Analysis of WEDM Using ANSYS and FEM

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Abstract:- Wire electrical discharge machining (WEDM) is widely used in machining of conductive materials when precision is considered as a prime importance. This work proposes a three dimensional finite element model (using ANSYS software) and new approach to predict the temperature distribution at different pulse time as well as stress distribution in wire. A transient thermal analysis assuming a Gaussian distribution heat source with temperature-dependent material properties has been used to investigate the temperature distribution and stress distribution. Thermal stress developed after the end of the spark and residual stress developed after subsequent cooling. The effect on significant machining parameter pulse-on-time has been investigated and found that the peak temperature sharply increases with the parameter.

Keywords: *ANSYS, WEDM, Residual Stress, Thermal Stress, Temperature.*

I. INTRODUCTION

Wire electrical discharge machining process is a mostly used non-conventional material removal processes. This is use for manufacturing difficult shape and profile of hard materials. This is considering as a distinctive variation of the conventional electrical discharge machining processes. In the WEDM, demand is growing for high rate cutting speed and high accuracy machining for improve the productivity of product and also for achieve high excellence quality in machining job. In wire electrical discharge machining process a always travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05–0.3 mm is used, which is precisely controlled by a CNC system. Here role of CNC is very important. The function of CNC is unwind the wire from a first spool, and feed throughout the work-piece, and takes it on a second spool. Generally wire velocity varies from 0.1 to 10 m/min, and feed rate is 2 to 6 mm/min. A direct current is used for generate high frequency pulse to the wire and the workpiece. The wire (electrode) is hold in tensioning device for decreases the chance of producing inaccurate parts. In wire electrical machining process, the workpiece and tool is eroded and there is no direct contact between the workpiece and the electrode, and this reduces the stress during machining.

WEDM was initially developed by manufacturing industry in the since 1960. The development technique is replaced the machined electrode used in electrical discharge machining. In 1974, D.H. Dulebohn introduced the optical line follower system which is automatic control the shapes of the part to be machined by the wire electrical discharge machining process. In 1975, it was popular rapidly, and its capability was better understood by manufacturing industry. When the computer numerical control system was introduced in WEDM process this brought about a most important development of the machining proce.

Consequently the wide capability of the wire electrical discharge machining process was widely exploited for any through-hole machining owing to the wire, which has to pass through the part to be machined. The common application of wire electrical discharge machining process is the fabricate the stamp and extrusion tools and dies, fixtures and gauges, prototypes, aircraft and medical parts, and grinding wheel form tools.

II. MATERIALS AND METHODS

In the wire EDM, a series of rapid electric spark occur in the gap between tool (wire) and workpiece. Addition of particles into the dielectric fluid makes this process more complex and random. The following assumptions are made without sacrificing the basic features of the wire EDM model to make the problem mathematically feasible.

A. Thermal Model of Wire EDM

The working principal of WEDM is as same EDM process, when the distance between the two electrodes (wire and the workpiece) is reduced the intensity of electric field in the volume between the electrodes (wire and the workpiece), become greater than the strength of the dielectric, which breaks, allowing current to flow between the two electrodes. For this reason the spark will generated.

B. Finite Element Analysis Procedure Using ANSYS Software

➢ *Thermal Analysis of Brass Wire*

The general finite element modeling procedure consists of the following steps:

- *Preferences*
  - ✓ *Thermal*

- *Preprocessing*
  - ✓ *Definition of Element Type*
  - ✓ *Material Properties Definition*
  - ✓ *Model Generation*
  - ✓ *Meshing*

- *Solution*
  - ✓ *Defining Initial Condition*
  - ✓ *Applying Boundary Condition*
  - ✓ *Applying Load*
  - ✓ *Solving For Results*

- *Post Processing*
  - ✓ *Reading Result File*
  - ✓ *Viewing Results*

➢ *Process of Thermo-Structural Modeling*

- *Open Mechanical Apdl (Ansys).*
- *Go To File > Change Title And Give A New Title For The Example.*
- *Preferences*
- *Preprocessing>Element Type> Add/Edit/Delete*

- ✓ *Click on Add*
- ✓ *Select Thermal Solid on the Left List and Brick 8 Node 70 on Right List(I.E. Element Type) Click on Ok*
- ✓ *Close*
- ✓ *Material Properties>Temperature Unit>Celsius>Ok*
- ✓ *Material Models>Thermal >Conductivity>Isotropic>Ok ,Put Value>Density Put Value>Specific Heat Put Value>Material Exit*
- ✓ *Modeling>Create>Cylinder>Sold Cylinder>Put the Dimensions*
- ✓ *Meshing>Mesh Tool> Smart Size 6>Mesh >Ok*

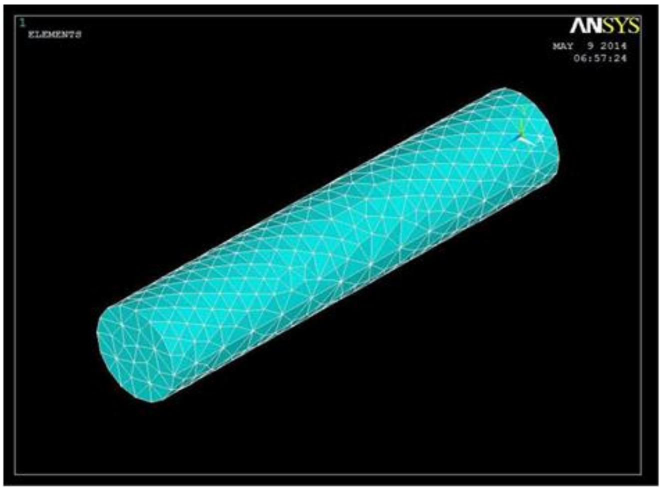

Fig 1 Three-Dimensional View of the Meshed Model

- ✓ *Physics> Environment>Write >Physics File Title>Thermal>Ok*
- ✓ *Element Type>Switch Element Type>Change>Element Type>Thermal To Structural>Ok*
- ✓ *Material Properties>Structural>Linear>Isotropic>Thermal Expansion>Ok>Exit*
- ✓ *Physics> Environment>Write >Erase Thermal>Write Structural>Ok*
- ✓ *Solution>New Analysis Type>Transient>Full>Ok*
- ✓ *Solution Control>Putting The* T_{on} *Time> Automatic Time Stepping ON>No. Of Subsets*
- ✓ *Define Loads>Apply>Functions>Read File>Ok*
- ✓ *Thermal>Heat Flux>On Element>Select Proper Element>Ok*
- ✓ *Initial Condition>Define>Pick All>Temperature>21*^{0}*C*
- ✓ *Solve >Current LS*

