International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.4., 2015 (July-Aug)

RESEARCH ARTICLE

ISSN: 2321-7758

STUDY AND ANALYSIS OF WIRE ELECTRICAL DISCHARGE MACHINING (WEDM) THROUGH ANSYS AND FINITE ELEMENT METHOD (FEM)

AVINASH SHILPI*, EARNEST VINAY PRAKASH, PRABHAT KUMAR SINHA, MANISH KUMAR

Department of Mechanical Engineering, Shepherd School of Engineering and Technology,
Sam Higginbottom Institute of Agriculture Technology and Sciences,
Deemed University Allahabad (U.P.) INDIA

AVINASH SHILPI

ABSTRACT

New developments in the machining of materials have become a hard task for Electrical Wire Discharge Machining process used for machining an alternative materials in future. Wire electrical discharge machining (WEDM) is widely used in machining of conductive materials when precision is considered as a prime importance. This is an electro-thermal non-traditional machining process, where electrical energy is used to create the electrical spark and material removal takes place due to thermal erosion of work piece due to spark discharge. 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, EDM,WEDM, Gaussian Theorem, Residual stress, Thermal stress, Temperature

INTRODUCTION

Wire EDM process is mostly used for the processes of removal of unconventional materials. This is used for the production of shape and profile of hard materials difficult. Considering this variation is as distinctive processes of wire EDM process is mostly used for the processes of removal of unconventional materials. This is used for the production of shape and profile of hard materials difficult. Considering this variation is as distinctive processes of electrical discharge machining conventional. In line cutting, demand is growing for high-speed, high cutting speeds for machining accuracy Improve productivity and product getting high also for the excellence of the quality of work in process. In the process of EDM wire to travel always wire electrode made of thin copper, brass or tungsten in diameter, 0.05-0.3mm is used, which is precisely controlled by the CNC system. Here the role of the CNC is very important. The function of the CNC is to relax the thread from a first reel, and feed along the piece, and it takes a second coil. Generally wire speed varies from 0.1 to 10 m/min, and the feed is from 2to 6mm/ in. A DC current is used to generate high-frequency press for the wire and the work piece. The wire (electrode) is hold in tension device for decreases the likelihood of producing parts inaccurate. In the process of processing electric wire, the work piece and the tool is eroded and there is no direct contact between the work piece and the electrode, it reduces stress during machining.

WEDM INITIALLY has been developed by the manufacturing industry in the development since 1960. The technique is replaced with the electrode used in EDM machined. In 1974, DH Dulebohn follower introduced the automatic control system of the optical line that is the shape of the work piece by the wire EDM process. In 1975, it was popular rapidly, and its capacity was better understood the manufacturing industry. When the numerical control system Introduced in WEDM process this brought one most important development of the manufacturing process. Consequently, the large capacity of the process of EDM wire has been widely exploited for any machining through hole due to the wire, which must pass through the work piece. The common application of the process of wire EDM is the manufacture the stamp and extrusion dies, fixtures and gauges, prototypes, aircraft and medical components, tools and grinding wheel module. The symmetrical pattern of line cutting is as shown:

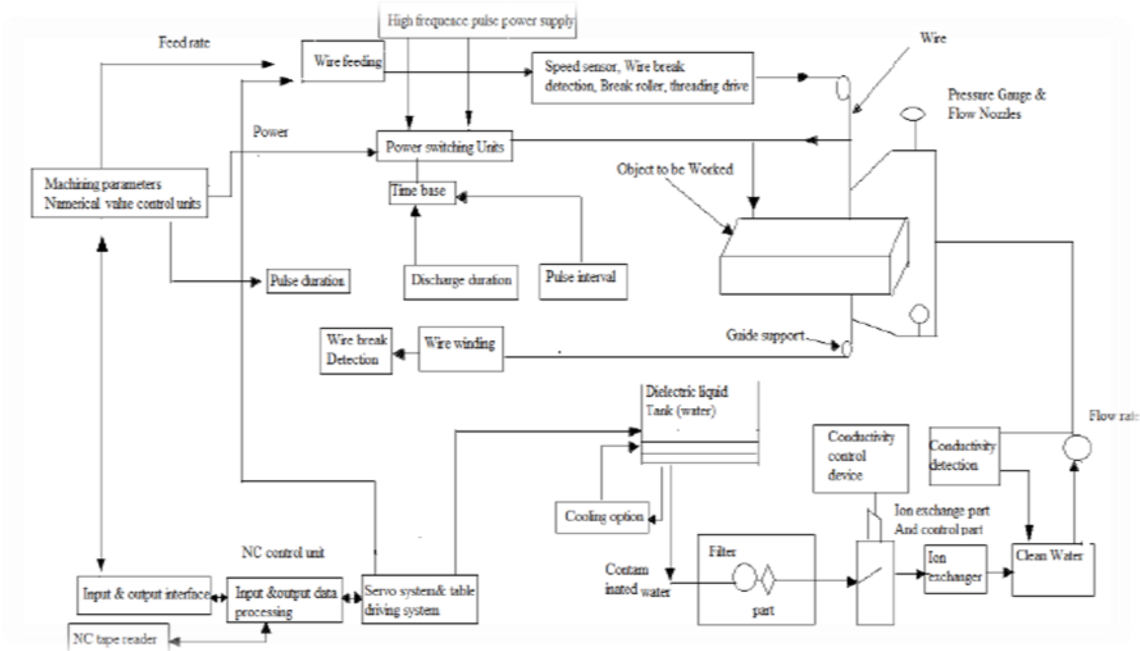


Fig-Schematic diagram of WEDM (Source: Dutta and Mahapatra)

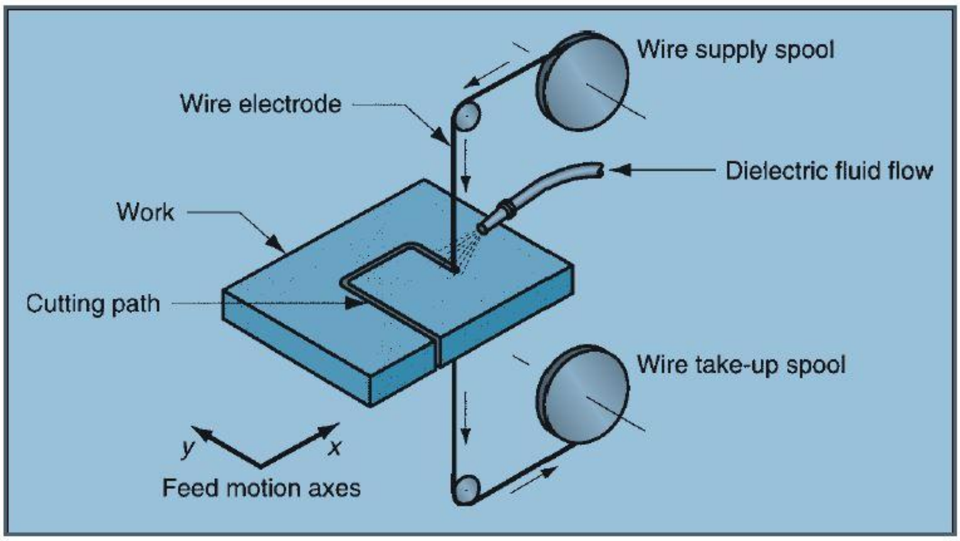


Fig- Wire Electrical Discharge machining process

Objective:

- To determine the stress distribution, displacement and temperature distribution in wire electrode tool of Wire Electrical Discharge Machining analysis through Finite Element Machining analysis.
- To develop a thermos structure model of wire electrode tool for analysing the effect of built-in temperature to the machining performance.
- Using new material for electrode to increase high melting point of tool

Wire Electrical Discharge Machining Process:-

The basic EDM process is really quite simple. An electrical spark is created between an electrode and a work piece. The spark is visible evidence of the flow of electricity. This electric spark produces intense heat with temperatures reaching 8000 to 12000 degrees Celsius, melting almost anything. The spark is very carefully controlled and localized so that it only affects the surface of the material. The EDM process usually does not affect the heat treat below the surface. With wire EDM the spark always takes place in the dielectric of deionized water. The conductivity of the water is carefully controlled making an excellent environment for the EDM process. The water acts as a coolant and flushes away the eroded metal particles.

