RESEARCH USING CAE ON PERFORMANCES EVALUATION FOR MACHINE TOOL ORIENTATION AND CLAMPING DEVICES

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Rezumat. *În lucrare sunt prezentate etapele CAE, care au în componenţă CAD-FEM pentru stabilirea variantei constructive şi de încărcare optime a unui dispozitiv de fixare modular pentru piese prismatice şi circulare. Astfel de dispozitive se utilizează la prelucrări pe maşini-unelte cu comandă numerică, performante, între care şi centrele de prelucrare prin frezare cu 5 axe CNC. Se prezintă metodologia de analiză şi rezultatele aplicării acesteia. Se stabilesc modalităţi de analiză numerică, în condiţii definite de încărcare, pentru identificarea zonei cea mai solicitată din structura dispozitivului. Se recomandă ca în zona respectivă să fie amplasat un senzor de deformaţie. Acesta constituie o etapă importantă necesară transformării dispozitivului într-unul mecatronic.*

Abstract. *The paper presents the stages of CAE, which is composed by CAD-FEM for determining optimal construction and loads for a modular fixture device for prismatic and circular work-pieces. Such devices are used for processing on CNC performance machine tools, like machining centres including 5-axis CNC milling machines. It is presented the methodology of analysis and results of its application. Are established numerical analyses ways, in the conditions defined by the loadings and identified the most solicited area of the device structure. It is recommended in that the area be placed a strain sensor. This is an important step needed transformation into a mechatronic device.*

Keywords: modular clamping, clamping force, finite element analysis, deformation, sensors

1. Introduction

Numerous papers presented the importance of using guidance and clamping modular systems for the cutting machines. Devices in general are an important part of the technological system [3, 4, 5, 9]. These are defined by the features and functions specific to the type of the cutting process, technological process, the size and direction of cutting forces and moments. Choosing and using of the best variant of machine-tool has influences on processing accuracy, productivity and input costs in the manufacturing of new products.

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Devices represent, from technologic point of view, constructive and functional, units [1, 2, 4, 6, 7, 9], which establish and maintain the orientation of the half finished products and/of the tools in surface generation process. Also some of the modern devices may accomplish functions of the machine-tool, as: ensuring surface generation movements or auxiliary movements (for example positioning), the interface between the half finished product/tool and the machine tool [3, 4, 5]. For this was created the possibility to adapt sensors which can measure and sent signals regarding the level of the control parameters of the cutting process [5, 6].

Adopting of the constructive and command technical solutions contributed in a great part, along the others systems to the optimization of the processing process on machine-tools with numerical command. It became of a great importance the improvement of the positioning / orientation / actuating and fixing of the half finished products on the machine-tool. Also was improved the modulatization degree and the possibility of them reconfiguration. Are rapidly chosen the device components elements, in concordance with the mentioned functions, workpiece configuration and precision demands. Thus, in modern manufacturing exist a great variety of devices, determined, first by the multiple functions that must be accomplished by them, regardless the constructive variant and the actuating mode.

Modular orientation and clamping devices are proven to be the most used devices on the CNC machine-tools in flexible fabrication. For orientation and precise and rigid clamping of different modules can be used two systems: orientation on cylindrical surfaces like pin-cylinder bore and clamping with screws, figure 1.1.; orientation on plane surfaces (positioning-fixing T channels), simple collar and T collar, fixing by T collar, screws, nuts and double ended bolts, figure 1.2.

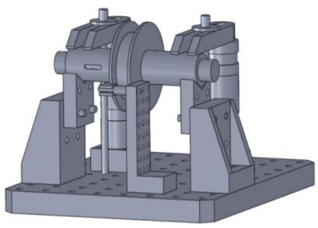

Fig. 1.1. Modular device – clamping with screws and manual actuating [12].

Fig. 1.2. Modular orientation and clamping device [12].

