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STUDY ON MACHINING DEVIATIONS CAUSED BY MODULAR FIXTURE RIGIDITY

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Abstract: *Modular fixtures are used to ensure the orientation and position of workpiece during machining, inspection and assembly. Specific to modular fixture due to the complexity, overall size and the high number of components, the general stiffness if affected. In this paper there are presented the causes that can lead to the diminishing of the accuracy of clamping when using modular fixtures, and several deformation patterns that result from experimental research of multiple joints modular structures, that can lead to a series of deviations of orientation-positioning and clamping deviations during clamping and machining. Specific clamping cases are presented and evaluated from the point of view of deviations caused by diminished rigidity during machining of parts clamped in modular fixtures.*
Key words: *modular fixture rigidity, machining deviations*

1. INTRODUCTION

Fixtures are used in technological systems for orienting-positioning and clamping of parts during the process of machining, measuring and also during the assembly process. The particularity of modular fixtures is the fixture structure there are only modularized or standardized elements [1, 2].

The law of modularity for fixtures refers to the specific core functionality, structural, shape and dimensional correlation of modules selected by the fixture manufacturer, considering various multipliers for generation of different fixture component size [1, 2]. Also, modules should be usable in any position and be interchangeable without the use of measuring equipment.

Specific to modular fixtures is the temporary nature of the construction, for low batch production and after the end of the manufacturing task the modular fixture is disassembled and the individual modules will be reused in another different modular fixture. Modular fixtures can replace universal or special fixtures and clamp a wide range of parts.

The modules from the modular fixture structure are machined to a high level of precision in order to assure the fixture's overall precision, stiffness and damping capacity. This maintains workpiece stability under the influence of static and dynamic mechanical loads generated by machining processes [3, 4, 5, 6].

Alongside precision the rigidity is an important fixture requirement, in order assure the dimensional/ geometrical precisions, during machining, inspection, assembly, especially for difficult machining and severe geometric conditions.

The static stiffness of the technological system is calculated as the ratio between the force (clamping and cutting forces) in a given direction and the elastic deformation of the technological system measured in the same direction [6].

The study of a technological system stiffness/ rigidity in general and a modular fixture in particular is challenging. Whereas the total deformations consist of relative rigid motion/ displacement between modules and elastic deformation of each module which in turn can be divided in contact and elastic deformation.

During the operation of the modular fixture the clamping and resulting cutting forces are transmitted to the fixture structure through the part, that leads to deformations and generate deviations of orientation and position of the technological bases. Fixture support deformations/ displacements can alter the orientation and positioning of parts during machining. High stiffness is therefore a key requirement for technological devices in general and modular devices in particular.

The static stiffness of the modular fixture structure can be used to assess the accuracy of a machining process and "resistance" to vibration. The static and dynamic rigidity/stiffness of a modular fixture is dependent by the number and arrangement of the modules within its structure.

The aim of the paper is to develop a modelling methodology for generating/ determining machining deviations caused by low stiffness of modular fixtures.

2. MATERIALS AND METHODS

Analytical determination of static stiffness of modular fixtures is difficult to assess because of the large number of modules found in the structure, resulting multiple joints, about which there is limited information regarding the behaviour under the cutting forces. Also, modules that create the joints have specific geometrical deviations (in terms of dimensions, shape, relative position, waviness and roughness) for the contact surfaces. These deviations can lead to orientation and positioning errors, as well as clamping errors during clamping and machining [2].

Most common type of joint resulting in the modular fixture structure are:

- joints loaded axially in the normal direction;

- joints loaded transversally, with axial pretension (in the normal direction);

- joints loaded by torque, with axial pretension (in the normal direction).

The deformation process of the fixture – workpiece assembly starts under the action of the clamping forces of the workpiece in the fixture, where the state of tension cand be easily determined analytically and continues under the action of the cutting forces, variable in value and dissipation direction. In this deformation mechanism, the contact deformation has significant role especially in the case of modular fixture, affecting the overall machining accuracy.

Author's previous work o modular fixture rigidity performed on modular fixture structures that are loaded on axial direction (considering the static component of clamping and cutting forces) have highlighted a series of deformation/ stiffness curves. Previous work was focus on studying deformation behaviours of modular structure consisting of base plate and one module. The material of the teste modules was 38MoCrAl09, which after heat treatment and nitrating treatment reached a surface hardness of 880-1100 HV.

The deformation highlighted during loading experiments will cause deviations during clamping and machining.

The deformation curves that are experimentally determined indicate that the structure presents uneven stiffness in the case of the structure with modules containing crossed channels, respectively asimetric structure, versus modules with uniform structure that present a total uniform deformation.

