Process parameter effects on wire cut EDM machining of hybrid aluminium metal matrix composites: An experimental research

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Abstract:

Globally, the composite materials are widely used in important industries. By using traditional machining techniques, it is extremely difficult to cut metal matrix composite materials that have reinforcement. Hence, non-traditional machining techniques are used to get around these challenges. With these materials, Wire Electrical Discharge Machining (WEDM) has greater capabilities for cutting complicated forms with high precision. For the reinforced metal matrix composite and hybrid aluminium metal matrix composites, the effects of process parameters for wire electrical discharge machining, such as voltage, pulse on-time, pulse -off time, and current, were examined in this work (HAMMCs). Stir casting is used to create silicon carbide (SiC) and boron carbide (B4C) reinforced aluminium 7075. Using the design of experiments method, the casting and machining processes were carried out in WEDM. Several sets of tests' material removal rates were examined. The impact of reinforcing weight fraction on metal removal rate was discussed. Also, the produced specimen's microstructure, surface roughness, and hardness were evaluated, with the results being assessed. It has been noted that as surface roughness and reinforcing weight percentage rise, the rate of metal removal decreases.**Keywords**: Reinforcement, Microstructure, hardness, surface roughness, material removal rate, wire electrical discharge machining.

1. Introduction

due to its high toughness, low coefficient of thermal expansion, and high strength-to-weight ratio MMCs are frequently employed in industries due to their high wear resistance [1, 2]. The hybrid Aluminum Metal Matrix Composites are widely employed in various applications where weight and strength are crucial considerations when compared to metals. The various strengthening processes and their formability are the primary benefits of particle reinforced composite [3, 4]. The HAMMCs have a low density and a high coefficient of thermal expansion[5]. HAMMCs are frequently employed in the automotive industry because of their good mechanical qualities [6]. Stir casting can be used to create HAMMCs. By choosing the proper processing parameters, such as stirring speed, time, and metal temperature, homogeneous mixing can be achieved. consistent particle feed rate and preheating mould temperature [7, 8]. Due to its excellent formability qualities, 7075 is the best aluminium alloy to use when creating metal matrix composites. [9-13]. The aluminium matrix's mechanical strength and hardness are increased by the addition of SiC and B4C particles. properties. To improve the stiffness and strength of particle reinforced HAMMCs, reinforcement is included into the matrix of the bulk material [14–16].

The metal matrix composite materials that are reinforced by conventional machines are exceedingly challenging to machine. In order to evaluate the metal removal rate employing atypical machining techniques, numerous research projects have been carried out. Nonetheless, it was discovered that wire electrical discharge machining was efficient for processing composite materials[17]. Using different process parameters, Ahmed et al [18] investigated the metal removal rate for the combinations of aluminium, silicon carbide, boron carbide, and aluminium silicon carbide-glass. According to Satish Kumar et al. [19], an increase in SiC particles in the matrix will cause a reduction in the rate at which metal is removed. Zirconium-based ceramic materials were used by B. Lawers et al. to study the material removal mechanism in EDM [20]. The characteristic investigations of an Al7075 metal matrix embedded with SiC as reinforcement particles were examined by V.C. Uvaraja et al. [21].

The MMCs can be machined using a variety of unorthodox methods, including abrasive jet machining, electrical discharge machining, and laser beam machining. However, because it is costly, wire cut electric discharge machining is utilised. Wire electrical discharge machining is the unconventional machining technique in which material is removed from the work piece by the application of spark between the wire electrode and workpiece in dielectric medium. Most of the research work is reported on Al 7075 with different reinforcement such as silicon carbide, silicon, boron carbide, titanium, alumina etc. But none of them had attempt for Al 7075 with two types of reinforcements like SiC and B4C.

Hence with the view of the above literature the main objective of the present work is to forecast the effect of addition of SiC and B4C particulate in the metal matrix. The effect of weight fraction of reinforcement in the metal has been analysed with respect to metal removal rate.