Reconfiguration of the modular device is usually done manual and also the help of the industrial robots, which also realise the operation of fine adjustment of the modules. Are designed, manufactured and used sets of modular elements for automatic configuration, in principal, were the device motherboard is electromagnetic. This solution is used because the automatization of the orientation and clamping of the modules by the systems applied at the modular elements devices, manually reconfigured is complicate and uneconomical.

In general this type of systems is for applications at which during the working process are developed forces with low or medium values. This is the case of the finishing or assembly processes.

2. Methodology for the analysis of the behaviour of the orientation and clamping devices

The functional role of orientation and clamping of the workpieces during the processing it is defined on the base of the loadings (cutting forces and moments, them directions, mode of action) established in a precise mode in the design stage.

Thus are determining on the bases of some economic criteria the optimal variant regarding the structure, the actuating system and the constructive solutions of the component elements. These take into consideration the position and the number of elements which assure the orientation function, supplementary support, fixing, position changing, adjustment, tools guidance, linking with the machine tool.

Parameters that are taken into consideration when is realised a clamping configuration, are established taking into consideration: the technologic processing type, the shape, dimensions and the rigidity of the workpiece (rectangular, cylindrical, plate, frame, disk, etc.), its material (steel, cast, aluminium, iron), actuating system. Are also imposed others technical and economical requests regarding the accomplishment a specific modularization degree and of adaptation at flexible manufacturing [8]. The device behaviour in the working processes is determined by the static rigidity and the dynamic behaviour during cutting process, some static and dynamic disequilibrium and the rigidity of the assembly device-workpiece or device-tool.

The application point, the direction and the sense of the clamping forces are established as to be maintaining the equilibrium of the workpieces on the supports and to avoid its deformation in the points or in the contact zones. It is necessary for the elements of the orientation and clamping system to be dimensioned in order to ensure the keeping of the workpiece position during processing and to ensure the requests of the process. Because of the great number of shapes, materials of the workpiece and processing requests of the workpieces surfaces, and also the cutting forces directions are needed different strategies for designing the clamping scheme, being necessary, in most of the time the cancelling of six freedom degrees (rotations and translations). A general methodology for determining the optimal clamping force and of the factors that are taken into consideration is represented in figure 2.1. Performance analysis of the devices supposes going through a methodology that comprises the following steps [9]: the study of the work-piece, analysis of technologic procedures and process parameters, determining the necessary clamping numbers for processing the work-piece, establishing the orientation surfaces and production type.

