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DYNAMIC BEHAVIOUR OF THE MECHANICAL PRESSES

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Abstract: *The aim of this paperwork is to determine the dynamic behaviour of the structure of eccentric mechanical press. The researches are oriented on theoretical and experimental directions, both concerning with determination of structure displacement and strain evolution, at the levels of reinforcing elements and workspace in dynamic regime. The theoretic researches are performed by means of dynamic analysis upon FE model. The press is load by experimentally determined forces. After running the analysis the displacement can be determined. The experimental researches are performed on PAI 6 press, equipped with resistive and piezoelectric sensors for determination of the machine displacements. The results and conclusion of this study will be used for experimental validation of FEM model.*

Key words: *transient dynamic analysis, eccentric press, theoretical and experimental researches.*

1. INTRODUCTION

The paperwork is part of a complex study by structural optimisation of eccentric mechanical press. The structural optimisation procedure is based upon successive running of some analyses by finite element method on the parametrical model of the press assembly. The finite elements method, and in general the numerical methods, supply a large quantity of information as for stresses and strains state, but for relaying with absolute confidence on the obtained results it must be verified by another methods, experimental methods for instance.

For experimental validation of the parametrical model by finite elements of the mechanical eccentric press PAI 6 and of the finite elements analyses performed on it, many experimental researches were performed on the real physical model of the press.

2. EXPERIMENTAL RESEARCHES

The analysis of the dynamic behaviour of the mechanical eccentric press PAI 6 was performed using the experimental layout presented in the Fig. 1. The mechanical eccentric press PAI 6, (1), was equipped with: resistive tensometric sensor (5), used to determine the strains at the reinforcing ribs level of the frame; the acceleration piezoelectric sensor KD 35a (7), used to determinate the displacements of the upper part of the frame on the vertical direction; tensometric force sensor (2), mounted in the connecting rod – ram joint, used for the loading force control.

The data acquisition process was performed using a data-acquisition board PCM–DAS 16S/12, Computerboards Inc. The connection between the sensor and acquisition board was realised using the conditioning modules MA-UNI BMC Systeme GmbH, (4). The calibration of the tensometric force sensor was performed on the tensile/compression test machine INSTRON 4303, and for the calibration of the accelerometer KD 35a the vibration measuring device SM 211 VEB Meβelektronik (6) was used.

The signals generated by the sensors, corresponding to the three measured values: the strain on the reinforcing rib of the frame, the displacement of the upper part and

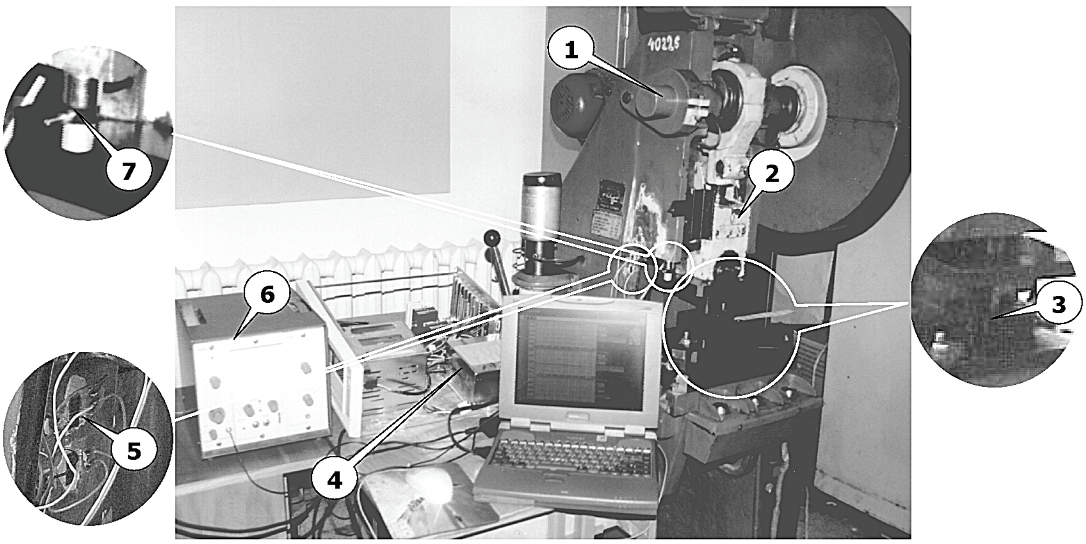

Fig. 1. Experimental layout.

the loading force of the press, are simultaneously achieved using a virtual instrument created in the LabView software.

