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FINITE ELEMENT ANALYSIS OF THE ELASTO-PLASTIC DEFORMATIONS DURING CHIP REMOVING PROCESSING OF THE ELECTROLYTIC COPPER AND GRAPHITE ELECTRODES, USED FOR ELECTRICAL EROSION PROCESSING

Traian BUIDOS
University of Oradea, Managerial and Technological Engineering Faculty,
tbuidos@uoradea.ro

Abstract: this paper presents a study concerning the chip removing process of copper and graphite electrodes that are used at electrical erosion processing of very narrow slits and complex profiles with thickness under 1 mm, frequently met in thermoplastic materials injection moulds. The finite elements method was used to analyze the electrodes deformations during chip removing.

1. INTRODUCTION

The finite elements method is a digitization procedure, by means of which the infinite variance equations system of the elasto-plasticity theory is transformed in a finite approximated equations system. This transformation is made by digitizing the studied deformable body by means of a virtual mesh. The resulting finite elements are considered to be related only in the nodes of the mesh, and the generalized displacements made in these points are the variances of the problems, thus they are the unknowns of the finite system.

The displacements, efforts and deformations in the nodes of this digitalized structure can be determined by means of structure matrix calculus method, which, in comparison with the classic methods, feature the advantage of a simple expression and a very effective way of calculus organization by means of electronic computers.

The fundamental equation of the finite elements method was determined assuming a linear behavior of the body:

$$[K]\cdot\{q\}=\{R\} \tag{1}$$

which led to the acceptance of the generalized Hooke's law as a constitutive equation:

$$\{\sigma\}=[D](\{\varepsilon\}-\varepsilon_0)+\{\varepsilon_0\} \tag{2}$$

In case of non-linear problems (such as the elasto-plastic behavior), this cannot be put into a linear law, but into the following one:

$$F(\{\varepsilon\}\cdot\{\sigma\})=0 \tag{3}$$

The characteristic curve, traced in real stress versus real specific deformation coordinates, is often nominated as "flowing curve" because it features the necessary stresses in order to make a metal plastically flow to a given specific deformation. This may lead to intricate mathematical expressions, when it is used together with the plasticity theory equations. This is why it is accustomed to replace the real flow curve with schematized flow curves (fig.1), which simplify the mathematical expressions without averting too much from the physical phenomenon.

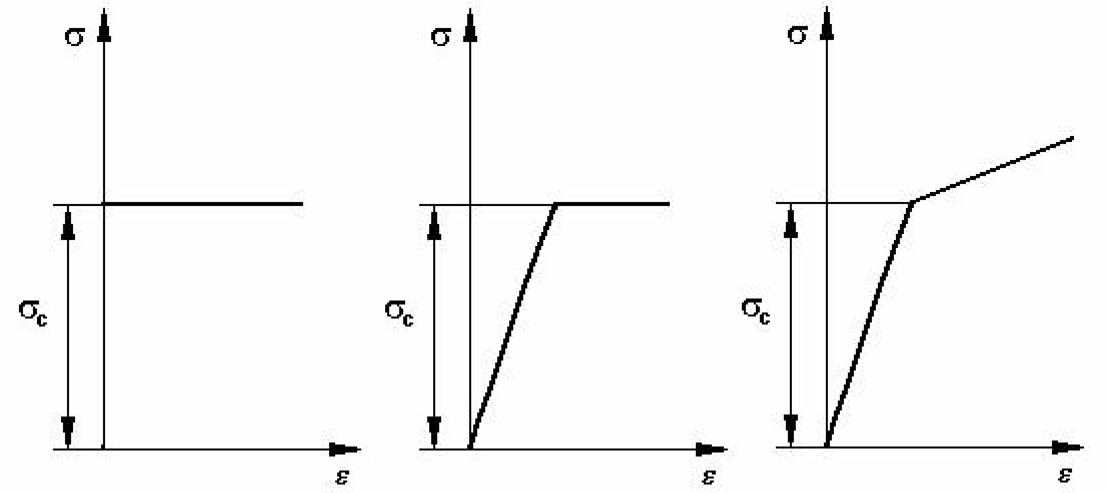

Fig.1. The schematized flow curves: a) perfect plastic material; b) perfect plastic material with an elastic deformation; c) material with linear elastic and plastic behaviors.

