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TO THE QUESTION OF ELECTRICAL DISCHARGE MACHINING OF THE STEEL WORKPIECE WITH THE STEEL ELECTRODE

Abstract: *The impact of electric discharge on the processed surface of the steel workpiece in the conditions of electrical discharge machining with the steel cylindrical electrode was considered in the article. The electrical and thermal parameters of electrical discharge machining were calculated for the pulse duration of 0.5 s. The depth of the deformed layer of the workpiece material is presented in the three-dimensional view.*

Key words: *the electrode, the workpiece, electrical discharge machining, the ring, the deformed layer.*
Language: *English*
Citation: Chemezov, D., et al. (2020). To the question of electrical discharge machining of the steel workpiece with the steel electrode. *ISJ Theoretical & Applied Science, 06 (86),* 545-550.
Soi: http://s-o-i.org/1.1/TAS-06-86-100 ***Doi***: https://dx.doi.org/10.15863/TAS.2020.06.86.100
Scopus ASCC: *2209.*

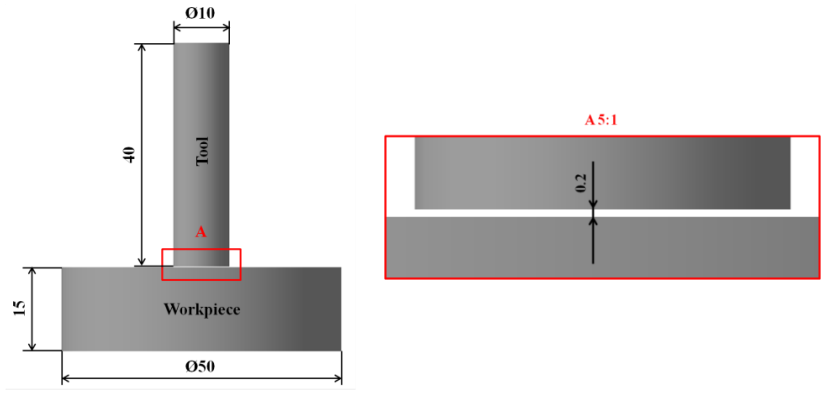
Introduction

Electrical discharge machining (EDM) is the progressive type of processing of various conductive materials. EDM can be carried out both with electrodes (for forming the blind profile) and with wire (for cutting the through profile). The low performance and the low-forecast tool wear are the main disadvantages of EDM. Some researches of the effective implementation of EDM are presented in the works [1-10].

Electric discharge that causes local heating of processed material passes between the surfaces of the tool and the workpiece in the process of EDM. The temperature increases intensively on the surface layers and leads to melting of the workpiece material in the short period of time. Thus, EDM includes the combination of thermomechanical, hydrodynamic, electrical and other processes. The presentation of intensity of volumetric deformation of the workpiece material will allow to choose the rational modes for roughing or finishing EDM. Let us consider thermal deformation and changing the volume of the workpiece material during EDM with the steel electrode.

Materials and methods

The passing process of discharge current between the surfaces of the electrode (the tool) and the workpiece was modeled according to the condition of the computer experiment. The electrode was the solid cylinder. The workpiece was the solid disk. The electrode and the workpiece were made of structural steel. The models for the computer experiment are presented in the Fig. 1.



A ***B***

Figure 1 – The models for the experiment: *A* – The orientation and the models dimensions of the tool and the workpiece; *B* – The detail section that explains the size of the spark gap.

EDM was carried out in the gas environment. Electric discharge of 10000 mA and duration of 0.5 s occurred in the spark gap. Voltage during EDM was accepted 25000 mV.

The size of the finite element indicates the accuracy of the computer calculation. The three-dimensional models of the tool and the workpiece after splitting into the finite elements are shown in the Fig. 2. The size of one element was accepted 1.5 mm. The mesh on the workpiece model was denser, which increased the accuracy of the simulation results in the processing zone.

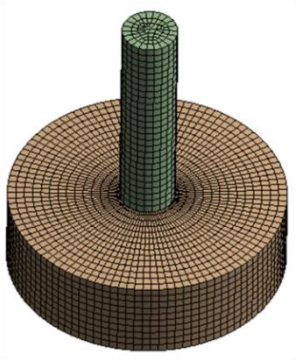


Figure 2 – The view of the models after splitting into the finite elements.

Calculation

The main part of the calculation of EDM is presented in the generated report.

***** ANSYS SOLUTION ROUTINE *****

USE A MAXIMUM OF 1 EQUILIBRIUM ITERATIONS EACH SUBSTEP

*** WARNING *** CP = 5.195
Using 1 iteration per substep may result in unconverged solutions for nonlinear analysis and the program may not indicate divergence in this case. Check your results.

