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RESEARCH ARTICLE

Comparison of surface roughness of ductile cast iron using Taguchi design

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Abstract

Surface roughness (SR) is measured and compared for both the solid and hollow copper electrode by using the Taguchi design. All the machining parameters are kept constant for both the electrodes. By increasing the pulse ON from 6 µs to 8 µs and 8 µs to 10 µs, the surface roughness increases first and then it decreased. By increasing the pulse OFF from 5 µs to 7 µs and 7 µs to 9 µs, the surface roughness increased slightly and then it decreased. The SR is increased by increasing the current from 5 to 10 A and 10 to 15 A. But in flushing pressure, the SR first decreased from 10 to 15 Kg/cm^2 and then increased when the flushing pressure increases from 15 to 20 Kg/cm^2. From this experimental work, it can be concluded that SR is high for hollow electrode when compared with the solid electrode at the same machining parameters.

Keywords: Surface roughness, Taguchi design, copper electrode, pulse OFF, flushing pressure.

Introduction

The advent of ductile cast iron has given a boost to the design engineers. Initially, it was considered as a wonder metal in the field of metallurgy of cast irons. During few decades it was a challenge to make ferritic grade ductile iron as-cast condition for applications (Paknikar, 2009). Machining is required to get the final shape of the casted product. The influence of EDM parameters like electrode material, flushing, electrode dimension, depth of cut on the removal rate, the electrode wear, accuracy and surface texture was carried out. An experimental analysis was carried out on die casting by using both copper and graphite electrodes. The important parameters of EDM were electrode material, injection flushing and geometry of cutting on removal rate, electrode wear and surface quality was discussed by Lonardo and Bruzzone (1999). The optimization of drilling of Al_2O_3/6061Al composite is carried out using rotary electro-discharging machining reported by Chung and Hwa (2000). The material removal rate, surface roughness and electrode wear rate were verified during this optimization of the machining technique. Seven independent parameters were also chosen as variables in evaluating the Taguchi method.

Various electric parameter e.g. polarity, peak current, pulse duration, and powder supply voltage and non-electrical parameter e.g. rotational speed of the electrode, injection flushing pressure, and the number of eccentric through-holes in the electrode were used. The electrical group has a more significant effect than the non-electrical group on the machining characteristics. The effect of various parameters of EDM electrode i.e. hollow and solid during the machining of ductile cast iron were studied and experimented by analyzing the surface roughness of the machined hole. Taguchi L9 orthogonal array is used to perform this experiment and the comparison of surface roughness is done between the solid and hollow electrode.

Materials and methods

Experimental design: All the experiments have been conducted using the electrical discharge machine model S-35, Sparkonix. Figure 1 shows drilling of work-piece by EDM in which holes are already made with the help of the solid electrode and drilling by hollow electrode by using EDM on the ductile cast iron work-piece is taking place. Various EDM parameters are used for the machining purpose which is mentioned in Table 1 (Rahul Mehra *et al.,* 2012).

Fig. 1. Drilling of holes by using solid and hollow copper electrode.

Table 1. Parameters for experimentations.

Parameters	Level		
	1	2	3
Peak current (A)	5	10	15
Pulse ON (µs)	6	8	10
Pulse OFF (µs)	5	7	9
Flushing pressure (Kg/cm^2)	10	15	20

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Calculation of surface roughness: An experimental optimization is done by calculating the SR using the levels and parameters for both solid and hollow electrode. Figure 2 shows the surface roughness tester which is used for measuring the surface roughness of the work piece. The effect of parameters i.e. pulse on time, pulse off time, current and jet pressure, some of their interactions were evaluated using ANOVA to analyze surface roughness of the material at different levels.

Fig. 2. Surface roughness tester.

Results and discussion

The surface roughness is measured with the help of the surface roughness tester. The results for the machining of the ductile cast iron on EDM by using solid and hollow copper electrode are shown in Table 2. The results for the machining of the ductile cast iron on EDM by using hollow copper electrode are shown in Table 3. By increasing the pulse ON, during the machining of ductile cast iron by both the solid and hollow electrode, first there was increase in the mean of SR from 6 µs to 8 µs and then there was a decrease in the mean of SR from 8 µs to 10 µs as shown in Figure 3. Keeping the pulse ON 6,8,10 µs constant, the SR is high for hollow electrode when compared with the solid electrode. This is due to the fact that since less metal is removed from the work-piece in the form of small crater by increasing pulse ON as discussed earlier.

