MODELING AND SIMULATION OF WEDM PROCESS FOR INCREASE PRECISION AND MACHINE SURFACE QUALITY

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ABSTRACT: The paper deals with modeling and simulation of Wire Electrical Discharge Machining (WEDM) process using Mastercam and Comsol Multiphysics to assure precision and surface quality of machined surfaces. Two items were approached: right and inclined cutting of interior contours and lead-in and lead-out tool paths as well as corner generation of exterior contour. Some solutions to increase the precision and surface quality for the problems were presented.

KEYWORDS: modelling, simulation, WEDM, precision, quality.

1. Introduction

Wire discharge electrode processing is currently one of the best known electrothermal processing.

Wire electrode erosion processing is a process of electrothermal processing by which the material is removed due to electrical discharges, which occur between the wire electrode and the part. The waste resulting from the electric arc area is removed by the circulation of the dielectric liquid. [1].

The plasma channel generated between the cathode and the anode converts electricity into thermal energy.

The tool used is a wire-shaped electrode which in processing is carried from one coil to another to eliminate the influence of the loss of wire material on the processing accuracy [2].

The wire electrode is guided by two conical bores which are positioned above and below the machined part. The movement of the upper guide on the Z axis ensures the possibility of adjusting the distance between the two guides. The cutting of the semi-finished product is done with an advance movement ‘s’ in relation to the wire, coordinated by the computer, in two directions X, Y. The current software allows the development of CNC programs by non-specialized personnel [3].

2. Literature review

Through the initial WEDM version, simple contour plate parts were machined. The advantages of EDM are: efficient production capacity, burr-free cutting, excellent finishes [4].

The wire electrode was vertically tensioned by two guide subsystems. The speed of movement between the electrode and the workpiece was 2-6 mm/min. The movement of the upper guide support horizontally allowed the processing of conical surfaces [5].

The diameter of the wire electrode was 0.01-0.3 mm, with a length between 7-12 Km, so as not to interrupt the processing. Its conditions were flexibility and resistance to traction and bending. [6]. With the help of a multi-roller system, the machining precision is achieved by rolling and tensioning the thread (fig.1). Figure 2 shows the WEDM processing.

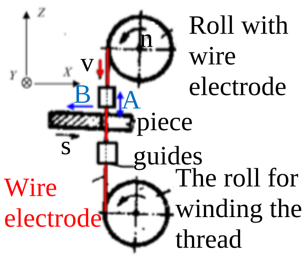


Fig. 1 WEDM kinematics

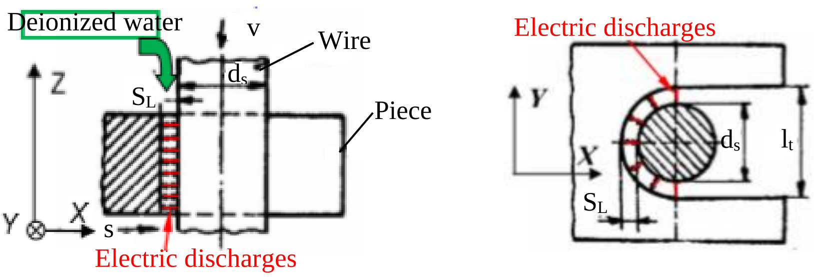


Fig. 2 WEDM processing

The preferred working fluid is deionized water, which by its fluidity removes detached particles. A disadvantage is the appearance of electrolysis, which could cause the wire to break [7].

The mechanical part of the WEDM process is described by the computer-controlled workpiece and a mechanism for driving the wire electrode through the workpiece with a mechanical tension. The speed of movement of the wire electrode is very high, in order to avoid its thinning during the process. The rectilinearity is ensured by the action of forces of 0.04-0.7 daN. The spark generator allows various forms of electrical pulses depending on the working conditions. The improvement of the pulse generator focused on the variation of the characteristics of the processing pulse. Another goal was environmental protection. Electrostatic induction feeding methods have been investigated to eliminate its parasitic capacity.

The place of passage, from one thickness to another of the piece, represents an area of instability of the process. In this sense, a subsystem has been developed that uses the information during the process and modifies it. Spark frequency information, variable gap error, abnormal spark ratio during a sampling period were used [8].