The conversion of the acquisitioned signals, from mV in mm/mm or kN, are doing after the acquisition, using the calibration functions of the sensors, for displacement and force. For strains the following relation was used:

$$\varepsilon = \frac{-4V_r}{\mathrm{GF}\left[\left(1+\upsilon\right)-2V_r\left(\upsilon-1\right)\right]}\cdot\left(1+\frac{R_L}{R_g}\right), \qquad (1)$$

where: GF – gauge factor, ν – the Poisson's ratio, R_L – wiring cables resistance, R_g – gauge resistance, V_r – the value of the acquisitioned signal.

The loading of the structure was performed with the force from the processing process, by mounting a die on the machine. The variation of the loading force was realised by changing the mechanical and geometrical characteristics of the blanks, the material respective the blank thickness. For the experimental work blank with 2, 1.5, 1 and 0.4 mm thickness was used. Using these processing blanks loading forces between 0–35 kN, which cover the loading force domain in approximate percentage of 60%, were obtained.

Experimental data were statistically analysed, for a significance threshold by $\alpha = 0.05$, pursuant to STAS 2872/2-86, applying the Student test to discard the aberrant errors, respective the Cochran test to verify the dates repartition in the measurements range. For every material type and material thickness, and for every loading force of the structure, three measurement ranges were performed by 12 reiterations. In Table 1 the statistical analysis of the experimental data is presented: force, displacements and specific strain, at a blank processing by 2.0 mm thickness.

Graphical interface of the virtual acquisition instrument, for a measurement range, is presented in Fig. 2.

3. THEORETICAL RESEARCHES

Theoretical research regarding the transient dynamic behaviour of the mechanical eccentric press structure was performed using the finite element method. For this purpose, the mechanical press assembly PAI 6 was modelled geometrical and with finite elements, on whom transient dynamic analyses was applied, for miscellaneous loading forces, which were determined experimentally by means of the experimental layout presented in

Table 1

The statistical analysis of the experimental dates (blank with thickness g = 2.0 mm)