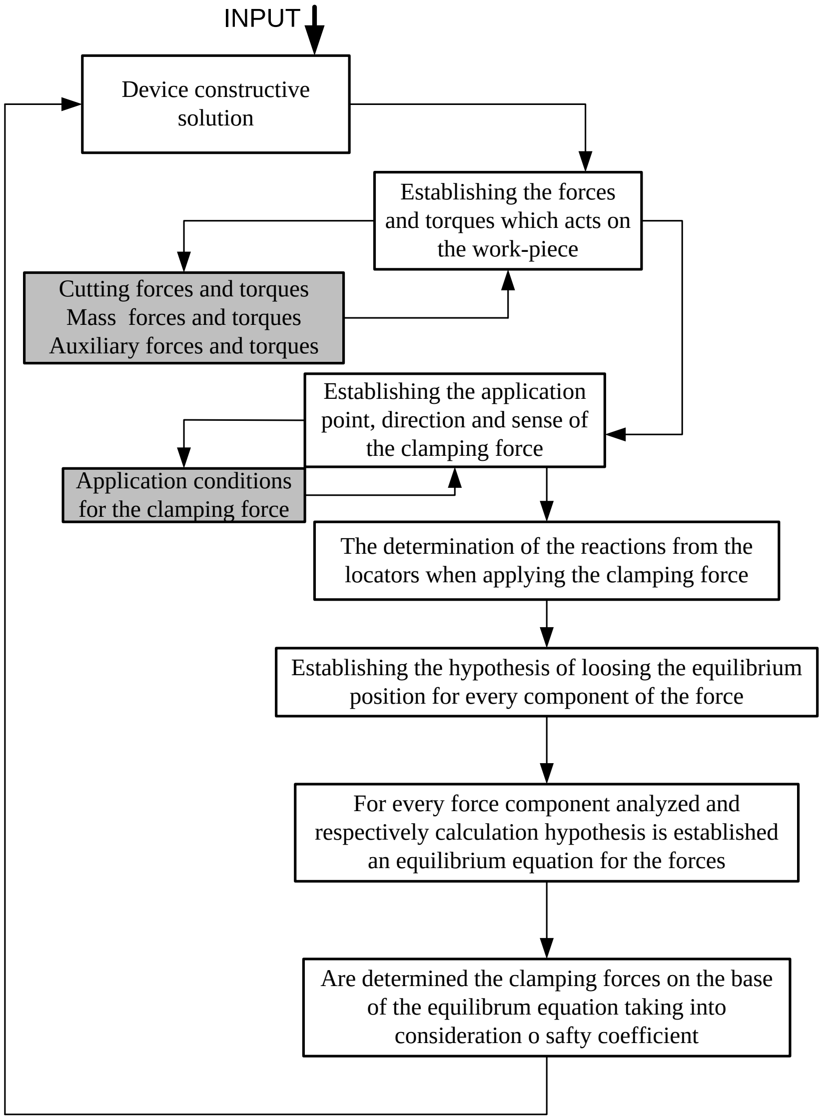

Fig. 2.1. Methodology for determining the optimal clamping force [8].

3. The functional and constructive analysis

Because of the multiple processing possibilities that are assured by the processing centres with 5 axis and numerical command, it exist the opportunity to realise products more and more complex, in o short time and with high precision. Using a performant orientation and clamping device it represent a principal condition for obtaining a good precision on such a machine tool. In figure 3.1 [13] it is represented a clamping system which permit the processing of a complex workpiece using 5 different processing axis, from one clamping.

The clamping process involves the contact establishment (penetration) between the interchangeable pins and the workpiece. Optionally the device can be dotted with plane pins for clamping workpieces with easy deformable surfaces. The modular device principles elements are indicated in figure 3.2. [13].

Fig. 3.1. Modular clamping system[13].

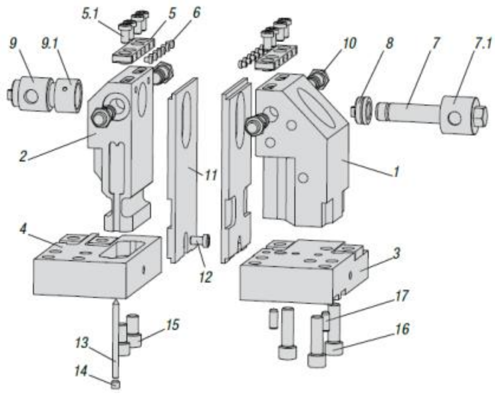

Fig. 3.2. Device components: 1, 2 - jaws, 3, 4 – base plate , 5, 6- clamping pins, 7, 7.1, 8-spindle and tension element, 9-spindle extensions with housing element 9.1, 10-clamping screw, 11- guidance support, 12, 13, 14, 15, 16, 17 – fastening elements

The clamping device presented in this constructive variance [13] can develop clamping forces till 42 kN, is realised in modular variance and can be used for the clamping of complex workpieces, o different dimensions, with diameters between 22...236 mm and highs up to 250 mm, by using specific adaptation elements.

4. Application regarding the use of the FEM analysis for the orientation and clamping devices

The finite element method represent a approximate numerical calculation method, which can be used when it is necessary to evaluate the specific deformation, displacements or stress, or in the case of a geometry that is dimensional defined or for a specific load, for defined supported conditions and for known material conditions.

