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Comparative study of tool machinery sliding systems; comparison between plane and cylindrical basic shapes

D O Glăvan[1], T Babanatsas[1], R M Babanatis Merce[1] and A Glăvan[2]

[1]University "Aurel Vlaicu", Department of engineering, Arad, Romania
[2]Rug University of Groningen, Faculty of Mathematics and Natural Sciences, Groningen, Netherlands

E-mail: glavan@fortuna.com.ro

Abstract. The paper brings in attention the importance that the sliding system of a tool machinery is having in the final precision of the manufacturing. We are basically comparing two type of slides, one constructed with plane surfaces and the other one with circular cross-sections (as known as cylindrical slides), analysing each solution from the point of view of its technology of manufacturing, of the precision that the particular slides are transferring to the tool machinery, cost of production, etc.
Special attention is given to demonstrate theoretical and to confirm by experimental works what is happening with the stress distribution in the case of plane slides and cylindrical slides, both in longitudinal and in cross-over sections. Considering the results obtained for the stress distribution in the transversal and longitudinal cross sections, by composing them, we can obtain the stress distribution on the semicircular slide. Based on the results, special solutions for establishing the stress distribution between two surfaces without interact in the contact zone have been developed.

1. The influence of the shape of sliding surfaces in sliding process of the whole tool-machine

The first part of our study is referring to the case of cylindrical slides. In order to determine what is really happening in all zones of interest we have to create a mathematical model with all phenomena that are generated by the manufacturing process, all stress that is acting on the structure, the generated forces and torques, action and reaction and distributed forces.

The resultant of the forces is affecting the semicircular slide, and the formulas for acting stress has been deducted previously, is broken down using both the transversal direction of the slide, and the longitudinal direction [1], [2].

In a transversal cross section, the resultant affecting the slide, as proved previously, in a spot characterized by an angular position and by coordinates y and z, will break down in a f(x) distribution curve, which is characterized by a maximum stress value in its transversal cross section of P_{max}, and a contact length T/2, as presented in Figure 1.

