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DEVELOPMENT A GROUP FIXTURE SYSTEMS FOR MACHINING CENTERS

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Abstract: *A special problem in the construction of the fixture is a limited workspace of machines and large overall dimensions of the workpiece. This problem is especiall pronounced during machining in more work plane at machining centers. In these cases, recognize fixture systems can not be applied. The dedicated fixture systems, in parinciple, could satisfay the basic function but have a number of disadvantages in terms of high costs and low flexibility, especially when it comes to machining process of geometrical and technological similar workpiece. This paper presents a model of group fixture system that allows cutting process with different cutting tools in four work plane. Construction of group fixture system has been optimized from the aspect the minimum required workspace of machines. This very complex problem of design was solving through optimization phase of a large number of conceptual solutions, phases of numerical analysis of structures and phase of calculate making errors.*
Key words: *group fixture, finite element analysis, stiffness.*

Razvoj sistema grupnih pribora za obradne centre. *Poseban problem prilikom konstruisanja pribora je ograničen radni prostor mašine alatke i velike gabaritne dimenzije radnog predmeta. Ovaj problem je posebno izražen u procesu obrade u više ravni rezanja na obradnim centrima. U ovim slučajevima, postojeći sistemi pribora se ne mogu primeniti. Specijalni sistemi pribora, u principu, ispunjavaju osnovne funkcije, ali imaju brojne nedostatke u pogledu visokih troškova i niske fleksibilnost, posebno kada je reč o procesu obrade geometrijski i tehnološki sličnih radnih predmeta. U radu je prikazan model grupnog sistema pribora koji obezbeđuje proces rezanja sa različitim reznim alatima u četiri ravni obrade. Konstrukcija grupnog sistema pribora je optimizovana sa aspekta minimuma potrebnog radnog prostora. Izuzetno kompleksan problem projektovanja je rešen kroz optimizaciju faze velikog broja konceptualnih rešenja, fazu numeričke analize konstrukcija i fazu proračuna grešaka izrade.*
Ključne reči: *grupni pribori, metod konačnih elemenata, krutost.*

1. INTRODUCTION

Design of fixture systems in conditions of limited workspace of machines is a very complex problem. Especially when cutting processing is performed on the thin-walled workpieces in more work plane, which is more often case in cutting process on horizontal milling machine centers [1]. Small dimensions of workbenches machining center, in the processing of parts of larger dimensions, disabling the formation of stable structures of the fixture systems [2].

In the theory of fixture, systems have been developed many techniques related to the fixture layout optimization to achieve optimal effects. Developed techniques finite element analysis (FEA), artificial neural networks (ANN), genetic algorithms (GA) and many other combined techniques allow solve many problems. Chen et al. [3] presented the results related to the fixture layout design and clamping force optimization procedure based on the GA and FEA. Deng et al. [4] presented a model-based framework for determining the minimum required clamping force, which ensures the dynamic stability of a fixture workpiece during machining. Xiuwen et al. [5] reported a model for improving workpiece location accuracy by optimizing the clamping force. Ishikawa and Aoyama [6] used the GA to determine the optimal clamping condition for an elastic workpiece. Kaya [7] presented a GA-based continuous fixture layout optimization method. Krishnakumar and Melkote [8] presented a GA-based discrete fixture layout optimization method to minimize the deformation of the workpiece under static conditions. Liu et al. [9] is proposed a method to optimize the fixture layout in the peripheral milling of a low-rigidity workpiece. Liao [10] used the GA to find the optimal numbers of locators and clamps as well as their optimal positions in sheet metal assembly such that the workpiece deformation and variation are minimized. Mittal et al. [11] presented a dynamic model of the fixture-workpiece system to analyze the fixturing stability of the system. Meyer and Liou [12] presented a methodology to generate the configuration of fixture, which was under dynamic machining. Padmanaban et al. [13] used an ant colony algorithm-based discrete optimization method and optimized the fixture layout under dynamic conditions. Tan et al. [14] described the modeling, analysis, and verification of optimal fixturing configurations by the methods of force closure, optimization and finite element modeling. Zuperl et al. [15] developed an intelligent fixturing system, which adaptively adjusts variable clamping forces to achieve minimum elastic deformation of the workpiece according to the cutter position and the dynamic cutting forces. Tian et al. [16] presented an approach for optimally selecting the locating positions of workpieces and identifying feasible clamping regions that meet the requirements of the form-closure principle for fixture layout. Xiong et al. [17] proposed two quantitative indices, sum of all normal contact forces and the maximum normal contact force, to assess form-closure fixtures. Vishnupriyan et al. [18] proposed a method of using an ANN for the prediction of dynamic workpiece motion. They optimized parameters of the ANN using a GA to achieve better prediction capability of the ANN. Dai et al. [19] described a method for application of a rule-based reasoning on the modular element database, which can be used effectively for integrating with a CAD system and for modeling fixture subassemblies. Vukelic et al. [20] presented a system for computer-aided fixture design. The structure of this system is based on modular principle, and uses data base and knowledge base. Lin and Huang [21] presented modular fixture planning system, which combines the pattern recognition capability of the neural networks and the concept of group technology to group the workpieces with different patterns but identical fixture modes into the same group. Gologlu [22] presented a rule-based reasoning methodology for setup planning and datum selection incorporating machining and fixturing constraints. Hu et al [23] proposed a method of selecting type for checking fixtures that harnesses advantages of neural networks. This method is attempted to capture relevant domain knowledge and is used to produce acceptable solutions. Vukelic et al. [24] used a combination of feature-based, knowledge-based and geometry-based methodology for development complex system for fixture selection, modification and design.

