Indian Journal of Engineering & Materials Sciences
Vol. 26, June-August 2019, pp. 200-204

Form tolerances investigation in EDM process for super alloys using multiple holes electrodes

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Received 10 April 2017; Accepted 9 July 2019

The present work focuses on experimental quality analysis of electrical discharge machining (EDM) of two super alloys namely Inconel 718 and Inconel 625 with different diameter of hole of multiple holes copper electrodes. The diameter of hole of multiple holes in electrode, pulse current and (Ton) pulse on time have been chosen as process parameters to conduct the experiment trails. The MRR, EWR and form tolerance have been considered as output responses.

Keywords: Electrical discharge, Machine, Multi hole, Electrode, Form tolerance, Super alloys

1 Introduction

Due to their enhanced mechanical and thermal properties, the nickel-contained super alloys are widely employed in some aerospace components, turbines, motors for rocket and space crafts[1-4]. These alloys are difficult to machine by using conventional machining processes due to capable of withstanding high temperature and highly corrosive resistant. In the recent past, a few research studies have been used for different machining tools like coated and uncoated PCBN tools, film coated tools, tungsten carbide (K20) insert and different powder coated tools on high speed dry and wet conventional machining processes[5-7] to machine these super alloys. Despite the emergence of new alloy tools, the super alloys are considered as difficult - to - machine materials in conventional machining process[6,7]. These reasons make electrical discharge machining process as the best suited in machining of super alloys. EDM is one of the successful, less expensive and widely employed in non-traditional machining processes irrespective of materials' hardness like these super alloys[8-20]. EDM has been explored to machine these alloys by using electrodes made up of different materials.

Traditionally, in EDM process electrical conductive any material is used as tool electrode to machine super alloys and this process is found to be with less in Material Removal Rate (MRR). A few researches were carried out by using hallow brass and copper electrodes, rotary single and multi-channel electrodes, bundled small tube electrode to promote the MRR and to decrease the electrodes wear rate[8-11]. While the above researches improved MRR, the impact of electrode on other quality requirements such as form tolerances (Cylindricity and circularity) were ignored. All the previous researches ignored the analysis on cylindricity and circularity of the holes made on these components by EDM. Recently, micro-EDM drilling of Inconel 718 was optimized by some researcher for hole narrow and hole dilation using Grey relational analysis[17,20].

In this research work, a challenge has been made to promote MRR and reduce EWR by machining with different multiple holes electrodes having holes in the order of Ø 0.008 cm, Ø 0.016 cm and Ø 0.024 cm on EDM while machining of Inconel 625 and Inconel 718, respectively. Our survey of literature reveals that there is no more works on cylindricity and circularity while machining of Inconel 718 and Inconel 625 in EDM process by using these multiple holes electrodes. Consequently, as an attempt the form tolerances were analyzed in EDM of Inconel 625 and Inconel 718 by using these multiple holes electrodes[17]. Taguchi technique was used to develop design of experiments (DoE) to reduce the number of trails[15-17].

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2 Materials and Methods

In the present investigation, the die sinking SPAKONIX–EDM was used to carried out the experimental trails. The machine had a maximum current capacity of 15A. The Inconel 718 and 625 work material and copper electrode material were connected to the positive and negative polarity, respectively. The machine had 10 pulse on time (T_{on}) setting and 10 pulse off time (T_{off}) setting. The kerosene was flushed with 0.5 kg/cm^2 pressure between electrode and super alloy by using center flushing technique. Three multiple hole electrodes as shown in Fig. 1 were employed in EDM processes.

The mass loss of the copper and as well as super alloys were measured with an 10^{-3} digital accuracy in terms of grams.

Expression used for calculating Material Removal Rate (MRR) is:

$$= \frac{\text{Mass of workpiece material machined}}{\text{Machining time}} \ (\text{g / min}) \quad \ldots (1)$$

Expression used for calculating Electrode Wear Rate (EWR) is:

$$= \frac{\text{Mass of electrode material that worn out}}{\text{Machining time}} \ (\text{g/ min}) \quad \ldots (2)$$

The form tolerance for circular electrodes was calculated by TESA micro-hite 3DCo-ordinate Measuring Machine (CMM).

