Annals of the Academy of Romanian Scientists
Series on Engineering Sciences
ISSN 2066 – 8570 Volume **7**, Number **2**/**2015**

FINITE ELEMENT ANALYSIS OF MODULAR FIXTURES STRUCTURE STIFFNESS ON AXIAL DIRECTION

Dragoş Florin CHITARIU[1],
Cătălin DUMITRAŞ[2],

Rezumat. *Lucrarea prezintă un studiu privind aplicarea analizei cu elemente finite în cercetarea rigidității structurilor de dispozitive modulare formate din placă de bază şi module cu rol de corp de dispozitive sau de reazem, rezultând structuri de dimensiuni apropiate dar forme diferite, cercetările fiind bazate pe rezultate experimentale. Deformaţiile evidenţiate indică posibilitatea de deformaţie axială neuniformă sub acţiunea unei sarcini uniforme, caz care poate determina apariţia abaterilor unghiulare şi liniare de orientare-poziţionare şi de prelucrare.*

Abstract. *The paper presents a study of modular structure rigidity formed of base plates and locator/ body fixtures modules, resulting structures with similar dimensions but with different modules using finite element analysis, based on a series of experimental results, in order to correlate the results. The highlighted deformation indicates the possibility of axial irregular deformation under axial uniform deformation may lead to orientation and position deviations of the workpiece during clamping and machining (angular and linear displacement of the measurement base).*

Keywords: Fixture, modular fixture, module, FEA.

1. Introduction

Modular fixtures are characterized by the fact that all the elements are coming into their structure normalized, standardized. By non-permanent assembly, various fixtures can be built for clamping the most varied workpiece, in various machining conditions [1, 2]. From the entire complex of factors that characterize the machining deviations o special role have the deviations that are caused by the deformations of the technological system [3, 4]. Among the deformations of the technological system a significant proportion is attributed to the modular or regular fixtures.

In general, static and dynamic rigidity of technological system and modular fixture, in particular, are influenced by the number, arrangement and static

[1]Title: Assist., PhD, Eng., Machine-Tools Department, Faculty of Machine Manufacturing and Industrial Management, Technical University "Gheorghe Asachi" of Iasi, Street Prof. Dr. Doc. D. Mangeron, 67, Iaşi, Romania, (chitariudragos@gmail.com).
[2]Prof., PhD, Eng., Machine-Tools Department, Faculty of Machine Manufacturing and Industrial Management, Technical University "Gheorghe Asachi" of Iasi, Street Prof. Dr. Doc. D. Mangeron, 67, Iaşi, Romania, (dumitrascata@yahoo.com).

stiffness of the modules within the fixture structure. In order to study the stiffness, it is necessary to study the static and dynamic rigidity of the components from the analyzed structure [4, 5].

The information regarding the calculation of total deformation, composed of deformation of elastic contact between the modules and the modules, from the field of Machine-tools and Fixtures, can be used by analogy to calculate, evaluate, the contact deformations (contact stiffness) and elastic deformations of the modules which compose the modular fixture structure [1, 2, 3, 4 , 5]. The deformations of the modular fixtures will be transmitted to the workpiece and will affect the accuracy of the machined workpiece.

The research of the deformation and stress using finite element analysis is necessary due to the large number of mathematical models / relationships, that don't provide detailed information on the application conditions. Also, achieving experimental results require the designing and manufacturing of test stands and the results on displacement / strain measurement is limited to a reduced number of "points" and don't provide an image of stress and strains distribution across the fixture.

The goal of the paper is to obtain a valid work methodology for determine de overall stiffness of modular fixtures- workpiece assembly and valid results for deformation, stress values and distributions in the modular fixture structure in order to assess the deviations that may occur during clamping and machining of the workpiece.

In the paper a work methodology is proposed in order to determine the values for the total deformation that can lead to geometrical deviations, caused by static forces on axial (vertical) direction, of modular structures.

Method

In order to develop the experimental methodology, the Machinery construction, Machine tools, and Fixture field has been considered [2, 3, 4, 5, 6, 7, 8, 9]. The proposed methodology contains the following stages:

1. Identification of the bibliographic sources on: deformations under axial force of joints found in modular fixture; 2. Selection of modules and modular structures for analysis; 3. Selection of the finite element analysis software; 4. Development of the 3D models of modules; 5. Selection of input parameters; 6. Establishing of the research conditions; 7. Pre-processing and parameter input; 8. Analyses fulfilment; 9. Presentation and comparing results obtained from finite element analysis the experimental results.

