FEM SIMULATION OF ULTRASONIC AIDED EDM OF PROFILED SURFACES AT MACROGEOMETRIC LEVEL

Daniel GHICULESCU*, Constantin RÂNEA*, Laurențiu LUPU**

**POLITEHNICA University of Bucharest, 313 Splaiul Independentei, sect. 6,*
*e-mail: ghicu@the.prod.pub.ro; **ICTCM Bucharest, Sos. Olteniței 103, sect. 4,*
e-mail: llaur@ictcm.ro

Abstract:

The paper deals with an analysis through finite elements method (FEM) of material removal mechanism at electrodischarge machining (EDM) finishing comparatively with ultrasonic aided EDM (EDM+US) finishing at macro geometric level. The method is designed to be applied to profiled surfaces, e.g. active surfaces of injection molds. The temperature distribution after an EDM pulse resulted form FEM analysis, leads to establishing the working strategy for machining the profiled surfaces with some required details.

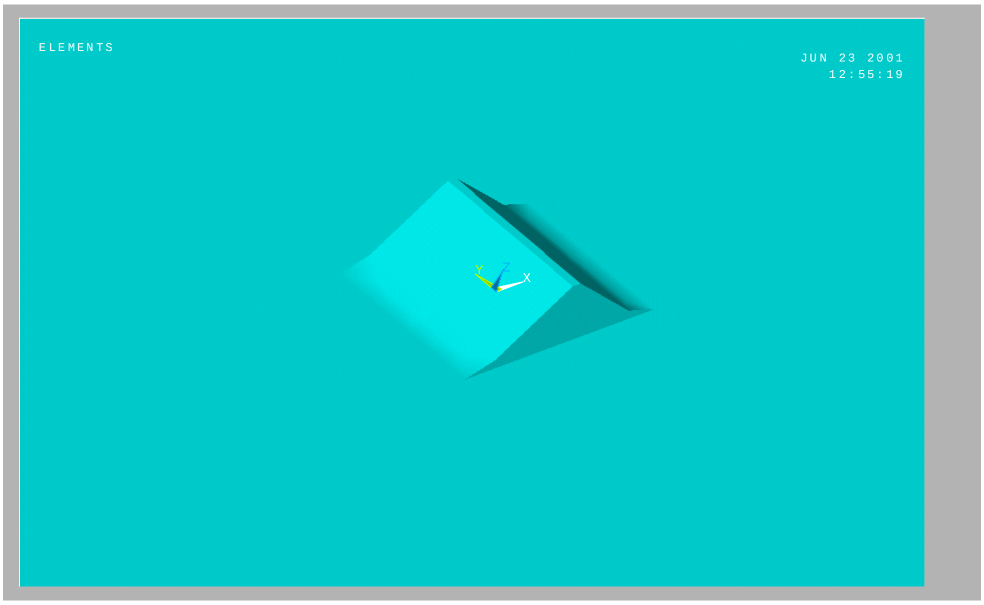
Key words: FEM, EDM, ultrasonics, profiled surfaces.

1. INTRODUCTION

Electrodischarge machining (EDM) and even more ultrasonic aided EDM (EDM+US), which is a relative recently developed nonconventional technology are characterized by a very intricate mechanism of material removal insufficiently explained. Taking into account that the paper deals with profiled surface machining, namely the active surfaces of injection molds with very fine details, the problems related to clarification the material removal mechanism are doubly difficult. A solution to approach the problem is finite elements method (FEM), able to provide temperature distribution after a discharge and to lead to a conclusion concerning crater dimensions and possibilities to generate the required profiles.

Our previous works [1], [2] deal with comparative modeling of removal mechanism of EDM and EDM+US finishing confirming the experimental results obtained on different kind of mold steels [3]. Our actual researches represent a significant forward step from modeling plane surfaces machining at macro geometric level to profiled surfaces EDM-ing at macro and micro geometric level. Because of limited space, the current work presents only the analysis method of material removal mechanism at macro geometric level.

Electrodischarge machining (EDM) products evacuation from the gap at finishing is very difficult because of very narrow interelectrode gap (less than 10 μm), especially when machining great size surfaces, leading to a weak machining rate. The aiding of the process by longitudinal ultrasonic (US) vibrations of tool which creates *cumulative microjets,* at the end of an oscillation period T_{US}, characterized by great pressure, is able to remove EDM products from the gap and amazingly improve material removal rate (V_W) [1], [2]. Important increase of V_W parameter through ultrasonic (US) longitudinal vibrations of the electrode tool at EDM finishing (EDM+US) was reported by some researchers like D. Kremer et al. [4], [5], [6], L. Jinchun, D. Songyan [7], V. I. Serepot, I.D. Rudaia [8]. The art mentioned above does not provide data concerning the improvement of other output main technological parameters of EDM+US such as surface roughness (R_a) and volumetric relative wear



(ϑ), in comparison with those resulted from classic EDM finishing as in [3].

