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COMPARATIVE STUDY REGARDING THE LINKING ELEMENTS IN THE FINITE ELEMENTS MODELS

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Abstract: *The aim of this paper is to make a comparative study of the static behaviour of the eccentric presses, using the finite elements method, on the rigid structure respectively on the flexible structure. The finite elements modelling of the component elements of the presses are done in two ways: node by node link type (rigid structure) or using a linking element spring damper type (flexible structure). On this two structure is successively applied a number of static analysis, in aim to determinate the strain of working area and the design of the stiffness graphic.*

Key words: *eccentric presses, finite element method, linking elements, rigid structure, flexible structure.*

1. INTRODUCTION

A machine tool is a complex technical assembly, which must respond to a vast range of requirements. This range suffered in the last years big changes. So, it is necessary to increase the machine accuracy at dynamic, static and thermal stress while regarding the environment a decrease of noise and of the energy spent is carried out. For designing the stress elements modern computing procedures were utilised, which facilitated the determination of the stiffness, giving the opportunity to optimise the complex shape component elements.

2. NUMERICAL RESEARCHES

The geometric modelling of the press assembly PAI 6 was performed with the ANSYS pre-processor, PREP 7. In order to obtain the model closest to the reality and which has the shortest necessary computing time, following considerations have been made:

- the heterogeneous areas from the structure were approximated with the homogeneous finite elements, with equivalent thickness, with the same behaviour (holes or bracing's),
- unnecessary details were discharged (small joining radiuses or bay);.

The assembly of the press PAI 6 was modelled by subassemblies: the press frame, the eccentric shaft and the eccentric brushing, the pitman arm and his length control system, the ram, the guides respectively the structure base. The link between the subassembly was made in two ways:

1. Linking the correspondent nodes of the two subassemblies in order to create coincident nodes
2. Linking the correspondent nodes using the spring damper that assume and carry out the strains in all the directions.

For modelling with finite elements the assembly of press PAI 6 the SOLID 45 type finite elements was used for the design of the spatial structure of the frame and finite elements of COMBIN 14, in order to realised the link between the subassemblies. The characteristics of the material were modelled by the following parameters: Young's modulus E, density ρ, Poisson's ratio v. The real constants of the finite elements of COMBIN 14 type was made by calculating the stiffness (k) and coefficient of cushioning (c), of the bearings and sliding guides with jointed friction, based on the method from the speciality literature [1].

In order to determine the static stiffness of the press assembly and to design the force – strain graphic, a number of analyses about two-structure type were made, who was charged in the 0 – 63 kN range. In all cases of static load of the model the following were imposed: gravity acceleration 9810 mm/s^2 to the vertical direction, Oy; displacements constrain, 0 to the Ox, Oy şi Oz directions in the nodes from the bottom of the frame support. The load of the press with uniform forces distributed at the table machine level, on a surface considered as a medium situation surface of the tool on the table press and on the lower surface of the ram, considered as contact surface between the tool and the ram, Fig. 1.

In order to determine the strain of working area, two groups of characteristic nodes were defined, which define the working area of the frame. The first nodes group defines the bottom area of the ram, while the second group defines the header area of the table. The strain of the structure on the working area level is computed as the addition of the average displacements of the characteristic nodes to the three co-ordinated axes. Because significant strains appear on the Oy axis, the characteristics nodal displacements were processed only on this axis, their values being represented on a graphic depending on the load, Fig. 2.

In Fig. 3, are comparative presents, for rigid and flexible structures, the charts of nodal displacements on the Oy, for a load corresponding to the nominal force, 63 kN.