Experimental values	F_{j1} [kN]	F_{j2} [kN]	F_{j3} [kN]	ε_{j1} [mm/mm]	ε_{j2} [mm/mm]	ε_{j3} [mm/mm]	u_{j1} [mm]	u_{j2} [mm]	u_{j3} [mm]
***i*1**	2.5443	2.5508	2.2754	6.92E-05	6.90E-05	6.093E-05	0.0583	0.0583	0.0600
***i*2**	2.5557	2.5574	2.4787	6.93E-05	6.92E-05	6.093E-05	0.0589	0.0588	0.0629
***i*3**	2.7836	2.7836	2.6508	7.71E-05	0.000076	8.359E-05	0.0613	0.0614	0.0643
***i*4**	2.7902	2.7852	2.8934	8.00E-05	7.97E-05	8.972E-05	0.0642	0.0642	0.0667
***i*5**	3.0000	2.9934	2.9443	8.89E-05	8.89E-05	9.339E-05	0.0687	0.0686	0.0727
***i*6**	3.2787	3.2738	2.9721	8.89E-05	8.89E-05	9.385E-05	0.0699	0.0698	0.0732
***i*7**	3.3082	3.3016	3.2492	9.98E-05	9.96E-05	9.89E-05	0.0718	0.0719	0.0742
***i*8**	3.3082	3.3082	3.4410	9.98E-05	9.96E-05	0.0001151	0.0719	0.0720	0.0753
***i*9**	3.3541	3.3557	3.7541	0.000104	0.000104	0.0001165	0.0734	0.0732	0.0792
***i*10**	3.7492	3.7492	4.2033	0.000124	0.000124	0.0001188	0.0764	0.0766	0.0794
***i*11**	4.5557	4.5541	4.6377	0.000124	0.000124	0.0001222	0.0812	0.0810	0.0829
***i*12**	4.6885	4.6770	5.1049	0.000134	0.000134	0.0001376	0.0813	0.0815	0.0852
Number of measurements *n*	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Degree of freedom number ν	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Average F_n	2.9461	2.9442	2.8631	9.67E-05	9.6568E-05	9.93E-05	0.0697	0.0697	0.0730
$S_n^2 = \frac{\sum_{i,j=1}^{n}\left(x_{ij}-x_i\right)^2}{n-1}$	0.3252	0.3222	0.3856	4.84E-10	4.86E-10	5.69E-10	5.68E-05	6.20E-05	6.52E-05
Average $F_{(n-1)}$	0.20551	0.2055	0.2091	0.00009329	9.3099E-05	9.581E-05	0.0696	0.0697	0.0730
$S^2_{(n-1)}$	0.44683	0.4437	0.4784	0.00001937	0.0000194	0.0000216	0.0082	0.0082	0.0085
Student test									
$t_{(n-1)\ \mathrm{calculated}}$	1.2546	1.2773	2.3009	2.1391	2.1458	1.9363	1.4229	1.3974	1.4370
$t_{(n-1)\ \mathrm{tabled}}$	2.3060			2.2010			2.2010		
Cochran test									
$G_{\mathrm{calculated}}$	0.3366			0.2194			0.2096		
G_{tabled}	0.4748			0.4748			0.4748		
Observation	Significance threshold α = 0,05, STAS 2872/2-86.Applying the Student test one can observe that there are not aberrant values in the measurements range because $t_{(n-1)\ \mathrm{calculated}} < t_{(n-1)\ \mathrm{tabled}}$ Applying the Cochran test one can observe that the data allotment in the measurements range are normal b e-cause $G_{\mathrm{calculated}} < G_{\mathrm{tabled}}$								

the precedent chapter. The ANSYS 5.5 programme was used for modelling and for finite element analysis. The complex spatial structure of the press assembly was modelled with SOLID 45 finite elements. The structure materials were defined by characteristics chosen from library of the ANSYS 5.5 and they were defined by Young's modulus, density, Poisson's ratio and damping multiplier. The structure was constrained by cancelling all the degrees of freedom in the nodes from lower surface of the structure support.

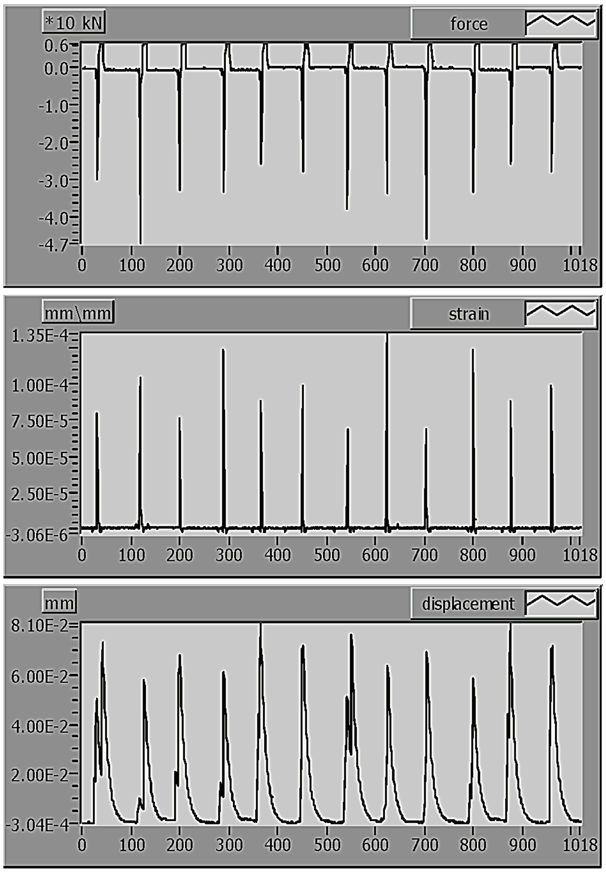

Fig. 2. Graphical interface of the acquisition instrument for processing a blank with 2 mm thickness.