- *Post Processing>Plot Results>Counter Plot>Nodal Solution>DOF Solution>Nodal Temperature>OK*
  - ✓ *Finish*
  - ✓ *Physics> Environment>Read >Structural>Ok*
  - ✓ *Solution Control>Putting The* T_{on} *Time> Automatic Time Stepping ON>No. Of Subsets*
  - ✓ *Apply>Structural>Displacement>Area>All DOF>OK*
  - ✓ *Solution Load Step>Write LS File>1>Ok*
  - ✓ *Analysis Type>Solution Control>Basic>Off Time>Transient>Ramped Loading*
  - ✓ *Defineload>Apply>Temperature>From Thermal Analysis>Brouse>File.Rth>Ok*

Post processing>plot results>counter plot>nodal solution>DOF solution>nodal temperature>OK

III. RESULTS AND DISCUSSION

A. ANSYS Model Confirmation

In this section we have firstly make a model of WEDM process for brass wire with parameter setting as given in Table 3. Later the value has been compared with Han et al. Fig. 6 shows temperature distribution in brass wire, which is approximately same of Han et al. model. So we can say that we are proceeding in right way. Thermal modeling has done in using ANSYS.

B. FEM Analysis

➢ *Thermal Modeling of Wire EDM for Single Spark in Brass Wire*

Main parameters of the thermal analysis (analysis parameters)

Table 1 Parameters Used for Thermal Analysis in WEDM Process

Parameter	**Unit**	**Value**
Peak current of electro-discharge	A	27
Voltage of electro discharge,	V	25
Duration of single pulse	μs	0.12, 0.26, 0.36, 0.52, 0.58,
Wire radius	Mm	1.2, 1.82
Convective coefficient	W/m^2 ^{0}C	0.05
Temperature of the dielectric Poisson’ ratio	0_C	3040
Coefficient of linear thermal expansion	K^1	21

