ABOUT THE STATIC BEHAVIOUR OF ELECTRO-DISCHARGE MACHINE

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Elementele de structură ale maşinilor de prelucrat prin electroeroziune sunt asemănătoare cu elementele de structură ale maşinilor-unelte clasice (maşini de alezat şi frezat, maşini de gaurit etc.), însă cu toate acestea, studiul comportării acestora nu a fost abordat în aceeaşi măsură. Având in vedere particularitățile procesului de prelucrare prin electroeroziune, cunoaşterea comportării statice a ansamblului format din principalele elemente de structură permite obținerea unei configurații optime a acestora (micşorarea greutății, creşterea rigidității etc.) precum şi îmbunătățirea performanțelor maşinii (aducerea acesteia în clasa de precizie necesară, corespunzătoare cu clasa de precizie a pieselor ce urmează a fi prelucrate - componente de ştanțe şi matrițe).

The structural elements of electro-discharge machines are similar with the classic machine tools structural elements (milling machine, drilling machine, etc.), but studying their behaviour was not approached in the same way. Taking into account the details of processing by electro-discharge machining, knowledge of the static behaviour of the whole assembly of the main structural elements allows for an optimal configuration of the structure (weight reduction, increased rigidity, etc.) and improves machine performance (bringing it in the necessary class precision, corresponding with class precision of the parts to be processed - stamp components and moulds).

Keywords: Structural elements, static behaviour, electro-discharge machine

1. Introduction

ELER 01 [1] is a machine for electro – discharged machining (EDM) with the electrode-type tools (solid, tubular, plate) of surfaces / parts that can not be processed by classical methods and processes (hard parts, complex surfaces, etc.).

The Romanian device ELER 01 for electro – discharged machining is equipped with a GEP50 F generator and used for rough processing or finishing holes of all types [1]. This equipment covers a very wide field of applications:

- plate processing assets from stamps and dies;
- processing metallic carbide die threading used to hold or extrude various shapes;

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- reconditioning of cavities in different moulds;
- processing of special material parts in aeronautics industry or nuclear reactors;
- processing of holes with very small dimensions (0.2 ... 0.4 mm), removal of broken tools as tap threading, auger, broach etc [2].

The machine can process a huge variety of metallic materials, such as all types of steel and cast iron, metal carbides and non-ferrous metal materials.

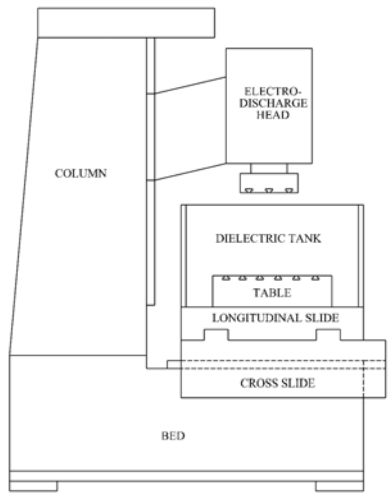


Fig. 1 ELER 01 machine

ELER 01 electro-discharged machine is made of the following parts, shown in figure 1 [1], [2]:

- **Structural** - bed, column, electro-discharged head, cross slide, longitudinal slide, table, dielectric tank;
- **Operating** - hydraulic actuators equipment, unit to drive the working head, the panel for action, command panel, pulse generator, aggregate circulation and filtration of dielectric liquid, connecting cables.

2. Current state of research in the field of electro-discharge machines behavior. The static analysis of bed and column structure elements for ELER 01 electro-discharge machine

The column and the bed of ELER 01 family machine are three-dimensional structures, consisting of plates and stiffener elements of diaphragm and stringers type. Figs. 2 and 3 show finite element models of these structures in the primary stage of the research [3].

