DESIGN AND CHECK OF THE MECHANICAL COMPONENTS BY THE PC APPLICATION

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The paper focuses especially on comparison of available programs for design and check of the mechanical components. The main aim of the paper is to analyse in the introductory part the individual programs from the perspective of content and functionality and consequently to compare the results experimentally in selected cases. The paper evaluates simplicity or complexity of work with the individual software types on the basis of input requirements [Bicejova 2016a]. The conclusion summarizes the issue and experience acquired in designing and in checking of the mechanical components.

KEYWORDS

design, calculation, program

1 INTRODUCTION

The paper deals with comparison of the selected software types for design and check of the mechanical components on the basis of diverse aspects. Comparison of the respective software types rests in general description of functions and option pursuant to experience acquired through their application. Evaluated are other aspects influencing the selection of the program for design and checks of the mechanical parts such as extend of deviation among the results of the selected types of problems [Mascenik 2016a]. The principal idea of the paper is to point out certain advantages or disadvantages of use of available software types for design and check of the mechanical components for a standard user on the basis of which there exists higher probability of selection of the correct software for calculation of random structural task.

2 SOFTWARE ANALYSIS FOR DESIGN AND CHECK OF MECHANICAL COMPONENTS

The introduction presents basic information on programs which shall be consequently compared in case of the selected types of problems. The information refers to versions of the particular program, content, types of the individual calculations, standardized parts and functions [Krenicky 2010]. Mentioned are the programs such as MITCalc, TDS Technik, Mechsoft and module Design Accelerator of the Autodesk Inventor program [Bicejova 2013a].

2.1 MITCalc

Program MITCalc (Fig. 1) is ranked among tabular calculators (Mechanical, Industrial and Technical Calculations). It works under the program of Microsoft Excel which must be installed. The program contains a broad scale of design and check calculations for everyday practice [Salokyova 2016a]. The integrated environment of the program offers the individual types of calculations (in metric and in inch units):

- ***toothing***: spur, conic, screw, planetary gearings,
- ***belts and chains:*** V-belt and toothed belts or roller chains,
- ***springs***: 15 types of springs (extension spring, forcing spring, helical spring, etc.),
- ***support, shaft and profile,***
- ***connections:*** screwed connections, shaft connections, force shaft connections, welded connections, pin connections,
- ***bearings:*** antifriction bearings SKF, INCH, FAG
- ***plates and shells*** [Mascenik 2016b].

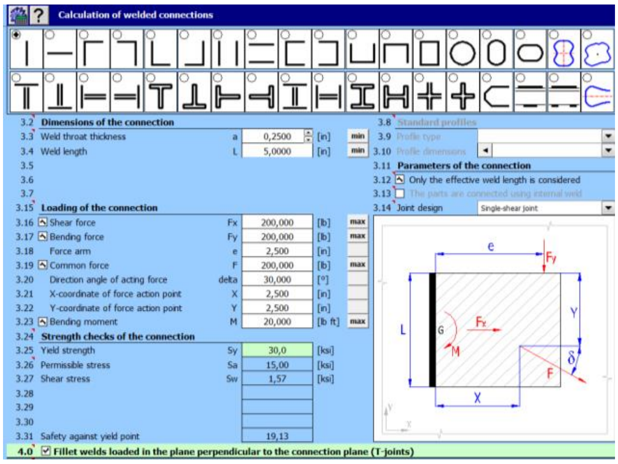

Figure 1. Working environment of the MITCalc program

2.2 TDS Technik

TDS Technik (Fig. 2) represents an engineering extension for the selected CAD systems yet it can operate as an independent unit. I tis issued as the extension for the systems by the companies of Solidworks (Solid Edge ST, SolidWorks), of Autodesk (AutoCAD, AutoCAD LT, AutoCAD Mechanical), Techsoft (ZWCAD), Bricsys (BricsCAD) or of Siemens (NX Unigraphics). The software disposes of a good basis although it does not rank among the products of large companies.