The majority of these studies refers to defining the optimum location of certain elements of the fixturing systems. In addition, discussed the issue of locating and clamping the workpiece of simple form, i.e. processing one surface with one cutting tool, which in most cases belong to the conventional treatment of universal machine tools. Considered the fixture systems have not universal character, already highly specialized and intended for processing workpieces simple geometry. Modern production conditions imposed by the need for fixtures that should provide a reliable locating and clamping of workpiece very complex shapes, when in a single clamping processing is performed with a large number of different cutting tools to cut in different planes. Modern cutting tools provide best production and economic effects when working in cutting regimes that are on the verge of endurance tool [25]. In such conditions processing, fixturing, due to the complex requests (high load levels, the required accuracy of processing and other requirements) are a serious problem in theoretical and in engineering terms.

The paper presents the conceptual design of the support structure of group fixtures intended for processing workpieces of complex shape on machining centers. Calculations of fixtures construction derived by the method of FEA. This paper is an example of computation of displacement in the cutting process of the transmission housing and provides examples of projected and realized construction of fixture for three similar technological workpieces in performance of treatment processes in four planes of cutting.

2. THEORETICAL BACKGROUND - FEM ANALYSIS

The stability of the workpiece in the fixture was analyzed in detail the method of finite elements. To perform the analysis used program FEMAP. Calculations were performed with 37617 tetrahedral finite element shapes and 66047 nodes. Workpiece was made of ductile iron NL 500-7, modulus of elasticity 160000 N/mm^2. Material of fixture is a steel alloy hardening with modulus of elasticity 220000 N/mm^2. Special attention was given to defining the boundary conditions. The boundary conditions can be viewed on the basis of a simplified 3D model shown in Fig. 1. Red color shows restrain achieved by clamping screws and pins for locating, and green color shows the workpiece contact with the base surface.

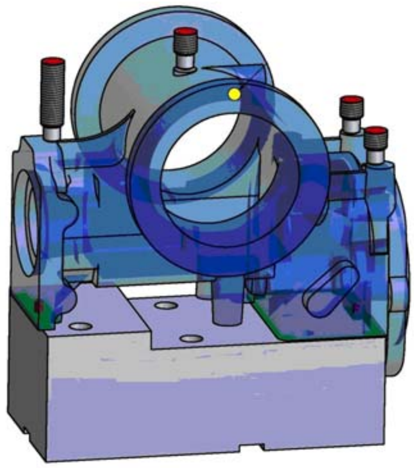

Fig. 1. The boundary conditions.