In regard to the working methodology there are detailed the steps related to: Modules selection: there were subjected to research modules (elements) from the modular kit SEM – 64 DISROM. The material for the modules is 38MoCrAl09, which after heat treatment and nitrating treatment, acquires a surface hardness of 880-1100 HV. The modules selected have section dimensions of 64×76 mm. These modules generally fulfil (most common) the functions of body components and orientation- positioning of workpieces.

Selection of the finite element analysis software: the finite element analysis software used was Deform 3D V10, usually this software is used for evaluation of elastic-plastic deformations of stamped/embossed parts and molds used in the corresponding processes.

The deformation problem used is elastic-plastic cold forming process, with elastic domain in use. In the case of this type of problem, the base plate is regarded as a half-mold, a rigid body that doesn't deform under the forces. The force transducer is regarded as a half-mold, the upper half-mold that also doesn't deform under the forces. A 160 steps analysis was used.

In the phase of meshing of the module a number of 12 933 elements have been used and a number of 3430 nodes. In the pre-process phase the speed of the force transducer is introduced, and in this case, a speed of 50 mm/s, similar to the speed used in experiments.

The contact elements are automatically generated based on the orientation-positioning scheme of components in the modular structure. Another step is the introduction of stroke conducted by the force transducer. This was correlated with the rate used in the experiments.

After completion of the pre-processing stage it follows the stage where the actual calculation takes place, namely the processing step. At this stage, the calculation is made as a "black-box" without user intervention.

Results

In table 1 are presented the main characteristics of the analyzed modules and the maximum experimentally measured elastic deformation [10].

Force was applied to the modules axially and the force was measured using a force transducer which was oriented and positioned on top of the module. Deformations were measured in two points with three displacement transducers. Two displacement transducers were installed on top of the module. Transducer 1 was oriented and positioned in the least rigid area at the intersection transverse channels; transducer 2 was oriented and positioned in the most rigid area.

Fig. 1 presents an image of the test stand designed, developed and used to experimentally determine rigidity modular fixtures [9].

