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A REVIEW OF DEVELOPMENT IN WIRE ELECTRIC DISCHARGE MACHINING

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Abstarct: *EDM process in which material is disintegrated from the work piece by a progression of discrete sparkles between the work piece and the wire terminal isolated by a meager film of dielectric liquid. The development of the wire is controlled numerically to accomplish the ideal three-dimensional shape and precision for the work piece. WEDM is utilized in apparatus and pass on making businesses, cars, aviation, atomic, PC and hardware businesses. The normal cutting speed, relative machining costs, precision and surface completion have been improved since the business beginning of the machines; significantly more improvement is as yet required to meet the expanding request of exactness and precision by various enterprises. The exhibition of WEDM relies much upon the wire cathode utilized. Metal wire is utilized widely as a wire anode in WEDM. Different elite anodes like zinc covered, dissemination strengthened, covered steel center wires and so on have been created to fulfill the machining needs. In the present examination, the business related to improvement expressions of wire cathode's materials, business related to impact of different information parameters on the presentation measures for WEDM process are portrayed.*

Keywords: WEDM, Cutting Speed, Surface Finish, Zinc coated, Diffusion Annealed.

I.INTRODUCTION

Wire-electro discharge machining (WEDM) has become an important non-traditionalmachining process, as it provides an effective solution for producing components made ofdifficult-to-machine materials like titanium, zirconium, etc., and intricate shapes, which arenot possible by conventional machining methods [1]. Wire Electro-discharge Machining(WEDM) is an adaptation of the basic EDM process, which utilizes a thin, continuouslymoving wire as an electrode. The wire electrode is drawn from a supply reel and collected ona take-up reel. This continuously delivers fresh wire to the work area.The wire is guided by sapphire or diamond guides and kept straight by high tension, which is
important to avoid tapering of the cut surface [2]. The mechanism of material removal inWEDM is similar to conventional machining process in which erosion effect produced by theseries of electrical sparks produced between the work piece & the wire electrode surroundedby stream of dielectric fluid continuously flowing in the machining Zone [3].temperature range of 8000°C–12,000°C exist between cathode and anode in the form ofthermal energy after applying voltage pulses between the work–piece and the wire electrodeduring WEDM process [4].

The most important performance measures in WEDM are material removal rate (or cuttingspeed), workpiece surface finish and kerf (cutting width). Discharge current, dischargecapacitance, pulse duration, pulse frequency, wire speed, wire tension, average workingvoltage and dielectric flushing conditions are the machining parameters which affect theperformance measures [5]. Wires used in wire electrical discharge machining are the core of the system. The requiredcharacteristics of the wire electrodes include not only the ability to generate an electricdischarge, but also mechanical strength at high temperature, high electrical conductivity andhigh heat conductivity [7]. Brass wire electrode is used extensively as a tool for WEDM.However, along with the recent diversification in applications of manufacturing fields,demand is expanding for a wire electrode with performance superior to the conventionalbrass wire electrode. These electrodes in use are generally zinc coated wire with acopper/brass alloy or steel core, the brass containing either a small amount of Cr, or a highconcentration of Zn. At present, the concern of EDM users is to shorten the machining timeof products [8].

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II.STUDIES RELATED TO WEDM PROCESS

WEDM is an essential operation in several manufacturing industries, which gives importanceto variety, precision and accuracy. Several researchers have attempted to improve theerformance characteristics namely the surface roughness, cutting speed, dimensionalccuracy and material removal rate. But the full potential utilization of this process is notompletely solved because of its complex and stochastic nature and more number of variablesinvolved in this operation. WEDM is the most widely and successfully used method formachining difficult to machine materials like super alloys and titanium alloys. Goodelectrical conductivity is a pre requisite for the fast machining of any material by WEDMprocess. In recent years, an extensive research has been carried out on WEDM relating toimproving performance measures by developing new wire electrodes. In the present study,the work of some researchers regarding development of wire electrodes are described.