Table 2. Results by solid electrode.

Pulse ON time (µs)	Pulse OFF time (µs)	Peak current (A)	Flushing pressure (Kg/cm^2)	Mean of SR
6	5	5	10	2.156
6	7	10	15	3.420
6	9	15	20	4.223
8	5	10	20	3.630
8	7	15	10	4.970
8	9	5	15	2.350
10	5	15	15	4.306
10	7	5	20	2.513
10	9	10	10	3.283

Table 3. Results by hollow electrode.

Pulse ON time (µs)	Pulse OFF time (µs)	Peak current (A)	Flushing pressure (Kg/cm^2)	Mean of SR
6	5	5	10	2.233
6	7	10	15	3.636
6	9	15	20	4.543
8	5	10	20	3.993
8	7	15	10	5.093
8	9	5	15	2.643
10	5	15	15	4.706
10	7	5	20	2.806
10	9	10	10	3.376

Fig. 3. Comparison of Pulse ON by solid electrode and hollow electrode on mean of SR.

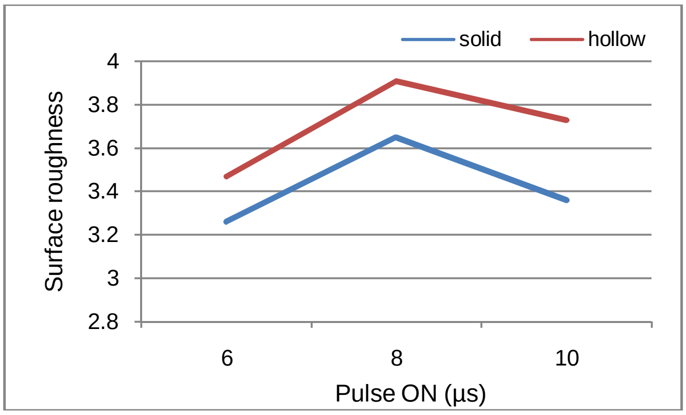
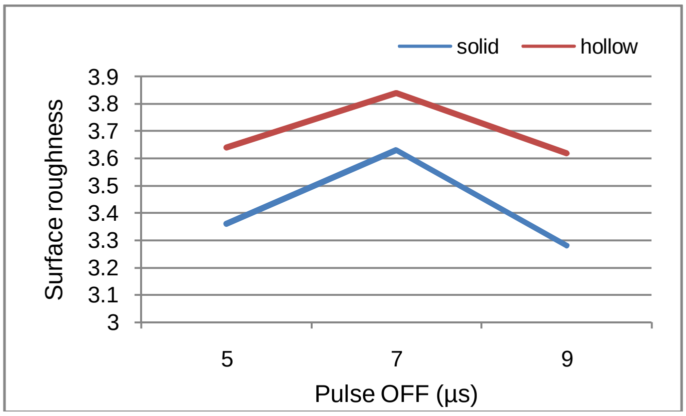


Fig. 4. Comparison of Pulse OFF by solid electrode and hollow electrode on mean of SR.



Long pulse on-time duration causes the plasma channel to expand, resulting in less energy density on work-piece, which is insufficient to melt and/or vaporize the work-piece material (Muller and Monaghan, 2000; Rahul Mehra *et al.,* 2012). By increasing the pulse OFF, during the machining of ductile cast iron by both the solid and hollow electrode, first there was an increase in the mean of SR from 5 µs to 7 µs and then there is a decrease in the mean of SR from 7 µs to 9 µs. There is an increase in the mean of SR as shown in Figure 4.