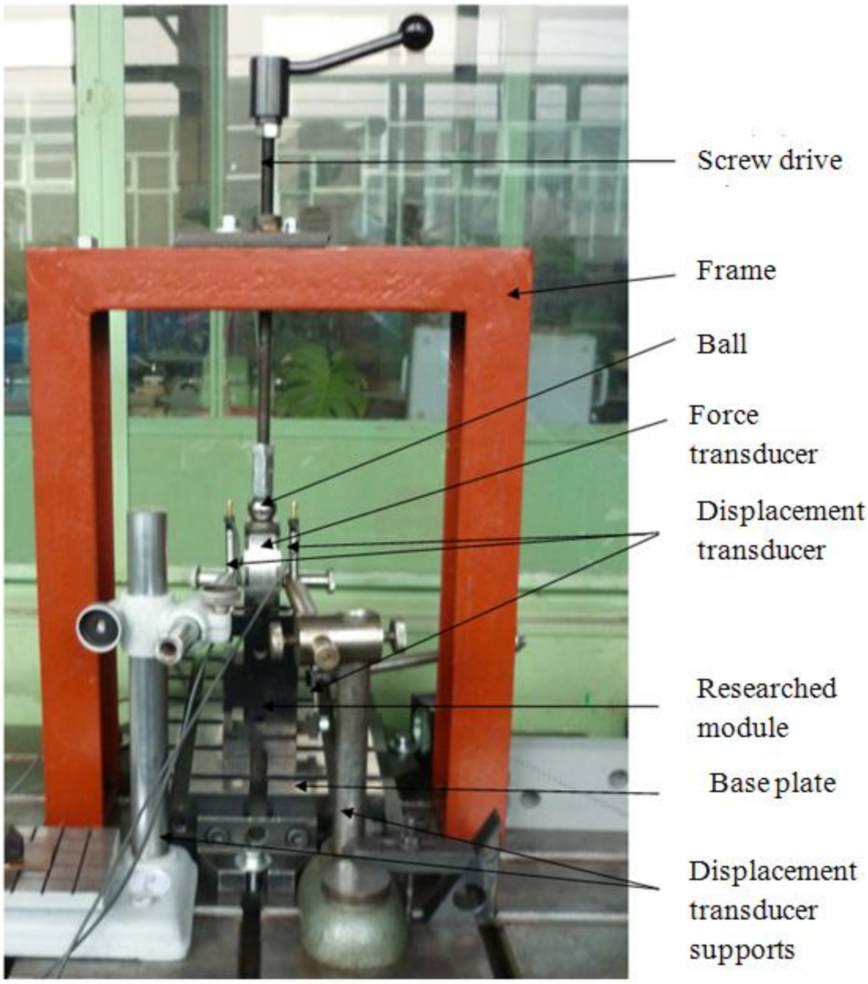

Fig. 1. – Test stand designed, developed and used to determine rigidity modular fixtures [10].

In fig. 2 is presented a model of the modular structure composed of base plate, type CCT – 003 with 6×3 slots, and a module, with transversal T channels with main dimensions 64×76×192 mm. On this structure the force transducer acted with an axial force.

In the pre-processing stage the displacement of the force transducer was introduced.

Deformations were measured at four points on the top surface of the module. Deformations evolutions in these points were highlighted using the "Point Tracking" feature.

In order to obtain the specified deformation the software calculated a force of 10.700 N, that is close to the experimental applied force of 10.000N [11].

Fig. 3 presents the maximal deformations measured on y axis, for the modular structure with module with three transversal T channels.

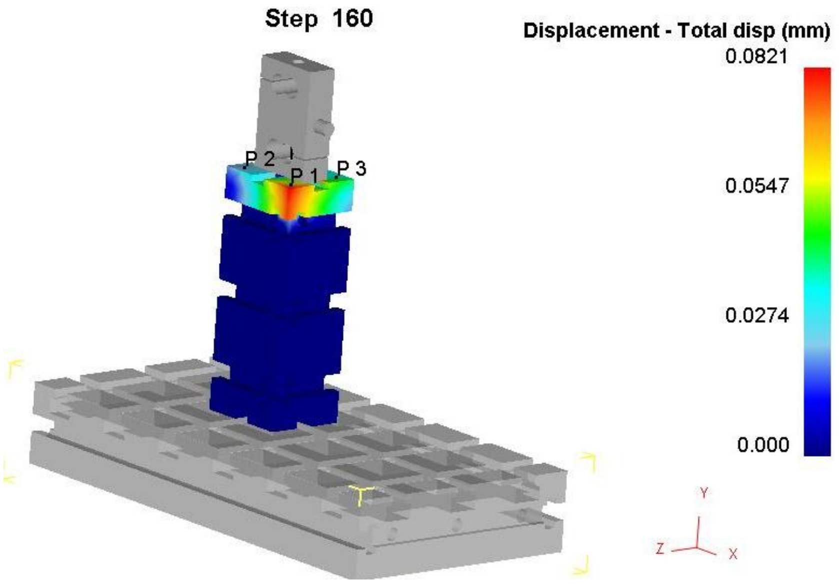

Fig. 2. Total displacement of the modular structure for modular structure with module with three transversal T channels.

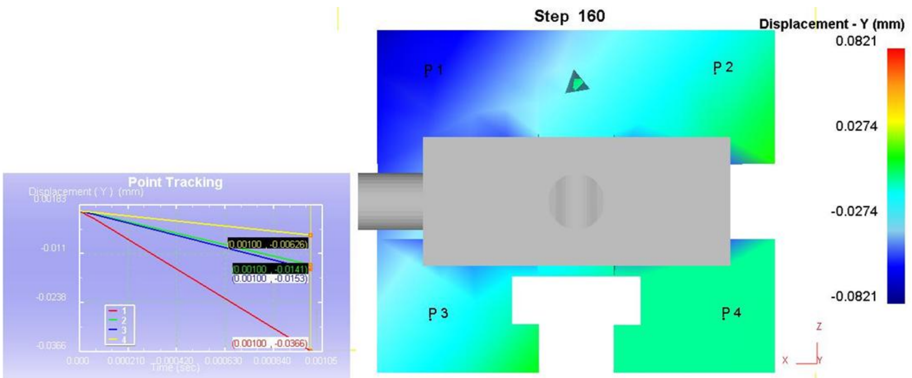

Fig. 3. Maximal deformations measured on y axis, for the modular structure with module with three transversal T channels.