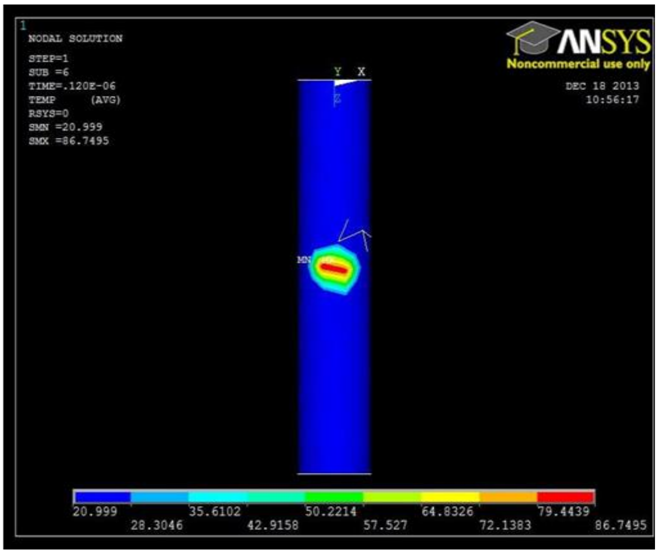

Fig 2 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=0.12μs

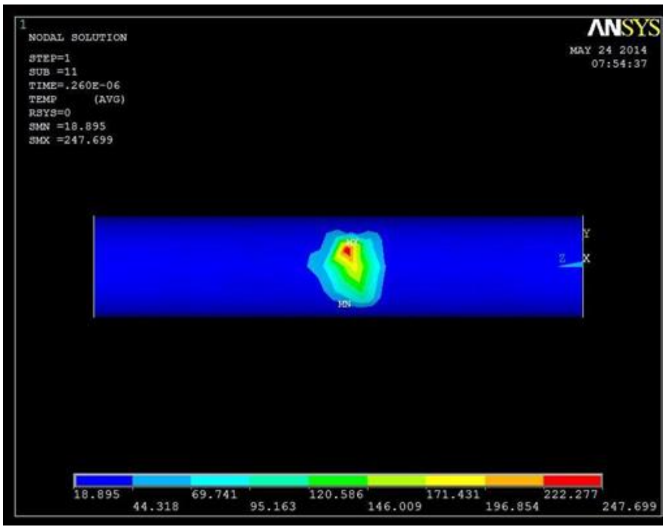

Fig 3 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=0.26μs

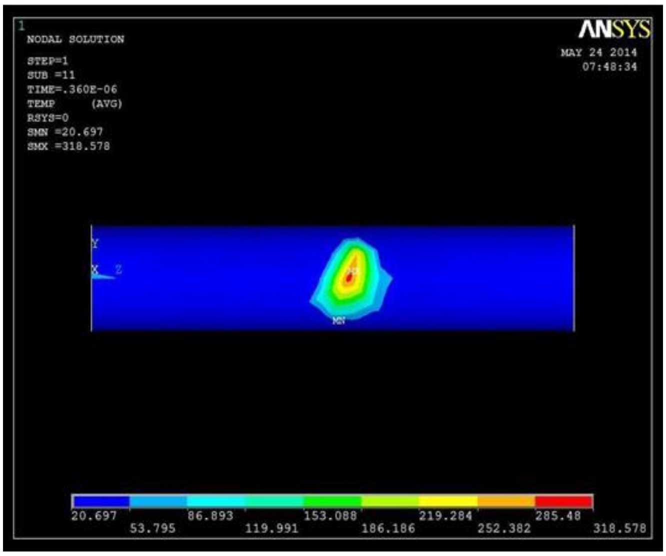

Fig 4 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=0.36μs

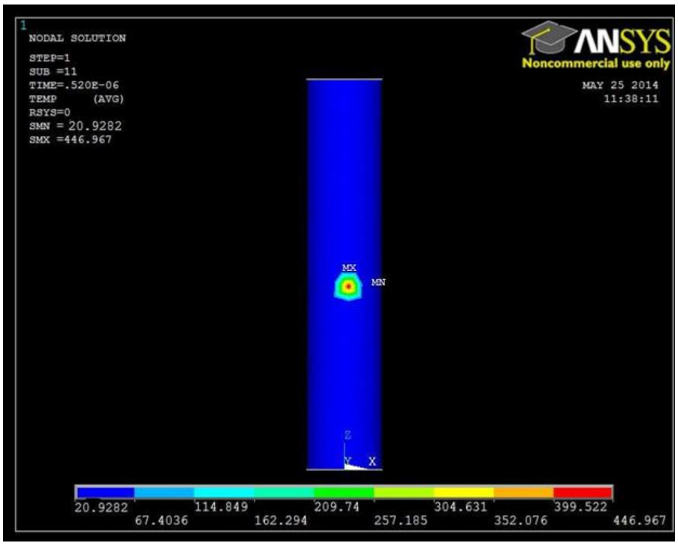

Fig 5 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=0.52μs

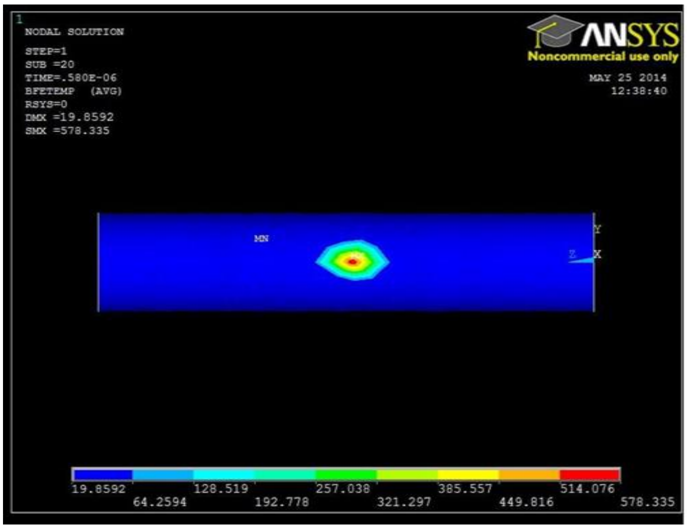

Fig 6 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=0.58μs

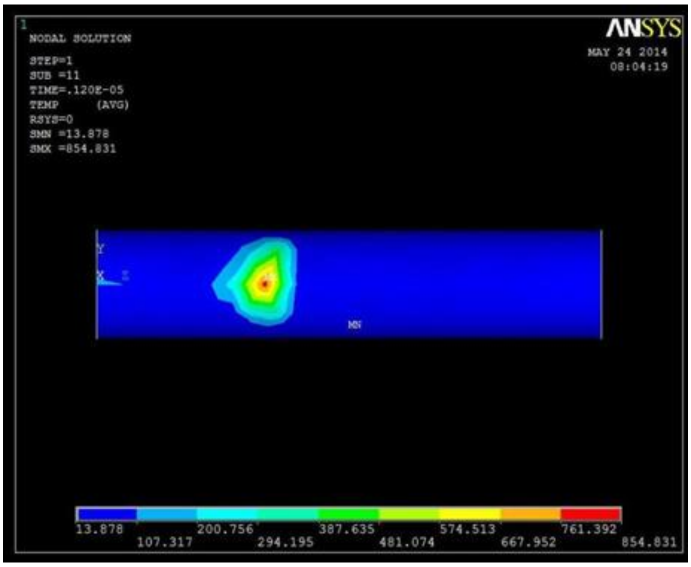

Fig 7 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}=1.2μs

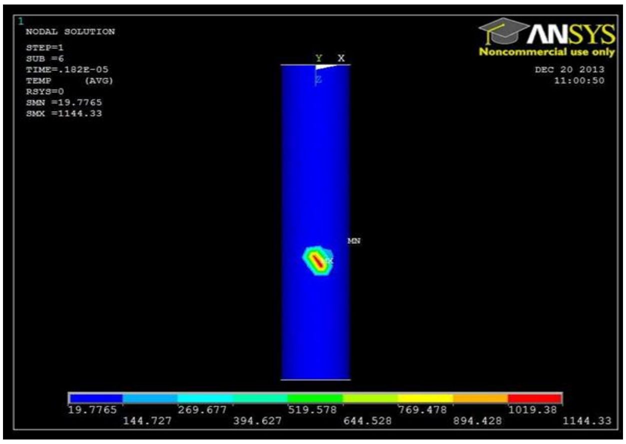

Fig 8 Temperature Distribution In Brass Wire With V=25V, I=27 A, P=0.38 And T_{on}= 1.82µs

- *Structural Modeling of WEDM in Molybdenum Wire*

In this section we have firstly make a model of WEDM process for brass wire with parameter setting as given in Table 4. Later the value has been compared with Saha et al. Fig. 6 shows displacement molybdenum wire, which is approximately same of Saha et al. So we can say that we are proceeding in right way. The structural analysis has done of molybdenum wire.

- *Displacement Analysis in the Wire Due to Tension:*

After solving for the temperature distribution we attempt to find the displacement in the wire. Now in this case molybdenum wire is used. Process parameters used for analysis is shown below Table 2

Table 2 Parameters used for structural analysis in WEDM process

Parameter	**Units**	**Value**
Radius of wire	Mm	0.125
Length of wire	M	
Tension	N	0.1
Initial temperature	K	
Working	K	13.7295

- The displacement graph is shown in below:

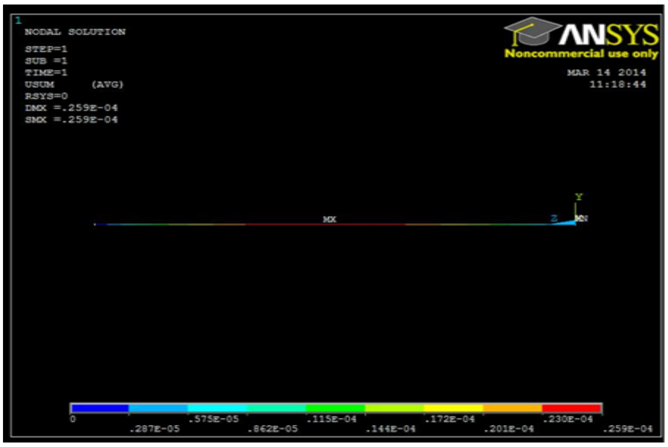

Fig 9 Nodal Solution of Displacement

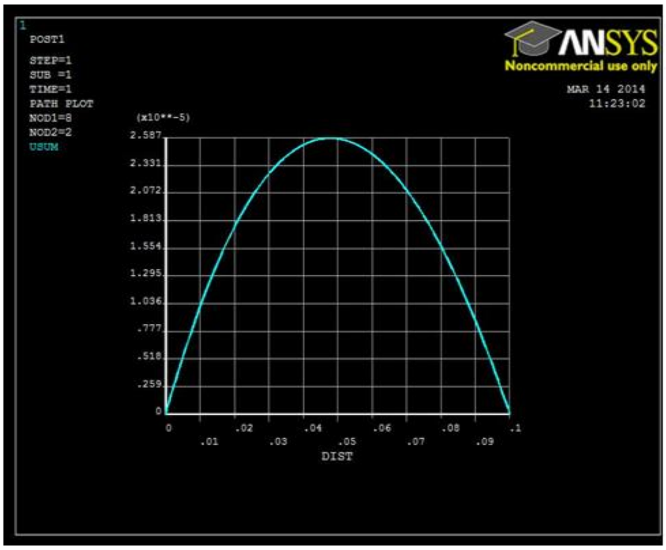

Fig 10 Graph of Displacement

- *Thermo-Structural Analysis of WEDM in Brass Wire.*
- *Thermal Stress Modelling of Micro Wire EDM for Single Discharge*