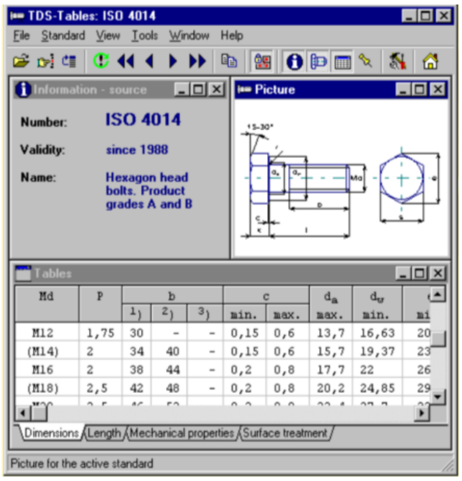

Figure 2. Working environment of TDS Technik

The program is completely constituted of several modules which can be used independently or in combination with other modules.

- *Tables:* Extensive database of standardized parts (connection parts, bearings, ropes, chains, solid semi-finished products, piping and fittings, electrodes, etc.).
- *Calculations:* Design and check calculations of the connection parts, springs, bearings, belts, chains, toothed wheels, supports, etc.

- *Bill of materials:* Generation and modification of bill of materials (sorting, printing, export of data, etc.). The tool can be used also for data import from the configuration of the Solid Edge program [Mascenik 2014a,b].

2.3 MechSoft

The Mechsoft program (Fig. 3) represents the implementation of design and structures of the mechanical products. It offers a complete set of guides by means of which mechanically correct parts are automatically generated by setting several simple or complicated mechanical attributes. Mechsoft contains extensive set of calculations involving standard mathematical equations and physical theories. Majority of the mechanical calculations automatically generate parametric components being inserted into a set [Mascenik 2016c]. Other calculations can be inserted into the set and connected with the parameters occurring in the application or in administrator of the connections. The connected reference information documents contain relations, algorithms and theory for each calculation. The method of calculations and of mutual connections conforms to the management concept of the program development [Puskar 2013].

<u>The Mechsoft program is gradually developed in individual versions:</u>

- MechSoft for AutoCAD
- MechSoft for Desktop
- MechSoft LT Technical
- MechSoft PROFI LT
- MechSoft for Inventor [Bicejova 2016b,c].

Basic user interface consists of four basic categories, i.e. part guide, calculation guide, knowledge database and individual parts (over one million of standardized parts included in more than 1500 standards). The program works with standards such as ISO, DIN, BS, NF, STN, CSN and JIS.

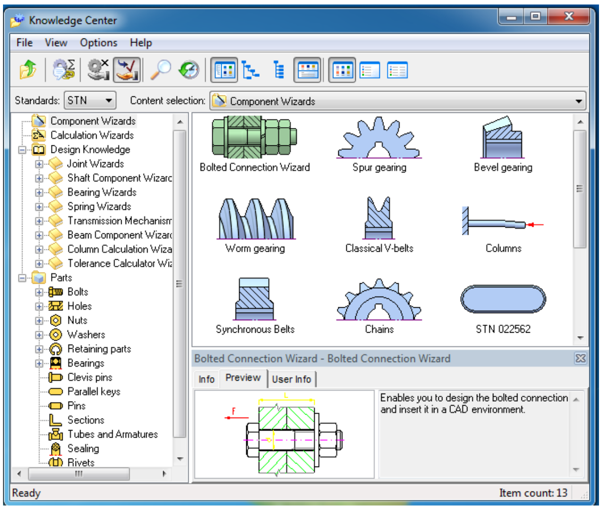

Figure 3. Working environment of the MechSoft program

2.4 Module Design Accelerator of the Autodesk Inventor Program

Design accelerator represents an extension of the Autodesk Inventor program (Fig. 4). The program allows fast generating of complicated parts and functions on the basis of technical data such as transfer ratio, torque, force and material properties. It consists of partial generators, mechanical calculators and engineering manual. The mechanical calculators employ standard mathematical formulae and theories to help the user design the components. The manual included in the model contains mechanical theory, formulae and algorithms applied in structure of the machines [Gaspar 2013].