Step used in WEDM process:

- **Spark Gap**

  Spark gap is known as space between work piece and electrode. To apply voltage and then spark will create throughout the space between these electrodes.

- **Kerf width**

  Kerf width is the sum of the wire diameter and double of spark gap. It measure by Infinite Focus Alicona machine

Part of Dielectric in WEDM Process:-

- **Removal process of waste particles** -

Waste cutting particle must be removed during machining from the erosion through dielectric.

- **Insulation** -

The main purpose of the dielectric is to insulate the work piece from the electrode.

- **Cooling**-

It avoid over heating of the electrode and generating wear. Dielectric must cool the both electrode and work piecedue to high temperature.

Thermal Model:

The discharge phenomenon in wire EDM can be modelled as the heating of the work piece by the incident plasma channel. The mode of heat transfer in solid is conduction.

Governing equation

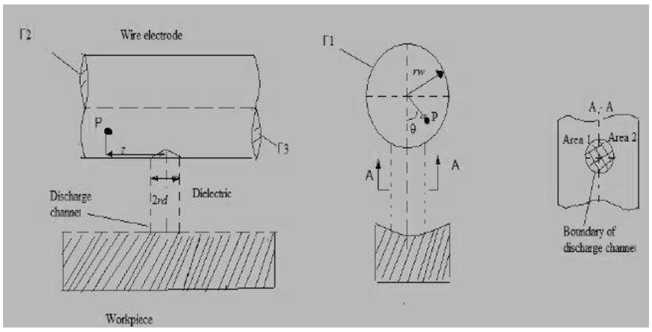


Fig 3

This is the equation for calculation of transient temperature distribution with in work piece. The differential governing equation of thermal diffusion differential equation in a model is governed by the following:

$$\frac{\partial}{\partial r}\left(kw\frac{\partial T}{\partial r}\right)+1/r^{2}$$

$$\frac{\partial}{\partial \theta}\left(kw\frac{\partial T}{\partial \theta}\right)+\frac{\partial}{\partial z}\left(kw\frac{\partial T}{\partial r}\right)+$$

$$q''' = \rho c\frac{\partial T}{\partial t}$$

Where *r* and are the radial and angle coordinates respectively, *z* is the axial coordinate, and ***c*** are the density and the specific heat of the wire material, ***KW*** thermal conductivity of the wire material and T is the temperature of the micro element in the wire.

BOUNDARY Condition:

Boundary condition is determine by mathematical equation for boundary area between area 1 & area 2

$$r = r_w$$

$$(rw \sin \theta)^2 + z^2 = r_d^2$$

r_d =radius of discharge channel

r_w = radius of radius

Γ1 = cylindrical boundary between wire and dielectric

From fig 3

Inside area 2, thermal equilibrium can be described as the following equations

If $\mathbf{r = r_w}$

and $(\mathbf{r_w \sin \theta})^2 + z^2 > r_d^2$

then $k_w \frac{\partial T}{\partial r} = h\,(T - T_0)$

where **h** = heat transfer coefficient

$\mathbf{T_0}$ = initial temperature of wire electrode

T = Temperature

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: Tungsten wire,

Properties of tungsten wire

Properties	Density	Thermal conductivity	Specific heat	Modulus of Elasticity	Bulk Modulus	Poisson's Ratio	Melting temperature	Shear Modulus
Unit	g/cm^2	W/m-K	J/kg-K	G Pa	G Pa		^0C	G Pa
Value	19.3	173	0.132	410	310	0.28	3422	161

Properties of Molybdenum wire

Properties	Density	Thermal Conductivity	Coefficient of linear thermal expansion	Young's modulus of elasticity	Poisson's ratio	Melting point	Shear modulus
Unit	kg /m3	W /m-K	K-1	G Pa		^0C	G Pa
Value	10280	139	4.8×10^{-6}	329	.31	2523	126

Heat Flux due to the wire electrode in a single spark

Assumed Gaussian heat distribution in this paper. If it is assumed that total power of each pulse is to be used only single spark can be written as follows

$$q(r) = \frac{k}{\pi R^2(t)} PVI \exp\left(-\frac{kr^2}{R^2 t}\right)$$

Where *q(r)* = heat flux at the radius of *r*

k = heat concentration coefficient (*k=4.5,* Kunieda et al. case)

R (t) = radius of arc plasma at the moment of *t*

P = energy distribution coefficient (P = *0.38*, Kunieda et al.)

