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## Study on the influence of the blank thickness on the dynamic behavior of mechanic eccentric presses

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# Study on the influence of the blank thickness on the dynamic behavior of mechanic eccentric presses

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**Abstract.** This paper presents a method for studying the dynamic behavior of mechanical presses with eccentricity based on a mathematical model. The novelty elements of the proposed model are as follows: the essential non-linear evolution of the force in process; the frictional force in the slider guides is also considered to have a non-linear character; the friction moments in the kinematic chain structure are considered different at start-up compared to the nominal regime and the weight of the slider together with the elements attached to it is taken into account. The equations characterizing the movement of the system were deduced starting from Lagrange's generalized equations. Finally, an interactive graphical interface was developed that allows the study of the influences of some constructive and adjusting parameters on the parameters that characterize the dynamic behavior of the working mechanism: the angular speed, the motor moment and the power consumed by the electric drive motor. The method was applied to the case of PAI 63 press. Based on the results obtained by changing the parameters mentioned above (around the existing values), a serie of conclusions were drawn that could lead to an improvement of the construction and the exploitation. of this machine.

## 1. Introduction

This paper presents a method based on a mathematical model which (relative to other models) is much closer to the physical model of the driving mechanism. This model was obtained on the basis of the known method of the reduction of all the components of the driving mechanism to an equivalent shaft, on which it acts on the one side the motor moment from the motor source, and-on the other side-the resisting moment from the working process and from de friction processes.

As new elements of the proposed model we can mention the following:

- The evolution essentially non-linear of the force from the working process;
- The friction force from the slider guides is considered as having a essentially nonlinear character too;
- The friction moments from the structure of the kinematic chain are considered different at the start relative to the function on the working process.

## 2. Presentation of the working method

The method proposed in this paper uses a mathematical model that has been achieved considering that the reduced inertia moment of the mobile sub-assembly is variable.



The equations which describe the system movement of were inferred starting from equation (1) – Lagrange equation [1].

$$\frac{d}{dt} \left( \frac{\partial E_c}{\partial \dot{q}} \right) + \frac{\partial E_c}{\partial q} = 0 \quad (1)$$

Equation (2) describe the situation if the rotation angle of the main shaft crank is taken as general coordinate.

$$\ddot{q} = \omega \quad (2)$$

and equation (3) describe the moving equations of the driving mechanism in the working phase, if we accept that the kinetic energy is  $E_c = J \cdot (\omega^2/2)$ , where  $J$  is the sum of the inertia moments reduced at the main shaft [2, 3].

$$\left\{ \begin{array}{l} \frac{d\omega}{dt} = \frac{M_{mv} \cdot \frac{1}{i} - M_{mv} \cdot \frac{\omega}{\omega_{0m}} \cdot \frac{1}{i^2} - R(F_d + F_f + G) \left( \sin \alpha - \frac{\lambda}{2} \sin 2\alpha \right)}{J_{red} + m_c \cdot R^2 \cdot \left( \sin \alpha - \frac{\lambda}{2} \sin 2\alpha \right)} - \\ \frac{M_f - 2m_c \cdot R^2 \cdot \left( \sin \alpha - \frac{\lambda}{2} \sin 2\alpha \right) \cdot (\cos \alpha - \lambda \cos 2\alpha)}{J_{red} + m_c \cdot R^2 \cdot \left( \sin \alpha - \frac{\lambda}{2} \sin 2\alpha \right)} \\ \frac{d\alpha}{dt} = \omega \end{array} \right. \quad (3)$$

The parameters that appear in the above equations have the following meanings:  $\alpha$  -the rotation angle of the main shaft;  $\omega$  -angular speed of the main shaft;  $\omega_{0m}$  -the synchronism angular speed of the electric motor;  $i$  -transmission ratio between the motor and the main shaft;  $R$  - the crankpin radius (eccentricity) of the main shaft (adjustable in the case of the PAI type presses);  $\lambda$  -the mechanical feature of the press or the rod coefficient ( $\lambda = L/R$ , where  $L$  is the length of the rod);  $J_{red, const}$  -the sum of the constant inertia moments at the main shaft;  $m_c$  -slider mass;  $G$  -the weight of the slider with the elements due to this;  $M_{mv}$  -the virtual maximum moment of the motor, parameter introduced at the linearization of the motor mechanical characteristic in the working zone;  $F_d$  -the deformation force developed in the working process;  $F_f$  -the friction force from the slider guides;  $M_f$  -the friction moment on the flywheel together with the working mechanism [4-6].