Fig1. Macro geometry: height - 0,1 mm; base width - 0,2 mm; surface superior width - 10 µm; length - 0,2 mm.

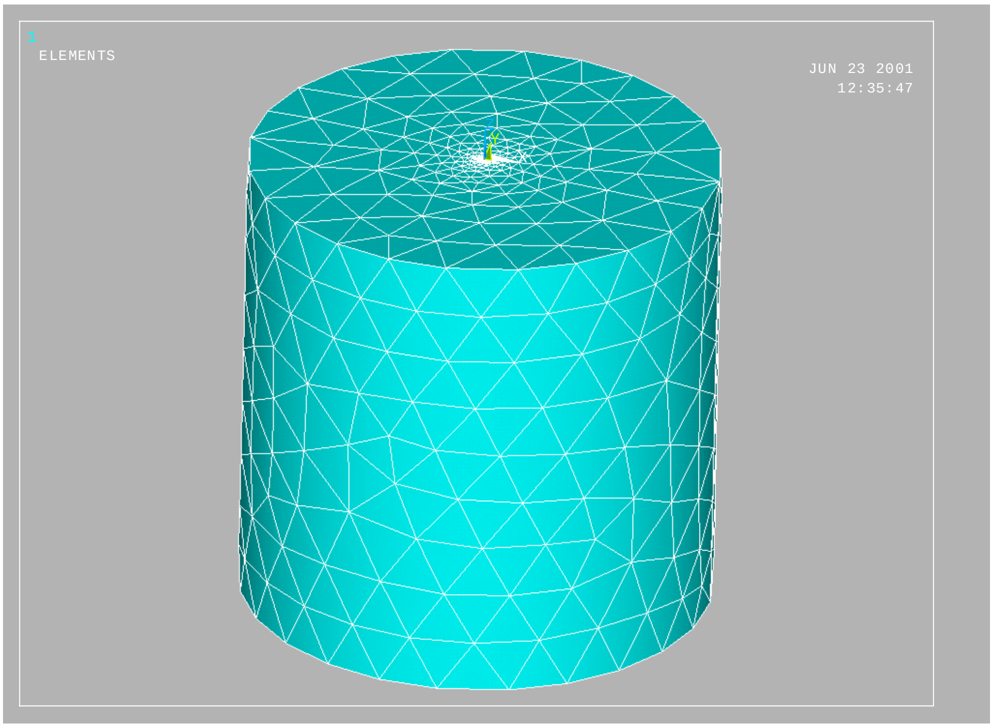
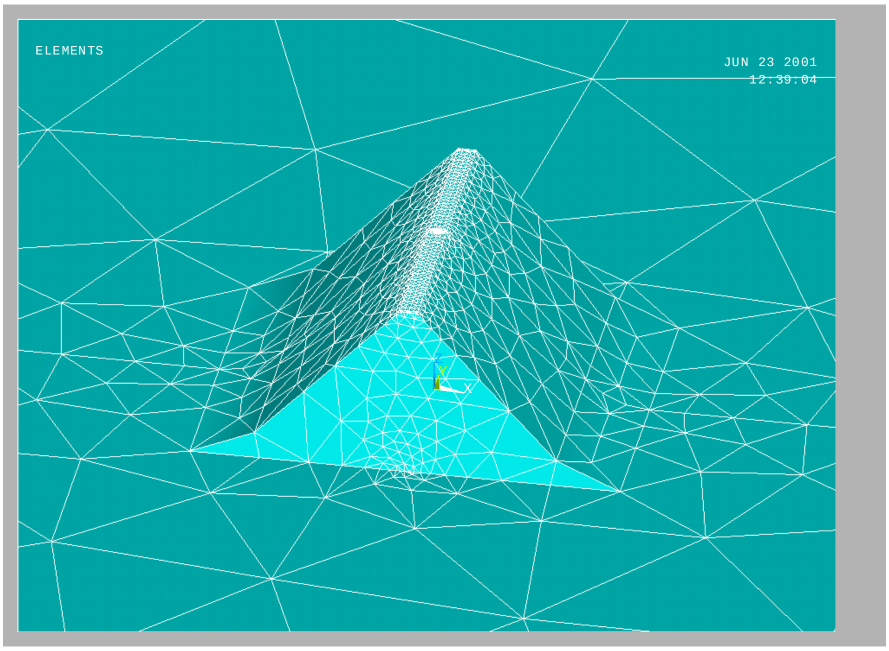


Fig. 2. The working piece discrete structure of cylindrical shape; radius - 5 mm; height - 10 mm.

