Serbian Tribology Society

SERBIATRIB '17

15th International Conference on Tribology

Faculty of Engineering
University of Kragujevac

Kragujevac, Serbia, 17 – 19 May 2015

INFLUENCE OF FRICTION ON INCREASE STIFFNESS OF MODULAR FIXTURE SYSTEMS

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Abstrakt: *The idea of development of modular fixture systems increased level of stiffness and flexibility based on modular fixture systems that are in the basic form of framed structures. It is assumed that the concept of forming assemblies of modular fixture systems provide greater rigidity and flexibility, greater reliability, which is especially important if you take into account the possible use of these accessories when processing on modern multi-axis numerical machines in which at once basing and tightening treatment performed with a number of different tools. The friction between structural elements of the modular fixture systems are analyzed.*

Keywords: *modular fixture systems, stiffnes, friction, structural elements.*

1. INTRODUCTION

The concept of modular fixture system composed of a number of interchangeable components originally developed in England at the beginning of World War II [1]. With the development of numerical machines (Numerical Control machine - NC) 1960 years, beginning more and more to develop and implement modular clamping accessories in the industry. Modular fixture systems play an important role in the modern manufacturing environment because they reduce the time and costs required for the design, and the time and costs during the changes fixture systems in a variety of manufacturing processes [2]. In addition, the modular fixture systems through the universal existence of exchangeable clamping elements allow for greater flexibility, the quality and volume of production. The flexibility of modular fixture systems derives from a large number of clamping configuration, ie. different combinations of clamping elements which can be connected to this base plate. Modular fixture systems basically consist of a base plate on which is placed fixture elements standard type and are used for different shapes and sizes of workpieces. The elements of a modular fixture systems be in the form of vertical and horizontal elements for the positioning, both vertical and horizontal clamping elements with a role to base, positioned and clamped the workpiece in a given position. A method of designing a modular fixture systems may be divided into four phases [3]:

- preparation of input data,
- planning modular fixture systems,

- the design modular fixture systems,
- verification.

Generally speaking, the modular fixture systems can be divided into two groups according clamping surfaces [4]:

- the surface of the base the T - the grooves and,
- basing surfaces with holes and threaded bore.

Automated design of a modular fixture systems means the process in which, without human interaction projects a corresponding modular fixture systems for the workpiece. Considering that the in today's widespread use of 3D design software, as input to a system that is able to automatically design a modular fixture systems to use the 3D model of the workpiece, with the technological data such as tolerances, surface roughness and other [5]. Modular elements of the clamping would need to have some level of intelligence is required [6]. In previous research, a large number of systems for automated design of modular fixture systems, or complete automation of any system has not been developed. More or less essential human interaction in defining the input data into the system.

Previous studies in the field of application systems for automated design accessories CAFD, globally, can be divided into two prominent fields of research include: optimization of modular fixture systems and the development of modular fixture systems. Different techniques were used to optimize the modular fixture systems:

- the method of the finite element [7]–[9],
- genetic algorithms [10]–[13],
- a combination of genetic algorithms and neural networks [14], [15],
- the finite element method, and genetic algorithm [16],
- genetic algorithms and algorithms ant colony [17].

This type of research, more or less, is focused on defining the optimal number of necessary elements for positioning and clamping the workpiece in a modular fixture systems. When we talk about the development of modular clamping kit, there are several systems that should be noted:

- a neural network [14], [15],
- case-based reasoning - CBR [18], [19],
- an expert system [20]–[23] and
- knowledge-based systems [24]–[26].

Analyzing literature which is directly related to this field of research has been observed that the systems of modular clamping of accessories based on the system console. A large number of studies designed to determine the performance of positioning, tolerance analysis, stability analysis, analysis of possible constraints, and optimize the clamping force. In addition, previous studies include: a method for determining automatic positioning and clamping the workpiece on the basis of mathematical models, algorithms to select the position for positioning and clamping, which provides maximum mechanical leverage, the kinetic analysis based on the planning of clamping tension arrangement and dependence shrinkage based on the analysis of the accessibility automatically select settings taking into account the tolerance factor, and the occurrence of possible failures of the clamping devices, as well as the geometrical analysis based n a 2D planning clamping accessories. Principles of clamping equipment and research based on the finite element method are also the subject of considerable research. The finite element method, it is in most cases used for analysis of the behavior of stress and strain of the system the workpiece / chucking device in relation to the applied force of processes of cutting and clamping process. It also carried out a large number of optimization and developed a large number of mathematical algorithms in order to minimize as much displacement and deflection.

