DESIGN OF A MATERIAL CUTTING DEVICE WITH OPTION OF LENGTH ADJUSTMENT OF WOODEN CUTTING SUBSTANCE

JOZEF MASCENIK

Technical University of Kosice

Faculty of Manufacturing Technologies with a seat in Presov

Department of Technical Systems Design and Monitoring

Presov, Slovak Republic

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e-mail: jozef.mascenik@tuke.sk

The aim of the paper is a structural design of a cutting device with option of length adjustment of cutting material. The introductory part of the paper is devoted to an analysis of available devices standardly employed in the process of wooden substance cutting. The core of the paper contains structural design and calculation of the individual parts, disposition solution of the device and a complete visualisation in the 3D models[Krenicky 2010]. The final part of the paper points out a necessity of application of newly-designed devices intended for wooden substance cutting as such case offers an absolute waste less utilization of wooden substance.

KEYWORDS

stand,cutting, splitters

1 INTRODUCTION

Nowadays, it is very important to be particular about renewable resources. The wooden substance ranks among those resources. The wooden substance can be gained through cutting of rapidly growing plants grown especially for the given purpose as well as through technical cutting of naturally regenerated tree species from the lands or by waste wood from commercial wood logging. The waste wood is difficult to be stored due to its uneven dimensions and structure. For the complicated manipulation and better commercial use the waste wood should be processed at the place of piling. Processing is performed by means of substance shortening to reach the particular and identical length which would be followed by transport to the households in the form of firewood. This option offers utilization of wooden substance only to a limited degree and unutilized waste is left.[Balazikova 2016] The second option refers to processing of the substance by means of a splitter directly at the point of occurrence or at log dumps from the place of which the substance is transported directly to a recipient usually in high-cube containers for further processing or storage. Processing of the substance is more advantageous when being performed by means of the splitter as the wooden substance is utilized to the fullest with no waste left.

The term splitter may refer to a material cutting device. The material is cut into small parts with dimensions of 5-50 mm according to need of utilization. Smaller parts can be employed in further processing aimed at production of wooden briquettes and pallets. Cutting material with bigger dimensions might be used as fuel in bio power stations, for composting or for decorative purposes in gardens. In the markets the splitters can be found in diverse dimensional variants and a possibility of cutting device selection is offered as well[Pavlenko 2016].

Categorization of Material Cutting Devices

Nowadays, the market offers a number of machines for wooden substance processing of diverse types or in different variants. Correct selection of a feeding device in relation to a type and to a drive of splitting mechanism can assure maximal performance of a machine[Murcinkova 2013]. An appropriately selected basic frame assures simple machine manipulation. In dependence on machine utilization a suitable size of the cutting machine must be selected as well. Extensively unutilized device as to capacity leads to increase of costs regarding total operation and maintenance which could impact the profit.

Categorization According to the Drive Type of the Cutting Tool

Drive from an Electric Motor

The machines driven by an electric motor are stationary in major cases. These machines are used especially in households and for seasonal use. Diameter of wooden substance reaches approximately 40 mm with the motor performance of 3000 W. Their disadvantage rests in a close electric energy source which is rather limiting for the machine use.

Drive from an Output Shaft of a Tractor

Such drive type ranks among the most frequently used drives especially for the versatility and availability. The performance of the output shaft of the tractor is transferred by means of a cardan shaft to a machine gearing. This drive type requires meeting of a performance condition of the machine. Performance of tractors can reach up to 150 kW and diameters of wooden substance even 450 mm. In case of such drive the splitters are protected against damaging by a cardan friction clutch[Gaspar 2013].

Drive with Inherent Driving Motor

The category includes especially the splitters with the highest performance. These devices fixed directly to a chassis of a lorry or to an independent chassis. In some cases the machine is driven by the motor with performance of even 1000 Hp with the option of grinding the substance with diameter of 1000mm.

