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WIRE FAILURE ANALYSIS IN WIRE-EDM PROCESS

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ABSTRACT

In wire-EDM process wire failure is a major problem and it increases machining processing time, decreases machining efficiency and the quality of the machined surface. This paper deals with experimental and theoretical study of wire-EDM process. Wire erosion rate, which leads to wire failure is analysed using experimental results obtained by machining Mild steel, OHN steel and HCHCr steel work materials using bare brass and zinc coated brass wires. Temperature and stress distribution on work and tool during machining and its effect on performance on wire-EDM process is reported. SEM, EDAX and ANN results are analysed to study the failure characteristics of wire-tool.

Key words: Wire-EDM, Wire Failure, ANN

1. INTRODUCTION

The early researchers made an attempt to reduce the rupture risk of wire by selecting longer pulse off time. But this decreases the machining rate and also is unable to completely avoid the wire rupture [1]. Present authors have reported the effect of variation of input parameters like discharge current and discharge time on process parameters like surface finish, material removal rate, wire wear rate, cutting speed, power consumption and wire erosion rate [2][3][4]. In early studies, FEM package is used to carry out the thermal analysis of cutting tools [5][6].

In this paper an attempt has been made to co-relate the experimental and theoretical results to study the failure of wire tool in wire-EDM process.

2. EXPERIMENTATION

Machining tests were conducted on work materials of varying hardness like Mild steel, OHN steel and HCHCr steel. Bare brass and zinc coated brass wires are used as tool to study the machining process on Electra elcut-334 machine. Input parameters are recorded and plotted. Wire erosion rate, the ratio of material removal rate to wire wear rate, is analysed to study the failure characteristics of tool.

SEM photographs and EDAX results taken on machined work surface and wire surface are studied.

3.THERMAL ANALYSIS

Temperature and stress distribution on work and tool during machining has significant effect on tool wear characteristics in wire-EDM process. Using a powerful FEM package, a three dimensional model of wire-EDM process consisting of a work piece, a wire tool separated by a spark gap flooded with the dielectric fluid is generated. When a pulsed current is applied in the gap between the work piece and the tool, the spark is generated in the gap between them.

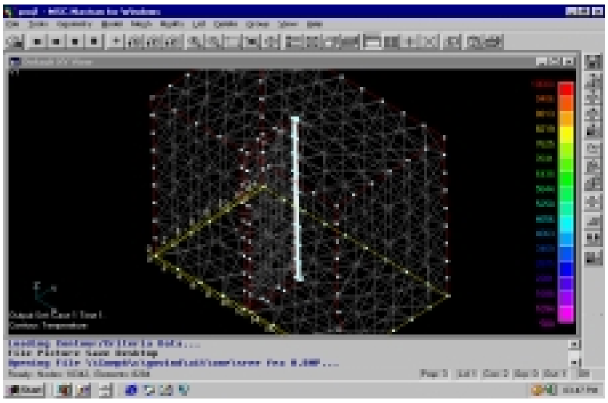


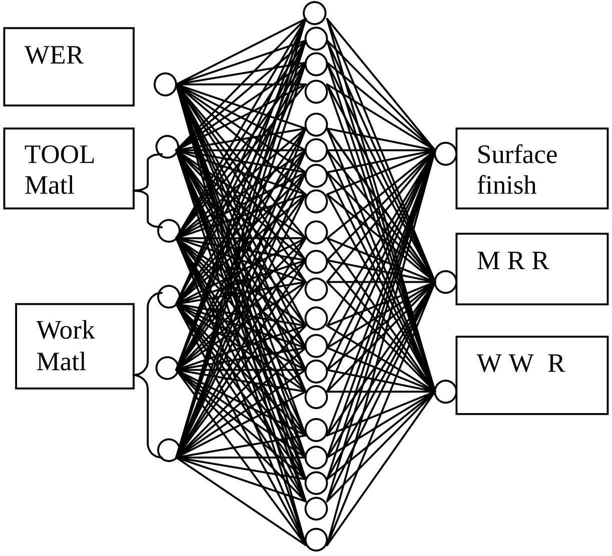
Figure1: Three-dimensional wire frame model of work piece with wire and dielectric in wire EDM process

The analysis is made by generating the stipulated working conditions imposed on the tool. At the selected area with the spark induced spark temperature is assumed as 10000^0c. Heat flux is applied corresponding to the discharge current and pulse interval.

