

# Improving the performance of EDM deep hole using multi-hole interior flushing electrode

S. Chuvaree, K. Kanlayasiri

Department of Industrial Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

E-mail : c.suppawat@gmail.com

**Abstract.** In conventional flushing, when increasing the machining depth, the flushing ability becomes insufficient for ejection of the debris from machining gap. Debris concentration in the gap spark causes a process instability, low performance and high machining time etc. This paper proposes an innovative method of flushing technique for electrical discharge machining (EDM) of deep hole process. Tool electrode was specifically fabricated for flushing on the efficiency and stability of machining to promote the ejection of debris from machining gap. The performance of the deep hole process by electrical discharge machining under different flushing condition are presented. The results showed that the flushing through the tool electrode and multi-hole interior flushing are more preferred than side flushing. The result include 26.10% reduction in machining time (50 mm. in depth) when using multi-hole interior flushing electrode. In addition, the application of electrode multi-hole interior flushing electrode with electrode rotation improves the material removal rate (MRR) by 35.28% with 58.04% higher surface roughness (Ra).

## 1. Introduction

One of the important factors in a successful deep-hole EDM operation is the removal of debris from the machining gap. The flushing of these debris out of the machining gap is very important in preventing secondary spark and enhancing performance of machining. In the EDM process, the workpiece and tool electrode are submerged in dielectric fluid. The material removal process takes place as effect of electrical sparks occurring between tool electrode and workpiece that are separated by dielectric fluid [1]. The dielectric fluid is fed into small gap to remove debris particles that are generated by EDM and maintain the stability of machining condition. If the debris accumulates in the machining gap, the electrical conductivity of the dielectric liquid will be increased, leading to secondary spark phenomena as well as process instability and poor machining conditions. The influence of flushing of dielectric plays a crucial role during the whole process. Improper flushing can result in sparking that high electrode wear, increased machining time and surface finish [1–2].

To enhance the flushing of debris, the desired machining can be achieved by using a side jet flushing of fluid directed into the machining gap. However, the effectiveness of side flushing is limited when the machined depth is increased due to the ejection of debris from machining gap is extremely difficult and it produces a tapered opening in the workpiece [3–7]. L Li *et al.* [8], studied flushing technique using bundled electrode compared with a solid electrode in machining Ti6Al4V. It has been proved that bundled electrodes can endure a much higher peak current than solid electrode



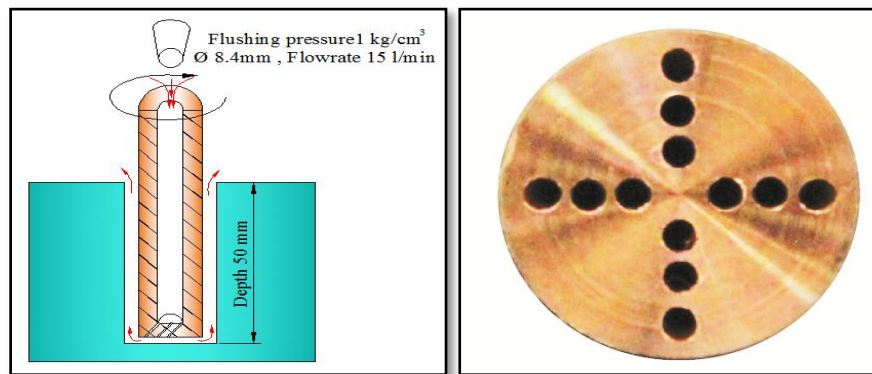
which results in a substantially higher material removal rate (MRR) and a comparably lower tool wear ratio (TWR). R Nastasi *et al.* [9], proposed the application of deep slotted tools in EDM drilling process compared with cylindrical and helical electrode. The results showed that at a machining depth of 5 cm, the higher MRR could be obtained using deep slotted tool.

In the EDM deep hole process, the viscous resistance in the narrow discharge gap causes difficulty in removal of debris and bubbles from the sparking area and abnormal discharge are occurred and resulting in extensive performance of deep hole process. Since, several methods such as electrode jump high, side flushing, mono hole inner flushing and reverse flow flushing have been established [3–6], but the application of the flushing technique for deep hole drilling has been very less reported.

This research proposes an EDM machining technique for deep hole by using multi-hole interior flushing electrode. The material removal rate (MRR), working time (Wt.) and surface roughness (Ra) have been carried out on the AISI P20 tool steel. The performance of the deep hole process by electrical discharge machining under different flushing condition are presented.

## 2. Experimental Setup

The experiments were carried out on 50 mm. depth of cylindrical hole in AISI P20 tool steel with ARISTECH CNC-EDM model 430. The EDM was carried out macro-scale machining with copper electrode as outside diameter of 12 mm, inner hole diameter 8.4 mm and the bottom of electrode was specifically designed that the dielectric running directly through internal diameter of tool electrode using multi channels inferior flushing (12 holes with a diameter of 1 mm.) as shown in Figure 1.