Categorization According to the Cutting Mechanism Type

Drum Mechanism

On a rotating roller the knives are located along the rotation axis which means that increasing diameter of wooden substance does not require immediate change of diameter of the cutting drum-roller. Smaller structural dimensions and horizontal placing of the drum are rather advantageous therefore the gearing does not need to be solved through a conical gearing. Ventilation effect of a device inevitable for emptying is negligible and thus independent transfer of chips from a drum to a storage tank. The first option is to let the chips fall onto a conveyor belt placed under the drum from which the chips are conveyed to the storage tank. The second option rests in installation of an emptying device behind the drum which shall blow the chips into the storage tank[Puskar 2012]. During cutting the cutting angle varies from maximal to minimal which influences the quality of chips therefore it is suitable especially for the uneven substance.

Disc Mechanism

The mechanism ranks among the most widespread ones due to its simplicity and efficiency. It works on the basis of principle of a rotating disc with diameter ranging from 500 mm up to 2000 mm to which two even seven knives according to size are fixed perpendicularly to the rotation axis. Circumferentially along the

roller and linearly to the rotation axis the blades are placed. Those serve for emptying of a cutting chamber therefore the emptying mechanism is not needed. High inertial moment allows even in case of high cutting performance employing of a driving unit with the performance lower than the one of a drum mechanism.

Mechanism with a Conical Screw Blade

In case of a screw splitting mechanism a conical thread with variable ascent gradually getting wider can be observed. When transferring the stable bottom of a splitting mechanism the splitting substance is gradually cut by a conical screw rotating above the stable bottom.The thread splitting mechanism is employed in processing of substance of up to 200 mm.

Mechanism with a Contra-Rotating Cutting Edge

The splitting mechanism works on the principle of two contra-rotating shafts with the identical diameter with the knives fixed to it. Their number and placement is the same. In certain point the knives encounter and thus the substance is cut. In case of this mechanism the feeding device is not necessary as the substance is continually drawn in by means of cutting knives. The length of a chip cannot be adjusted in such case as it depends on size of cutting material[Vojtko 2009].

Categorization According to Means of Transport

Drawn Splitters

The splitters dispose of inherent single axle chassis inevitable for transport. They are connected by means of a tie rod to the drawing device or to the ball suspension of a vehicle. In major cases the chassis comprises of a combustion engine serving for drive of the device. The advantage rests in fast transport to the place of destination[Bicejova 2016a,b].

Carried Splitters

The carried splitters rank among the most frequently used from the point of view of structure of the basic frame. The basic frame is adjusted to assure fastening into a three point suspension of the tractor. In this case the weight of the entire splitter must not exceed the suspension lifting force.

Splitters with Inherent Chassis

The group includes the splitters with high performance. Those are fixed to the chassis of the truck. To assure high performance the splitters contain inherent driving combustion engine. As a standard a hydraulic arm is fixed to the chassis of the vehicle designed to feed the wooden substance.

Stationary

Such types of the splitter are ranked especially among gardening splitters which serve for recycling of the minor wooden garden waste. They are typical for low weight and price. The splitters are standardly driven by the electric motor[Smeringaiova 2016].

Categorization According to the Type of the Feeding Mechanism

Without Feeding Mechanism

It ranks among the simplest devices. The wooden substance is manually or through a self-weight fed into a cutting mechanism. The method is rather physically demanding and dangerous as the substance might fling out of the machine. At the same time even size of the cutting substance is not guaranteed.

With Automatic Feeding Device

This type of the feeding mechanism is connected especially with the splitter with a conical helix with the contra-rotating cutting edge. The cutting mechanism automatically draws the wooden substance in by means of which the identical size of chips. Its length cannot be adjusted.

With a Driven Feeding Mechanism

The driven feeding mechanism is the most frequently used. It is constituted of two contra-rotating rollers. The lower roller is usually stable and the upper one, so-called snub roller is horizontally movable. In case of splitters with higher performance the lower roller is replaced by a conveyor belt. By adjusting the rotation speed of the lower roller or of the conveyor belt the size of the chip can be adjusted. The drive is secured by hydraulic motors or through gear mechanism from the output shaft of the machine.