The static analysis was carried out using the ANSYS program in order to determine the state of stress, which may alter the relative position part-tools, for three separate cases of loading, shown in Fig. 4:

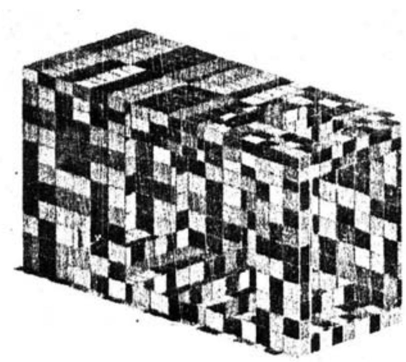


Fig. 2 Bed finite elements model

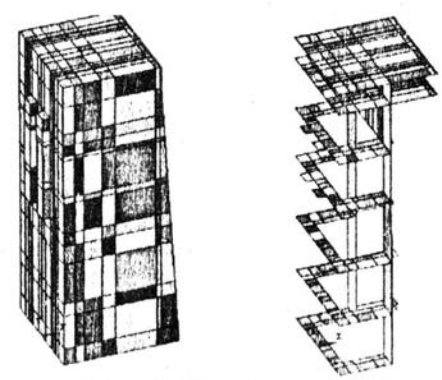


Fig. 3 Column finite elements model

a) The table and the part in the extremity position relative to the column;
b) The table and the part in the middle position;
c) The table and the part in the area close to the column.

The three loading cases where selected in order to show the influence of placing the part together with the working dielectric tank at the extremity table race and in the central position. The column weight was considered uniformly distributed on the bed area contact.

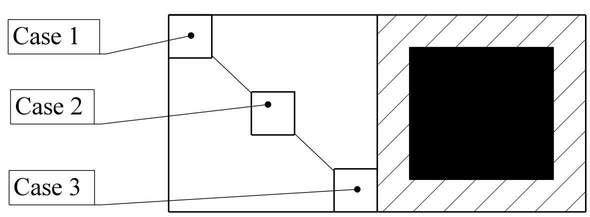


Fig. 4 Different loading case for bed analysis

The bed stress results for the most unfavorable case, when the parts are near the column, are shown in Fig. 5. In this situation, the weight of column is added to the weight of the part. The result is that, although the stresses and the deformations are not big, the bed is stressed precisely in the least rigid area.

The column model was considered in the upper position of the working head on the column, taking into consideration the worst-case scenario. The loading of the structure was an equivalent pressure on the column guide, that was meshed with solid finite elements. Fig. 6 presents the results of the finite element analyses.

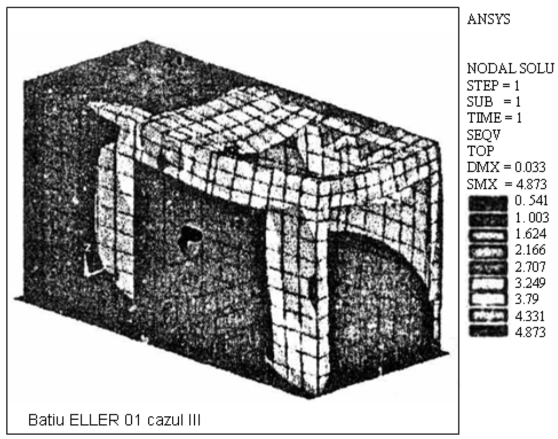


Fig. 5 Bed static deformation for loading case 3

The results of the static analysis for bed and column of electro-discharge machine ELER 01, show us the possibility to optimize the main structure, both in terms of configuration and shape for some areas of their structure.

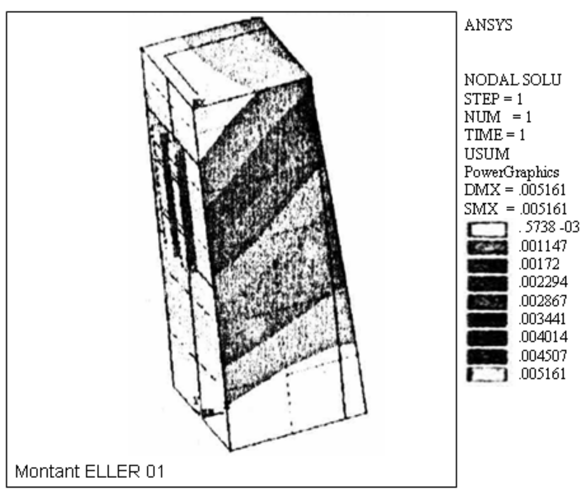


Fig. 6 Column static deformation

3. The ELER 01 machine bed optimization

One of the objectives of the paper is to find opportunities that allow the increase of the static precision of electro-discharge machine tools. As we pointed out at the beginning of the paper, these types of machines are built to work with high precision (for example, dies and moulds manufacturing). Any deformation of the technological system, because of its reaction to different stresses, can generate irrecoverable errors (or recoverable with higher costs).