After running the analyses the following date were processed:

- the strains of the press structure at the level of the reinforcing ribs of the frame on the vertical direction – y, on an element which corresponds to the application place of the strain gauge used for experimental researches;
- nodal displacements of the upper part of the frame, in the nodes which correspond to the acceleration piezoelectric sensor location used for experimental researches.

The evolution of the displacements and strains measurements for a complete processing cycle, experimentally determined compared with the ones obtained by numerical analysis with FEM, for a blank with 2.0 mm thickness, are presented in Figs. 3 and 4.

4. CONCLUSION

Analysing the time evolution of the displacements of the upper frame part and of the strains of the frame (Figs. 3 and 4), determined theoretical, using numerical analyses by finite element method and experimental using the experimental layout presented in the chapter 2, some conclusion may be drawn:

- the form of the both curves, the displacement respective the specific strain, are nearly the same for both determinations;

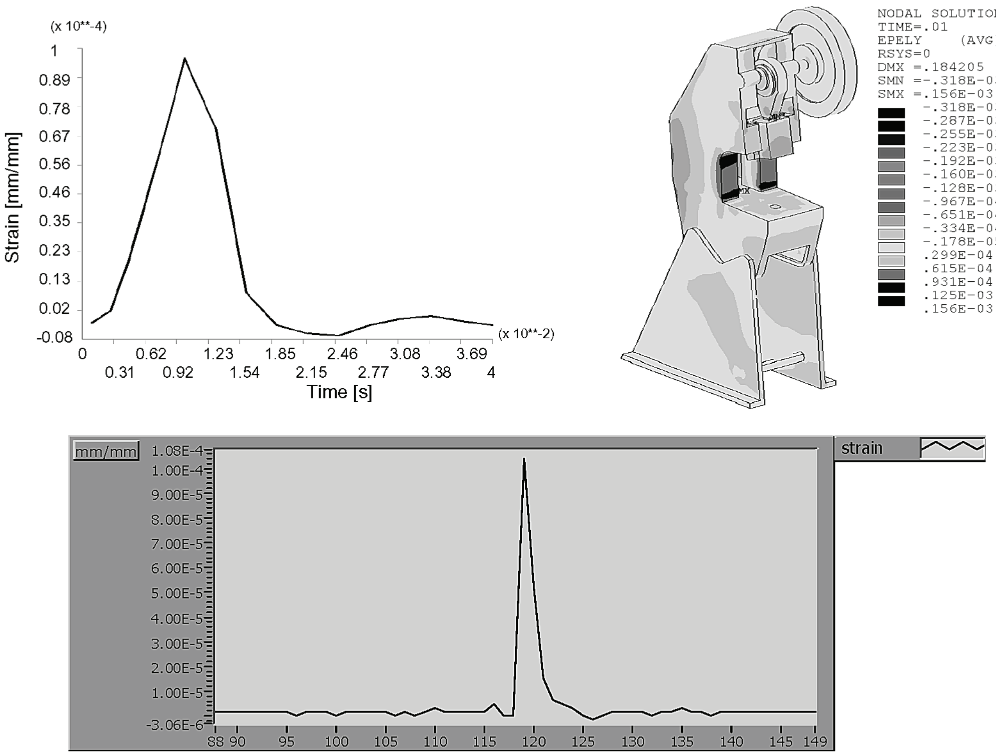

Fig. 3. The evolution of the strains, for a processing cycle.