The expression of the motor moment reduced at the main shaft, in the working zone, is described by the equation (4).

$$M_m = M_{mv} \cdot \frac{1}{i} - M_{mv} \cdot \frac{\omega}{\omega_{0m}} \cdot \frac{1}{i^2} \quad (4)$$

By integrating the differential equations (3) are obtained the evolutions of the rotation angle of the crankpin  $\alpha$  and of the angular speed  $\omega$  as function of time.

For numerical simulation of the behavior of an eccentric mechanical press, a software application was developed in the programming language C#. The C# language, together with the related software ecosystem (.NET framework), is a modern development environment for the Windows platform, providing a suite of software libraries for graphical interfaces, numeric simulation, algorithms, databases, or network communication.

The application has the following technical features:

- Graphic interface made in the Windows Presentation Foundation (WPF), which allows you to configure all parameters of the press, engine, or simulation parameters;
- Numerical integration of angular velocity through the Simpson and Runge-Kutta methods, with the ability to configure the sampling frequency;
- Linear value interpolation of the final angle using the MathNet. Numerics software library [7];
- Support for different units of measurement in configuring physical values (via the Units Net library) [8];
- Graphic representation of the deformation force, angular speed, engine torque and power evolution with zoom and panning capabilities through the Oxy Plot library (Open source Library for Graphics Design) [9];
- Save and load the hard disk simulation configuration;
- Save the simulation results in Excel format.

From the infrastructure point of view, the application has been developed so that the code for the simulation can be used independently of the graphical interface. In other words, the simulation and graphical interface are organized as independent modules.

The graphical interface allows the study of the influences of some constructive and adjusting parameters on the evolution of the rotation speed of the main shaft and also on the evolutions of the motor moment and the consumed power on the driving motor [10, 11]. With the help of this graphical interface we could modify the values of the following parameters: the inertia moment of the flywheel; the transmission ratio between the motor and the main shaft; the crankpin radius (eccentricity) of the main shaft; the length of the rod; the slider mass; the rod mass; the friction moment of the flywheel with the working mechanism; the friction force between the slider and its guiding; the deformation force; the moment of the deformation force application (expressed by the angular position of the crankpin). The graphical interface is presented in figure 1.