Heat transfer occurs when there is a temperature difference with in a body, between a body and its surrounding medium. Thermal analysis is used to determine the temperature distribution in the work part and tool.

The wire under tension is progressed into the work part during wire-EDM process. The stresses developed due to tensile load acting on wire tool are analysed. Further the combined effect of thermal stresses and tensile stresses on work and tool are analysed.

4.ARTIFICIAL NEURAL NETWORK APPLICATION



Input layer with 6 neurons   Hidden layer with 20 neurons   Output layer with 3 neurons

Figure 2: Artificial Neural Network Model

Figure 2 illustrates the artificial neural network designed to study the wire erosion in wire-EDM process. The process of designing a neural network is an iterative process. In this theoretical study, wire erosion rate, the ratio of material removal rate to wire wear rate, two types of tool materials and three types of work materials of varying hardness are taken as independent input variables. Correspondingly six neurons are chosen in the input layer. In output layer, neurons representing the process parameters such as surface finish, material removal rate and wire wear rate are chosen. There exists a relation ship between the number of variables involved and number of hidden layers [7]. As the number of variables increases the number of hidden layers also increases.

Back propagation algorithm provides computationally efficient method for training artificial neural network [8].

Activation unit j in the hidden layer $X_j^h = \sum W_{ji}(X) + b_i$
where i = 1to 6 is the neurons in the input layer and
j = 1 to 20 is the neurons in the hidden layer.
Output signal from unit j in the hidden layer
$\phi_j^h = 1/(1+\exp(-X_j^h))$
Activation unit k in the output layer $X_k^o = \sum W_k^j \phi_j^h$
Mean square error for the k^th output $E = (1/3 \sum d_k - o_k)^2$
Where d_k is the actual output o_k is the predicted output
If $d_k \neq o_k$ update the weights in the hidden layer so that o_k moves towards d_k

Initial weight $\Delta Wt = \eta * X * o_k$ where η is the learning rate parameter.

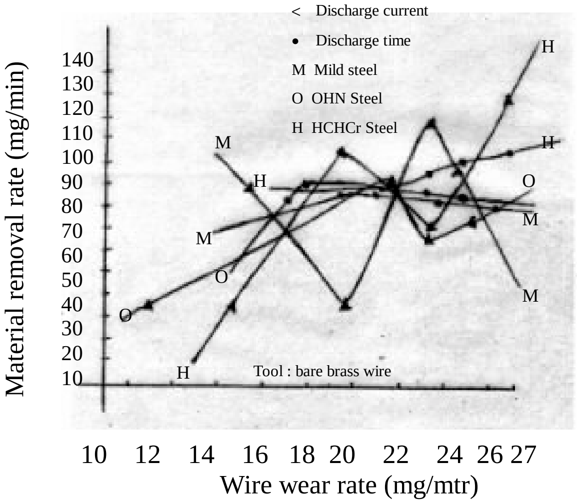


Figure3: Variation of material removal rate with wire wear rate when machined with bare brass wire

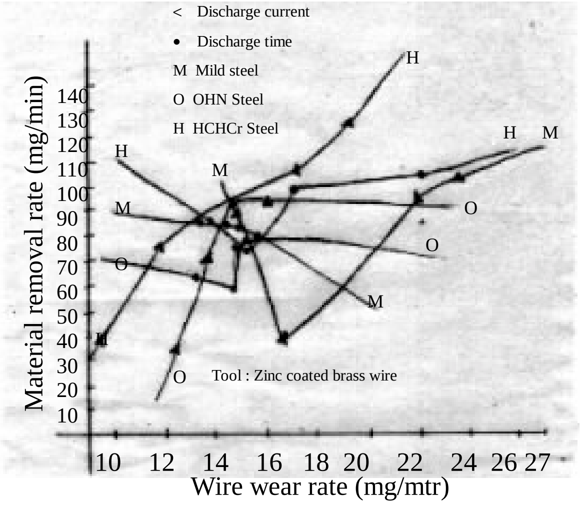


Figure4: Variation of material removal rate with wire wear rate when machined with zinc coated brass wire

Figures 3 and 4 show that the material removal rate decreases with increased hardness for lower rate of wire wear. When machined with bare brass wire, at higher rate of wire wear material removal rate increases even for harder materials. With both bare brass and zinc coated brass wires wear caused by the increased discharge time has no much effect on material removal rate, where as the increase in the rate of wear of zinc coated brass wire due to change in discharge current results in increased material removal rate as shown in figure 4.