After applying the static analysis for a mechanic structure can be determined deformations: specific (strain), equivalent, maximum, minimum, tangential deformations, the maximum deformation intensity, normal specific deformations, tangential, deformation energy, the principal vector, terminal deformations, plastic equivalent specific deformation, stress: equivalent (von-Mises), maximum, medium minimum, maximum tangential stress, stress intensity, normal stress, principal vector, error, local results, predefine sets of results: stress (stress tools), fatigue tools, information regarding the contact (contact tools): state of contact, information regarding friction, pressure in the contact zone, penetration [10].

The evaluation of the clamping device using the finite element method was realised for two different configurations for the device: one that it is used for prismatic workpieces, as in figure 4.1 and 4.2, and the other one for cylindrical workpiece, figure 4.3 and 4.4, table 4.1

Table 4.1. Clamping device configurations

Device configuration	Workpiece
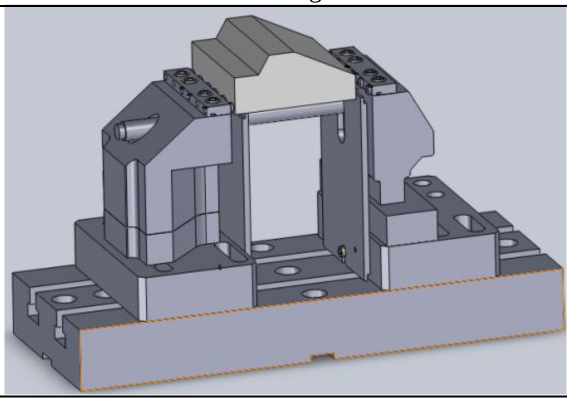	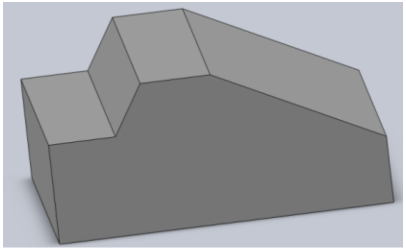
Fig. 4.1. Device configuration for prismatic workpiece.	**Fig. 4.2.** Prismatic workpiece.
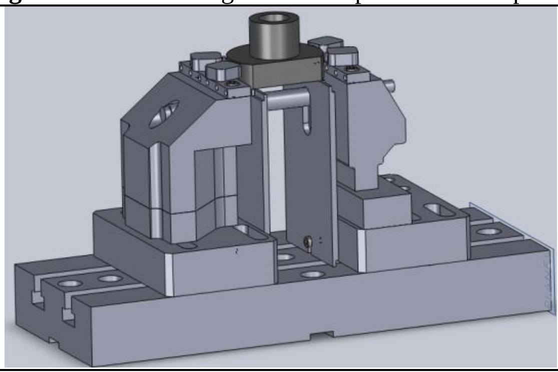	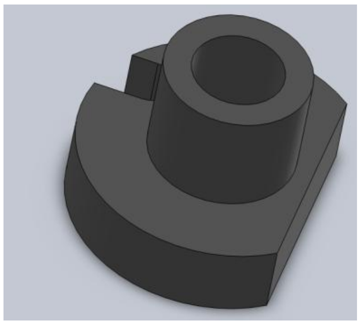
Fig. 4.3. Device configuration for cylindrical workpiece.	**Fig. 4.4.** Cylindrical workpiece

4.1. First case - Prismatic workpiece

The tool recommended to be used in the manufacturing process was chosen from a company catalogue [11]. For processing the chosen surface milling was used a four teeth tool, D_c= 50 mm diameter (milling tool type Coro Mill R360, square inserts PM- R290-12 T3 08E CB50). Working conditions for roughing milling: a_p=3 mm, a_e=25 mm, f_z=0.04 mm/teeth, v_c=230 m/min, n_c=1387 rot/min, v_f=222 mm/min, k_r=65^0, as in figure 4.5.

The roughing milling with the specific tool generates the largest cutting forces, of which was taken in the consideration the component F_z, in the normal direction to the machined surface.

The values established for the clamping forces on every screw are 500 N, and the ones estimated for the cutting forces are F_z 400 N. The cutting moment was determined using specific software [14], its value being 8 Nm.

