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Electrical discharge machining of 6061 aluminium alloy

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Abstract: The wire electrical discharge machining (EDM) of 6061 aluminium alloy in terms of material removal rate, kerf/slit width, surface finish and wear of electrode wire for different pulse on time and wire tension was studied. Eight experiments were carried out in a wire EDM machine by varying pulse on time and wire tension. It is found that the material removal rate increases with the increase of pulse on time though the wire tension does not affect the material removal rate. It seems that the higher wire tension facilitates steady machining process, which generates low wear in wire electrode and better surface finish. The surface roughness does not change notably with the variation of pulse on time. The appearance of the machined surfaces is very similar under all the machining conditions. The machined surface contains solidified molten material, splash of materials and blisters. The increase of the pulse on time increases the wear of wire electrode due to the increase of heat input. The wear of wire electrode generates tapered slot which has higher kerf width at top side than that at bottom side. The higher electrode wear introduces higher taper.

Key words: wire electrical discharge machining (EDM); 6061 aluminium alloy; material removal rate; kerf width; surface finish

1 Introduction

Machining processes remove unwanted material from a bulk workpiece and introduce the shape of the final product [1]. In conventional machining, the unwanted material is separated as chips by plastic deformation due to application of force by sharp cutting tools [2]. Electrical discharge machining (EDM) is one of the most extensively used non-conventional material removal processes where electrical discharge is used to machine electrically conductive parts regardless of hardness [3]. The electric discharge generates high thermal energy which removes material by erosion [4]. EDM process takes place in a dielectric fluid where the tool is one electrode in the shape of the cavity to be produced and the workpiece to be machined is the other electrode. The tool is then fed toward the workpiece in a controlled path to produce the shape of electrode or its movement [5]. The electrode and the workpiece do not make direct contact during EDM process. Therefore, this process eliminates issues related to chatter and vibration. EDM is a multipurpose process for machining intricate or complex shapes, which has typical advantage in the manufacture of mould, die, automotive, aerospace and surgical components from materials which are difficult to be machined by conventional methods. It is possible to drill a hole as small as 0.1 mm by EDM [3]. There are many researches on the EDM of different materials such as titanium alloys, alloy steel and metal matrix composites [5−8]. But there are very few investigations on the EDM of aluminium alloy. SELVAKUMAR et al [9] investigated wire electrical discharge machining (WEDM) of 5083 aluminum alloy using Taguchi experimental design (L9 orthogonal array) method, where pulse on time, pulse off time, peak current and wire tension were input parameters and the surface roughness and cutting speed were output parameters. The optimal machining parameters for the maximum cutting speed and the minimum surface roughness were decided based on the signal-to-noise (S/N) ratio. Finally, additive model was employed for prediction of all (34) possible machining combinations and a handy technology table was reported using Pareto optimality approach. Though this study presented some information on several input and output parameters on EDM of 5083 aluminum alloy,

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it does not give any information of underlying mechanisms. DAVE et al [10] also used Taguchi methodology to study microholes generated on 1100 aluminum alloy using micro-electro-discharge machining. Gap voltage, capacitance, pulse on time, electrode thickness and electrode rotation were input parameters, and top radius, bottom radius, taper angle and electrode depletion were output parameters. Though the above two studies presented some information on several input and output parameters on EDM of 5083 and 1100 aluminum alloys, it does not give any information of underlying mechanisms.

Aluminium alloys are well known as easy to machine materials in traditional machining because of high thermal conductivity and low hardness [11,12]. However, in case when a part with very complex shape needs to be produced then EDM can be the best option in terms of time and cost. Therefore, it is imperatively needed to understand the electrical discharge machining of 6061 aluminium alloy, which is the most popular among all the aluminium alloys. Considering the above facts, the electrical discharge machinability of 6061 aluminium was studied in terms of material removal rate, surface finish, kerf/slit width and wear of wire electrode. This will help the research community as well as the industry people to understand the behaviour of 6061 aluminium alloy when it needs to be processed by wire EDM.

2 Experimental

A series of wire electrical discharge machining (wire-EDM) of 6061 aluminum alloy were carried out by FANUC ROBOCUT α-0iD. The machining conditions and the compositions of 6061 aluminum alloy are given in Tables 1 and 2, respectively. The experimental parameters (variables as well as constants) were based on limitations of the wire-EDM as well as most commonly used values in the literature. The fixed parameters during machining were wire speed 10 m/min, flushing rate 10 L/min, open circuit voltage 85 V, servo voltage 44 V and zinc coated brass wire of diameter 0.25 mm. A 7 mm-long slot was produced on a plate of 137 mm × 42 mm × 9 mm in each experiment. Two important parameters, pulse on time and wire tension were varied during the experiments. The pulse on time controls the heat input and the wire tension controls the flexibility of the wire, i.e., the mechanical ability for carrying on the process steadily [7,8,14]. The cutting speed, kerf width, surface roughness and wire wear were investigated in this study.

Table 1 Experimental conditions

Experiment No.	Wire tension/N	Pulse on time/μs
1	17.64	1
2	17.64	2
3	17.64	3
4	17.64	4
5	14.70	4
6	11.76	4
7	8.82	4
8	5.88	4

Table 2 Chemical compositions of tested 6061 aluminum alloy (mass fraction, %) [13]

Mg	Si	Cu	Fe	Mn	Cr	Zn	Ti	Al
0.9	0.41	0.16	0.26	0.07	0.04	0.01	0.01	Bal.

3 Results

3.1 Material removal rate

The effect of pulse on time on the cutting speed is presented in Fig. 1. It shows that the cutting speed increases with the increase of pulse on time. The pulse on time controls the heat generation and spark formation. The increase of pulse on time increases the heat generation which improves the material removal and extends the heat for longer time, which helps to remove material efficiently. Thus, longer pulse on time increases the material removal rate. The increase of material removal rate is linearly proportional to the increase of pulse on time.

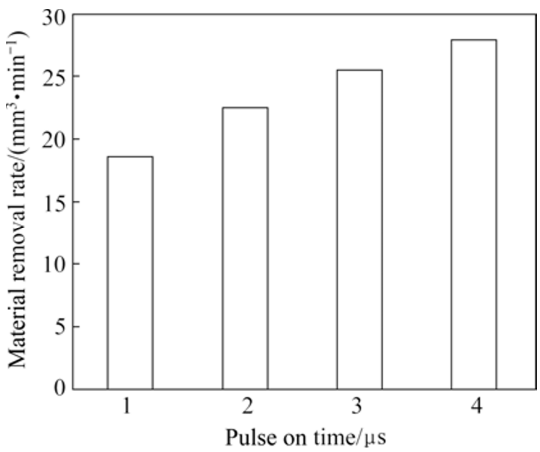

Fig. 1 Effect of pulse on time on cutting speed at wire tension of 17.64 N

Figure 2 presents the effect of wire tension on the material removal rate. It shows that the material removal rate is not affected by the wire tension significantly. The wire tension does not have anything to do with the temperature and spark but it controls the flexibility and straightness of the wire. The little variation of material