Table 1—Composition of Al 7075 by weight percentage

Elements	Si	Fe	Cu	Mn	Ni	Zn	Ti	Mg	Cr	Al
% by weight	0.06	0.18	1.63	0.074	0.05	5.62	0.049	2.52	0.22	Balance

2. Experimental procedure:

MMCs and HMMCs Specimens were fabricated using stir casting process. A die with the 100X 100X 50 mm is used to prepare the specimen. Al 7075 was melted above its melting point and the reinforcement silicon carbide 20 microns and boron carbide 8 microns are added. Uniform stirring is done using stirrer. Once the reinforcement are mixed well ,the bottom portion of the furnace is opened and made to flow in the die which was kept down the furnace. After cooling the specimen was taken from the die. Four specimens Al7075 reinforced with 3% SiC, 3% SiC 3% B4C, 7% SiC 4% B4C and 4% B4C composites were made with the same procedure. The stir casting set up is shown in the Fig

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

[1]. Al7075 with reinforcement materials and fabricated specimen are shown in the Fig 2and 3 respectively. Then the machining were conducted on the wire electrical discharge machine manufactured by Electronica India Pvt Ltd Fig [4]. A brass wire of 0.25 mm diameter was used as the cutting tool. Fabricated MMCs and HMMCs of dimension 100x100x 50mm were used as the work piece. The distilled water was used as dielectric medium. The four input process parameters namely voltage (V), pulse-on time (TON), pulse-off time (TOFF) and current (C) were selected and experiments are conducted based on the design of experiments approach using L18 orthogonal array. The various process parameters were shown in the table 1.

A small portion of the composite materials were cut and the surface of the specimens were polished using various grades of emery sheets. Then the mirror finishing was obtained by polishing the specimen on a disc polishing machine using velvet cloth with Alumina suspension. The samples were etched using Keller's reagent and microstructural observation has been done using optical microscope. Rockwell hardness test at load of 100kgf was carried out on the composite samples. Various indentations at a gap of 1mm has been made and the average of hardness readings has been taken as hardness value. The surface roughness on the EDM machined surface was measured using Mitutoyo surface roughness tester(SJ-210). Material removal rate is calculated using the formula below:

MRR = (2Wg+D) X t X (L/ T) mm^3/min Where ,

Wg is the spark gap im mm, D is the diameter of the wire, t is the thickness of the workpiece in mm , L isthe distance travelled by the tool in mm and T is the time taken to cut one profile in min.