III.STUDIES RELATED TO DEVELOPMENT OF WIRE ELECTRODE MATERIAL

U.S Pat. No. 4,262,185 (1981) developed a method and apparatus for measuring the electricalresistance of the wire electrode of an EDM machine in the machining zone formed by the wire electrode in conjunction with the work piece, and in varying the machining current orthe amount of traction exerted on the wire, or both, as a function of the measured electricalresistance, such as to maintain the electrical resistance of the electrode wire within apredetermined range. U.S Pat. No. 4,287,404 (1981) suggested a wire electrode formachining a metallic workpiece by electrical discharges. The active surface of wire electrodecomprising of at least 50 % by weight of a metal or an alloy selected from the groupconsisting of Zinc, cadmium, tin, lead, antimony or bismuth. The mechanical strength of the

wire and the intensityof the current flow through the wire had been proposed to be greatly increased by providing awire having the steel core surrounded by a layer of copper or silver provided in turn by theprotective thermal coating consisting of materials for example Zinc, cadmium, tin, lead ,antimony or bismuth .U.S Pat. No. 4,341,939 (1982) disclosed a metallic wire electrodecoated with at least one layer of a metal having low temperature of vaporization and film ofmetal oxide on the metal layer. The metallic coating was preferably made of zinc andsubjected to an oxidizing thermal or electrolytic treatment such as to form on the surface ofthe metallic layer a thin film of metal oxide. U.S Pat. No. 4,424,432 (1984) developed a wireelectrode material for travelling –wire type electrical discharge machining. Electrode materialconsists of 0.1 to 3.0 % by weight Zirconium, 0.3 % to 10 % of zinc and rest of compositionis copper. U.S Pat. No. 4,673,790 (1987) suggested a wire electrode for use in electrodischarge machining formed essentially of Cu, including Zinc of 5 through 38% by weightand Si of 0.1 through 0.5 % by weight so as to suppress sputtering of electrode material to theworkpiece and to improve workability. The wire electrode may include Zn of 30 through 40% by weight, Si of 0.1 through 1.2 % by weight and Al of 0.01 through 0.2 % by weight inaddition to copper. U.S Pat. No. 4,717,804 (1988) developed an electrical discharge

machining electrode which comprises a composite member having an electrically conductiveentirely metal wire length of ferrous alloy metal for its core and with said core being cladwith a layer of copper whose outer surface is oxidized and coated with graphite. U.S Pat. No.4,952,768 (1990) developed an electrode for precision electric discharge machining formedby silicon or other materials, a base of a low melting point metal or an alloy of such a lowmelting point metal is covered with a layer composed of a mixture of the metal and a highdensity inorganic compound. U.S Pat. No. 5,196,665 (1993) suggested a method formanufacturing a multilayer electrode wire comprising the steps of : superimposing a pluralityof alternate fine layers of a first metal with high electrical conductivity and a second metalwith low melting and vaporization point onto a core made of electrically conductive material;finishing superimposed alternate fine layers with a layer of second metal ; and cold drawingthe superimposed fine layers and finishing layer to cold form the electrode wire withoutcausing any of the metals to diffuse into an adjacent layer. U.S Pat. No. 5,315,087 (1994)developed a wirecut electrical discharge machining apparatus having silicon particlessuspended in a dielectric solution that fills the machining gap.

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The silicon particles may besuspended in the dielectric solution prior to a machining operation or they may be mixed withthe dielectric solution directly in the machining gap. Also, a silicon-coated electrode may beutilized. The silicon overcomes many of the limitations associated with conventionaldielectric solutions, by allowing more uniformity of conductivity. U.S Pat. No. 5,808,262(1998) suggested process of manufacturing spark erosion electrode. The core of the electrodewas made of low zinc alpha brass with top layer of highly rich zinc beta and gamma brass tofacilitate better flushability of the electro-erosion process, and to achieve higher tensilestrength of the core material of the electrode. Aoyama et al. (1999) had describe thedevelopment of coated wire electrode to achieve high speed cutting and accurate machining.