2. METHOD DESCRIPTION

Some specific cases of macro geometries encountered at machining of active surfaces of the molds were studied. The shapes were of 0,1 mm order technological achievable. E. g. in figures presented in the paper, we display the modeling method of



removal mechanism in case of generating a protuberance as a prismatic shape located on the frontal surface to be EDM-ed (fig. 1).

Fig. 3. Mesh in interest zone at macrogeometric level.

The discrete structure was obtained with SOLID 70 and 87 elements provided by specialized library of ANSYS 5.7, which take into account the changing of aggregate state. We used also used the same package for geometric modeling because of its improved facilities comparing to previous versions.

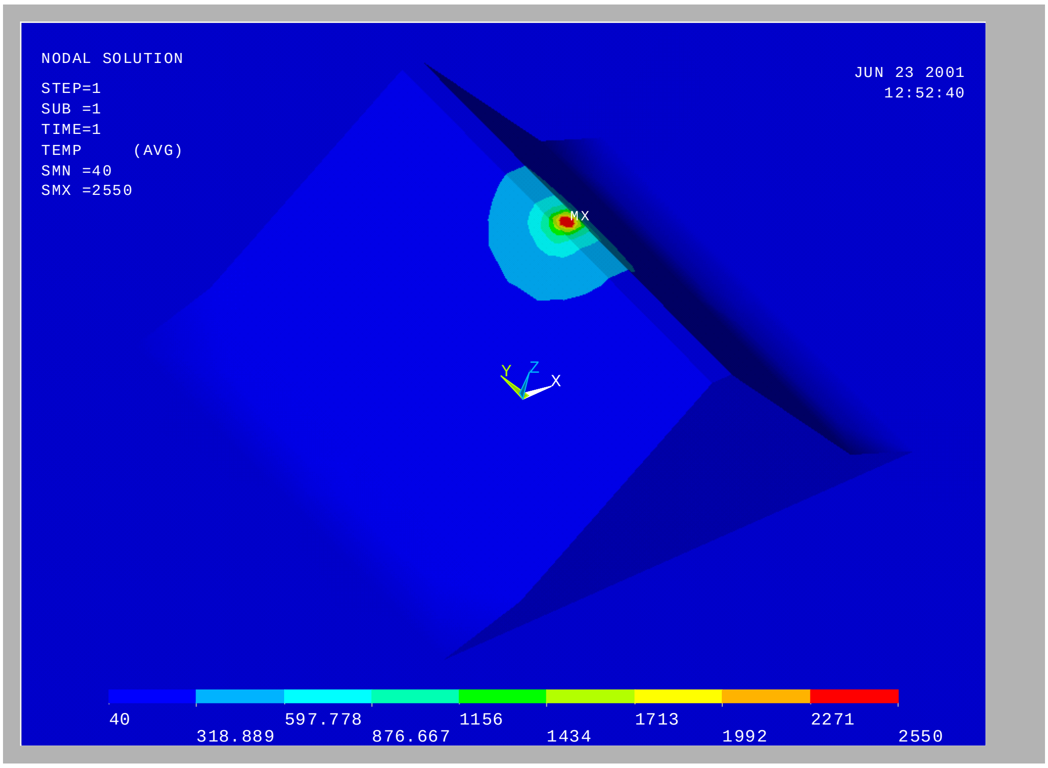


Fig. 4. Temperature distribution on machined active surface of injection mold after a commanded pulse time t_i= 4 μs and Feα constituent.