The basic steps that lead to solving of some problems of the plasticity theory using the finite elements method are:

a) Quantization of the assembly, adopting finite elements with adequate shapes and properties for each portion;
b) Choosing the interpolation function that would assure the convergence and compatibility of the solution;
c) Determining of the elements rigidity matrix and of the load vector;
d) Assembling of the structure elements rigidity and of the load column vector;
e) Expansion of the equations system for obtaining the nodal displacement vector {q} of the structure;
f) Determining the elementary nodal displacements;
g) Determining the specific deformations $\{\varepsilon(x,y)\}$;
h) Determining the elementary stress vector $\{\sigma\}$;
i) Re-computing the rigidity matrixes;
j) Re-cycle from point d).

2. DEFORMATION MODELING AT ELECTRODE CHIP-REMOVING PROCESSING

In order to analyze the chipping behavior of the electrode materials, sets of 2D electrode models were realized. The models were defined for two materials (electrolytic copper and graphite), and models of different electrode lengths and thickness were realized for each material. Fig.2 shows the electrode geometry, and fig.3 shows the finite element digitization. The model loading is shown in fig.4.

The distributed force is difficult to calculate for special materials; this is why the following algorithm was applied:

1. Step by step, greater and greater chipping forces were applied on the copper electrode model until a 0.02 mm deformation was obtained (for a deformation over 0.025 mm the electrode does not fulfill the processing precision requirements), assuming that this is the maximum admissible deformation;
2. The values of the distributed forces were then applied on the graphite models and the resulted deformations were comparatively analyzed.

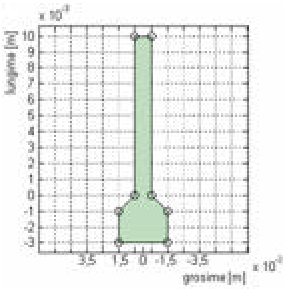

Fig.2. Geometric model of the electrode.

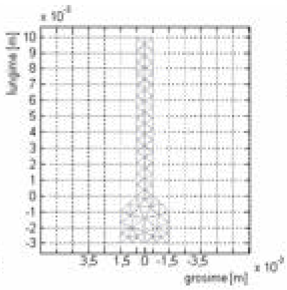

Fig.3. Finite elements digitization.

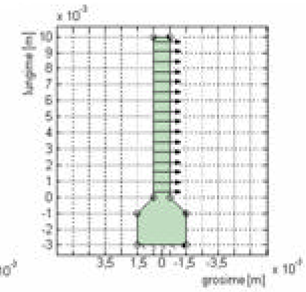

Fig.4. Fixing and loading of the model.

3. RESULTS OF THE MODELING

The finite elements method in MATLAB R12 FEMLAB was used for modeling the loading of the electrodes during mechanical processing. For both copper and graphite, 36 models were made of 0.5 – 0.6 – 0.7 – 0.8 – 0.9 – 1 mm thickness and 10 – 11 – 12 – 13 – 14 – 15 mm length, which allow the comparative study of the deformations during processing; some of these representations are shown in fig.5 ÷ 16.

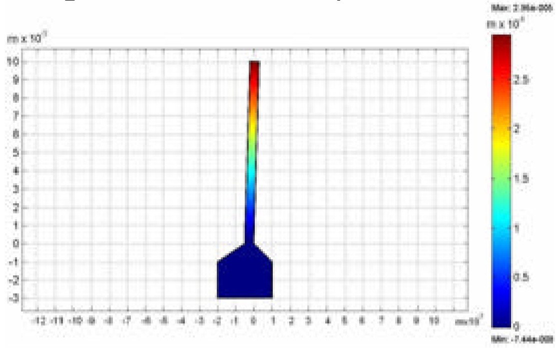

Fig.5. Copper 05/10.