The simulation of the device behavior under the clamping and cutting forces has as results the determination of the most stressed parts and the maximum deformations of the work-piece, fixing clamps, in order to identify the possibilities to positioning of the deformation sensors, for transforming the device in a mechatronic one.

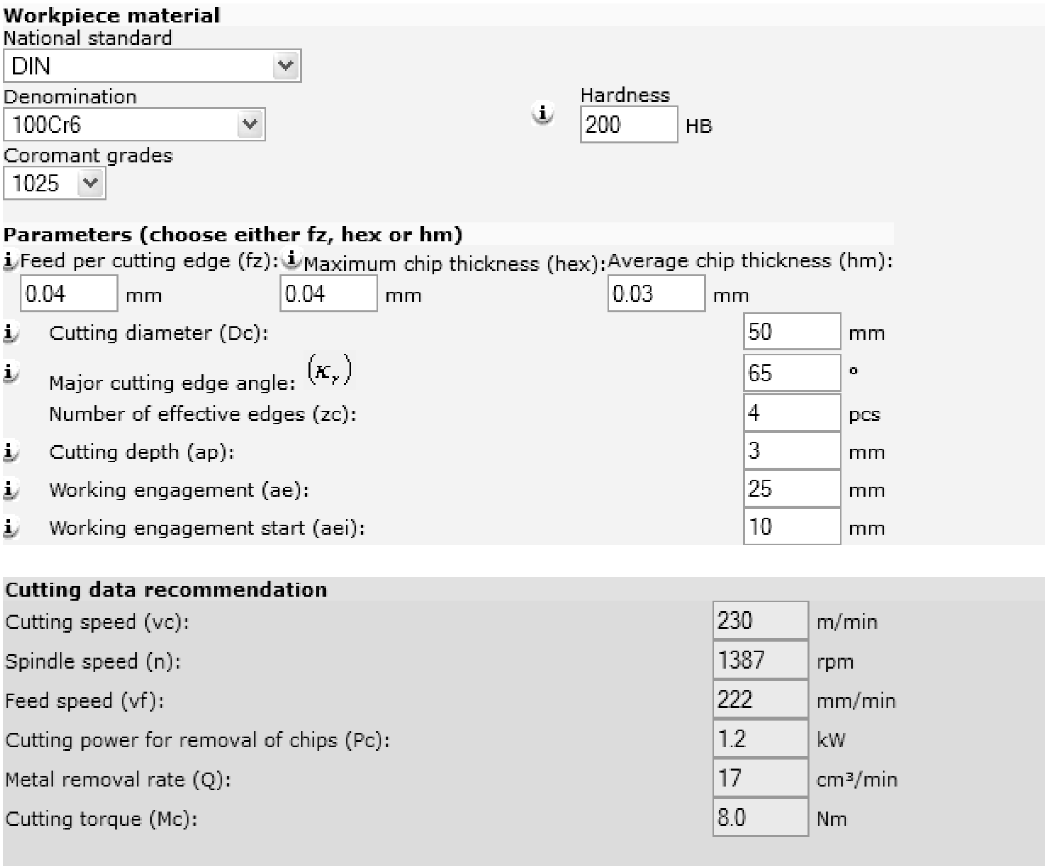

Fig. 4.5. Specific parameters for the cutting process.

In figure 4.6 it is represented the experimental setup for simulating the device behavior under cutting forces and momentum actions.

Clamping force developed by the device is F_{cl} = 50 N, on every pin and is represented by forces A:L.

M represent the cutting momentum and it is M_c = 8 Nm and N the cutting force F_c = 400 N.