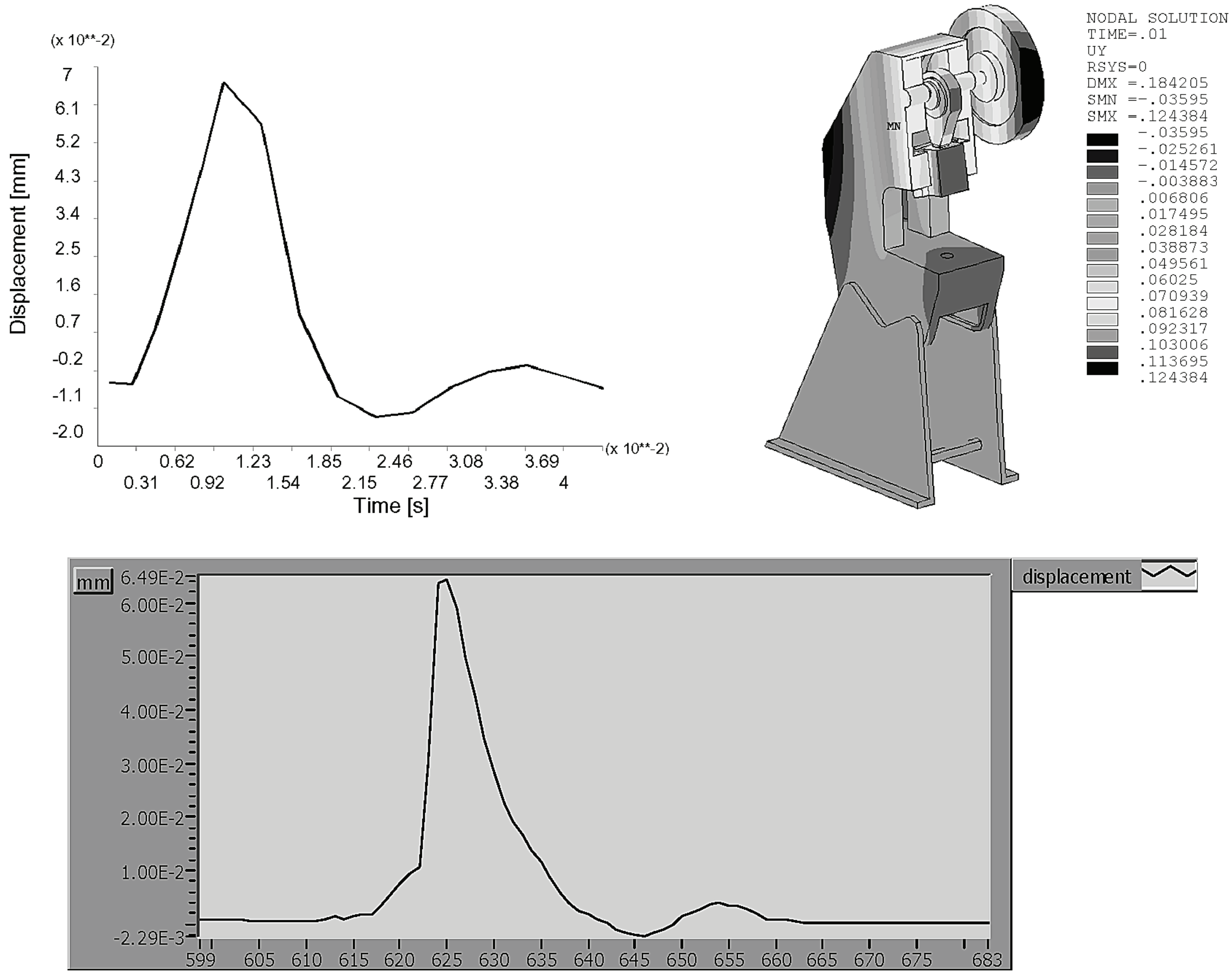

Fig. 4. The evolution of the displacements, for a processing cycle.

- the difference between the corresponding values for damping period and amplitude, for the two type of analyses, experimental and numerical one, is smaller than 5%.

In Fig. 5 the values of the upper part range displacements of the structure and the specific strain at the reinforcing ribs level, depending on the loading force of the press are presented.

According to the theoretical and experimental researches regarding the transient dynamic behaviour of the mechanical eccentric press PAI 6, the experimental validation of the finite element model of the press was obtained. This will be used for further dynamically structural optimisation researches.

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