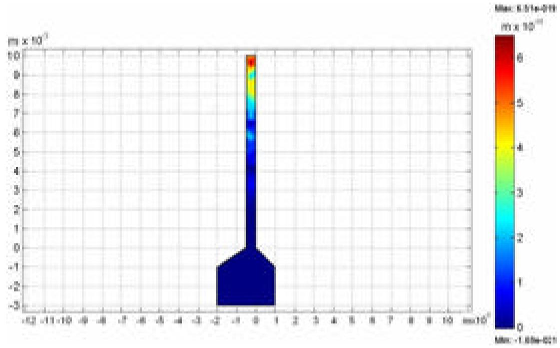

Fig.6. Graphite 05/10.

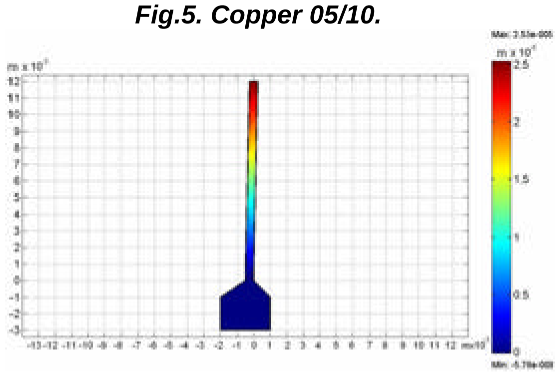

Fig.7. Copper 05/12.

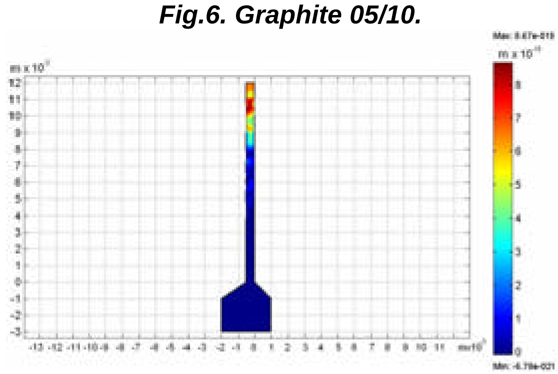

Fig.8. Graphite 05/12.

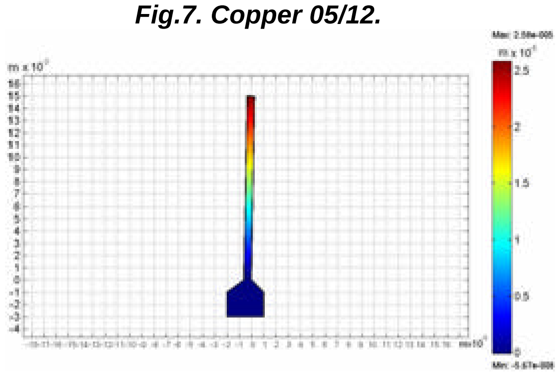

Fig.9. Copper 05/15.

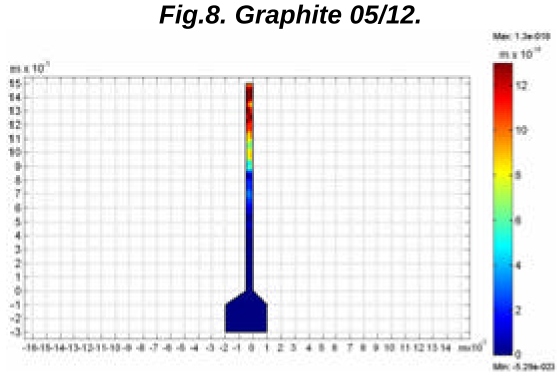

Fig.10. Graphite 05/15.