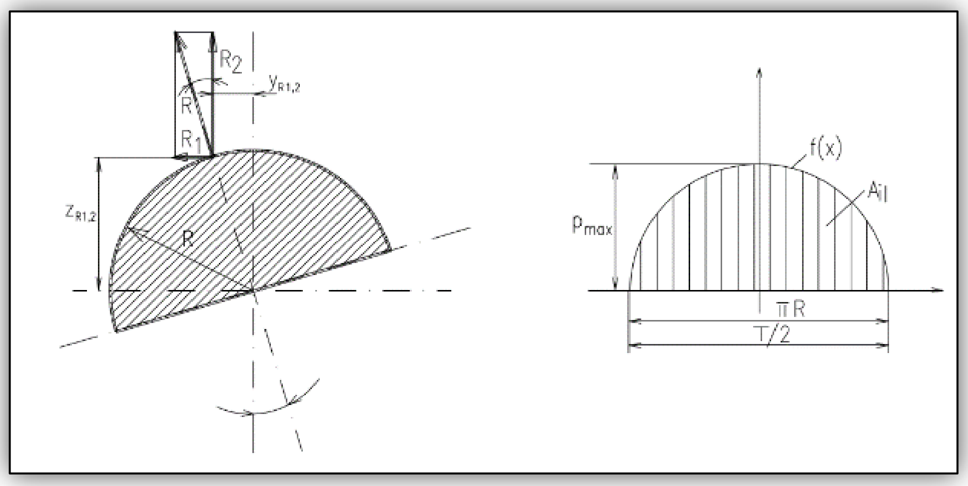

Figure 1. The resultant in a transversal cross section

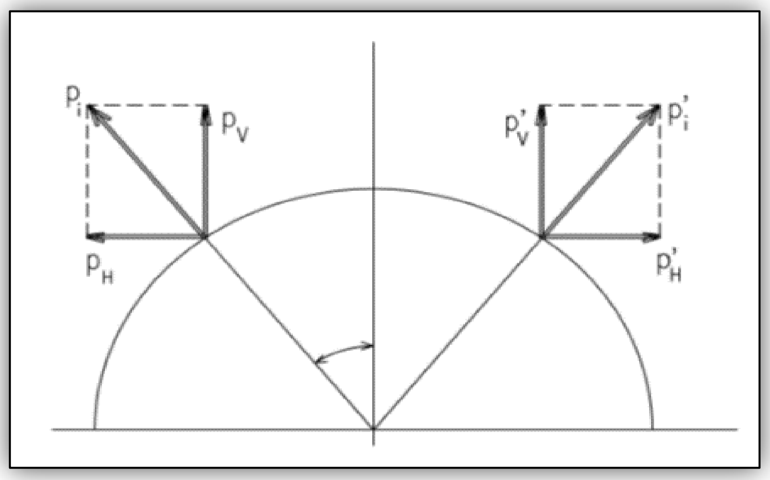

Figure 2. Reaction in the semi-circular slide

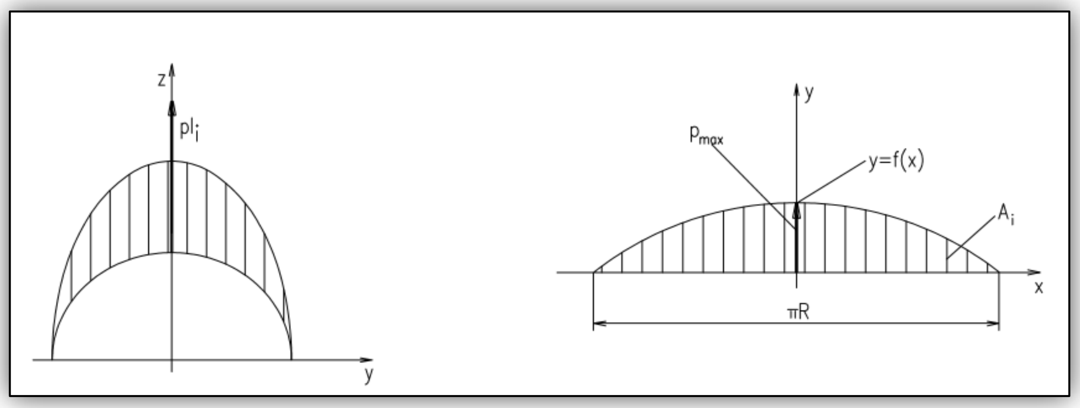

Figure 3. The broken-down stress in a transversal cross section

A specific feature of the semicircular slide is the fact that the reaction components on the horizontal axis will cancel each other out generating just a compression stress on the horizontal section of the slide, with low value fact that is not affecting at all the precision of the structure and of course the final precision of the manufacturing process. Only the vertical components will be left and they will count in the precision balance, as shown in the Figure 2 [3].

The broken-down stress values in the transversal cross section are displayed in Figure 3.

2. Experimental conditions

For this particular shape of the sliding surfaces we can write the following equations:

$$\begin{cases} p_H = p_i \sin a_i \\ p_V = p_i \cos a_i \\ \overline{p_H} + \overline{p_H} = 0 \end{cases} \tag{1}$$

The break-down in the transversal cross section allows us to anticipate the fact that the distribution curve will be of a cosine type. However, two variants will be considered in the calculation.

Two function variants which could define the stress curve in a transversal cross section were analyzed: the harmonic and the polynomial functions [2], [4].

2.1. Distribution according to a harmonic function

The following general formula was used:

$$f(x) = b \cdot cos\omega x \tag{2}$$

In order to determine the b and ω constants, the area between the f(x) function and the OX axis is equaled to the longitudinal stress corresponding to the respective I point that is defining the A_i cross section [5-8]

$$p_i l = A_i \tag{3}$$

but:

$$A_i = \int_{\frac{\pi R}{2}}^{\pi R} f(x)dx = \int_{\frac{\pi R}{2}}^{\pi R} b \cdot cos\omega x dx = 2\frac{b}{\omega} sin\omega x \begin{cases} \frac{\pi R}{2} \\ 0 \end{cases} \tag{4}$$

$$\omega = \frac{2\pi}{T} \tag{5}$$

but the T period meets the following condition, according to the diagram:

$$\pi R = \frac{T}{2} \Longrightarrow T = 2\pi R \Longrightarrow \omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi R} = \frac{1}{R} \tag{6}$$

$$\Longrightarrow A_i = 2bR\ (\sin\frac{\pi R}{2} - \sin 0) = 2bR \tag{7}$$

$$\begin{cases} A_i = 2bR \\ \omega = \frac{1}{R} \end{cases} \tag{8}$$

and therefore the formula for the distribution function of the stress in the transversal cross section will be as follows:

$$\Longrightarrow f(x) = \frac{p_i l}{2R} cos\frac{1}{R}x \tag{9}$$

2.2. Distribution according to a polynomial function

The general formula of a polynomial function is as follows [9-11]:

$$y = f(x) = -ax^2 + b \tag{10}$$

$$x = 0 \Rightarrow f(x) = b \tag{11}$$

$$A_i = 2\int_0^{\frac{\pi R}{2}} f(x)dx = 2\int_0^{\frac{\pi R}{2}} (-ax^2 + b)dx =$$

$$= 2\left(-\frac{ax^3}{3} + bx\right)\begin{cases}\frac{\pi R}{2} \\ 0\end{cases} = 2\left(-\frac{a}{3}(\frac{\pi R}{2})^3 + \frac{b\pi R}{2}\right) \tag{12}$$

$$x = \frac{\pi R}{2} \Rightarrow \begin{cases} f(x) = 0 \\ f(x) = -ax^2 + b \end{cases}$$

$$\Rightarrow -a\left(\frac{\pi R}{2}\right)^2 + b = 0 \tag{13}$$

$$A_i = p_i l \Rightarrow -\frac{a\pi^3 R^3}{12} + \frac{b\pi R}{2} = p_i l \tag{14}$$

$$\Rightarrow b = a\frac{\pi^2 R^2}{4} \tag{15}$$

$$\Rightarrow a = \frac{24}{\pi^3 R^3} p_i l \tag{16}$$

$$\Rightarrow b = \frac{6}{\pi R} p_i l \tag{17}$$

Therefore, the polynomial function that could define the stress distribution in the transversal cross section is expressed as follows:

$$f(x) = -\frac{24}{\pi^3 R^3} p_i l \cdot x^2 + \frac{6}{\pi R} p_i l \tag{18}$$

Experimental studies have proved that the stress distribution in a transversal cross section occurs according to a harmonic function of cosine type, this being the closest to test results [12].

In the case of the plane sliding system it is immediate that the stress distribution is a linear one, the distribution of the stress in the cross over section being related with the value of forces and the coordinates of the pressure point where they are applied [13-15].

3. The distribution type

The distribution type of the stress in the longitudinal cross section is influenced by the slide length, by the point of application of the force and by whether there is a closing facet or not.

There are three main distribution variants: the trapezoid distribution, with its idealform being the rectangular distribution, the complete triangular distribution and the incomplete triangular distribution, the latter having several variants itself [9-12].

3.1. The trapezoid distribution variant

$$\delta = kp \tag{19}$$

$$\varphi_y = \frac{\delta_{Amax} - \delta_{Amin}}{H} = \frac{P_{Amax} - P_{Amin}}{H} \tag{20}$$

$$P_{Amin} = \frac{A}{aH} - \frac{6M_A}{aH^2} \tag{21}$$

$$P_{Amax} = \frac{A}{aH} + \frac{6M_A}{aH^2} \tag{22}$$

$$\Rightarrow \varphi_y = \frac{12M_A k}{aH^3}\ ;\ \frac{x_A}{H} - \frac{M_A}{aH} < \frac{1}{6} \tag{23}$$