The idea of development of modular fixture systems increased level of stiffness and flexibility based on modular fixture systems that are in the basic form of framed structures. It is assumed that the concept of forming assemblies of modular fixture systems provide greater rigidity and flexibility, greater reliability, which is especially important if you take into account the possible use of these accessories when processing on modern multi-axis numerical machines in which at once basing and tightening treatment performed with a number of different tools.

2. BASIC SYSTEM CONFIGURATION OF MODULAR FIXTURE SYSTEMS

The basic configuration of a modular fixture systems of frame type is illustrated in Figure 1. The frame of the modular fixture systems is formed with the outer faces of the base plate which can be easily connected with other elements which are used for clamping work cartwheel within modular fixture systems. The above-described basic elements are mounted on a base plate which by means of screws fixed to the table working machines. The supporting structure of this type of modular fixture systems consists of a base plate, the pillar (guide rail) of the mounting plate and the carrier guide rail.

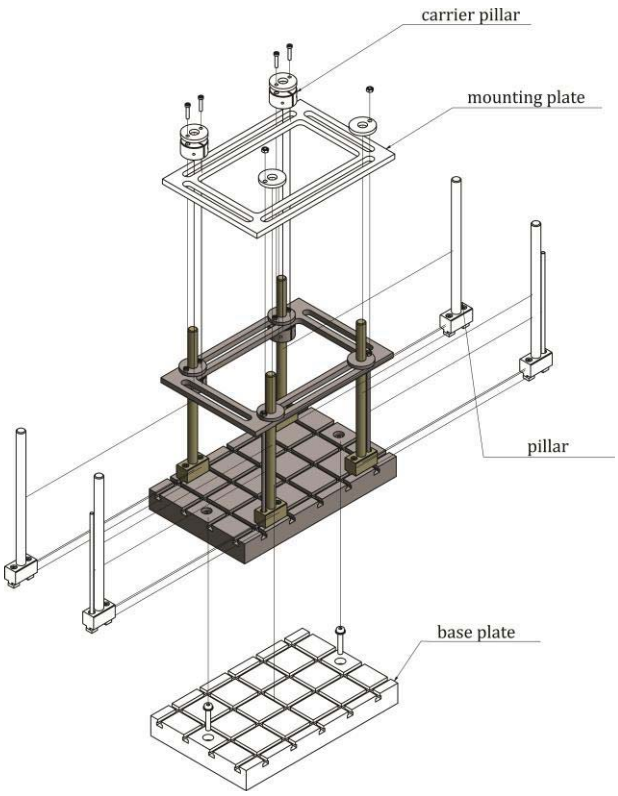


Figure 1. The basic configuration of the modular fixture systems

After defining the dimensions of the workpiece, with respect to the base plate, approach to the design of the modular fixture systems. Pillars can slide along the groove by the base plate and clamping elements can be fixed anywhere along the groove. Depending on your needs can be installed more poles. To increase the stiffness of the bearing structure of modular fixture systems, if necessary, the poles are placed stiffeners. After fixing pillars are mounting and fixing of the mounting plate by means of the carrier poles at a certain height.

3. THEORETICAL INVESTIGATIONS

Under the influence of the transverse external load bracket is bent, ie. comes to its bending axis. The focus of arbitrary cross section at a distance, z, from the left end moves perpendicular to the axis of the console size, u. This move is known as a deflection. The function u (z) is the equation of the elastic line bent axis bracket (Figure 5.4). In close the cross-section, at an infinitesimal distance dz, the deflection will be u + du, where du increment of deflection. Given that the distance is infinitely small, we can consider that the line CD is right, that is. that this line coincides with the tangent to the elastic line at point C. The angle ϕ which this tangent forms with the original axis of the bracket is known as a slope.

Theoretical consideration deflection and slope for a particular case console loaded by force F on the free end (Figure 2).