<u>*Program contains the following types of calculations:*</u>

- Design and calculation of a screwed connections.
- Design and calculation of pins and journals (safety pins and journals, cross pins and journals, radial pins and journals).
- Design and calculation of supports and suspension stays.
- Design and calculation of plates.
- Design and calculation of shafts.
- Design and calculation of toothed wheels (front wheels, conic wheels, worm wheels).
- Design and calculation of bearings (ball bearings, tapered roller bearings, roller bearings, spherical-roller bearing, needle roller bearing).
- Design and calculation of belts (V-belts, toothed belts) and chains (roller chains).
- Design and calculation of splines.
- Design and calculation of cams (rotary cams, feed cams, cylindrical cams).
- Design and calculation of connections with equilateral involute splines.
- Design and calculation of brakes (drum brakes, disc brakes, band brakes, cone brakes).
- Design and calculation of gripping connections (split hub, unilaterally slotted hub and bevel hub).
- Design and calculation of a working screw.
- Design and calculation of springs (forcing springs, tension springs, disc and helical springs).
- Design and calculation of welds (abutting welds, fillet welds, hole and slot welds, point welds).
- Design and calculation of soldered connections (splayed connections, abutting connections, lapped and stepped connections).
- Calculation of tolerance and location [Balazikova 2016].

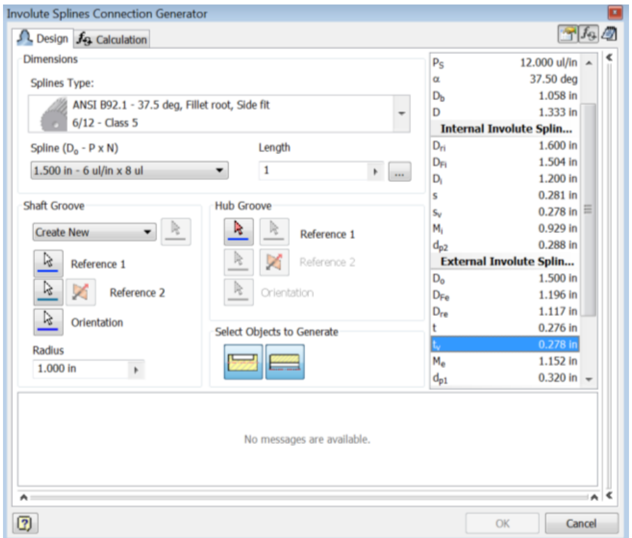

Figure 4. Working environment of the Autodesk Inventor program

3 EXPERIMENTAL DETERMINATION OF DEVIATIONS OF THE RESULTS AMONG THE SELECTED SOFTWARE TYPES

Determination of deviation of the calculation results was performed on the basis of four selected types of examples:

- Calculation of a screwed connection torque.
- Calculation of intensity of shear stress acting in the welded connections.
- Calculation of pressure in involute spline of a shaft and inevitable minimal and functional length of spline.

- Calculation of shear forces and bending moment of the support [Bicejova 2013b].

To assure more thorough comparison of results among employed software types a manual calculation of three selected problems is presented further.

3.1 Manual Calculation of Pressure in Involute Spline of the Shaft and Inevitable Minimal Functional Length of the Spline

It is the case of calculation of the pressure in the involute spline (Fig. 5) when only half of the tight pen height is taken into consideration [Mascenik 2011].