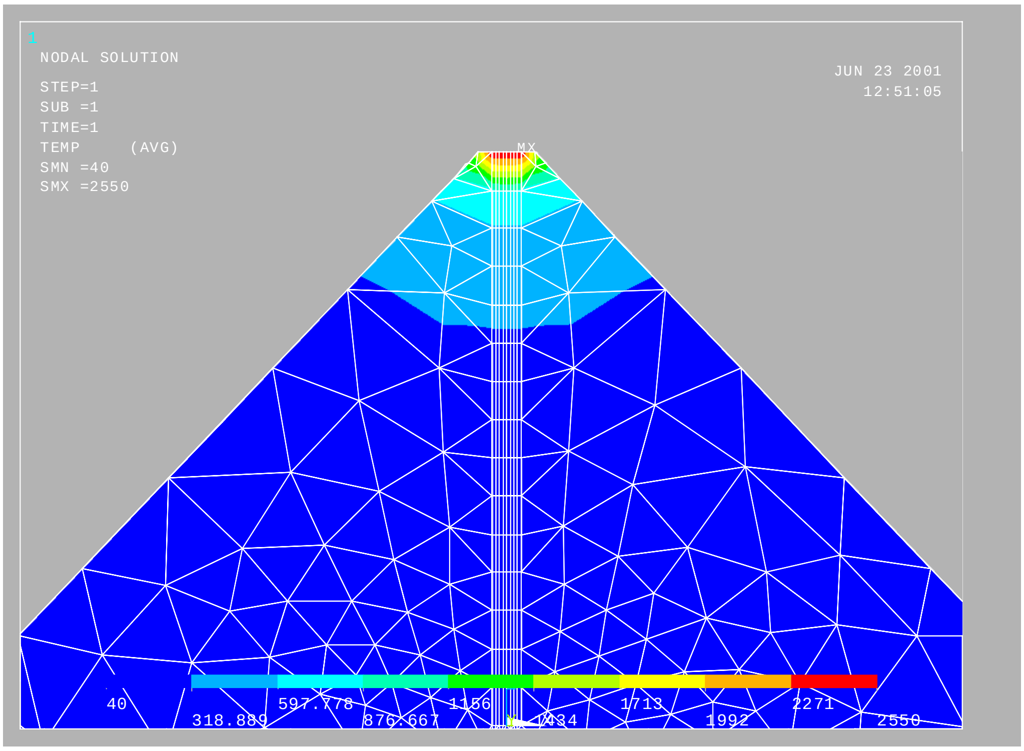


Fig. 5. Mesh and temperature distribution in cross section after a commanded pulse time t_i= 4 μs and Feα constituent.

The mold active elements used for simulation were of mm order in agreement with real cases in which the dimensions of technological systems are much greater than EDM spot dimensions (fig. 2). Thus, the zones with temperature of 40 ^{o}C (dielectric liquid temperature) are much greater than thermal influenced zones (fig. 4).

In the zone of interest, in the proximity of cathode and anode spot, the elements had very small dimensions of µm order increasing progressively to the outer part of workpiece surface, finally reaching values of mm order (fig. 3).

The type of *boundary conditions* were:

(1) constant temperature surface;

(2) constant thermal output flux.

In order to put the condition (1), it was introduced the simplifying hypothesis that temperature in the cathode and anode spot is constant. Taking account of Utsumi's measurements concerning the spot temperature [9] and the Conn's hypothesis related to narrowing of the plasma channel in the cathode zone [10] previously experimentally confirmed [3], we considered for the finishing using *commanded pulses* and *positive polarity*, the temperature in the cathode spot is t_{spot} = 2550 ^{o}C and its radius R_{cs} = 2.5 µm. In case of relaxation pulses (negative polarity), temperature of anode spot is t_{spot} = 2500 ^{o}C and its radius R_{as} = 10 µm. For the condition (2), the constant thermal output flux was Φ = 0.1 W / mm^2.

It was also taken into account the influence of thermo-physics characteristics of the main constituents of the mold steels because their dimensions are comparable with craters dimensions resulted from pulse discharge. The input data concerning the *material characteristics* were the thermo-physics characteristics of the main constituents of the mold steels structure, namely Fe α and Fe_3C.

It was studied temperature distribution at the end of pulse time in different sections (fig. 5, 6) in order to establish the connection with craters dimensions previously experimentally determined [3]. The simulation of discharge located on the time scale in the proximity of the cumulative microjets phase, at the final of an ultrasonic oscillation [1], [2] aims to emphasize the essential part of ultrasonics in material removal mechanism.

