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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

BY

DRAGOŞ CHITARIU[*] **and NICOLAE GHERGHEL**

“Gheorghe Asachi” Technical University of Iaşi,
Department of Machine Tools

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Abstract. The paper contains a research methodology developed for the study of the static rigidity of some “normal” modules from the structure of modular fixtures. There were considered the modules deformations, under the action of axial static force. The static force considered was composed from: assembly forces, tightening forces and the static component of the machining forces. A measuring scheme for forces and deformation was elaborated and, also, the measuring equipments were chosen. The modules to be studied were identified and a test stand was developed.

Key words: fixture, modular fixture, methodology, module, deformation, rigidity, contact rigidity, total rigidity.

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[*] Corresponding author; *e-mail*: chitariudragos@gmail.com

1. Introduction

The technological system composed of: machine, cutting tool, fixtures and work piece, is not perfectly rigid, but it deforms under the action process forces.

The notion of *system rigidity* (*stiffness*), in general, therefore of technological systems also, represents the system capacity to oppose deformation under the action of exterior forces (Korsakov, 1963).

Of the entire complex of deviations that compose the total machining deviations, a special role has the deviations caused by the deformations of the technological system under the action of process forces. Among the deformations of the technological system, a significant proportion is due to the deformations of the regular or *modular fixtures*.

The *rigidity* (*stiffness*) of a *regular* or a *modular fixture* can be defined as the ratio of the force (or torque) acting on the fixture, in a particular direction, and the deformations (linear or angular) of the structure, in the same direction or not.

The *rigidity* (*stiffness*) is one of the fixtures requirements, in order not to decrease the dimensional/ geometrical precisions, during machining, inspection, assembly, especially for difficult machining and severe geometric conditions (Gherghel & Seghedin, 2002; Gherghel & Seghedin, 2006).

The knowledge of *static stiffness* is required for both primary evaluation of “resistance” to vibration and for evaluating the accuracy of machining process. Both static and dynamic rigidity, of a modular fixture, is determined by the number, arrangement and *static stiffness* of the modules within the device structure (Rong *et al.*, 1999).

In the process of *clamping*, relatively large (elastic-plastic), *contact deformations* occur, between the *orientation-position surfaces* of the workpiece and the fixture. These deformations, together with the fixtures deformations and sometimes the machine-tools deformations, lead to displacement of workpiece in relation to the *supports*, thus creating “*dimensional*”/ *position deviations*.

Due to the slots (in the case of T slots type *modular fixtures*, that use T slots for orientation and positioning of modules) or of holes (in the case of *hole and dowel* type modular fixtures, that use cylindrical surfaces for orientation and positioning of modules) machined in the body of the modular elements, the *rigidity* of the *modular fixture* is affected. During machining, the machining forces are transmitted through workpiece to the fixture, which cause the deformation of the fixtures structure and the position deviations of the supports.

From the analysis of the *Machinery construction* field (Korsakov, 1963; Picoş *et al.*, 1992), the *Machine tools* field (Ispas, 1998; Chiriacescu, 2004; Yoshimi, 2008), and the Fixture field (Tache & Brăgaru, 1976; Gherghel, 1981; Tache *et. al.*, 1982; Gojinețchi & Gherghel, 1992; Zhu *et al.*, 1993; Rong & Zhu, 1999; Li & Melkote, 1999; Liao *et al.*, 2000; Rong *et al.*, 2005; Zheng, 2005), regarding the deformation of friction joints in the axial direction, under the action of the static forces, it was found that the *total deformation* is composed from the deformation of the *contact joints* (joints of friction) and the *elastic deformation* of the structural elements.

In Fixture field are presented, only, values for *contact rigidity* (*stiffness*) between the workpiece and supports/ clamping elements without values for the *total* (*overall*) *rigidity* (*stiffness*) (consisting of contact rigidity and intrinsic rigidity) of fixtures components which compose the fixture structure (Tache & Brăgaru, 1976; Gherghel, 1981; Tache *et al.*, 1982; Gojineţchi & Gherghel, 1992). The Fixture literature, also, does not present information regarding the methodology used to obtain these results, or the application field.

The knowledge (information, data) for the calculation of the *contact deformations* known (measured), from the field of Machine-tools and Fixtures, can be used by analogy to evaluate the *contact deformations* (*contact stiffness*) between the modules which compose the *modular fixture* structure.