From nodal displacements analysis for characteristics nodes of the working area one can observe a strain of working area on Oy direction, which increases the

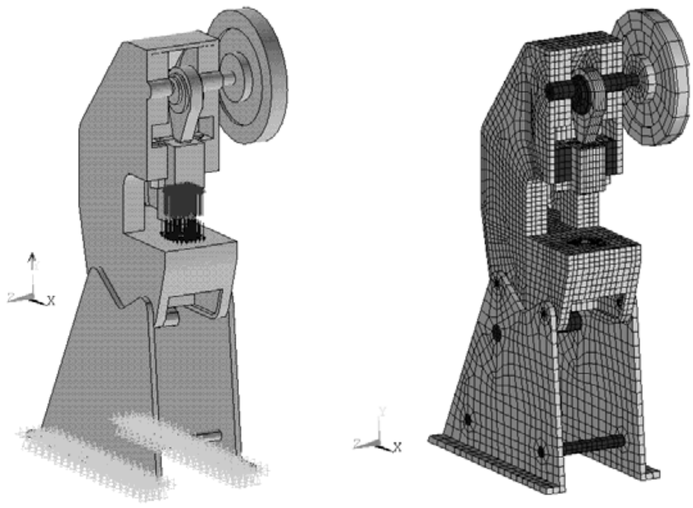

Fig. 1. Geometric and finite element model of the press PAI 6.

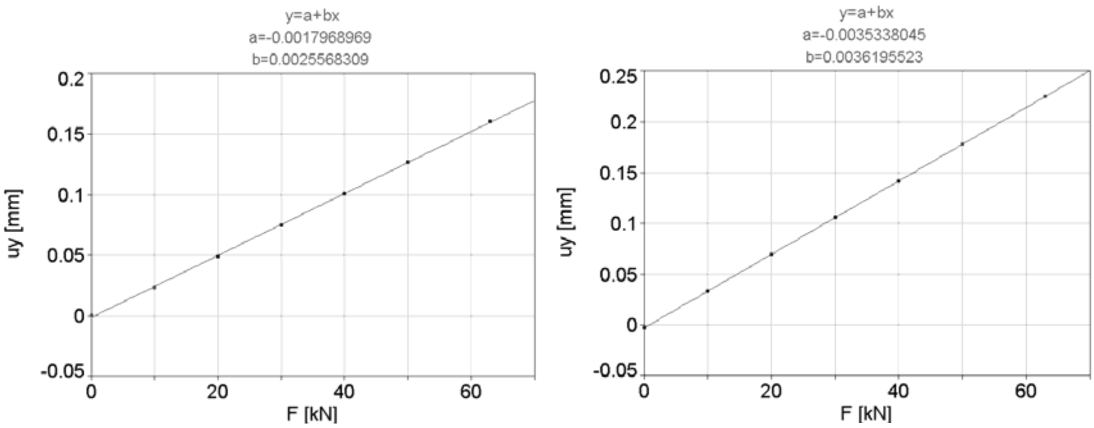

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Fig. 2. Dependence force – strain, on the Oy direction; a – rigid structure, b – flexible structure.