In Fig. 1 and Fig. 2 the force applied is corresponding to the static component of assembly, clamping and cutting forces. Several loading and unloading were performed to highlight a hysteresis phenomenon and the repeatability of the elastic deformations.

The contact deformation varies between 0.006 – 0.008 mm, provided that the value of the contact surface area is similar and the roughness Ra varies between 0.4 and 0.8 µm.

Previous results from fig. 1 and 2 indicate the deformation behavior of two similar structures consisting of one modular fixture module and a base plate. The two modules have the same dimensions but different structures (T-slot, holes) asymmetric structure versus symmetric structure [5].

The force is applied though a force transducer two displacement transducers measure the total deformation (contact and elastic) on the top of the modular structure and another displacement transducer is placed near the module and base plate for contact deformation measurement.

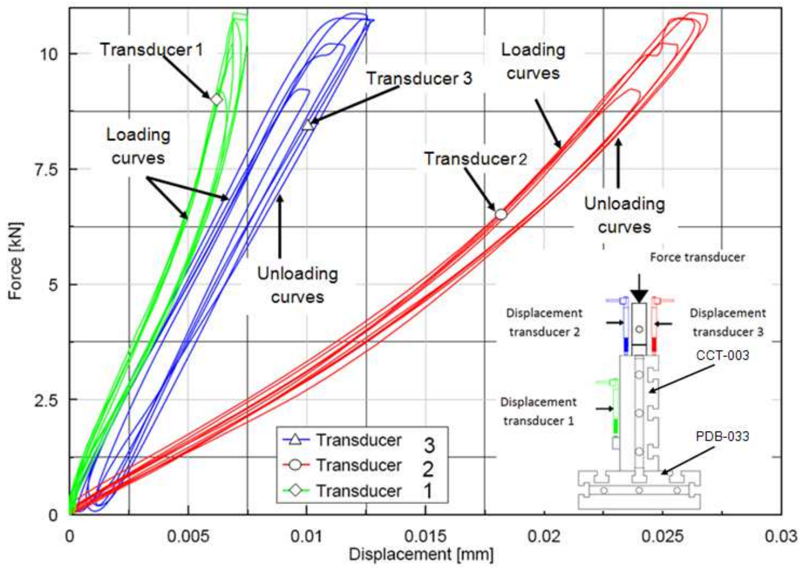


Fig. 1. Deformation (stiffness) curves for structures with asymmetric construction [5]

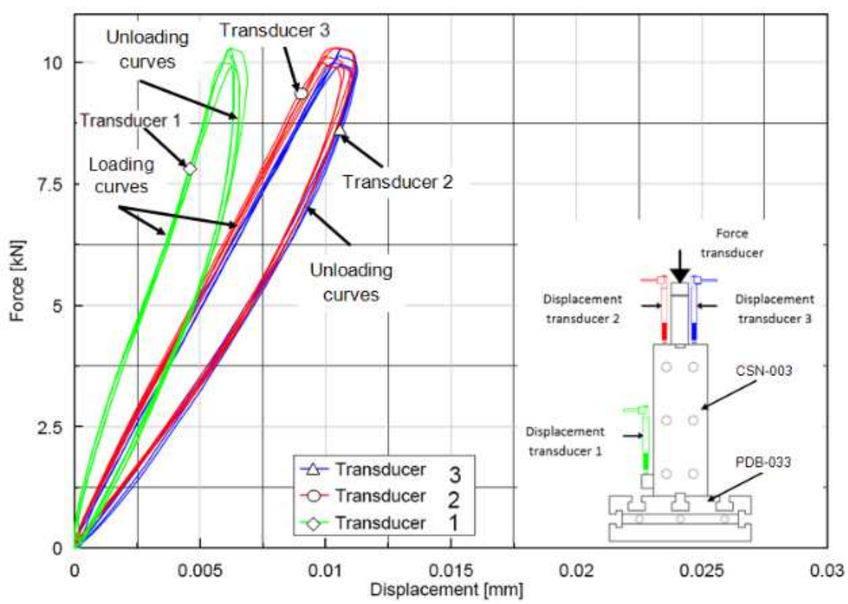


Fig. 2. Deformation (stiffness) curves for structures with symmetric construction [5]

Large differences, between total maximum deformation values measured, presented (Fig.1) indicate an inclination/ tilting of the top surface of the module under symmetrically applied loading on axial direction, that can lead to orientation-positioning deviations, is the workpiece is placed on top side of the module.

The influence of rigidity of technological fixtures in general and modular fixtures in particular on machining accuracy can be investigated theoretically and experimentally

For the theoretical approach, it is necessary to develop graphical diagrams/models showing how the deformations are generated.