Fig. 1 — Multiholes electrode.

The numbers of experiment trails were reduced by using Taguchi approach. A total of three parameters namely diameter of hole of multiple holes, current and T_{on} were selected as the input parameter. It was designed to have 3 levels, namely low, average, and high which represented by 1, 2 and 3, respectively, as shown in the Table 1.

3 Results and Discussion

The calculated MRR, EWR, and measured form tolerances for electrical discharge machined super alloys are given in Table 2 and Table 3.

In general, the improved MRR is one part of the main goals of any EDM process. In this work, the effect of three different diameter of multiple hole electrodes made up of copper are analyzed while machining of super alloys using EDM. Figure 2 shows the multiple holes electrode having Ø 0.24 mm holes. It gives higher MRR when compared to that is given by the multiple holes electrodes having Ø 0.08 mm holes. In the multiple hole electrodes having holes of Ø 0.08 mm is having less spark area due to large number of holes area. Therefore, MRR is less while using it. At the same time, when using this electrode, the maximum amount of dielectric fluid is flushed through this electrode which tends to reduce the discharge energy due to continuous protection of work piece. This is also a reason for low MRR. On the other hand, electrode having minimum numbers holes of Ø 0.24 mm is having high spark area. This increases the MRR. Whereas the MRR was given by the electrode having holes of Ø 0.16 mm falls between other two MRR.

Table 1 — Machining parameters and their levels.

	Parameter	Unit	Level l	Level 2	Level 3
A	Diameter of multihole electrode	mm	0.08	0.16	0.24
B	Current	A	4	8	12
C	Pulse on time	µs	200	400	600

Table 2 — INCONEL 718 data.

S.No.	Diameter of multihole electrode(mm)	Current (A)	Pulse on time (µs)	Flu.pressure (kg/m^2)	MRR (g/min)	EWR (g/min)	Circularity (mm)	Cylindricity (mm)
1	0.08	4	200	0.1	0.003	0.0009	0.0337	0.0441
2	0.08	8	400	0.2	0.067	0.00016	0.0112	0.0135
3	0.08	12	600	0.3	0.082	0.00016	0.0536	0.0633
4	0.16	4	400	0.3	0.045	0	0.0710	0.0913
5	0.16	8	600	0.1	0.062	0	0.0205	0.0093
6	0.16	12	200	0.2	0.094	0.0088	0.0557	0.0602
7	0.25	4	600	0.2	0.033	0	0.5584	0.0102
8	0.25	8	200	0.3	0.050	0	0.0791	0.0538
9	0.25	12	400	0.1	0.049	0	0.0100	0.0185

From Fig. 2 to Fig. 8, it is inferred that the MRR and form tolerance measures for Inconel 718 are better than those Inconel 625. This is might be due to low melting point (1336 ºC) and high thermal conductivity (11.4 W/m K) of Inconel 718 when compared with high melting point (1,350 ºC) and low thermal conductivity (9.8 W/m K) of Inconel 625.

The MRR is increasing with respect to discharge current. This is because the increase in discharge power and impulse energy as the peak current increased. Consequently, the MRR get increased due to the raise of melting and vaporizations of super alloys.

The MRR was varied with respect to T_{on} duration. The MRR is increased up to 400 µs and then the MRR is decreased on further increase in T_{on}. Increasing T_{on} increases the input energy. This promotes the extra chopping on the gap between the multiple holes electrode and super alloys materials. This is producing a short circuit which reduces the quality characteristics of EDM processes.

Figures 3 and 4 show the effect of electrode hole diameter on circularity and cylindricity deviation. From Fig. 3, it is clear that the variation in circularity deviation increases with electrode hole diameter. This is due to the reason that the increase in electrode hole diameter with less number of these electrodes holes leads to higher spark area in the circumference of the electrode. Due to this reason, the circularity gets increased. The cylindricity initially reduced and then increased as shown in Fig. 4.

