Thermal Modeling of Wire EDM Process through ANSYS

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Abstract-In this paper an analysis of thin wire of materials like brass bronze and copper through ANSYS has been presented. Thermal modeling of thin wire of copper, bronze and brass has been carried by using some governing equations of conduction. Wire EDM is one of the material removal processes which is non- convectional and widely used. It is used for manufacturing difficult shape and profile of hard materials which is a distinctive variation of the usual EDM process, to upgrade productivity and quality; need of rate cutting speed and high accuracy machine working on the same principle is growing fast. A thin copper, brass and bronze wire of diameter 0.05–0.3 mm electrode wire is used in wire electrical discharge machining process FFA meshed is developed and at various pulse rate wide range of temperature and stresses has been achieved which are discussed in the chapter of result and discussions

Keywords-Stress Variation, Temperature Variation, Thermal Modeling, Equation of Conduction, FEA Mesh.

I. INTRODUCTION

One of the material removal processes- “Wire electrical discharge machining process” is non- convectional and widely used. It is used for manufacturing difficult shape and profile of hard materials which is a distinctive variation of the usual EDM process, to upgrade productivity and quality; need of rate cutting speed and high accuracy machine working on the same principle is growing fast. A thin copper, brass or tungsten wire of diameter 0.05–0.3 mm electrode wire is used in wire electrical discharge machining process. It is strictly controlled by a CNC system. CNC plays a very important. It unrolls the wire from first spool and connects work-piece to take it to a second spool. Usually wire velocity can be from 0.1 to 10 m/min, and feed rate can be 2 to 6 mm/min, to generate high frequency pulse within workpiece and wire; direct current is used. In order to reduce the chance for production ofinaccurate parts, wire is held in tensioning device. There is a lower stress within the workpiece and electrode because there is no direct contact between them during machining.

In 1960, manufacturing industries developed WEDM. The developed technique is now replaced by machine electrodes used in electrical discharge machining. Optical line follower system in 1974 was introduced by D.H. Dulebohn, which automatically controlled the part shapes machined in wire electrical discharge machining process. In 1975itspotential was accepted by manufacturing industry making it popular.

Introduction of computer numerical control system in WEDM process has led to the phenomenal development in machining process. However, the ability of WEDM process was widely ill- used for those machine process which are used to make holes completely through the substance. Various features of wire electrical discharge machining process are:

1. Fabricatingthe stamp
2. Extrusion tools and dies
3. fixtures and gauges
4. Prototypes
5. Aircraft and medical parts
6. Grinding wheel form tools

The structured diagram of WEDM is as shown Figure 1.1.

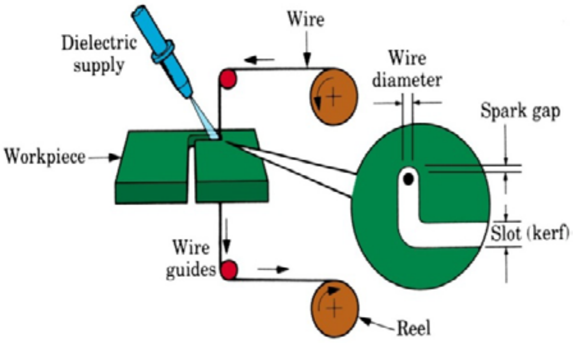


Figure 1.1 WEDM Process

Removal method of wire electrical machining is comparable to the conventional electrical discharge machining process where, erosion effect on work piece by the spark was done. Through the series of spark material is eroded from work piece, happening between workpiece and wire and is segregated by dielectric liquid, and is regularly used in machining zones. In recent years, a wire electrical discharge machining process is commonly conducted in a container which is filled with dielectric liquid and is completely submerged in it. Through this method of wire electrical discharge machining, it supports the stabilization of temperature and further, effective flushing when there is difference in thickness of workpiece. It usually uses electrical energy to produce the plasma channel within the cathode and anode and also to build thermal energy within the temperature range of 8,0000C to 12,0000C or higher which can be, 20,0000C.

This produces significant amount of heat and melts the material on each pole surface. If the oscillating DC supply between 20,000 and 30,000 Hz is turned off, it will led to breakdown of plasma channel, causing the abrupt decrease in temperature and allowing to move dielectric liquid to support the plasma channel and movement of particles which are molten to each poles surface as microscopic debris.

