EDM drilling of Inconel-718 using copper tube electrode

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Abstract

In recent years, materials with unique metallurgical properties such as Inconel-718 have been developed to meet the demands of extreme applications. In this paper an experimental investigation has been carried out to study the influence of various parameters like peak current, pulse-on time and dielectric flushing pressure on EDM deep-hole drilling of Inconel-718. Copper tube of external diameter 2.5 mm and internal diameter 1 mm was selected as the tool electrode which provides flow of dielectric through the electrode, thereby making the process of flushing less critical. Moreover, the performance of machining is evaluated in terms of material removal rate (MRR), electrode wear ratio (EWR) and overcut. Optical microscope was used to judge the quality at the rim of the drilled holes. Peak current, pulse-on time and flushing pressure were found to be the most critical parameters in EDM deep-hole drilling of Inconel-718.

1. Introduction

Inconel-718 is an extremely hard and difficult-to-cut material used especially in oil and gas industry, aerospace industry and automobile sector because of its superior strength, temperature and corrosion resistance. Significant researches have been carried out to machine this material with conventional machining processes. Conventional drilling of Inconel-718 is difficult due to rapid work hardening. On the other hand, because of high yield strength chip breaking becomes difficult which results in choking and inefficient cooling. The combined effect of work hardening and inefficient flushing leads to an increase in temperature near the machining zone. Increased temperature leads to adhesion wear, diffusion wear followed by micro

chipping and ultimately catastrophic failure of the tool [1]. To overcome all these problems, Electro Discharge Machining (EDM) is one of the important and cost-effective method of machining difficult-to-cut materials such as Inconel-718, as it provides contact free machining. In EDM, material is removed by a sequence of electrical discharges from electric pulse generators with the dielectric fluid supplying between the tool and workpiece. The heat generated by the sparks results in removal of material by melting and vaporization. No mechanical cutting forces exist between the workpiece and tool.

2. Experimental details

The experiments were performed on a Makino Edge 2, a high precision EDM machine tool. The machine features a table size of 500 × 350 mm^2 and an axis travel capability of 300 × 250 × 250 mm^3 in X, Y, Z axes respectively. The performance of the EDM drilling process is evaluated by the MRR, EWR and overcut. The MRR was calculated as the average volume of material removed per unit time. EWR is expressed as the ratio of volume of material removed from electrode to the volume of material removed from the workpiece at the same unit time. The parameter settings for the experimentation are shown in Table 1.

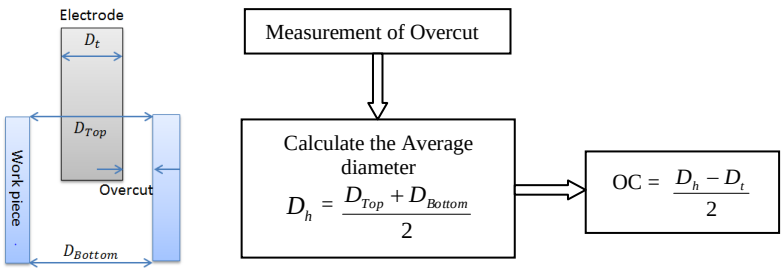

Figure 1 Steps in measurement of overcut

Table 1: Parameter settings

Thickness of the workpiece, mm	30
Electrode diameter, mm	2.5 (Int. dia.= 1 mm)
Peak Current, Amp	10, 12.5, 15
Electrode rotation speed, rpm	160
Voltage, V	80
Pulse on time, µs	50, 60, 70, 80
Flushing pressure, MPa	0.05, 0.065
Dielectric medium	EDM oil

3. Results and Discussion

The influence of peak current and T_{on} on MRR, EWR and overcut is shown in the Figure 2. With the increase of peak current the rate of material removal and electrode wear increases. It can be attributed that MRR is proportional to the product of energy per pulse and pulse frequency. Increasing the value of peak current increases the pulse energy and ultimately, a higher MRR and EWR. On the other hand, MRR increases with the increase of T_{on} until 70 µs. Beyond 70 µs, it starts decreasing with increase in T_{on}. This can be explained on the basis that short pulses cause less energy in the gap for melting and vaporization, whereas long pulse duration leads to an increase in expansion of plasma channel. Increased plasma channel causes less energy density on the workpiece, which is not sufficient to melt and vaporize the workpiece material [2]. Figure 2c shows the variation of overcut with peak current for the different settings of pulse on time. It has been found that with the increase of peak current, the overcut increases for all the settings of T_{on}. At lower peak current, small volume of material is removed from the workpiece per discharge resulting in small craters, which in turn leads to low overcut.