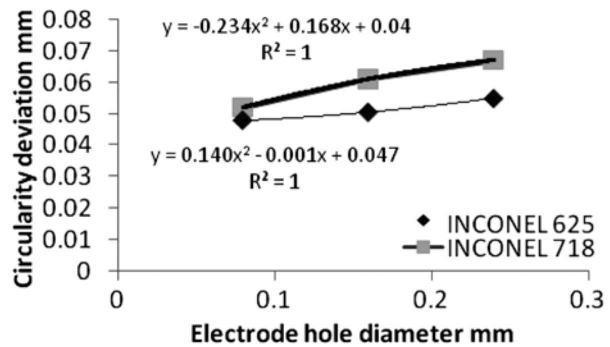

Fig. 3 — Electrode hole diameter versus circularity.

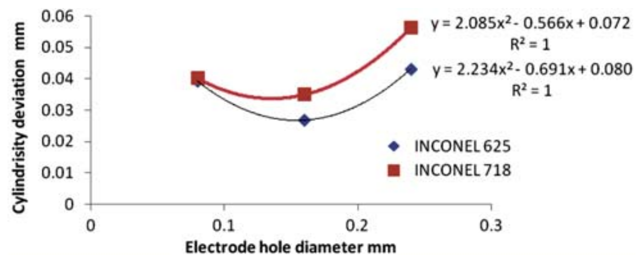

Fig. 4 — Electrode hole diameter versus cylindricity.

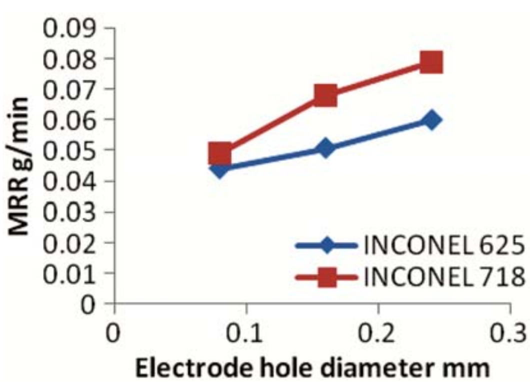

Fig. 2 — Electrode holes versus MRR.

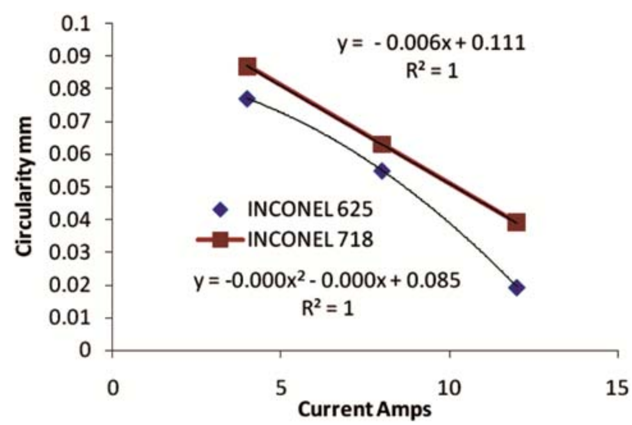

Fig. 5 — Current versus circularity.

Table 3 — INCONEL 625 data.

S.No.	Diameter of multihole electrode(mm)	Current (A)	Pulse on time (µs)	Flu.pressure (kg/m^2)	MRR (g/min)	EWR (g/min)	Circularity (mm)	Cylindricity (mm)
1	0.08	4	200	0.1	0.009	0.002	0.0183	0.0441
2	0.08	8	400	0.2	0.045	0.001	0.1042	0.0125
3	0.08	12	600	0.3	0.086	0.002	0.0216	0.0613
4	0.16	4	400	0.3	0.013	0.0005	0.085	0.0533
5	0.16	8	600	0.1	0.048	0.0017	0.0625	0.0003
6	0.16	12	200	0.2	0.099	0.0002	0.0043	0.0272
7	0.25	4	600	0.2	0.022	0.0027	0.1294	0.0482
8	0.25	8	200	0.3	0.059	0.0074	0.0011	0.0528
9	0.25	12	400	0.1	0.074	0.0078	0.0320	0.0345

The sparking area takes place bottom of the electrode as well as it is lateral face also. Therefore, the EWR increases with current and it also affects the cross sectional area of the electrode. As the current increases further the circularity deviation increases to a peak value and then it decreases as shown in Fig. 5.