II. PROBLEM STATEMENT

- It is used for manufacturing difficult shape and profile of hard materials which is a distinctive variation of the usual EDM process.
- To upgrade productivity and quality; need of rate cutting speed and high accuracy machine working on the same principle is growing fast.
- A thin copper, brass or tungsten wire of diameter 0.05–0.3 mm electrode wire is used in wire electrical discharge machining process.
- It is strictly controlled by a CNC system.

III. OBJECTIVE OF THE PRESENT WORK

- To determine the temperature distribution, displacement and stress distribution in wire electrode tool of WEDM using FEM analysis.
- To develop a thermo-structural modeling of electrode wire tool for analyzing the effect of built-in temperature for the machining performance.

IV. SCOPE OF PRESENT WORK

- Dies and punches for Electronic and hierological components.
- Devices used in biomedical and in micro surgery.
- Precise flexures used in micro positioning systems.

V. REVIEW OF PREVIOUS WORK

Kunieda and Furudate [2] defined the progress in a new dry wire electrical discharge machining method. They conducted an experiment using gas atmosphere instead of dielectric liquid. For improving the accuracy of finish cutting, the oscillation of the wire electrode is required so that it can minimize the minor small process reaction force. Elevated accuracy and finish cutting may be recognized in dry-wire electrical discharge machining. But, some disadvantages of dry-wire electrical discharge machining like lower material discard rate compared to conventional wire electrical discharge machining and lines are more likely to be generated over the finish surface.

Okada et al. [3] introduced a fine wire electrical discharge machining using thin wire electrode.In wire electrical discharge machining process, proper distribution of spark location is essential to achieve the stable machining performance. But, it is difficult to accurately measure the division in spark location by the traditional branched electric current method where workpiece is considered as thin. Hence, they introduced a new method to analyze the distribution of spark location using a high-speed video camera. From this camera, locations of sparks are identified and analyzed through the recorded images. The machining criterion such as servo voltage, pulse interval time and wire running speed are significantly effects on the distribution of spark location.

Cabanesa et al. [4] introduced a methodology which facilitated to avert breakage of wire andunsteady situations as both of them reduces the performance of machining process and also causesreduction in the quality of components in wire electrical discharge machining. The given approach establishes the technique to be followed in an order for understanding the causes of breakage of wire and its unsteadiness. A series of pointers are provided in relation to discharge energy, ignition delay time, and peak current, so that we can evaluate the patterns of its unsteadiness or instability in a machining. With comparing the series of pointers with the previously calculated threshold values; breakage of wire risk can be seen, which is used to develop tactics for the better performance of WEDM process.

Thermal analysis of brass, copper and Bronze wire (FEA)

Brass Zn = 40%, Cu = 60%

Properties	**Unit**	**Value**
Density	Kg/m^3	8522
Thermal conductivity	W/m-K	110.7
Specific heat	J / kg-K	385
Modulus of Elasticity	G Pa	102-125
Bulk Modulus	G Pa	108
Poisson's Ratio		0.331
Melting temperature	^{0}C	930
Shear Modulus	G Pa	40
Solidus	0_C	785
Stress relief temperature (1 hr)	0_C	2600_C

VI. METHODOLOGY

For thermal modeling and FEA analysis thin wire of material like brass, copper and bronze has been selected and certain important parameters which are required for the modeling are computed in the tables below.

Cu wire

Properties	**Unit**	**Value**
Density	Kg/m^3	8954
Thermal conductivity	W/m-K	386
Specific heat	J / kg-K	383
Modulus of Elasticity	G Pa	117
Bulk Modulus	G Pa	123
Poisson's Ratio		0.355
Melting temperature	^{0}C	1084

Shear Modulus	G Pa	45
Solidus	0_C	890
Stress relief temperature (1 hr)	0_C	2550_C

Bronze – phosphorous

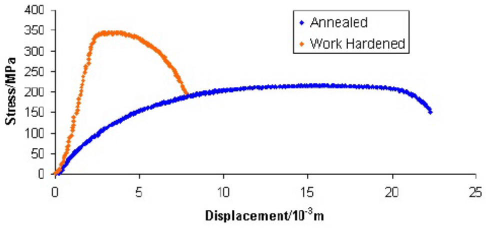
Properties	Unit	Value
Density	Kg/m^3	8780
Thermal conductivity	W/m-K	54 @ 20 ^0C
Specific heat	J / kg-K	355
Modulus of Elasticity	G Pa	96-120
Bulk Modulus	G Pa	112
Poisson's Ratio		0.34
Melting temperature	^0C	955
Shear Modulus	G Pa	44.8
Solidus	0_C	890
Stress relief temperature (1 hr)	0_C	2600_C