Loads workpiece and fixtures are also simulated to determine the maximum value of the machining load in areas that will not cause a displacement greater than 0.03 mm. Permitted displacements are determined based on the allowable machining errors of the workpiece and certain values of safety, which should be introduced with regard to the impacts that are not taken into account. On the other hand, simulated load values represent the maximum value of the cutting force with which allowed to operate on the workpiece. The values of cutting forces are input to the calculation of the maximum value of cutting (cutting depth and feed), the geometry of the cutting tools and the optimization technology of the finished product. On this way, in terms of fixtures set border conditions related to the choice of cutting tools (selection cutting tool geometry), which will allow the maximum production given the available stability of the workpiece in the fixture, optimization processing technology (for example, a combination of rough and finish milling or milling "wiper" plates) and a choice of cutting that will, for a limited displacement of the workpiece in certain zones to ensure maximum production.

The calculation was performed by the FEA in the critical cutting zone. Varied the intensity and direction of cutting forces (Fig. 2) in the areas of processing and specific and sensitive directions (directions of greatest compliance), direction and intensity of the load, which is very important from the aspect of applied ways of basing the clamping of the workpiece.

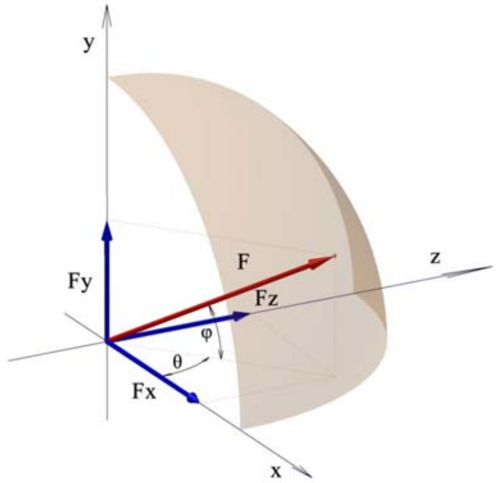

Fig. 2. The direction of the resulting cutting forces.

The results of FEA are intended to assist in the selection of the machining and geometry of cutting tools, in order to ensure the required maximum productivity with regard to the stability of the workpiece in the fixture with regard to the displacement of the workpiece, which to a certain extent constitute making mistakes of workpiece.

The 3D diagram (Fig. 3) represents the total displacement of the workpiece in the function of the direction of the cutting force (in the function of the angles φ and θ). From the diagrams can be clearly seen that the deformation of the workpiece dependent on the direction of the force and the position of the cutting zone. Just based on the quantification of these differences was optimized cutting tool selection and optimization of cutting parameters of choice in certain zones cutting.

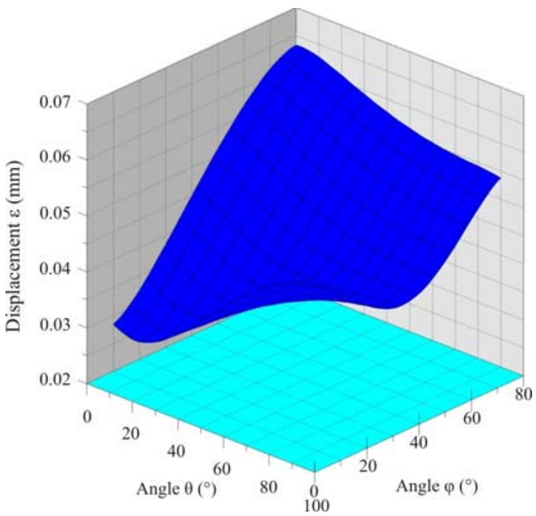

Fig. 3. Total displacement of the workpiece in the fixture depending on the direction of the cutting force.

In Fig. 4 shows the 3D model of the workpiece with a network of finite elements and deformations in the direction of the X axis during machining in a designated zone. From the Fig. 4 can be observed that the maximum deformation localized in a narrow cutting zone as a result of concentrated forces (F=1000N; φ=30, and θ=20) and a thin wall in the zone.