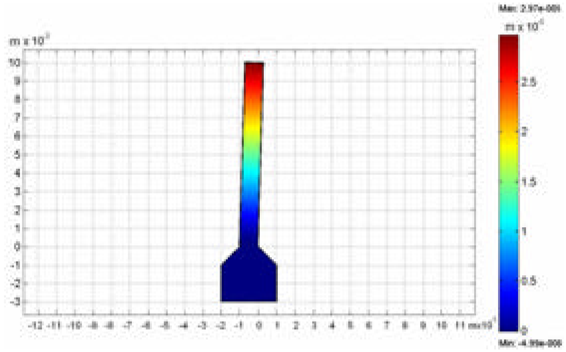

Fig.11. Copper 1/10.

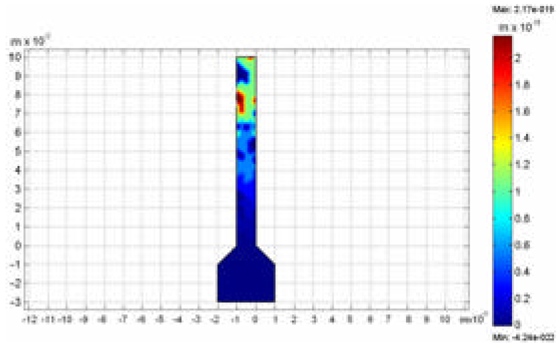

Fig.12. Graphite 1/10.

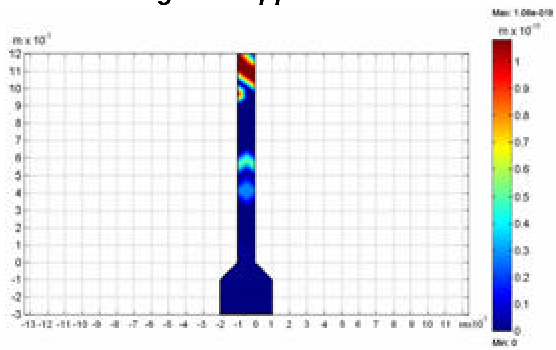

Fig.13. Copper 1/12.

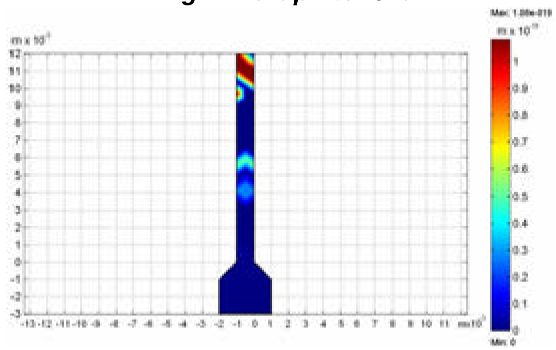

Fig.14. Graphite 1/12.

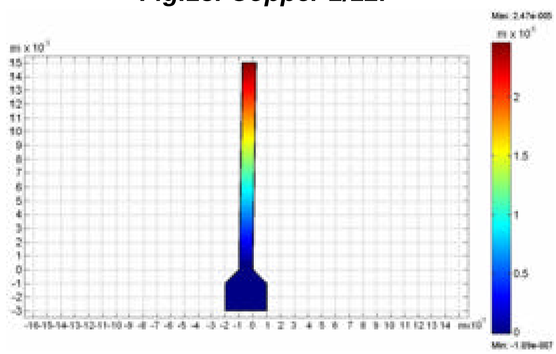

Fig.15. Copper 1/15.

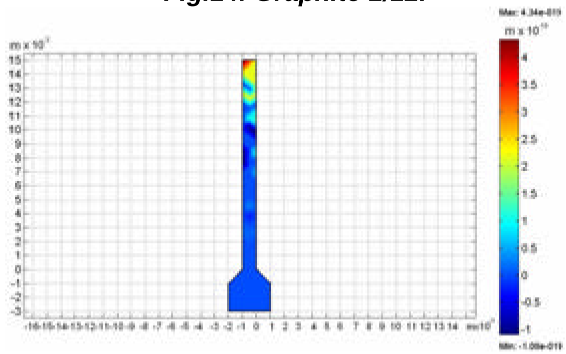

Fig.16. Graphite 1/15.

