Experimental Investigation of the AISI H-13 die steel by Wire-Cut EDM

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Abstract---
The current study is done to provide a comprehensive report on the machining of AISI H-13 Die Steel with bare and coated wire electrodes. The study is carried out for the pulse duration-on time and pulse duration-off time process parameters effect on both electrodes and surface roughness is taken as response parameter of material along with the best viable combination of process parameter for machining.

Key words: AISI H-13 Die Steel, Wire-cut EDM, Surface Roughness.

1. Introduction

In engineering world, new techniques are being used to ease the machining process. Especially non-conventional energy sources like light, sound, electrical, mechanical, chemical, electrons and ions are new attractive concepts. With the new continues industrial and technological growth, recent developments to machine harder and difficult materials, which have wide application in various fields like nuclear engineering, aerospace and other industries. Still the processing time and surface texture with smooth surface are the major concerns for operators [1].

With daily challenges of machining materials with high strength & temperature resistant and difficult-to-machine, suggestion comes out to be to use EDM process. EDM machining is used to remove material even for small batches [2]. The moment of electrode is controlled by numerically control system. The smooth instant spark occurs sufficiently, it exhibits a pressure between workpiece and electrode which results in of a very high temperature and at such high pressure and temperature (8000 C-12000 C) that some metals get melted and evaporated at the same time. The investigation of Conductive zirconias containing 22 to 44 vol% NbC or Tic was done through wire-cut EDM. They evaluate the surface roughness and machining rate by varying process parameters like pulse duration and duty factors and share the feasible conditions for the process [3]. The various process parameters pulse time, open circuit voltage, wire speed and dielectric fluid pressure was experimentally investigated on wire-cut EDM process on AISI 4140 steel having 10mm thickness with 0.25 brass wire electrode to see the effect on response parameters which are surface texture and cutting speed. His findings are that increasing pulse time, wire speed, open circuit voltage and dielectric fluid pressure increases the surface roughness and cutting rate [4]. The investigation was also done by wire-cut EDM for machining Al2O3p/6061Al composite by taking different levels of variables like pulse duration to identify the effects on response parameters. All experiments were conducted on a FANUC W1 CNC EDM machine with 0.25mm brass wire electrode. As well as, they see the impact of wire electrode while machining the Al2O3p/6061Al composite because of its repeatedly breaking, which
emphasises on the work suggesting locations of possible wire breakage and the reason for same during machining [5].

2. Materials and Methods

FANUC ROBOCUT Alpha 1-iE CNC Wire-Cut EDM was used to carry out the experiments. AISI H-13 die steel is being used as workpiece material for present investigation. AISI H-13 is special hot-worked chromium tool die-steel with good hardness and toughness properties. Tool steels are used to construct the die components subject to wear. The nominal composition is shows the composition of the AISI H-13 Die Steel with a significant contribution of carbon (0.356 %), Silicon (0.885%), Chromium (5.109%), molybdenum (1.220%) and rest is Fe.

Table 1: Composition of Work piece Material in percentage

|    | Fe   | C    | Si   | Mn   | P    | S    | Cr  | Mo  | V    |
|----|------|------|------|------|------|------|-----|-----|------|
|    | 90.75| 0.356| 0.885| 0.439| 0.015| 0.016| 5.10| 1.22| 0.802|

The roughly cuboid plate is being machined on milling machine so that it becomes a complete cuboid with 210mm x 70mm x 31mm plate. After that, it goes on grinding machine where it is been grind to remove all inaccuracies in the workpiece so that it become ready for machining on Wire-cut Edm machine. The machine has a mechanism of a wire feed through the workpiece via a hole which is already drilled into the workpiece to allow the pass through to cut. The workpiece is being machined by two different wires i.e. hard brass wire (uncoated wire) and zinc coated brass wire (coated wire) in this experiment. Zinc coated brass wire consists of a layer (approx. .6 micron) zinc coating over a core brass alloy.