The deformation results of this machine are low, because the technological process forces that characterize electro physics process do not have higher values. Only a precise analysis using the finite element method can yield results with practical and theoretical importance. Based on this analysis an optimization process for the main structure elements can be efficient for manufacturers and users of these machines.

Bed description

The bed is the structural element that supports all components of the machine subassembly. It has a very important role because it must ensure the relative position between the electrode tool and the half-finished part. This relative position has a high influence in the manufacturing precision of the electro-discharge machining process. The bed has a parallelepiped form, made in welded construction. It is provided with access holes on the sides and back and stiffeners as can be seen in figure 7.

In the upper area, the bed is provided with guides for machine mobile elements (cross slide) and a surface for placing the machine column. The column aligns on the bed and is attached to it by screws. The bed is sitting on the concrete foundation through four rubber bumpers that allow vibration reduction, both from the adjacent working machine and possible vibrations generated by ELER 01 machine.

The material used in bed construction is carbon steel OL42 usually used for constructions, with the following technical characteristics:

- Ultimate stress σ_0 = 420 … 520 [N/mm^2];
- Yield strength σ_y = 240 [N/mm^2];
- Elongation at break δ = 25 %
- Young’s modulus E = 2 ... 2,1 x 10^5 [N/mm^2]
- Shear modulus G = 8 ... 8.1 x 10^4 [N/mm^2]
- Poisson’s ratio 0.24…0.28

Mathematical model for finite element calculation

The electro-discharge machine bed was meshed with Shell elements [4] with a 10 mm size and, as much as possible, with quadrilateral elements.

The bed was meshed 29598 with Shell finite elements and 30,763 nodes (Fig. 8).

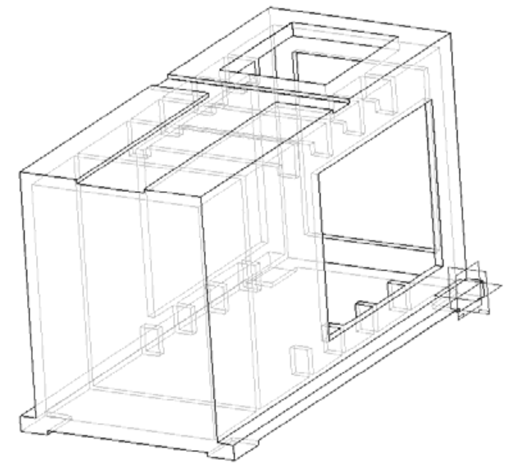


Fig. 7 The bed 3D model

As can be seen on the model, the structure stiffeners and holes are highlighted. The thickness differences can be set-up in the program, when that surface is meshed, by using a real constant linked with the finite element. On the entire structure, five real constants define the walls thickness. The mesh was done manually, in small steps, because the automatic mesh, provided by the finite element software, is not good enough for relevant results.

The program used for finite element analysis is ANSYS [4].

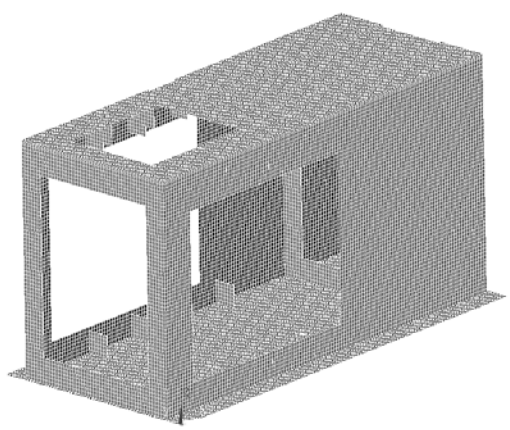


Fig. 8 Bed finite elements model

The bed static analysis implies its loading with the forces of gravity, of the electro-discharge structure elements (subassemblies) mounted on it. This way, the load comes from the adding column, working head and the inside column equipment on the one hand, and on the other hand from the two slides (longitudinal and transversal) together with the machine table and the half-finished part. Before starting the bed optimization, its deformation must analyze. Fig. 9 shows the deformation shape of the bed. The maximum deflection is located in the middle of the structure and is 30.3µm.