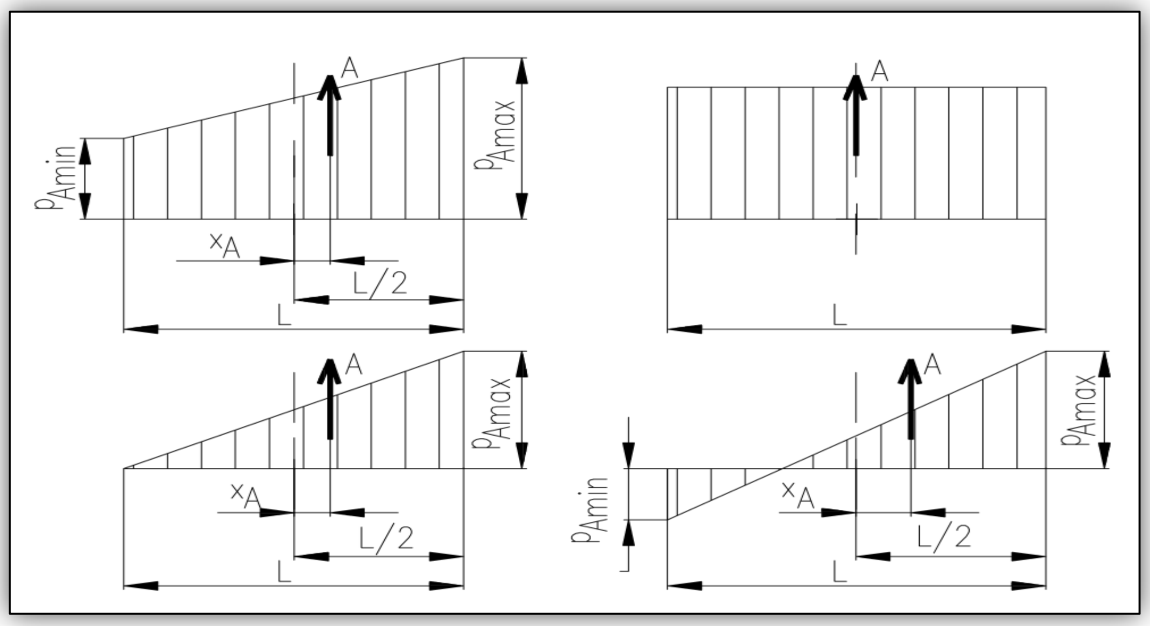

Figure 4. Trapezoid distribution of stress

3.2. The triangular distribution variant $H_m<H$

We will analyze only the variant where the closing facet is not involved, since there is no closing facet in the semicircular slide, Figures 5, 6 and 7 [11], [16].

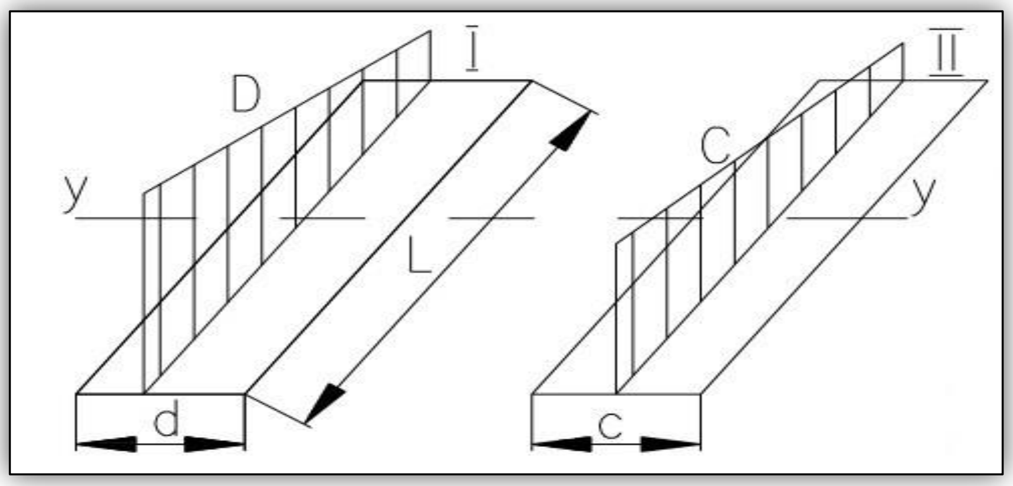

Figure 5. Trianghiular distribution of stress

$$\Delta > \varphi(H - H_m) \tag{24}$$

$$\varphi_y = \frac{\delta_{Amax}}{H_m} = k\frac{p_{Amax}}{H_m} \tag{25}$$

$$p_{Amax} = 4\frac{A^2}{3a(AH-2M_A)} \tag{26}$$

$$H_m = 3H(\frac{1}{2} - \frac{M_A}{AH}) \tag{27}$$

$$\varphi_y = \frac{12M_A k}{\lambda a H^3};\ \lambda = \frac{M_A}{AH}(1 - \frac{2M_A}{AH}) \tag{29}$$

under the conditions presented in Figures 5, 6 and 7.

