An Experimental Study on Tool Materials For Wire Eletric Discharge Machine

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Abstract— **Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. The applications of WEDM are in automobiles, aero-space, medical instruments, tool and die industries. In the recent years an extensive research has been carried out on WEDM relating to improving performance measures, optimizing the process variables, monitoring and controlling the sparking process, simplifying the wire design and manufacture, improving the sparking efficiency by various researchers. This process decreases the machining rate and also is unable to completely avoid the wire rupture. This paper is focused on developing a new tool material through powder metallurgy on the objective of avoiding wire rupture in WEDM. In this paper an attempt has been made of theoretical results to the study the properties of the wire EDM tool materials and theoretical approach is carried out in this work for evaluating the unique properties of already used wires in WEDM with the new developed tool material.**

Keywords— Wire EDM, Tool materials, wire failure.

I. INTRODUCTION

Wire electrical discharge machining is a form of EDM in the category of non–traditional machining process. This is widely used for die–steel in die manufacturing. Electrically conductive materials are cut using electro–thermo mechanism by a series of discrete discharges between the wire electrode and the work piece in the presence of dielectric fluid. An extremely high temperature occurs in the region where discharge occurs causing melting and removal of work surface. The dielectric fluid flashes the debris from machining zone. This method is widely accepted for producing components with intricate shapes and profiles. However, WEDM utilizes a continuous travelling wire electrode made of thin copper, tungsten or brass wire of diameter ranges 0.05–0.03 mm, that have the capacity to produce a very small corner radius. A mechanical tensioning device is used to produce tension in the wire. Since, there is no direct contact between the work piece and the wire causing elimination of much stress between them [1]. WEDM process can be successfully employed to cut electrically conductive materials independent of their hardness, shape and toughness [2-3]. In addition, the WEDM process is able to machine high strength temperature resistant materials (HSTR) and heat treated steels. Fig. 1 shows the working process of the WEDM.

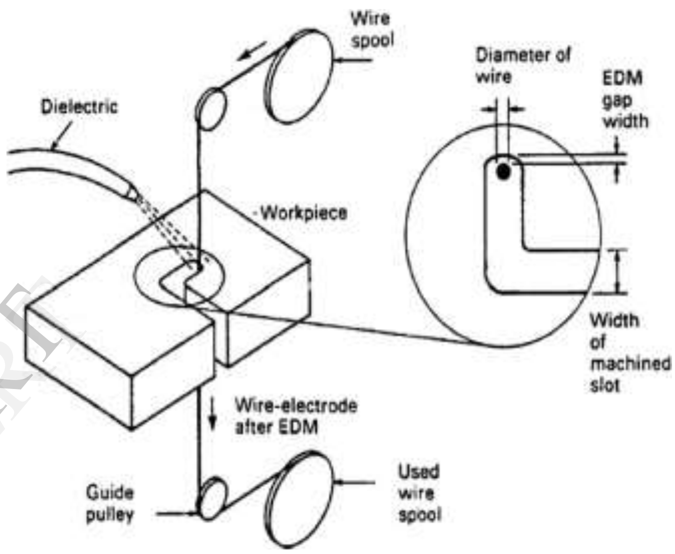
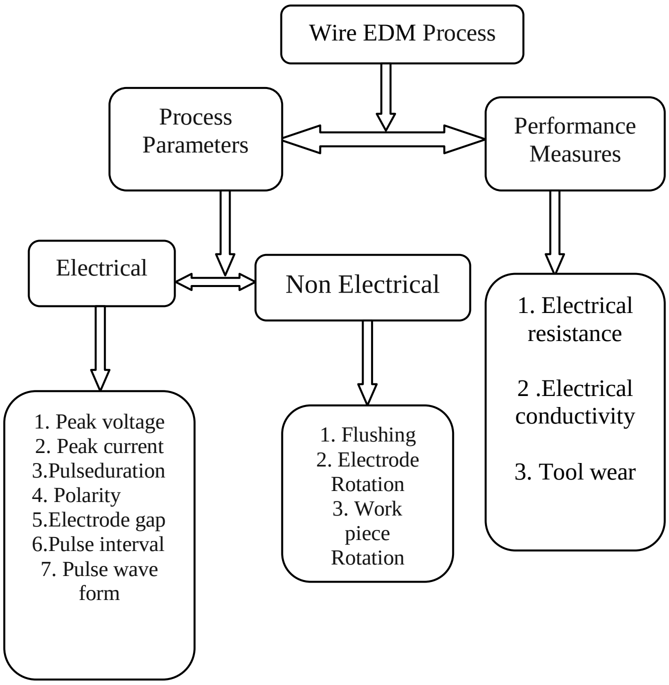