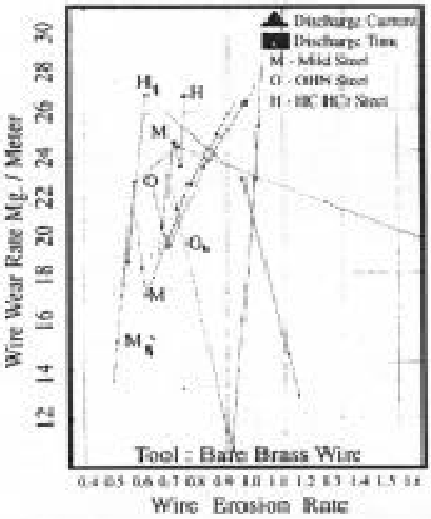


Figure5: Variation of wire wear rate with wire erosion rate when machined with bare brass wire

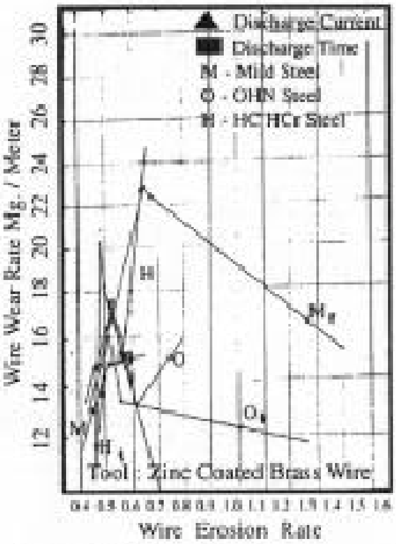


Figure 6: Variation of wire wear rate with wire erosion rate when machined with zinc coated brass wire

Figures 5 and 6 illustrate the variation of wire wear rate with increased wire erosion rate when machined with bare brass and zinc coated brass wires. Wire wear rate shows the same trend as material removal rate with increased wire erosion rate due to varied discharge current, where as with increased wire erosion rate due to varied discharge time, wire wear rate shows increasing trend. Zinc coated brass wire performs better when compared to bare brass wire because of its low wear rate. Although the material removal rate increases with an increase in discharge current care should be taken to limit it as it increases the wire wear rate also which may lead to the breakage of the wire assisted by the imposed stressed condition in the wire during machining.

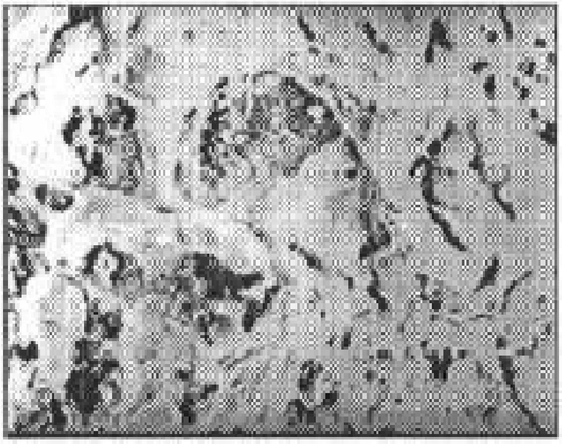


Figure 7: SEM photograph of bare brass wire used to machine HCHCr steel work piece at 6 amperes of discharge current

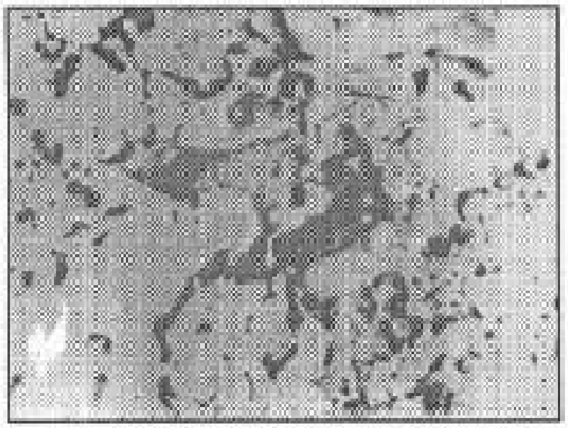


Figure 8: SEM photograph of zinc coated brass wire used to machine HCHCr steel work piece at 6 amperes of discharge current

From figures 7 and 8 it is observed that crater formed on the bare brass wire surface is severe with increased work material hardness for the same.

