2 after the optimization process [source: own study]

In Figure 13, the stress analysis and mesh values of the geometry after optimization process are presented. The weight of the system is 43,561 kg.

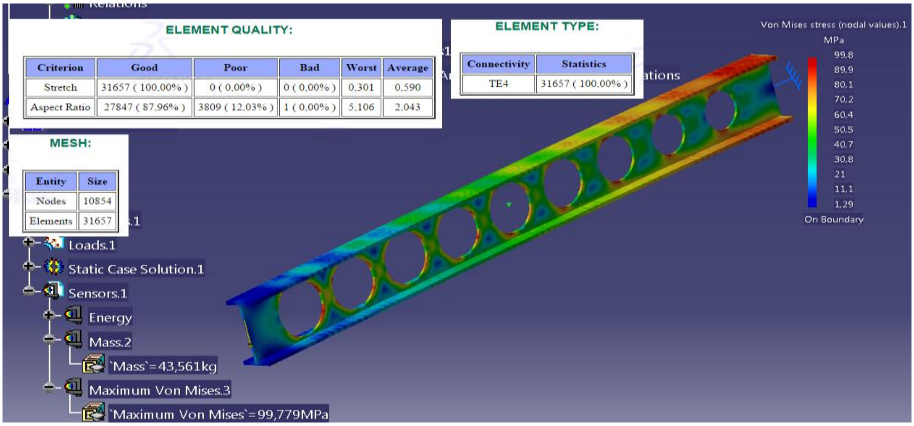

Fig. 13. Stress analysis of Optimization-2 [source: own study]

Although the mass of the system is 42,023 kg in Optimization-1, the minimum mass in Optimization-2 is 43,561 kg. In the third step, a triangle hole is applied to a triangular I profile cantilever beam.

2.3. Optimization-3: Triangular I Profile Cantilever Beam with a Triangular Hole

The optimization parameters are defined for a triangular hole for a triangular plate with a thickness of 7,5 mm. In Figure 14, three of the optimization parameters are presented. The length of 2000 mm is constant and the maximum height of the profile is determined by the program itself.

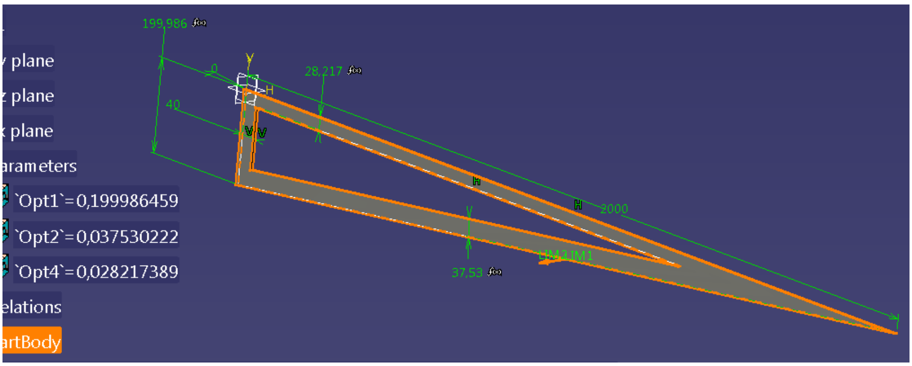

Fig. 14. Triangular I Profile Cantilever Beam with a Triangular Hole [source: own study]

The aspect ratio value of I profile, obtained in Optimization-3, is 87,25. When the finite element method (FEM) is used for I profile with the same mesh size, the aspect ratio is observed as 80,25. In figure 15 and 16, the mesh structure of both triangular I profile centilever beam with a triangular hole and I profile are given respectively.

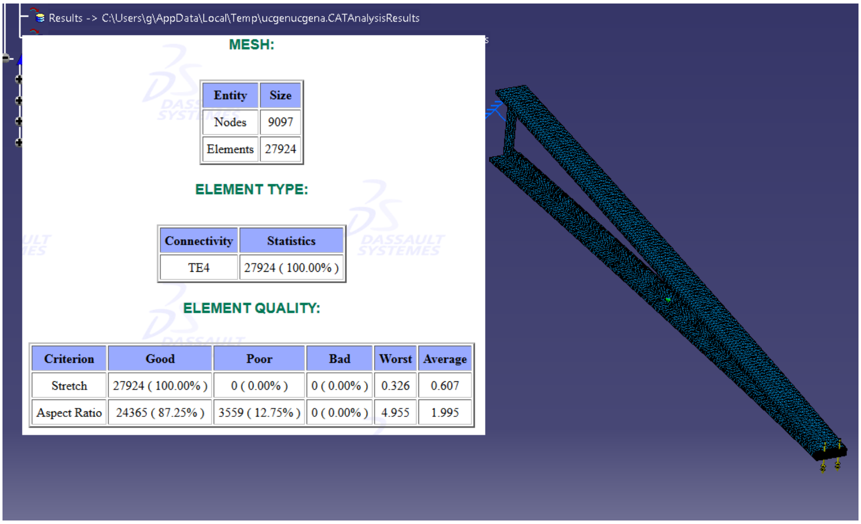

Fig. 15. Triangular I Profile Cantilever Beam with a Triangular Hole mesh structure [source: own study]

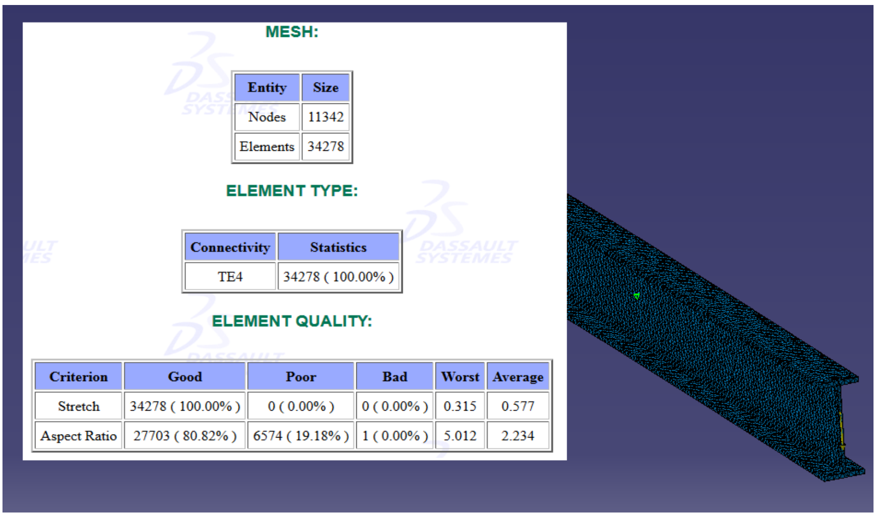

Fig. 16. I profil mesh structure [source: own study]

In Figure 17, the stress analysis of the geometry after optimization process is presented. As it can be seen from the figure, the maximum stress occured through the beam is 99.7 MPa which is smaller than maximum value and the mass of the profile is 37.9 kg.

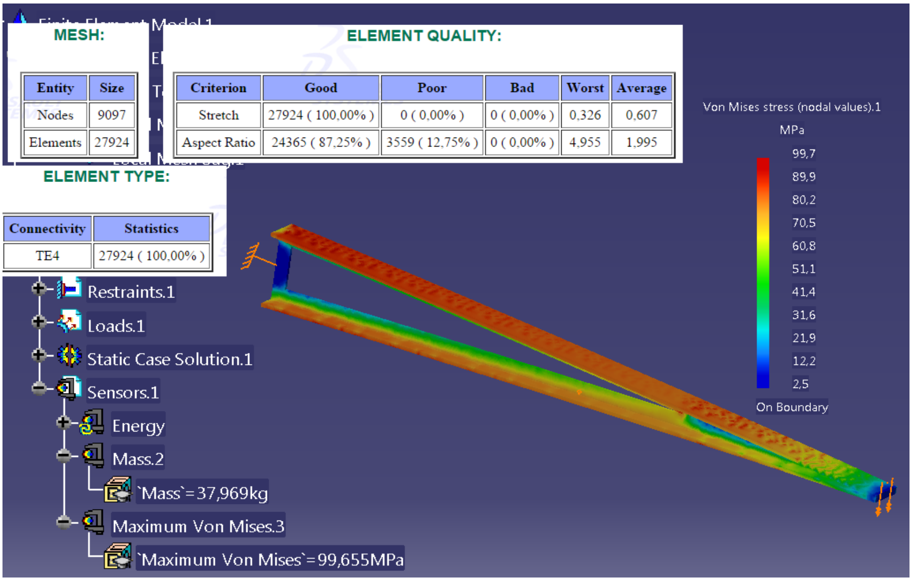

Fig.17. Stress analysis of Optimization-3 [source: own study]

In Table 1, in order to obtain the minimum mass for specific constraints such as stress values and geometrical properties, optimization processes of three cases for I profile cantilever beam with 10 kN at one edge are presented. A decrease of % 27,14 is provided in Optimization-3.

Tab. 1. Optimization Process of the Profiles – Minimizing the Mass [source: own study]

	Mass [kg]	**Decrease in Mass [%]**
I Profile	52,112	–
Optimization-1	42,023	20
Optimization-2	43,561	16,41
Optimization-3	37,969	27,14

3. CONCLUSION

Optimization process has great importance in the design of machine parts and constructions. In this study, although I profile beam is a simple structure, for a beam with a length of 2000 mm and height of 200 mm, 14,143 kg is gained after the optimization process.

Optimization process has many advantages especially in the design of complicated strctures. The maximum stress value changes depending on the aspect ratio.

Optimization requires modern computers with hi-tech hardware and latest software in order to reduce the computing time during the design process. The analysis in this study are achieved by a work station with the properties of 2.4 GHz CPU, 1 TB HDD, 48 GB RAM.

Comparing with the other types of analysis, optimization consumes much evaluating time.

Due to the changing in geometry, mesh structure of the system also changes. Thus, the analysis reports should be controlled again after the optimization.

If minimum weight is targeted in the optimization by CATIA, the process should begin with an initial weight heavier than the minimum value.

A stress-weight optimization of a system does not provide a correction in stress analysis unless the stress analysis is achieved properly. With an inaccurate stress analysis value, only swapping of two incorrect values will be at stake.

REFERENCES

[1] VALAKOS I. M., NTIPTENI M. S., NIKOLOS I. K.: *Structural optimization of a central Impeller Using Different Evolution in Catia Environment.* Operational Research An International Journal 7 (2), 2007, p. 185–182.

[2] RAJAM V., MURTHY P. V. K., M.V.S. KRISHNA M., RAO G. M. P.: *Design Analysis and Optimization of Piston using CATIA and ANSYS.* Internaltional Journal of Innovative Research in Engineering & Science, 2 (1) 2013, ISSN 2319–5665.

[3] FERRIRA R., HERNANDES J.A.: *Structural Optimization of Reinforced Panels Using Catia V5*. 19th International Congress of Mechanical Engineering, November 5–9, 2007, Brasillia.

[4] KONIG O., WINTERMANTEL M.: *CAD-based Evolutionary Design Optimization with CATIA V5*. EVEN – Evolutionary Engineering AG, Zurich, Switzerland, Weimarer Optimierungs – und Stochastiktage 1.0, December 2004.

[5] IRSEL G., ALTINBALIK T., ÇAN Y.: *Failure Investigation of the Disc Harrow Profiles and Redesigning by CATIA Analysis*. Applied Mechanics and Materials 729, 2015, p. 181–186.

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Abaqus, Deform 3D, Numerical analysis, Stress

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NUMERICAL ANALYSIS OF AN ALUMINIUM PROFILE UNDER BENDING USING ABAQUS AND DEFORM-3D

Abstract

The paper describes the process of symmetric bending of an aluminium specimen using two independent environments for numerical analysis. A FEM analysis is performed on an aluminium channel section. A comparison is made between the bending process performed in the Abaqus environment and that run with the Deform-3D system. In both numerical analysis systems, the crucial point is to determine the state of reduced stresses for a designed computer model. The paper provides a visual comparison of the profiles subjected to bending; it also determines displacements and stresses in the tested structures. To perform a nonlinear static analysis, we define a material model, determine boundary conditions, interactions as well as generate a mesh. The results produced with the two numerical systems agree to a very high extent.

1. INTRODUCTION

Aluminium channel section profiles are widely used in a number of building fields and mechanical engineering. These profiles are frequently used to ensure support and higher rigidity of structures. An advantage of using channel section profiles is their relatively high weight strength compared to their relatively small weight. The most widely used profiles are made of aluminium. Irrespective of their length, channel section profiles can carry exceptionally heavy loads, that is why they are commonly applied. The situation changes when these structures are exposed to loads that cause bending. A great deal of studies mainly

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investigate the state of effort and instability for specified critical forces of channel section structures. Most analyses describe buckling states of thin-walled profiles subjected to precisely specified axial loads. In particular, the works [3, 4, 6, 7] investigate rigidity and buckling states for specifically defined boundary conditions. There is a scarce number of publications that deal directly with the problem of cross bending in open channel profiles. The studies [5, 8, 9] report the result of bending and stresses in channel section profiles obtained with Abaqus 6.14. Profile forming is very often used to produce decorative elements and frame constructions for the automotive industry. The process of forming aluminium profiles is described in the work [2]. Other publications report the numerical results of bending processes performed using Deform-3D [1, 10, 11]. The numerical environments described in this paper are two totally independent simulation packages. Abaqus is a system for numerical analysis of strength, thermal and electric processes, flow analysis etc. Deform-3D is mainly used for plastic analysis and formation of plasticized structures. The two programs cannot be operated jointly, nor do they enable rapid file sharing due to their totally different numerical environments. The objective of this paper was to compare the state of strength of two identical models of channel section profile. The analysis of a plastic-elastic model takes into account non-linear behaviour of material. Due to reaching the yield point, the material's rigidity changes in relation to the elastic range. The numerical simulations did not took account of material temperature or the temperature affecting the model from the outside. In terms of material strength, bending is a state of object deformation wherein a straight non-deformed beam becomes curved after the application of load. There are numerous theories about types of bending and relationships describing this process. Nonetheless, this paper focuses on investigating stresses and their distribution within the entire model. Although beam resistance to transverse loads has been studies for a very long time, solving it using two totally independent systems is an innovative approach to this problem.

2. MATERIALS AND METHODS

The investigation was performed on a channel section beam made of aluminium. The beam had a length of 250 mm, a thickness of 2 mm and the standard dimensions of 40x20 mm. The material model was ascribed the properties of PA45 aluminium, also denoted as 6061. Young’s modulus was 70000 MPa, the Poisson ratio was 0.33. The yield point R_e, was 250 MPa, the maximum strength R_m, was 300 MPa, while the elongation at maximum strength was roughly set to 9 %. The material properties of the described model were defined in an identical way for both numerical environments. Description of the analysis was consistent with the mathematical relationships presented below, where σ – stress, ε – strain, v – strain rate, T – temperature.

$$\sigma = f(\varepsilon, v, T) \tag{1}$$

Material properties defined in Abaqus are described above, while the plastic properties assigned in the Deform-3D system are listed in a figure below.

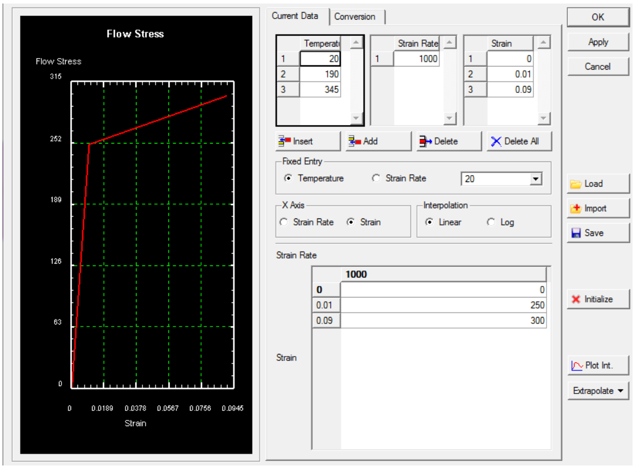


Fig. 1. Plastic characteristics of the tested material [source: own study]

A table given below lists the chemical composition of the modelled aluminium alloy.