V = voltage between anode and cathode during discharge occur

I = peak current

r = distance from the centre of arc plasma.

Spark Radius

In Wire Electrical Discharge Machining Spark radius is most important parameter for thermal modelling process. Experimentally measure is very difficult because spark radius is very short pulse duration (in micro second).

Semi empirical equation of spark radius termed as "equivalent heat input radius" which is function of

Discharge current = I (A)

Discharge on time = ton (µs)

It will be much realistic when compared with other approaches

Spark radius = $(R) = (2.04e^{-3}) I^{0.43} t_{on}^{0.44} \quad (\mu m)$

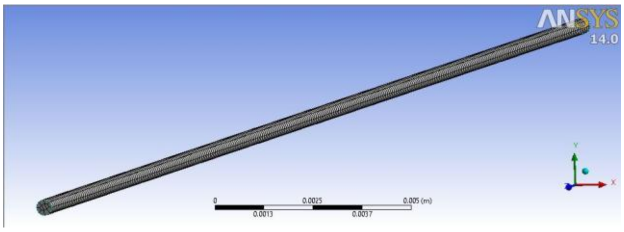
Finite Element Analysis Procedure using ANSYS software

Thermal analysis of Tungsten Wire, FEM analysis through ANSYS APDL

Material Dimension:-

Radius=0.06mm,

Length=304.8mm



ANSYS model confirmation

In this section we have firstly make a model of WEDM process for Tungsten 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 Tungsten wire, which is approximately same of Han et al. model. So we can say that we are proceeding in right way. Thermal modelling has done in using ANSYS

FEM analysis:

Thermal modelling of wire EDM for single spark in Tungsten wire

Main parameters of the thermal analysis (analysis parameters)

Parameter	Unit	Value
Peak current of electro- discharge	A	30
Voltage of electro discharge	V	28
Duration of single pulse	µs	0.06, 0.16,0.26,0.36, 0.52, 0.58, 1.2, 1.82
Wire radius	Mm	0.06
Temperature of the dielectric	^{0}C	21
Poisson' ratio		0.28
Coefficient of linear thermal expansion	K^{-1}	4.5

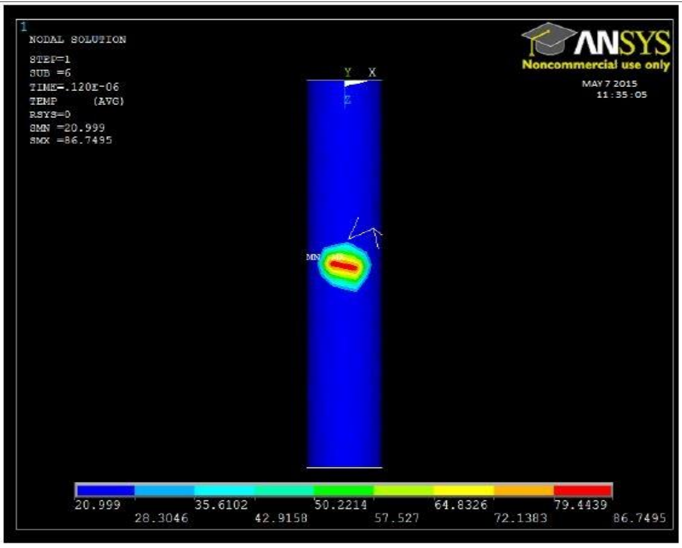


Fig- Temperatur distribution in Tungstenwire with V= 28, I=30A, P=0.35, ton=0.06µs