2 CURRENT CUTTING DEVICE DESIGN

The presented cutting device is designed for household utilization or for smaller businesses. Its basic structure is adjusted to assure fastening into a three point suspension of the tractor which shall drive it through the output shaft. The device is equipped by feeding rollers which are driven by hydraulic and mechanical gearing. A light-weight trailer can be connected behind the device to assure collection of cutting material. In case of small volume of cutting substance it represents an advantage from the point of view of utilization of a single driving mechanism which is the tractor. Minimal input parameters required for the cutting device are as follows: performance P=80Hp (59655.992W) at 540 rev/min.

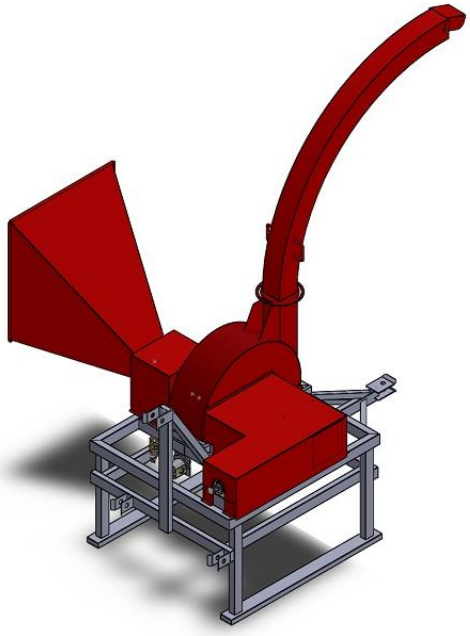

Figure 1. Designed splitter

In the design of the device a disc cutting mechanism is applied with two cutting knives and emptying blades. To assure higher flexibility the cutting disc is fixed to a main shaft by screws. The cutting knives can be easily disassembled to assure easy sharpening.

Assumed circular section *"S"* of the material with maximal diameter $d_{mat} = 100mm$.

$$S = \frac{\pi . d_{mat}^{\ 2}}{4} = \frac{\pi . 100^2}{4} = 7853.981 \text{ mm}^2$$

Force F inevitable for material cutting if considered is *4 MPa* of τ_{Dshear}.

$$\tau_{Dshear} = \frac{F}{S}$$

$$F = \tau_{Dshear}.S = 4.7853{,}981 = 31415.942\ N$$

Action *"A"* inevitable for material cutting in one rotation. The rotation disc with two knives is taken into consideration and thus double action is performed in one rotation.

$$A = 2.F.d_{mat}$$

$$A = 2\ .31415.942\ .0{,}1 = 6283.185\ J$$

Action inevitable for material cutting and minimal performance of the machine can be used for expressing of the needed rotations of cutting mechanism rotor on the basis of the following relation:

$$P = \frac{A}{t} \quad \rightarrow t = \frac{A}{P} = \frac{6283.158}{59655.992} = 0.1053\ s$$

$$n_{dis} = \frac{1}{0.1053} = 9.33\ rev/sek$$

$$9.33\ rev/s = 560\ rev/min$$

n_{disc} = cutting disc rotations [rev/min]

Calculation of transferred torque in case of output shaft of the tractor[Mascenik 2016a].

$$M_k = \frac{P.60}{2.\pi.n} = \frac{59655.992.60}{2.\pi.540} = 1016.942Nm$$

Calculation of axial force acting upon the main shaft produced from the cutting edge of the knife.

$$\tan 25° = \frac{F_a}{F_r} \quad \rightarrow F_a = F_r.\tan 25° = 31415.992.\tan 25° = 14649.487$$

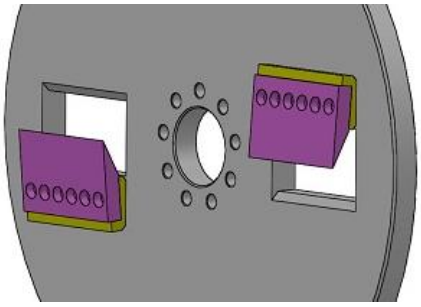

Figure 2. Part of the cutting disc

In sharpening of the knives the thickness is reduced and thus larger cutting gap is formed and the clearance results in imperfect cut. To avoid the occurrence, an opposite movable cutting edge is thus proposed which prevents formation of the clearance. The opposite cutting edge comprises of milled grooves allowing such movement The cutting edge is fixed by means of fours screws M10x45 with internal hexagon STN 02 1143 standard[Bicejova 2013].