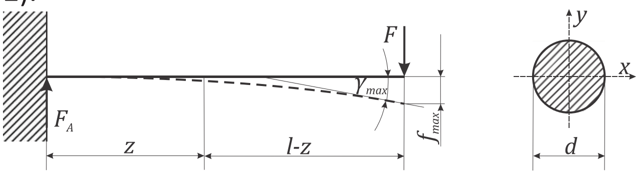


Figure 2. Elastic line console loaded at the free end

From the strength of materials known to the deflection console loaded by force F on the free end:

$$Bu = \frac{Fl^3}{6}\left[3\left(\frac{z}{l}\right)^2 - \left(\frac{z}{l}\right)^3\right]. \tag{1}$$

respectively:

$$f_{\max} = \frac{Fl^3}{3B}. \tag{2}$$

At console with variable cross section shown in figure 2 at the calculation of the deflection are taken into account the moments of inertia of the increased moment of inertia of the work and the console of circular cross section. Calculation of deflection takes place over two fields (field AC and CB feld).

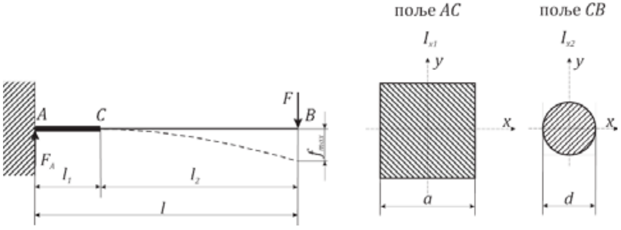


Figure 3. Deflection console with variable cross section

On the basis of the previously calculated deflection u_{AC}, u_C and u_{CB} the total deflection, or an elastic console line with variable cross section shown in Figure 2 would be:

$$u = \frac{Fl_1}{2B}\left(2l - l_1\right) + \sin\gamma_C \cdot \frac{180^o}{\pi} \cdot z_1 + \\ + \frac{Fl_2^3}{6B} \cdot \left[\left(\frac{z_1}{l_2}\right)^2 \cdot \left(3 - \frac{z_1}{l_2}\right)\right]. \tag{3}$$

4. EXPERIMENTAL INVESTIGATIONS

The experimental investigations on the elements that make up the bearing structure of the modular frame of the fixture system are sufficient indicator of the impact of different sizes load at the behavior of the fixture system/ the workpiece.

During the presentation of experimental analyses it is used specially designed device that works on a mechanical principle, and to check the reading obtained independent parameters used coordinate measuring machine DEA Global Performance using measurement software PCDMIS.

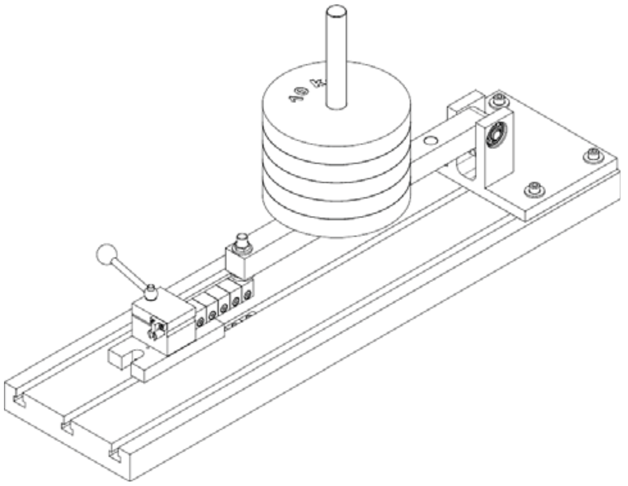
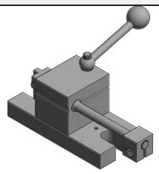
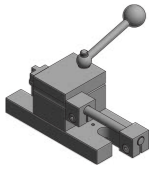
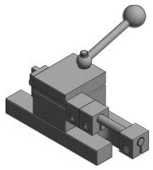
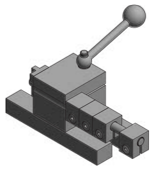
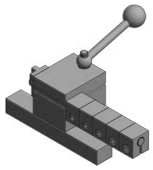


Figure 4. Mechanical measuring device

It was conducted five experimental tests. In conducting out of the experimental tests it was carried out by changing the cross section of the modular guide elements of the fixture system by the addition of stiffening. Each of the experimental tests is conducted and involved a load side guide to the values of normal load Fn, given in table 1.