The development of graphical models for the generation/ determination of machining deviations caused by the low rigidity of modular devices is important for understanding the specific phenomenology and for the most accurate and rapid assessment of the partial machining, control, assembly, etc., machining.

The block diagram of the proposed methodology is presented fig. 3.

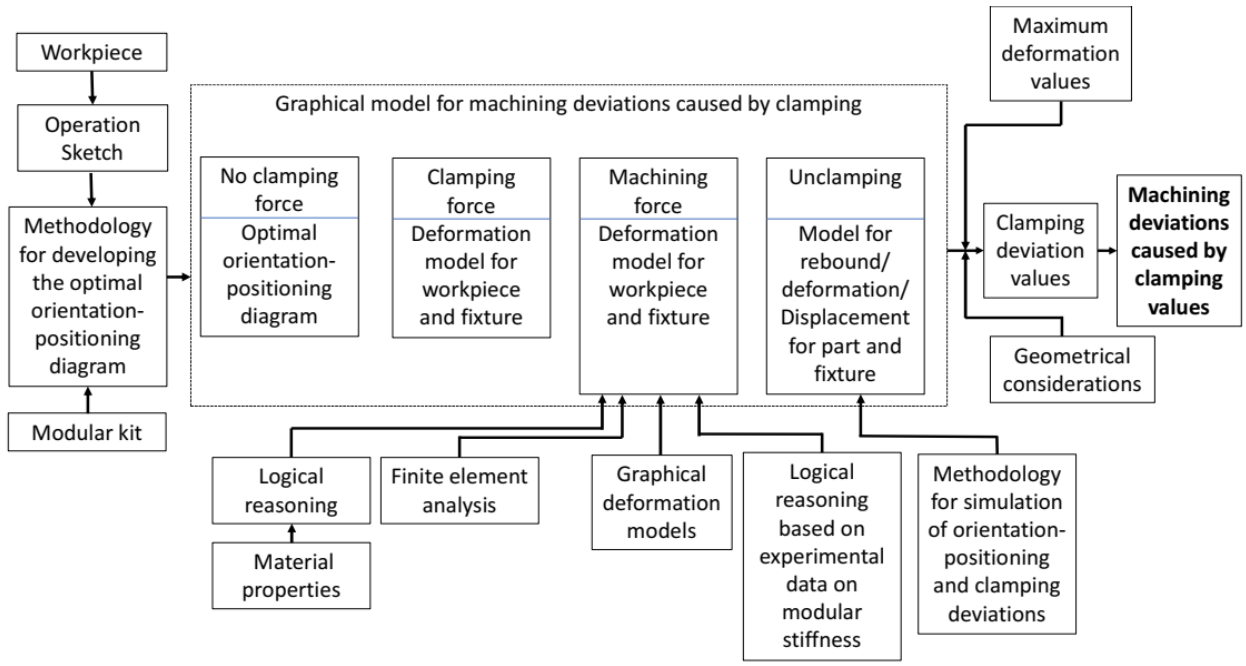


Fig. 3. Graphical modelling methodology for generating/determining machining deviations caused by low stiffness of modular fixtures

Under the action of the clamping and machining forces, contact deformations occur in the joints and elastic deformations of the workpiece and of the modules from the fixture structure. Based on the fig. 1 and 2 and applying Graphical modelling methodology from fig. 3, estimations of the machining deviations can be made following the next methodology.

It can be observed that the elaboration of the proposed models involves logical sequences/ activities, in a dynamic, evolutionary sequence:

— elaboration of the optimal orientation-positioning-clamping model;

— elaboration of the deformation/ displacement model of the modules and the work under the action of the minimum clamping force, respectively of the preliminary clamping force S (initial, prestressing, adjustment).

— modelling the deformation/displacement (δs) of the modules and workpiece under the action of the maximum clamping force Smax and the main clamping force S;

— modelling the recovery/return of the deformation/ displacement of the modules and workpiece upon removal of the clamping force (loosening) and the occurrence of the clamping deviations As;

— calculating the values of the clamping deviations As and the values of the machining deviations caused by the clamping.

— the results of finite element analysis,

— the theoretical and experimental results related to the deformation/stiffness of the modules, respectively modular devices (deformation/stiffness curves, values, mathematical models, FEA) [8].