Tab. 1. Chemical composition of aluminium alloy [1]

Chemical composition [%]							
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
0.3- 0.6	0.1- 0.3	max 0.1	max 0.1	0.35- 0.6	max 0.05	max 0.15	max 0.1

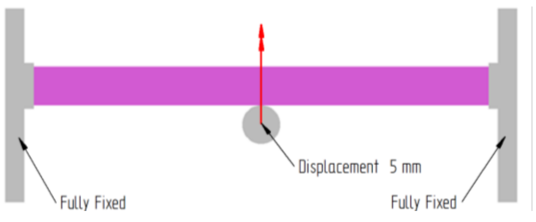
The tested material was characterized by good strength, fatigue strength and bending strength. Aluminium PA45 is an Al – Mg – Si – Cu alloy. This alloy is subjected to supersaturation and artificial ageing at a suitable temperature and for a suitable time. Owing to its properties, this alloy can be easily subjected to metal forming operations such as bending and press forming, which enables forming complicated shapes of profiles and sheet metal plates.

To perform Deform-3D calculations, the material properties of aluminium are imported from external tables. To perform a numerical simulation in Deform-3D, it was necessary to create spatial models using some other CAD program, since Deform-3D only enables the design of basic geometric solids, such as cuboid and cylinder models. However, models of solids designed in other programs can be imported to Deform-3D into a CAD file. We designed the models of solids using Solid Edge ST7, and then exported them to files with the extension *.stl. Following the import of the models and fixing them in a way that reflected the real system, the channel section solid was assigned relevant plastic-elastic material properties via creation of a material model. Next, we indicated the regions of surface interaction and set a friction factor between the tools and aluminium (μ=0.2). The channel section profile was fixed in the measuring system such that the forming tool presses on the lower surface of the element. The profile was subjected to bending by a 20 mm diameter roll. The boundary conditions describing the motion of the tools were set such to reflect the real behaviour. The profile-bending roll moves at a constant velocity of 2 mm/s (which must be defined in the program) over a distance of 5 mm. The profile of a thin-walled channel section was mounted on two fully fixed supports.

The numerical simulation in the Abaqus environment was performed in a similar manner. First, we drew the channel section profile stretched to a desired length. Other subassemblies were also designed using this system. After that, we defined material properties of aluminium described earlier in this paper. Next, all the above were put together via functions available in the program in order to continue the FEM analysis. We determined the relationships pertaining to contact between cooperating tangential and normal surfaces for a friction factor typical of aluminium. The numerical model was examined only based on nonlinear static analysis in accordance with Newton's first law of motion where forces of inertia do not occur (i.e. the system does not accelerate). The boundary conditions were defined in the same way as in Deform-3D where the profile-supporting elements were fully fixed, while the 20 mm diameter roll underwent a uniform displacement in the opposite direction relative to the Y axis, which led to symmetric bending of the fully fixed thin-walled channel section profile.

The numerical models and their boundary conditions are shown in a figure below.

a)



b)

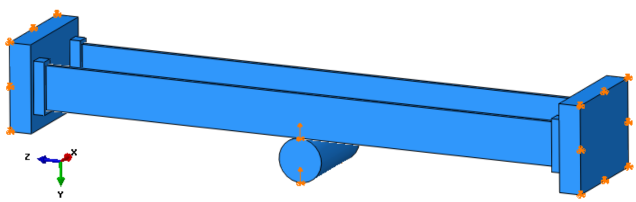
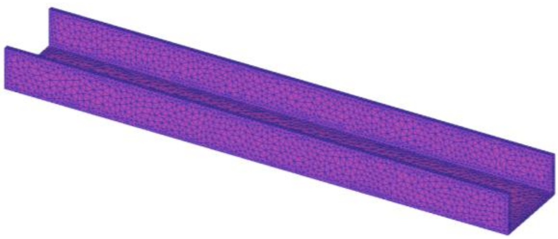


Fig. 2. Numerical model and its boundary conditions:
a) Deform-3D, b) Abaqus [source: own study]

The final stage of defining the numerical process involved generating a finite element mesh. The mesh in Deform-3D was defined according to the program's capacity (it was impossible to select any other mesh type). The mesh of the channel section was made up of 29671 tetragonal elements.

The discretization process was run differently in the Abaqus software. This program enables the user to determine a mesh depending on demand and results accuracy. Initially, the discretization involved model partitioning to obtain a structure with a uniform type of mesh element. Following the model partitioning, we obtained the best possible type of hexagonal elements – C3D8R (i.e. elements with three degrees of freedom, eight nodes and reduced integration). The mesh was made up of 15032 elements and 22992 nodes for the channel section, the supports and the bending roll. Despite the much smaller number of finite elements and thus a much lower density of this mesh, the results are similar to those of the tetragonal mesh obtained with Deform-3D. The FEM mesh generated in both environments for numerical analysis is shown in a figure below.

a)



b)

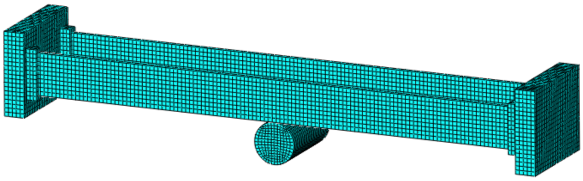


Fig. 3. Numerical model and it FEM mesh:
a) Deform-3D, b) Abaqus [source: own study]

3. RESULTS

This study investigated a bending process by the finite element method. In the analysis, we compared the tested material's strength properties and the numerical results obtained with two FEM-based simulation programs. The study involved investigation of reduced stresses and displacements at forced displacement of the profile-bending roll. Below we provide figures illustrating the agreement of the results produced with Deform-3D and Abaqus.

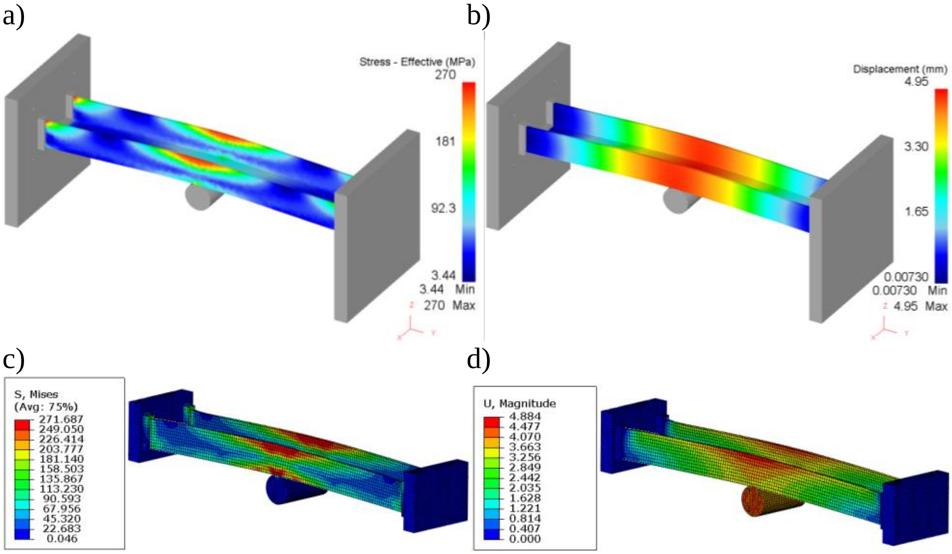


Fig. 4. Numerical results of stresses and displacements: a) effective stress in Deform-3D, b) displacement in Deform-3D, c) effective stress in Abaqus, d) displacement in Abaqus [source: own study]

The numerical results obtained with Abaqus and Deform-3D show very high agreement. The simulations performed in Deform-3D led to the production of a deformed profile made of aluminium alloy. The profile was subjected to bending to about 5 mm, which led to deformation of the profile's arms. The highest stresses can be observed in the upper part of the profile's arms and the effective stress is almost 270 MPa. The yield point is exceeded after the bending roll has travelled a distance of about 2.2 mm.

The Abaqus results show very high agreement. As the roll travels, the stresses gradually increase to reach 271.7 MPa at the maximum displacement of about 5 mm. At 2.23 mm, the stresses exceed the yield point**.**

The results of reduced stresses produced using two different numerical systems differ only by 0.6 %. By defining the problem via setting parameters of the model, material properties, interactions, boundary conditions and numerical meshing, we could compare different types of physical and mechanical problems. The high agreement between the FEM results means that the numerical computations are precise, irrespective of employed advanced systems for investigating different processes such as bending. Despite the fact the number of the FEM mesh elements (tetragonal elements) used in the Deform-3D model is almost twice as high, the results are similar to those of the hexagonal mesh model in Abaqus. The similarity of stresses and displacements indicates accuracy of the analysis results produced using two independent numerical environments.

4. CONCLUSIONS

Numerical analysis reflects real operating conditions very closely, hence it can provide a number of solutions to be implemented in practice. The research on thin-walled channel section structures under bending is widely used to determine a degree of profiles exertion with specified material properties. The simulations enabled determination of effective stress in crucial regions of the structure. The results can be visually presented to illustrate modes of the profile's deformation during the simulation.

The FEM analysis results have led to formulation of the following conclusions:

- the numerical results show very high correspondence despite the application of different computational procedures (nonlinear statics in Abaqus and kinetics in Deform-3D),
- the parallel results prove that the plastic-elastic properties of the material were defined in a similar way,
- the numerical results are similar despite the use of different types of FEM mesh,
- irrespectively of the applied computational procedure, the boundary conditions were defined in the same way for both programs (fixing, displacement),
- the Abaqus and Deform-3D results of reduced stress for the applied displacement of the bending roll are corresponding,
- the shape of beam deflection and the regions of concentration of the maximum stresses are similar.

The analysis of the bending process for a thin-walled aluminium channel section profile led to determination of stresses and displacements.

The applied simulation software packages based on different computational algorithms produced similar results. Despite the use of two independent programs, the obtained modes of beam deflection are similar and the results of the effective stress agree to a very high degree.

The results open up possibilities for analyzing similar problems as well as further investigation of the problem discussed in the paper, e.g. with respect to specimen failure.

The results are confronted with both the assigned material properties and the results obtained using two independent programmes for material strength testing, Abaqus and Deform-3D, which are ideal tools for investigating stresses and displacements in thin-walled open channel structures.

REFERENCES

[1] CHIBA R., YOSHIMURA M.: *Solid-state recycling of aluminium alloy swarf into c-channel by hot extrusion*, Journal of Manufacturing Processes, 17, 2015, p. 1–8.

[2] CHOI Y., YEO H.T., PARK J.H., OH G.H., PARK S.W.: *A study on press forming of automotive sub-frame parts using extruded aluminum profile*, Journal of Materials Processing Technology, 2007, p. 85–88.

[3] DEBSKI H., JONAK J.: *Failure analysis of thin-walled composite channel section columns*, Composite Structures, 132, 2015, p. 567–574.

[4] DEBSKI H., KUBIAK T., TETER A.: *Experimental investigation of channel-section composite profiles behavior with various sequences of plies subjected to static compression*, Thin-Walled Structures, 71, 2013, p. 147–154.

[5] KUBIAK T., KACZMAREK L.: *Estimation of load-carrying capacity for thin-walled composite beams*, Composite Structures, 119, 2015, p. 749–756.

[6] KUBIAK T., SAMBORSKI S., TETER A.: *Experimental investigation of failure process in compressed channel-section GFRP laminate columns assisted with the acoustic emission method*, Composite Structures, 133, 2015, p. 921–929.

[7] MANIA R. J., KOLAKOWSKI Z., BIENIAS J., JAKUBCZAK P., MAJERSKI K.: *Comparative study of FML profiles buckling and post buckling behavior under axial loading*, Composite Structures, 134, 2015, p. 216–225.

[8] PASZKIEWICZ M., KUBIAK T.: *Selected problems concerning determination of the buckling load of channel section beams and columns*, Thin-Walled Structures, 93, 2015, p. 112–121.

[9] RÓŻYŁO P.: Optimization of I-section profile design by the finite element method, Advances in Science and Technology Research Journal, 10(29), 2016, p. 52–56.

[10] WANG D., XU K., JIANG Z., LI R., ZHANG X., ZHANG Y., QIN S.: *Research on the cracking of the thick steel plate in the bending process,* IEEE, 2014, p. 5020–5023.

[11] ZHANG L. H., ZHANG Z. C., LI S. Y., CUI H., CUI H. X.: *FE simulation and bending speed optimization of N-TR continuous grain flow forging process for solid heavy crankshaft*, Obróbka Plastyczna Metali, 2006, p. 3–13.

[12] Abaqus HTML Documentation.

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information resource, content analysis, content monitoring, content search, electronic content commerce systems

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INFORMATION RESOURCES ANALYSIS IN ELECTRONIC CONTENT COMMERCE SYSTEMS

Abstract

The article is dedicated to the development of unified methods and software tools for processing information resources in the electronic content commerce systems. A new detailed classification of electronic commerce systems and electronic content commerce systems is proposed. A formal model and generalized typical architecture of electronic content commerce systems are declared. Architecture and models of electronic content commerce systems are built.

1. INTRODUCTION

Active development of the Internet has increased the need for operational data production/strategic design and implementation of new forms of information services [1]. Documented information prepared in accordance with the needs of the users of an information product or commercial content, and the main object of processes of electronic content commerce [1–2, 12–13, 20]. Issues of design, creation, implementation and maintenance of electronic content commerce system (ECCS) is relevant, taking into account such factors as the lack of theoretical justification of standardized methods and the need for the standardization of software tools to process information resources.

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There is a mismatch between the methods and means of the processing of information resources and the principles of ECCS [1, 5]. A practical factor in the processing of information resources in ECCS linked to the problem of growing volumes of content in the Internet, the rapid development of electronic business, the rapid spread availability of the Internet, expanding the set of information products and services, the demand for commercial content [1]. Principles and techniques of electronic content Commerce is used when creating the online stores (selling eBooks, Software, video, music, movies, picture), systems on-line (Newspapers, magazines, e-learning, publishing houses) and off-line distribution of content (copywriting services, Marketing Services Shop, RSS Subscription Extension), cloud storage and cloud computing [1]. Work in this area is the world's leading manufacturers of means of processing of information resources as Apple, Google, Intel, Microsoft, and Amazon. The theoretical factor processing of information resources in electronic content Commerce is associated with the development of methods and means of formation, management and maintenance of content. In the scientific papers of Lande D. researched and developed mathematical models of electronic information flows [4, 14–15]. Zipf G. proposed an empirical law distribution of word frequencies in natural language [14–15]. Authors are described the content lifecycle in the works [3, 6–7, 10–11, 16–19, 21–25]. Kaiser J., Glaser, Lasswell H., Holsti O. will founded and developed methodology content analysis [9, 20]. EMC Corporation, IBM, Microsoft, Alfresco, Open Text, Oracle and SAP have developed specifications Content Management Interoperability Services for Web services interface that enables interoperability between content management systems e-business [8].

The aim of this work is to develop methods and software tools for the processing of information resources to improve the efficiency of electronic content commerce through the increased sales volume of commercial content.

The studies were conducted according to the plan of research works of National University "Lviv Polytechnic" in the framework of the state budget theme "Development of methods, algorithms and software for modelling, design and optimization of intelligent information systems based on Web technologies "WEB" (number of state registry. 0102U001171). The study is part of research projects of the Department of Information systems and networks of National University "Lviv Polytechnic".

2. CONTENT PROCESSING

2.1. Content features

The content has several interpretations according to the direction of application [1]. In the field of computer science content is information create content (e.g., texts, graphics, multimedia) information resource; the set of all values and quantities, which operates an information system; some generalized notion of data without predetermined patterns [1–2, 20]. Accordingly, the information resource is a collection of structured and/or unstructured arrays of content in the information system, for example, libraries, archives, repositories, collections, websites, handbooks, dictionaries, banks/bases/data warehouses, systems e-commerce etc. [1]. The market of content distribution provides the technological process of preparation of the operational content available through information resources and dependent on perception, display, and conservation of its values. To study and solve a range of tasks moderators information systems formalize, analyze, format and structure the content. Structuring process is the definition of a unit of content, methods and the order of their combination with each other and the formation of large content items from small [1–2, 14–15, 20]. Formed the content entered in database/data warehouse, where determine its direction and subject matter, for example, electronic publications with a large coefficient of demand from visitors and users of the information resource (Fig. 1). Structured content is concentrated, for example, in ERP/CRM and unstructured content in e-mail, working papers of arbitrary format and tools to ensure teamwork and stored, for example, ECMS [1].