In order to make a synthesis of the diagrams shown in fig.5 ÷ 16, the 3D diagrams of the maximum forces for electrolytic copper (fig.17) and maximum deformations for graphite (fig.18) versus electrode length and thickness were drawn. The data of these diagrams are enclosed in tab.1 ÷ 2.

Tab.1. Maximum admissible chipping forces [N/m] upon electrolytic copper electrodes for a maximum deformation of 0.02 ÷ 0.03 mm.

		Electrode length [mm]					
		10	11	12	13	14	15
Electrode thickness [mm]	0,5	2550	2070	1720	1470	1250	1070
	0,6	3750	3050	2500	2110	1800	1550
	0,7	5100	4100	3430	2870	2470	2140
	0,8	6850	5550	4500	3800	3280	2850
	0,9	8765	6965	5865	4965	4165	3625
	1	10000	8880	7280	6080	5230	4430

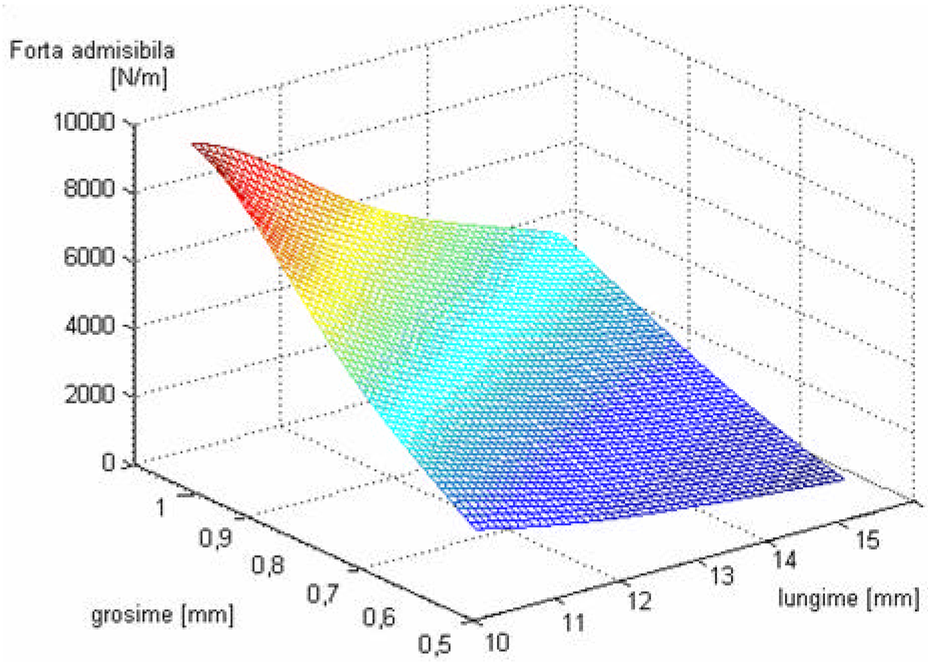

Fig.17. Diagram of the maximum admissible force versus length and thickness of the electrolytic copper electrode.

Tab.2. Displacement at graphite electrodes chipping [mm x 10^{-4}], by applying the chipping forces used for electrolytic copper.