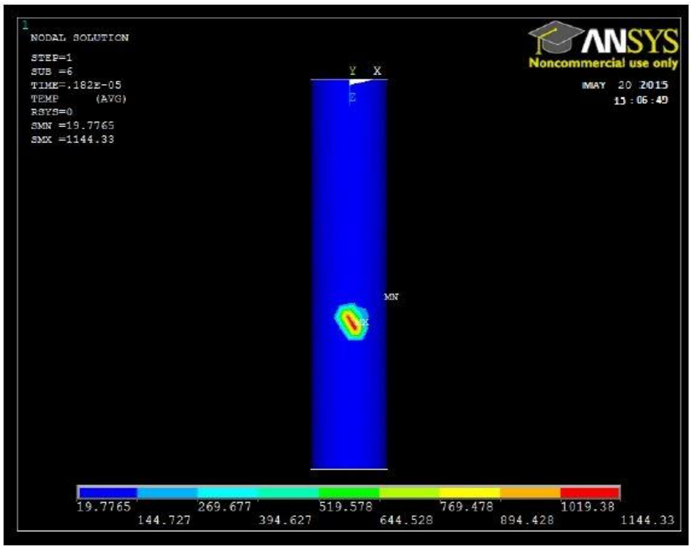


Fig- Temperatur distribution in Tungstenwire with V= 28, I=30A, P=0.35, ton=1.82µs

Structural modelling of WEDM in molybdenum wire

In this section we have firstly make a model of WEDM process for Tungsten 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

Parameters used for structural analysis in WEDM process

Parameter	Units	Value
Radius of Wire	Mm	0.125
Length of Wire	M	0.1
Tension	N	13.7295
Initial Temeprature	K	273
Working Temperature	K	390

Fig - Graph of displacement

Thermo-structural analysis of Wire Electrical Discharge Machining in TUNGSTEN wire

