A STUDY ON HIGH ASPECT RATIO MICRO HOLE BY EDM PROCESS

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Abstract - Nowadays production of micro parts, micro tools and micro moulds play a major role in the manufacturing industries towards miniaturization. Consequently micro-holes are very regular element used in automobile, aerospace, chemical and medical fields etc. High aspect ratio hole has become a major challenge in the machining. Overcut is an important factor that must be minimal, as larger overcut leads to precision error in micro tools. This paper addresses the high aspect ratio micro hole in stainless steel by Electrical Discharge Machining (EDM) process and the influence of operating parameters on performance measures.

Index Terms – High aspect ratio, stainless steel, EDM.

1. INTRODUCTION

Current technologies in micro machining are high-speed micro drilling, micro-EDM and laser micromachining. Micro - EDM plays an important role in the manufacturing of micro components regardless of their hardness which is electrically conductive. In the machining process of micro-EDM, there is no physical contact between the tool and workpiece. On the contrary, the electric discharge from the tool erodes the workpiece. Due to high hardness, temperatures withstand capability and less corrosion effects, stainless steel has been used in automobile, medical and chemical industries. The need for fuel injection nozzles in engines, heat-emission holes in turbine blades, cooling holes in chemical reactors [1], micro holes for filters, high aspect ratio holes in colimeter for space applications [2] increases the demand for high aspect ratio micro hole.

Ferraris et al. [3] used insulated tool electrode to achieve ultra high aspect ratio of greater than 30. Tang et al. [7] adopted electrochemical machining to drill a high aspect ratio of deep spiral tube. Zhong et al. [5] proposed a theoretical model based on Hagen-Poiseuille equation and surface tension to predict the control factors of the high aspect ratio micro hole drilled by EDM. Zhao et al. [8] brings out the ultrasonic vibration in micro EDM to achieve the high aspect ratio of 15 mm. Biffi and Tuissi [9] machined a deep micro hole of length 1.8mm using fibre laser. Qin et al. [10] used carbon fiber as a core material and achieved a very high aspect ratio of 1800 by direct casting method. Sheu et al. [12] reported micro hole with aspect ratio of 15 has been achieved using vibrating workpiece with deionized water as a dielectric medium. Wang et al. [4] utilized the disk micro tool for the machining of deep micro hole in stainless steel. They have used electrochemical micro machining (EMM) and achieved aspect ratio of 12.3. Yu et al. [13] machined a micro hole in stainless steel with aspect ratio of 29 by using planetary movement and ultrasonic vibration in EDM. Hamdan et al. [6] optimized the surface roughness by taguchi method in high speed machining of stainless steel using coated carbide tool.

From the literature study, the high aspect ratio holes must have high-precision interior dimensions and high surface finish for their effective functionality. Due to high ductile nature of stainless steel, the high aspect ratio micro hole has been a very difficult process [11]. This paper analyzes the effect of operating parameters on machining time, overcut and tool wear while achieving the high aspect ratio of 92 in stainless steel by micro-EDM process.

2. EXPERIMENTAL WORK

The experiments have been carried out in Electronic super drill CNC micro EDM. The schematic layout of experimental setup has been shown in Fig 1. Brass is used as a tool electrode with 0.48 mm dia and 310 mm of length. Stainless steel has been used as a workpiece with dimensions 44x44x51. An alternative dielectric can be used in this experiment is de-ionized water instead of hydrocarbon oil. The de-ionized water promotes better and
Fig. 1 Schematic layout of experimental setup.

Safe machining environment [14]. Better spark discharge can occur due to no carbon deposition. Additionally, the dielectric medium enhances the cooling and flushing properties between the electrodes.

The experiment has been carried out with four variables such as voltage, current, T_{on} and T_{off} at 3 levels with different combinations. L_9 (3^4) orthogonal array has been followed by taguchi design. Totally 9 experiments has been done instead of 81 (3^4). The experimental design has been shown in Table 1. The machining time has been recorded at each setting. The length of the tool has been measured after every machining. The geometry of the hole has been studied with the help of optical microscope – MM 25 IS.

Table 1. Experimental design (L_9 orthogonal array).

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<th>Trial No</th>
<th>Voltage (V)</th>
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3. RESULTS AND DISCUSSION

The influence of operating parameters on response variable has been discussed here. The machining time, tool wear and over cut are the major parameters measured in the experiments. A high aspect ratio of 92 has been achieved. The entry and exit hole has been shown in Fig 2. Due to arcing at the initial stage, the entry surface has more heat affected zone when compared to exit surface. The entry and exit diameter of the hole has been measured using metal vision software V1.11 to calculate the overcut difference. The tool wear has been calculated in lengthwise, by subtracting the length of the tool after machining, from the original length.

By using Minitab 17, L_9 orthogonal design has been analyzed for the experiment. Fig. 3 shows the influence of operating parameters on machining time, tool wear and overcut. From the graph, it is evident that current is the most influencing factor for machining time and tool wear and T_{off} is the major influencing factor for the overcut. A minimum machining time of 197s has been achieved. The tool wear, initially increases to a certain value, except voltage, for an increase in any one of the parameter keeping others constant, and then decreases. A minimum of 35 mm difference in the length of the tool has been achieved. Overcut must be in minimum range as it leads to precision error. The overcut decreases steeply to a definite value for any increase in voltage, current and T_{on}, and afterwards it increases steeply to a certain value for voltage and T_{on} but there is slight decrease in overcut for further increase in current. In the case of T_{off}, there is a gradual decrease in overcut for increase in T_{off} and reaches a lowest level when compared to other parameters. An over cut difference of 0.02 mm has been achieved in the high aspect ratio hole of stainless steel by EDM process.
4. CONCLUSION

This paper presented the high aspect ratio micro hole in stainless steel by EDM process. A high aspect ratio of 92 has been achieved. By using Taguchi’s orthogonal analysis, the effect of operating parameters on response variables has been examined. Current has the major influence factor for machining time and tool wear and Toff has the major effect on overcut. A minimum machining time of 197 s and an overcut difference of 0.02 have been attained.

REFERENCES