In the present work, the Taguchi’s method has been used to plan the experiments. L9 orthogonal array is being used for experiment conduction. Signal to noise ratio (S/N) is used for analysis of responses. The loss function is linked with the quality matrix of the system. The loss associated with the process of product can be minimized by maximizing the S/N ratio. The (S/N) ratio in terms smaller the better (SB) is calculated. The process parameters like pulse duration -on time and pulse duration-off time for the present investigation is being taken is shown in table with levels.

Table 2: Machining parameters and their levels

| Process Parameter | Symbol | Units | Level 1 | Level 2 | Level 3 |
|------------------|--------|-------|---------|---------|---------|
| Pulse-on Time    | Ton    | µs    | 6       | 8       | 10      |
| Pulse-off Time   | Toff   | µs    | 18      | 20      | 22      |

The Taylor-Hobson Surtronic3+ surface roughness tester is used to measure surface roughness.

3. Results and Discussion

The surface roughness was noted down with two no. of trials with same process parameters under same conditions to avoid any bias in investigation. The work piece with their raw data and S/N ratio for each work piece are given in table for each trial.
| Exp. No. | Surface Roughness with Zinc coated wire electrode | Surface Roughness with brass wire electrode |
|---------|-----------------------------------------------|---------------------------------------------|
|         | Surface Roughness (µm) | S/N Ratio | Surface Roughness (µm) | S/N Ratio |
|         | R1 | R2 | | R1 | R2 |
| 1       | 2.32 | 2.35 | -7.36592 | 2.54 | 2.58 | -8.16506 |
| 2       | 2.51 | 2.49 | -7.95887 | 2.71 | 2.69 | -8.62733 |
| 3       | 2.59 | 2.61 | -8.29953 | 2.79 | 2.83 | -8.97435 |
| 4       | 3.10 | 3.05 | -9.75719 | 3.19 | 3.21 | -10.1030 |
| 5       | 2.88 | 2.90 | -9.21801 | 3.10 | 3.12 | -9.85525 |
| 6       | 2.74 | 2.72 | -8.72331 | 2.91 | 3.07 | -9.51653 |
| 7       | 3.25 | 3.22 | -10.1976 | 3.59 | 3.54 | -11.0414 |
| 8       | 3.12 | 3.09 | -9.84133 | 3.32 | 3.35 | -10.4620 |
| 9       | 3.19 | 3.21 | -10.1030 | 3.41 | 3.43 | -10.6806 |

Effect of process parameter on the surface roughness with brass electrode and coated electrode is being shown below in figure (1) and figure (2).

![Main Effects Plot for SN ratios](image)

**Figure 1**: Effect of process parameter on surface roughness with zinc coated wire (S/N ratio)

Figure (1) shows that the first value of Pulse duration-on time ($Ton_1$) and the second value of Pulse duration-off time ($Toff_2$) provide the minimum value of surface roughness with zinc coated electrode. The same extent of the parameters ($Ton_1$ and $Toff_2$) are the feasible optimum levels for least surface roughness with zinc electrode in Wire-cut EDM process are achieved by raw data analysis.
Figure 2: Effect of process parameter on surface roughness with brass wire (S/N ratio)

Figure (2) shows that the third value of Pulse duration-on time (Ton₁) and the first value of Pulse duration-off time (Toff₂) provide the low value of surface roughness with brass electrode. The same extent of the parameters (Ton₁ and Toff₂) are the feasible optimum levels for the minimum surface roughness with brass wire electrode in Wire-cut EDM machining are resulted by raw data analysis.

4. Conclusions

The surface roughness values for AISI H-13 die steel after machining with coated electrode is less than AISI H-13 die steel machined with brass electrode. The lesser surface roughness is desirable. Zinc-coated wire electrode leads to better surface texture compare to brass electrode. The brass wire with zinc coating facilitates a higher tensile strength for wire electrode. Wire electrodes having tensile strength on higher side shows good thermal resistance property in high temperature and maintain straightness even with vibration and mechanical tension in wire electrode. As well as, the uniform layer of zinc on core provides good discharge characteristics. Electrodes which have properties like discharge characteristics and higher tensile strength can be achieved through finer discharge which can be created with zinc coated wire. Low surface roughness is being achieved in case of coated electrode machining surface as compare to brass wire electrode, overall quality of machining surface get improved after machining with coated electrode. It will further help to achieve better responses.

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