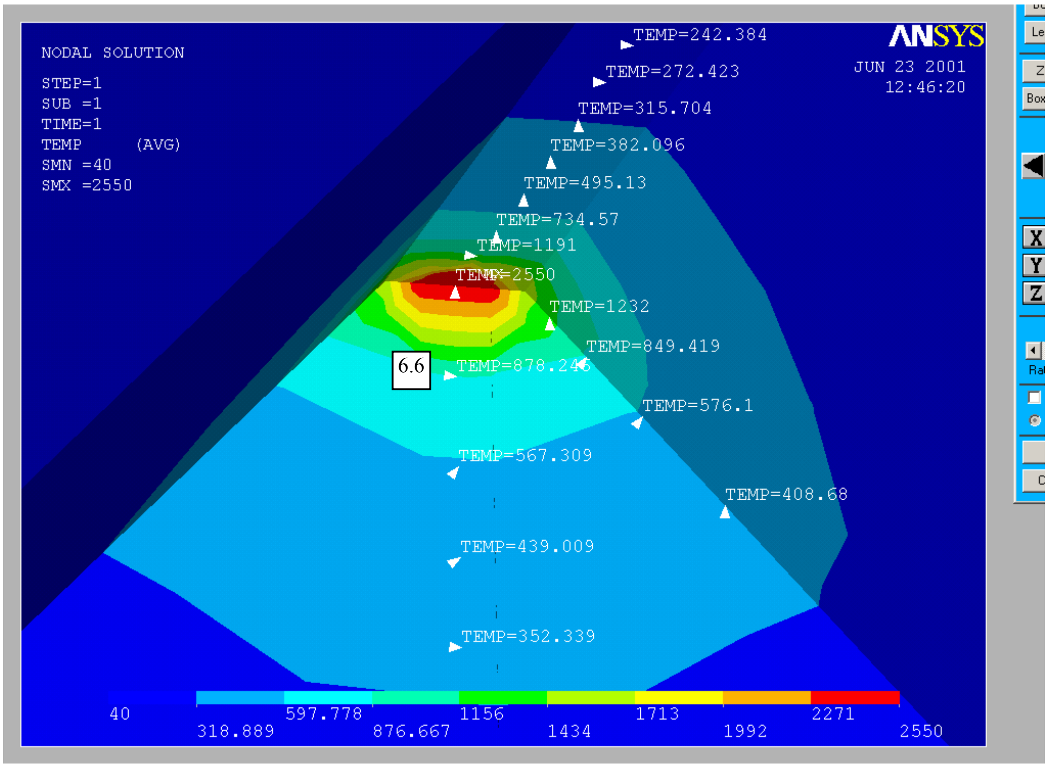


Fig.6. Temperature distribution in cross section and frontal surface emphasizing the temperature [°C] *and distances* [μm] *corresponding to nodes from interest zone after a commanded pulse time* t_i*= 4* μs *and Fe*α *constituent.*

3. CONCLUSIONS

Data of FEM simulation of EDM discharge, which are in agreement with our previous experimental results [3] highlight the influence of machined macrogeometry on material removal mechanism:

1. Craters dimensions produced at EDM and EDM+US depend on the shape – convex and concave - of profile to be machined.

2. In case of concave shape, it is recommended to reduce the level of discharge energy because the large crater dimensions produced in this case can be inappropriate in achieving fine details.

3. At EDM+US finishing, the volume of removed material by a single discharge can be 4…5 times greater than the one produced in case of classic EDM in same working conditions. Taking account of these, it is strongly recommended to reduce the power of actuating the acoustic head beside the pulse energy level.

4. Temperature distribution obtained through EDM discharge simulation provided by FEM in specific cases of machined profiles can forward offer

supplementary indications concerning working strategy to be adopted to achieve desired profiles through EDM and EDM+US finishing.

References:

1. Ghiculescu, et al. [2000] Modeling of the Finishing Process by Ultrasonic Aided EDM with Commanded Pulses, *ICMAS 2000, TCMM*, Editura tehnicã, p. 263-268.

2. Ghiculescu, D. Marinescu, N. I., [2000], A Model Regarding the Removal Mechanism at Ultrasonic Aided EDM Finishing with Relaxation Pulses, *CITN 2000-Braşov*, Editura Printech.

3. Ghiculescu, D., Vlase, A. [1998] Finishing EDM Technology Aided by Utrasonics, *Revista Română de Mecanică Fină şi Optică*, p. 705-710, Supliment Nr. 2.

4. Kremer, D. et al., [1983], Ultrasonic Machining Improves EDM Technology, *ISEM 7*, Birmingham.

5. Kremer, D. et al. [1989], Effects of Ultrasonics Vibrations on the Performances in EDM, *Annals of the CIRP*, Vol.38/1.

6. Kremer, D., Lhiaubet, C., [1991]. A Study of the Effect of Synchronizing Ultrasonic Vibrations with Pulses in EDM, *Annals of the CIRP*, Vol.40/1.

7. Liu Jinchun, Du Song, [1986], Ultrasonic and EDM Combined Machining of Micro-hole, *ISEM 8*, Moscow, p. 40-46.

8. Serepot, V. I., Rudaia, I. D. [1990], Method of Electrodischarge Machining Aided by Ultrasonic Vibrations, *Electronnaia Obrabotka Materialov* nr. 2. p. 90-92.

9. Utsumi, T. [1971], Measurements of cathode spot in vacuum arcs, *Applied Physics Letters*, 18, p. 218-220.

10. Conn, W. [1959], Technishe Physik der Lichtbogenschweißung, *Springer-Verlag* / Berlin, Götingen, Heidelberg, J.F. Bergman / München.