**Figure 1.** Tool electrode using multi holes inferior flushing

The special rotary chuck has been fabricated for EDM deep hole process and mounted to the EDM machine. The tool rotation helps in improving the flushing ability and removal of debris from the machining gap during EDM of deep hole process [10]. During the EDM deep hole process the flow rate of dielectric flushing was set on a constant value. The experimental conditions were shown in Table 1. The material removal rate (MRR) is defined as equation (1)

$$\text{MRR (g/mm}^3\text{)} = (\text{initial weight} - \text{final weight}) / \text{machining time} \quad (1)$$

**Table 1.** Experimental conditions

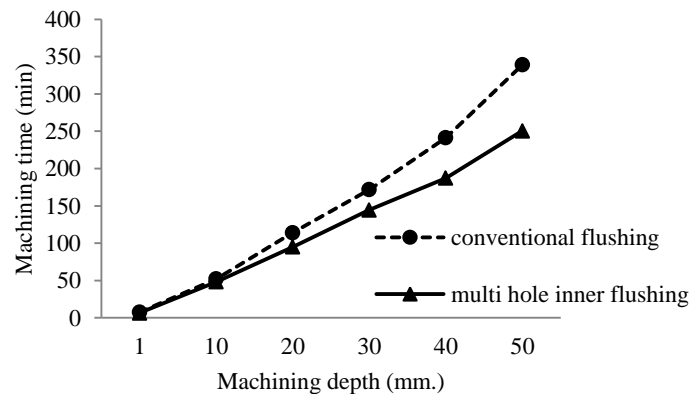
S.N.	In put parameters	Values
1	Pulse on-time	150 $\mu\text{s}$ .
2	Pulse off-time	20 $\mu\text{s}$ .
3	current	15 A.
4	Voltage	150 V.
5	Electrode rotational speed	0, 35, 70, 105, 140 and 175 rpm.
6	Polarity (Electrode)	+

7	Flushing Pressure	1kg/cm <sup>2</sup>
8	Machining depth	50 mm.
9	Dielectric fluid	EDM oil-TOTAL DIET MS 700

### 3. Result and Discussion

#### 3.1 Machining Time

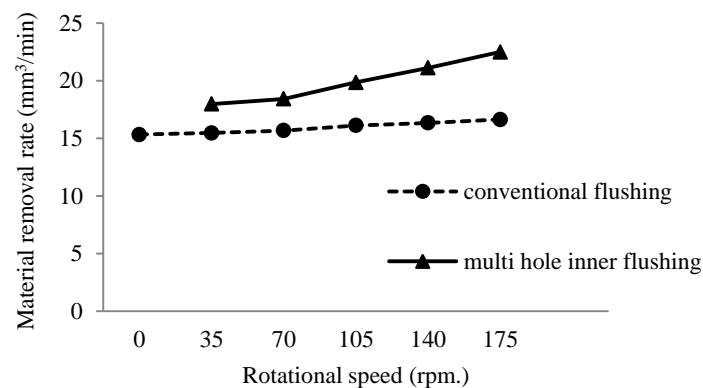
When increasing the machining depth, the flushing of debris out of the machining gap is very important problem. In this section, a comparison between solid electrode using side flushing and solid electrode using multi-hole interior flushing is observed. As the results shown in Figure 2, it is evident that the reduction of machining time resulted from the influence of flushing condition under multi hole inner flushing. When the machining depth is increased, the multi-hole interior flushing disposes the debris out of the machining gap. Consequently, the spark intensity becomes better than side flushing and thus the machining time is reduced. At a depth of 50 mm, machining time is reduced from 339.01 minutes to 250.53 minutes when using multi-hole interior flushing electrode.



**Figure 2.** Machining time VS machining depth with different flushing condition

#### 3.2 Material removal rate

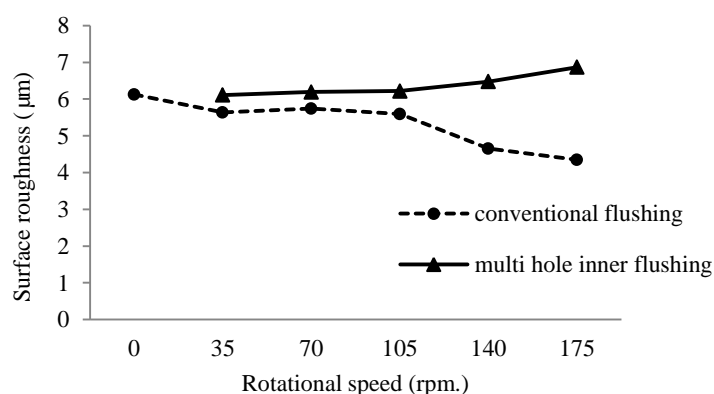
In this experiments, the obtained MRR under conventional side flushing and multi holes inner flushing with different electrode rotational speed are illustrated in Figure 3. Under a multi hole inner flushing electrode with electrode rotation, the highest MRR of 22.485 mm<sup>3</sup>/min. is achieved. It is assumed that the effect of electrode rotation couple with multi holes inner flushing causes the increase in MRR. The fresh dielectric is fed through multi-hole interior electrode and flowed out of small gap between electrode and workpiece to remove debris particles continuously. Moreover, the electrode rotation during EDM deep hole process promotes cleaning of debris in machining gap. As a result, complete spark occurs and is better than side flushing electrode.