But the contact surfaces of *modules* are accompanied by a series of geometrical deviations (dimensional, shape, relative position, waviness, roughness) which are leading to a series of deviations of orientation-positioning and clamping deviations. These deviations accompany the assembly process of the *modular device* and the clamping process of the workpiece, and the machining process.

The need to conduct experiments results from difficulty of analytical determination of the geometrical deviations (dimensions, shape, relative position, waviness, roughness) of the *modules*, based on research identified in Fixture field.

In this paper we propose an experimental methodology for the determination of the deformation values which can lead to geometric errors, due to static loading on axial direction of “normal” *modules*.

2. Research Methodology, Measuring Equipments, Researched Modules and Test Stand

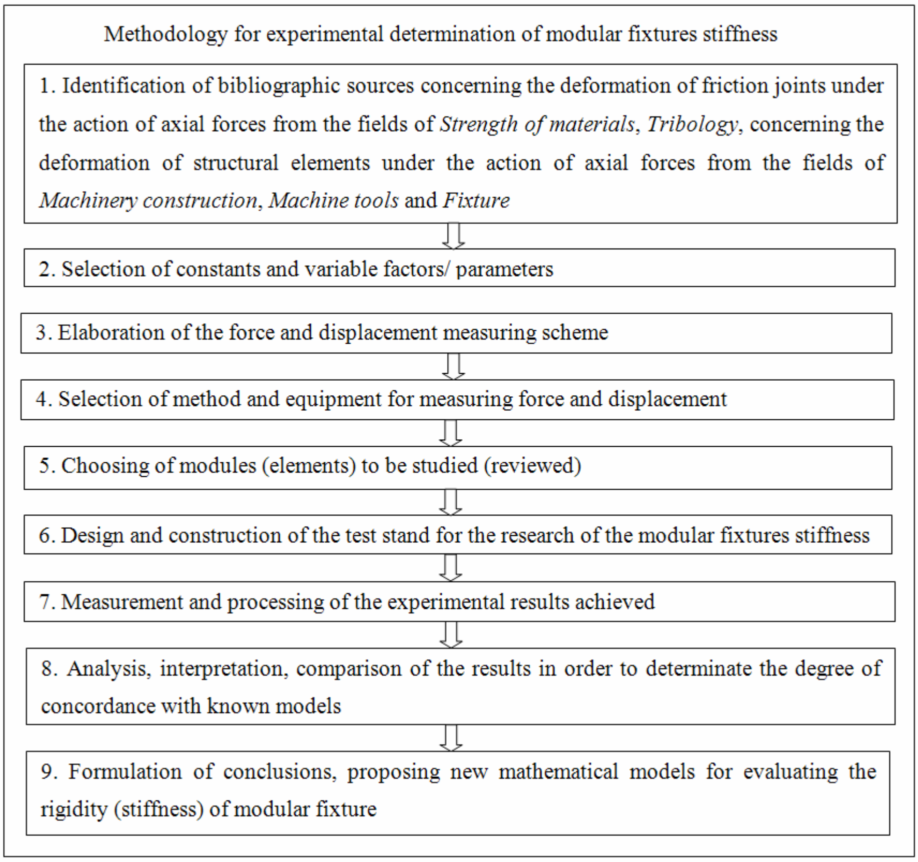
2.1. Research Methodology

In order to develop the experimental methodology, the Machinery construction field (Korsakov, 1963; Chiriacescu, 2004), and the Machine tools field (Yoshimi, 2008), has been considered. It is considered that the contact deformations of joints, under axial loading, from the structure of the technological systems are specific to reduced loads and the elastic deformations are specific to high loads. By analogy, it is assumed that, the deformation process, in the case of *modular fixture*, is similar.

Fig. 1 shows the methodology developed and used to determine the rigidity in the axial direction.

Regarding the methodology, the steps regarding the selection of constant and variable parameters, data acquisition equipment, data measuring and data processing are detailed.

In this paper, from the array of factors (parameters) that affect the stiffness of modular fixtures, the constant factors considered are: module type, orientation-position of modules in relation with the base plate, number of joints in the structure. The variable factors (parameters) considered are: axial force, module shape, module size.