Fig 1 Stir Csting Set up   Fig 2 Al 7075 , SiC and B4C Reinforcemen

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

Fig 3 Fabricated specimen

Fig 4 Wire electrical discharge machine

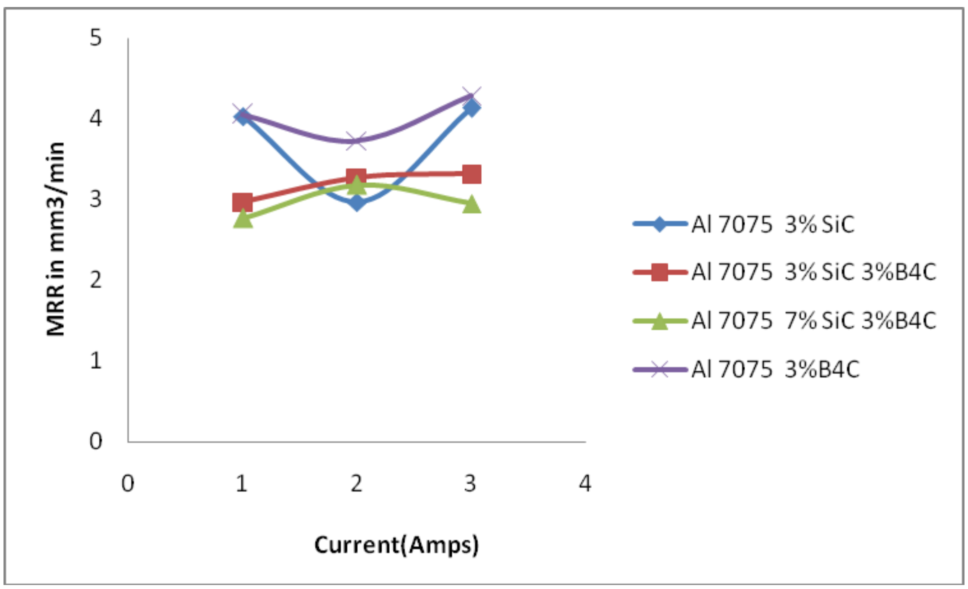


Fig 5 (c)

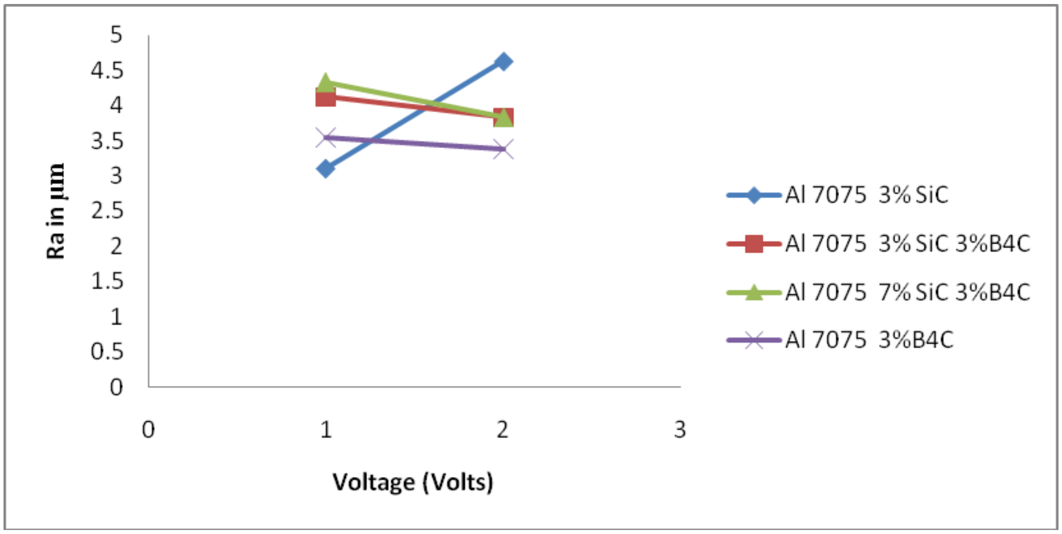

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Ra in µm
0
1
2
3
Voltage (Volts)
Al 7075 3% SiC
Al 7075 3% SiC 3%B4C
Al 7075 7% SiC 3%B4C
Al 7075 3%B4C

Fig 6 (a)