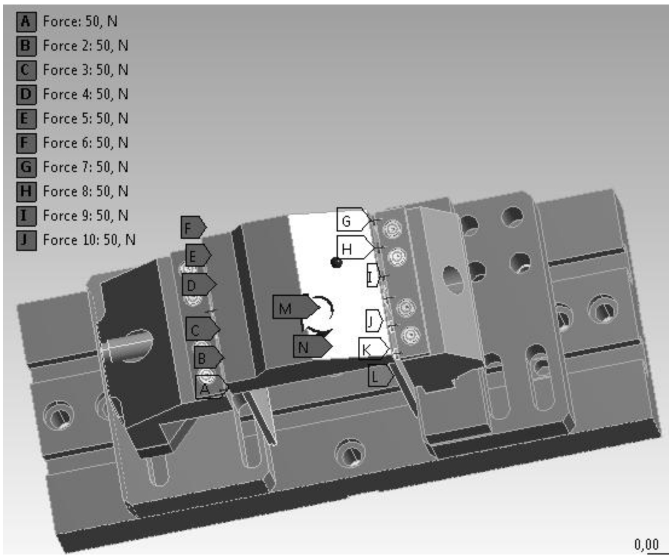

Fig. 4.6. Experimental setup for prismatic workpiece – Case I.

The result obtain after the simulation, represented in the figure below, deformations in figure 4.7 and stress in figure 4.8, represent a direct result of the applied clamping and processing force and are concentrated on the main element of the assembly – the workpiece.

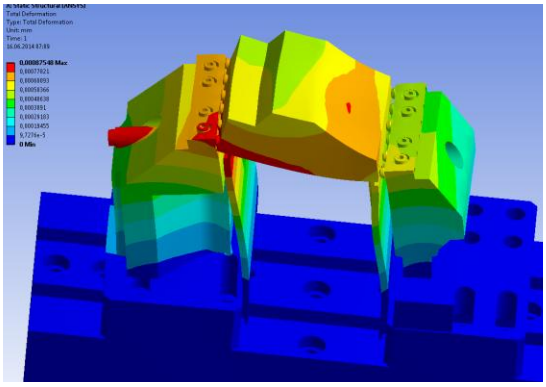

Fig. 4.7. Total deformation.

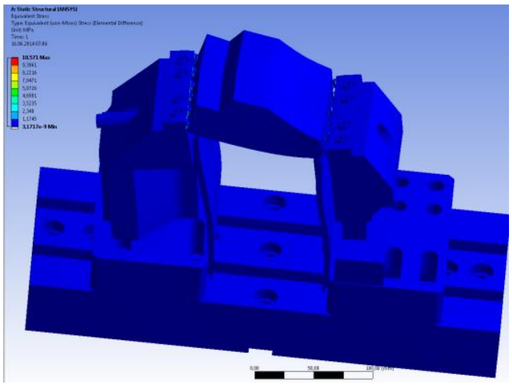

Fig. 4.8. Equivalent (von-Mises) Stress.

4.2. Second case - Cylindrical workpiece

For the second case were realised the channel, using a Coro mill-plura high feed cuter, of a diameter of 20 mm, chosen from a company catalogue [11]. In figure 4.9 it is represented the experimental setup for simulating the device behavior under cutting forces and momentum actions. Clamping force developed by the device is F_{cl}= 50 N, on every pin and is represented by forces A:D. E it represents the cutting force, and it is the resultant between the axial force F_{ax}= 40 N and the feed force F_{fe}= 190 N.

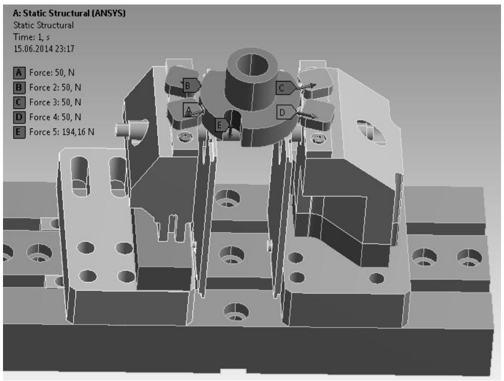

Fig. 4.9. Experimental setup for cylindrical workpiece – Case II.

