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RESEARCH ARTICLE

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STRUCTURAL AND THERMAL ANALYSIS FOR WIRE-CUT ELECTRO DISCHARGING MACHINE PROCESS

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ABSTRACT

The wire cut electro-discharge machining (WEDM) is one of the most common and most accepted nontraditional machining processes used. It is a electro-thermal process and is based on the eroding effect of an electric spark on both the electrode and work piece. 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 by using ANSYS. Thermal stress developed after the end of the spark and residual stress developed after subsequent cooling.

Keywords: WEDM, ANSYS, Residual stress, Thermal stress, Temperature.

I. INTRODUCTION

Wire EDM (Vertical EDM's kid brother), is not the new kid on the block. It was introduced in the late 1960s', and has revolutionized the tool and die, mold, and metalworking industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer. It can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminum, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the workpiece, so there is no physical pressure imparted on the workpiece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the workpiece

Working principal of WEDM

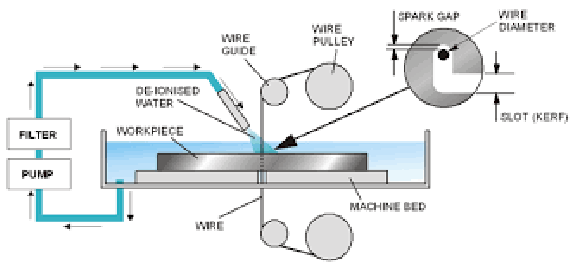

Fig.1. WEDM process

The Spark Theory on a wire EDM is basically the same as that of the vertical EDM process. In wire

EDM, the conductive materials are machined with a series of electrical discharges (sparks) that are produced between an accurately positioned moving wire (the electrode) and the workpiece. High frequency pulses of alternating or direct current is discharged from the wire to the workpiece with a very small spark gap through an insulated dielectric fluid (water). Many sparks can be observed at one time. This is because actual discharges can occur more than one hundred housand times per second, with discharge sparks lasting in the range of 1/1,000,000 of a second or less. The volume of metal removed during this short period of spark discharge depends on the desired cutting speed and the surface finish required. The heat of each electrical spark, estimated at around 15,000°to 21,000°Fahrenheit, erodes away a tiny bit of material that is vaporized and melted from the workpiece. (Some of the wire material is also eroded away) These particles (chips) are flushed away from the cut with a stream of de-ionized water through the top and bottom flushing nozzles. The water also prevents heat build-up in the workpiece. Without this cooling, thermal expansion of the part would affect size and positional accuracy. Keep in mind that it is the ON and OFF time of the spark that is repeated over and over that removes material, not just the flow of electric current

2. THERMAL ANALYSIS OF WIRE EDM

The working principal of WEDM is as same EDM process, when the distance between the two electrodes (wire and the work piece) is reduced the intensity of electric field in the volume between the electrodes (wire and the work piece), 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.

2.1 Material properties

In wire EDM process, huge thermal energy is generated, so material properties are required for analysis this process. In this paper two materials are taken:

Brass wire

The chemical composition of brass is 62% Cu and 38% Zn.

Table 1: Properties of brass wire

Properties	Unit	Value
Density	Kg/m^3	8495
Thermal conductivity	W/m-K	116
Specific heat	J / kg-K	382
Modulus of Elasticity	G Pa	98
Bulk Modulus	G Pa	142
Poisson's Ratio		.32
Melting temperature	^0C	1085
Shear Modulus	G Pa	35
Solidus	0_C	882

Molybdenum wire

Table 2: Properties molybdenum wire

Properties	Unit	Value
Thermal Conductivity	W /m-K	139
Coefficient of linear thermal expansion	$_K$-1	4.9×10^{-6}
Density	kg /m^3	10285
Young's modulus of elasticity	G Pa	330
Poisson's ratio		.32

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Shear modulus	G Pa	128
Melting point	0_C	2525