The performance of the WEDM process is achieved by the introduction of powder particles, which modify the removal mechanism of the material. The arrangement of particles in form of a chain facilitates the early generation of electrical discharges. The resulting effects relate to improved material removal rate and improved roughness. These materials are tungsten carbide, cobalt.

WEDM enhancement can be defined by combining it with other unconventional processes, such as ultrasonic field vibration assistance, electrochemical discharge, or abrasive electrode processing.

The WEDM system is defined by input factors and output parameters. Input factors are related to the workpiece or WEDM machine devices. In recent years, the efforts of researchers have been directed towards improving the process of wire EDM for the processing of superalloys. These specific materials can be: nickel alloys, titanium alloys, shape memory metal materials, nickel-titanium alloys [9].

3. Simulating the WEDM process using Mastercam

The simulation of the WEDM process will be performed in the Mastercam program. The first step is to make the piece with the inner contours. Draw the contours and extrude with the help of ‘Extrude’ (fig.3). The semi-finished product is defined using the Bounding Box command.

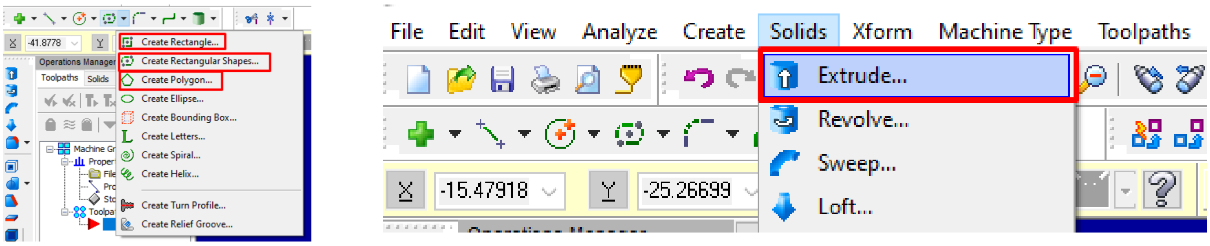


Fig. 3. Creating the semi-finished product

The outer contour parameters change. To do this, move the thread point three mm out of the lead distance menu. Set the input and output path to be a 0.5 mm radius arc, entering the lead menu and selecting ‘Line and arc’ and ’Arc and line’. When obtaining overlap, three mm are noted, so as not to leave through the entry point, which increases the accuracy (fig.4). The second step is to define the threading points. (Thread Point). Define a point on the outside of the contour and a point on the inside of each inner contour (fig.5).

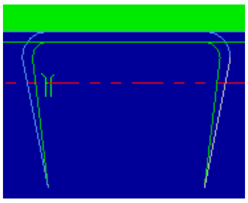


Fig.4 Input trajectory

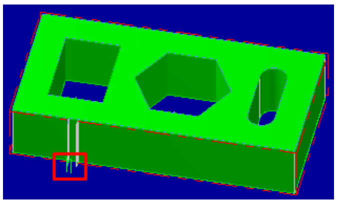


Fig. 5 The piece with the inner contours

The first time the inner contour is processed, from which we will help to catch the piece with the help of some flanges, in order to process the outer contour.

From the Toolpath→Contour menu, define the first inner contour, by clicking on the threading point and on the contour. The processing settings menu opens. A wire with a diameter of 0.3 mm is used, the processing gap being 0.05 mm. The other contours are also selected. Improved accuracy is achieved by approximating the two guides in the Taper menu.

When processing the inner contours, a bridge must be placed, at which point the processing stops and the cut part is caught. This is done from Parameters→Cut parameters→Tab. Choose the value of the 4 mm bridge and check the ‘skin cuts’ after tab to finish the surface.

From the Parameters window of the outer contour, the fish tail type and a radius of 0.5 mm are chosen in the corner submenu. The trajectory of the wire on the corner of the outer contour is selected as a fish tail for an increase in accuracy. This fish tail trajectory involves an exit from the contour, a complete circular motion and a entry into the next contour. (fig.6). To avoid breaking the thread, use a dot, which is set from the cut parameters menu, by checking the tab option (fig.7).

In the Parameters menu, the slash is made by selecting the Taper option and choosing a specific angle. Figure 8 shows the sloping cut.