Figure 5. Model of the shaft connection with the hub by a tight spline

The following values are given:

$$P = 6\,kW,$$
$$n = 720\,rev.min^{-1},$$
$$d = 42\,mm,$$
$$l = 45\,mm,$$
$$p_{Dov} = 80\,MPa$$
$$pero\ bxh = 12x8$$

Calculation of shaft torque:

$$\omega = \frac{2.\pi.n}{60} = \frac{2.\pi.720\,rev.min^{-1}}{60} = 75{,}398\,rad.s^{-1}$$

$$Mk = \frac{P}{\omega} = \frac{6000\,W}{75{,}398\,rad.s^{-1}} = 79{,}58\,Nm$$

Calculation of pressure in the involute spline:

$$l_s = l - b = 45mm - 12mm = 33\,mm$$
$$p_v = \frac{2.Mk}{d.\frac{h}{2}.l_s} \le p_{Dov}$$
$$\frac{2.79{,}58.10^3\,Nmm}{42.\frac{8}{2}.33mm} \le 80\,MPa$$
$$\mathbf{28{,}708\,MPa} \le 80\,MPa \rightarrow SATISFACTORY$$
$$\boldsymbol{p_v = 28{,}708\,MPa}$$

Calculation of minimal functional length of the spline:

$$p_v = \frac{2.Mk}{d.\frac{h}{2}.l_s} \le p_{Dov} \rightarrow l_s \ge \frac{2.Mk}{d.\frac{h}{2}.p_{Dov}} = \frac{2.79{,}58.10^3\,Nmm}{42.\frac{8}{2}.80\,MPa} = \mathbf{11{,}842\,mm}$$
$$\boldsymbol{l_s = 11{,}842\,mm}$$

3.2 Manual Calculation of Magnitude of Shear Stress in the Welded Connection

In the individual calculation of the fillet weld the entire length of the weld is taken into consideration. The task of the problem is to detect the magnitude of shear stress of a T-fillet weld stressed by perpendicular shear (through acting of normal force) [Mascenik 2012].

The following values are given:

$$F_N = 8\,kN$$
$$l = 50mm$$
$$z = 6mm$$
$$R_e = 235\,MPa$$
$$k = 1{,}5$$
$$\alpha_\perp = 0{,}75$$

Calculation of partial (normal) stress from tractive force and height of the fillet weld with β standing for coefficient of thickness of the fillet weld (Fig. 6):

$$a = 0{,}7.z = 0{,}7.6\,mm = 4{,}2\,mm$$
$$\beta = 1{,}3 - (0{,}03.z) = 1{,}3 - (0{,}03.6) = 1{,}12$$
$$\tau_\perp = \frac{F_N}{S_{zv}} = \frac{F_N}{2.a.l} = \frac{8000\,N}{2.4{,}2.50mm} = \mathbf{19{,}047\,MPa}$$

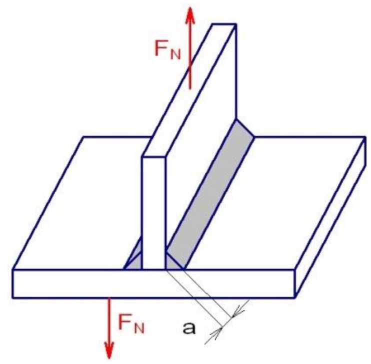

Figure 6. Scheme of the welded connection

Calculation of final (comparing) stress:

$$\tau_v = \frac{\tau_\perp}{\alpha_\perp} \le \tau_{Dov}; \tau_{Dov} = \beta.\frac{R_e}{k}$$
$$\frac{19{,}047\,MPa}{0{,}75} \le 1{,}12.\frac{235\,MPa}{1{,}5}$$
$$\mathbf{25{,}396\,MPa} \le 175{,}47\,MPa$$
$$\boldsymbol{\tau_v} \le \tau_{Dov} \rightarrow SATISFACTORY$$

3.3 Manual Calculation of Torque of the Screwed Connection

To perform calculation of the screwed connection (Fig. 7) by a through-bolt in the selected programs it is inevitable to insert inevitable coefficients into calculation such as coefficient of tightness (pre-stress) of the connection, coefficient of input force, coefficient of friction in the connection and entered coefficients (coefficient of friction between a matrix and a support plate, and coefficient of friction of the threads of the screwed connection) [Halko 2013].