2.2 Thermo-structural modeling

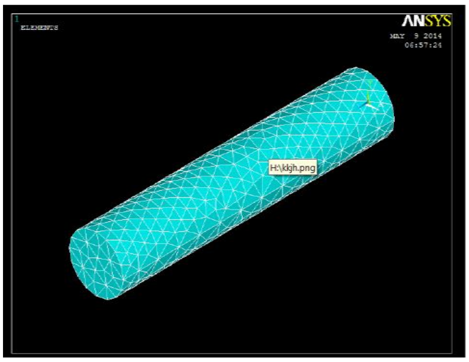

Fig.4: Three-dimensional view of the meshed model

3. 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

3.1. Thermal modeling of wire EDM for single spark in brass wire

Main parameters of the thermal analysis (analysis parameters)

Table 3: 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, 1.2, 1.82
Convective coefficient	$W/m^2\ ^0C$	3040
Temperature of the dielectric	^0C	21
Poisson' ratio		0.31
Coefficient of linear thermal Expansion	K^{-1}	1.9×10^{-5}

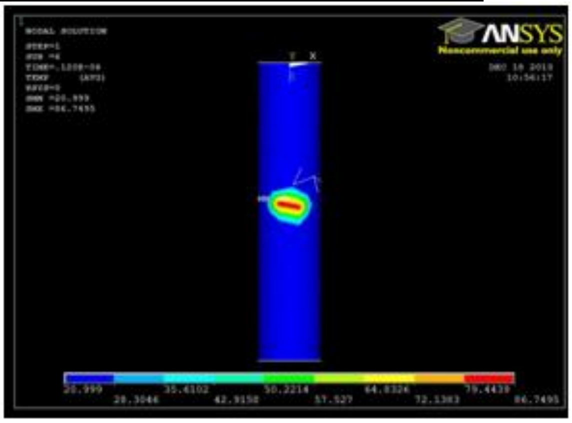

Fig5: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=0.12µs

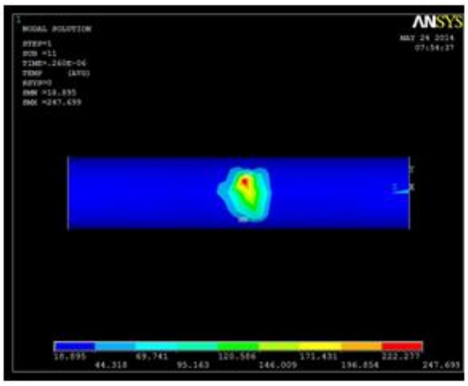

Fig.6: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=0.26µs

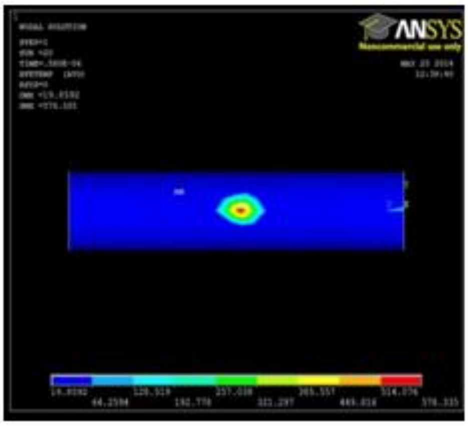

Fig.7: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=0.36µs