The „Point tracking“, feature presents the deformations in four points where the displacements transducers were placed on the experimental tests [11]. The red curve refers to point P_1, the curve refers to point P_2, the blue curve refers to point P_3, and the yellow curve refers to point P_4.

Thus, point P_1 (red curve from fig. 2) was placed where deformations measurement was carried out by the displacement transducer 1, corresponding to the intersection of the channels T, the less rigid side of the module. Point P_1 (yellow curve from fig. 2) was placed at the most rigid side o f the module.

The returned calculated value for P_1 point (0.036 mm) is higher than de experimental value (0,03 mm). For the P_1 point the calculated value (0.006 mm) is lower than experimental value (0.02 mm).

The module with three transversal T slots deforms asymmetrically, in the less rigid side, at the T slots intersection, the deformations 85 % higher than in most rigid side, where there are no slots or holes.

In fig. 4 is presented a model of the modular structure composed of base plate, with 6×3 slots, and module type CSN – 003, with transversal holes with main dimensions 64×76×192 mm. The same loading and measuring scheme was also used.

Fig. 5 presents the maximal deformations measured on y axis, it can be seen that the calculated deformations for P_1, P_2, P_3, P_4 have similar values, 0.008 mm compared to the experimental value of 0.011 mm. Also, the calculated force was higher, 12.900 N compared to the experimental value of 10.000 N [11].

The measured deformations indicate a symmetrically, uniform deformations for the for modular structure with module with transversal holes.

Table 1 presents the experimental and FEA calculated deformations for the analyzed modular structures.

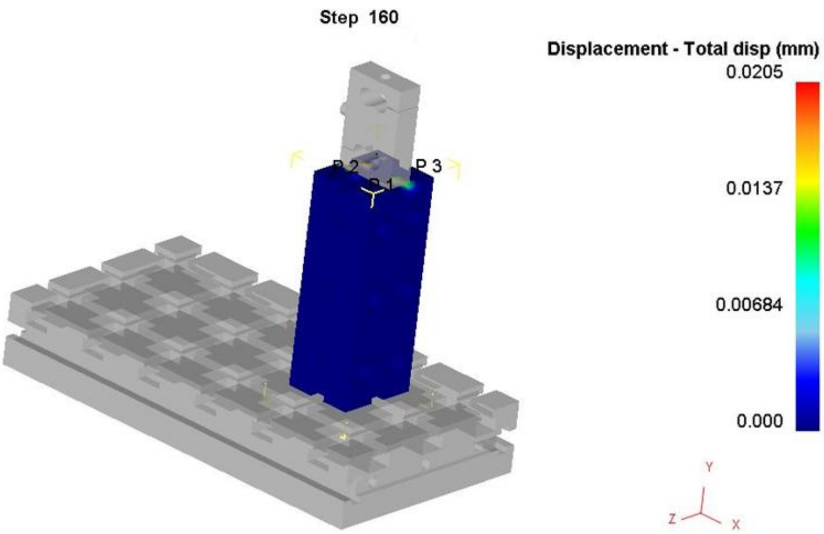

Fig. 4. Total displacement of the modular structure for modular structure with module with transversal holes.

Table 1 presents the experimental and FEA calculated deformations for the analyzed modular structures.

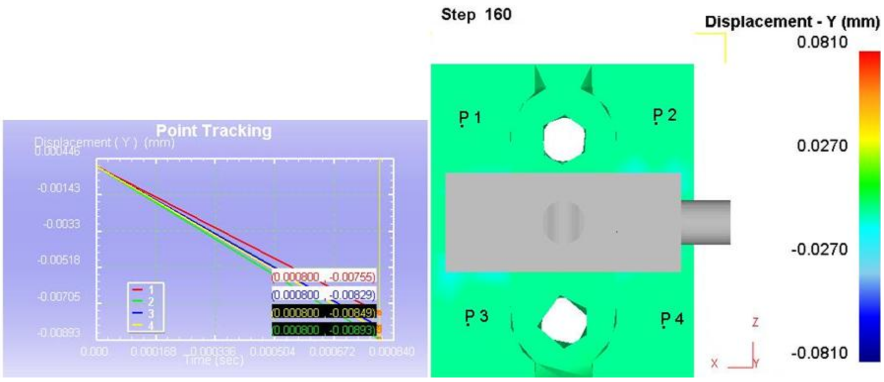

Fig. 5. Maximal deformations measured on y axis, for the modular structure with module with three transversal holes.