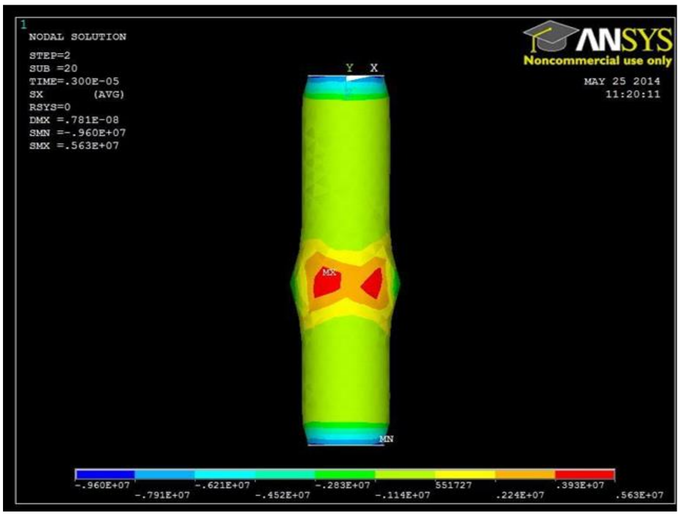

Fig 11 Thermal Stress in X-Component at T_{on}=0.12µs

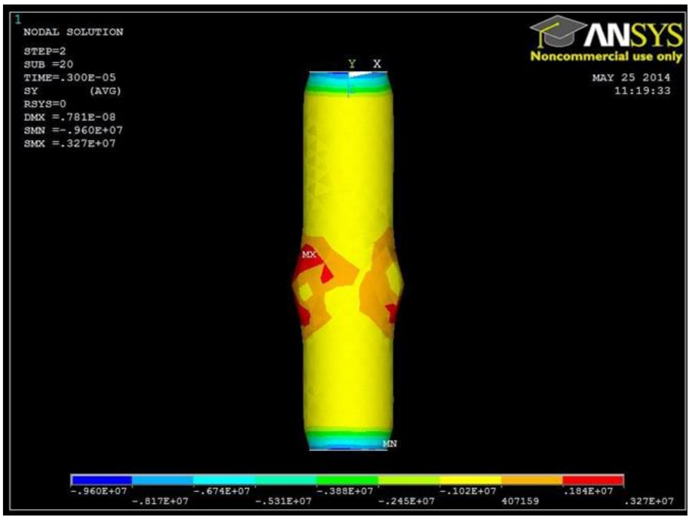

Fig 12 Thermal Stress in Y-Component at T_{on}=0.12µs

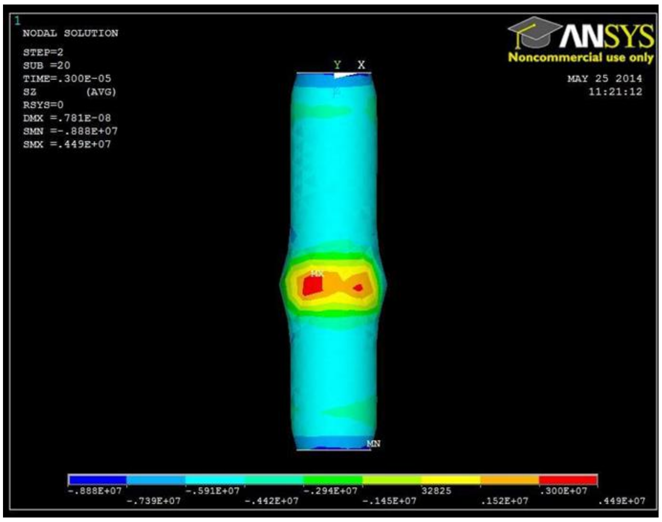

Fig 13 Thermal Stress in Z-Component at T_{on}=0.12µs

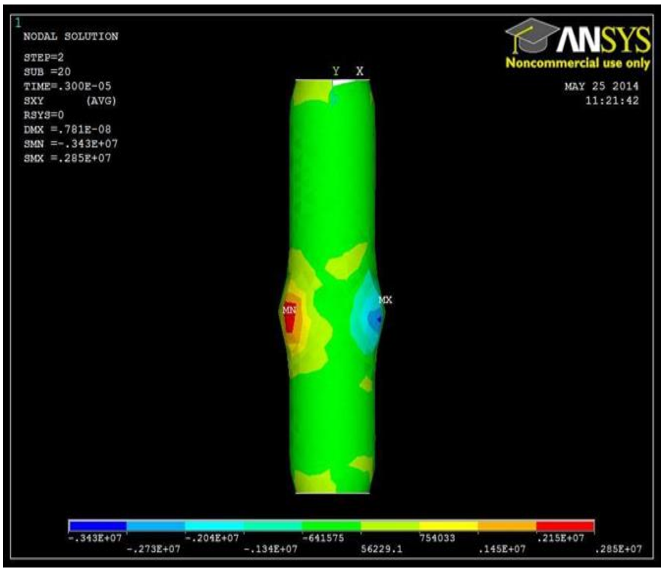

Fig 14 Thermal Shear Stress in XY Component at T_{on}=0.12µs

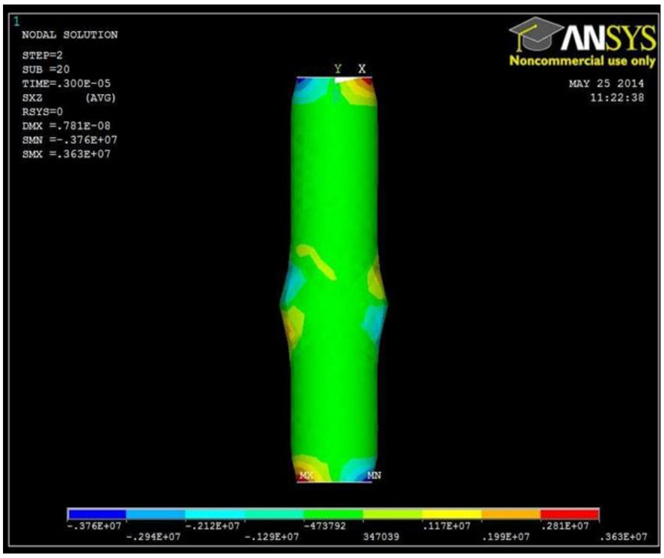

Fig 15 Thermal shear stress in XZ component at t_{on}=0.12µs

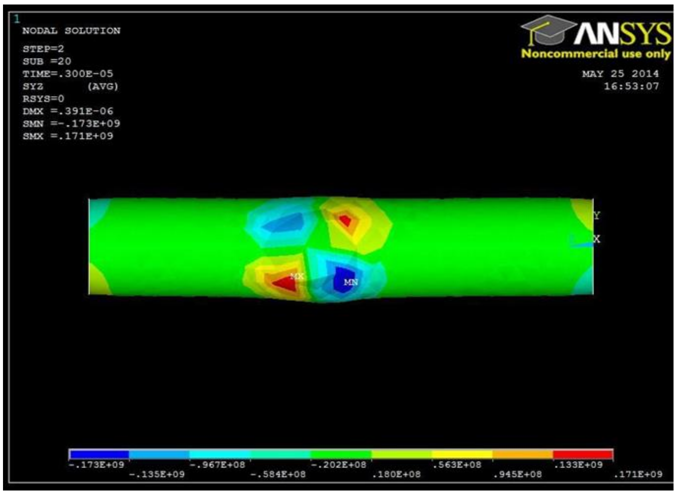

Fig 16 Thermal Shear Stress in YZ-Component at T_{on}=0.12µs

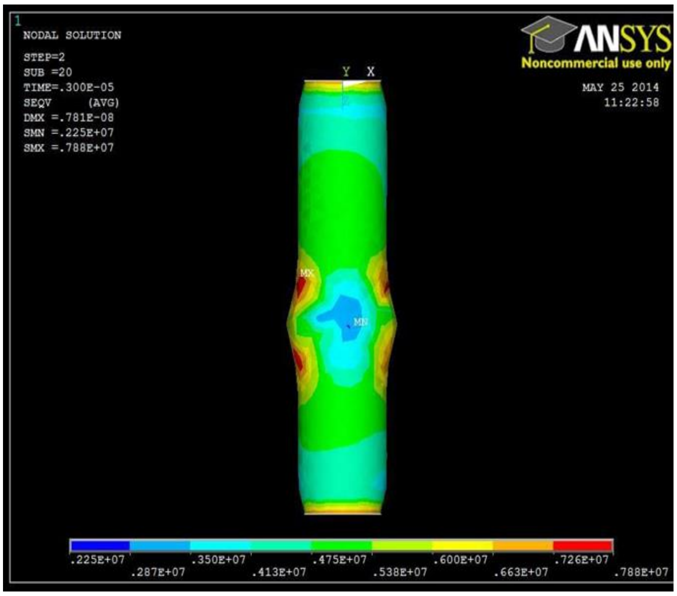

Fig 17 Residual Stress at T_{off} = 3µs

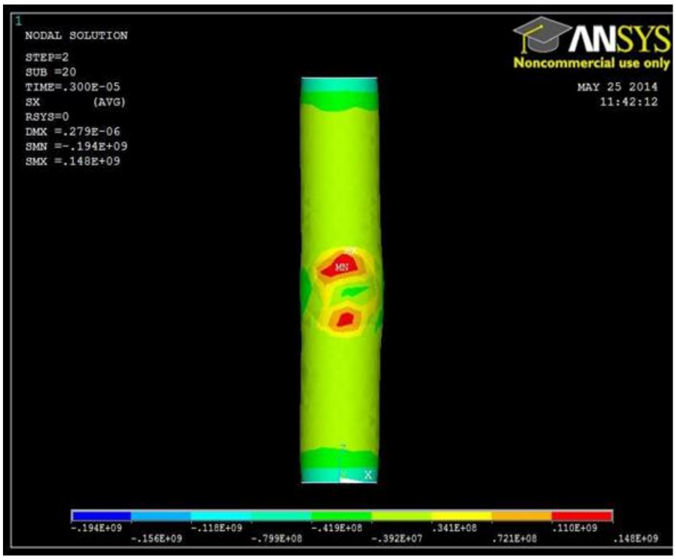

Fig 18 Thermal Stress in X-Component at T_{on}=0.52µs

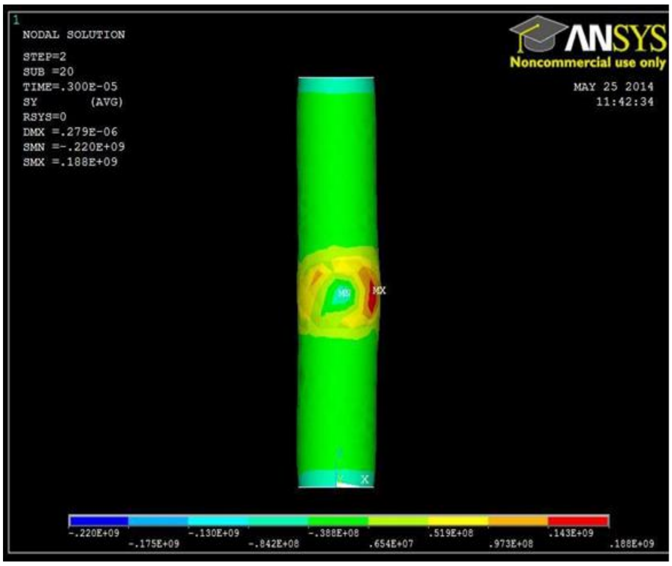

Fig 19 Thermal Stress in Y-component at t_{on}=0.52µs

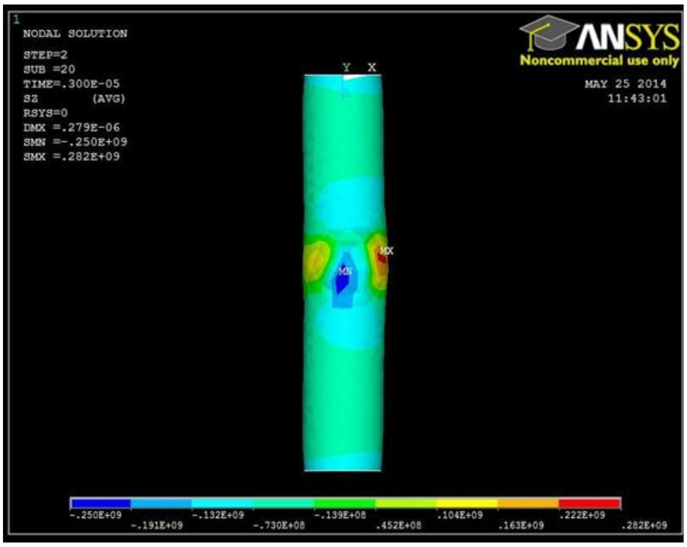

Fig 20 Thermal Stress in Z-Component at T_{on}=0.52µs

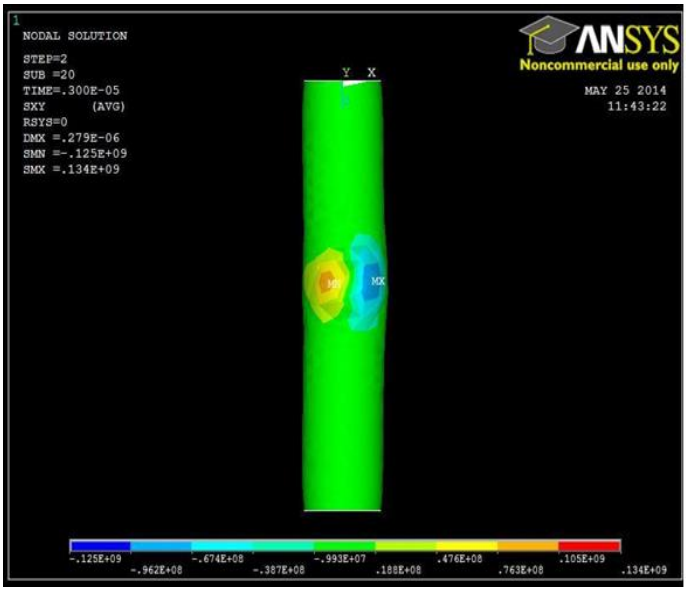

Fig 21 Thermal Shear Stress in XY-Component at T_{on}=0.52µs

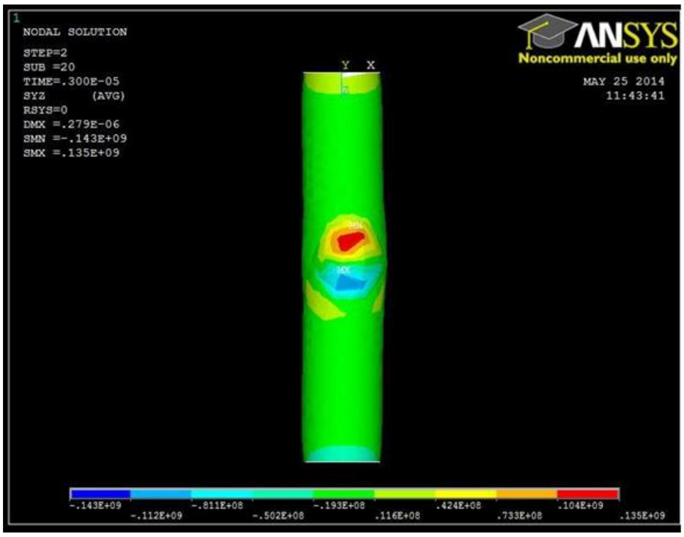

Fig 22 Thermal Shear Stress in YZ-Component at T_{on}=0.52µs

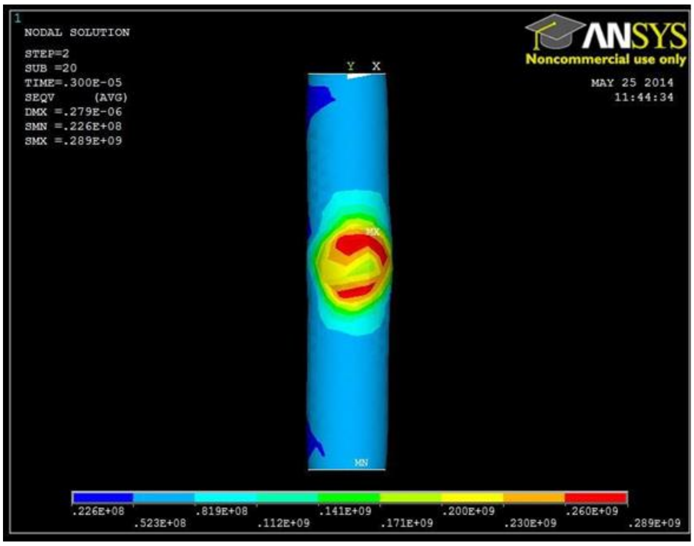

Fig 23 Residual Stress at t_{off}= 3µs

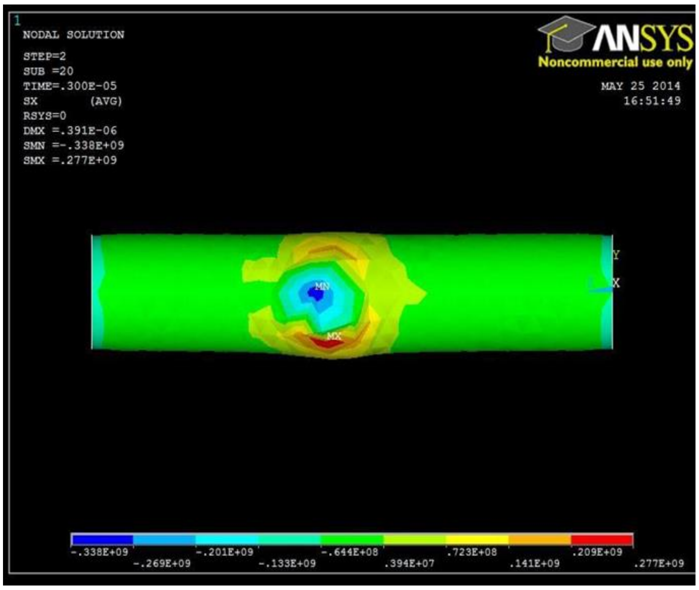

Fig 24 Thermal Stress in X-Component at T_{on}=1.82µs

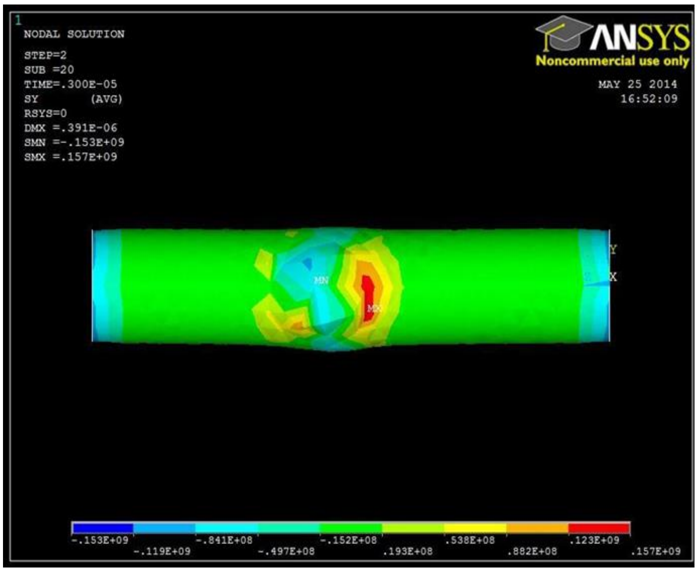