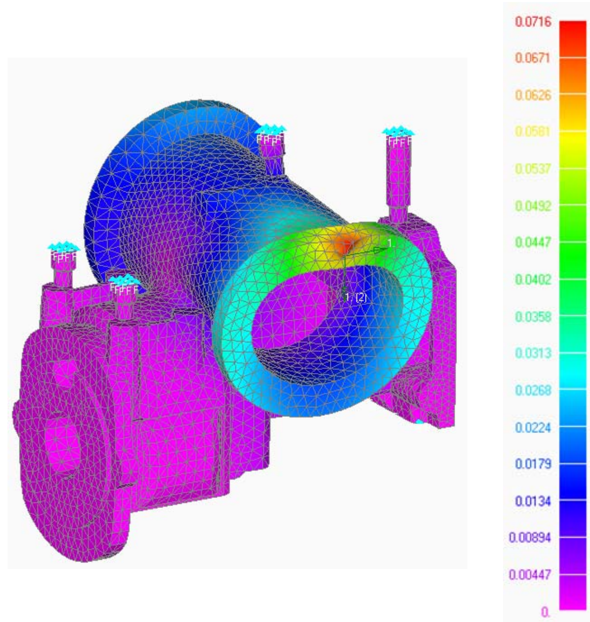

Fig. 4. 3D model of the workpiece with a network of finite elements and scale of displacement when φ =70 and θ =10.

Dependence of the size of the deformation of the angles φ and θ for a given zone is shown in Fig. 5. and 6.

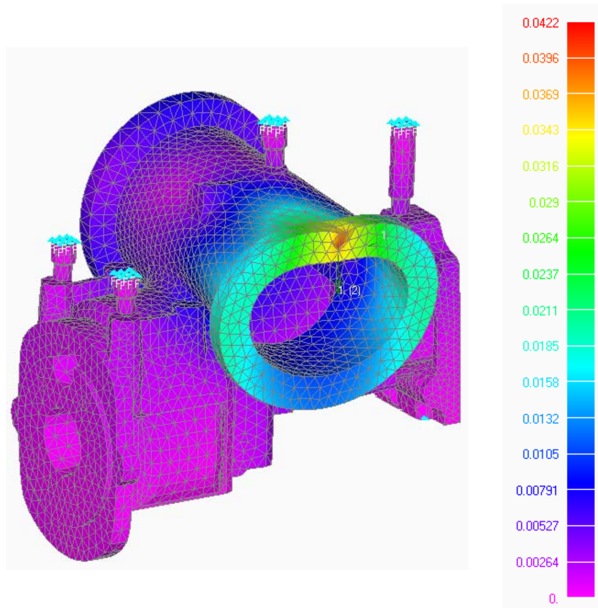

Fig. 5. 3D model of the workpiece with a network of finite elements and scale of displacement when φ=70 and θ=30.

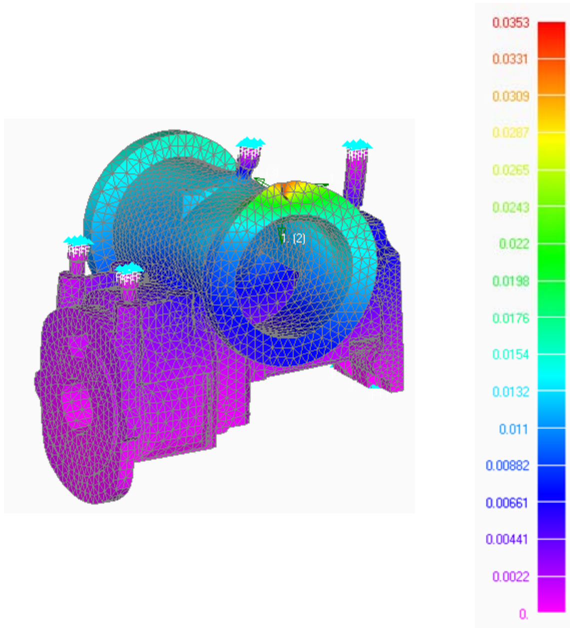

Fig. 6. 3D model of the workpiece with a network of finite elements and scale of displacement when φ=60 and θ=60.