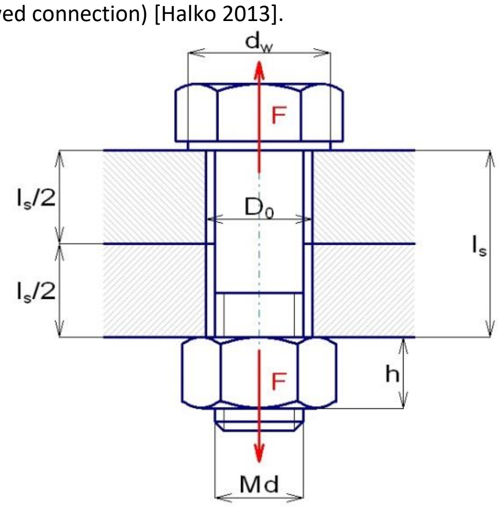

Figure 7. Scheme of the screwed connection

The values of the coefficients are selected according to the determined intervals according to structure and operating conditions of the connection. The task of the problem is to detect the magnitude of the inevitable torque of the screwed connection so that axial force F_Q is reached [Murcinkova 2013]. The following values are given:

$$Screw\ M20x2{,}5$$
$$F_Q = 5000N$$
$$d_w = 35\ mm$$
$$D_o = 21\ mm$$
$$d_2 = 18{,}376\ mm$$
$$f_m = 0{,}1$$
$$f' = 0{,}115$$

Calculation of friction diameter D_T:

$$D_T = \frac{2}{3} \cdot \frac{{d_w}^3 - {D_o}^3}{{d_w}^2 - {D_o}^2} = \frac{2}{3} \cdot \frac{35^3mm - 21^3mm}{35^2mm - 21^2mm} = 28{,}583\ mm$$

Calculation of gradient angle γ and angle φ' and coefficient of friction f' in threads in case of which f_m is coefficient of friction between the matrix and the support plate:

$$f' = \frac{f_m}{cos\frac{\alpha}{2}} = \frac{0{,}1}{cos30°} = 0{,}115$$
$$tg\gamma = \frac{p}{\pi . d_2} = \frac{2{,}5\ mm}{\pi . 18{,}376\ mm} = 2°35{,}9' \rightarrow 2{,}598°$$
$$f' = tg\varphi' \rightarrow \varphi' = arctgf' = arctg0{,}115 = 6°33' \rightarrow 6{,}55°$$

Calculation of torque on the basis of the moment to eliminate the friction in threads M_{tz} and the moment to eliminate the friction between the support plate and the matrix M_{tm}:

$$Mt_z = F_Q . tg(\gamma + \varphi') . \frac{d_2}{2}$$
$$Mt_z = 5000N . tg(2{,}598° + 6{,}55°) . \frac{18{,}376.10^{-3}m}{2} = 7{,}398\ Nm$$
$$Mt_m = F_Q . f_m . \frac{D_T}{2} = 5000N . 0{,}1 . \frac{28{,}583.10^{-3}m}{2} = 7{,}146\ Nm$$
$$Mt_u = Mt_z + Mt_m = 7{,}398Nm + 7{,}146Nm = 14{,}544\ Nm$$
$$\boldsymbol{Mt_u = 14{,}544\ Nm}$$

4 DETERMINATION OF DEVIATIONS OF THE PROBLEM RESULTS AMONG SELECTED SOFTWARE TYPES

The following tables (see Tables 1-5) contain the results of the selected calculated types of problems. In the final presentation the results are rounded to two decimal numbers which is sufficient for reaching the basic accuracy.

M - Manual calculations,
MC – MITCalc,
TT – TDS Technik,
MS – MechSoft,
DA - Design accelerator.