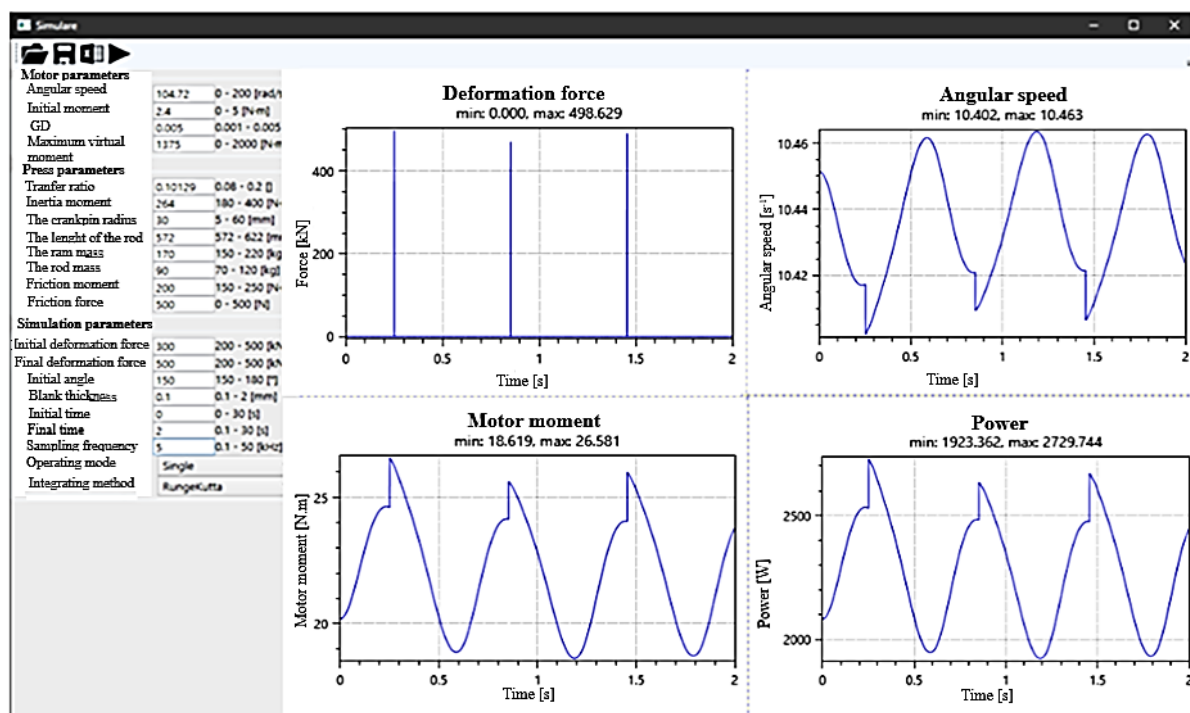


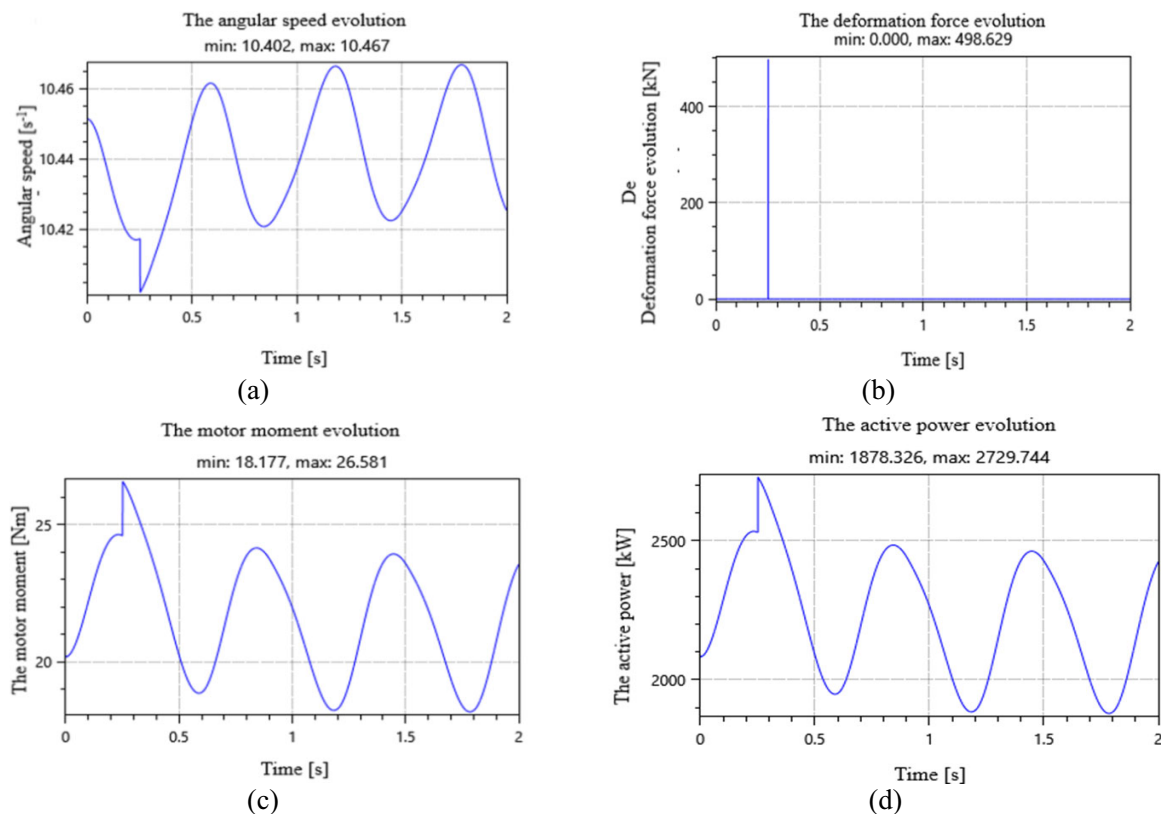
Figure 1. The graphical interface.