Methodology for experimental determination of modular fixtures stiffness

1. Identification of bibliographic sources concerning the deformation of friction joints under the action of axial forces from the fields of *Strength of materials*, *Tribology*, concerning the deformation of structural elements under the action of axial forces from the fields of *Machinery construction*, *Machine tools* and *Fixture*
2. Selection of constants and variable factors/ parameters
3. Elaboration of the force and displacement measuring scheme
4. Selection of method and equipment for measuring force and displacement
5. Choosing of modules (elements) to be studied (reviewed)
6. Design and construction of the test stand for the research of the modular fixtures stiffness
7. Measurement and processing of the experimental results achieved
8. Analysis, interpretation, comparison of the results in order to determinate the degree of concordance with known models
9. Formulation of conclusions, proposing new mathematical models for evaluating the rigidity (stiffness) of modular fixture

Fig. 1 – The methodology developed to determine the rigidity in the axial direction of “normal” modules.

In order to determine the rigidity on axial direction, the methodology will consider determining the ratio between the applied *force* to the assembled *modules* and the corresponding *deformation* (displacement) on the same direction. Data processing was performed by filtration using the “moving average” filter. The measuring scheme used is presented in Fig. 2.

Force was applied to the *modules* axially and the force was measured using a force *transducer* (Fig. 2) which was oriented and positioned on top of the module. Deformations were measured in three points with three *displacement transducers*. Two displacement transducers (Fig. 2) were installed on top of the module and another transducer was mounted on the module at a distance of 32 mm from the base of *module*. Transducer *2* (Fig. 2) was oriented and positioned in the area corresponding to the T channels intersection. Transducer *3* (Fig. 2) was oriented and positioned in the most rigid area, and transducer *1* (Fig. 2) was oriented and positioned at a height of 32 mm from the *base plate*.

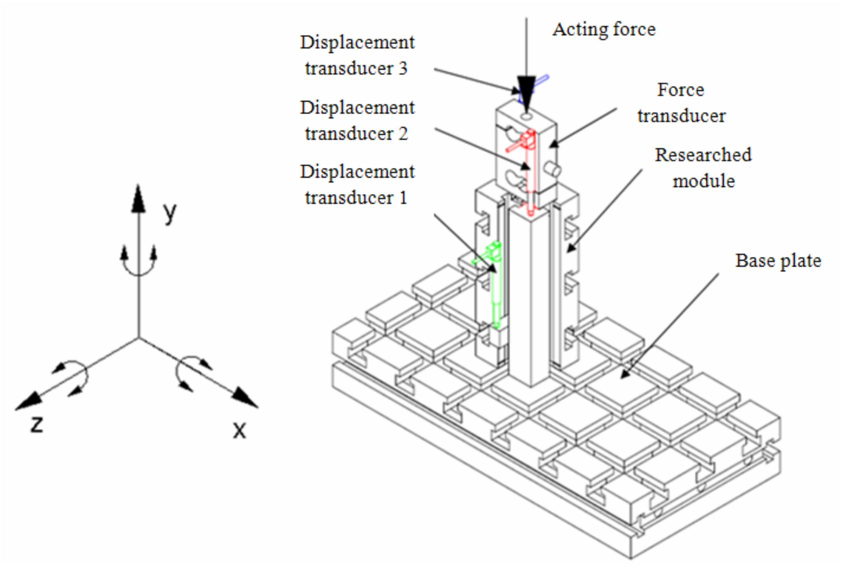


Fig. 2 – Measuring scheme of force and displacements.

Since the *Ra* roughness has a high impact on the contact rigidity it was measured for each module. The *Ra* roughness for the analyzed modules varies between 0.3 µm to 0.6 µm.

2.2. Measuring Equipments

Fig. 3 presents the measuring equipments used in the experiments.

The measuring equipment consists of:

a) force transducer CTL model 1000 made by Laumas Elettronica srl;

b) inductive displacement transducer type Wl/10mm made by Hottinger Baldwin Messtechnik;

c) multi channel electronic PC measurement unit made by Hottinger Baldwin Messtechnik;

d) computer.

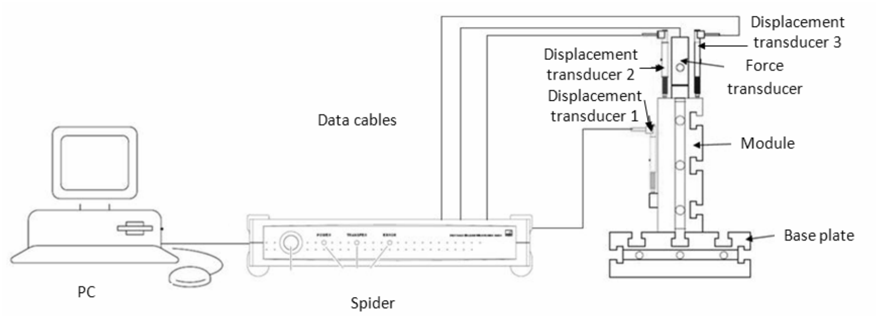


Fig. 3 – Measurement equipments.