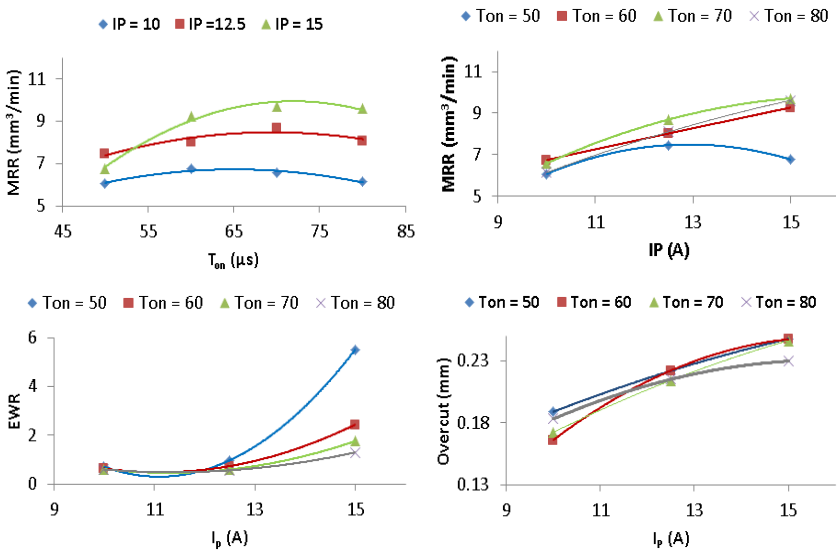

Figure. 2. Variation of MRR, EWR and overcut with peak current and T_{on}

Figure 3 depicts the influence of flushing pressure on the size of the hole obtained. With an increase in flushing pressure from 0.05 MPa to 0.065 MPa, enlargement of entry hole diameter is observed. This is due to the fact that increase in pressure causes wobbling at the tip of rotating electrode. Figure 4 represents the cut sections of the drilled holes. From the figure it can be seen that the holes are fairly straight with minimum taper.

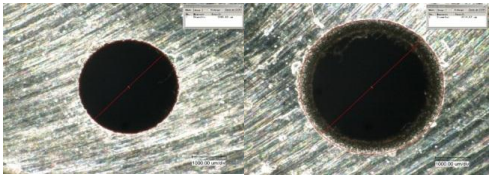

Figure 3 Variation of hole diameter with flushing pressure

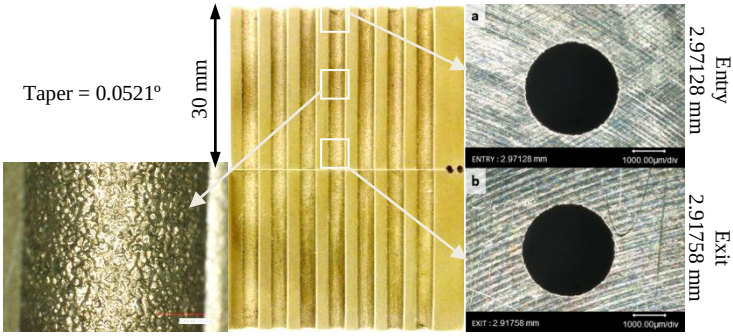

Figure. 4. Drilled holes (center), surface quality (left) and entry & exit (right)

4. Conclusion

In this study, deep-hole drilling capability of Inconel 718 using EDM has been studied. Peak current, pulse on time and flushing pressure were found to be the most affecting parameter. The drilled holes were found to be fairly straight with taper angle in the range of 0.003º- 0.195º. The results obtained would be a good source of information for the aerospace/oil and gas industry.

References

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