### 3. Working out the results

The study was made on the press PAI 63 wich has the following constructive and functional characteristics:

- nominal force  $F_N = 63\text{tf}$ ;
- motor type ASI 132M-38-6 (with the characteristics:  $P = 5.5\text{ kW}$ ,  $n_0 = 1000\text{ rot/min}$ ,  $n_n = 960\text{ rot/min}$ );
- the transmission ratio between motor and the flywheel,  $i = 0.10128$ ;
- the frequency of the slider drives,  $n = 90\text{ cd/min}$ ;
- the crankpin radius: adjustable between 5 and 60 mm;
- the length of the driving rod: adjustable between 572 and 622 mm;
- the friction moment of the flywheel together with the driving subassembly,  $M_f = 199.6\text{ N}\cdot\text{m}$ ;
- the slider mass,  $m_c = 170\text{ kg}$ ;
- the driving rod mass,  $m_B = 89\text{ kg}$ ;
- the inertia moment of the flywheel,  $J_v = 264\text{ N}\cdot\text{m}$ .

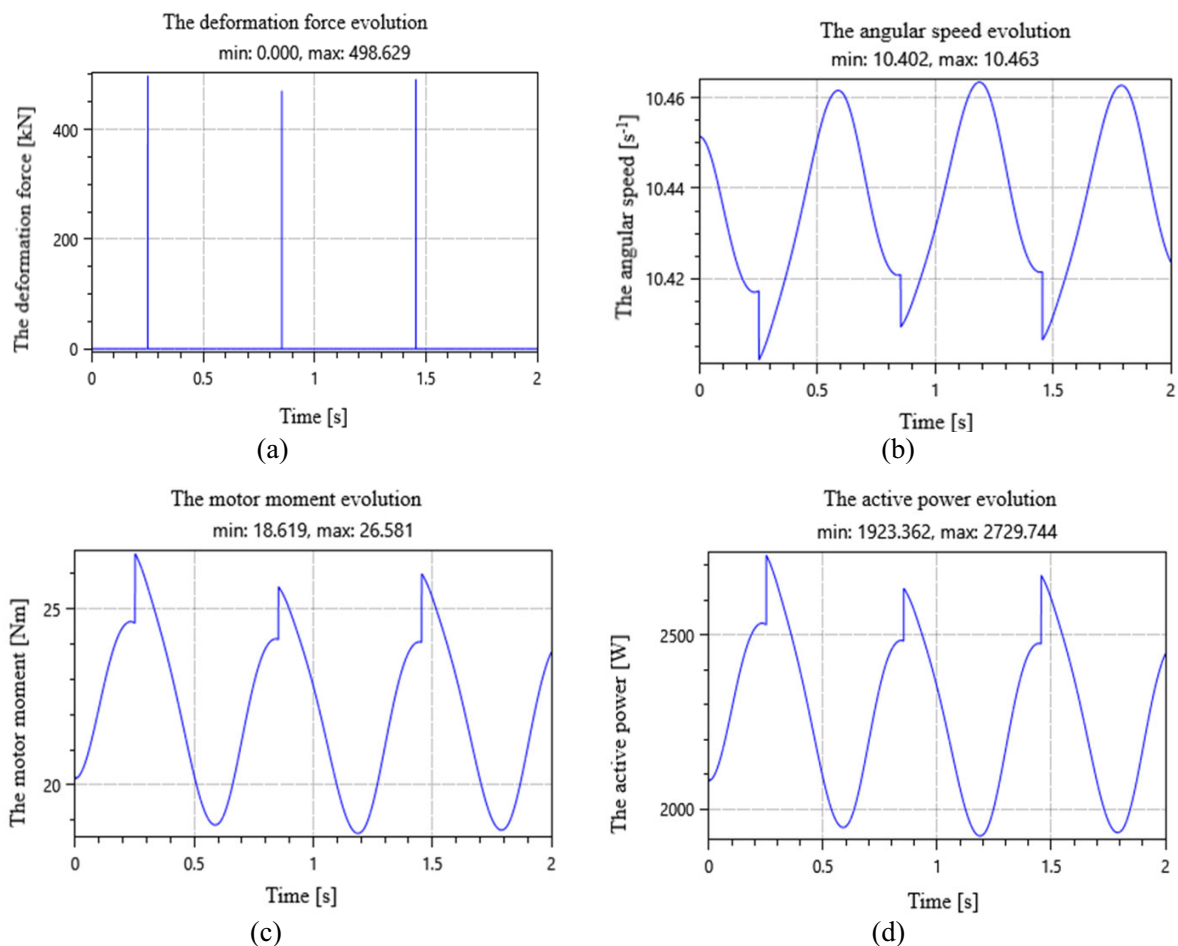
For the thickness of the blank, the following values were considered: 0.1mm; 0.3mm; 0.5 mm; 0.7 mm; 0.9 mm; 1.1 mm; 1.3 mm; 1.5 mm; 1.7 mm; 2 mm. For each value of the thickness of the blank, the graphical interface provides dynamic parameter evolutions: angular velocity, deformation force, motor moment, and active power. For example, for the blank thickness of 0.1 mm, the evolutions of the mentioned parameters in a single regime are shown in figure 2.



