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SOME ASPECTES ABOUT ED WIRE CUTTING PRODUCT QUALITY

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ABSTRACT

Numerically controlled electro discharge wire cutting process has increasingly been applied in producing various required profiles of hard and heat treated materials. However, there is little published work concerning the effect of ED wire cutting conditions on surface integrity of the machined components. Knowledge of the nature and quality of the surfaces produced under various ED wire cutting consitions is of considerable industrial impimportance.

The objective of this work is to investigate, in a comperhensive manner, the effects of the wire feed rate, wire diameter, pulse duration, and the effective acting length on the surface integrity of both high speed and tool steels.

The surface region of the machined components is examined using a wide variety of diagnostic techniques. The results of the investigation show that a wide variety of geometrical surface features are generated at varius ED wire cutting conditions. The results also show that a heat affected zone in the surface region is generated that contains variations in hardness and microstructure. The results, in conjunction with those obtained from previous work will lead to a better understanding of the performance of the ED wire cutting and will aid in the production of surfaces of high integrity.

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INTRODUCTION

Electro discharge machining (EDM) is the process in which the material is eroded as a result of an electrical discharge between tool and work. Metal particles are removed by a series of discrete sparks that occur in the machining gap between electrode and the workpiece. The metal particles at the point of discharge aremolten due to the resultant short-lived, very high temperature rise. These particles partially vaporized and removed from the melt by mechanical and electromagnetic forces [1]. The working medium is a dielectric that washes the eroded material away and simultaneously acts as a coolant.

EDM process is very often the final operation performed on the workpiece because it can be readily carried out on heat-treated material. However, machining must be effected in such a way that tha structures of the machined surfaces are compatible with the functions of the component in the end product This demands a careful execution of all steps of EDM, with allowance also being made for thermal influences on the under surface [2].

The EDM technique has developed greatly over the last twenty years, and is now widely used as a production tool. Probably its widest use is in diemaking where, after machining, the material (which are predominatly ferrous alloys) are often subjected to severe service conditions. Even with the more efficient process, substantial changes can occur in the workpiece surfaces, changes which may affect the performance of the finished parts. These surface changes are a direct result of the sparkerosion process and may, to some extent, be predicted [3].

Besides the substantial improvement in stock removal and wear rates since electric discharge machining was introduced into industry around 1954 [4], still greater advances have bee made in the surface quality and precision of the workpieces. Numerically controlled electro discharge wire cutting (N/C EDWC) began in 1969 [4] . The process uses a travelling wire as a trepanning tool and represents an important development in EDM technology. The relative advance of the cutting tool to the work does not have a constant velocity, but must be varied in accordance with condition existing in the gap through the process depending on the progress of the cut.

The ED wire cutting process is used for cutting hard materials and cermets and for parting off crystalts and metallurgical specimen for laboratory use. Recent years have seen increasing application for numerically conttolled table to guide the workpiece through the motions necessary to produce a required profile . The technique is of considerable value, especially in the production of tools and dies directly from hardened steel.

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The wire is usually in a vertical configuration with deionized water as the dielectric, Either in submerged or in flow mode.

While NC wire spark crosion possessing significant advantages over EDM [5], it is not without its problems and those unique to the electrode itself center around its inherent lake of rigidity. Disturbances from external snd internal sources generate vibratory motion which exerts considerable influence on the repetitive sparking process.

The production of good finshing products can hardly be achieved on ED wire cutting machins because the results depend on the machine, material, and cutting conditions. The surface is sually matt, clean and without visible directional machining marks [5]. Some errors may lead to the presence of grooves. These errors include poor flushing, wire breakage, unstable operation wrong setting, and dirty or worn wire guides.

The intermittent pulsing of spark produces distinct craters on the surface of the workpiece of size of the discharge channel and resulting surface comprises a series of overlapping craters[2,3] . The impression of overlapping craters is not sufficient,however, to describe the surface characteristics fully, as the metal ions in the spark gap and any molten metal present may resolidify to form spheres that coming from the gaseous phase being hollow [2-4] . These may be incorporated either partially or totally in the surface layers Also, at this time , the molten surface layers will solidify and cool very rapidly and the resulting contraction produces tensile and possibly cracks in the surface [6].