In Fig. 7 is shown the workpiece (transmission housing) and the chosen cutting tools based on conducted budget provides the minimum displacement at maximum productivity.

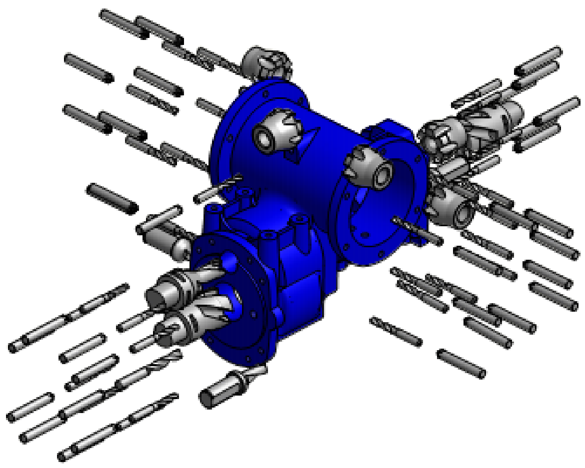

Fig. 7. Cutting tools used for machining.

3. DESIGNED SOLUTIONS OF FIXTURES

Based on the results of theoretical considerations adopted the concept of a group supporting structure of fixtures intended to locating and clamping of given workpieces. The supporting structure is a form of a closed frame.

This concept of structure has been optimized in terms of dimensions of a machining centers and dimensions of the technology of family housing agricultural machines.

Optimization of the structure is covered FEA of structures of varying the dimensions of the supporting elements and real loads, as well as, calculation parts making mistakes. The result of optimization is designed and implemented the construction of high performance in terms of stability and processing performance with multiple cutting tools at four levels. In Fig. 8 show only some of the possible applications of this type of construction.