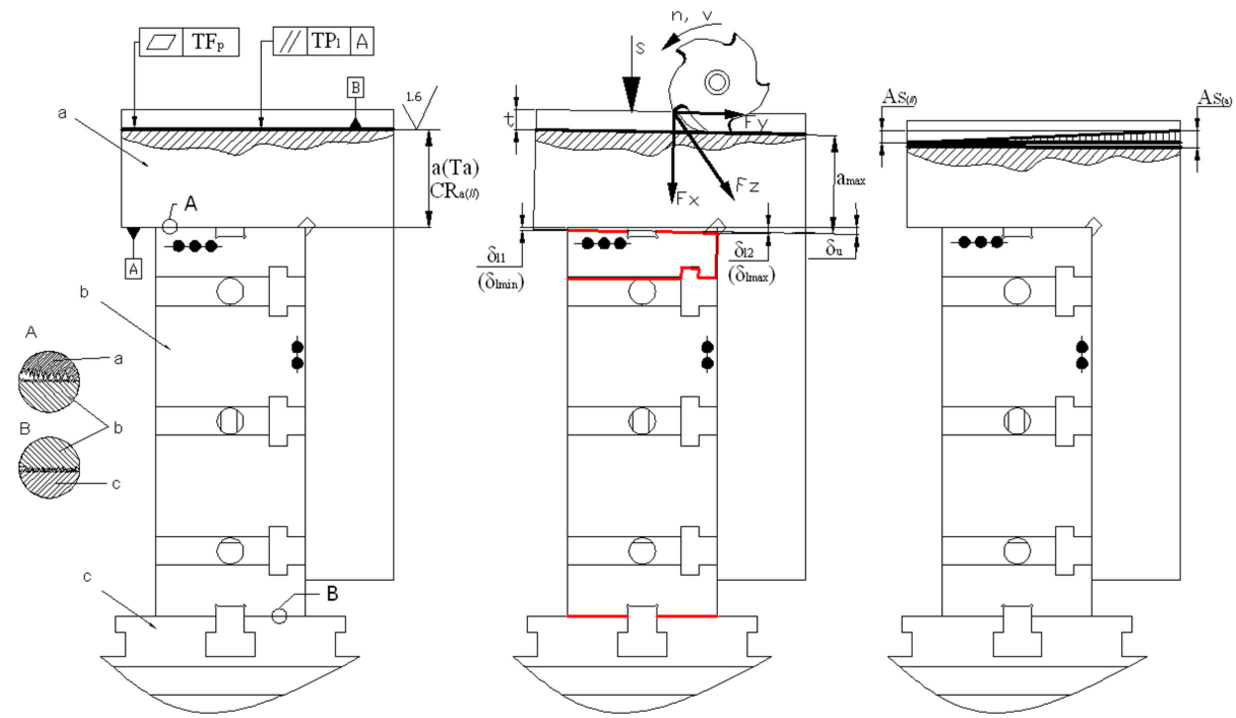
3. RESULTS

By applying the presented modeling methodology, the next example was developed.

In fig. 4 an example of a graphical model of the occurrence of dimensional deviations, shape deviations and relative positional deviations (orientation and position) is presented. The case of machining a channel with a milling cutter is presented.

In the case of the active surface of the support, materialized by the module, shows deviations from parallelism, these are transferred to the machined surface, fig. 4.a

Clamping deflections are caused by contact deformations between the workpiece and the fixture structure's supports/modules, marked in red fig. 4.b. but also by the inherent elastic deformations of the part and modules.



a. b. c.

Fig. 4. Example of a graphical model of the deformation and the generation of the clamping and machining deviation respectively of the modular fixture structure in a milling operation

4. CONCLUSION

The methodology designed for developing graphic models for generating/determining processing deviations caused by the low rigidity of modular devices is important for understanding the specific phenomenology and for the most correct and rapid evaluation of the potential deviation that can occur during clamping and machining right from the design stage.

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. Examples of graphical models for generating deformations, developed according to the proposed methodology, confirm the viability and importance of the proposed methodology and can form the basis for the development, by analogy, of similar models for any modular structure integrated into a given technological system.

Further research will include the analysis of the entire structure of the workpiece-fixture assembly.

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Studiu privind abaterile de prelucrare cauzate de rigiditatea dispozitivelor modulare

Dispozitivele de modulare sunt utilizate pentru a asigura orientarea și poziția piesei de prelucrat în timpul prelucrării, controlului și asamblării. Specific dispozitivelor de fixare modulare, datorită complexității, dimensiunii totale şi numărului mare de componente, rigiditatea generală este afectată. În această lucrare sunt prezentate cauzele care pot duce la diminuarea preciziei de strângere atunci când se utilizează dispozitive de prindere modulare, precum și o serie de modele de deformare care pot fi dezvoltate pe baza concluziilor din cercetarea experimentală Deformațiile structurilor modulare cu îmbinări multiple pot duce la o serie de abateri de orientare-poziționare și de strângere în timpul strângerii și prelucrării. Sunt prezentate și evaluate cazuri specifice de strângere din punctul de vedere al abaterilor de orientare și poziție cauzate de diminuarea rigidității în timpul prelucrării pieselor prinse în dispozitive modulare.

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