Thermal modeling of brass, bronze and copper wire

Parameter	Unit	Value
Peak current of electro-discharge	A	30
Voltage of electro discharge,	V	24.9
Duration of single pulse	µs	0.14, 0.28, 0.42, 0.56, 0.70, 1.1, 1.72
Wire radius	Mm	1
Convective coefficient	W/m^2 ^0C	3040
Temperature of the dielectric	0_C	21
Poisson' ratio		.31
Coefficient of linear thermal expansion	K-1	1.9×10^-5

VII. RESULT AND DISCUSSION

Temperature distribution at different pulse rate in micro seconds has been presented and also stress distribution for the wire against displacement has been shown in the Figure 7.1.



Graph showing stress against displacement for bronze in tensile test

Figure 7.1 Stress vs Displacement Graph

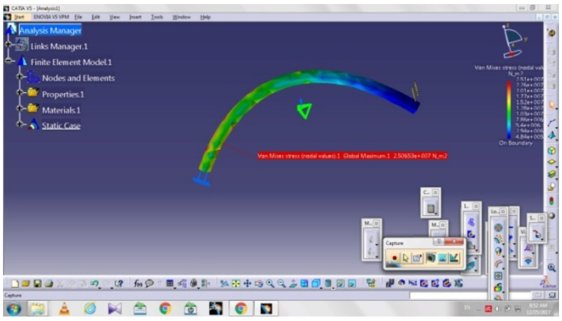


Figure 7.2 Temperature distribution in Copper Wire

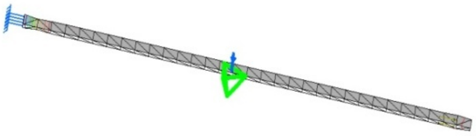
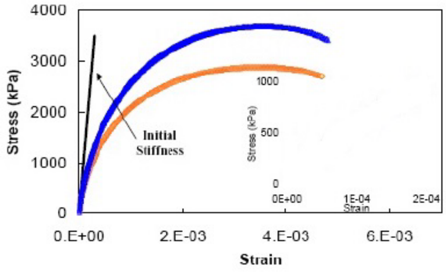


Figure 7.3 FEA Mesh of Copper Wire



Graph showing stress against displacement for bronze in tensile test

Figure 7.4 Stress vs Stain Graph

Temperature distributions at the end of the pulse time are shown to know the effects on WEDM. The temperature distribution during single discharge is calculated with the energy input constant parameter Ip= 30 A, voltage =24.9V with varying pulse time. At pulse time = 0.14 µs, corresponding temperature is 92.8 At pulse time = 0.28µs, corresponding temperature is 258.70C. At pulse time = 0.42 µs, corresponding temperature is 411.60C. At pulse time = 0.56 µs, corresponding temperature is 546.90C. At pulse time = 0.70 µs, corresponding temperature is 589. 50C. At pulse time = 1.4 µs, corresponding temperature is 870.80C. At pulse time = 1.63 µs, corresponding temperature is 11100C. Further increasing the pulse time is not possible because, at temperature 110900C, the brass wire melts.

VIII. CONCLUSION

Finite element modeling was carried out. Certain parameters such as spark radius, discharge current and discharge time period, 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 = 0.14 µs, corresponding temperature is 92.80C and maximum residual stress is 815 Mpa. At pulse time = 0.28 µs, corresponding temperature is 258.70C and .At pulse time = 0.42µs, corresponding temperature is 411.60C. At pulse time = 0.56 µs, corresponding temperature is 546.90C and the maximum compressive stress is 288Mpa in y-component, and maximum residual stress is 289 Mpa. . At pulse time = 0.70 µs, corresponding temperature is 589.5. At pulse time = 1.4 µs, corresponding temperature is 870.80C. At pulse time = 1.63 µs, corresponding temperature is 11100C and the maximum compressive stress is 428Mpa for ton=1.63µs in y-component, and maximum residual stress is 490 Mpa.

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