Table 1. Maximum and minimum deformations measured and calculated by the FEA software

No.	*Module*	*CCT-003*	*CSN – 003*
1.	Maximum measured elastic deformation	0.0335 [mm]	0.0115 [mm]
2.	Maximum FEA calculated measured deformation	0.036 [mm]	0.00893 [mm]
3.	Minumim measured elastic deformation	0.021 [mm]	0.011 [mm]
4.	Minimum FEA calculated measured deformation	0.006 [mm]	0.0075 [mm]

Conclusions

FEA results allow the study of deformation and stress values and distributions in the modular fixture structure. Considering this, it is possible to reconfigure the modular structure, an intervention on the modular device structure in order to achieve optimal fixtures structure in terms of rigidity, while maintaining optimal scheme targeting-positioning and clamping.

The highlighted deformations, of modules from fixture structure, may cause deviations during clamping and machining. Deviations caused by the uneven stiffness, of modules from fixture structure, may cause "dimensional"/ position deviations (linear displacement of the measurement base) and deviations of shape and orientation-position (angular displacement of the measurement base) of the machined surfaces of the workpiece. The construction of the fixture body must be such as the flow of forces to be closed through modules with a symmetric construction.

After the results of FEA analysis there are some differences between the experimental values and the finite element analysis values for deformations and force. The differences are caused by the fact the FEA software doesn’t allow the control of *contact elements* between the modules, also the software uses ideal bodies that don't allow machining deviations. From experimental results, o large proportion of the deformations is caused by the contact deformations, so, future research will use FEA software that allows the control of the contact elements.

REFERENCES

[1] Gherghel N., *Construcţia şi exploatarea dispozitivelor*, vol. 1, (Inst. Polit Iaşi, **1981**).

[2] Gherghel N., Seghedin N., *Concepţia şi proiectarea reazemelor dispozitivelor tehnologice*, (Tehnopress, Iaşi, **2006**).

[3] Korsakov V.S., *Precizia prelucrării mecanice* (trad. din Ib. rusă), (I.D.T., Bucureşti, Romania 1963).

[4] Y. Rong, Y. Zhu, *Computer Aided Fixture Design*, (Marcel Dekker Inc., New York, **1999**).

[5] Yoshimi Ito, Modular design for machine tools, (The McGraw-Hill Companies, New York, **2008**).

[6] Asante James N., *A Combined Contact Elasticity and Finite Element-Based Model for Contact Load and Pressure Distribution Calculation in a Frictional Workpiece-Fixture System*, Int. J. Adv. Manuf. Technol., **39**, (**2008**), pp. 578 ─ 588.

[7] Kashyap S., DeVries W.R., *Finite Element Analysis and Optimization in Fixture Design*, Structural Optimisation, **18**, (**1999**), pp. 193 ─ 201.

[8] Chitariu D., Gherghel N**.**, *Research on determination of contact deformation between clamping element and workpiece*, ModTech International Conference ─„*Modern Technologies, Quality and Innovation ─ New face of TMCR*“„ Sinaia, România, (**2012**), pp. 229 ─ 233.

[9] Chitariu, D., *Experimental Research Regarding Static Rigidity in Axial Direction of" Narrow" Modules from Modular Fixtures Structure*. Applied Mechanics & Material **657** (**2014**), pp. 514-518.

[10] Chitariu D., Gherghel N., Experimental *Research Regarding Static Rigidity in Axial Direction of "Normal" Modules from Modular Fixtures Structure. I. Research Methodology, Measuring Equipments, Researched Modules and Test Stand*, Bul. Inst. Polit. Iaşi, Univ. Tehnică „Gheorghe Asachi" din Iaşi, Tomul **LIX** (LXIII), Fasc. 1, (**2013**), Iaşi, p. 101 ─ 110.

[11] Chitariu D., Gherghel N., *Experimental Research Regarding Static Rigidity in Axial Direction of „Normal" Modules from Modular Fixtures Structure. II. Results*, Bul. Inst. Polit. Iaşi, Univ. Tehnică „Gheorghe Asachi" din Iaşi, Tomul **LIX** (LXIII), Fasc. 1, (**2013**), Iaşi, pp. 111 ─ 118.