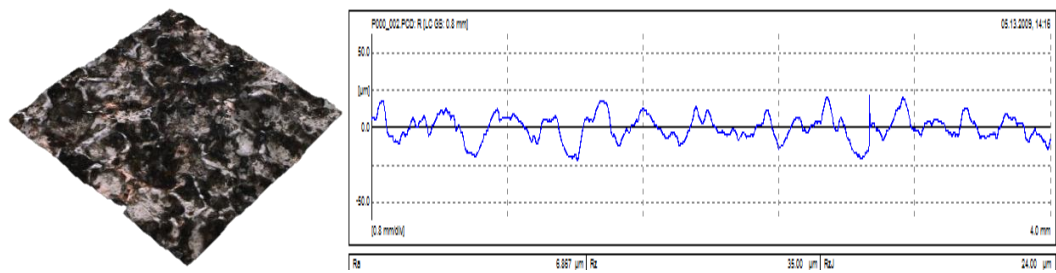
**Figure. 3** MRR under conventional side flushing and multi hole inner flushing with different electrode rotational speed at a depth of 50 mm.

### 3.3 Surface Roughness

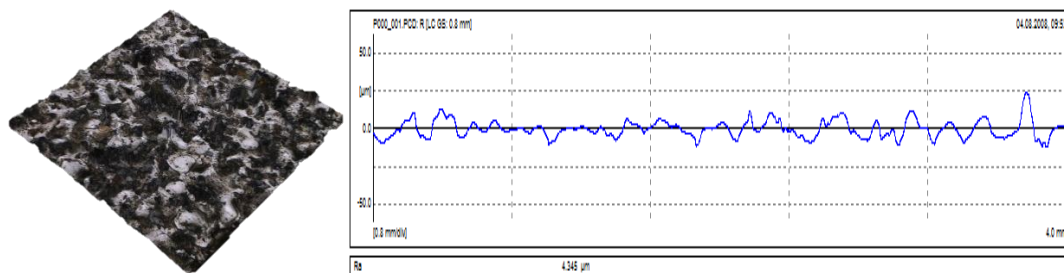
In this experiments, the effects of improved flushing increases MRR and reduces machining time. At the same time, process stability is increased because tool rotation induces fresh dielectric into the discharge gap as the used dielectric is forced out due to the centrifugal force. According to Figure 4, it is observed that when using conventional electrode via side flushing the surface roughness is improved with increasing electrode rotation speed. The surface roughness with the fixed electrode is  $6.125 \mu\text{m}$ , whereas it is approximately  $4.345 \mu\text{m}$  for the electrode rotation at 175 rpm. It is assumed that the debris is uniformly distributed and re-solidified on the surface leading to smoother surface. However, the flushing effect is limited when using multi-hole interior flushing electrode. Too much cleaning of the spark gap always increases surface roughness because of the rapid recovery of dielectric strength in spark gap. As a result, the spark intensity is very violent and thus higher MRR is obtained with a higher surface roughness [3, 5, 7]. Figure 5, shows the surface topography analysis by optical profilometer of the machined surface under different electrode flushing and electrode rotation.



**Figure 4.** Influence of electrode rotation on surface roughness under conventional side flushing and multi hole inner



a) Multi-hole flushing electrode at 175 rpm of electrode rotation ( $R_a$  : 6.867  $\mu\text{m}$ )



b) Side flushing electrode at 175 rpm of electrode rotation ( $R_a$  : 4.345  $\mu\text{m}$ )

**Figure 5.** Surface topography under different electrode flushing and electrode rotation

#### 4. Conclusion

In this present work, a new flushing method is proposed and the performance of EDM deep hole process using newly proposed multi-hole inferior flushing is compared with side flushing on the AISI P20 tool steel. The following conclusions can be drawn from the experiment.

- The improved flushing increases MRR and reduces machining time. At the same time, process stability increases because tool rotation induces fresh dielectric into discharge gap as the used dielectric is forced out due to the centrifugal force.
- 26.10% reduction in machining time (50 mm. in depth) when using multi-hole interior flushing electrode is achieved.
- The multi-hole interior flushing electrode with electrode rotation improves the material removal rate (MRR) by 35.28% with 58.04% higher surface roughness ( $R_a$ ).

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