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Keeping the pulse OFF 5, 7, 9 µs constant, the SR is high for hollow electrode when compared with the solid electrode. It is because of correct flushing of the debris with sufficient pulse off-time duration. Due to sufficient time for more accurate flushing the SR is increased as debris does not affect the machined surface (Mahamat *et al.,* 2011). By increasing the current, during the machining of ductile cast iron by both the solid and hollow electrode, there is a gradual increase in the mean of SR as shown in Figure 5. Keeping the current 5, 10, 15 A constant, the SR is high for hollow electrode when compared with the solid electrode. This is due to the fact that an increase in discharge current increases the pulse energy that leads to an increase in heat energy rate, which is subjected to both of the electrodes, and in the rate of melting and evaporation. Thus, the SR increases with discharge current (Puertas *et al.,* 2004).

By Increasing the flushing pressure from 10 to 15 Kg/cm^2, during the machining of ductile cast iron by both the solid and hollow electrode firstly there is a decrease in the mean of SR as shown in Figure 6. But further on increasing the flushing pressure from 15 to 20 Kg/cm^2, during the machining there is a increase in the mean of SR. Keeping the flushing pressure 10, 15, 20 Kg/cm^2 constant, the SR is high for hollow electrode when compared with the solid electrode. Firstly at low jet pressure of the SR decreases slightly due to the collection of the debris but when the jet pressure increases up to more higher value, due to the more pressure, the debris sweep out quickly resulting in the slightly increase in SR (Can Ogun and Akaslan, 2002).

Conclusion

The following conclusions can be made on surface roughness for solid and hollow electrode:

1. By increasing the Pulse ON or Pulse OFF, during the measurement of SR for ductile cast iron by both the solid and hollow electrode, firstly there is an increase in the mean of SR and after which there is a decrease in mean of SR.
2. By increasing the current, during the measurement of SR for ductile cast iron by both the solid and hollow electrode there is an increase in the mean of SR.
3. By increasing the flushing pressure from 10 to 15 Kg/cm^2, during the measurement of SR for ductile cast iron by both the solid and hollow electrode, firstly there is a decrease in the mean of SR but further on increasing the flushing pressure from 15 to 20 Kg/cm^2, during the machining there is a increase in the mean of SR.
4. Keeping the constant machining parameters combinations, the SR is high for hollow electrode when compared with the solid electrode. Therefore, solid electrode provides better surface finish and minimum surface rough roughness.

Fig. 5. Comparison of current by solid electrode and hollow electrode on mean of SR.

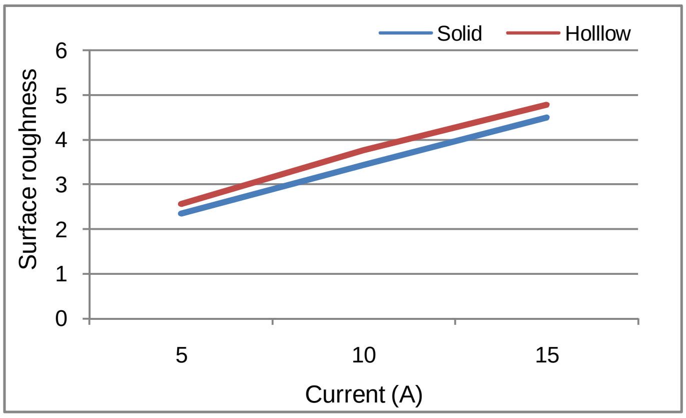
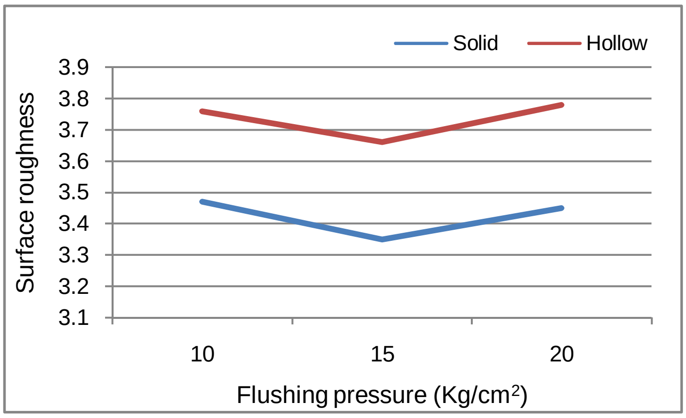


Fig. 6. Comparison of flushing pressure by solid electrode and hollow electrode on mean of SR.



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