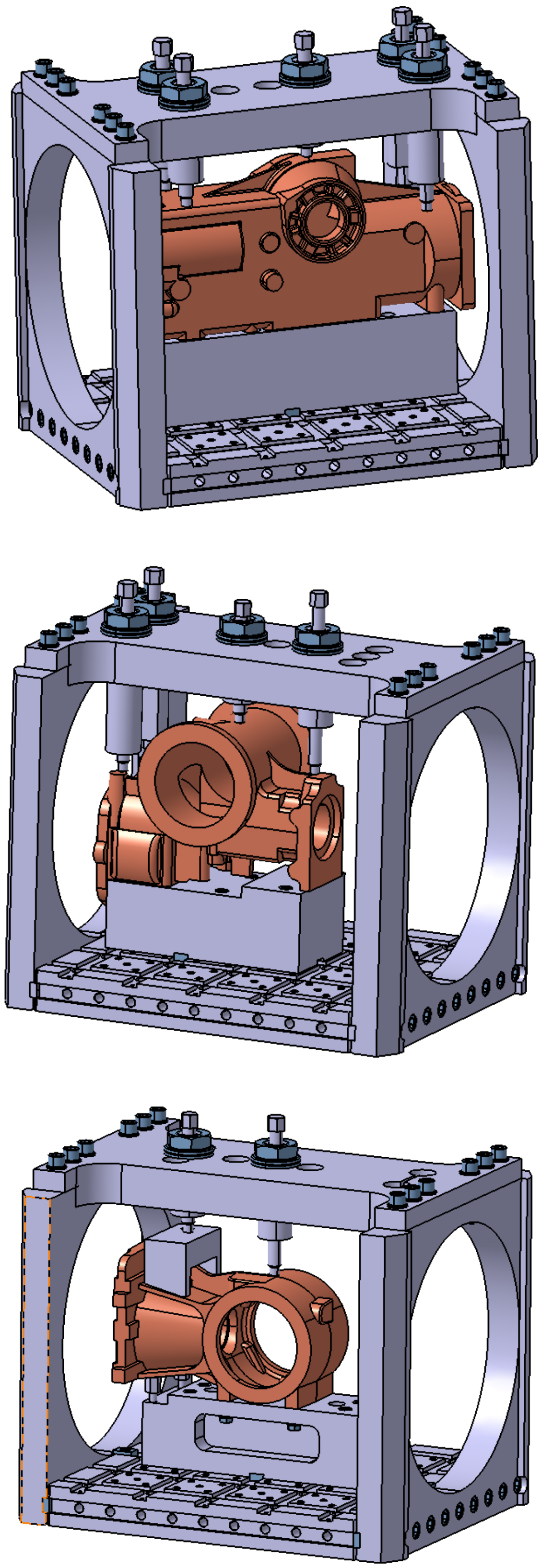

Fig. 8. 3D models of group fixture systems for machining centers.

4. DISCUSION

Based on the review and analysis of literature sources can be said that a small number of research deals with the problem group fixtures intended for the processing on machining centers. Fixtures of this type should provide a reliable and basing clamping workpiece when in a one locating and clamping processing performed with a number of cutting tools that cut in different cutting planes. Problem fixture design is particularly acute when the dimensions of the parts to be processed very close overall dimensions of working table (pallet machining center).

Adopted preliminary design support structure group fixtures intended for the production of housings of different shapes and sizes has, compared to other types of fixtures, a number of advantages in terms of:

- flexibility,
- structure stiffness, and
- open structure suitable for access and processing of various types of cutting tools.

The flexibility of the structure is reflected in the fact that by changing only a small number of elements to locating and clamping screw design can be adapted for different purposes (basing housing and contraction of various shapes and sizes). The base plate to supporting and the upper bearing plate (bracket clamping elements) are made as modular construction elements as shown construction expands the possible application area.

Calculations supporting structure of fixtures group derived method of FEM analysis indicate high stiffness, i.e. small deformations that occur in the real values of simulated load. Based on the results of calculation support structure can be concluded that the simulated load of 1000 N, according to X, Y and Z axis, causing the maximum displacement of structural elements less than 0.007 mm. Adopted regimes finishing processes, according to calculations which are not presented in this paper, do not produce cutting forces greater than 1000 N, and that just means that simulated real load. Connections of structural elements were achieved through the channels and wedges for alignment and a large number of high load capacity bolts. Compiliance connections generated in this way can be neglected if one takes into account a number of elements for the connection load capacity elements and high precision manufacturing of all elements of fixture.

Showed construction of group fixtures is open and enables access and processing of various types of cutting tools. It being possible to use cutting tools with very small overhangs. Small overhangs cutting tools, as it is known a very positive effect on reducing vibration, increasing tool life and improve surface quality. During the processing of the holes some cutting tools perform planetary motion with the spindle turning center undisturbed enters the inside of the the supporting frame. Basing workpiece is realized via centering pins. The construction of this type is very suitable for this type of supporting of the workpiece although the much wider field of application. In fact, changing elements to supporting this type of of fixtures can also be applied to the processing of parts that are based over a long plug and processing workpieces that are based on the principle supporting prismatic element or disc elements. It should be noted that they are exposed to physical solutions implemented and the treatment processes fully meet function.

5. CONCLUSION

According to obtained results it can be concluded that the proposed conceptual design group fixtures intended for processing of family housing on machining centers fulfill the conditions required of stiffness, flexibility as well as the condition of an open type of construction.

Calculations carried out by the method FEM analysis shows that expected levels of load of supporting structure of fixtures displacement is very small. Small displacement of elements of supporting structure fixtures provide the required angle of the exercise tolerance and quality of the surfaces in terms of processing a large number of cutting tools that cut in different planes cutting.

Open type of construction of fixtures provides great flexibility in terms of the possibility locating and clamping of various elements, in particular parts form the casing. It should be noted that in the present case, the adopted concept of supporting structure of fixtures allow it to be on a workbench of the machining center processing parts of large dimensions of which could not be provided fixtures of a different type. The authors believe that it exposed the construction of fixtures can build on additional elements and significantly expand the area of its application.

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