Fig 1 working process of WEDM

A. Electrical Parameters

Major electrical parameters are discharge voltage, peak current, pulse duration and pulse interval, electrode gap, polarity, and pulse wave form. Discharge voltage is related to spark gap and breakdown strength of the dielectric fluid. The open-gap voltage before electric discharge increases until ionization path is created between work piece and electrode. Once the current starts flowing, the voltage drops and stabilizes at the working gap level. Thus a higher voltage setting increases the gap, which in turn improves the flushing conditions and helps to stabilize the cut. Peak current is the amount of power used in discharge machining and is considered as most significant process parameter. The current increases until it reaches a preset level during each pulse on-time, which is known as peak current. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area. This is the most important parameter because the machined cavity is a replica of tool electrode and excessive wear will hamper the accuracy of machining. New improved electrode materials like graphite, can work on high currents without much damage [4].



The three requirements for high-speed cutting and high precision machining are: (i) mechanical strength at high temperatures for good heat resistance, (ii) high electrical conductivity for good calorification resistance, and (iii) high heat conductivity for efficient heat release. In addition, the wire electrodes have to be very straight to allow automatic threading and they need improved drawability and stability during commercial production to achieve good cost performance. [5]

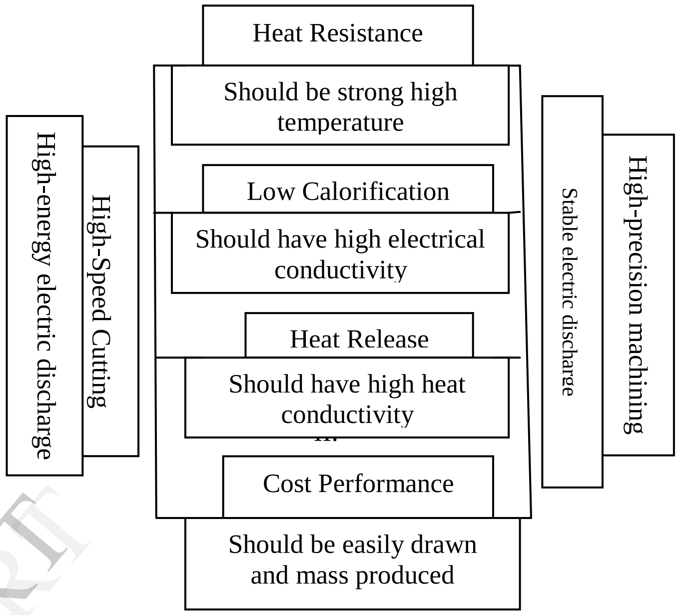


Figure.2 Performance Requirements for a Wire electrode

B. Tool material (electrode):

Engineering materials having higher thermal conductivity and melting point are used as a tool material for Wire EDM process of machining. Copper, graphite, copper-tungsten, silver tungsten, copper graphite, zinc and brass are used as a tool material (electrode) in Wire EDM. They all have good wear characteristics, better conductivity, and better sparking conditions for machining. Copper with 5% tellurium, added for better machining properties. Tungsten resist wear better than copper and brass. Brass ensures stable sparking conditions and is normally used for specialized applications such as drilling of small holes where the high electrode wear is acceptable (Metals Handbook, 1989). The factors that affect selection of electrode material include metal removal rate, wear resistance, desired surface finish, cost of electrode material manufacture and material and characteristics of work material to be machined.

C. Properties Required For Wire Electrodes And Developmental Objectives

Generally, wire electrodes should satisfy the following : (i) accurate machining, (ii) high cutting speed for high productivity Figure 2 summarizes the performance requirements for a wire electrode. The electric discharge must be stable for high-precision machining and high energy for high-speed cutting.