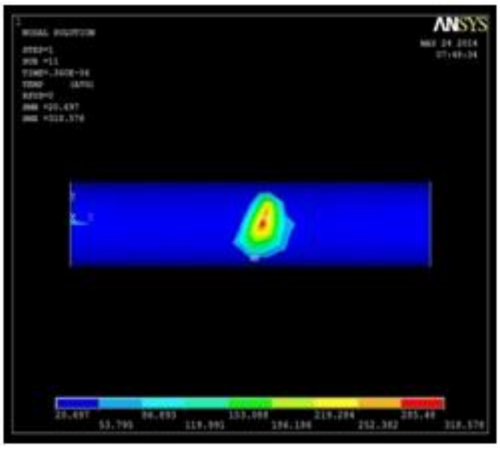

Fig.8: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=0.58µs

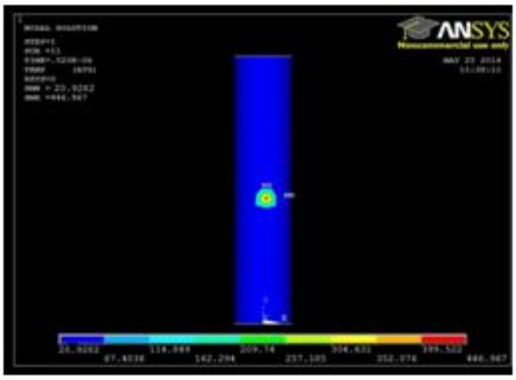

Fig.9: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=0.52µs

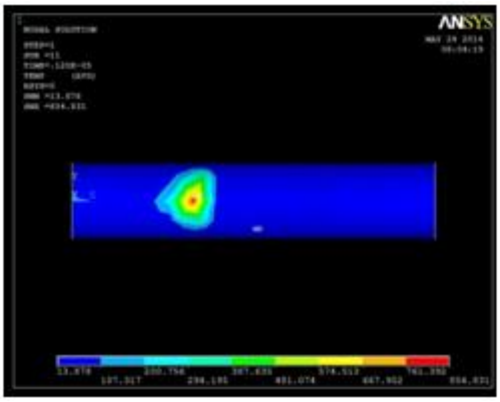

Fig.10: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton=1.2µs

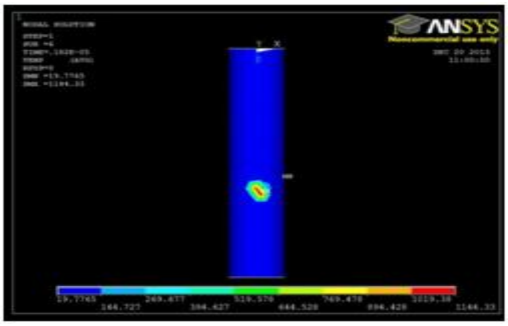

Fig. 11: Temperature distribution in Brass wire with V=25V, I=27 A, P=0.38 and ton= 1.82µs

5. STRUCTURAL ANALYSIS 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. 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 4.

Table 4: Parameters used for structural analysis in WEDM process

Parameter	Units	Value
Radius of wire	Mm	0.125
Length of wire	M	0.11
Tension	N	13.7295
Initial temperature	K	275
Working temperature	K	392

The displacement graph is shown in below:

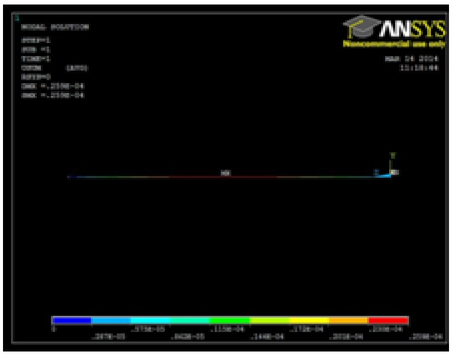

Fig. 12: Nodal solution of displacement

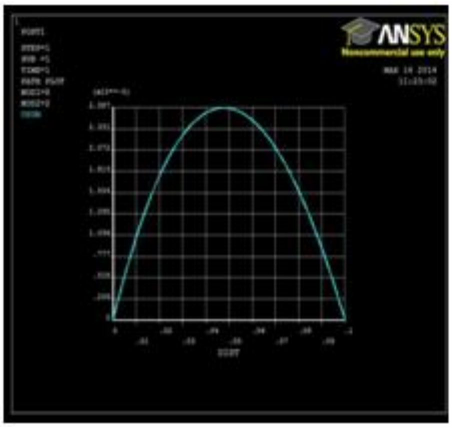

Fig. 13: Graph of displacement

5.1. Thermo-structural analysis of WEDM in brass wire.

Thermal stress modeling of micro wire EDM for single discharge

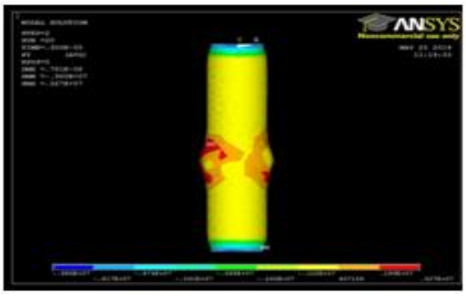

Fig. 14: Thermal Stress in X-component at ton=0.12µs

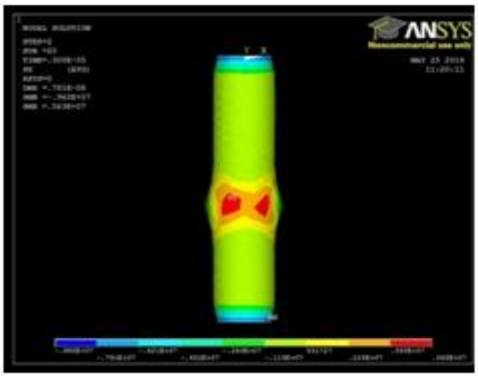

Fig. 15: Thermal Stress in Y-component at ton=0.12µs

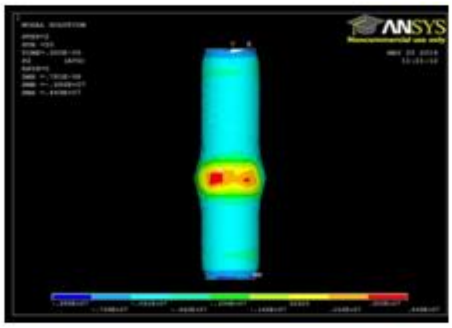

Fig. 16: Thermal Stress in Z-component at ton=0.12µs

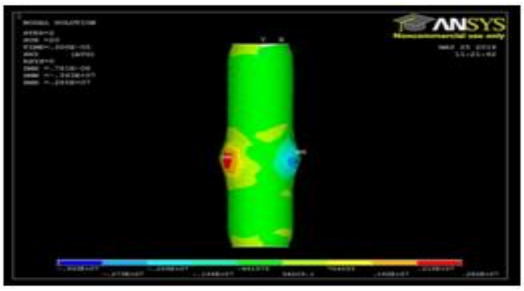

Fig. 17: Thermal shear stress in XY component at ton=0.12µs

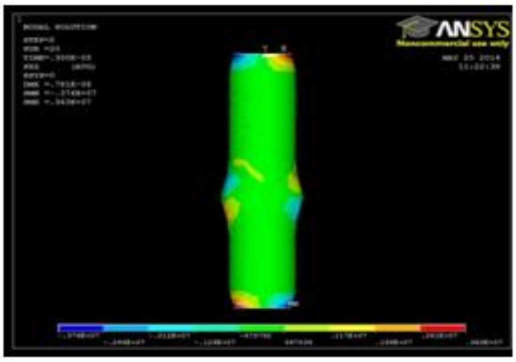

Fig. 18: Thermal shear stress in XZ component at ton=0.12µs

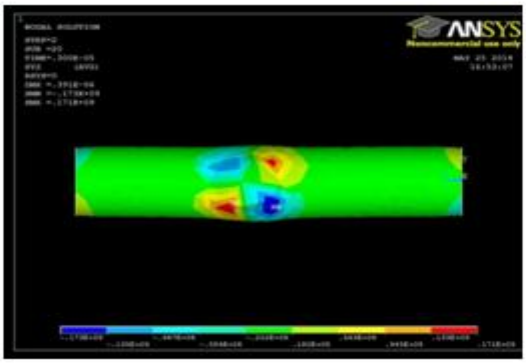

Fig. 19: Thermal shear stress in YZ-component at ton=0.12µs

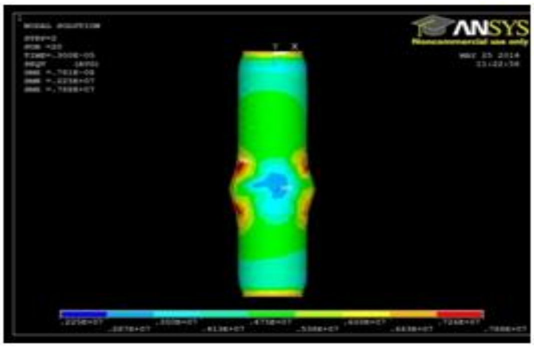

Fig. 20: Residual stress at toff = 3µs