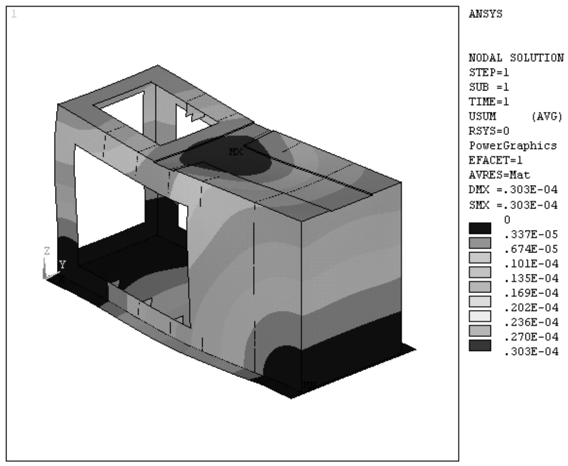


Fig. 9 Bed deformation shape

In order to see the influence of bed deformation in ELER 01 electro-discharge machine precision, a simplified block sketch is shown in Fig. 10, where:

α – angle between horizontal plane and locating surface of the column on bed;

β – angle between horizontal plane and locating surface of the slides on bed;

γ – angle between normal to the semi-finished located surface and normal to the tool electrode located surface;

δ – maximum deformation of the bed;

A – the distance between back surface of the bed and maximum deformation area;

B – the distance between front surface of the bed and maximum deformation area;

If the column deformation is equal to zero, we can write the following mathematic relations between the above parameters:

$$\gamma = \alpha + \beta \tag{1}$$

$$\alpha = \arctan \frac{\delta}{A} \tag{2}$$

The angle *γ* has a direct influence on the deviation from perpendicularity between the half-finished part and tool electrode. Taking into account the maximum displacement of the ELER 01 machine working head on vertical direction (length: 200 mm), the deviation from perpendicularity was determined as value 19.7 μm.

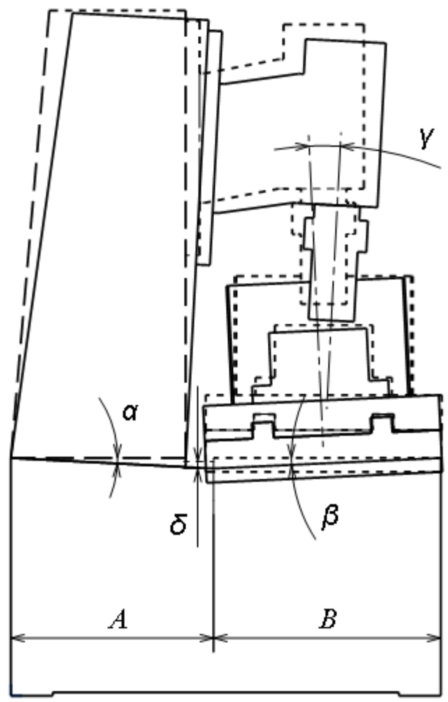


Fig. 10 ELER01 machine simplified block scheme

$$\beta = \arctan\frac{\delta}{B} \quad (3)$$

$$\gamma = \arctan\frac{\delta}{A} + \arctan\frac{\delta}{B} \quad (4)$$

Due to the degree of deviation from perpendicularity, the ELER 01 electro-discharge machine belongs to VI class precision.

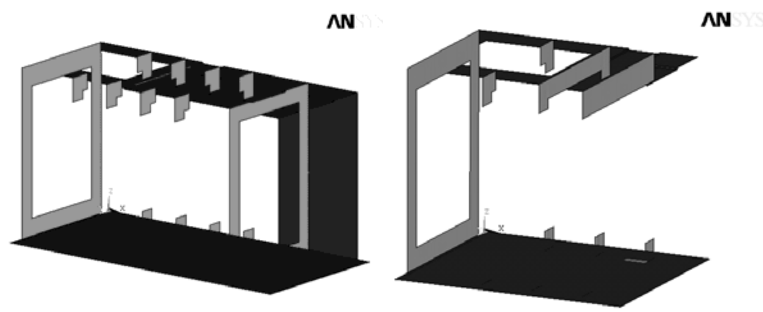
Given that electro-discharge machining process is used for creating precision products, stamp and moulds manufacture (tools, devices), and in general, it is a final process inside the technological flow, we can see that the machine precision regarding the relative position of the tool electrode and half-finished part is not satisfactory.

Another argument to support the above assumption is that in the execution of tools and devices (such as stamps and moulds), VI class precision is recommended. As a result, the ELER 01 machine precision must be at least one class higher than the precision of its parts run on it.