Also in this case, the result obtain after the simulation, represented in the figure below, deformation in figure 4.10 and stress in figure 4.11, represent a direct result of the applied clamping and processing force and are concentrated on the main element of the assembly – the workpiece.

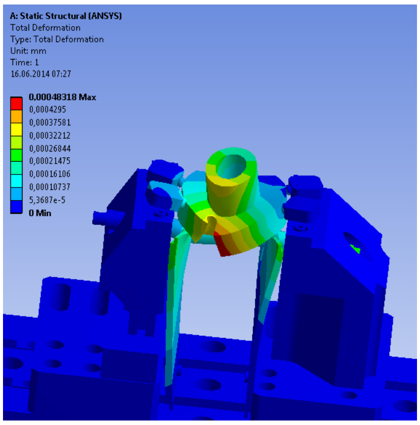

Fig. 4.10. Total deformation.

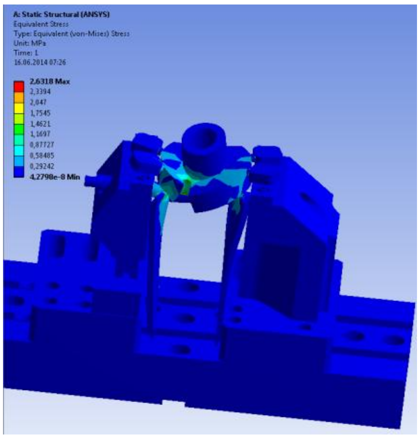

Fig. 4.11. Equivalent (von-Mises) Stress.

In figure 4.12 is shown the experimental setup for the second processing.

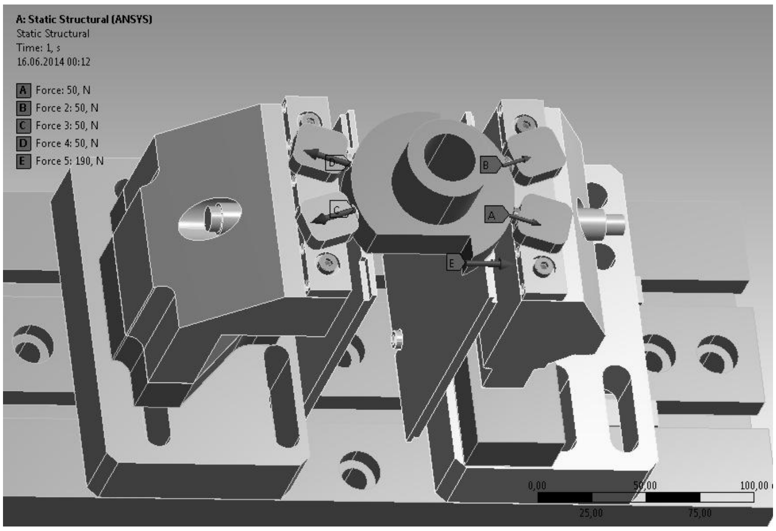

Fig. 4.12. Experimental setup for cylindrical workpiece – Case III.

The result obtain after the simulation, represented in the figure below, deformations in figure 4.13 and stress in figure 4.14, represent a direct result of the applied clamping and processing force and are concentrated on the main element of the assembly – the workpiece.