		Electrode length [mm]					
		10	11	12	13	14	15
Electrode thickness [mm]	0,5	6,46902	7,55154	8,65489	2,10412	4,33681	10,30100
	0,6	2,68233	7,51295	4,33681	4,31272	9,58609	2,04213
	0,7	2,16840	1,60725	6,50521	2,16840	7,54897	2,64856
	0,8	1,08163	3,25261	4,24652	4,28536	4,33681	4,32375
	0,9	2,15026	2,14517	1,02502	6,44623	5,40212	4,29183
	1	2,16840	2,15861	1,08420	1,61852	0,76478	3,19855

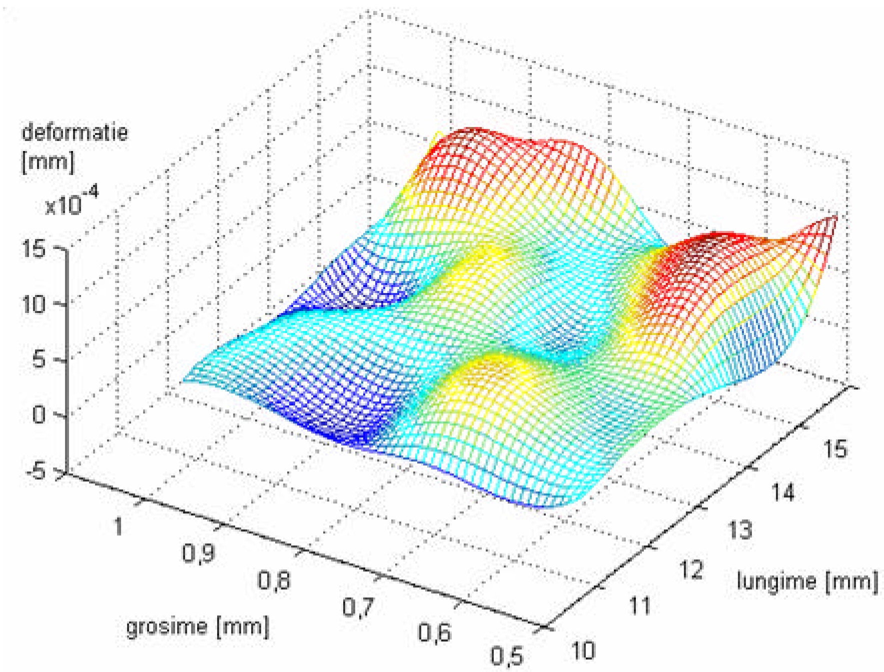

Fig.18. Diagram of the deformation versus length and thickness of the graphite electrode.

4. CONCLUSIONS

The modeling results show that the deformations of the graphite electrode model are much less than the ones of the copper electrode model, mainly in the case of thin walls. So we can affirm that, when using chip-removing processes, graphite is more convenient and, in some cases, it is the only solution because the deformations during the chip-removing process of the copper electrodes may become inadmissibly large. Fig.19 shows some electrodes that could be made only of graphite because the wall thickness is less than 1 mm.

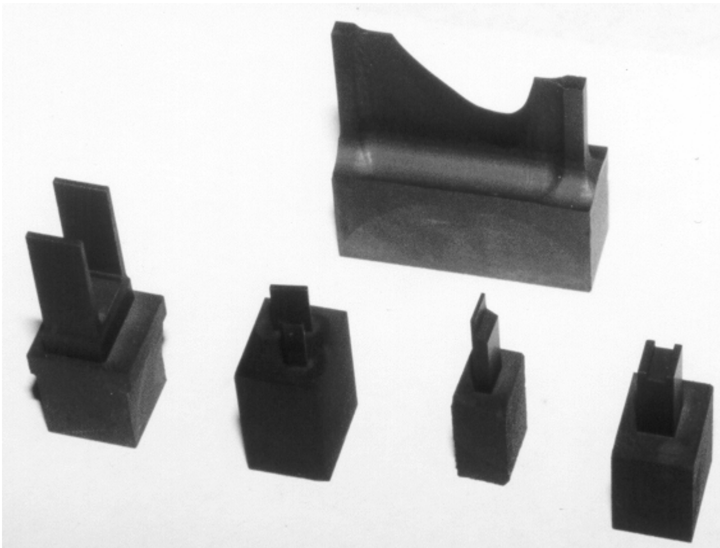

Fig.19. Graphite electrodes with thickness less than 1 mm.

5. REFERENCES

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