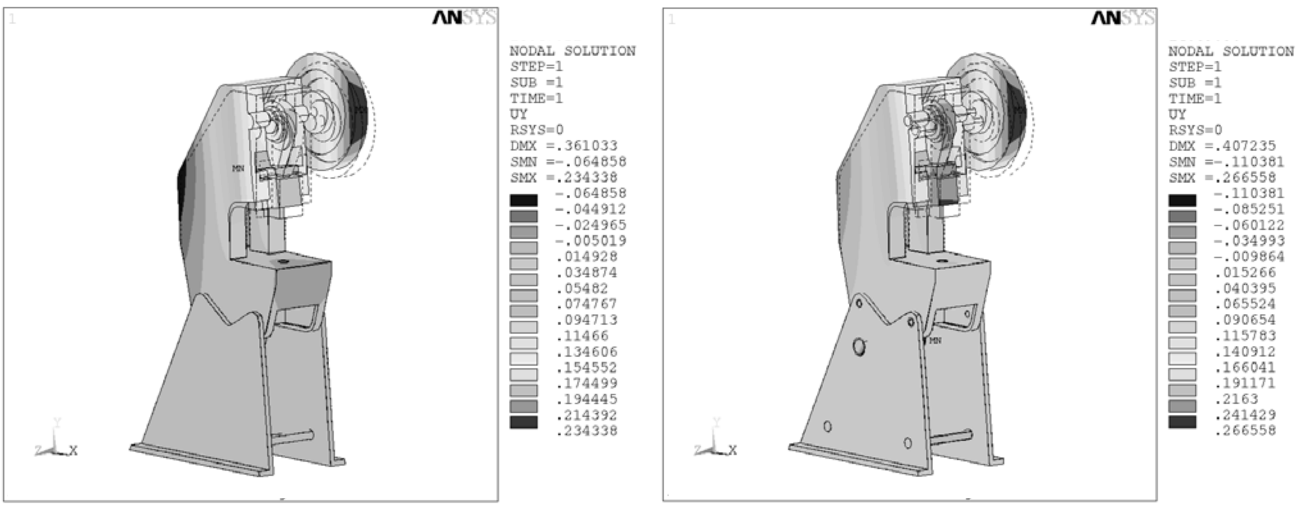

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Fig. 3. Nodal displacements on Oy axe; a – rigid structure, b – flexible structure.

working area, respectively increases the dimension between the main shaft axis and the table surface. For flexible structure the strain of working area is 0.225 mm while for rigid structure is 0.160 mm, at a load corresponding to a nominal force of the press. This strain of working area may influence the pieces accuracy made by deep drawing, stamping, etc.

For stress state analysis on the press assembly, the equivalent von Misses stress (σ_{ecv}) was evaluated by ANSYS programme by computing it as a square mean of the normal stress on the base, middle respectively the peak of the finite elements.

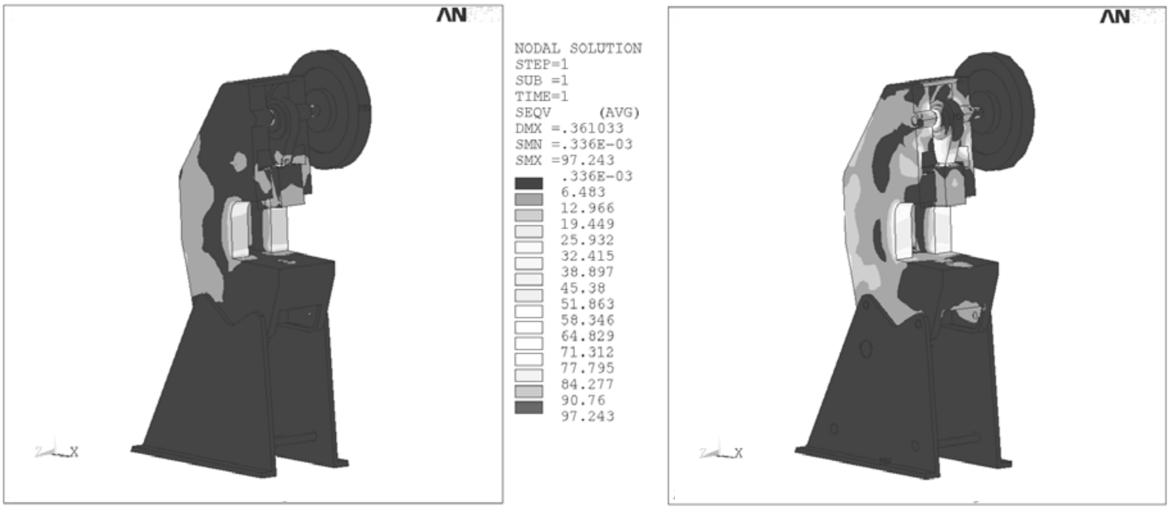

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Fig. 4. Equivalent von Misses σ_{ecv} stresses distribution; a – rigid structure, b – flexible structure.

By comparative analysis of the charts of the von Misses equivalents stresses, σ_{ecv}, a different distribution of the stresses for the two structures appears:

Maximum value of the equivalent stresses, at the whole assembly level, are 65.298 N/mm^2 in main shaft - for flexible structure, respectively 97.243 N/mm^2 in control elements of the pitman arm length – for rigid structure, Fig. 4;

In the case of the rigid structure, the reinforced ribs of the press frame and its medium area are heavy stressed. At this structure, the pitman arm is less stressed, only on its bottom, respectively in linked area with the control length element. Also, a stress concentrator at the ram stress, respectively on his guide surface, appears.

For flexible structure, the heavy stressed elements are the reinforced ribs, but taking off the stress at the press frame level, unlike the precedent case, is made on the whole height. In case of this structure, the stresses distribution in the pitman arm is modified, this being modified on the whole length. The stress concentrator on the ram doesn't appear at the level of the ram, which is being stressed uniform on the whole height.