	M	MC	TT	MS	DA
Mu [Nm]	14.54	15.54	17.7	16.36	14.85

Table 1. Results of calculations of tightening torque of a screwed connection

	M	MC	TT	MS	DA
Normal stress [MPa]	19.05	19.05	-	19.05	19.05
Reference stress [MPa]	25.4	25.4	23.18	25.4	25.4

Table 2. Results of calculation of shear stress in a welded connection

	M	MC	TT	MS	DA
Pressure [MPa]	28.71	35.5	28.71	28.71	31.9
Min. length of a spline [mm]	11.84	14.7	11.84	11.84	13.158

Table 3. Results related to calculations of pressure in involute spline of the shaft and of minimal functional length of a spline

In consequence of absence of the coefficients in the calculation, negligence of cross-section and material properties of the support in the calculation of shear forces and of bending moment of the support the deviation of differences among the individual calculations is zero [Salokyova 2016b].

	M	MC	TT	MS	DA
Ay [N]	850	850	850	850	850
By [N]	850	850	850	850	850
Mo(x$_1$) [Nm]	212.5	212.5	212.5	212.5	212.5
Mo(x$_2$) [Nm]	212.5	212.5	212.5	212.5	212.5

Table 4. Results of calculations of shear forces and bending moment of the support

	MC	TT	MS	MA
Program working on own platform	No	Yes	Yes	No
2D/3D output	Yes	Yes	Yes	Yes
Possibility to generate the results	No – only in the form of printing by the Excel program	Yes	Yes	Yes
Possibility to create connections among parts	No	Yes	Yes	Yes
Possibility to create bills of materials	Yes	Yes	Yes	Yes
Connection with company database	No	Yes	Yes	No
Extensiveness of calculations	High	Low	High	High
Variability of calculations	High	Low	High	High
System requirements	Low	Low	Low	High

Table 5. Comparison of the individual types of the selected software types

5 CONCLUSIONS

The introduction of the presented paper contains basic categorization and types of the splitters. Selected were the parameters for the design of device which complies with the requirements for processing of the wooden substance. The core of the paper introduces the design of the individual parts. The design of the cutting mechanism was performed structurally [Mascenik 2014b]. Other parts such as basic frame and hydraulic mechanism, conical gearing and the clutch were designed as well. All of these parts were modelled and calculated by means of programs. The final part defines relation between the length of cutting substance and revolutions of the feeding roller.

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REFERENCES

[Balazikova 2016] Balazikova, M. Assessment of ergonomic risks of the selected work activity by niosh method. Science, Business, Society. Vol. 1, No. 5 (2016), pp. 42-45. ISSN 2367-8380

[Bicejova 2013a] Bicejova, L. Water jet technology head vibration generation due to selected technology parameters fluctuation effect during alloy cutting. Applied Mechanics and Materials, Vol. 308, 2013, pp. 81-86. ISSN 1660-9336

[Bicejova 2013b] Bicejova, L. Abrasive kind and granularity changes affects to water jet technology head vibration during cutting HARDOX material thickness alternation process. Applied Mechanics and Materials, Vol. 308, 2013, pp. 75-79. ISSN 1660-9336

[Bicejova 2016a] Bicejova, L., Pavlenko, S., Mascenik, J. Measuring, processing and evaluating of technology head water jet vibration signal. In: Key Engineering Materials: Operation and Diagnostics of Machines and Production Systems Operational States 3, Vol. 669, 2016, pp. 205-211. ISBN 978-3-03835-629-5. ISSN 1013-9826.

[Bicejova 2016b] Bicejova, L. and Pavlenko, S. Experimental investigation and determination of abrasive granularity change impact to technology head vibration generating during awj technology steel cutting. In: Key Engineering Materials: Operation and Diagnostics of Machines and Production Systems Operational States 3, Vol. 669 2016, pp. 220-227. ISBN 978-3-03835-629-5, ISSN 1013-9826

[Bicejova 2016c] Bicejova, L. and Pavlenko, S. Influence of selected technological parameters on cutting surface roughness in material laser cutting In: MM Science Journal, Vol. 2016, No. September, pp. 973-976. ISSN 1803-1269, DOI: 10.17973/MMSJ.2016_09_201645

[Gaspar 2013] Gaspar, S. and Pasko, J. Influence of technological factors of die casting on mechanical properties of castings from silumin. Lecture Notes in Electrical Engineering, Vol. 240, 2013, pp. 713-722. ISSN 1876-1100