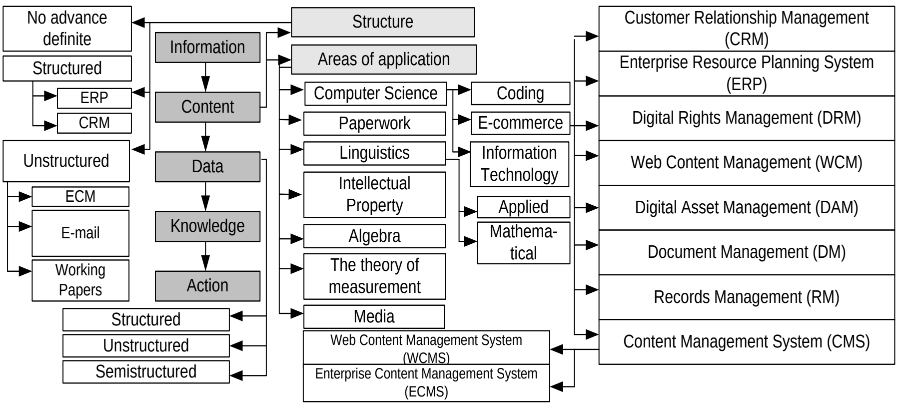

Fig.1. Classification patterns and directions for use content [source: own study]

2.2. Content lifecycle

Content lifecycle is a complex process, which passes the content while driving through different stages or phases of a publication with a set of properties, such as collaboration, records management, digital assets, and for other various IT [1–3, 6–8, 10–11, 16–25]. Existing toolkits for e-Commerce gives the administrator or the moderator system various options for management of content (form, formalize, organize, add, edit, delete), but not solve the problem of automatic processing of information resources. Therefore, for the implementtation of the life cycle of content, you need a Toolkit that implements the automatic processes of content formation, administration and support [1, 2, 20]. The content is characterized by the time of renewal or modification and has a set of specific properties (Fig. 2). The amount of content measured in units of the amount of information (bits/byte). The quantity and quality of content is describing the degree of user's interest in information resources, where he is placed [1, 5]. **Web content** is the content, text, visual, audio or a part of the experience of the medium [1, 5]. Economic content is an element of the economic activity of the subject of the e-business (Fig. 3). Content market on the basis of the Internet with the it knowledge management are the means that contribute to the functioning of e-business with the proliferation of commercial content and the growth of its profitability for the subjects of e-commerce [1–2].

2.3. Commercial Content features

Commercial content is the object of purchase/sale between the participants of e-commerce [1–2, 20], for example, information blocks, which are divided into syndicates (exchange rates, weather block), other announcements of topics/resources (with reference), reference information (holiday dates, event announcement, timetable), entertainment information (the joke of the day), advertising, buttons and links media partners, the statistics button. Managing business processes is an important stage in the life cycle of commercial content. To determine the relevance/accuracy of commercial content (the latest information on a particular issue) it is necessary to clearly manage business processes through workflow (automation processes control the flow of work in information systems).

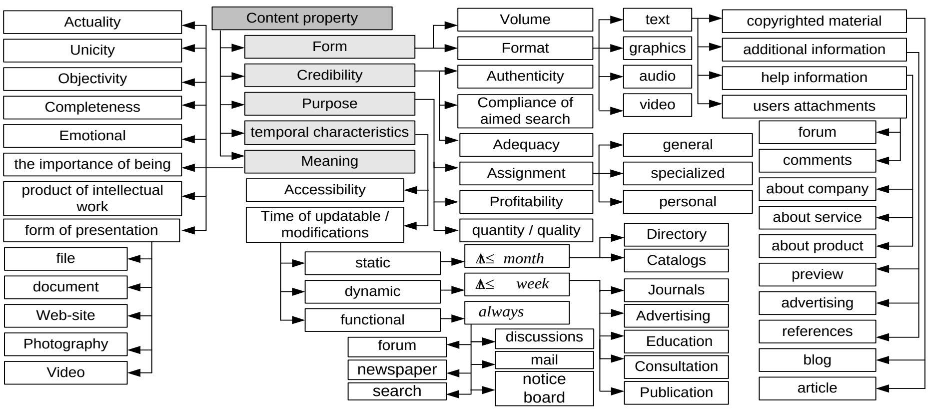

Fig. 2. The main properties of the content [source: own study]

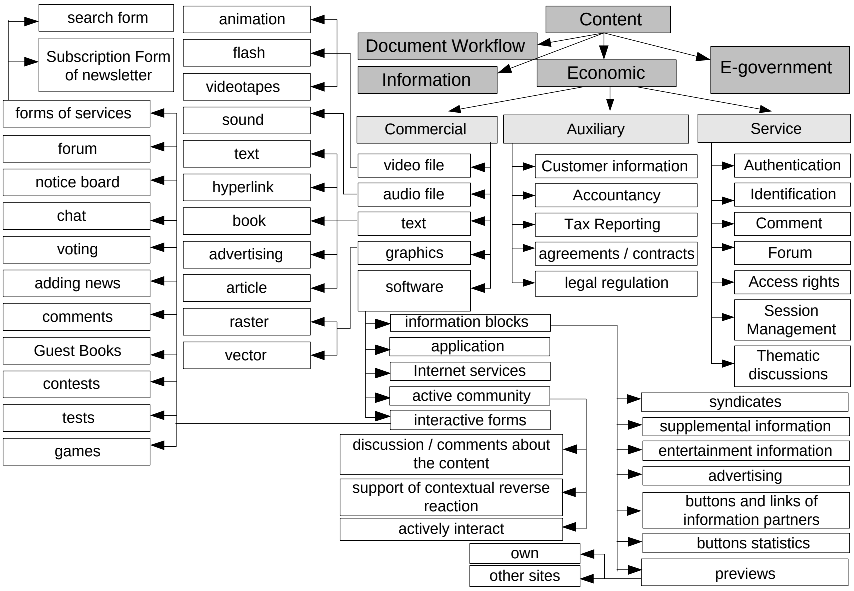

Fig. 3. Classification of commercial content [source: own study]

2.4. Electronic content commerce system

E-Commerce is a special case e-business, for which commercial content is a valuable asset (Fig. 4–5, Table 1). For fast business growth account effective policies e-Commerce: protection of intellectual property; interactive trust (protection and privacy of content); free/open trade; active investments in its infrastructure [1].

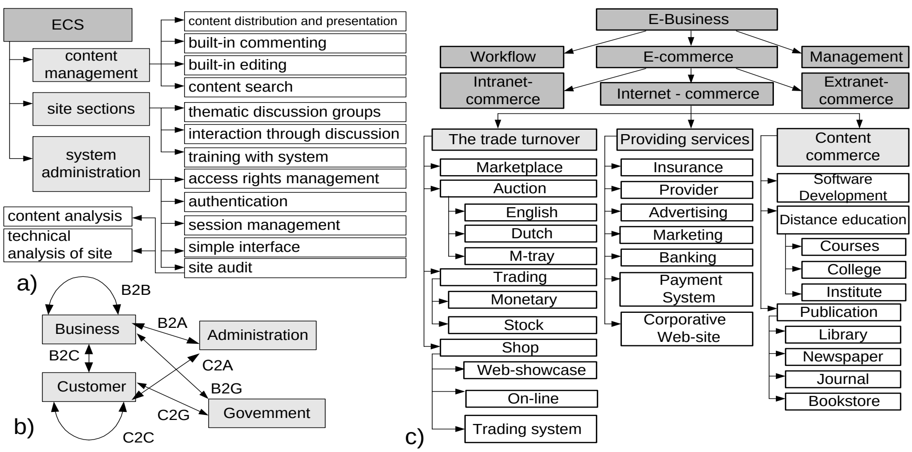

Fig. 4. a) Functions; b) the relationship and c) the typology of ECCS [source: own study]

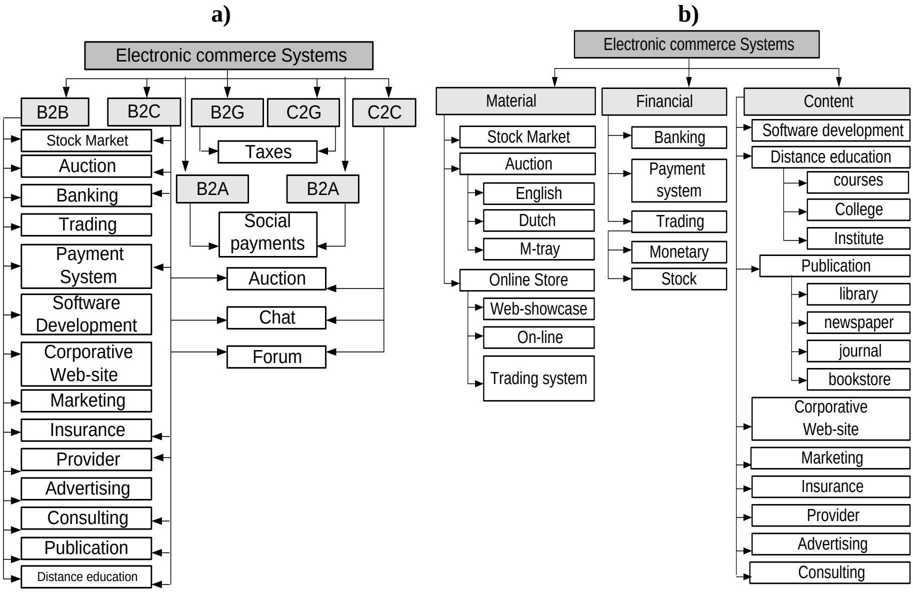

Fig. 5. (a) Category and (b) the business processes of e-commerce systems [source: own study]

Tab. 1. E-commerce categories [1]

Type	Category	The definition
B2B	Busines-to-Busines	business transactions between the companies;
B2C	Busines-to-Customer	electronic retail trade;
B2A	Busines-to-Administrarion	administrative workflow;
B2G	Busines-to-Government	transactions between companies and government agencies;
C2A	Customer-to-Administrarion	interaction with the administration (social benefits);
C2G	Customer-to-Government	interaction with government agencies (e.g., taxes);
C2C	Customer-to-Customer	commercial activity between individuals.

1. All forms of trade goods/services through electronic means, including the Internet, which gives you the opportunity to develop new markets, but the question of information security and intellectual property [1] that solves Digital legal management.

2. A wide range of interactive methods of conducting is the delivery/sale to consumers of goods/services.

3. Any form of business transactions, where the parties interact through it, and not in the process of physical exchange/contact. For example, an electronic data interchange, EDI – a processes set for content creating, processing, managing, transmitting, receiving, storing, use and destruction, which are carried out with integrity and with confirmation of the fact of its receipt [1].

4. The use of electronic communications and technologies, the electronic data to establish and modify relationships, value creation between organizations and individuals.

5. Doing business online in the following areas: direct sales of goods and services; banking and billing (payment system); the safe placement of content; corporate procurement.

To implement ECS is difficult because of such problems as cost, value, safety, interoperability [1]. The Internet provides alternative and complementary way of doing e-business, but ECS must be integrated with other systems to avoid duplication of functionality and maintaining their applicability, current work and reliability. When the ability of the ECS is automatically share content business reaches reduction of cost, improved performance, and increase agility-chains of added value.

2.5. The system of electronic content commerce

The system of electronic content commerce, ECCS is an information system automated support of processes of processing of information resources e-Commerce and promote the commercial content in global markets (Fig. 6, a) [1].

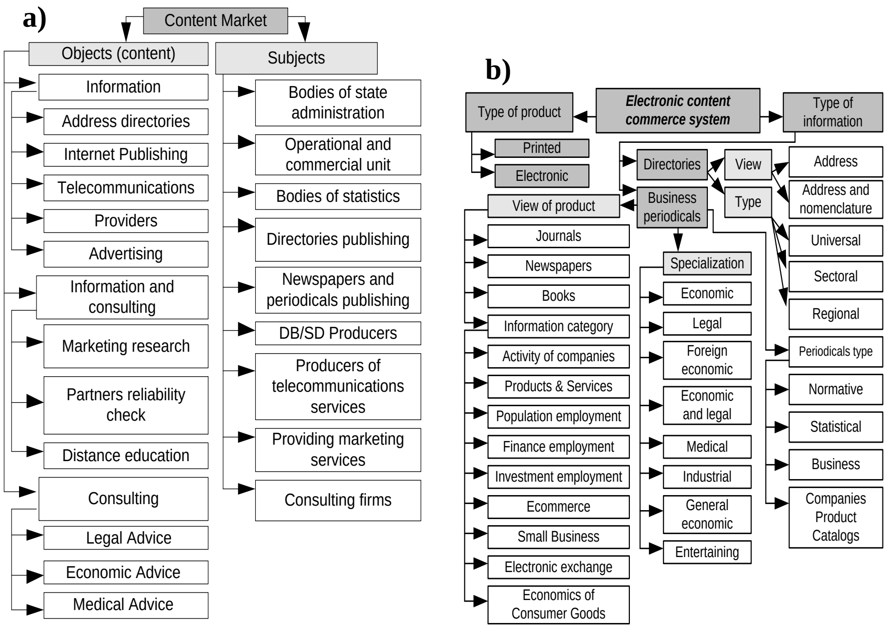

Fig. 6. ECCS classification by type (a) business and b) commercial content [source: own study]

3. PROCESSES IN ELECTRONIC CONTENT COMMERCE SYSTEM

Prospects of development of ECCS due to a combination of economic, social, technology, legal factors, significant among which are the multifunctional of the Internet; economic liberalization and the globalization of the economy; organizational and technical availability and economic efficiency of e-commerce for market participants. Depending on the range of content, level of information technology, status, way of creating ECCS divided into universal/specialized/ independent/niche; the elements of traditional publishing; corporate, private and rented. Content is an important factor of reference e-business with such features: a significant increase in the demand for content; the introduction of a fundamentally new technology through the rapid development of e-commerce; the rapid expansion of the software to create ECCS. The number of content streams is considerably greater than the movement of goods in industrial enterprises (Fig. 7) [1].

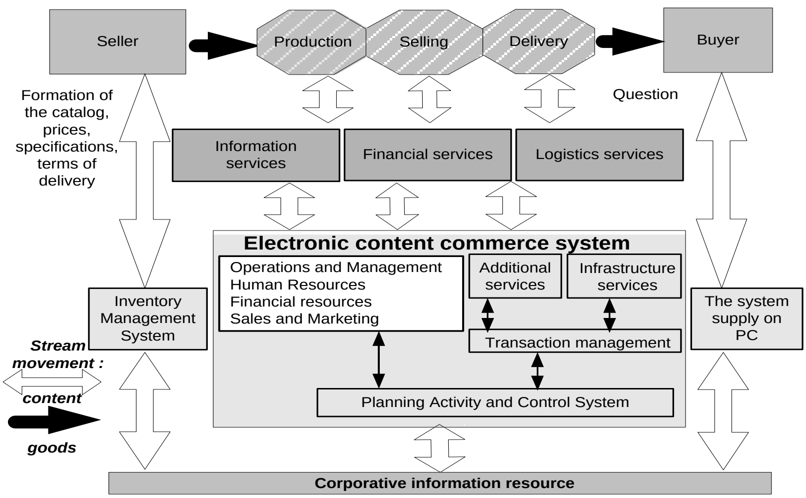

Fig. 7. Flow schematic content in ECCS [1–2]

The consumers of content satisfy the information needs in these ways: visit the information resources or database/data warehouse; periodically receive content by e-mail; connect to specialized systems/networks. Among the tasks of providing content highlight the insolvency of debtors, increased cost, minimization of tax payments, sales of products on the market. The main areas of research is the methods improvement and development of strategic planning e-business; introduction of quality management systems, personnel and content name flows and e-commerce technologies. Content consist of easily formalized and automated procedures (Fig. 8) at [1–2, 14–15, 20].

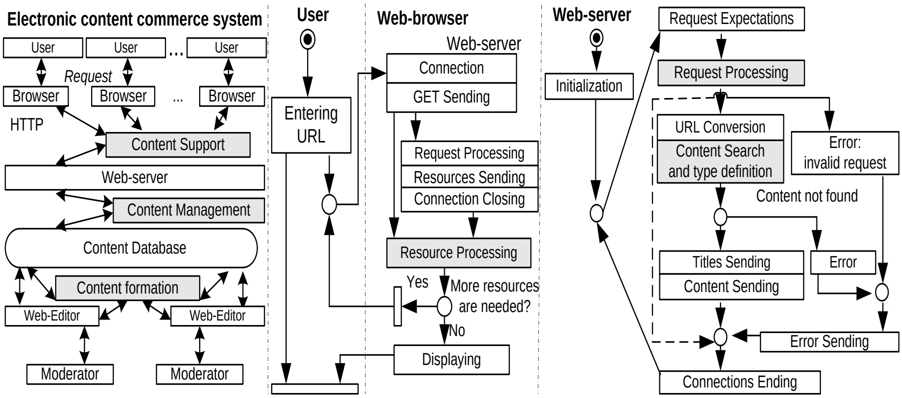

Fig. 8. The scheme of functioning of system of e-Commerce [1–2]

The core of the process of content sharing is ECCS. Processing of information resources in ECCS is a powerful and effective means of conducting e-business. ECCS is the main effective tool of e-commerce to implement practically any operations on the resource through a user-friendly interface (tab. 2) [1]. Information resource in ECCS is the link between users and the system (tab. 3). Administration system provides processing of information resources in ECCS (settings routines, administration of users/groups, management communication). ECCS mounts to information resources in a variety of applications, such as advertising, search engine optimization and special programs.