Fig 25 Thermal Stress in Y-Component at t_{on}=1.82μs

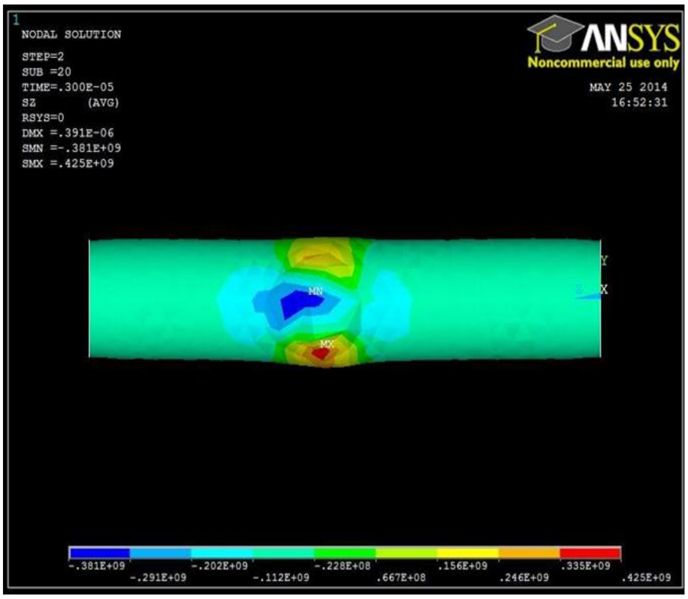

Fig 26 Thermal Stress in Z-Component at T_{on}=1.82μs

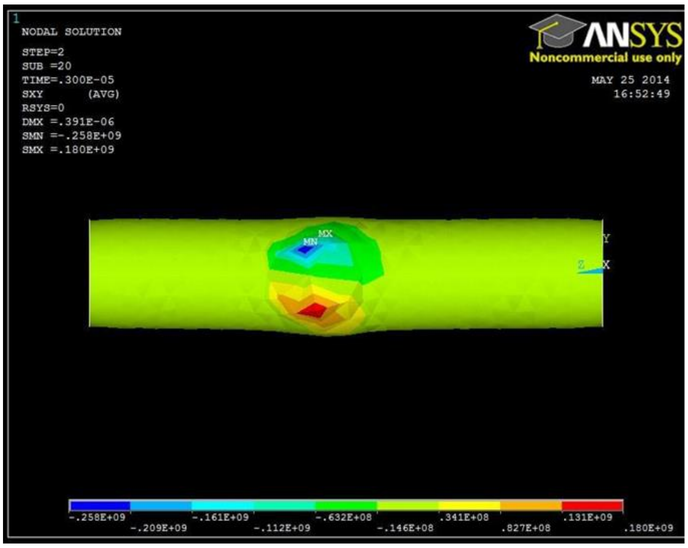

Fig 27 Thermal Stress in XY-Component at T_{on}=1.82μs

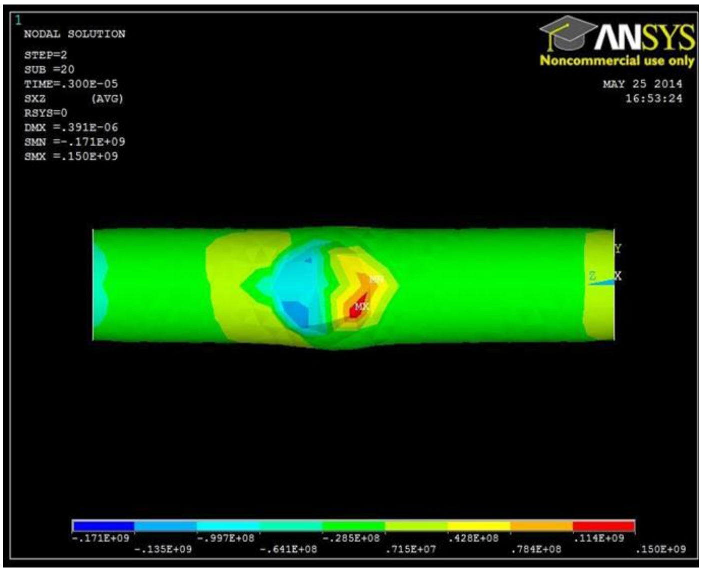

Fig 28 Thermal Stress in XZ-Component at t_{on}=1.82μs

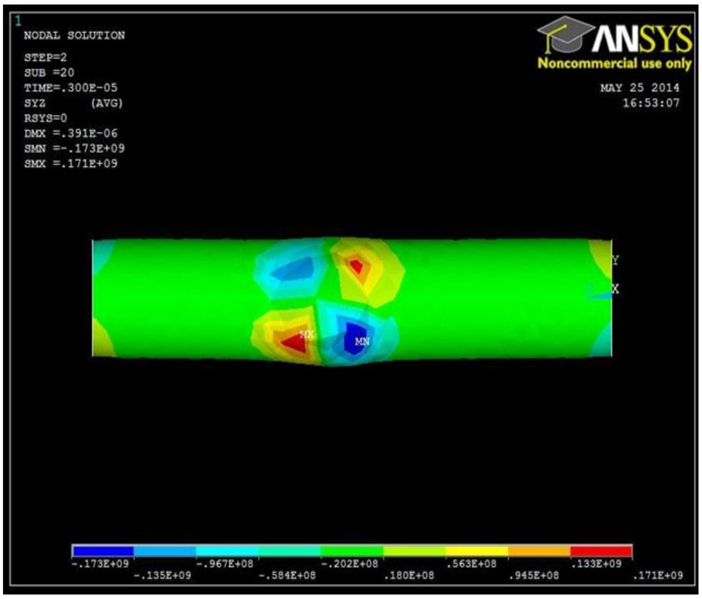

Fig 29 Thermal Stress in YZ-Component at t_{on}=1.82μs

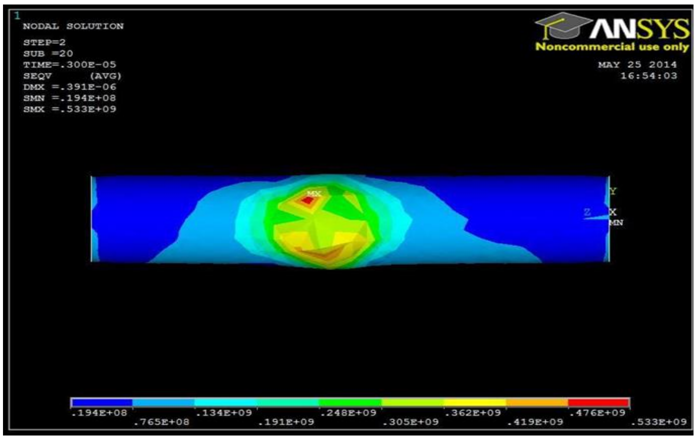

Fig 30 Residual Stress at T_{off}= 3 μs 2.5 Results and Discussions

Temperature distributions at the end of the pulse time are shown in Figs.(3- 9) to know the effects on WEDM. The temperature distribution during single discharge is calculated with the energy input constant parameter Ip= 27 A, voltage =25V with varying pulse time. At pulse time = 0.12 µs, corresponding temperature is 86.75^{0}C. At pulse time = 0.26 µs, corresponding temperature is 247.7^{0}C. At pulse time = 0.36 µs, corresponding temperature is 318.6^{0}C. At pulse time = 0.52 µs, corresponding temperature is 446.9^{0}C. At pulse time = 0.58 µs, corresponding temperature is 578.335^{0}C. At pulse time = 1.2 µs, corresponding temperature is 854.8^{0}C. At pulse time = 1.82 µs, corresponding temperature is 1144^{0}C. Further increasing the pulse time is not possible because, at temperature 1083^{0}C, the brass wire melt.