[Halko 2013] Halko, J. and Mascenik, J. Differential with an integrated, newly - developed two-stage transfer. Applied Mechanics and Materials: Materials Engineering for Advanced Technologies ICMEAT 2013. Vol. 510, 2014, pp. 215-219. ISSN 1662-7482

[Krenicky 2010] Krenicky, T. The Monitoring of Technical Systems Operation Using Virtual Instrumentation. In: Strojarstvo extra. No. 5 (2010), pp. 25/1-25/2. ISSN 1335-2938 (in Slovak)

[Mascenik 2011] Mascenik, J. and Gaspar, S. Experimental Assessment of Roughness Changes in the Cutting Surface and Microhardness Changes of the Material S 355 J2 G3 after being Cut by Non-Conventional Technologies. Advanced Materials Research, Vol. 314-316, 2011, ISSN 1022-6680

[Mascenik 2012] Mascenik, J. The evacuation of pressure moulds as progressive developments of die casting process, 2012. Acta Technica Corviniensis: Bulletin of Engineering, Vol. 5, No. 3, 2012, pp. 25-26. ISSN 2067-3809

[Mascenik 2014a] Mascenik, J. and Pavlenko, S. Aspects of alternative dispute creating bolted joint technology flowdrill. Applied Mechanics and Materials: 2nd International Conference on Mechanical Structures and Smart Materials, 2014, Kuala Lumpur, Malaysia. Vol. 680, 2014, pp. 186-189. ISSN 1660-9336

[Mascenik 2014b] Mascenik, J. and Pavlenko, S. Determining the exact value of the shape deviations of the experimental measurements. Applied Mechanics and Materials, Vol. 624, 2014, pp. 339-343, ISSN 1660-9336

[Mascenik 2016a] Mascenik, J. and Vojtko, I. Experimental monitoring and diagnostics of belt gears in testing device. MM Science Journal, Vol. 2016, No. September, pp. 964-968. ISSN 1803-1269, DOI: 10.17973/MMSJ.2016_09_201641

[Mascenik 2016b] Mascenik, J. Experimental determination of cutting speed influence on cutting surface character in material laser cutting. MM Science Journal, Vol. 2016, No. September, pp. 960-963. ISSN 1803-1269, DOI: 10.17973/MMSJ.2016_09_201639

[Mascenik 2016c] Mascenik, J., Pavlenko, S., Bicejova, L. A device designed to monitor new belt types with application of diagnostic system. MM Science Journal, Vol. 2016, No. September, pp. 931-934. ISSN 1803-1269, DOI:10.17973/MMSJ.2016_09_201624

[Murcinkova 2013] Murcinkova, Z. and Krenicky, T. Implementation of virtual instrumentation for multiparametric technical system monitoring, In: SGEM 2013: 13th international multidisciplinary scientific geoconference: Informatics, geoinformatics and remote sensing, 2013, Bulgaria - Sofia: STEF92 Technology, pp. 139-144, ISSN 1314-2704

[Puskar 2013] Puskar, M., Bigos, P., Balazikova, M., Petkova, V. The measurement method solving the problems of engine output characteristics caused by change in atmospheric conditions on the principle of the theory of optimal temperature range of exhaust system. Measurement: Journal of the International Measurement Confederation (IMEKO), Vol. 46, No. 1, 2013, pp. 467–475, ISSN 0263-2241

[Salokyova 2016a] Salokyova, S. and Krenicky, T. Analysis of the effects of factors in relation to vibration of technological head during the splitting of construction steels through hydro-abrasive splitting. Key Engineering Materials, Vol. 669, 2016, pp. 216-219. ISSN 1013-9826

[Salokyova 2016b] Salokyova, S. Measurement and analysis of mass flow and feed speed impact on technological head vibrations during cutting abrasion resistant steels with abrasive water jet technology. Key Engineering Materials, Vol. 669, 2016, pp. 243-250. ISSN 1013-9826

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