Tab. 2. Tools classification of electronic content commerce systems [1–2]

Name	Definition
Corporate website	Information page/resource data about the company, project, content, type of activity, proposals for cooperation, which has a hierarchical structure and the optimum scheme of the functioning (Berko et al., 2009).
Internet publishing	The sort of online shop where the goods for sale – urgent for some time, thematic content, classified and presented at the information resources.
Provider	Providing access to the Internet and information services.
Internet advertising	Commercial promotion of consumer qualities of goods for the purpose of increasing demand.
Distance education	Courses on the profile or e-learning (where the content is a lot of knowledge) followed by production of a document about the study course in their field or specialty.
Content portal	A complex system for managing business processes and content name flows of the company created on the basis of the corporate information resource and is integrated with ECCS.
Internet marketing	Management system production/marketing activities of the enterprises/companies, based on a comprehensive analysis of the market, study/demand forecasting, pricing, advertising, coordination of planning and funding, creating new types of content, and the like.

Name	Definition
Software development	Design, development and maintenance in the on-line mode via the Internet.
Subscribe to content	The subsystem of automatic thematic subscribe to newsletter content.
Content distribution	The electronic subsystem periodic distribution of content among users.
Web-showcase (information resource)	Allows you to organize the trade only to order; does not allow to establish trade via the Internet; does not reduce operating expenses and for the maintenance of the state; clumsy and inflexible solutions for managing and organizing marketing activities; inefficient and unprofitable trade organization.
The content management system	Allows you to establish trade via the Internet; reduces operating costs and in staff; clumsy, but flexible solution from the point of view of management and organization of marketing campaigns; ineffective and inefficient organization of trade.
The system of electronic content Commerce	Allows you to establish trade via the Internet; reduces operating costs and in staff; effective and flexible solution from the point of view of management and organization of marketing campaigns; efficient and cost-effective organization of trade; the creation of more one-off costs in comparison with Web content management system showcase.

Tab. 3. Information resource components of electronic content commerce systems [1]

Name	Appointment
The menu constructor	Management of various types of menus and adding new paragraphs; creating a submenu in unlimited quantities; easy to edit the name of the menu; delete, copy or move menu.
The content editor	Edit the content of any page in accordance with the needs; the introduction of content pages manually in the field or by copying from another editor; format the content in accordance with the requirements, insert graphics, links, flash movies on the page.
Linking pages	Prelingually page to any other, after which this page has the same content; the abolition of linking and restore the original content.
Manage pages	Setting the page title, keywords, meta tags, the date of publication; the abolition of the date of publication; if necessary, hide pages from the menu, which is accessible only with a direct link to it.
Pages	Set the content of the information resource to the user. Used for HTML markup and consist of many fragments of the body (the main content and sidebar (sidebar navigation).
Snippets	Code snippets with content that is contained in several places information resource.
Layout	Theme General layout is responsible for page design and issue of the pages in any desired way, for example, to generate the body and sidebar of the page, or generates only the body element for page version for printing.

Internet marketing involves the use of strategies and directions of traditional direct response marketing and special areas of research that apply to e-business the Internet space. Internet marketing is not only the trade of content, but also information space, software, business models and so forth [1]. Google, Yahoo, and MSN lifted to a new level and have segmented the market of Internet advertising, offering e-business services for local advertising. Through automation of the process of audience research is increasing, and costs are reduced. The number of streams of content is more than the movement of goods in industrial enterprises. A major proportion of the content consists of easily formalized and automated procedures. The main problem is the lack of a common approach to process modelling, design and development of ECCS.

Model of ECCS filed as:

$$S = \langle X, Q, C, V, H, Function, T, Z, Y \rangle, \tag{1}$$

where: $X = \{x_1, x_2 \dots, x_{n_X}\}$ – a lot of content from various sources,

$Q = \{q_1, q_2 \dots, q_{n_Q}\}$ – many of the requests for information of users,

$C = \{c_1, c_2 \dots, c_{n_C}\}$ – many commercial content,

$V = \{v_1, v_2 \dots, v_{n_V}\}$ – the terms set of tracking content and external influences of the environment on the system,

$H = \{h_1, h_2 \dots, h_{n_H}\}$ – the conditions set of content management,

$Z = \{z_1, z_2 \dots, z_{n_Z}\}$ – the set of components of an information resource,

$T = \{t_1, t_2 \dots, t_{n_T}\}$ – the time of transaction and content management,

$Y = \{y_1, y_2 \dots y_{n_Y}\}$ – a set of output characteristics of the system,

$Function$ – the operator of the formation of the output data of ECCS.

The process of content S management system describe the operator

$$y_j(t_p + \Delta t) = Function(x_i, q_d, c_r, v_l, h_k, t_p, z_w), \tag{2}$$

where: x_i – the visitor/user to the content management system [5].

The value of $y_j = \{a_1, a_2, \dots, a_g\}$, where a_1 is the number of visits for the time period Δt, a_2 is the average time of visit information resource (min:s) over a period of time Δt, a_3 is the bounce rate (%) over a period of time Δt, a_4 is achieved the target of the search, a_5 is dynamics content (%), a_6 is number of page views a_7 is number of page views per visit, a_8 is new visits (%), a_9 is absolutely unique visitors, a_{10} is source of traffic, in %, etc [5]. Influence quantities x_i, q_d, c_r, v_l, h_k on values z_w and y_j as a result the ECCS are unknown and unexplored [1, 5]. The model does not reveal the links between inputs, content, output and processing of information resources in the system. This justifies the purpose, relevance, appropriateness and direction of the study.

The main steps involved in processing of information resources in electronic content commerce is the formation, administration and support of content that have the following bundles *content* $\rightarrow$ *content formation* $\rightarrow$ *database* $\rightarrow$ *content management* $\rightarrow$ *information resource or a user request* $\rightarrow$ *content management* $\rightarrow$ *information resource* $\rightarrow$ *support content* $\rightarrow$ *database*. ECCS Model filed as

$$S = \langle X, Q, Formation, H, C, V, Management, Support, Z, T, Y \rangle, \qquad (3)$$

where: X – a lot of content from various sources,
Q – many user requests,
$Formation$ – the operator of the formation of content,
H – a number of conditions of formation and management of content,
C – a lot of commercial content,
V – terms set of tracking content and external influences on system,
$Management$ – operator content management,
$Support$ – operator support content
Z – the set of components of an information resource,
T – the time of the information resources transaction and processing,
Y – many of the statistical data of the system.

The operator of a profit-content is display commercial content to a new state that differs from the previous introduction of a new piece of content that complements its previous state. The operator in the management of commercial content is display commercial content to a new state that differs respectively from the previous values of the governing parameters (relevance, completeness, relevance, authenticity, credibility) that meet pre-specified requirements. The operator of the commercial content – display commercial content in a collection of values, which form as a result of analysis, monitoring, evaluation, user interaction, search engines and other information resources, which is the basis for making decisions regarding the formation and management of content. Stage of formation of the content described by the operator $Formation$ of the type $c_r = Formation(u_f, x_i, t_p)$, where u_f is conditions set of content formation $u_f = \{u_1(x_i), \ldots, u_{n_U}(x_i)\}$. The contents are as follows:

$$c_r = \left\{ \bigcup_f u_f \,\middle|\, (x_i \in X) \wedge (\exists u_f \in U), U = U_{x_i} \vee U_{\overline{x_i}}, i = \overline{1,m}, f = \overline{1,n} \right\}.$$

Stage content management is described by the operator $Management$ of the type $z_w = Management(q_d, c_r, h_k, t_p)$, where Q is multiple requests, H is multiple conditions of electronical commercial content management $H = \{h_1(c_{i+1}, q_d), \ldots, h_{n_H}(c_{i+n_H}, q_d)\}$. Content management filed as

$$z_w = \left\{ \bigcup_{k=1}^{n_H} h_k(c_{i+1}, q_d) \middle| \begin{array}{l} (c_{i+k} \in C) \wedge (q_d \in Q) \wedge (h_k \in H_q), \\ H = H_{q_d} \vee H_{\overline{q_d}}, i = \overline{1, n_C}, d = \overline{1, n_Q}, k = \overline{1, n_H} \end{array} \right\}.$$

Stage accompany content is described by the operator *Support* of the type $y(t_p + \Delta t) = Support(v_l, h_k, c_r, z_w, t_p, \Delta t)$, where v_l is the set of terms of tracking content and the effects of the environment on the system, that is $v_l = (v_1(q_i, h_k, c_r, z_w, t_p), \ldots, v_{n_V}(q_i, h_k, c_r, z_w, t_p))$. Output implemented

$$y_j = \left\{ \bigcup_l v_l \middle| \begin{array}{l} (\exists q_d \in Q) \wedge (\exists z_w \in Z) \wedge \wedge (\forall v_l \in V) \wedge (\forall (c_r \wedge q_d) \in h_k), \\ V = V_{q_d} \vee V_{\overline{q_d}}, d = \overline{1, n_Q}, l = \overline{1, n_V}, w = \overline{1, n_Z}, r = \overline{1, n_C}, k = \overline{1, n_H} \end{array} \right\}.$$

Content formation is a set of measures ensuring control data from various sources to create commercial content with a set of values, such as relevance, reliability, uniqueness, completeness, accuracy, and the like. Content management is the complex measures of the values support of the defining parameters of content, relevance, completeness, relevance, authenticity, validity of certain requirements by a set of criteria. Content support is a set of measures to ensure the functioning of the system of electronic content Commerce according to certain requirements and any further changes to these requirements. For full featured ECCS characterized by a complex system of interrelated operations, methods, techniques, presented in Fig. 9.

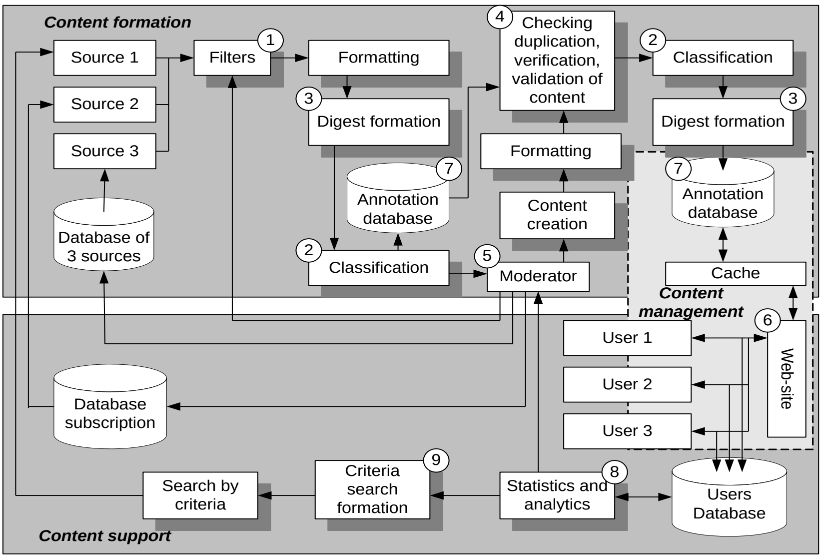

Fig. 9. Methods of processing information resources in ECCS [source: own study]

As a result of the analysis of functioning of system of electronic content commerce S and maintenance of the content C is set $Y = \{Y_P, Y_T, Y_C, Y_R\}$ according to the conditions $V = \{V_P, V_T, V_C, V_R\}$, where $Y_P = Y_{Pc} \vee Y_{Pq}$ – is a subset of information portraits content Y_{Pc} and users Y_{Pq}, Y_T – a subset of the thematic subjects of the content Y_C - is a subset of the tables of the relationship of content Y_R – is a subset of the ratings of the content $V_P = V_{Pc} \vee V_{Pq}$ – the set of conditions of formation of information portraits, V_T – many terms of the identification of thematic subjects, V_C – many of the terms of the construction of tables of the relationship of content, V_R – lots of options, content rating calculation. A lot of information portraits commercial content Y_{Pc} is served as $Y_{Pc} = BuInfPort(V_{Pc}, C, H, Q, T)$, and the many portraits of users Y_{Pq} represented as $Y_{Pq} = BuInfPort(V_{Pq}, Q, H, Z, T)$, where $V_P = V_{Pc} \vee V_{Pq}$ – is the set of conditions of formation of portraits, $BuInfPort$ - is the operator of the formation of portraits $Y_P = Y_{Pc} \vee Y_{Pq}$. The variety of thematic subjects of content Y_T is represented as $Y_T = IdThemTop(C, H, Q, V_T, T)$, where V_T – is the set of terms identifying the subjects of the content, $IdThemTop$ - the definition statement of the thematic subjects of the content Y_T. Multiple tables of the relationship of content Y_C is represented as $Y_C = ConCorrTablConc(C, V_c, T)$, where V_C – is the number of conditions for construction of tables of interconnection, $ConCorrTablConc$ – operator of the construction of tables of the relationship. Many ratings of commercial content Y_{Rc} submitted as $Y_{Rc} = CalRankConc(C, Q, H, Y_C, V_{Rc}, Spam, Tonality, T)$, but many of the ratings served as moderators Y_{Pq}, submitted as $Y_{Rm} = CalRankConc(C, Q, H, Y_C, V_{Rm}, T)$, where $V_R = V_{Rc} \vee V_{Rm}$ – many parameters for the calculation of ratings of content, $Tonality(Q^+, Q^0, Q^-, T, H)$ is a key criterion of the content, $Spam(Q, T)$ is the definition statement filtering comments, $CalRankConc$ - statement of rating content and moderators $Y_R = Y_{Rc} \vee Y_{Rm}$. Many source statistics Y are presented as $Y = \{Y_P, Y_T, Y_C, Y_R\} = Support(V, C, Q, H, Z, T, \Delta T)$, or

$$Y = \{Y_P, Y_T, Y_C, Y_R\} = Support(V_P, V_T, V_C, V_R, C, Q, H, Z, T, \Delta T),$$

where $Y_P = Y_{Pc} \vee Y_{Pq}$ is a subset of information portraits content and users, Y_T is a subset of the thematic subjects of the content, Y_C is a subset of the tables of the relationship of content, $Y_R = Y_{Rc} \vee Y_{Rm}$ is a subset of content ratings and moderators, $Support$ – operator support content.

Subsystem of development of commercial content is implemented in the form of complexes, the content monitoring to collect content from a variety of data sources that enable the creation of a content database in accordance with the information needs of users. As a result of harvesting and primary processing of the content is reduced to the format, classified according to certain categories and he is credited with the handles keyword. This facilitates the implementation of process management commercial content. Tasks of subsystem content management: formation, rotation of databases and access thereto; creating operational and historical databases; personalization of the user experience, storage of personal user requests and sources, statistics of work; provision of search in databases; generation of output forms; information exchange with other databases; creation of an information resource. The subsystem of management of commercial content is implemented by caching (view subsystem generates the page once, and it is several times faster loads from the cache, which is updated automatically after a certain period of time or when changes are made in certain sections of the information resource, or manually by the administrator) or the formation of information blocks (save blocks at the editing stage of the information resource and page Assembly of these blocks at the request of the relevant page by the user). Subsystem support content provides for the formation of information portraits; identifying a thematic scenes of content; creation of a table of the relationship of content; content rating calculation, identification of new developments in content streams, tracking, and clustering. Analysis of the results of the commercial content allows determining the reasons for the formation of the target audience on the set of characteristics of functioning of ECCS. Adjusting thematic set of commercial content, its uniqueness, efficiency of its formation and adequate management of them according to individual needs regular user, you can simulate the boundaries of the target social audience and the number of unique visitors from search engines.

4. RESEARCH RESULTS ANALYSIS

There are posted software of developed systems implementation with subsystems of information resources processing (Tables 4, 5) in e-business organization over the Online Newspaper (ON) and Online Journal (OJ). Fig. 11–12 presents the work results of the developed systems in the form of graphs. So the all stages presence of the commercial content lifecycle significantly increases the visits and unique users amount of information resources.