A thorough review of previous work concerning ED wire cutting have shown that most of investigations sited were concerned with the principle of the process itself [7-11] . There is little published work concerning the effects of ED wire cutting conditions on surface integrity of the machined component. The ifluences of the input parameters such as pulse generator type [7,8] , control systems [9,10] , or die electric fluid flushing [11] on material removal rate and tool electrode wear have been investigated in a comperhensive manner theoretically and experimentally.

Wells and willey [12,13] and wilson [14] have studied the variation in surface roughness due to changing fluid veloicty. It was generally found that the produced surface roughness decreases wiht an increase in the fluid velocity in the range from 2 to 4 m/sec., and then slighly increases a higher values. Scalai and Vignale [6] have studied the influence of EDM Puls shape on machined surface. They investigated a new type of EDM pulse generator which has theoretically better performance than the usual controlled EDM generators. It was found that the macro- and micro-geometrical features of the machined surfaces machined with the new type generator are similar to those machined with the usual devices.

Knowledge of the nature and quality of the surfaces of machined components produced under various ED wire cutting conditions is of considerable industrial importance. It is well known that dynamic loading is a principal factor in the design of many modern structure and therefore design capabilities are frequently limited by the fatigue, creep, or stress corosion cracking characteristics. Failure almost always begine at or near the surface of a component [16-18] .

Surface region is usually interpreted as including surface and subsurface structure. Surface integrity of machined surface is described in terms of surface topography and surface and subsurface metallurgy. Sufrace region damage, as a result of metal cutting,usually leads to a reduction in fatigue life, creep life, and resistance to stress corosion cracking.

Little work has been carried out in an attempt to determine the effects of ED wire cutting process on surface integrity of machined component. Even in those investigations [4,6,12-15] where the effects of some parameters of ED wire cutting process on surface quality have been examined, the approach used has usually been restricted to an examination of single facet of surface integrity such as subsurface structure change. Detailed descriptions of surface integrity is in general lacking. It is clear that when using ED wire cutting process, the surface integrity of the machined component is where the greatest need for further fundamental research exists.

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EXPERIMENTAL WORK

The present work was conducted on EDM wire Cutting machine with the following specification :-

* Machine
  - type: : AGICUT 315
  - power : AGIEPULS-100D -ACC
  - control : numerically controlled table
  - pulse generater : DA14
* Measuring Equipment
  - Surface was exaimened as follows
  - surface roughness: Talysurf 6 with talydata 2000
  - surface hardness : Hardness tester ......
  - surface defects : Tool maker Metroscope
  - microstructure : Optical microscope
* Tool
  - thin coated copper wire (Ø 0,2-0,3 mm) wounded continuously between two spools.
* Workpieces
  - Two sets of specimen were used :
  - flat specimen (Line cutting) : High speed steel
    : Hardness R_c = 60
  - circular spec.(contour cutting): Alloy steel
    - C = 0,15%
    - M_n = 1 %
    - C_r = 1 %
    - W = 1,2 %
    - Hardnes = 60-62
* Test Conditions
  - Machining fluid : tap water
  - wire cutting speed ; 100 mm/min.
  - feed rate :
  - flat spec. : 0,3 -0,6 mm/min
  - Circular spec. : 0,65 - 5,9 mm/min
  - pulse duration 15-100 μ sec

EXPERIMENTAL RESULTS AND DISCUSSION

a- Surface Roughness

As stated an EDM surface compri the normally microsecopic craters associated with the discrete discharges and bassically of a "matt" appearance. Structurally the surface comprises a resolidified epitaxial layer within the shallow craters.

Due to the nature of material disintegration with EDM and the complexity of nature of the craters created on the machined surface, the assessement of the surface roughness with profile meter becomes acceptable to certain limit only, the alternatif method has not been yet introduced.

1. Effect of Feed Rate

A set of a flat specimen were ED wire machined with different feed rates (0,33 - 2,47 mm/min.) under the conditions stated at figure(1). The results showed that the decrease of the feed rate inhances the surface roughness measured in the same direction of wire feed increasing the feed rate from 0,33 to 2,47 mm/min the surface roughness increased from 1,25 to 2,1 μm

In addition to that mentioned befor, EDM wire cutting is subjected to transverse oscillation (vibrations) affecting on surface texture. This vibration is function of tension, density, and guide of the wire and also pulse frequency.