Thermal stress modelling of micro wire EDM for single discharge

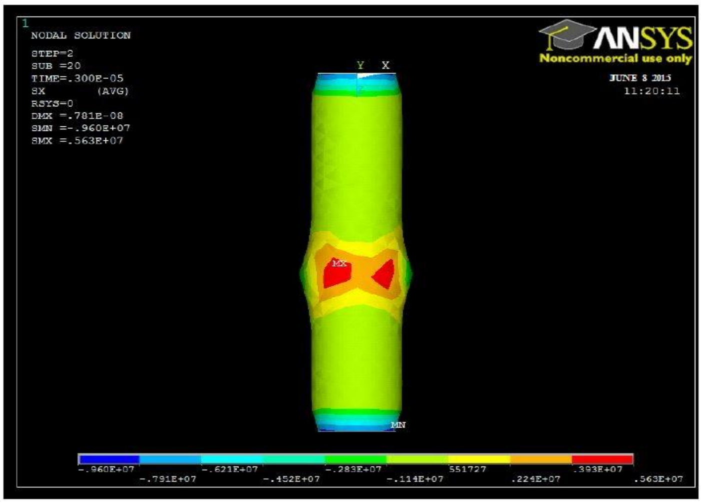


Fig- Thermal stress in X-component atton=0.12 µs

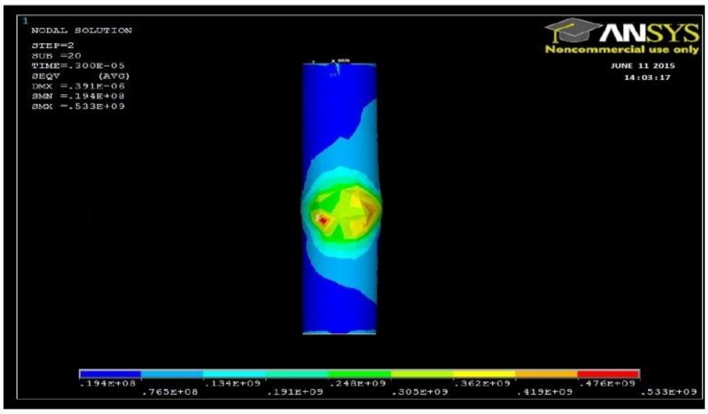


Fig- Residual stress at , ton=3 µs

DISCUSSION THE RESULT

Pulse time at end of temperature distribution are shown in Figure to know the effect of Wire Electrical Discharge Machining. Temperature distribution during single discharge is calculated with the energy input constant parameter I= 30A, voltage =28V 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 3422^{0}C, the Tungsten wire melt. Distributions of stress in WEDM process, listed at the end of heating cycle are presented. Here, Heat flow of Gaussian distribution is used to calculate the temperature distribution. After that varying the parameter that is the pulse duration, and the study of thermal stress are presented. Fig shows the different pulse time of thermal stress. 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 is because during the pulse duration, the flow of heat supplied to the tool electrode for a very short period (in µs).The maximum compressive stress is 563MPa for ton=0.12µs in X-component, and maximum residual stress is 778 MPa. The maximum compressive stress is 288Mpa for ton=0.52µs in Z-component and maximum residual stress is 288 MPa. The maximum compressive stress is 425Mpa for ton=1.82µs in Z-component and maximum residual stress is 533 MPa.

Conclusion

3D FEM 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 modelling 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 86.75^{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 ton=1.82µs in Z-component, and maximum residual stress is 533 Mpa. In Further increasing the pulse time is not possible because, at temperature 3422^{0}C, the Tungsten melt but this is much better than Brass wire and any other wire because of Tungsten have a high melting point.

REFERENCE

[1]. M.R. Patel, A. Barrufet, P.T. Eubank, D.D. DiBitonto, Theoretical models of the electrical discharge machining process—II: The anode erosion model, Journal of Applied Physics 66 (9) (1989) 4104–4111.

[2]. Speeding, T. and Wang, Z., (1997), parametric optimization and surface characterization of wire electrical discharge machining process, Precision Engineering, 20, pp.5-15.

[3]. D.S. Kumar, Heat and Mass Transfer, 10th edition, S.K. Kataria& Sons, Delhi, 2000.

[4]. V. Yadav, V. Jain, P. Dixit, Thermal stresses due to electrical discharge machining, Int. J.Mach. Tools Manuf. 42 (2002) 877–888.

[5]. Saha, S., Pachon, M., Ghoshal, A.and Schulz d, M.J. (2004) Finite element modeling and optimization to prevent wire breakage in electro-discharge machining Mechanics, Research Communications, vol. 31,pp. 451–463.

[6]. Ramakrishnan, R. and Karunamoorthy, L.,(2006), Multi response optimization of wire EDM operations using robust design of experiments, International journal of advanced manufacturing technology, 29, pp. 105–112.

[7]. Allen, X. Chen, Process simulation of micro electro-discharge machining on molybdenum, Journal of Materials Processing Technology 186 (2007) 346–355.

[8]. Cabanesa, I., Portilloa, E., Marcosa, M. and Sa´nchezb, J.A. (2 0 0 8) An industrial application for on-line detection of instability and wire breakage in wire EDM, journal of materials processing technology, vol. 1 9 5, pp. 101–109.

[9]. H.Singh, R.Garg Effects of process parameters on material removal rate in WEDM, Journals of achievements in materials and manufacturing engg.Vol. 32, issue 1, jan 2009.

[10]. Datta, S. and Mahapatra, S.S. (2010)Modeling, simulation and parametric optimization of wire EDM process using response surface methodology coupled with grey-Taguchi technique, International Journal of Engineering, Science and Technology, vol. 2, pp. 162-183.

[11]. Donald B.Moulton (Usa)., Edm Network Sugar Grove, IL USA Fundamentals of WEDM pp 3-7

[12]. Gautamkocher, Karan Chopra et al "Investigation of Surface integrity of AISI D3 tool steelAfter EDM" International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2,Issue 4, April 2012

[13]. Sorabh., Manoj.,NeerajNirmal.,(Jan-Feb 2013)., A literature review on optimization of machining parameters in wire edm.pp-492-494.

[14]. ANSYS Advanced analysis procedure manual, ANSYS 14.0, ANSYS Inc.