The new wire electrodes consist of a thin copper zinc alloy layer and core material with high resistance and high electrical conductivity. Two types had been developed: one is called"High – Falcon" (HIF) and is a copper alloy coated with a single phase brass layer. It isapplicable when users want high cutting speed and accuracy. The other is called "High-Eagle" (HIE) and is a copper alloy coated with a double-phase brass layer. It is applicable forwidespread use when users want faster cutting, but do not require as high accuracy. U.S Pat.No. 6,291,790 (2001) developed an wire electrode for wire electrode-discharge machiningincludes a core and a plurality of coating layers covering the outer peripheral surface of thecore. The core and the plurality of coating layers are formed of different materials, and eachof coating layers is made of a metal or a metal alloy including the metal selected from thegroup consisting of Cu, Sn, Ag,Al, Zn, Cs, Se, Te, Mg, Bi, Ti, P, Cr, Fe. U.S Pat. No. 6,362,447 (2002) suggested thatelectrode wire for EDM can be made comprising a core metallic wire formed of Cu -0.02 to0.2 Zr alloy or Cu-0.15 to 0.25 Sn-0.15 to 0.25 in alloy. The wire had sufficient conductivityand also reasonable cost. U.S Pat. No. 6,348,667 (2002) developed a wire electrode withwhich the corrosion, in particular of the not eroded surfaces of the hard metal block isprevented. This purpose was attained by selecting a wire electrode for the spark erosioncutting of hard metals, the wearing outer coat of which consists of a metal or a metal alloy,which is not nobler than the binder contained in the hard metal, and by the metal or the metalalloy having an electrode potential which is less than or equal to ϕ=-0.28V, referred to astandard hydrogen electrode. Kuroda et al. (2003) developed high-speed and high-precisionmachinability wire (HIR) and ultra-high-speed cutting (HIS) wire. Both wire electrodesconsists of a thin copper zinc alloy layer and core material.

In HIR wire copper Zinc core hadbeen coated with Brass wire whereas in HIS the core had been coated with copper, tin andIndium. The HIR electrode was used for high-speed and accurate cutting, and the HISelectrode for super-high-speed cutting. U.S Pat. No. 6,566,622 (2003)suggested that a wire electrode, and a method for making it, for use in spark-erosive havingan electrically conductive core essentially absorbing the tensile forces. The wire electrode hasfurthermore a coating which wears during erosion, which coating consists of two layers. Sucha wire electrode is suited for both quick cutting and also for fine cutting of workpieces. Thewire electrode has for this purpose an inner layer of the coating, which serves the quickcutting process and consists of an essentially homogeneous alloy. Whereas the outer layer ofthe coating is provided for the fine cutting and has a zinc content of above 80 wt.%, wherebythe layer thickness of the outer layer lies at 1/5 of the layer thickness of the remainingcoating. U.S Pat. No. 0,138,091 (2006) developed a method of manufacturing a zinc-coatedelectrode wire for electro discharge machining using a hot dip galvanizing process bysubjecting a wire to the series of processes of firstly surface forming, pre-coating, maincoating, secondly surface forming, heat treating and drawing, which is advantageous in termsof uniformly coating zinc on the wire by the hot dip galvanizing process and thus reducingmanufacturing cost, thereby achieving economic benefits. U.S Pat. No. 0,295,695 (2007)suggested an EDM wire having an outer coating of epsilon phase brass and a process formanufacturing the EDM wire is provided. The process includes coating a copper bearingmetallic core with zinc. The zinc coating is then converted to epsilon phase brass by heattreating the wire at a temperature low enough to minimize or eliminate any resulting changesin the mechanical properties of the wire. The coated core wie may be drawn to a finish sizeprior to heat treatment which will result in a wire with a substantially continuous epsilonphase coating. Okada et al. (2008) had studied the effect of surface quality of Brass coatingwire on wire EDM characteristics.