With the uncoated brass wire also the deterioration of work surface at higher discharge current is observed. But the damage of the work surface is observed to be less with zinc coated brass wire compared with bare brass wire.

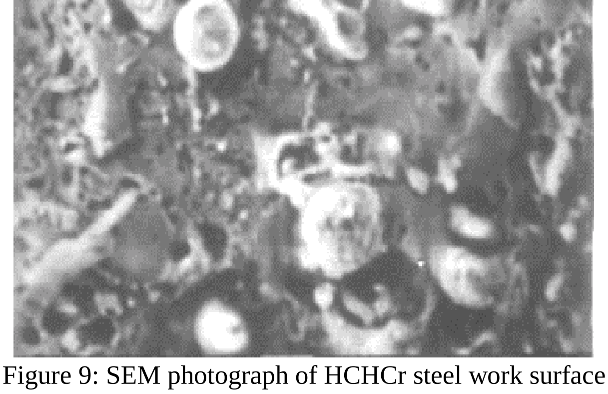


Figure 9: SEM photograph of HCHCr steel work surface machined with bare brass wire at discharge current 8 Amperes

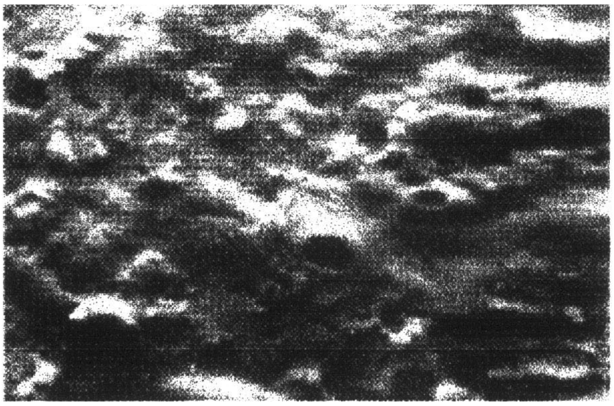


Figure 10: SEM photograph of HCHCr steel work surface machined with zinc coated brass wire at 8 Amperes

From the EDAX images shown in figures 11 and 12, it is found that tool material is transported on to the work surface and from the work, iron is transported on to the tool surface, even though there is no physical contact between work and tool in wire-EDM process. This affects the wire tool properties, physical parameters and tool behavior. The properties of the machined surface are also affected by the transportation of the tool material on to the work [9]. Shock impulses in the spark gap causes the detached work particles to strike the work surface and weld on to the wire surface.

Figure 13 illustrates the distribution of temperature in the cutting region. Different colors illustrate the range of temperature at different regions. Maximum temperature is observed near the spark area.

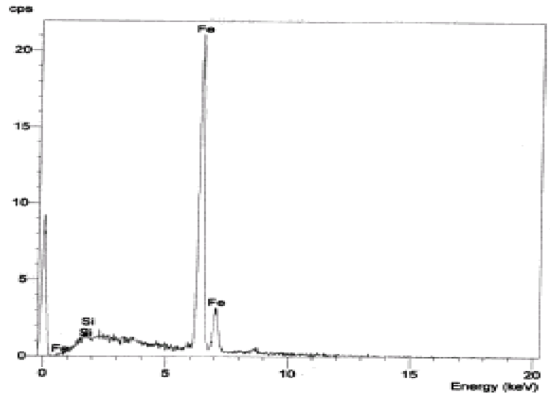


Figure 11: EDAX image of Mild steel work surface machined with zinc coated brass wire