Table 1. Experiment plan and program

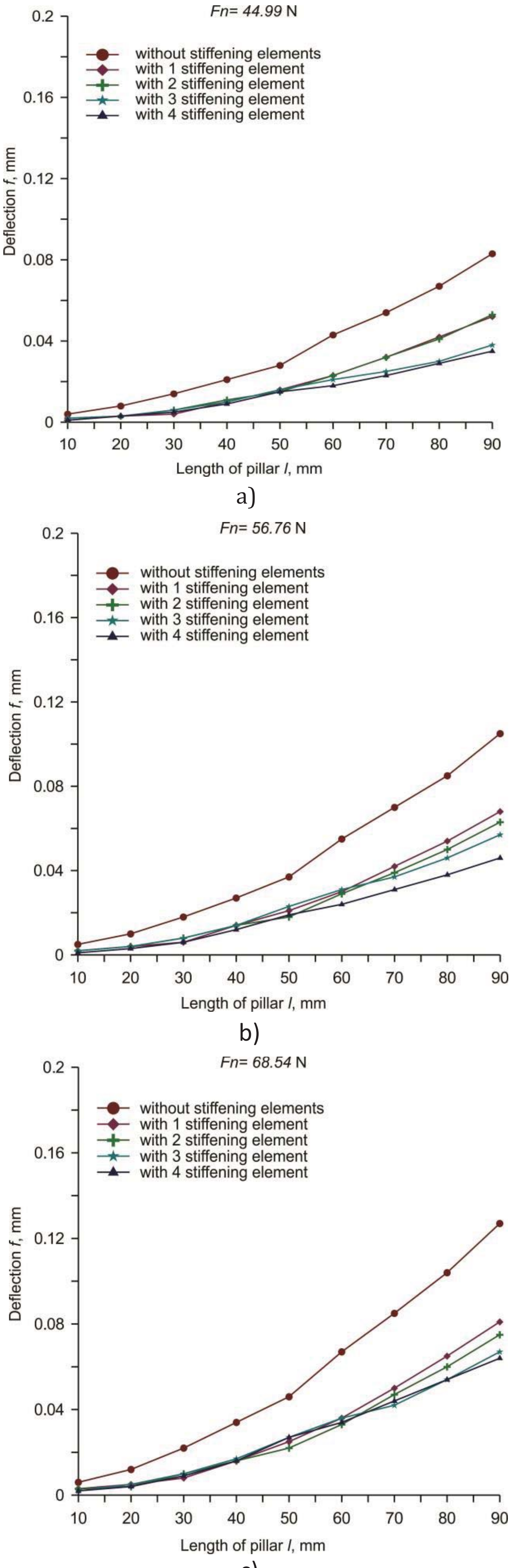
Experiment no.	Stiffening elements	Fn, N
1.		44.99, 56.76, 68.54, 80.31, 92.08, 103.85
2.		44.99, 56.76, 68.54, 80.31, 92.08, 103.85
3.		44.99, 56.76, 68.54, 80.31, 92.08, 103.85
4.		44.99, 56.76, 68.54, 80.31, 92.08, 103.85
5.		44.99, 56.76, 68.54, 80.31, 92.08, 103.85

The result of experimental tests was to determine and compare the differences of elastic line guides with and without stiffening elements. Due to the volume of experimental data, the paper will be displayed only static processed results.

5. EXPERIMENTAL ANALYSES OF RESULTS

According to the experimental analyses described in chapter 7, and the results shown in Table 4, it was followed by analysis of the behavior of deflection under the action of the abovementioned loads. The obtained experimental results of the elastic line of the guide without the stiffening elements and the stiffening elements are shown as the diagram in Figure 5. The primary result of the experimental analyses is to show the real behavior of a structural element of the modular fixture systems to the effects of stress. It is believed that the experimental analyses conducted on a moving structural elements sufficient indicator of reliability and overall system rigidity modular fixture systems.