They aimed towards optimize the thickness & quality ofBrass layer for higher performance fine wire EDM. The SKD 11 (thickness-10mm) was usedas work piece and steel core wire with brass coating was used as tool electrode. The conclusion of the study was that the material removal rate increases with increasing thecoated Brass thickness (< 1.45 μm). At thickness (>1.45 μm), the material removal rate doesnot increases very much. Kapoor et al. (2010) had reported in the study regarding recentdevelopments in wire electrodes for achieving high performance. The work focuses onevolution of EDM wire from copper to brass and from brass to various coated wire, whichhas helped make wire EDM machining, the method of choice for high-speed productionapplications, as well as applications requiring improved contour accuracy and improvedsurface finishes. Some of the characteristics of high performance wire electrodes have beenpresented, which significantly increase the wire electrical discharge machining productivity.

IV.STUDIES RELATED TO EFFECT OF PROCESS PARAMETERS ON THE PERFORMANCE PARAMETERS

Tosun et al. (2003) investigated the effect of the cutting parameters on size of erosion craterson wire electrode. Brass wire of 0.25 mm diameter and AISI 4140 steel was used as tool andwork piece materials respectively. The experiments were conducted under the differentcutting parameters. Results showed that increasing the pulse duration, open circuit voltage,and wire speed increases the crater size, whereas increasing the dielectric flushing pressuredecreases the crater size. The level of importance of the machining parameters on the crater
size was determined by analysis of variance (ANOVA) method. Hascalyk et al (2004) hadexperimentally studied the effect of WEDM process parameters such as open circuit voltage, pulse duration , wire speed and dielectric fluid pressure on machining characteristics of AISID5 tool steel. The brass wire was used to perform the WEDM operation. The optical &scanning electron microscopy (SEM) was used for analyzing the metallurgical structure. Theconclusion of this study was that the surface roughness increased when the pulse duration& open circuit voltage were increased. The dielectric fluid pressure & wire speed notseeming to have much of influence. The density of cracks in heat affected zone increases withincrease in pulse duration & open circuit voltage.

Furthermore , the cracks penetrate into heataffected zone depending on pulse energy. Hewidy et al. (2005) carried out Wire electricmachining of Inconel 601 material on ELEKTTA MAXICUT 434 WEDM. Brass wire ofdiameter 0.25 mm was used as electrode. The models for correlating the inter-relationships ofvarious WEDM machining parameters of Inconel 601 material had been established usingresponse surface methodology . Results show that the volumetric metal removal rate can beobtained at peak current (IP) of 6 A, TOFF of 3 μs wire tension of 7N and water pressure of 3Mpa. Surface roughness was best achieved at peak current (IP) of 5 A, TOFF of 1 μs wiretension of 9 N and water pressure of 0.5 Mpa. Singh and Garg (2009)performed experimentson ELECTRONICA SPRINTCUT WEDM machine. The effect of pulse on time, pulse offtime, gap voltage, peak current, wire feed, wire tension on material removal rate of hot diesteel (H-11) using one variable at a time approach. Brass wire (CuZn37) with 0.25 mmdiameter was used in the experiments. the optimal set of process parameters has also beenpredicted to maximize the material removal rate. Results showed that value of maximummaterial removal was 30.24 mm^2/min at IP of 230 A whereas minimum material removal was12.48 mm^2/min at IP of 50 A . Wire tension had negligible effect on material removal rate.Kumar et al.(2015) had present a study which highlights the work of various researchers inthe field of WEDM for various process parameter like(Pulse on time, Pulse off time, Wirefeed rate, Peak current, Servo voltage etc) and their affect on performance measures like(Material Removal Rate, Surface Roughness, Surface Integrity, wire lag and inaccuracy etc).Some suggestions for future research was also outline.

CONCLUSION

The new developed high cutting speed wires can increase the production rate by asignificant amount as compared to generally used brass wire and zinc coated wire.
There is high need to work on the development of wire electrodes andoptimization of process parameters in order to fullfill the future market demands. It is very much essential to optimize the process parameters to achieve the desireresults.

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