DO NOT USE PREDICTOR METHOD FOR ALL DEGREES OF FREEDOM

SPECIFIED CONSTRAINT VOLT FOR PICKED NODES
REAL = _LOADVARI62 IMAG = 0.00000000

ALL SELECT FOR ITEM = NODE COMPONENT =
IN RANGE 1 TO 80428 STEP 1

80428 NODES (OF 80428 DEFINED) SELECTED BY NSEL COMMAND

SELECT COMPONENT _CM33

*GET _NODNUM FROM NODE ITEM = NUM MIN VALUE = 1483.00000

SPECIFIED NODAL LOAD AMPS FOR SELECTED NODES 1483 TO 1483 BY 1
REAL = _LOADVARI33 IMAG = 0.00000000

COUPLED SET = 1 DIRECTION = VOLT TOTAL NODES = 224
MAXIMUM COUPLED SET NUMBER = 1

ALL SELECT FOR ITEM = NODE COMPONENT =
IN RANGE 1 TO 80428 STEP 1

80428 NODES (OF 80428 DEFINED) SELECTED BY NSEL COMMAND

*** WARNING *** CP = 5.257
Element shape checking is currently inactive. Issue SHPP, ON or SHPP, WARN to reactivate, if desired.

*** WARNING *** CP = 5.413
Material number 4 (used by element 18190) should normally have at least one MP or one TB type command associated with it. Output of energy by material may not be available.

*** NOTE *** CP = 5.444
This nonlinear analysis defaults to using the full Newton-Raphson solution procedure. This can be modified using the NROPT command.

*** NOTE *** CP = 5.444
The conditions for direct assembly have been met. No .emat or .erot files will be produced.

*** NOTE *** CP = 5.444
It is highly recommended to use the solution control option by issuing the SOLCONTROL, ON command for this problem for robustness and efficiency.

*** NOTE *** CP = 6.131
It is highly recommended to use the auto contact setting option by issuing CNCHECK, AUTO command for this problem in order to achieve better convergence.

*** NOTE *** CP = 6.131
Symmetric deformable-deformable contact pair identified by real constant set 3 and contact element type 3 has been set up. The companion pair has real constant set ID 4. Both pairs should have the same behavior.
ANSYS will keep the current pair and deactivate its companion pair, resulting in asymmetric contact.
Electrostatic contact is activated.

Contact detection at: Gauss integration point
Average contact surface length 1176.9
Average contact pair depth 1481.5
Default pinball region factor PINB 0.25000
The resulting pinball region 370.37
Initial penetration/gap is excluded.
Bonded contact (always) is defined.
Electric contact capacitance coef. ECC 0.65574E+12

*** NOTE *** CP = 6.131
Min. initial gap 200 was detected between contact element 18261 and target element 18764.
The gap is closed due to initial settings.

*** WARNING *** CP = 6.131
The geometric gap/penetration may be too large. Increase pinball radius if it is a true geometric gap/penetration. Decrease pinball if it is a false one.

*** NOTE *** CP = 6.131
Symmetric deformable-deformable contact pair identified by real constant set 4 and contact element type 3 has been set up. The companion pair has real constant set ID 3. Both pairs should have the same behavior.
ANSYS will deactivate the current pair and keep its companion pair, resulting in asymmetric contact.
Electrostatic contact is activated.
Contact detection at: Gauss integration point
Average contact surface length 747.17
Average contact pair depth 1500.0
Default pinball region factor PINB 0.25000
The resulting pinball region 375.01
Initial penetration/gap is excluded.
Bonded contact (always) is defined.
Electric contact capacitance coef. ECC 0.65574E+12

*** NOTE *** CP = 6.131
Min. initial gap 200 was detected between contact element 18328 and target element 18248.
The gap is closed due to initial settings.

SUMMARY FOR CONTACT PAIR IDENTIFIED BY REAL CONSTANT SET 3
Max. penetration of -7.275957614E-12 has been detected between contact element 18276 and target element 18733.

Max. geometrical gap of 200 has been detected between contact element 18258 and target element 18681.

*** WARNING *** CP = 9.173
Contacting area 78538884.
Max. pinball distance 370.370007.
One of the contact searching regions contains at least 22 target elements.

SUMMARY FOR CONTACT PAIR IDENTIFIED BY REAL CONSTANT SET 4

*** NOTE *** CP = 9.173
Contact pair is inactive.

Range of element maximum matrix coefficients in global coordinates
Maximum = 2.943955282E+17 at element 18311.
Minimum = 7.605535165E+15 at element 513.

*** ELEMENT MATRIX FORMULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 1809 SOLID231 0.468 0.000259
2 16380 SOLID231 3.822 0.000233
3 413 CONTA174 0.094 0.000227
4 413 TARGE170 0.031 0.000076
Time at end of element matrix formulation CP = 9.2040596.
CURRENT CONVERGENCE VALUE = 0.1702E+20 CRITERION = 0.1702E+17

SPARSE MATRIX DIRECT SOLVER.
Number of equations = 75192, Maximum wavefront = 551

*** NOTE *** CP = 13.806
Sparse solver maximum pivot = 5.855352997E+17 at node 1483 VOLT.
Sparse solver minimum pivot = 4.283506717E+15 at node 25678 VOLT.
Sparse solver minimum pivot in absolute value = 4.283506717E+15 at node 25678 VOLT.