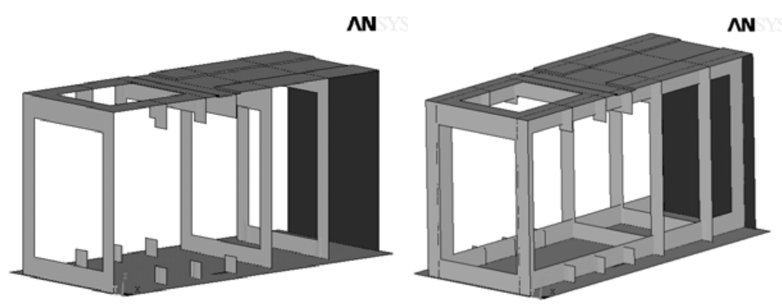
Therefore, the bed optimization has as a main goal the increase of the bed stiffness in order to reduce the maximum deformation.

Starting from the above-mentioned comments, the bed optimization was done by successive discrete calculations / runs, until the result was acceptable. Furthermore, we present the main actions taken:

a) Moving the stiffeners near the area of maximum deformation, on the X axis direction by 20 mm, in order to complete their transversal (cross) direction figure 11 *b*;
b) Complete the stiffeners vertically, in order to create a transversal diaphragm, figure 11 *c*;
c) Adding two longitudinal diaphragms, figure 11 *d*.



a) initial stiffeners *b)* completing cross stiffeners



c) a new cross diaphragm *d)* two longitudinal diaphragm

Fig. 11 Stiffeners evolution during optimization process

Fig. 12 presents the bed deformation mode and the deformation value. In the new configuration, the maximum deflection is 21.9 μm.

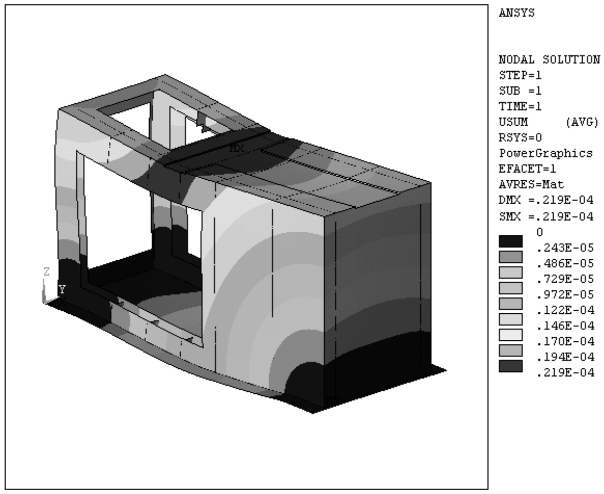


Fig. 12 Bed deformation shape after structural optimization

4. Conclusions

The maximum bed deformation was sensibly reduced, which means that the bed stiffness increases with 27.7%.

By adding additional stiffeners, the entire bed weight increases by 18.2% (initial weight 553 kg). By reducing the bed deformation, the deviation from perpendicularity between tool electrode and half-finished part is 14.2 μm, compared to 19.7 μm initially. The new lower value of the deviation from perpendicularity value changes the machine precision to V class of precision.

R E F E R E N C E S

[1] *** Instrucțiuni de folosire pentru Maşini de prelucrat prin electroeroziune ELER01-GEP50F, (1982). (Instruction guide for EDM ELER 01-GEP50F), Electrotimiş, Timişoara, Romania (in Romanian).

[2] *I. Gavrilaş, N. I. Marinescu,* Prelucrări neconvenționale în construcția de maşini (Electro physical technologies on machine building), Edit. Tehnică, Bucharest, Romania (in Romanian), 1991.

[3] *T. Aurite, C., Pupăză, L. Băluță,* Cercetări privind comportarea elementelor portante din construcția maşinilor de prelucrat prin electroeroziune (Research about EDM structure elements behaviour). Conferința de Tehnologii Neconvenționale, Universitatea POLITEHNICA din Timişoara, 1999.

[4] *** ANSYS – Theory Manual. Swanson Analysis Systems, Inc. PO Box 65, Johnson Road, Houston. PA 15342 – 0065.

[5] *L. Băluță,* Studii privind comportarea elementelor de structura ale maşinilor de prelucrat prin electroeroziune (Studies about EDM structure parts behaviour). Teza de doctorat, Universitatea POLITEHNICA din Bucuresti, 2007 Romania (in Romanian).