This result is adquating with the emperical formula for determination the CLA when conventional machining

$$CLA\ (R_a) = C.\frac{f^m}{R}$$

f = feed rate

R = wire radius

where constant C and exponent n can be calculated

Figs (2) and (3) show samples of the surface profile and bearing area diagram of the some surfaces decreasing the feed rate leads to an improvement of the dibres evacuation and there-fore an improvement of the surface roughness is secured

As for the conventional machining where atten tion must be paid for the relative direction between R_a measure and motions (V,S) for EDM wire cutting the direction of R_a measure relative to feed rate plays an important role. Figure (4) shows that the measurment of R_a in ridge direction ($\perp$

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to wire feed direction) was2,4 μm whil R_a at the wire feed direction was 1,4 μm.
a Similer relations were deduced for EDM wire contouring cutting of a circular cross section specimen machined under specified conditions as indicated in Fig. 5. It can be noted that the relation between surface roughness and feed rate is independant on the type of machine motion (line or contour), increasing of feed rate leads to an increase of surface roughness R_a

2. Effect of Acting Length

The thickness of workpice (h) to be ED wire machined represents the acting length of wire. Figure (6) shows that increasing of (h) leads to on improvement of the surface roughness, with a copper wire Ø 0,3mm the increase of workpiece thickness from 10 to 150 mm decreases the surface roughness (R_a) 40 %, this can be due to the stability of the acting part of the wire at the cutting zone.

3. Effect of Wire Diameter

Fig. (6) shows the retlation between surface roughness wire diameter. It can be seen that, the surface roughness for large diameter is higher than that of smaller ones. The decrease of the wire diameter leads to a decrease of the surface roughness, the consumed energy plays an important role where the nomber of discharging points for,larger wire diameters is usually highr than that for smaller ones.

4. Effect of Pulse Duration.

The pulse energy is often quoted in the literatures as being an important machine parameter. As with many types of machining, EDM metal removal rate is inversely proportuional to surface roughness. Fig.(7) shows that the increase of the pulse duration during ED wire cutting leads to an increase in the surface roughness. That can be due to the difficulty of the process of the evacuation of the debris from the cutting zone. In other words,the duration of the debris evacuation is inversly proportional to the frequency and therefore the surface roughness increases.

b. HARDNESS

The micro hardness of the specimen was examined, the results showed that the variation of the hardness due to the ED wire cutting is significant inthe zone of 10 times of the measured R_{max}

C. DEFECTS

ED wire cutting has been yielded surface with deep grooves or cavities owing to "preferred channels" for electrosparking . the depth of such cavities reached 1,6 times the maximal roughness depth (Fig.8)

CONCLUSION

* The surface roughness is proportional to feed rate independant on the type of motion (Line or contouring)
* The surface roughness is min if the direction of R_a measure is the same for the direction of the wire feed, and maximum for the directional to feed rate
* The increase of the acting length of the EDM wire leads to can improvementof the surface roughness
* Decreasing of EDM wire diameter decreases the surface roughness
* The increase of pulse frequency decreased the surface roughness
* Due to EDM wire machining the hardness of surfaces is effected
* The surfaces produced yeild grooves and cavities.

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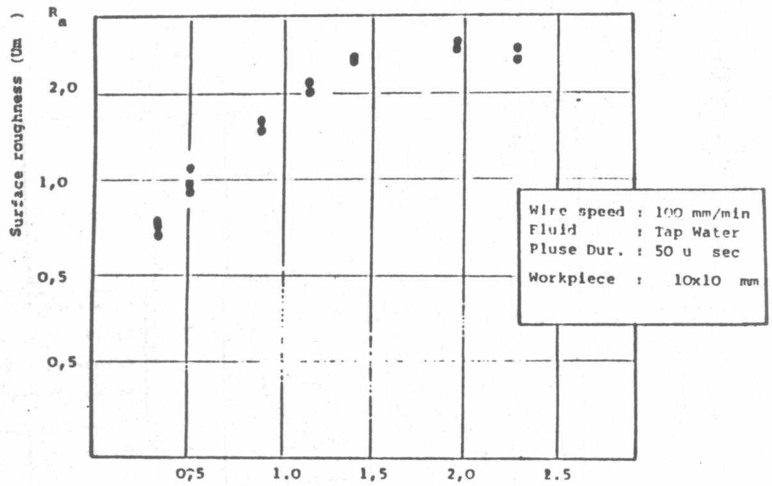