II. RESEARCH BACKGROUND

Many researchers have worked in WEDM their findings include surface softening, effect of process parameters on surface finish and material removal rates. The common conclusions of all these studies focused on improving surface finishing and metal removal rate by changing the operating parameter such as pulse on time, pulse off time. kerf width, wire speed wire tension etc. comparatively, very few studies have been undertaken to avoid wire breakage by using coated wire electrodes and developing new electrode material. jatinder kapoor et al (2010) evaluate EDM wire from copper to brass and from brass to various coated wire, which has helped make wire EDM machining, the method of choice for high-speed production applications, as well as applications requiring improved contour accuracy and improved surface finishes Roger kern (2008) recommended the way of selecting material for electrode by examine the properties of metallic and graphite electrode materials [6]. Hiromitsu Kuroda et al (2003) studied composition of core material for coated wire electrodes with a composite structure, a zinc concentration enhancing technique and a control technique for the structure [7]. Seigi Aoyama et al (1999). developed two types of coated wire electrodes, the HIF electrode for high-speed and accurate cutting, and the HIE electrode for super-high-speed cutting [8]. Roger kern examined causes of wire breakage and acknowledged some common myths of improving wire EDM productivity [9]. Rajurkar.K.P et al (2008) describes an on-line WEDM monitor, and proposes a control strategy to prevent wire rupture by analyzing the large number of sparking frequency which is correlated with the wire breakage phenomena [10]. B.J. Ranganath et al (2003) analyzed the failure characteristics of wire tool with the help of SEM, EDAX and ANN results [11]. Bhola Jha et al (2011) reported a review on the research relating to EDM electrode design and its manufacturing for improving and optimizing performance measures and reducing time and cost of manufacturing [12]. Current researchers have explored a number of ways to improve electrode design and devised various ways of manufacturing. This paper deals with theoretical approach of developing new electrode material through powder metallurgy and correlate the tool wear with electrical resistances.

III. EXPERIMENTATION

A. *Material Selection*

The selection of the most appropriate electrode material is a key decision in the process plan for any EDM job. Properties of different electrode materials and their influence on EDM performance as well as on fabrication of electrodes have been summarized in EDM handbooks. The important variables to be considered for selection of electrode material are material removal rate, tool wear rate, surface roughness, machinability and material cost. Electrode material should have the basic properties like electrical and thermal conductivity, a high melting temperature, low wear rate, and resistance to deformation during machining. Electrode materials fall into two main categories: metallic and graphite. The primary advantage of metallic electrode materials is their electrical conductivity and mechanical integrity. Mechanical integrity is especially important in both sharp corner and poor flushing conditions [12]. Pure copper powder is used in the electrical and the electronics industries because of its excellent electrical and thermal conductivities. Copper can produce very fine surface finishes, even without special polishing.

B. *Particle size:*

Generally, the smaller the particle size, the better the mechanical properties of the copper, resulting in finer detail, better mixing, and better work piece surface finish.

TABLE 1 PHYSICAL AND CHEMICAL PROPERTIES OF COPPER

Physical State	Solid
Form	Spherical particles
Color	Reddish Brown
Odour	Odourless
Boiling Temperature	2324ºC
Melting Temperature	1083ºC
Density	8.93 m/cm³

Due to the combination of its high density, melting point and high wear resistance, tungsten has been selected as electrode material. It is the important to note that Tungsten has poor electrical conductivity, cuts much slow than Brass or Copper.

TABLE.2 PHYSICAL AND CHEMICAL PROPERTIES OF TUNGSTEN(W)

Physical State	Solid
Form	Irregular Fine particles.
Color	Grey
Odour	Odourless
Boiling Temperature	5930ºC
Melting Temperature	3370ºC
Density	19.3 gm/cm³