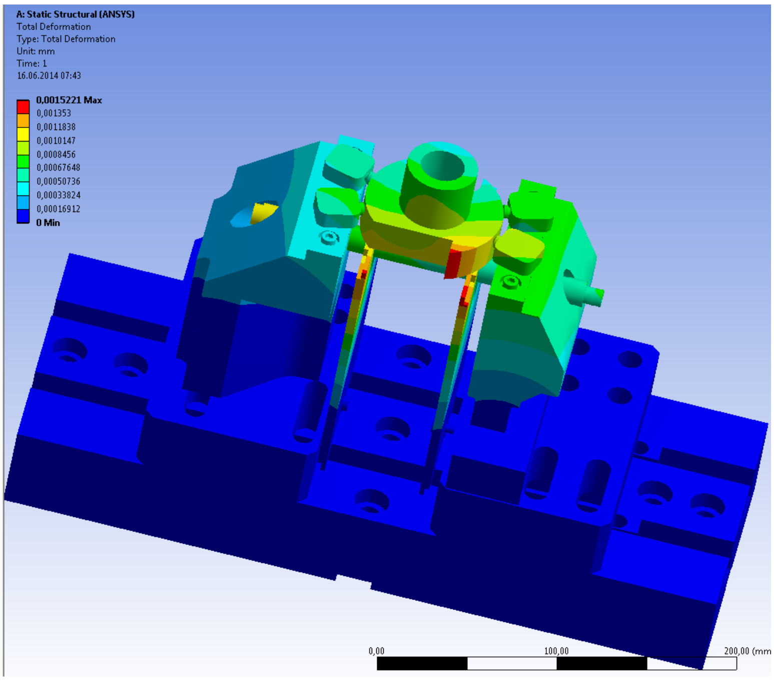

Fig. 4.13. Total deformation.

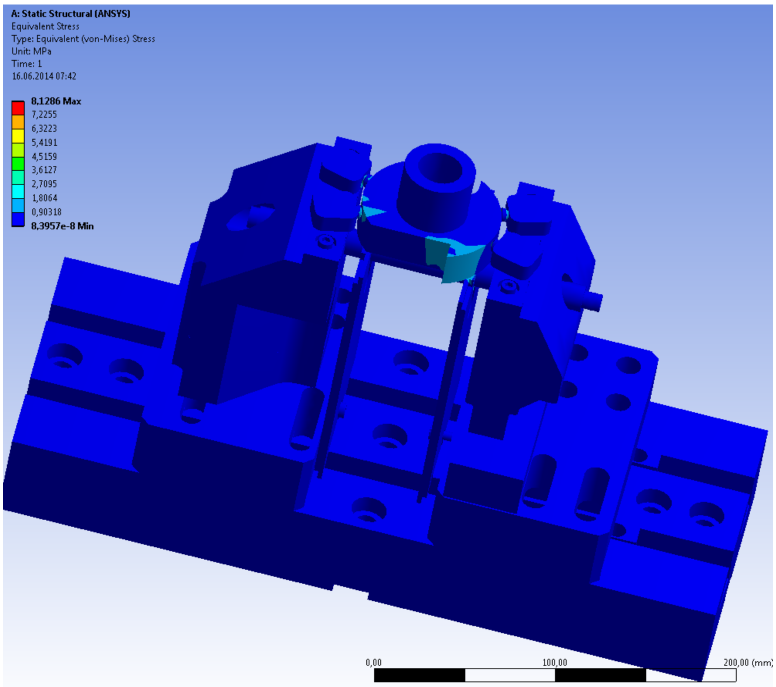

Fig. 4.14. Equivalent (von-Mises) Stress.

In table 4.2 are presented the deformation for the most solicited elements from the clamping device structure, in the three processing cases.

Table 4.2. Deformation of the device elements

Crt. nr.	Device element	Deformation [mm]		
		Case I	**Case II**	**Case III**
1	Workpiece	0.00086369	0.00048316	0.001522
2	Clamping pins	0.00083289	0.00018285	0.0010051
3	Clamping screw	0.00087548	0.00025188	0.0011733
4	Support plate	0.00086343	0.00023765	0.0014761
5	Screw of the support plate	$1.85e^{-5}$	$2.95e^{-5}$	$3.45e^{-5}$

Conclusions

In the paper are presented the CAE stages, with great importance in the determination of the optimal constructive variant and loadings of the orientation and fixing device, analysis that have as an objective the establishing of the most stressed elements of them structure.

On those elements it is recommended the emplacement of a deformation sensor for transforming the device in a mechatronic one.

For the analysed device the sensors represent a need reflected by the present results.

The recommended elements for sensors emplacement are different taking into account the configuration of the device: clamping screw, clamping pins, support plate or the support plate screw.

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