Fig.1-The Relation Bet. surface Roughness R_a and Frr Rate for - Lines Cutting

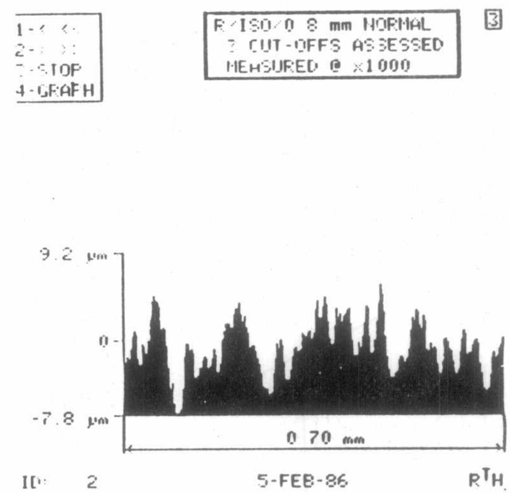

Fig.2 Surface Profile of ED Wire Machined Surface

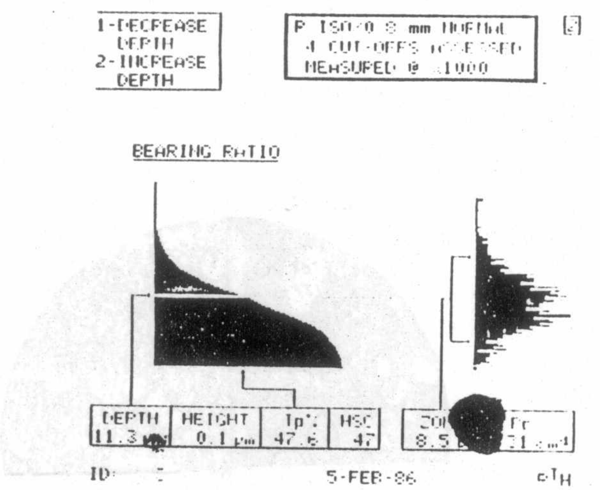

Fig.3 Bearing Diagram of Surface Profil

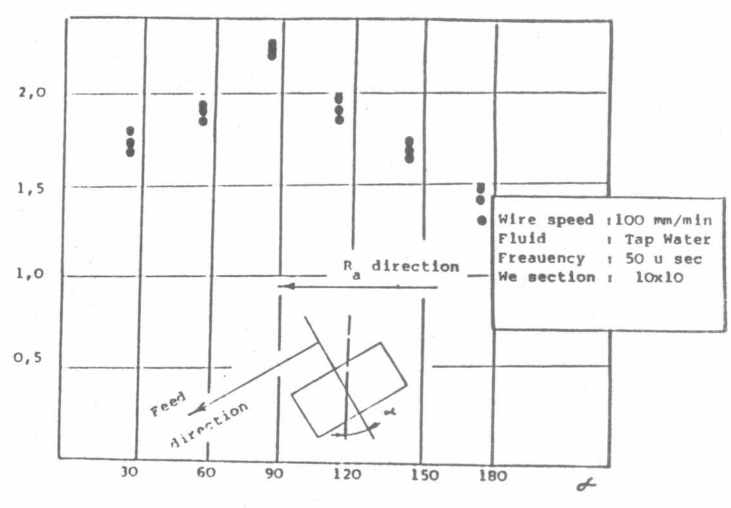

Fig.4-The Relation Bet. Angles of R_a Measure and Feed Direction

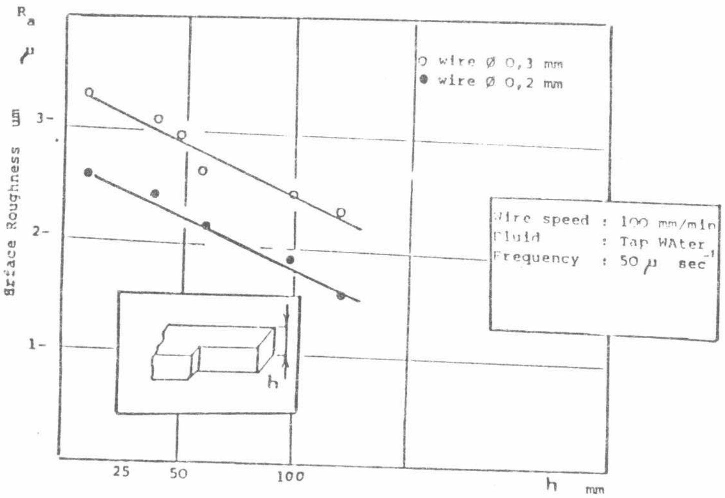