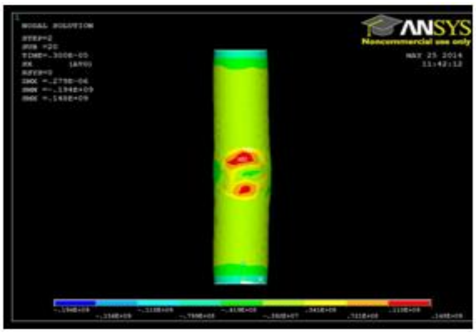

Fig. 21: Thermal Stress in X-component at ton=0.52µs

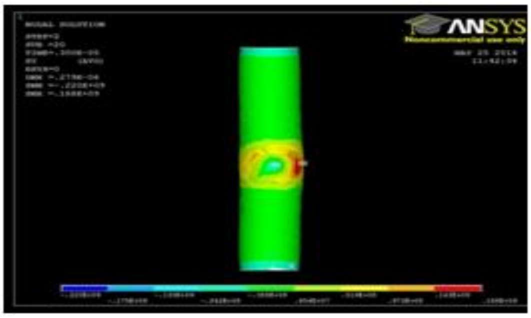

Fig. 22: Thermal Stress in Y-component at ton=0.52µs

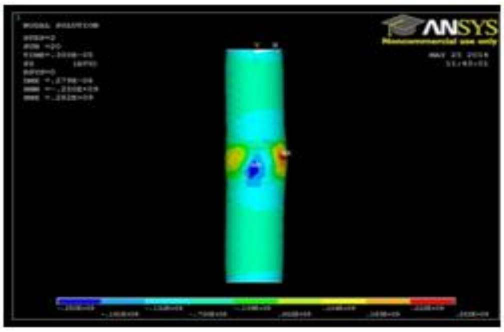

Fig. 23: Thermal Stress in Z-component at ton=0.52µs

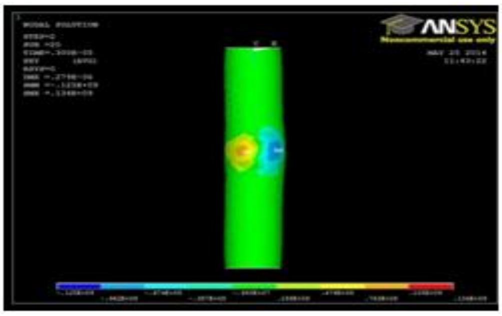

Fig. 24: Thermal shear stress in XY-component at ton=0.52µs

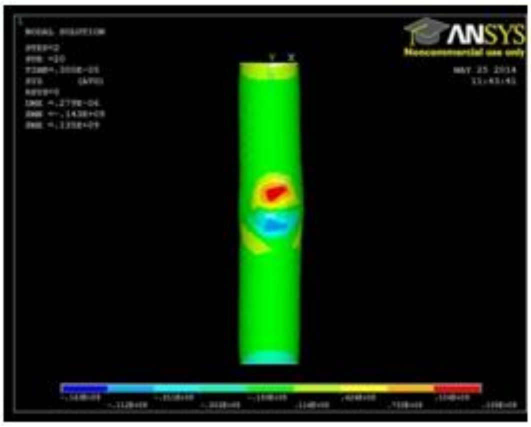

Fig. 25: Thermal shear stress in YZ-component at ton=0.52µs

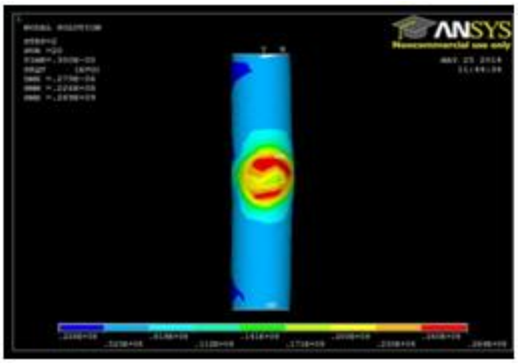

Fig. 26: Residual stress at toff= 3µs

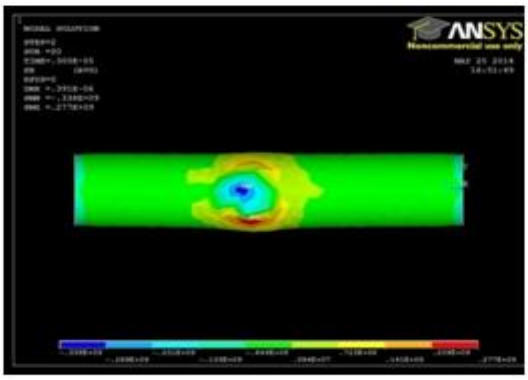

Fig. 27: Thermal Stress in X-component at

ton=1.82µs

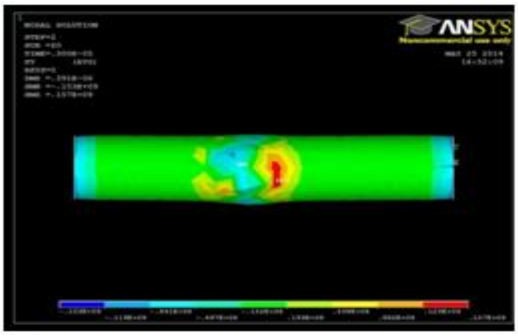

Fig. 28: Thermal Stress in Y-component at ton=1.82µs

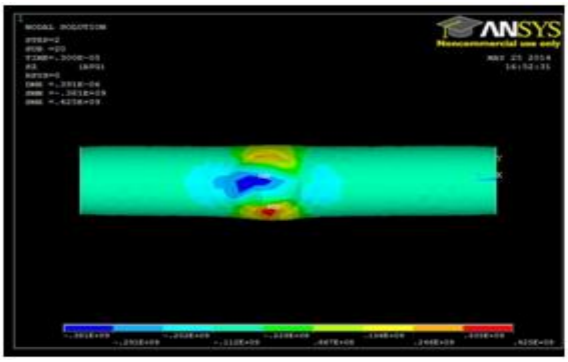

Fig. 29: Thermal Stress in Z-component at ton=1.82µs

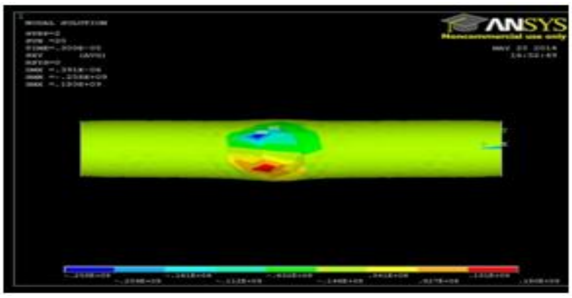