As the current increases the cylindricity deviation increases as shown in Fig. 6. Because of higher current discharge energy which is increase the electrode wear as well as the cylindricity deviation. Unlike the cylindricity deviation, the circularity deviation is not increasing continuously. This is due to the reason that the continuous machining will produce taper in the machined hole which will increase the cylindricity deviation and circularity deviation is measured in a single plane which is not increasing continuously.

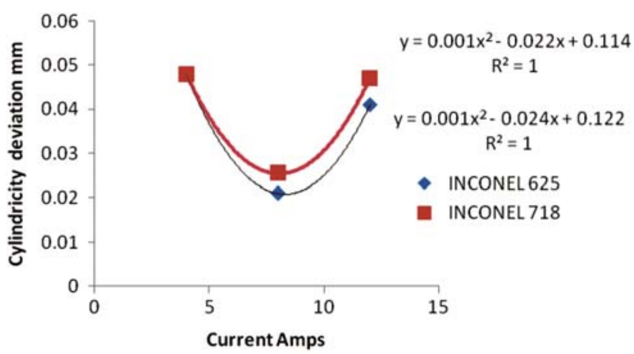

Fig. 6 — Current versus cylindricity.

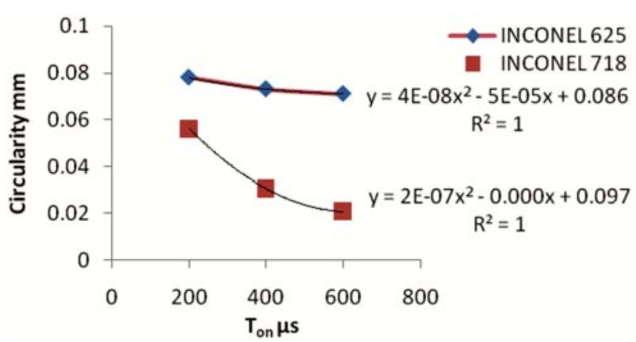

Fig. 7 — T_{on} versus circularity.

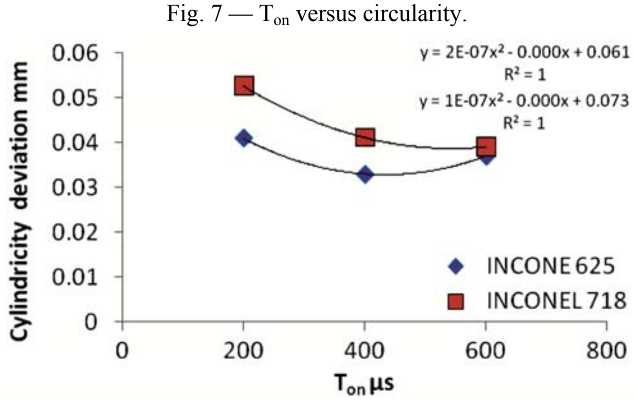

Fig. 8 — T_{on} versus cylindricity.

Figures 7 and 8 show that the variations of MRR and EWR with respect to T_{on} duration. As the T_{on} increases, the circularity and cylindricity are gradually reduced up to 400 µs. Then, further increased T_{on} enhances cylindricity.

4 Conclusions

In this work, the Taguchi L_9 array table was employed to design the experimental works for Electrical Discharge machining of super alloy like Inconel 718 and Inconel 625 with help of multiple holes electrodes the subsequent conclusions was made:

(i) The MRR of EDM in machining selected super alloy increases with increase in spark discharge area which is higher for multiple hole electrodes having holes of Ø 0.24 mm.

(ii) The direct impact on MRR is shown by the variation in discharge current and it also affects the form tolerance.

(iii) The increase in T_{on} improved the MRR initially, but the further increase let to decreased MRR.

(iv) The value of cylindricity deviation and circularity deviation first reduces with an increment on T_{on} values (up to 350 µs) and then improved with an additional increment in the T_{on} values.

(v) Use of multi hole electrode gives very high value MRR when compared to EDM with rotation of electrode and EDM with increased flushing pressure. It also gives negligible EWR with considerable MRR.

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