*** ELEMENT RESULT CALCULATION TIMES
TYPE NUMBER ENAME TOTAL CP AVE CP

1 1809 SOLID231 0.312 0.000172
2 16380 SOLID231 2.480 0.000151
3 413 CONTA174 0.062 0.000151
4 413 TARGE170 0.031 0.000076

FINISH SOLUTION PROCESSING

Results and discussion

The simulation results are presented by the color contours of the total electric field intensity, the total current density, Joule heat and the volume on the workpiece model (the Fig. 3). The total electric field intensity and the total current density have the same distribution in the volume of the workpiece model. In the central part of the processed area of the workpiece, intensity of these electrical parameters is less than in

the peripheral part. Maximum intensity is expressed by the contour ring.

During EDM, the heat source is partly surface in nature, partly formed by Joule heat released inside of the workpiece. Joule heat is defined as the product of the electric field intensity and the current density. Significant heat generation will occur on the periphery of the processed surface. Heat is released unevenly in the area of the contour ring.

The depth of the deformed layer of the workpiece is presented in the Fig. 3, *C*. The deformed volume of the workpiece material has the sphere shape. The maximum diameter of the deformed workpiece material equal to 1.5*d* of the electrode, the maximum depth equal to 0.4*d* of the electrode (*d* is the electrode diameter, mm).

The workpiece volume increases in the direction from the center to the periphery at destruction of the surface layers of material. The volume increases up to 8 times. At the same time, the volume practically does not change in the most deformed material of the workpiece.

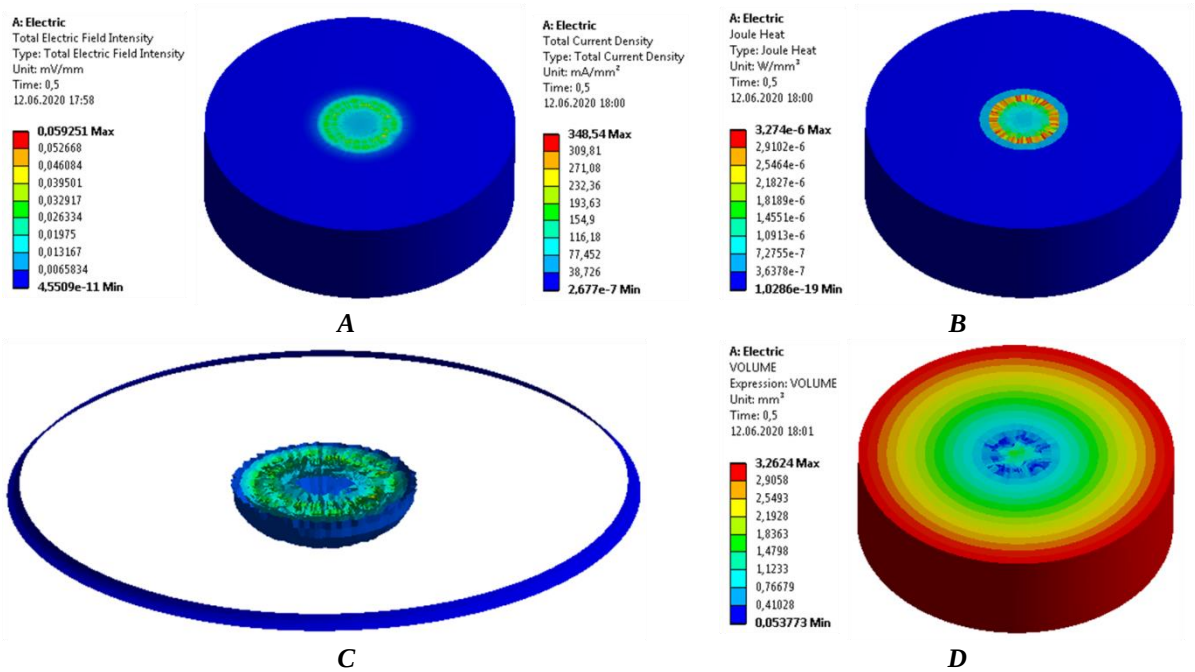


Figure 3 – The simulation results: *A* – The total electric field intensity and the total current density; *B* – Joule heat; *C* – The depth of the deformed layer of the workpiece; *D* – The volume.

Conclusion

EDM with the steel cylindrical electrode is accompanied by the formation of the peak heat ring, which is located on the periphery of the deformation area of the steel workpiece. The depth of deformation (destruction) of material increases from the periphery to the center of the processed surface layer of the workpiece.

Authors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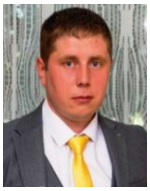
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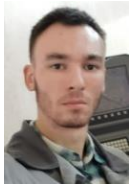
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Sergey Markov

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