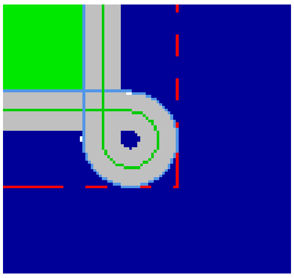


Fig. 6 Fish tail

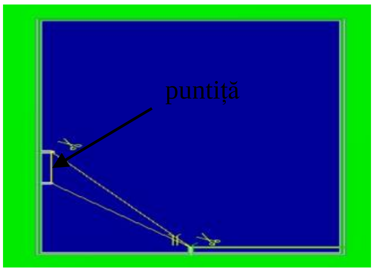


Fig. 7 The location of the deck

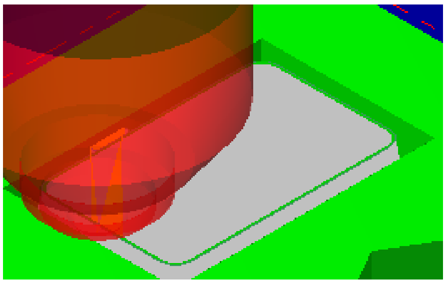
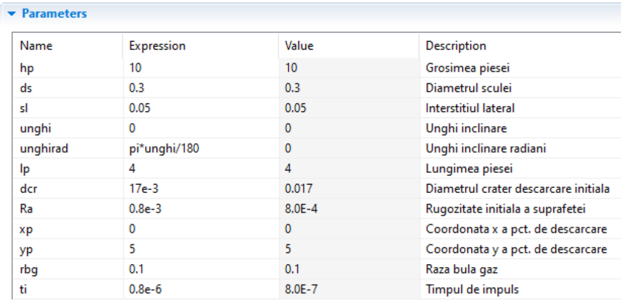


Fig. 8 Inclined cutting

4. Comsol Multiphysics modeling and simulation of the WEDM process

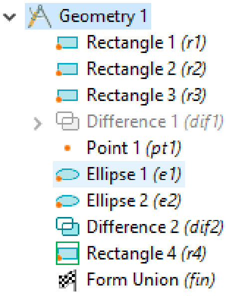
Figure 9 shows the parameters of the straight cut model. Figure 10 creates the necessary geometry for the simulated models, consisting of geometric elements such as rectangle, ellipse, point.



Parameters

Name	Expression	Value	Description
hp	10	10	Grosimea piesei
ds	0.3	0.3	Diametrul sculei
sl	0.05	0.05	Interstitiul lateral
unghi	0	0	Unghi inclinare
unghirad	pi*unghi/180	0	Unghi inclinare radiani
lp	4	4	Lungimea piesei
dcr	17e-3	0.017	Diametrul crater descarcare initiala
Ra	0.8e-3	8.0E-4	Rugozitate initiala a suprafetei
xp	0	0	Coordonata x a pct. de descarcare
yp	5	5	Coordonata y a pct. de descarcare
rbg	0.1	0.1	Raza bula gaz
ti	0.8e-6	8.0E-7	Timpul de impuls

Fig. 9 Model parameters



Geometry 1
- Rectangle 1 *(r1)*
- Rectangle 2 *(r2)*
- Rectangle 3 *(r3)*
- Difference 1 *(dif1)*
- Point 1 *(pt1)*
- Ellipse 1 *(e1)*
- Ellipse 2 *(e2)*
- Difference 2 *(dif2)*
- Rectangle 4 *(r4)*
- Form Union *(fin)*

Fig. 10 Creating geometry

The material allocated for the workpiece is C120, a hardened steel with more than 60 HRC,used for the active surfaces of the punching machines. The boundary conditions for straight cutting are described in the figures 11,12 and 13. The boundary conditions for inclined cutting are described in the figures 14, 15 and 16.