Tab. 4. The results of systems operation [source: own study]

№	Web-resource	Address	Type
1	Fotoghalereja-vysocjkykh	fotoghalereja-vysocjkykh.com	OJ
2	Vgolos	vgolos.com.ua	ON
3	Tatjana	tatjana.in.ua	OJ
4	Presstime	presstime.com.ua	ON
5	AutoChip	www.autochip.vn.ua	OJ
6	Kursyvalyu	kursyvalyut.com	ON
7	Good morning	dobryjranok.com	ON
8	Information for Businesses	goodmorningua.com	OJ
9	LvivSchoolNumber3	зсш3львів.in.ua	OJ
10	Victana	victana.lviv.ua	OJ

Tab. 5. The results of systems operation in the time period from 10.2010 to 03.2014 [source: own study]

Characteristic	1	2	3	4	5	6	7	8	9	10
Content formation	30	100	10	40	20	90	70	60	0	50
Content management	90	100	50	80	30	40	60	20	0	70
Content supporting	30	100	10	40	20	50	80	60	0	70
Uniqueness content	100	80	100	70	30	20	50	40	100	60
Average visit duration	4:41	2:14	3:56	2:04	1:51	1:02	2:27	8:12	0:46	4:15
Denial Rate(%)	56,14	71,90	53,15	83,08	55,67	82,92	68,15	48,0	97,02	32,92
Conversion Rate	7,83	0	0	0	12,51	0	0	0	0	0
Pages / Visit	4,54	1,93	3,96	1,67	2,59	1,59	2,17	3,24	1,67	5,78
New Visits	65,45	41,68	52,57	39,88	73,88	82,39	57,23	28,0	97,32	42,86
Returning Visit	34,55	58,32	47,43	60,12	26,12	17,61	42,77	72,0	2,68	57,14

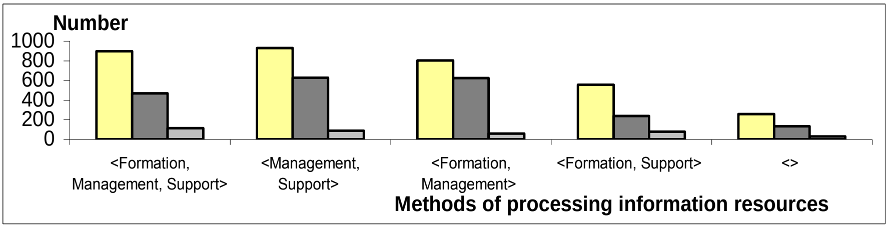

Fig. 11. Statistical analysis of the "Fotoghalereja-vysocjkykh" functioning (1 – Number of all visits, 2 – Number of visits of permanent users, 3 – Number of implementing content) [source: own study]

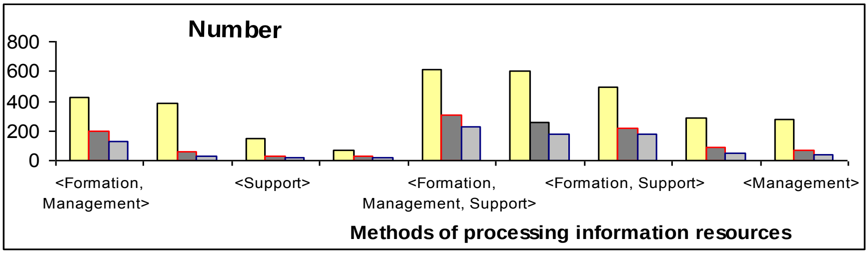

Fig.12. Statistical analysis of functioning «Victana» (1 – resources visiting of the target audience, 2 –resources visiting by permanent users, 3 – content implementation of permanent users) [source: own study]

Service keeping statistics visits Web-resource allows us to estimate the increase in sales of commercial content which depending directly proportional increase in the number of visits an Web-resource, the number of permanent users, the prospects of marketing events (Fig. 13). The subsystems presence of content creation, management and support in ECCS increases sales volume of content to the permanent user at 9%, active involvement of unique visitors, prospective users and expand the limits of the target and regional audience by 11%, viewed pages by 11%, visiting time and Web-resources by 9%. The results are the ECCS development in the form of online newspaper and online magazine with the subsystems of content formation, management and support.

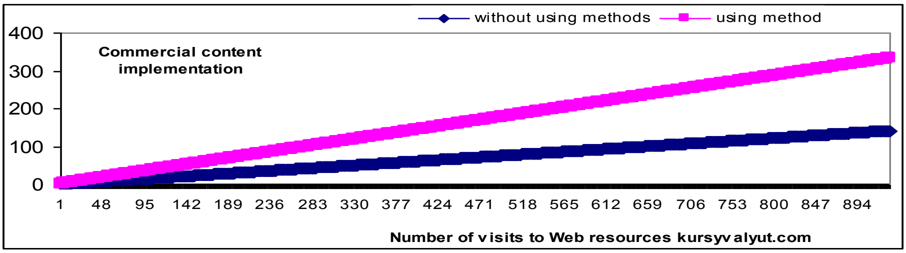

Fig. 13. Regressive analysis of increased sales of commercial content [source: own study]

5. CONCLUSIONS

In the solution of urgent scientific task of the research and development of methods and means of processing of information resources ECCS using the developed classification, mathematical software and the generalized architecture of ECCS are proposed. Researched and improved classification of ECCS based on the analysis and evaluation of such systems, which allowed defining, refining and justifying their choice of functionality for the design lifecycle of commercial content. Developed a method for the generation of commercial content by improving its life cycle to define requirements manage the flow of commercial content, which allowed to automate the collection of data from various sources, identify duplication and formatting of the commercial content, the definition of key words and the formation of the digests, of the sampling distribution of commercial content to improve its life cycle and requirements definition stream management commercial content. Improved method of managing the commercial content based on the results of its formation and analysis of system performance to determine the values of the parameters in the management of commercial content, relevance, aging, completeness, accuracy, relevance, authenticity, authenticity. Rosalina method commercial content based on the statistical analysis of the functioning of ECCS to change the values of control parameters and requirements of development of commercial content, which increased the sales volume of commercial content to the permanent user by 9%.

Improved structure of ECCS based on the analysis of processes of processing of information resources, non-existing presence of subsystems of content formation, management and support that gave way to the stages of the life cycle of commercial content and to develop recommendations for the design of typical systems. In work the problem of developing methods and software for creating, administering and maintenance of information products in the form of a theoretically grounded concept by automating the processing of information resources in ECCS to increase sales of permanent content to the user, the active involvement of potential users and the expansion of the boundaries of the target audience. A new approach to application and implementation of business processes is formulated for the construction of systems of electronic content commerce. A complex method of content formation, the operational method of content management and complex method of commercial content support are developed. Software tools of content formation, management and support are developed. Designing and implementation Methods of electronic content commerce systems on the example of online newspapers, which reflects the results of theoretical research, are developed.

REFERENCES

[1] BERKO A., VYSOTSKA V., PASICHNYK V.: *Systemy elektronnoyi kontentkomertsiyi*. NULP, Lviv, Ukraine, 2009.

[2] BERKO A., VYSOTSKA V., CHYRUN L.: *Features of information resources processing in electronic content commerce*. Applied Computer Science, 10 (2), 2014, p. 5–19.

[3] BOIKO B.: *Content Management Bible*. Hoboken, 2004.

[4] BOLSHAKOVA E., LANDE D., NOSKOV A., KLYSHYNSKYY E., PESKOVA O., YAHUNOVA E.: *Avtomatycheskaya obrabotka tekstov na estestvennom yazyke y kompyuternaya lynhvystyka*. MYEM Publ., Moscow, 2011.

[5] CLIFTON B.: *Google Analytics*. Vil'jame Publ., Moscow, Russia, 2009.

[6] *Content Management Professionals*. Access: http://www.cmprosold.org/resources/poster

[7] DOYLE B.: *Seven Stages Of The Cm Lifecycle*. Econtentmag.Com, 2010. www.econtentmag.com/articles/ articlereader.aspx?articleid=13554&authorid=155.
[8] EMC, IBM, MICROSOFT: *Content Management Interoperability Services.* Version 0.5. EMC, Hopkinton, 2008.
[9] FEDORCHUK A.: *Kontent-monitoring informacionnyh potokov*. 2005. Access: http://www.nbuv.gov.ua/articles/2005/05fagmip.html
[10] HACKOS J.: *Content Management for Dynamic Web Delivery*. Wiley, Hoboken, 2002.
[11] HALVERSON K.: *Content Strategy for the Web*. Mass, New Riders Press, 2009.
[12] *Department for Business, Enterprise, Technology and Science*. 2012, Access: http://www.sharewales.com/wp-content/uploads/2012/01/E-commerce-Systems.pdf
[13] *Ignify eCommerce Technical Architecture*. 2014, Access: http://www.ignify.com/Ignify-eCommerce-Technical-Architecture.asp
[14] LANDE D.: *Osnovy intehratsii informatsyonnyh potokov*. Engineering, Kyiv, 2006.
[15] LANDE D., FURASHEV V., BRAYCHEVSKYY S., HRYHOREV O.: *Osnovy modelirovaniya i otsenki elektronnyh informatsionnyh potokov*. Kyiv, Ukraine, 2006.
[16] MCGOVERN G., NORTON R.: *Content Critical*. Upper Saddle River, NJ, 2001.
[17] MCKEEVER S.: *Understanding Web Content Management Systems: Evolution, Lifecycle and Market*. Industrial Management & Data Systems, 103 (9), 2003, p. 686–692.
[18] NAKANO R.: *Web Content Management: Collaborative Approach*. AWP, Boston, 2002.
[19] PAPKA R.: *On-line News Event Detection, Clustering, and Tracking*. Thesis for the degree doctor of philosophy. Massachusetts University Amherst, 1999.
[20] PASICHNYK V., SCHERBYNA Y., VYSOTSKA V., SHESTAKEVYCH T.: *Matematychna linhvistyka*. Novyy Svit – 2000, Lviv, Ukraine, 2012.
[21] ROCKLEY A.: *Managing Enterprise Content: A Unified Content Strategy*. Reading, Mass, New Riders Press, 2002.
[22] STONE W.: *Plagiarism, Duplicate Publication and Duplicate Submission: They Are All Wrong!* IEEE Antennas and Propagation, Vol. 45, № 4, 2003.
[23] SULLIVAN D.: *Invisible Web Gets Deeper*. Search Engine Report. 2002. searchenginewatch.com/sereport/article.php/2162871.
[24] *Content Management Possibilities Poster*. Access: http://metatorial.com
[25] WOODS R.: *Defining A Model For Content Governance*. 2010, www.contentmanager.net/magazine/article_785_defining_a_model_for_content_governance.html

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worm wheel, teeth profile, milling, rotary burr

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COMPUTER AIDED MACHINING OF SIMPLISTIC WORM WHEEL TEETH PROFILE

Abstract

Creating a simplified worm wheel profile leads to approximating it through the use of sections. The worm gear notch created through approximation is inaccurate and does not ensure proper meshing. However, this method is commonly exploited because of economic reasons such as the use of universal milling machines and tools. In summary, machining worm wheel teeth with a simplified tooth profile is less complex thus less time consuming.

1. INTRODUCTION

The traditional method of machining worm wheel teeth is worm gear hobbing. Worm gear hobs or cutters mounted on shafts are the most used tools for this machining operation. Subsequently, there is a need to prepare and set a tool end with specific geometry after each machining operation because each tool can only be used to cut one type of worm gear. Achieving the desired worm wheel profile and accuracy depends on how well the CAD model is prepared as well as the placement of tool paths on the side walls of the teeth.

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Currently, worm drives are designed through the use of simplified worm tooth profiles in many devices. This approach is suitable for devices that do not require a high level of infallibility nor accurate meshing. These transmissions are used in household appliances and simple agricultural equipment.

The complex shape of the side surface of worm wheel teeth completely depended on the convolution shape, that works with worm gear, because of this the correct machining if the teeth requires the use of special tools and machine. This ensures the right contact between gear teeth, which directly influence its properties of exploitation. There are a few methods of worm wheel teeth machining in industry, which allow the meeting of requirements [1–4]. Their choice dependent on many factors, which may include: machine wheel parameters, its precision, production size etc. Contemporary developments of computer techniques grant new possibilities in a field of worm wheel teeth machining. This concerns CAD/CAM software as well as CNC machines. There are many machining possibilities of these systems, which allow for the shaping of worm wheel teeth. It should be noted that this is possible through the use conventional machines and equipment, without a doubt this is positive feature of this method [5]. We usually apply hobbing methods for the execution of wormwheels. A wormwheel executed in this manner has the full tooth outline. In order to apply a different method of execution, we simplify the tooth geometry. It shall be remembered that a gear executed in this way will have lower power train capability. However, in case of certain products, it is permissible to reduce durability parameters of gears, taking into consideration the benefits of simplistic component machining.

2. THE PROCESS OF CREATING WORM WHEEL MODEL

In order to create a simplistic wormwheel model, full wormwheel model needs to be first determined, and then simplified. It shall be stressed that a wormwheel model does not have to be accurate. In order to create a full wormwheel model, we may use the treatment simulation method, or analytic derivation presented in the literature [2, 5]. It shall be stressed that the important thing is not the selection of the method, but the determination of basic wormwheel gear geometry. The information provided in the source may serve for this purpose [1, 2]. This article presents the application of the treatment simulation method, because the tooth outline in a wormwheel is a component with a high level of complexity. One of the difficulties with modelling the shape of a tooth results from profile changes along the width of a wheel. The simulation method is based on repeating specific operations of Boolean algebra. Such operations in CAD software allow for determining the sum, difference and product between solids. In the considered case, our activity consists in immersing the tool in the properly prepared wheel envelope and performing the difference operation. This process is performed multiple times, with changing positions of the tool and the treated wheel. The result of our activity will be discreet surface, i.e. consisting of elements of actual surface. The process of cutting wormwheel teeth using the simulation method with the application of Boolean algebra is presented in picture 1.

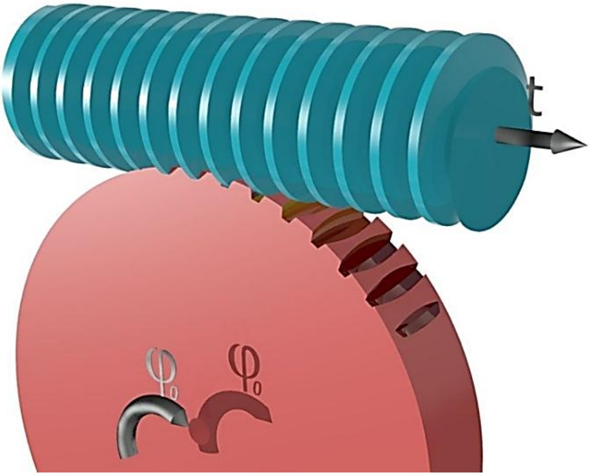

Fig. 1. The process of cutting wormwheel teeth using the simulation method with the application of Boolean algebra [source: own study]

The above picture presents the types of changes in consecutive steps and values of particular changes concerning rotation and translation of solids. In this case, the change of positions involves wormwheel rotation and worm displacements.

$$t_o = \frac{p_o}{2} \tag{1}$$

where: $t_o[mm]$ – elementary displacement,
$p_o[mm]$ – axial scale;

$$\varphi_o = \frac{360°}{2z_2} \tag{2}$$

where: $\varphi_o[°]$ – elementary angle of rotation,
z_2[-] – number of wormwheel tooths;

Relationship [1] and [2] allow for determining the size of displacement in the function of angle of rotation. It is certainly possible to apply different translations and rotations of solids, but this requires deriving appropriate relationships:

$$\varphi_0 = \frac{\varphi_c}{l_k} \tag{3}$$

where: $\varphi_0[°]$ – elementary angle of rotation,
$\varphi_c[°]$ – total angle of rotation,
l_k[-] – number of steps;

The process of rotation, displacement and difference should be performed with full meshing of wormwheel tooth and worm. On the basis of the achieved rotation, the number of steps necessary to generate the wormwheel groove outline shall be determined. In order to increase accuracy, the wormwheel angle of rotation and worm displacement should be reduced properly. The number of repetitions usually depends on various parameters. During the process of its selection, the required accuracy and time necessary for performing the iteration process shall be determined. The equipment capabilities may also constitute a significant factor, because the arising model is an element with irregular surface, generating high load during display. After performing all iterations, we cut the model along the central plane and project the resulting area against this plane. Then we create the curve outline. The lateral surface outline may be approximated to any number of sections. The number of sections depends on the method and time required for the execution of an element. This also provides information on how exactly the curve will be represented. Picture 2 presents the formed tooth profile curve.