Fig 6 the Relation bet. Acting Length and Surface Roughness R_a

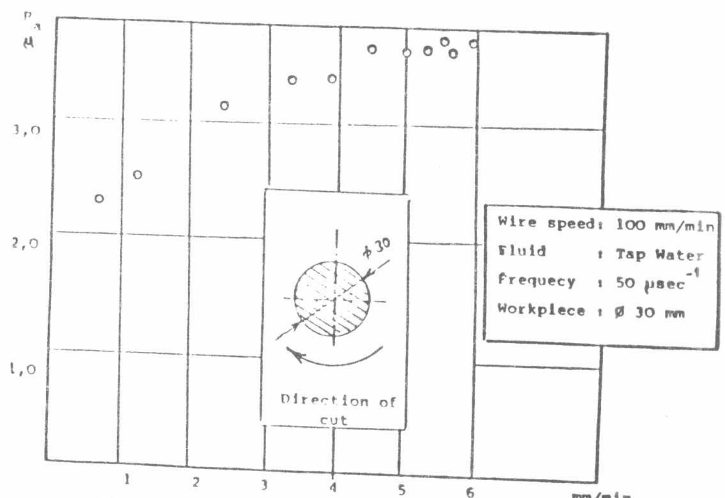

Fig.5-the Relation Bet. Surface Roughness R_a and Feed rate for contouring cutting

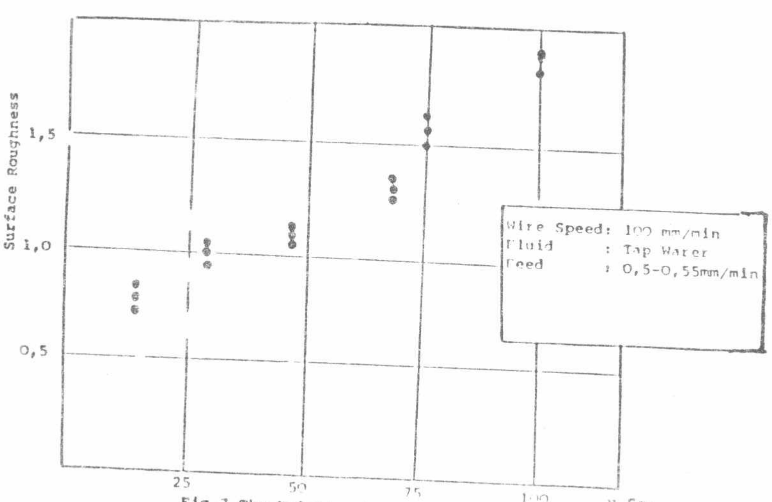

Fig.7 The Relation bet Pulse Frequency and Surface Roughness

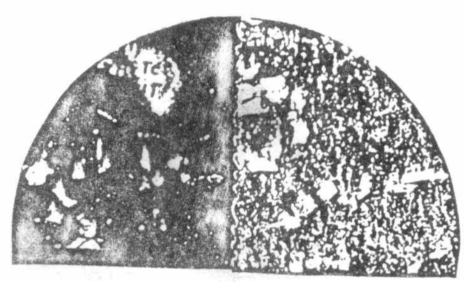

Fig.8 Defects on ED Wire Machined Surface