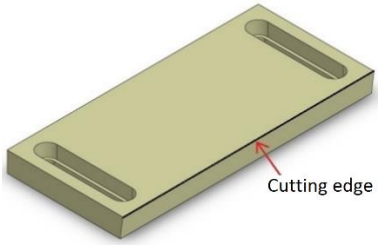

Figure 3. Cutting edge opposite to cutting knife

Design of a Load-Bearing Structure

In case of meeting the requirement related to maximal possible efficiency of device desired is easy manipulation with the device even in terrains with limited accessibility. The structure with inherent chassis is possible yet rather demanding as to finances and structure. With the proposed size of the mechanism the most advantageous variant for transfer is fastening into a three-point mechanism of the tractor. The option appears to be the most favourable regarding finances and structure.

Basic Frame

The basic frame is structured to allow fastening into a three point suspension of the tractor. The basic dimensions of the fastening components are designed and unified into a three point suspension. The entire basic frame is welded from the standardized profiles to which other parts are fixed such as rectangular clutch, cutting mechanism, feeding mechanism. At the end of the frame a connecting device is fixed which allows connecting of a light weight trailer.

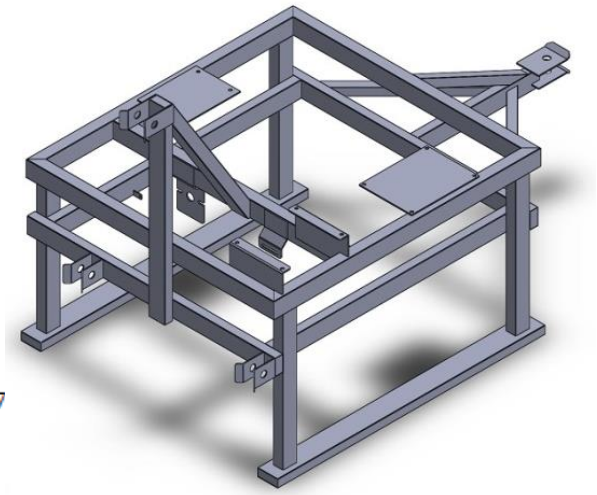

Figure 4. Basic supporting frame

One of the parts of the supporting frame is an exhaust stack allowing regulation of direction of the substance blown off from the cutting area. It is made from metal sheet with thickness of 2 mm and with square section of 150 mm. Its direction can be manually adjusted in the range from 0° to 90°. The stack is fixed to the cutting mechanism by a screwed joint which in loosening of the screws gets loosened by which stack slewing is allowed [Bicejova 2016b].At the end of the stack a rectifier of cutting substance incidence can be observed by means of which angle of incidence of substance into the storage tank is adjusted. The smaller the angle, the further shall the substance fall. The rectifier is adjusted manually by the screw joint [Mascenik 2014].

Figure 5. Exhaust stack

An access duct is other part which the basic frame comprises of. The delivered cutting substance is fed into it. The duct is made of the metal sheet with thickness of 2.5 mm. It has a shape of a truncated pyramid at the beginning of which an intake opening is flanged due to high stiffness. Its end is conveyed to feeding rollers and reinforced by the square

profile. The hangers are fixed to one side of the access duct to hang it down during transport.