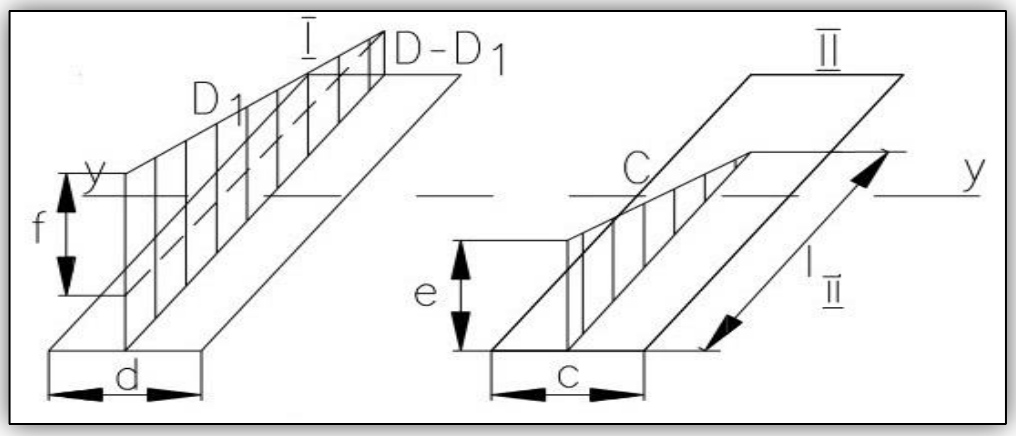

Figure 6. Trianghiular distribution of stress

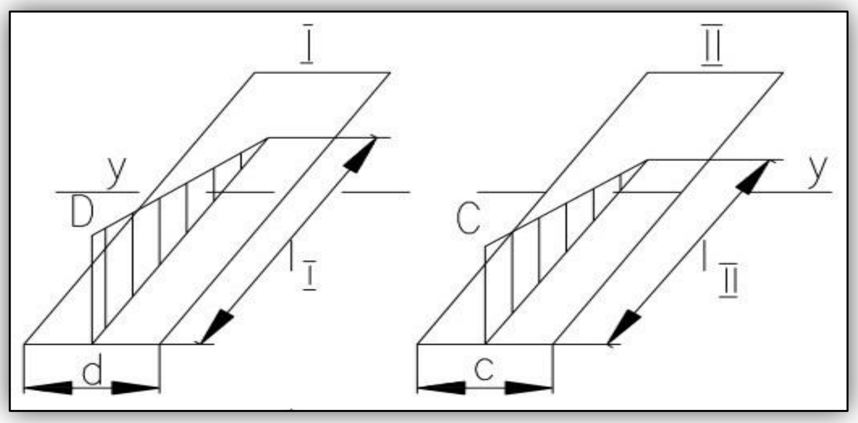

Figure 7. Trianghiular distribution of stress

4. Conclusions

Considering the results obtained for the stress distribution in the transversal and longitudinal cross sections, by composing them we can obtain the stress distribution on the semicircular slide, as shown in the Figure 8.

In the case of circular slides in the cross section, in median line of the section, we determined a value of distributed forces that is considerably higher than the values situated at the borders of the interval, fact that conduct us to the conclusion to recommend the use of this type of slides on cases of low stress manufacturing machines (basic on smaller machines).