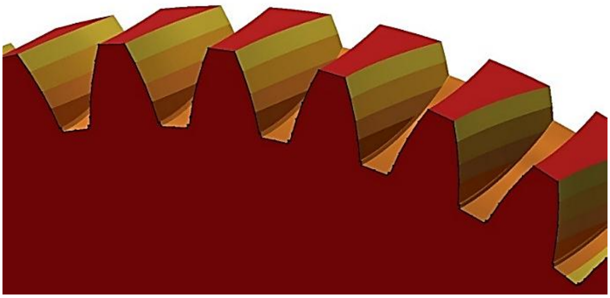

Fig. 2. Tooth profile curve [source: own study]

The following step consists in creating a full inter-tooth groove outline based on tooth thickness in characteristic section. For the purpose of appropriate deduction, the curve projected on tooth reference cylinder and inclined by an appropriate angle shall be derived (Picture 3). Helix can also be derived instead of a curve.

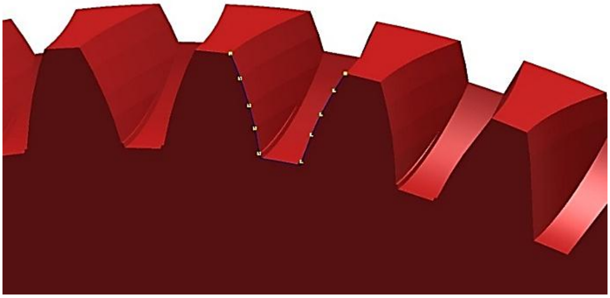

Fig. 3. Approximate shape of tooth space with characteristic point [source: own study]

The final element consists in executing the previously created outline dragging, formed along the leading curve, taking into consideration the guide surface. Picture 4 presents a finished model of simplistic wormwheel.

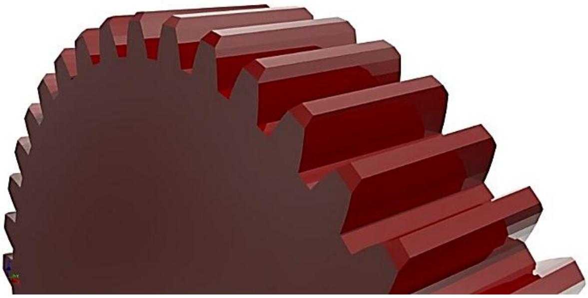

Fig. 4. Simplistic wormwheel model [source: own study]

Tooth outline executed in this manner is a simplistic representation. In order to achieve a full model of wormwheel, the dragging operation should be repeated in circular array.

3. MACHINING OF SIMPLISTIC WORM WHEEL TEETH PROFILE

In traditional machining methods, wormwheel tooths are shaped in the envelope manner. The applied tools are hobbing cutters or blades fastened in the rod performing circular motion. In order to ensure proper meshing of worm gear, the tool should be geometrically consistent with the worm in wormwheel machining. Therefore, it is required to prepare each time a tool with specific geometry, because only one type of wormwheel can be cut by means of one tool.

With the application of contemporary machining assistance CAD/CAM computer systems, the machining process of wormwheel tooths is entirely different from the above-described methods based on envelope treatment. The achievement of assumed shape and accuracy of the wormwheel depends on the correct preparation of CAD model and arrangement of tool paths on the lateral surface of tooths.

In traditional machining with the application of CAD/CAM systems, formation of tooths consists in roughing and finishing. The advantage of this type of machining is the application of universal tools, as well as four- and five-axis machine tools. This method is limited with regard to the possibility of using cutters for treatment of inter-tooth grooves, which requires the application of cutters with small diameters in small wheels. Finishing consists in lining tooth side with the application of ball end cutters. The disadvantage of this method is the machining time, which is long in this case, and the technology is not usable for serial applications.

Machining of simplistic wormwheel tooth profile consists in generating tool paths for the machining of simplistic lateral surface of a tooth. The execution of tool paths for simplistic outline is significantly easier and less time-consuming than in case of outlines created by means of the simulation method. Machining of simplistic wormwheel consists in applying four-axis CNC machine tool and four-axis strategy of side cutter treatment. The arrangement of tool paths on tooth sides is presented in picture 5.

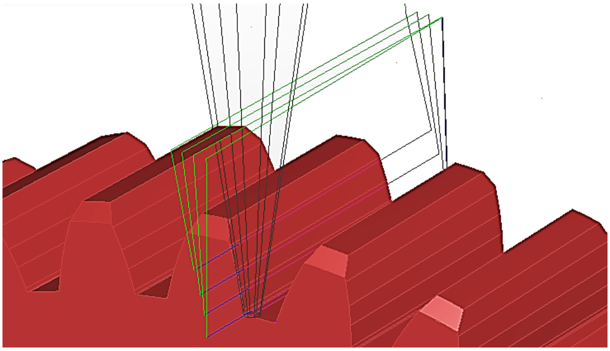

Fig. 5. Tool paths on tooth side [source: own study]

In the case of simplistic wormwheel tooth outlines, preparation of tool paths is very easy due to the simplified tooth side. Treatment time is much shorter than in traditional treatment methods. Such approach to designing and manufacturing is frequently applied in the case of low responsible gears. In treatment, most frequently applied are side and face shank cutters. The application of conic file cutters is a novelty presented in this article. Due to the diversity of shapes and blade geometry, these tools are becoming widely applied in CNC treatment.

An additional advantage of these tools is a wide range of sizes, which makes them outstandingly useful in the treatment of wormwheels of different sizes. These tools were widely described in item [6].

Each path is generated separately on each surface of simplistic side of wormwheel tooth. Picture 6a presents simulation of 3D machining of one wheel groove, picture 6b shows comparison between the cut groove and the model.

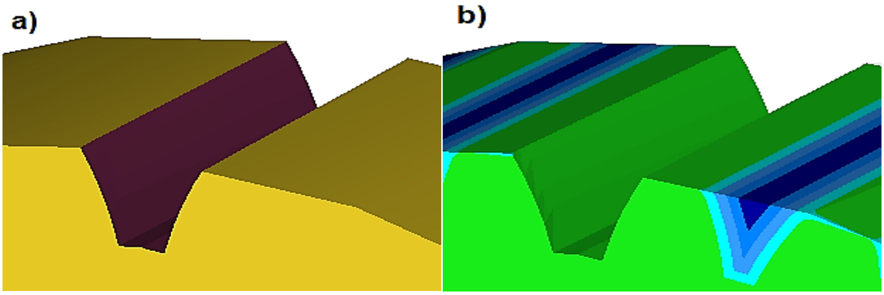

Fig. 6. Tooth space machining simulation a) tooth space after simulation, b) comparing tooth space before and after machining [source: own study]

Picture 7a presents simulation of machining in CAM system. Such simulation allows for detecting any collisions between the tool and the machine tool. Picture 7b presents the actual treatment of wormwheel on Haas VM3 machine equipped with a dividing head.

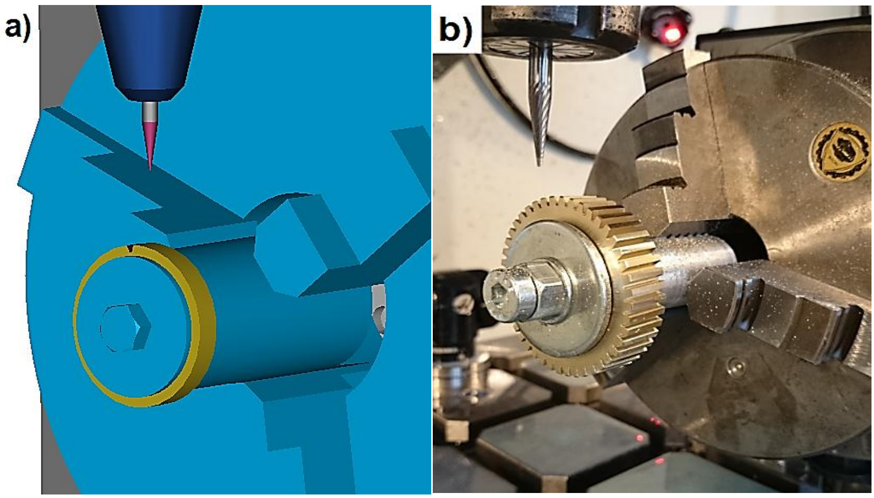

Fig. 7. Simplistic tooth space machining: a) CAM simulation, b) machining on machine [source: own study]

4. CONCLUSIONS

The main advantage of the presented technology of wormwheel machining is the maximum simplicity of the model outline and application of CAM systems for generating simple tool paths for conventional CNC machine tools and universal tools. The simplification of tooth profile is widely used by multiple manufacturers of different types of tools containing work gear units. Such approach is obvious from the economical perspective, because the manufactured devices are supposed to be cheap and they are designed for specific duration. However, from the consumer point of view, with certain degree of engineering knowledge, elements executed in this manner can be easily designed and performed.

REFERENCES

[1] CROSHER P. W.: *Design and Application of the worm gear.* ASM International, 2002.

[2] DUDAS L.: *The theory and practice of worm gear drives.* Penton Press, 2000.

[3] GNAT K.: *Machining of enveloping wormwheels in piece production.* Mechanik, 8–9, 2008.

[4] MARCINIAK T.: *Technologia przekładni ślimakowych.* Wydawnictwo Naukowe Instytutu Technologii Eksploatacji – PIB. Łódź 2013.

[5] DUDAS L.: *Modelling and simulation of a new worm gear drive having point-like contact.* Springer – Verlag, London 2012.

[6] WYDRZYŃSKI D., SKOCZYLAS L.: *Wykorzystanie pilników obrotowych w obróbce skrawaniem.* Wybrane zagadnienia i problemy z zakresu budowy maszyn cz.1, Rzeszów 2014.

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Hotels, Online social networks, Internet, e-commerce, Cross-sectional study

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THE IMPORTANCE OF INTERNET AND ONLINE SOCIAL NETWORKS IN THE SPANISH HOTEL SECTOR

Abstract

This paper is a cross-sectional study on the use of Internet and Online Social Networks in the Spanish hotel sector compared to Spanish companies in other sectors. The conclusions from this extensive survey are that the use of online social networks is more important and is more developed in the hotel sector than in Spanish companies in general. However, although it gives considerable importance to online social networks, the hotel sector needs to revise its rules of usage. The use of new tools such as e-commerce to sell the hotel stays must increase, and marketing efforts should be geared more towards online social networks because the hotel sector is currently losing ground in a market that generates more and more potential clients and sales by the day.

1. INTRODUCTION

The Internet and online social networks are tools that generate great opportunities for businesses. It has provided a new view of communications and commerce in the business sectors both in terms of the number of users and the way to publicize and sell products [10].

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The number of Internet and online social network users and the percentage who use these media daily are growing relentlessly [1].

This phenomenon offers a business opportunity for many sectors, but in the hotel sector its usage is an absolute necessity. Hotels need to have a presence on the Internet and on online social networks to remain competitive; this presence acts as the main source of information for tourists when booking a stay and enables them to compare opinions on the hotel with other customers [20].

The hotel's presence on the Internet is based on e-business opportunities while the use of online social networks is aimed at attracting their users [3].

In sum, we discuss the adaptation of companies to a new market that is an opportunity for many firms but is essential for the hotel sector. For this, we have studied one of the countries with the most hotel beds in Europe, Spain [4], a country whose economy is influenced to a large degree by hotel sector and tourism.

The goal of this scientific research is to ascertain if the use of online social networks is more prominent in the hotel sector than in the business sector in general in Spain. We also attempt to find out whether the use of online social networks is considered important in this sector especially as it can greatly benefit the service sector by opening up constant communication with customers.

And the paper is structured as follows: the next section provides a literature review on importance of the hotel sector in Spain and the adaptation of the hotel sector to new ICT market. The third section describes our data compilation method and sample size, in addition to describe variables used to define the use of online social networks in the hotel sector and the business sector in general. The fourth section presents the results of our analysis on 7 tables (whose variables are listed in the third section): Importance of the Internet, Website presence, Presence on online social networks, Use of e-commerce to sell, Use of rules governing employee use of the Internet and online social networks, Association to 'Presence on online social networks' in the Spanish business sector and Association to 'Presence on online social networks' in the Spanish hotel sector. At the final, we discuss and conclude the paper.

2. LITERATURE REVIEW

2.1. The hotel sector in Spain

Spain is one of the biggest tourist destinations in the world, and tourism accounted for 10.9% of total GDP in 2012 [7] and 12.2% of total employment nationwide in 2013 [8]. It is the primary source of job and wealth creation in the Spanish economy.

And according to figures for 2014, hotel sector accounts for 72.96% of overnight stays, with 81.6% of tourists who choose it as accommodation. Data from the National Statistics Institute of Spain in 2014 [9] show that there were 294.4 million overnight stays in 2014 (190.24 million generated by foreign tourists, of whom more than 94 million were from Germany and the UK) an increase of 2.9% on the previous year in which Spain was still deeply immersed in its economic crisis, all of which are reasons enough to study how technology can further contribute to this sector.

Clearly the tourism industry in Spain needs ICT for contacting destinations and to enable clients and hotels to interact [6], points that are necessary to foment greater customer numbers and customer satisfaction, and to ensure quality service [2].

2.2. The adaptation of the hotel sector to new ICT market

The adaptation of the hotel sector to this new market, imposed by computerization and its various applications (the Internet and online social networks) and customer demand, has been rapid. Two of the main causes of this accelerated change have been the extent of this computerization in companies in the hotel sector [13] and the importance given to information acquisition [12]. Information plays a fundamental role in decision-making in companies [23], and no more so than in the hotel sector.

The changes resulting from this adaptation in hotel companies and companies in the rest of the business sector have been studied by authors like Infante et al. [11, 14], Nicolau and Santa-María [18], Probert et al. [19], Trainor [22] and Ip et al. [15], all of whom agree on the changes and benefits that this new market offers companies:

The Internet:

- Attracts new customers through marketing and advertising in the web environment: Presence on the Internet and online social networks.
- Develops new markets and distribution channels for products. Business becomes globalized.
- Updates processes, improves communication within the company and reduces economic costs and saves time.
- Opens a communication channel with customers via the company website, email and online social networks.
- Develops new products based on the information extracted from web usage.

Online social networks:

- Generate customer loyalty: keep clients informed of all company activities.
- Enhance brand image (branding).
- Feedback on products and services from customers. The importance of customer service, which is essential in the hotel sector.

3. METHODOLOGY

The goal of this scientific research is to ascertain if the use of online social networks is more prominent in the hotel sector than in the business sector in general in Spain. We also attempt to find out whether the use of online social networks is considered important in this sector especially as it can greatly benefit the service sector by opening up constant communication with customers.

To this end, the researchers designed two different surveys to analyze online social network usage in the Spanish hotel sector (48 companies analyzed) and in the Spanish business sector (410 companies analyzed). Questionnaires were are sent out by post or email to these companies (defined by the Arkin and Colton formula, reproduced by Sierra in 2003 [21], using the 'Fomento de la Producción' journal's database [5] and selected through 'random sampling without replacement' procedure). The mailshot took place in 2012 and was validated in 2013. The survey is not broad (5 variables) and it avoids problems of lack of response, in addition to having had prior contact with companies.

$$n = \frac{Z^2 \text{ x } N \text{ x } p \text{ x } q}{E^2(N\text{-}1) + Z^2 \text{ x } p \text{ x } q} \qquad (1)$$

In the Spanish hotel sector, the values that define the sample size are: N = 417; confidence level = 95.5%, E = 9%, p = 0.5, q = 0.5 and Z = 2. And in the Spanish business sector, these values are: N = 24,187; confidence level = 95.5%, E = 4.9% (lower margin because it is a larger population), p = 0.5, q = 0.5 and Z = 2.

And the 5 variables that we have used to define the use of online social networks in the hotel sector and the business sector in general are [16, 17]: Importance of the Internet, Website presence, Presence on online social networks, Use of e-commerce to sell and Use of rules governing employee use of the Internet and online social networks.

4. RESULTS

We have performed an empirical study with non-parametric variables (qualitative variables): the qualitative variables are not numeric and, therefore, do not meet one of the requirements of Normal Distribution. Therefore, the analysis of this cross-sectional study is performed through the X2 test, a statistical method that is used to analyze the association between two qualitative variables.