**Figure 2.** The dynamic parameters evolution in a single regime.

The dynamic parameters evolution in a repeat regime are presented in figure 3. In this case the constructive and functional parameters have the following values:

- The transmission ratio between the motor and the flywheel,  $i=0.10129$ ;
- The inertia moment of the fly wheel:  $J_v=264 \text{ Nm}$ ;
- The crankpin radius,  $R=30 \text{ mm}$  (maximum);
- The length of the rod,  $L=572 \text{ mm}$  (minimum);
- The slider mass,  $170 \text{ kg}$ ;
- The rod mass,  $90 \text{ kg}$ ;
- The friction moment,  $200 \text{ Nm}$ ;
- The friction force,  $500 \text{ N}$ ;
- The initial deformation force,  $300 \text{ N}$ ;
- The final deformation force,  $500 \text{ N}$ ;
- The initial angle,  $150^\circ$ .



**Figure 3.** The dynamic parameters evolution in a repeat regime.

The extreme values of the dynamic parameters in the both regimes are presented in table 1 (for “single” regime) and table 2 (for “repeat” regime).

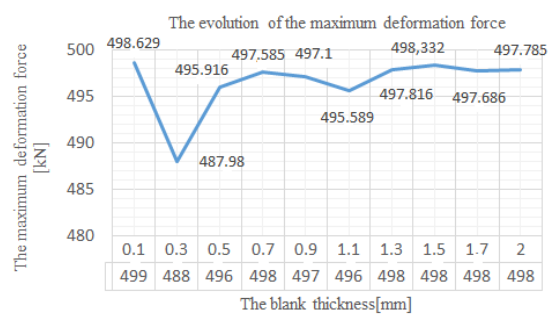
**Table1.** The dynamic parameters extreme values in the “single” regime.

g [mm]	F <sub>s</sub>		$\omega_s$		M <sub>ms</sub>		P <sub>s</sub>	
	max	min	max	min	max	min	max	min
0.1	498.63	0	10.467	10.402	26.581	18.182	2.729.744	1.879.132
0.3	487.98	0	10.467	10.38	29.374	18.182	3.010.372	1.879.165
0.5	495.416	0	10.467	10.355	32.647	18.182	3.337.625	1.879.165
0.7	497.585	0	10.467	10.331	35.783	18.195	3.649.637	1.880.157
0.9	497.1	0	10.467	10.308	38.78	18.201	3.946.523	1.880.762
1.1	495.589	0	10.467	10.286	41.64	18.207	4.228.496	1.881.344
1.3	497.816	0	10.467	10.261	44.858	18.213	4.544.265	1.882.003
1.5	498.332	0	10.467	10.238	47.896	18.219	4.840.983	1.882.633
1.7	497.686	0	10.467	10.216	50.754	18.225	5.118.774	1.883.232
2	497.785	0	10.467	10.182	55.119	18.234	5.540.689	1.884.16

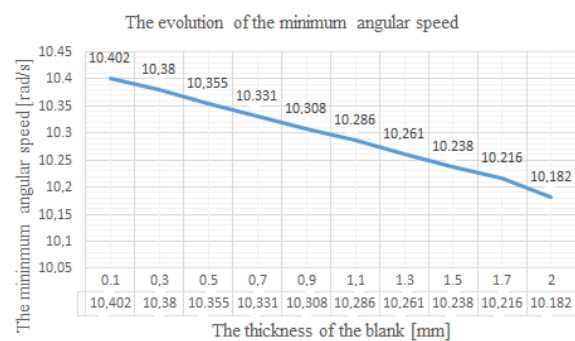
**Table 2.** The dynamic parameters extreme values in the “repeat” regime.