Copper Tungsten combines the high electrical conductivity of copper with the high melting point of tungsten. The combination of these two metals creates an electrode material with very good wear properties. Copper Tungsten is unmatched for its wear resistance, holds up very well in sharp corners, and is readily machined and ground without the burr issues associated with Copper. Copper Tungsten cannot be manufactured by conventional alloying techniques, since the Copper would vaporize before the Tungsten began to melt. That is why Copper Tungsten is made by the powder metal process. Copper and Tungsten powder are pressed into a pre-form and then sintered. During sintering, the material shrinks by approximately 25% and great care must be taken to avoid porosity, which is a common defect in some Copper Tungsten electrodes. Copper Tungsten is generally sold in the 70W:30Cu grade. It is possible to purchase Copper Tungsten with different ratios. A higher copper content would improve the surface finish and cutting speed. A lower Tungsten content would increase the strength of the wire and gives more wear resistance

TABLE.3 WEIGHT RATION OF CU AND W

Sl. No	Weight ratio in Grams		Applied pressure in kn/m^2	Time in min.
	Cu	W		
1.	70	30	10	10
2.	75	25	10	15
3.	80	20	12	20
4.	85	15	15	25
5.	90	10	17	30
6.	95	5	18	40

C. Billet Preparation

Atomized copper powder is selected as base material and Tungsten is added in the weight ratio shown in table.1 to prepare the billet. The metal powder mixer is loaded into the die and pressed in the form of billet by help of Universal Testing Machine. Copper based billet is so soft than others so pre heat is need to handle freely.Table2show the preheat temperature of the billets. Fig 2 shows the billet preparation by using universal testing machine.

Fig 2 Billet preparation

TABLE.4 PRE HEAT TEMPERATURE

Sl.No	Weight ratio		Temperature In °c	Time in hours
	Cu	W		
1.	70	30	200	1hr
2.	75	25	200	1hr
3.	80	20	220	1hr
4.	85	25	220	1hr
5.	90	10	240	1hr
6.	95	5	240	1hr

D. SINTERING

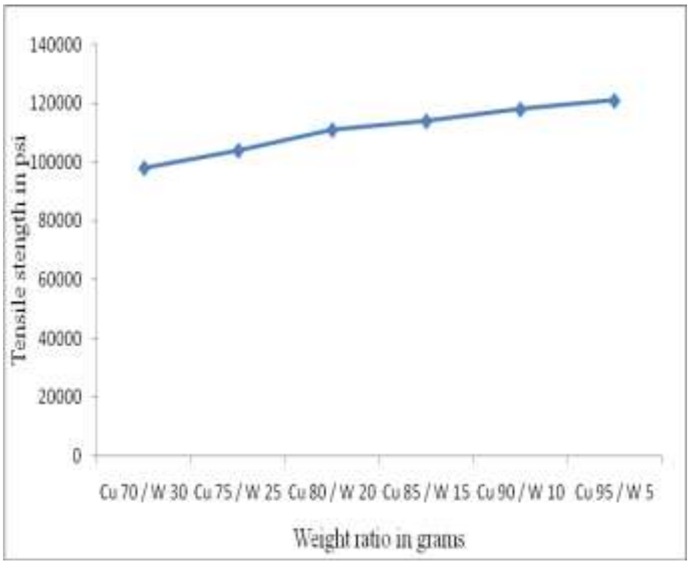
Sintering is a method used to create objects from powders. It is based on atomic diffusion. Diffusion occurs in any material above absolute zero, but it occurs much faster at higher temperatures. In most sintering processes, the powdered material is held in a mold and then heated to a temperature below the melting point. The atoms in the powder particles diffuse across the boundaries of the particles, fusing the particles together and creating one solid piece, because the sintering temperature does not have to reach the melting point of the material.

Table.5 SINTERING TEMPERATURE

Sl. No	Weight ratio		Temp. in °c	Temp. Maintaining Duration in hours
	Cu	W		
1.	70	30	500	10
2.	75	25	500	10
3.	80	20	600	10
4.	85	25	600	10
5.	90	10	700	10
6.	95	5	700	10

IV. ANALYSIS

After sintering each billets are cleaned for measure the hardness number in Rock Well hardness testing machine. From the Rockwell hardness number chart, tensile strength of each billet is calculated. The graph 1 shows the tensile strength variation occurs when changing the weight ratio. Normally copper has good tensile property that shows in the deviation by increasing the copper weight ratio.