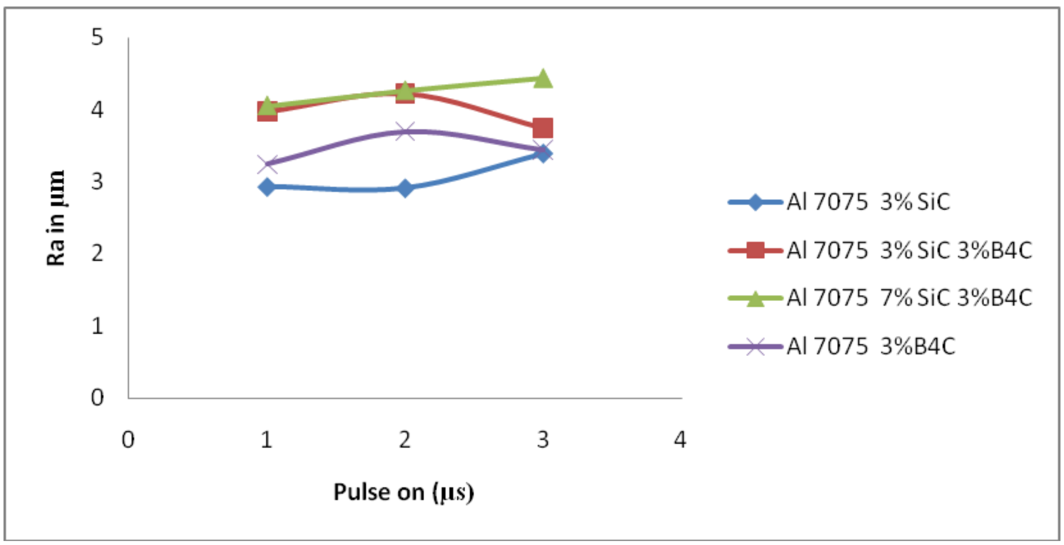

5
4
3
2
1
0
Ra in µm
0
1
2
3
4
Pulse on (µs)
Al 7075 3% SiC
Al 7075 3% SiC 3%B4C
Al 7075 7% SiC 3%B4C
Al 7075 3%B4C

Fig 6 (b)

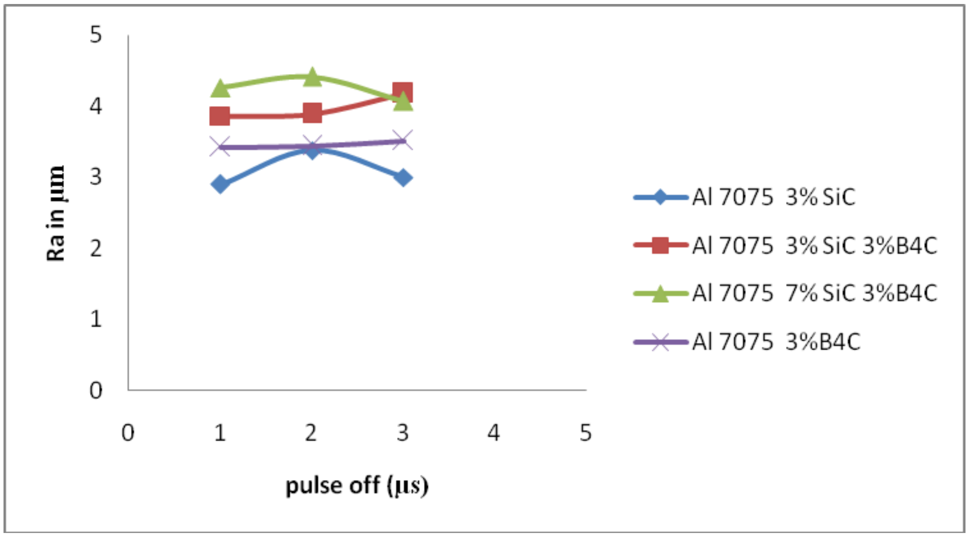


Fig 6 (c)