2.3. Researched Modules

There were subjected to research *modules* (elements) from the modular kit SEM – 64 DISROM, made in Romania.

General characteristics of the SEM – 64 DISROM modular kit are: basic dimensions (distance between channels) – 64 mm, channel width – 14 mm diameter of threaded holes – M12 and M6, diameter of screws and bolts – M12 and M6, holes – Ø 13 mm.

Fig. 4 presents the base plate with 6 × 3 channels on which the modules were oriented and positioned. Fig. 5 presents the normal modules from SEM – 64 DISROM modular kit.

The "normal" module means that the modules section dimensions are 64 × 76 mm. These modules generally fulfil (most common) the functions of body components and orientation-positioning of workpieces.

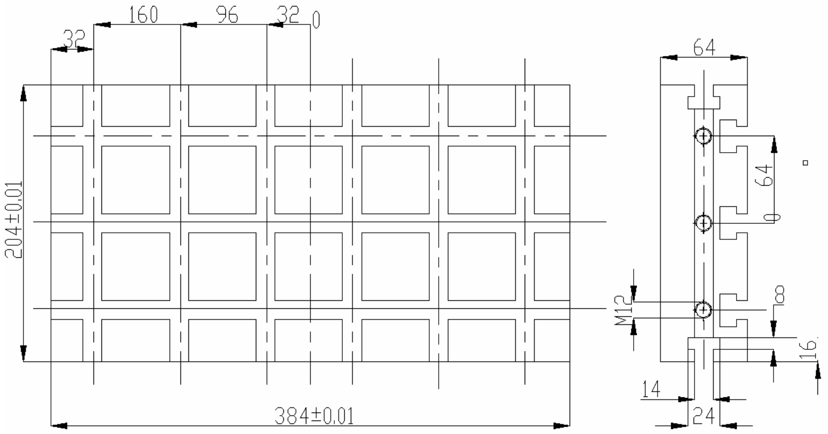


Fig. 4 – Base plate PDB 033 with 6 × 3 channels from SEM – 64 DISROM modular kit.

The material for the modules is 38MoCrAl09, which after heat treatment and nitrating treatment, acquires a surface hardness of 880-1100 HV. Active surface roughness *Ra* is between 0.4 and 0.8 μm.

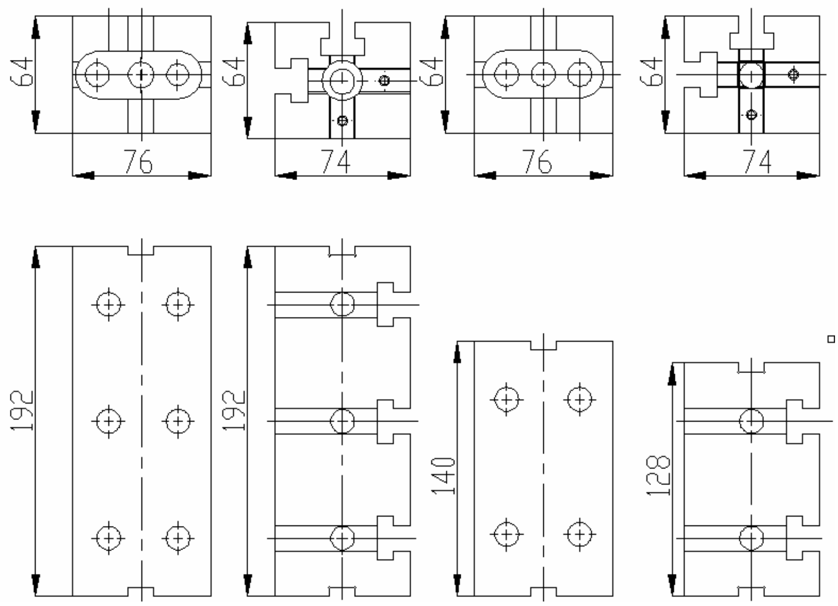
In Fig. 5 are shown the following types of modules from SEM – 64 DISROM modular kit:

a) normal module CSN – 003, (Fig. 5 *a*); main dimensions 64×76×192 mm;

b) module with transversal T channels CCT – 003, (Fig. 5 *b*); main dimensions 64×76×192 mm;

c) normal module CSN – 002, (Fig. 5 *c*); main dimensions 64×76×128 mm;

d) module with transversal T channels CCT – 002, (Fig. 5 *d*); main dimensions 64×76×128 mm.



a *b* *c* *d*

Fig. 5 – Normal modules from the SEM – 64 DISROM modular kit.