Table 1 shows that the importance attached to the Internet by companies in hotel sector is similar to that in the Spanish business sector with no significant differences. The X2 calculated (4.778) is less than the critical X2 (7.81) with degree of freedom equaling 3 and level of significance at 0.05. Both sectors are aware of the importance of the Internet in their markets, almost half of the companies consider it essential and no company ignores its significance.

Tab. 1. Importance of the Internet in the Spanish business sector [source: own study]

	Importance of the Internet										Total	
	Not important		Moderately important		Normal		Very important		Essential			
Sector	N	%	N	%	N	%	N	%	N	%	N	%
Spanish business sector	0	0%	7	2%	93	23%	134	33%	175	43%	409	100%
Spanish hotel sector	0	0%	0	0%	9	19%	11	23%	28	58%	48	100%
Total	0	0%	7	2%	102	22%	145	32%	203	44%	457	100%

This importance is demonstrated by the existence of web pages in both sectors, Table 2 also reveals a lack of significant differences, the X2 calculated (0.404) is less than the critical X2 (3.84), with degree of freedom at 1 and level of significance 0.05. All sectors recognize that if they do not have a website, they are invisible; 96% of companies in the Spanish business sector have websites and 98% of the companies in the hotel sector.

Tab. 2. Website presence in the Spanish business sector [source: own study]

	Website				Total	
	No		Yes			
Sector	N	%	N	%	N	%
Spanish business sector	16	4%	392	96%	408	100%
Spanish hotel sector	1	2%	47	98%	48	100%
Total	17	4%	439	96%	456	100%

Nowadays having a website is not enough; millions of people communicate via on online social networks and, therefore, companies are obliged to make their presence felt on these networks as well (Table 3). This tool can generate advertising and sales if well-managed. But in this variable, we find significant differences between the Spanish business and hotel sectors. The X2 calculated (49.998) is greater than the critical X2 (5.99), with degree of freedom at 2 and level of significance 0.05.

The extent of online social network presence differs in the two sectors. We observe that all firms in the Spanish hotel sector can be found on these networks or plan to be there, while 35% of companies in the business sector have no presence on the social networks and do not intend to change that stance. This reveals the value placed on online social networks by the Spanish hotel sector.

Tab. 3. Presence on online social networks in the Spanish business sector [source: own study]

	Presence on online social networks						Total	
	Yes		No, but it seems important		No, and don't to have one			
Sector	N	%	N	%	N	%	N	%
Spanish business sector	135	33%	128	31%	144	35%	407	100%
Spanish hotel sector	40	85%	7	15%	0	0%	47	100%
Total	175	39%	135	30%	144	32%	454	100%

Both forms of presence on the Internet (via websites and online social networks) are used to sell a product (Table 4). But there are significant differences between the two sectors in terms of e-commerce. The X2 calculated (22.402) is greater than the critical X2 (3.84), with degree of freedom at 1 and level of significance 0.05. More than half of companies in the business sector (57%) do not transact via e-commerce compared to81% of companies in the Spanish hotel sector that do. It underlines the importance of e-commerce in the hotel sector.

Tab. 4. Use of e-commerce to sell in the Spanish business sector [source: own study]

	Use of e-commerce to sell				Total	
	No		Yes			
Sector	N	%	N	%	N	%
Spanish business sector	225	57%	173	43%	398	100%
Spanish hotel sector	8	19%	35	81%	43	100%
Total	233	53%	208	47%	441	100%

It is remarkable that there are no significant differences between the two sectors in terms of the rules governing employee usage of Internet and online social networks (Table 5). The X2 calculated (1.359) is less than the critical X2 (3.84), with degree of freedom equal to 1 and level of significance at 0.05. Firms need to revamp these rules and make better use of this tool to improve company performance.

Tab. 5. Rules governing employee use of the Internet and online social networks in the business sector [source: own study]

	Rules governing use of the Internet and online social networks				Total	
	No		Yes			
Sector	N	%	N	%	N	%
Spanish business sector	144	35%	265	65%	409	100%
Spanish hotel sector	21	44%	27	56%	48	100%
Total	165	36%	292	64%	457	100%

Finally, we analyzed all these variables regarding online social networks in each of the two sectors to determine if there was a link between the existence of online social networks and the other variables.

In the Spanish business sector, we noted that whether a company has a presence on online social networks or not (but they plan to in the future, or not) varies according to the importance the company gives to the Internet, the existence of a company website and the use of e-commerce to sell their products (Table 6). But this does not happen in 'Rules governing use of the Internet and online social networks for employees’, because 63% of companies which have no presence on online social networks, and do not intend to have one, have rules governing use of the Internet and online social networks for employees. The data show that, the highest percentage of companies with these rules are those with on online social network presence (69%).

The figure for companies that give considerable importance to the Internet or consider it essential have a presence on online social networks, or plan to have one, amounts to 69% of cases, while around half the companies that give little or no importance to the Internet or have no presence on online social networks (48%).

No company without a website has a presence on online social networks (4%), although there is a high percentage of companies that have a website but no presence on online social networks (65%). There is a clear dependence between having a website and an online social network presence, which is because the companies analyzed are not inconsiderable in size (turnover of over 2 million euros per year). Today, many small businesses have a presence on online social networks but no website.

The survey revealed that 60% of companies with an online social network presence use e-commerce to sell their products and 73% of companies with no presence (and do not plan to have one) do not use e-commerce to trade, so it is obvious that companies should move onto social networks as a way of attracting customers and boosting sales.

Tab. 6. Association to 'Presence on online social networks' in the Spanish business sector [source: own study]

	Level of significance	Degree of freedom	Critical X^2	X^2 calculated
Importance of the Internet	0.05	6	12.59	15.49
Website	0.05	2	5.99	8.395
Use of e-commerce to sell	0.05	2	5.99	29.818
Rules governing use of the Internet and online social networks	0.05	2	5.99	1.45

In the Spanish hotel sector, we find no significant differences in the presence on online social networks or not (but they plan to have one, or not) depending on the importance that the company gives to the Internet, the existence of a website and the use of e-commerce to sell (Table 7). And neither, in terms of the rules governing employees and their use of the Internet and online social networks according to presence on online social networks.

In this sector, all companies maintain an on online social network presence or plan to do so, which is symbolic of the importance of this phenomenon for this sector.

Most companies that ascribe great importance to the Internet or consider it essential (81%) have a presence on online social networks (82.5%). And almost all companies have websites (98%); few have no presence at all on online social networks (15%). In addition, all companies with a presence on online social networks have a website.

Of the 81% of companies that use e-commerce to sell their products, 83% of them already have presence on online social networks, but only 60% of companies with an on online social network presence have rules governing employee use of the Internet and online social networks for employees; clearly there is room for improvement here.

Tab. 7. Association to 'Presence on online social networks' in the Spanish hotel sector [source: own study]

	Level of significance	Degree of freedom	Critical X^2	X^2 calculated
Importance of the Internet	0.05	2	5.99	0.674
Website	0.05	1	3.84	5.839
Use of e-commerce to sell	0.05	1	3.84	0.926
Rules governing use of the Internet and online social networks	0.05	1	3.84	0.716

This analysis reveals the considerable extent of online social network presence across the Spanish hotel sector, far more so than in the business sector as a whole in Spain which is less advanced in this aspect. It indicates the importance of online social networks for the hotel sector, and the need to refresh the rules governing employee use of the Internet and online social networks.

5. DISCUSSION AND CONCLUSION

After performing this comparative cross-sectional study on the Internet and online social network use between the Spanish hotel sector and the Spanish business sector, with particular focus on presence on social networks, we find two areas which show significant differences (the presence on online social networks and the use of e-commerce to sell), but none were found with regard to the level of importance attached to the Internet and the existence of a website, and the rules governing Internet and online social network use for employees.

Both Spanish hotels and companies in general are aware of the importance of the Internet in their markets, which is demonstrated by the fact that nearly have a company website, and they all recognize that they could not survive or prosper without one. But having a website is not enough, as millions of people are present on the online social networks and, therefore, a company presence in that field is deemed very necessary. At this point, we find the first significant difference between the two sectors, the extent of presence on online social networks varies in that all companies in the Spanish hotel sector are visible on these networks, or plan to be, while 35% of companies in the business sector have no presence and do not plan to have one. This reveals the value of online social networks for the Spanish hotel sector. One disturbing piece of data is the scarcity of rules governing employee use of the Internet and online social networks (and improper use of these tools can create serious problems for companies). There are no significant differences in this variable in the sectors analyzed.

These two forms of Internet presence (through websites and online social networks) are used to sell, physically and electronically, but not all companies carry out e-commerce trade. This is not true of the hotel sector where e-commerce is essential; more than half of companies in the business sector (57%) do not use e-commerce to sell, as opposed to 81% of companies in the Spanish hotel sector.

A more detailed analysis of presence on online social networks in these sectors shows that there are significant differences in the Spanish business sector in this area according to the importance the company gives to the Internet, the existence of a website and the use of e-commerce to sell. But we find no significant differences in the ‘Rules governing use of the Internet and online social networks for employees’, which depends on whether these companies have an online social network presence or not. In the hotel sector, there is no relationship between the existence of online social networks and the variables described above, although we emphasize that all companies in this sector have a presence on online social networks or plan to have one soon.

Finally, we can say that the use of online social networks is more pronounced in the hotel sector than in the general company sector in Spain, the former giving this tool far more importance.

To sum up, the hotel sector in Spain has a well-developed presence on Internet and online social networks, and ascribes great importance to a presence on online social networks (with infrastructures that have been created to take full advantage: branding, advertising, sales, ...), but this sector needs to improve the level of implantation of rules governing the use of the Internet and online social networks for its employees, for misuse of these tools can cause headaches. The Spanish business sector must also improve, by increasing the use of e-commerce to sell and by making its presence felt on online social networks whose importance they should recognize, because online social networks now provide a market that is expanding by the day and offer more and more sales opportunities.

This study is limited to the big companies (companies whose turnover exceeds two million euros annually) because they are companies with many employees and their ICTs have a critical role, the reason for their high percentages. This limitation may be removed in future studies and extend this study to all companies (small, medium and big companies) and to comparisons with other business sectors.

REFERENCES

[1] AIMC (Association for Media Research). *Navegantes en la Red* (08-03-2013). Retrieved June 2015 from http://www.aimc.es/-Navegantes-en-la-Red-.html

[2] DIXIT S. K.: *A study of guest's expectation and perception of hotel service quality: case of Khajuraho, India*. Enlightening Tourism. A Pathmaking Journal, 3 (2), 2013, p. 125–141.

[3] DWIVEDI M., YADAV A., VENKATESH U.: *Use of social media by national tourism organizations: a preliminary analysis*. Journal of Information Technology & Tourism, 13 (2), 2012, p. 93–103.

[4] Eurostat, the statistical office of the European Union. *Bed places in hotels and similar establishments (2000-2013)*. Retrieved June 2015 from http://ec.europa.eu/eurostat/web/products-datasets/-/tour_cap_nat

[5] Fomento de la Producción. *España 25.000* (2011). Retrieved October 2012 from http://www.fomentodigital.com/busqueda/empresa/espana25000.jsp

[6] GUEVARA A. *Informática aplicada al turismo*. Pirámide, Madrid, 2003.

[7] IET1 (Tourism Institute of Spain). *Tourism Satellite Account of Spain* (2012). Retrieved June 2015 from http://www.iet.tourspain.es/es-es/estadisticas/otrasestadisticas/cuentasatelite/paginas/default.aspx

[8] IET2 (Tourism Institute of Spain). *Annual report on Employment in the tourism sector* (2013). Retrieved June 2015 from http://www.iet.tourspain.es/es-es/estadisticas/otrasestadisticas/empleoturistico/encuestapoblacion/paginas/informespublicaciones.aspx)

[9] INE (National Statistics Institute). *Hospitality and Tourism* (2014). Retrieved June 2015 from http://www.ine.es/inebmenu/mnu_hosteleria.htm

[10] INFANTE-MORO A., INFANTE-MORO J. C., MARTINEZ-LOPEZ F. J., GARCIA-ORDAZ M.: *Currícula en SI/TI en las empresas españolas: Estudio longitudinal (2001–2011)*. Certiuni Journal, 1, 2015, p. 76–85.

[11] INFANTE-MORO A., MARTINEZ-LOPEZ F. J., GARCIA-ORDAZ M., INFANTE-MORO J. C.: *El teletrabajo en las grandes empresas del sector hotelero: El caso español*. Turitec 2014: X congreso nacional turismo y tecnologías de la información y las comunicaciones, 2014, p. 309–321.

[12] INFANTE-MORO A., MARTINEZ-LOPEZ F. J., GARCIA-ORDAZ M., INFANTE-MORO J. C.: *Information exchange in big companies of the Spanish hotel sector: an inside and inter-organizational comparative analysis*. TMS Algarve 2014: Management Studies International Conference, 2014, p. 209–220.

[13] INFANTE-MORO A., MARTINEZ-LOPEZ F. J., INFANTE-MORO J. C.: *The Extent of Computerization in big companies of the Spanish Hotel Sector*. Enlightening Tourism. A pathmaking Journal, 5 (2), 2015, p. 126–154.

[14] INFANTE-MORO A., ZAVATE A., INFANTE-MORO J. C.: *The influence/impact of Semantic Web technologies on Social Media*. International Journal of Information Systems and Software Engineering for Big Companies (IJISEBC), 2 (2), 2015, p. 18-30.

[15] IP C., LEUNG R., LAW, R.: *Progress and development of information and communication technologies in hospitality*. International Journal of Contemporary Hospitality Management, 23 (4), 2011, p. 533–551.

[16] JUSSILA J. J., KARKKAINEN H., ARAMO-IMMONEN H.: *Social media utilization in business-to-business relationships of technology industry firms*. Computers in Human Behavior, 30, 2014, p. 606–613.

[17] MISLOVE A., MARCON M., GUMMADI K. P., DRUSCHEL P., BHATTACHARJEE B.: *Measurement and analysis of online social networks*. 7th ACM SIGCOMM conference on Internet measurement, 2007, p. 29–42.

[18] NICOLAU J. L., SANTA-MARIA M. J.: *The effect of innovation on hotel market value*. International Journal of Hospitality Management, 32 (0), 2013, p. 71–79.

[19] PROBERT D., DISSEL M., FARRUKH C., MORTARA L., THORN V., PHAAL R.: *The process of making the business case for technology: A sales and marketing perspective for technologists*. Technological Forecasting and Social Change, 80 (6), 2013, p. 1129–1139.

[20] SHETH, J., SHARMA A.: *International e-marketing: opportunities and issues*. International Marketing Review, 22 (6), 2005, p. 611–622.

[21] SIERRA R.: *Técnicas de Investigación Social. Teoría y ejercicios*. Thomson Editores, Madrid, 2003.

[22] TRAINOR K.J.: *Relating Social Media technologies to performance: A capabilities-based perspective*. Journal of Personal Selling and Sales Management, 32 (3), 2012, p. 317–331.

[23] UCAKTURK A., VILLARD M.: *The effects of management information and ERP systems on strategic knowledge management and decision-making*. Procedia – Social and Behavioral Sciences, 99 (0), 2013, p.1035–1043.

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hip, endoprosthesis, FEA

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THE DESIGN AND STRUCTURAL ANALYSIS OF THE ENDOPROSTHESIS OF THE HIP JOINT

Abstract

The paper presents results of the preliminary structural analysis of model of the endoprosthesis of the hip joint. Basics of anatomy and biomechanical analysis of the hip joint were introduced. Based on data from atlas of human anatomy and medical imaging, the prototype of endoprosthesis was modelled using Solid Edge ST8 software. After determining physical properties of structural materials, the Finite Elements Analysis of the model was conducted using in SolidWorks software under various load conditions. Finally the results of analysis are presented.

1. INTRODUCTION

For many years a phenomenon called population ageing, linked with continuing low or negative population growth rate, is being observed. The most tangible repercussion is growing demand for medical services dedicated for elder. From orthopedics' point of view one of the most frequently performed procedures is hip replacement, or in other words an implantation of specially designed and manufactured endoprosthesis of hip joint to replace structures damaged or destroyed as a result of medical conditions or accidents.

Due to complicated structure and biomechanical properties of the hip joint it is necessary to maintain the best fitting possible to preserve functionality of the joint and assure comfort of the patient. Thanks to major breakthroughs

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and constant development in the field of medical imaging (mostly computed tomography and magnetic resonance imaging)it is possible to obtain more and more precise data on the anatomical structure of the hip joint. The analysis of that data is crucial in the process of building biomechanical models of the joint. All of the above mentioned information along with data on the structure of the human skeleton become the basis for the process of endoprosthesis designing. During the implantation they also have a huge influence on planning and performing a surgery.