Fig. 30: Thermal Stress in XY-component at ton=1.82µs

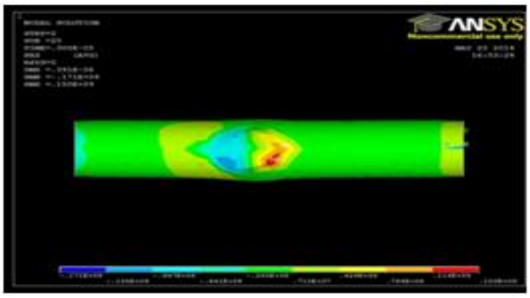

Fig. 31: Thermal Stress in XZ-component at ton=1.82µs

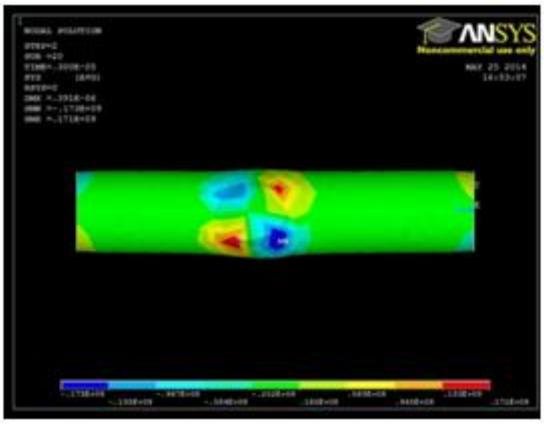

Fig. 32: Thermal Stress in YZ-component at ton=1.82µs

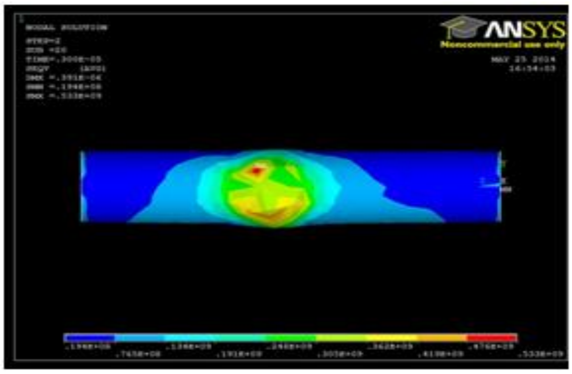

Fig.33: Residual stress at toff= 3 µs

RESULTS AND DISCUSSIONS

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 87.750C. At pulse time = 0.26 µs, corresponding temperature is 248.70C. At pulse time = 0.36 µs, corresponding temperature is 319.60C. At pulse time = 0.52 µs, corresponding temperature is 447.90C. At pulse time = 0.58 µs, corresponding temperature is 579.3350C. At pulse time = 1.2 µs, corresponding temperature is 856.80C. At pulse time = 1.82 µs, corresponding temperature is 11460C. Further increasing the pulse time is not possible because, at temperature 10850C, 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 564MPa for ton=0.12µs in X-component, and maximum residual stress is 779 MPa. The maximum compressive stress is 289Mpa for ton=0.52µs in Z-component and maximum residual stress is 289 MPa. The maximum compressive stress is 426Mpa for ton=1.82µs in Z-component and maximum residual stress is 535 MPa.

Conclusions

The FE model shows that, at pulse time = 0.12 µs, corresponding temperature is 86.75^{0}C and maximum residual stress is 778 Mpa. At pulse time = 0.26 µs, corresponding temperature is 247.7^{0}C and .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 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 578.335^{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 and the maximum compressive stress is 425Mpa for t_{on}=1.82µs in Z-component, and maximum residual stress is 533 Mpa. Further increasing the pulse time is not possible because, at temperature 1083^{0}C, the brass wire melt.

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