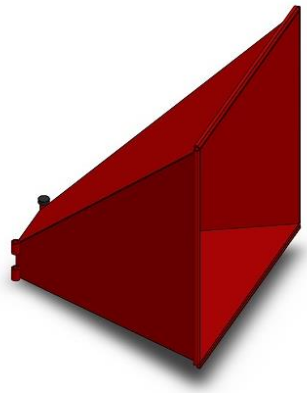

Figure 6. Access duct

3 DESIGN AND CALCULATION OF CHAIN GEARING

The feeding rollers replace the human force which an operator should produce to insert the wooden substance into the cutting device. The activity would be thus rather dangerous as the operator could get hurt easily. At the same time the rollers assure constant material deliver and the identical size of cutting material leading to improved and more economic utilization. The man produces the force by the hand pressure of approximately 330N.The feeding rollers are structured so that peripheral force equals to 330N, i.e. F_{ov}= 330N[Bicejova 2016c].

The resulting moment along the circumference of the feeding roller is as follows:

$$M_{ov} = F_{ov} \cdot \frac{d}{2} = 330.\frac{0,12}{2} = 19.8\ \text{Nm}$$

M_{ov} – torque along the circumference of the feeding roller,

d =120 mm – diameter of feeding roller.

To drive the feeding roller the chain gearing was selected to assure the identical length of cutting material. Tractive force of a chain shall be similar to the one which could be observed in case of circumference of rollers. The chain was selected according to the required feeding force F_P.

$$k = \frac{F_p}{F_o} \Rightarrow F_{PMIN} = k.F_o = 7.330 = 2310\ \text{N}$$

$k = 7$ – roller chain safety factor,
F_{ov}= 330N force acting in the chain.

Design of a Chain

The chain was selected according to STN 02 3311 08 B standard.In selection of the chain the attention was paid to force magnitude as well as to dimensions and conditions of the application. Calculation neglects centrifugal forces of the chain.

Parameters of the selected chain:

Rupture force	F_R = 17.80kN
Area of a joint	S = 50 mm^2
Spacing of the chain	t = 12.7 mm
Roller diameter	d = 8.51 mm

The number of chain wheels is *z=17*. Stress of the chain is performed by a tension pulley with a spring fixed to a basic frame. From the point of view of structure one more toothed stationary wheel should be inserted. Transfer of torque M_k from chain wheels to the feeding rollers is assured by a tight spline. Strength calculation of tight splines is carried out by the MechSoft program.

Diameter of a circle D_t

$$D_t = \frac{t}{\sin\frac{180}{z}} = \frac{12.7}{\sin\frac{180}{17}} = 69,12\text{mm}$$

Actual tractive force F_{Chain} of the pitch circle in case of the toothed wheel

$$F_{Chain} = \frac{M_{ov}}{\frac{D_t}{2}} = \frac{19.8}{\frac{0.06912}{2}} = 572.91\text{N}$$

$$F_p \geq F_{Chain}$$

$$17800\text{N} \geq 572.91\text{N} \rightarrow \text{applicable}$$

The actual force acting in the chain is negligible contrary to the force inevitable for the chain rupture. Therefore other strength calculations of the chain are not needed. The strength calculation and calculation of dimensions of the toothed wheels are carried out by the Mechsoft program[Mascenik 2016b].

Calculation of Revolutions of the Feeding Rollers

The evenness of the cutting substance depends on the rotation speed of the feeding rollers. It is inevitable to assure double shift of material of the cutting substance length per one rotation of a rotor and thus the speed must be adjusted accordingly.

Calculation of circumference of the feeding roller:

$$O_v = \pi.d = 3.14.120 = 376,8\ \text{mm}$$

O_v - circumference of the feeding roller.

Feeding rollers with diameter of *d*=120mm can shift the material by 376.8 mm per one rotation.To assure higher flexibility and utilization of the machine the cutting substance length can be adjusted by means of the hydraulic circuit.

Required length of the cutting substance is of L_1= 35mm

$$n_{v1} = \frac{O_v}{2.L_1} = \frac{376.8}{2.35} = 5.38$$

i_1= 5.3 rotations of the rotor can be ascribed to 1 rotation of the feeding roller. The gear ratio of 1:5.38 might be thus observed. The rotations of the feeding rollers in case of such gear ratio are of 100.3 rev/min.