2. HIP JOINT BIOMECHANICS

A hip joint is an example of a ball-and-socket joint, which is distinguished by a wide range of possible moves. In the human locomotor system it is one of the most exploited synovial joints, hence it is at greater risk of degenerative changes. The hip joint contains following structures: the pelvic bone, whose unate surface of acetabulum (or a cotycoloid cavity) creates an articular surface, the femur (or thigh bone)with the head located on the articular surface and the joint capsule surrounding mentioned structures, filled with synovial fluid to reduce friction. Additional elements are very strong ligaments that suppress excessive movement around the joint [1, 2].

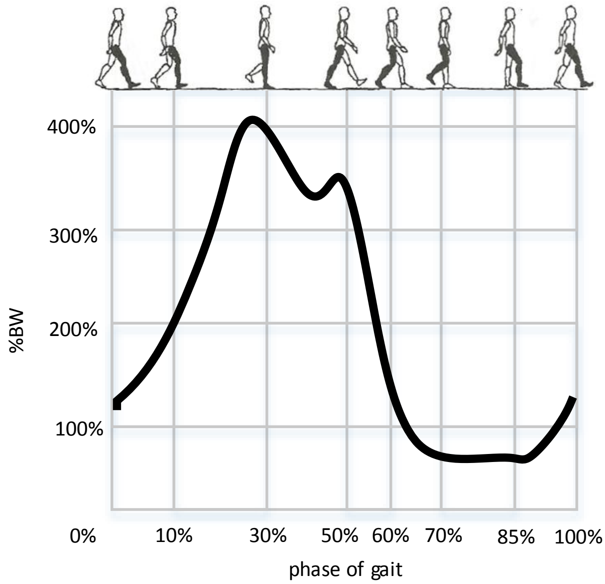

Fig. 1. Percentile contribution of body weight (%BW) in loads carried by the hip joint [1]

The hip joint carries static and dynamic loads, results of the body weight, forces from muscles in fluencing the joint and the gravity force. To maintain effective way of defining the load, the %BW unit (percent of body weight [N]) is used to describe forces of before mentioned reactions. Maximal forces influencing the hip joint are measured using instrumented hip implants with telemetric data transmission. Depending on used methods and a specificity of study forces values are between 369%BW and 400%BW [5, 6]. Angles, directions and values of vectors representing forces that influence the joint are changing depending on a function and a phase of a gait (Fig. 1) or an activity currently performed (bend/snap, abduction/adduction, rotational moves).

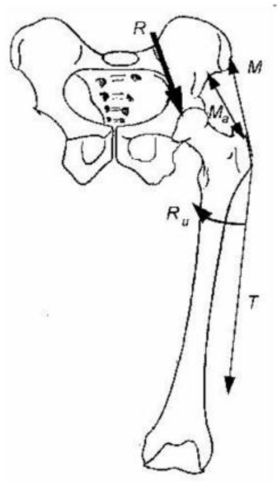

Fig. 2. The active model of loads in the hip joint [1]

During studies on properties of forces influencing the joint assumption is made, that while standing on both legs, the body weight is distributed equally on both limbs. In case of standing on a single leg, the force of reaction in fluencing the articular surface depends also (among other things) on the force generated by abductor muscles, which are required to maintain balance of the body (Fig. 2). However, the exact assessment of directions and values of all important forces is almost impossible, so while creating biomechanical models of hip joint it is essential to apply major simplifications [1, 2, 3, 4].

3. THE DESIGN OF THE ENDOPROSTHESIS OF THE HIP JOINT

For the purposes of studies the design and virtual prototype of the bipolar endoprosthesis of the hip joint was created. The model consists of prosthetic shaft inserted into properly prepared thigh bone of a patient, removable head, prosthetic socket and socket inlay, both spherically-shaped (Fig. 3). Elements of the prototype were designed and assembled in Solid Edge ST8, using sequence modeling tools. Implementation of two highly-efficient graphic modelers – Parasolid and D-Cubed allows combining direct modeling with precise control of geometry and gives engineers opportunity to conduct the designing process with speed and simplicity on a level, that has never been seen before.

Fig. 3. The model of the endoprosthesis of the hip joint (extruded view) [source: own study]

The structure of the shaft is based on the thigh bone, maintaining the value of an 125°angle measured between the body and the neck of the bone. It is shaped as a 122,5 mm nog (measured from the top of before mentioned angle to the shaft end) tapering in distal direction. The total length of the neck is 46 mm. The head in the shape of 30 mm diameter orb is mounted on octangular profile of the shaft's head, that fixes the head and prevents its rotation around the neck. Internal diameter of the socket in lay equals the diameter of the head, meanwhile external diameter is 40 mm. To stop slipping out the socket inlay out of the prosthetic socket, protrusions are designed on its external surface that match indentations on internal surface of prosthetic socket. The 50 mm internal diameter matches the diameter of the external diameter of the socket inlay [7, 8]. The prosthetic socket and socket in lay are placed on the properly prepared (drilling) cotycoloid cavityof the pelvic bone, which is the articular surface for the hip joint (Fig. 4). In choosing a place of mounting and determining above mentioned dimensions, data obtained from the atlas of the human anatomy [9] and X-ray images of the structure available in Webdatabase [10] were used.

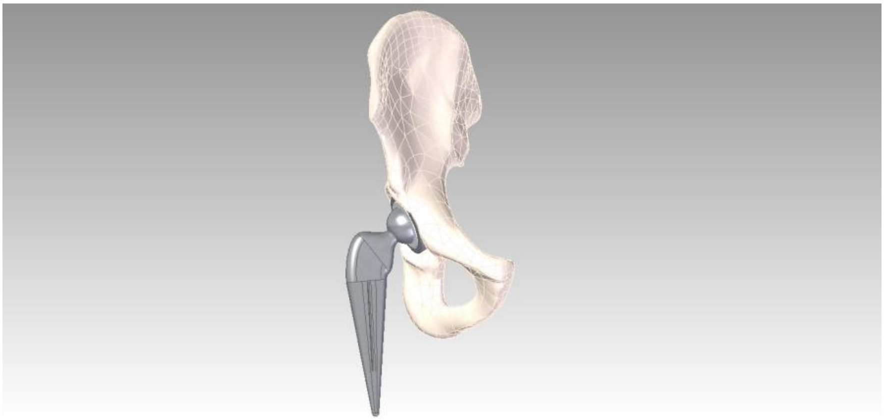

Fig. 4. The pelvic bone with mounted endoprosthesis of the hip joint (front view) [source: own study]

4. STUDY ON STRESS DISTRIBUTIONIN THE ENDOPROSTHESIS

The designed model was used to perform a series of preliminary studies including the stress distribution in the endoprosthesis with the use of Finite Element Analysis method. The performed studies are foundation for defining parameters for further exploitation of the prosthesis.

4.1. FEA method

Finite Element Analysis is one of basic methods of conducting a computer aided engineering calculations. It is one of the techniques of discretization of geometric systems, i.e. dividing a continuum into a finite amount of subareas.

Main principle of FEA is to divide geometric model into finite elements uniting in nodes, what creates the discrete geometric model, split in simply shaped subareas, called the finite elements. During FEM calculations other physical quantities are also being discretized: loads, tensions, restraints or other examples represented in the system with the use of continuous function. While performing the process of discretization software aims at maximally approximation of discreet and continuous form using approximation methods. After converting the data analysis follows, consisting in uniting individual elements as a whole using equilibrium conditions and displacement compatibilities. It results in receiving a set of algebraic, simultaneous equations – the mathematical description of analyzed problem. The equations are solved using the equilibrium conditions and their outcome used to compute sought quantities, i.e. tensions [11, 12, 13].

4.2. Methodology of studies

Studies were performer in SolidWorks Simulation software. The tool is often used as for conducting analysis for design teams. Its main advantage is the cost, much lower in comparison to any other FEA software. SolidWorks allows user to check a product for faults before manufacturing, which helps avoiding mistakes in early phase of designing process. In order to achieve credible results, materials (of which the element will be manufactured) were assigned to each element. Properties of materials are presented in Table 1.

Tab. 1. Table of materials [3, 14, 15]

Material	Element	Young's modulus [MPa]	Poisson's ratio
Titanium alloy ProtasulTi	Prosthetic socket	110000	0.3
Titanium alloy Protasul 100	Shaft, head	100000	0.3
Cortical bone	Pelvic bone	17000	0.3
Polyethylene	Socket inlay	1000	0.4

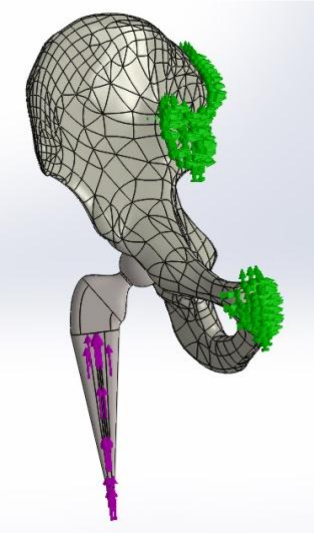

Fig. 5. Places offixing of the pelvic bone (green)and application of force (violet) [source: own study]

In order to receive correct results it was crucial to properly fix the model. For maintaining the best coherence with anatomical structure, the pelvic bone was fixed in the pubic symphisis and the sacroiliac (fig. 5).

In next step, the force was applied to the shaft of the endoprosthesis with value matching the value of the body weight (in N)during performing different activities [1]. In performed studies the value of the human body weight was set on 980 N, which was then assumed as 100% of body weight (%BW). Examination was conducted for reaction forces: 100 to 500%BW. Results of the analysis are presented in Table 2 and Figure 6.

Tab. 2. Maximal calculated stress for tested %BW [source: own study]

%BW	Maximal stress [MPa]
100	940
150	1464
200	2031
250	2646
300	3318
350	4056
400	4876
450	5799
500	6863

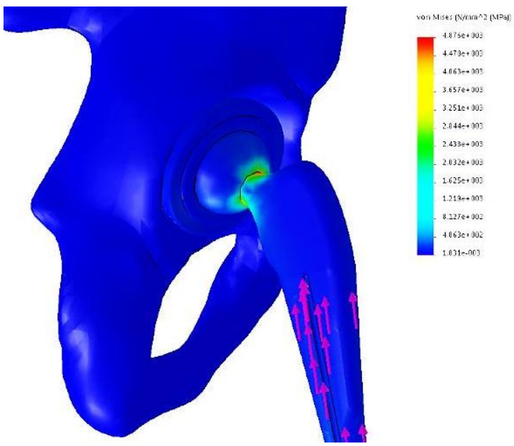

Fig. 6. Stress distribution for 400%BW [source: own study]

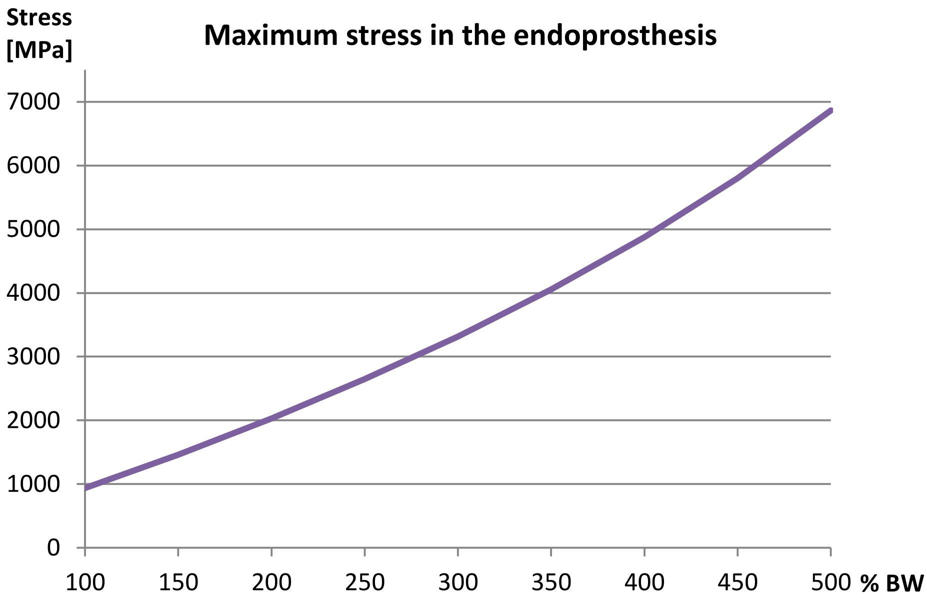

Fig. 7. The relation between stress in the endoprosthesis and%BW used as load in FEA [source: own study]

5. CONCLUSIONS

The unique structure of the hip endoprosthesis results in maximum stress accumulation in the neck of the endoprosthesis' shaft. Values of mentioned stress increase approximately linearly in relations to increasing force affecting the endoprosthesis. Observed phenomenon may pose as a starting point for a thesis, that the neck of the endoprosthesis' shaft is most probable location fora mechanical damage in situation of extremal load.

Modern IT technology, designing and development of biomaterial engineering can support the work of physicians (especially surgeons), because of the opportunity they create in carefully planning the course of procedures, reducing time of given procedure. Another advantage of mentioned techniques is the possibility of determining mechanical properties and a durability of implants already in designing phase.

REFERENCES

[1] BĘDZIŃSKI R.: *Biomechanika Inżynierska*. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 1997.

[2] WOŹNIAK W.: *Anatomia człowieka. Podręcznik dla studentów i lekarzy*. Elsevier Urban & Partner, Wrocław, 2003.

[3] MADEJ T.: *Modelowanie strefy ruchowej endoprotezy stawu biodrowego w aspekcie biomateriałów*. Ph. D. Dissertation. AGH University of Scienceand Technology, Kraków, 2008.

[4] TEJSZERSKA D., SWITOŃSKI E., GZIK M.: *Biomechanika narządu ruchu człowieka, Praca zbiorowa*. Wydaw. Naukowe Instytutu Technologii Eksploatacji – Państwowego Instytutu Badawczego, Gliwice, 2011.

[5] BERGMANN G.: *Hip contact forces and gait patterns from routine activities*. Journal of Biomechanics, 8, 2001, p. 859–861.

[6] BERGMANN G., GRAICHEN F., ROHLMANN A.: *Hip joint loading during walking and running, measured in two patients*. Journal of Biomechanics, 26, 1993, p. 969–990.

[7] ROŃDA J., WOJNAROWSKI P.: *Analysis of wear of polyethylene hip joint cup related to its positioning in patient's body*. Acta of Bioengineering and Biomechanics, 15 (1), 2013, p. 77–86.

[8] BRANIEWSKA M., ZUBRZYCKI J., KARPIŃSKI R.: *Komputerowo wspomagane projektowanie i wytwarzanie implantu stawu biodrowego*. Innowacje w fizjoterapii, 2, 2015, p. 147–170.

[9] WOŹNIAK W., JĘDRZEJEWSKI K.S.: *Sobotta. Atlas anatomii człowieka*, Elsevier Urban & Partner, Wrocław, 2012.

[10] http://lifeinthefastlane.com/resources/radiology-database

[11] EL-DIN F. EL-SHIEKH H.: *Finite Element Simulation of Hip Joint Replacement under Static and Dynamic Loading*. Ph.D. Dissertation. Dublin City University, Dublin, 2002.

[12] HUGHES T.J.R.: *The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*. Dover Publications, New York, 2000.

[13] RÓŻYŁO P.: *Numerical analysis of crack propagation in a steel specimen under bending.* Applied Computer Science, 11 (4), 2015, p. 20–29.

[14] TANAKA M., WADA S., NAKAMURA M.: *Computational Biomechanics: Theoretical Background and Biological/Biomedical Problems*. Springer, Tokyo, 2012.

[15] http://www.zimmergermany.de/content/pdf/de-CH/Sulene-PE-Durasul.pdf

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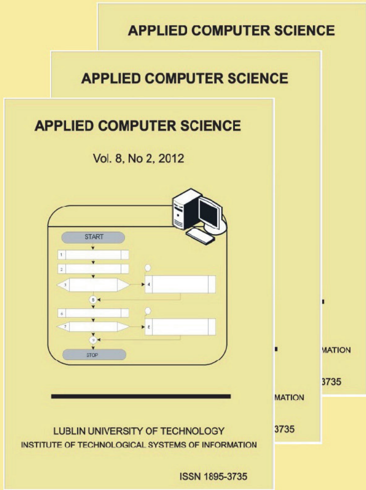

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