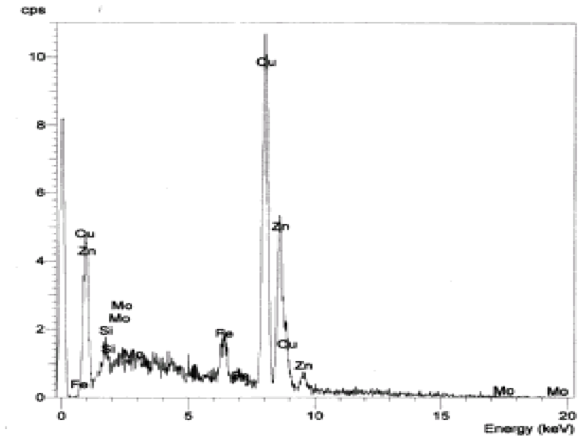


Figure 12: EDAX image of zinc coated brass wire used to machine Mild steel work piece

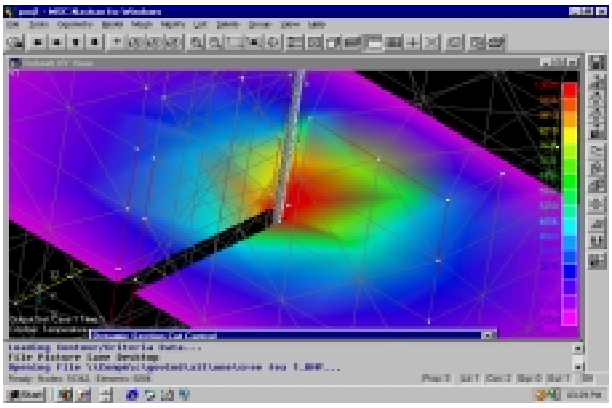


Figure 13: Temperature distribution on the work piece in the machining region

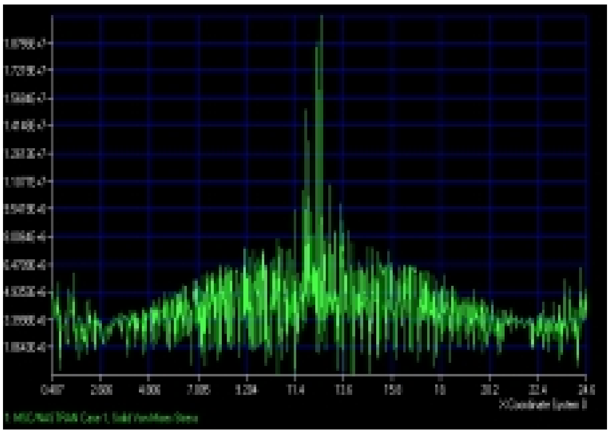


Figure 14: Variation of combined stresses during machining

The wire under tension with 800gm/cm2 (163N) is fed against the work piece during machining under specified discharge current and discharge time conditions. Heat generated and the force induced due to wire tension and imposed pulsed current during wire-EDM, results in the development of dynamic stresses in the machining process. Figure 14 illustrates the variation of combined stresses in the work piece along the cross section of the machining point.

Table 1: Comparison of actual and predicted values of process parameters from ANN for Mild steel and bare brass wire work and tool combination

WER= 1.61	Actual value	Predicted value
Surface finish (Microns)	0.40	0.48
Material removal rate (mg/min)	36.68	36.72
Wire wear rate	19.68	16.42

From Table 1 it is observed that the experimental results and predicted values obtained from artificial neural network model are compatible with one another. Artificial neural network analysis helps to find optimum process parameters theoretically for the safe working of the EDM process preventing the possibility of any physical failure of the wire tool.

6. CONCLUSION

1. Wire failure occurs in wire-EDM process as a result of severity in wire wear rate, which is a function of discharge current and discharge time.
2. For the same material removal rate, the wire wear rate is observed to be lower with zinc coated brass wire when compared to bare brass wire resulting in higher wire erosion rate.
3. The zinc coated brass wire performs better when compared to bare brass wire because of its low wear rate and lower breakage with increased discharge current conditions.
4. The transportation of the tool material on to the work and the transportation of the tool material on to the tool is observed in wire-EDM process. It affects the properties of the machined work surface and the working tool.
5. Finite element analysis helps to study the temperature and stress distribution on tool and work in wire-EDM process. This helps to select the optimum machining conditions, with a safe thermal and stressed condition, minimum tool breakage.
6. The computed values obtained from ANN technique are compatible with the experimental results and is helpful in selecting the optimum machining conditions for the process variables in multi- variant EDM process.

7. REFERENCES

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