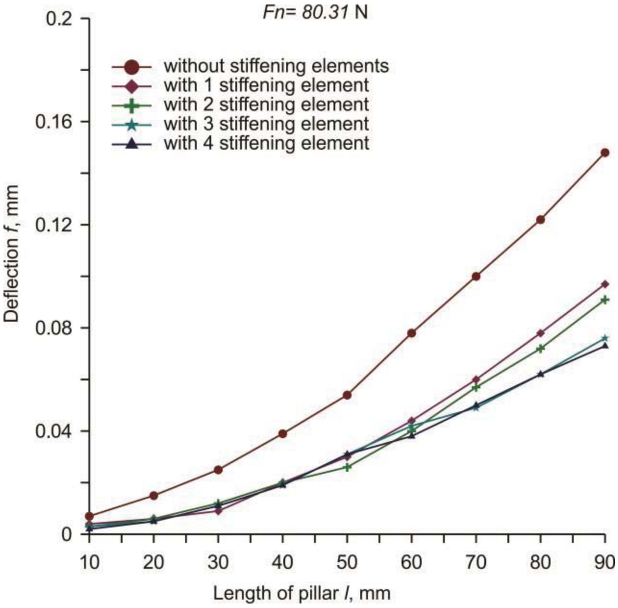
Analysis of the experimental results shown in Figure 5 a) can clearly see the reduction in the deflection f by the addition of stiffeners in relation to the guide without stiffeners. Reduction in the deflection f observed in the percentage of the measured end-point, in the guides with stiffening with respect to the guide without the stiffener is 37%. The deflection f, which is further observed reduction in, with two guides of the support in relation to the guide without the bracing of 36%. Deflection f, three guides with a stiffening element in relation to the guide of the support without it decreased by 54%, while the decrease of the deflection f, in the guides with a complete change of the cross-section, i.e. in the guides with four stiffening elements smaller in relation to the guide without stiffeners 57%. Based on the above, it can be concluded that the experimental research deflection f in the guides with a complete change of the cross section into a rectangular shape smaller by about 50% in relation to the guide of circular cross section.



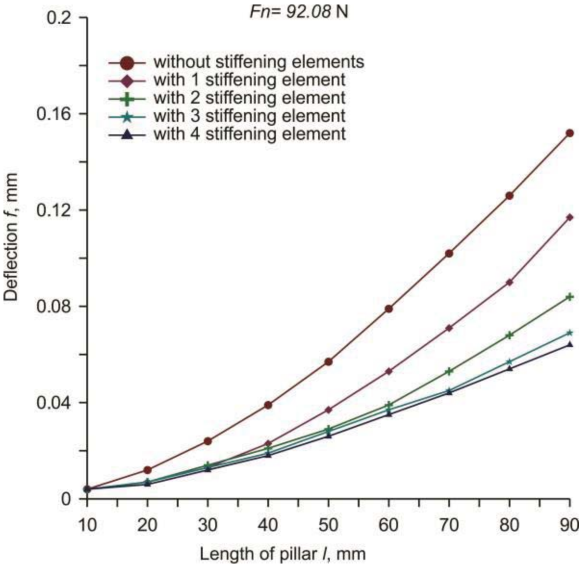
a)

b)

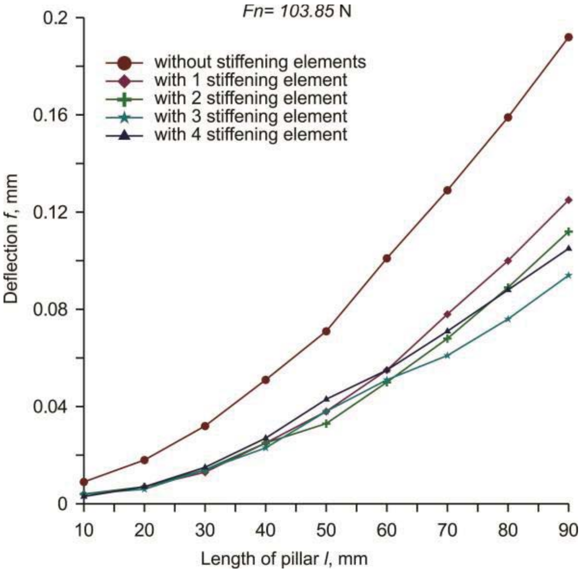
c)



d)



e)



f)

Figure 5. Display the experimental results of the elastic line guides under load a) $F_n = 44.99\,N$, b) $F_n = 56.76\,N$, c) $F_n = 68.54\,N$, d) $F_n = 80.31\,N$, e) $F_n = 92.08\ N$ and f) $F_n = 103.85\,N$

Further examination of experimental research in fact load Fn is an increase deflection f. The increase of the deflection f, and increase of the load Fn, expressed as a percentage is 26%, 53%, 78%, 104% and 131%.

6. CONCLUSION

Significant improvements in the stiffness of frame type modular fixture systems can be achieved by choosing an appropriate cross-section of the structural elements. Theoretical considerations, as well as the results in conducted experiments confirmed the assumption that the stiffness of the guides rectangular cross-section greater by 35-40% as compared to the stiffness of the guides of circular cross section.

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