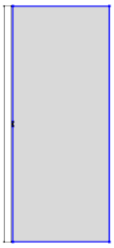


Fig. 11 Convective cooling in dielectric liquid

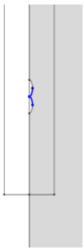


Fig.12 Temperature on the EDM spot

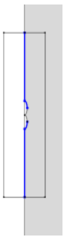


Fig.13 Thermal insulation of the gas bubble

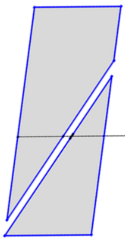


Fig. 14 Convective cooling in dielectric liquid

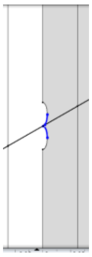


Fig. 15 Temperature on the EDM spot

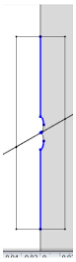
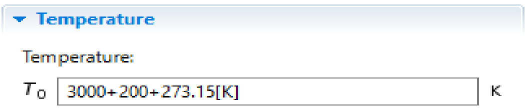


Fig. 16 Thermal insulation of the gas bubble

The temperature in the plasma channel area consists of the boiling point of the material and the overheating above the boiling point, shown in figure 17. Choose the heat transfer coefficient for convective cooling in dielectric liquid h=10 W/m^2*K [10]. Figure 18 shows the setting of the time-dependent model parameters where ‚ti’ is the discharge time.

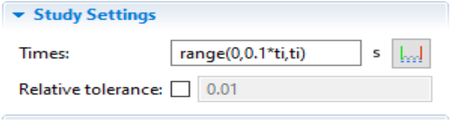


Temperature

Temperature:

T_0 3000+200+273.15[K] K

Fig. 17 Discharge temperature



Study Settings

Times: range(0,0.1*ti,ti) s

Relative tolerance: ☐ 0.01

Fig.18 Time-dependent study settings

Figures 19 and 20 show the discretizations of the models for straight and inclined cutting, and the generation of a corner with a 90° angle.

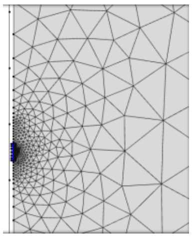


Fig. 19 Discretization of the model with free triangular elements for straight and inclined cutting

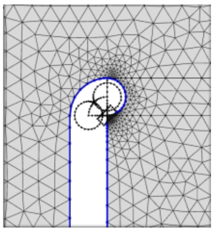


Fig. 20 Discretization of the model with free triangular elements for cutting a corner at 90° angle

Figures 21, 22, 23 and 24 show the creation of the geometry in front view to generate an outer contour with a 90° angle. In figure 28 the contour is generated by moving the center of the tool along an arc of a circle with the center of rotation in the corner of the profile cut by WEDM. Figure 29 creates the geometry after two previous discharges positioned near the corner. Figure 30 shows the geometry for generating the corner in the form of a living edge using a path with a loop (fish tail). Figure 31 shows the microgeometry of the surface after a discharge produced near the corner.

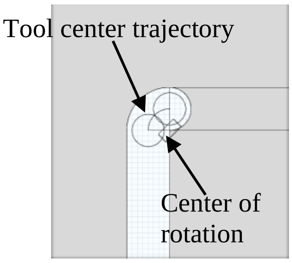


Fig.21 Generating the outer contour after an arc of a circle

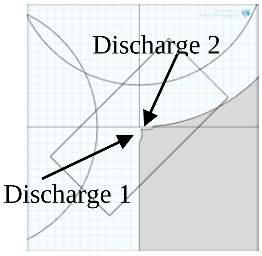


Fig.22 Microgeometry after two discharges

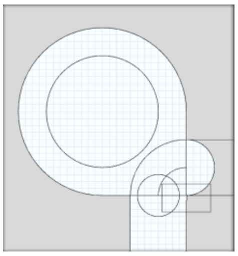


Fig.23 Generate living edge corner using fish tail

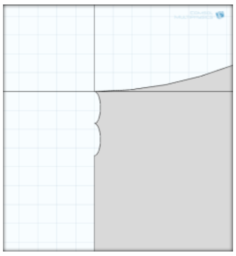


Fig.24 Microgeometry after a discharge

The boundary conditions for corner cutting with a circular arc are described in the figures 25, 26 si 27. The boundary conditions for cutting fish tail fangs are described in the figures 28, 29 si 30.