g [mm]	F <sub>r</sub>		$\omega_r$		M <sub>mr</sub>		P <sub>r</sub>	
	max	min	max	min	max	min	max	min
0.1	498.629	0	10.463	10.402	26.581	18.619	2.729.74	1.923.362
0.3	499.998	0	10.457	10.38	29.374	19.519	3.010.372	2.015.049
0.5	499.652	0	10.451	10.354	32.744	20.179	3.347.266	2.082.092
0.7	497.585	9	10.451	10.329	36.088	20.179	3.679.91	2.082.092
0.9	499.013	0	10.451	10.303	39.439	20.179	4.011.548	2.082.092
1.1	499.994	0	10.451	10.276	42.972	20.179	4.359.405	2.082.092
1.3	498.735	0	10.451	10.251	46.098	20.179	4.665.51	2.082.092
1.5	499.939	0	10.451	10.227	49.323	20.179	4.979.852	2.082.092
1.7	499.316	0	10.451	10.202	52.556	20.179	5.293.322	2.082.092
2	498.911	0	10.451	10.165	57.3	20.179	5.750.411	2.082.092

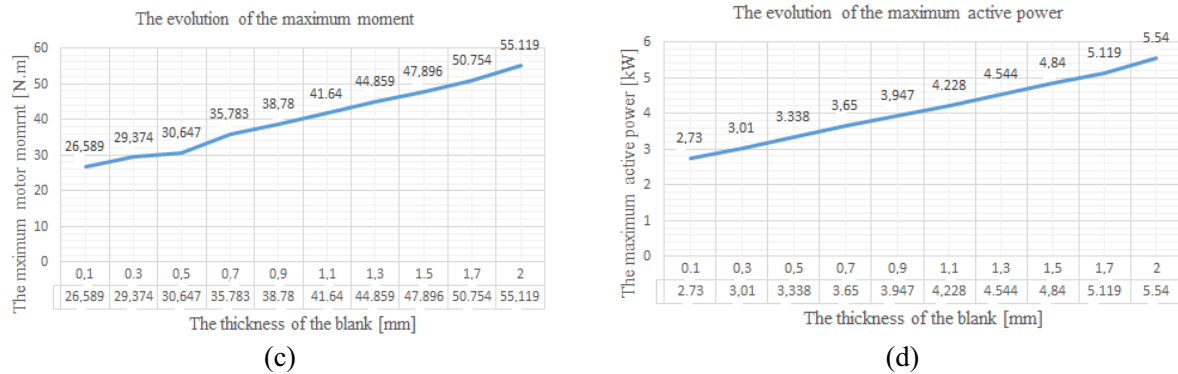
The simulation of the operation in the two variants (“single” and “repeat”) with varying the thickness of the blank in the conditions in which all the other parameters were kept constant, led to the results presented in table 1 (for “single” regime) and table 2 (for “repeat” regime); the dynamic parameters [7] extreme values evolution is presented in figures 4 and 5.



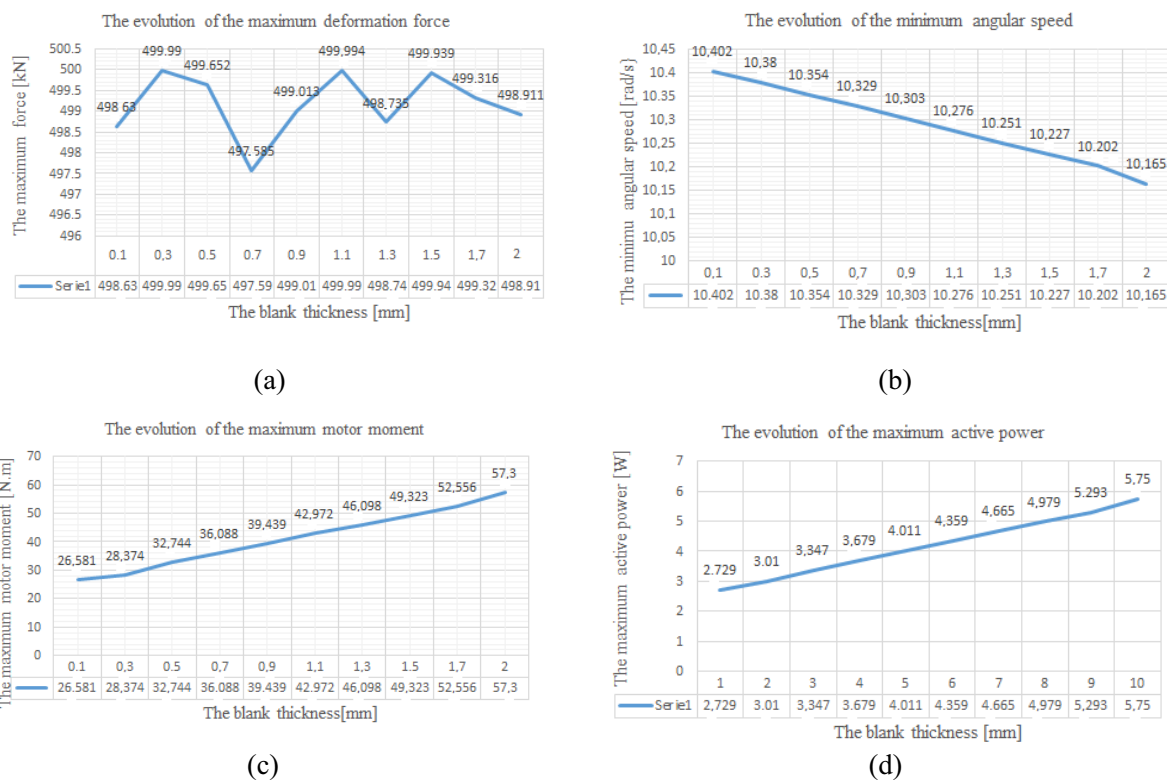
(a)