Graph 1 Weight ratio Vs Tensile strength

A. Formuation And Corelation

Resistivity of Copper = 1.68 x 10^{-8} Ω

Resistivity of tunsten = 5.6 x 10^{-8} Ω

R=ρ*l* / a

Where,

R = Resistance in Ω

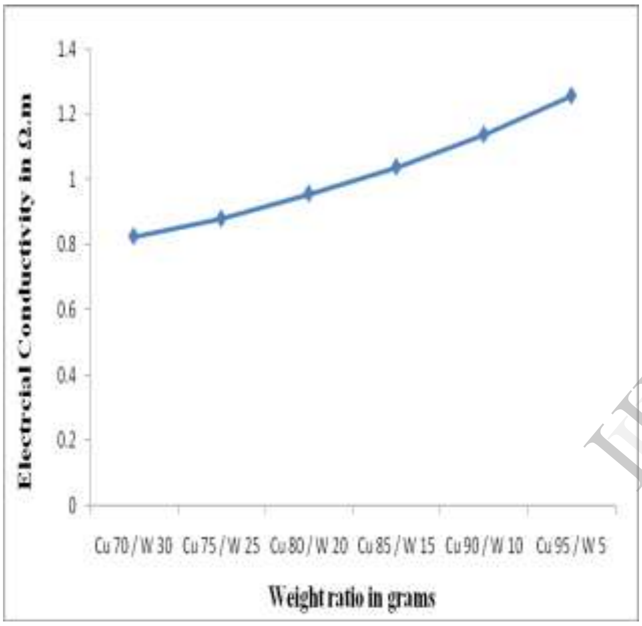
ρ = Resistivity in Ω - m

l = Length in mm

A = Area in mm

σ = 1/R

σ = electrical conductivity



Graph 3 Weight ratio Vs Electrical Conductivity

Electrical conductivity is directly propostional to electrical resistance, this variasion illustrated in the graph 3. Tungsten has poor electrical conductivity when comparing with copper. So the weight ratio of Tungsten is gradually decresed in the billtes combination. As a result the electrcial conductivity increased gradually. Table.5, 6 compares the details of electrical resistance and conductivity.

TABLE 5 COMPARISON OF ACTUAL COPPER AND TUNGSTEN

S.No	Copper Weight ratio Cu	Tungsten Weight ratio W	Resistance R	Electrical conductivity σ
1.	30	70	3.41	0.42
2.	25	75	3.15	0.38
3.	20	80	3.9	0.34
4.	15	85	4.71	0.30
5.	10	90	6.1	0.27
6.	5	95	7.2	0.23

TABLE 6 PREDICTED VALUES **COPPER AND TUNGSTEN**

S.No	Copper Weight ratio Cu	Tungsten Weight ratio W	Resistance R	Electrical conductivity σ
1.	70	30	1.212×10^{-6}	0.82
2.	75	25	1.137×10^{-6}	0.87
3.	80	20	1.045×10^{-6}	0.95
4.	85	15	9.625×10^{-7}	1.03
5.	90	10	8.794×10^{-7}	1.13
6.	95	5	7.962×10^{-7}	1.25

V. CONCLUSION

WEDM is a non–traditional machining process used to fulfil the requirement of several metal cutting industries. It is applied where there is need to produce complex two and three dimensional shapes through electrically conductive work piece using a wire electrode travelling longitudinally. This WEDM process is independent of hardness value of work piece and has been commonly applied where tight dimensional tolerances and high profile accuracy is needed. The ultimate goal of the WEDM process is to achieve an accurate and efficient machining operation without compromising the machining performance and wire breakage.

I. Wire failure occurs in Wire EDM process as a result of severity in wire wear rate, which is a function of discharge current.
II. The zinc coated brass wire performs better when compared to bare brass wire because of it slow wear rate and lower breakage with increased discharge current conditions.
III. Enrichment of Tungsten, which reduces property of current conductivity in wire electrode, It leads wire breakage.

IV. From this paper, as a result is suggested by increasing the weight ratio of Copper in wire has high tensile strength, electrical conductivity and low resistance.

V. By this low electrical resistance, wire wear is decreases. Copper can produce very fine surface finishes, even without special polishing, at the same time Tungsten gives wear resistance to the wire electrode.

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