The distinctive stress distributions in WEDM process, enumerated at the end of heating cycle are presented. Here, Gaussian heat flux distribution is used for the calculation of temperature distribution. Later on, by varying the parameter i.e. pulse duration, and study of thermal stresses are presented. Fig 10-34 shows the thermal stress in different pulse on time. Thermal stress developed after the end of the spark and residual stress developed after subsequent cooling. The nature of the maximum stress is compressive, and it is because during the pulse duration, the heat flux supplied to the tool electrode for a very short duration (in µs).The maximum compressive stress is 563MPa for t_{on}=0.12µs in X-component, and maximum residual stress is 778 MPa. The maximum compressive stress is 288Mpa for t_{on}=0.52µs in Z-component and maximum residual stress is 288 MPa. The maximum compressive stress is 425Mpa for t_{on}=1.82µs in Z-component and maximum residual stress is 533 MPa.

IV. SUMMARY AND CONCLUSION

In this dissertation, a robust three dimensional finite element model has been developed using ANSYS software to predict the temperature distribution at different pulse time as well as stress distribution in the wire of WEDM. A transient thermal analysis assuming a Gaussian distribution heat source with temperature-dependent material properties has been used to investigate the temperature distribution and stress distribution. Thermal stress was developed after the end of the spark and also residual stress was developed after subsequent cooling. Finite element modeling was carried out for a single spark with temperature-dependent material properties. Certain parameters such as spark radius, discharge current and discharge duration, the latent heat, the plasma channel radius and Gaussian distribution of heat flux, the percentage of discharge energy transferred to the tool electrode have made this study nearer to real process conditions. The FE model shows that, at pulse time = 0.12 µs, corresponding temperature is 86.750C and maximum residual stress is 778 Mpa. At pulse time = 0.26 µs, corresponding temperature is 247.70C and .At pulse time = 0.36 µs, corresponding temperature is 318.60C. At pulse time = 0.52 µs, corresponding temperature is 446.90C and the maximum compressive stress is 288Mpa in Z-component, and maximum residual stress is 288 Mpa. . At pulse time = 0.58 µs, corresponding temperature is 578.3350C. At pulse time = 1.2 µs, corresponding temperature is 854.80C. At pulse time = 1.82 µs, corresponding temperature is 11440C and the maximum compressive stress is 425Mpa for ton=1.82µs in Z-component, and maximum residual stress is 533 Mpa.

Further increasing the pulse time is not possible because, at temperature 10830C, the brass wire melt.

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