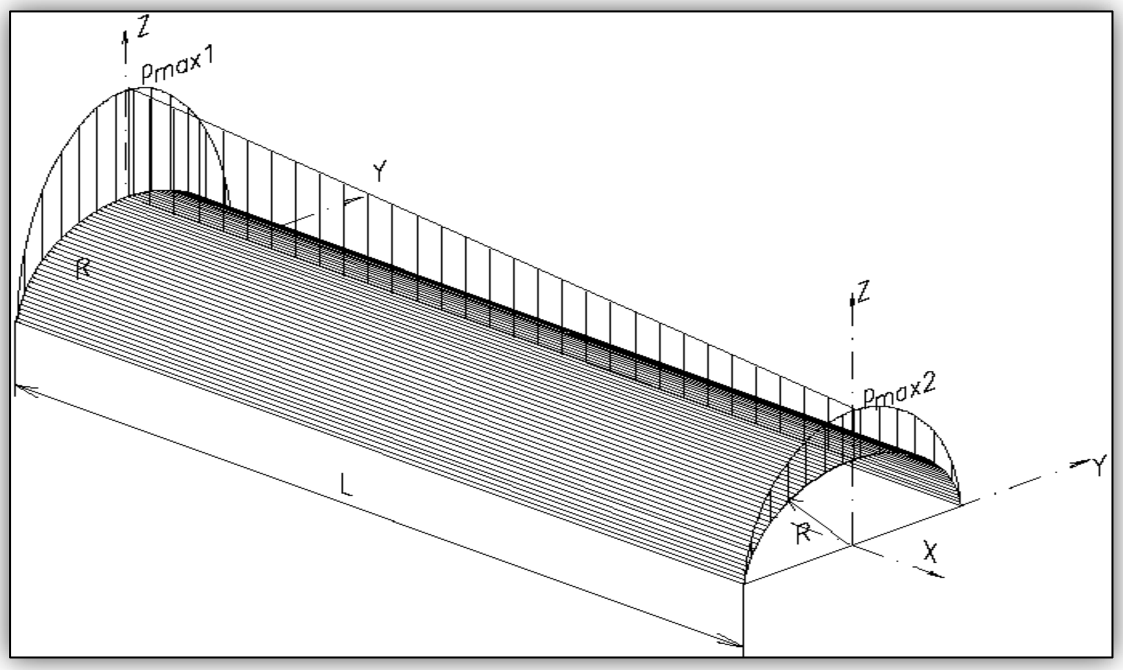

Figure 8. Triunghiular distribution of stress

The distribution in the longitudinal cross section being similar, the only determinant factor differencing the plane slides is the distribution in cross over section where we concluded that the differences between the maximum and the minimum values of pressureis much smaller than in the case of cylindrical slides, so we can recommend the plane sliding system to be used on bigger manufacturing machines where the cutting parameters and therefore the forces and torques acting on the structure are at least ten times higher.

References

[1] Meyer H, Fuchs F and Thiel K 2009 *Manufacturing Execution Systems: Optimal Design, Planning, and Deployment*, McGraw Hill, pp 105-120
[2] Kovalev V D, VasilchenkoY V and Dašiü P 2014 Adaptive optimal control of a heavy lathe operation, *Journal of Mechanics Engineering and Automation* **4**(4) 269-275
[3] Cîndea L, Hatiegan C, Gillich G R, Marta C and Nedeloni M 2012 Research Regarding Vibration Damping in Systems with a Degree of Freedom, *Scientific Bulletin of the "Politehnica" University of Timisoara, Transaction on Mathematics & Fhysics* **57**(1) 68-70
[4] Glăvan D O and Babanatsas T 2015 *Mașini unelte și agregate*, Editura Universității „Aurel Vlaicu", Arad, Romania
[5] Hakansson L 1999 *Adaptive Active Control of Machine-Tool Vibration in a Lathe – Analysis and experiments*, Lund University, Sweden
[6] Jacobson M O 1966 *Tehnologhia stankostroenia; "Maşinostroenie"*, Moscow, Rusia
[7] Pronicov A C 1957 *Iznov i dolgovecinosti stanko*v, Maşghiz, Moscow, Rusia
[8] Dreucean A 1984 *Maşini unelte şi control dimensional*; Litografia UPT, Timişoara, Romania
[9] Paizi Gh, Stere N and Lazăr D 1977 *Organe de mașini și mecanisme* Editura didactică și pedagogică București
[10] Sima Gh 2004 *Sisteme senzoriale utilizate la sudare*, Editura „Viata Arădeana", Arad, Romania
[11] Sima Gh, Glăvan D O, Popa A and Muncut S 2016 *Hard as a Rock or Deformation Controlled?* Soft Computing Applications. Advances in Intelligent Systems and Computing, vol **356,**

IOP Conf. Series: Materials Science and Engineering **294** (2018) 012068 doi:10.1088/1757-899X/294/1/012068

Springer, Cham
[12] Kacalak W and Tandecka K 2012 Effect of superfinishing methods kinematic features on the machined surface, *J. Machine Engineering* **4** 35-48
[13] Janecki D, Stępień K and Adamczak S 2010 Problems of measurement of barrel- and saddle-shaped elements using the radial method, *Measurement* **43**(5) 659-663
[14] Alquraana T, Kuznetsovb Yu and Tsvydb T 2016 *High-speed qlamping Mechanism of the CNC lathe with Compensation of Centrifugal Forces*, International Conference on Industrial Engineering, ICIE
[15] Dimitrova D and Szecsib T 2015 *Machining accuracy on CNC lathes under the lack of unity of the process and design data*, 48th CIRP Conference on Manufacturing Systems - CIRP CMS
[16] Radu I 2001 *Physical and mathematical pattern of a pneumatical oscilation system with two masses unlinear-D.N.4*, Magyar Tudomanyos Akademia, Kutatasi es fejlestesi tanacskozas, **25**(3), Kotet, Godolo, pp 305-309