(b)



**Figure 4.** The extreme values of dynamic parameters evolution in a single regime.



**Figure 5.** The extreme values of dynamic parameters evolution in a repeat regime.

#### 4. Conclusions

In this paper we studied the influence of the thickness of the blank on the values of the dynamic parameters: the deformation force, the motor moment, the angular speed and the active power. This study was carried out with the help of a graphical interface that allows changing the values of several constructive and functional parameters.

From the analysis of the results obtained resulted the following conclusions valid for both situations (single and repeat):



- The maximum values of the deformation force do not have a linear evolution;
- The maximum value of the angular speed is practically constant in both regimes;
- The minimum values of the motor moment have a little variation in the “single” regime and remain practically constant in the “repeat” regime;
- The minimum values of the active power have a little variation in the “single” regime and remain practically constant in the “repeat” regime;
- The motor moment maximum values and the active power maximum values are slightly larger in the “repeat” regime than the “single” regime.

We can conclude that the proposed method can be a very useful tool for optimizing the design and operation of eccentric mechanical presses.

## 5. References

- [1] Burlacu C 2000 *Theoretical and experimental researches on optimizing the design, construction and exploitation of mechanical presses with eccentric, from the point of view of the dynamic behaviour of the mechanical structure and the drive system* PhD. Thesis (Gh. Asachi Technical University) Iasi chapter 3 pp 34-39
- [2] Burlacu C 2001 Researches on the mechanic eccentric presses design, construction and exploitation optimisation using a simulation model *Annals of the Oradea University Fasc. of Mechanics* vol(s) BUP II 2284 pp 56-59
- [3] Available online: <https://github.com/angularsen/UnitsNet> (accessed on 05 April 2018)
- [4] Burlacu C and Vicol I 2010 Optimization of the exploitation of mechanic eccentric presses on the basis of a simulation model *Proceedings of the 14th International Conference on Modern Technologies, Quality and Innovation, ModTech 2010- ISI Proceedings* pp 155-59
- [5] Burlacu C 2001 Researches on the mechanic eccentric presses dynamic behavior using a mathematical model *Annals of the Oradea University Fasc. of Mechanics* vol(s) BUP II 2284 pp 67-69
- [6] Available online: <https://numerics.mathdotnet.com> (accessed on 05 April 2018)
- [7] Available online: <http://www.oxyplot.org> (accessed on 05 April 2018)
- [8] Burlacu C, Mircea D and Mihailide M 2003 Study on the dynamic behaviour of mechanic eccentric presses using a simulation model *Modern technologies, quality, restructuring Rev.* **3** pp 432-435
- [9] Burlacu C and Mircea D 2004 The optimization of design, construction and exploitation of mechanic eccentric presses by using a simulation model *Annals of the Oradea University Fasc. of Management and technological Engineering III(XIII)* pp 103-107
- [10] Burlacu C and Mircea D 2002 Research of the influence of the constructive parameters on the dynamic behavior of mechanic eccentric presses using a mathematic model *Meridian Engineering Rev.* **3** pp 114-118
- [11] Burlacu C 2007 Study on the influence of the working process beginning moment on the dynamic parameters of mechanic eccentric presses *Institute Polytechnic of Iasi Rev.* **XL(L)** pp 34-36