2.4. Test Stand Developed

Fig. 6 presents an image of the test stand designed, developed and used to determine rigidity modular fixtures.

The operating force was achieved manually by means of a screw mechanism. The test stand can be adapted in order to use hydraulic drive. In order to increase rigidity of the measurement system, there were used laboratory supports for the displacement transducers.

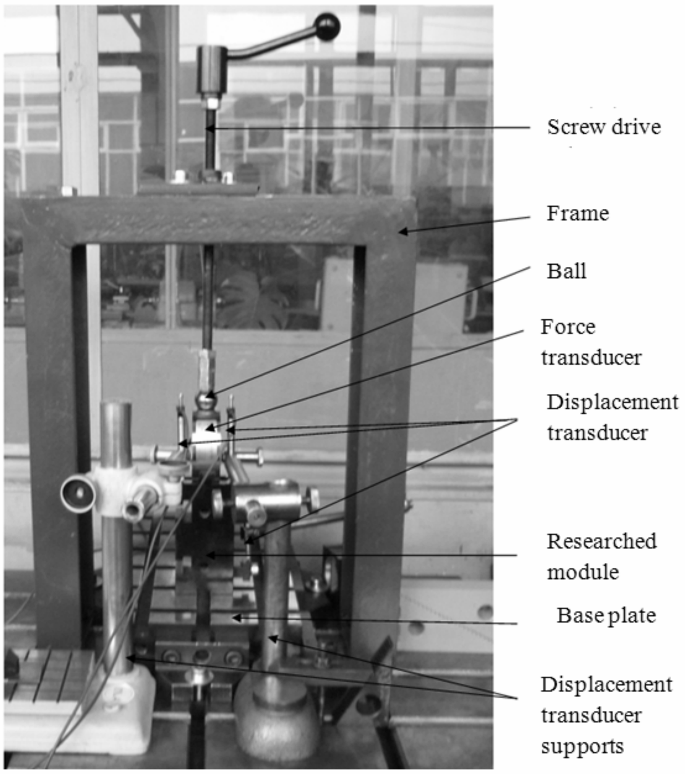


Fig. 6 – Test stand designed and developed to determine rigidity modular fixtures.

4. Conclusions

1. The research methodology developed for the study of the static rigidity of some “normal” modules from the structure of modular fixtures, represents a customizations of research methodologies of static rigidity (stiffness) of technological systems, machine tools, fixtures.

2. The research methodology developed is based on scientifically analysis of the modular fixtures, on knowledge of study techniques, both theoretical an experimental, of measuring methods of forces and displacements.

3. Based on the research, regarding the deformation of friction joints in the axial direction, under the action of the static forces, it was found that the *total deformation* is composed from the deformation of the *contact joints* (joints of friction) and the *elastic deformation* of the structural elements.

4. Based on the knowledge gathered, a measuring scheme, for forces and deformations, was developed. Also, measuring equipments were identified.

5. There were identified modules to be studied and a test stand was developed.

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CERCETĂRI EXPERIMENTALE PRIVIND RIGIDITATEA STATICĂ PE DIRECŢIE AXIALĂ A UNOR MODULE „NORMALE” DIN STRUCTURA DISPOZITIVELOR MODULARE

I. Metodologie de cercetare. Echipamente de cercetare. Module cercetate şi stand experimental

(Rezumat)

Este prezentată o metodologie elaborată pentru studierea *rigidităţii pe direcţie axială* a modulelor „normale”. S-au considerat deformaţiile modulelor sub acţiunea forţelor statice, pe direcţie axială: forţa de asamblare, de strângere şi componenta statică a forţei de prelucrare. S-a elaborat o schemă de măsurare a forţelor şi deformaţiilor şi s-au identificat echipamentele necesare pentru a materializa această schemă de măsurare. S-au identificat modulele care vor fi analizate şi s-a elaborat un stand experiemental pentru realizarea determinărilor.