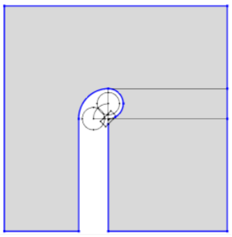


Fig. 25 Convective cooling in dielectric liquid

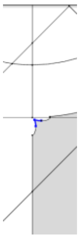


Fig.26 Temperature on the EDM spot

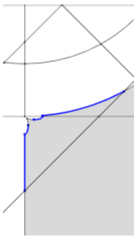


Fig.27 Thermal insulation of the gas bubble

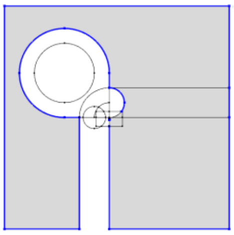


Fig.28 Convective cooling in dielectric liquid

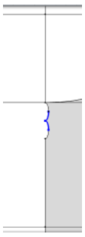


Fig.29 Temperature on the EDM spot

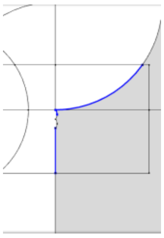
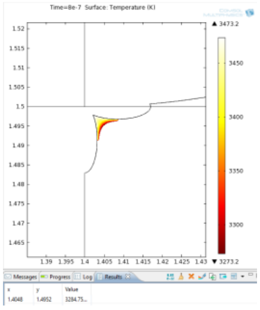
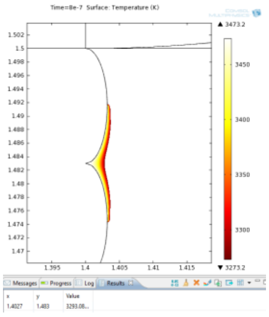


Fig.30 Thermal insulation of the gas bubble

The results from the modeling and simulation of the 90º corner generation are shown in the figures 31 and 32. In the first case, due to a very low feed rate, the probability of locating a discharge in the corner of the profile is very high. The corner is rounded due to the sample material shown in the figure 31. In the second case, when using the fishtail loop, the feed rate is high and the probability of locating the discharge in the corner of the profile is low (fig.32). In this case a sharp edge is obtained.



x	y	Value
1.4048	1.4952	3284.75...

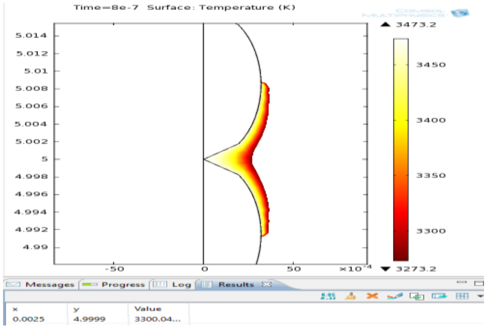


x	y	Value
1.4027	1.483	3293.08...

Fig. 31 Material removed at a single discharge produced in the corner of the profile

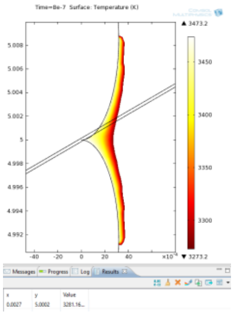
Fig. 32 Material removed at a single discharge produced near the corner of the profile

It is observed that on the right cut the depth of the crater produced by a single discharge is less than on the inclined cut. After simulating a similar discharge, 2.5 microns of the piece material is removed in the right cut, (fig. 33), and in the case of inclined wire cutting, 2.7 microns of the piece material is removed (fig. 34).



x	y	Value
0.0025	4.9999	3300.04...

Fig. 33 Material removed for a single discharge in case of straight cutting



x	y	Value
0.0027	5.0002	3281.16...

Fig. 34 Material removed in a single discharge in the case of inclined cutting

5. Conclusions

1. Straight and inclined cutting was modeled and simulated by WEDM, using Mastercam and Comsol Multiphysics, with the aim of increasing the precision and quality of the surface processed when cutting interior contours. Measures have been taken to introduce bridges that prevent the wire from breaking when the contours are closed, minimizing the distance between the guides to ensure the necessary accuracy. Finite element modeling has shown a lower depth of craters in straight cutting compares to inclined cutting and a better quality of the machined surface.

2. To increase the accuracy and quality of the machined surface, the input trajectories were used on an outer contour in the form of a circular arc, the generation of corners at 90° in the form of sharp edges with the help of the trajectory in the form of a loop (fish tail) in Mastercam. Finite element modeling in Comsol Multiphysics has shown the ability to achieve sharp edges by reducing the likelihood of producing discharges located on the corner of the profile as a result of maintaining a relatively high wire feed rate.

6. References

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