On both structures a stress concentrator appears at the level of the joint of the table with lateral plates, in the reinforcing ribs. The maximum values of the stresses of the concentrator level are 30,905 N/mm^2 for the flexible structure, respectively 29.570 for the rigid structure.

Comparing the obtained results on the both modelled structures with finite elements, the rigid and the flexible structure, one observes a different static behaviour of the both structures. Regarding the assembly strains distribution, the maximum values are modified and bigger than in the flexible structure case. The apparition of those differences is explained by the possibility to introduce the plays, respectively the modelling by finite elements damper spring type of the sliding bearing in the flexible structure case. The differences appear also in the taking off strains mode, by the press subassembly. So, in the case of rigid structure the most stressed subassembly is the press frame, who is taking the whole strain 88.43%, while the pitman arm is taking only 1.86 %. The eccentric shaft and the ram are taking approximately the same strain in the case of both structures, 4.69% and 5.02% for the rigid structure, respectively 6.16% and 7.01% for the flexible structure. The pitman arm is taking a bigger strain for the flexible structure 11.02%, while the strain taken by the press frame decrease at 75.81%. This modification of the strain state of the press assembly in the case of both structures appears in concordance with the stress state modification. So, by equivalent von Misses stress, one observe that a different stress of some subassembly like the press frame, the pitman arm and the ram. If the press frame is heavy stressed only in the medium area, at the flexible structure the stresses are distributed on the whole height. The same stress state is on the pitman arm, too, it is uniform stressed at the flexible structure. The stress concentrator of the ram level, who appears in the case of the rigid structure due to the link node on node without intermediary element between the ram and the guides, doesn't appear in the case of the flexible structure.

3. EXPERIMENTAL RESEARCHES

The analysis of the static and dynamic behaviour of the mechanical eccentric press PAI 6 was performed using the experimental layout presented in the figure 5. 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.

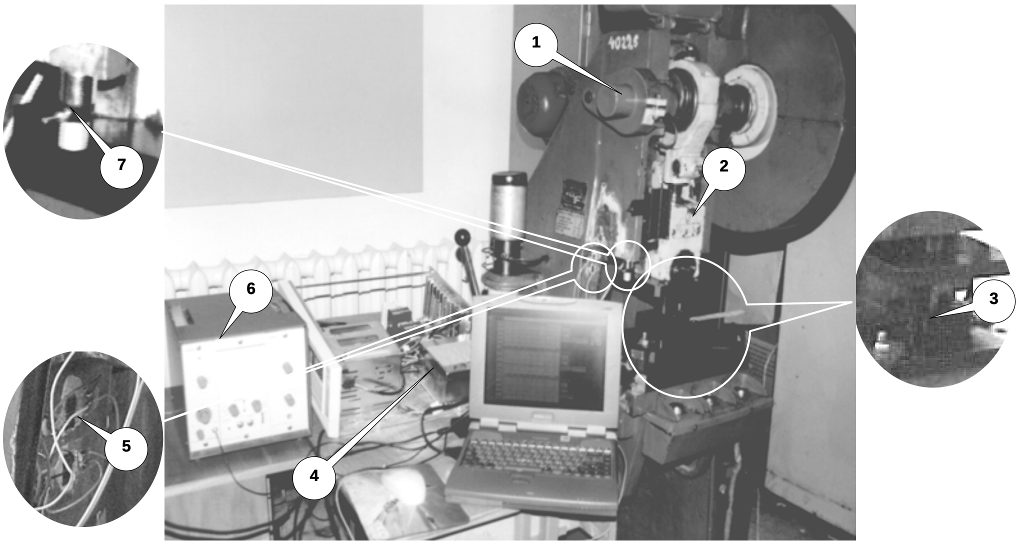

Fig. 5. Experimental layout.

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 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:

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

where: GF – gauge factor, v – 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.

4. CONCLUSIONS

Comparing the results obtained by numerical analysis and the experimental results, one observes that the flexible structure is the fidelity reflection of the real behaviour of the structure.

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