Required length of cutting substance is of L_2= 25mm

$$n_{v2} = \frac{O_v}{2.L_2} = \frac{376.8}{2.25} = 7.53$$

i_2= 7.5 rotations of the rotor can be ascribed to 1 rotation of the feeding roller. The gear ratio of 1:7.53 might be thus observed. The rotations of the feeding rollers in case of such gear ratio are of 71.7 rev/min.

Required length of the cutting substance is of L_3= 15mm

$$n_{v2} = \frac{O_v}{2.L_2} = \frac{376.8}{2.15} = 12.56$$

i_3= 12.6 rotations of the rotor can be ascribed to 1 rotation of the feeding roller. The gear ratio of 1:12.56 might be thus observed. The rotations of the feeding rollers in case of such gear ratio are of 42.9 rev/min[Mascenik 2016c].

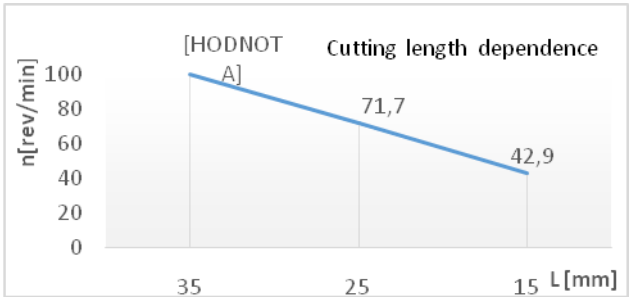

Figure 7. Dependence of the cutting substance length on revolutions of the feeding roller

4 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. 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.In: Science Business Society, Vol. 1, No. 5, 2016, pp. 42-45. ISSN 2367-8380

[Bicejova 2013] 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 2016a] Bicejova, L., Pavlenko, S., Mascenik, J. Measuring, processing and evaluating of technology head water jet vibration signal. 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. Influence of selected technological parameters on cutting surface roughness in material laser cutting. MM Science Journal, Vol. 2016, No. September, 2016, pp. 973-976. ISSN 1803-1269, DOI: 10.17973/MMSJ.2016_09_201645

[Bicejova 2016c] Bicejova, L. and Pavlenko, S. Experimental investigation and determination of abrasive granularity change impact to technology head vibration generating during AWJ technology steel cutting. Key Engineering Materials: Operation and Diagnostics of Machines and Production Systems Operational States 3. Vol.669, 2016,pp.220-227. ISSN1013-9826

[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

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

[Mascenik 2014] Mascenik, J. and Pavlenko, S. Aspects of alternative dispute creating bolted joint technology flowdrill. Applied Mechanics and Materials, Vol. 680, 2014, pp. 186-189. ISSN 1660-9336

[Mascenik 2016a] 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 2016b] 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

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

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

[Pavlenko 2016] Pavlenko, S. Determinitation of relation between influence of laser perfomance change and cutting surface character in laser cutting technology. MM Science Journal. Vol. 2016, No. September, 2016, pp. 952-955. ISSN 1803-1269, DOI: 10.17973/MMSJ.2016_09_201637

[Puskar 2012] Puskar, M. and Bigos, P. Method for accurate measurements of detonations in motorbike high speed racing engine. Measurement, Vol. 45, No. 3, 2012, pp. 529–534. ISSN 0263-2241

[Smeringaiova 2016] Smeringaiova, A. and Smeringai, P. Dynamic model of the test station for gear drives dynamic tests. Key Engineering Materials: Operation and Diagnostics of Machines and Production Systems Operational States 3,Vol. 669, 2016, pp. 434-442., ISSN 1013-9826

[Vojtko 2009] Vojtko, I., Matija, R., Halko, J., Misik, L. Group technology in design of production method. In: 23rd microCAD Conf., Section M - Production engineering and manufacturing systems, University of Miskolc, 2009,pp.245-248. ISBN 9789636618780

CONTACTS

M.Sc. Jozef Mascenik, PhD.
Technical University of Kosice
Faculty of Manufacturing Technologies
Department of Technical Systems Design and Monitoring
Bayerova 1, Presov, 080 01, Slovak Republic
+421 51 772 6321, jozef.mascenik@tuke.sk, www.tuke.sk