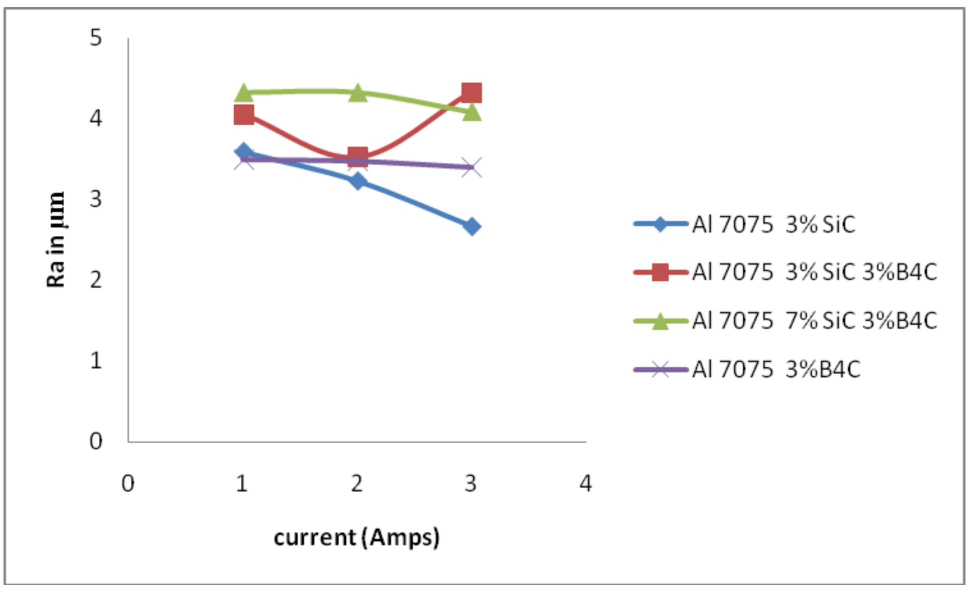


Fig 6 (d)

3. Results and discussion:

Material Removal rate:

It has been observed that the pulse on time and pulse off time are the important influencing factor for HAMMCs considered in this work. From the response graphs Fig 5(a-d) it is seen that for Al7075 7% SiC 3% B4C high voltage , high pulse on time and low pulse off time and high current resulted in higher Material removal rate. Also low voltage ,medium pulse on time , low pulse off time and low current results in increase in MRR for Al7075 3% SiC composites. The average MRR for Al7075 3% SiC is 3.97mm^3/min and Al7075 3%B4C is 4.01mm^3/min. The average MRR for Al7075 3%SiC 3% B4C and Al 7075 7% SiC 3% B4C was found to be 3.18mm^3/min and 2.97mm^3/min respectively. Low pulse on time, high voltage , low pulse off time with high current decreases the material removal rate in this Hybrid aluminum metal matrix composites. Hence the results shows that the increase in weight percentage of SiC and B4C decreases the Material removal rate in the composite material. The mechanical and thermal properties of HAMMC can be improved with addition of SiC and B4C particulates.

Surface roughness:

The size and weight fraction of the reinforcement particles determines the surface roughness . Gradual increase in pulse time gives greater surface finish. From the response graphs it has been observed that the average Ra for Al7075 3% SiC 3%B4C was found to be 3.98 µm and average value for 7% SiC 3% B4C was 4.25µm. It has been observed that the Ra value increases with increase in weight fraction of SiC and B4C particulates. The presence of reinforcement in the aluminum matrix resulted in higher roughness. It has been found that when the intensity of electric spark is more it produces crater on the workpiece and results in poor surface finish. On the other hand increase in pulse off time leads to lower Ra, due to erosion. Hence pulse on time and pulse off time are the most influencing parameters thatdetermine the surface roughness.

Microstructure and Hardness evaluation:

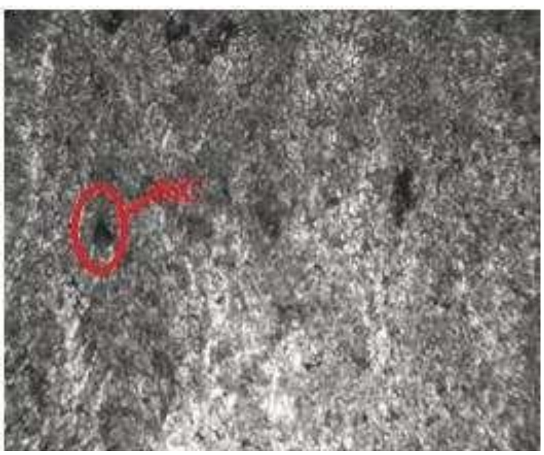


Fig a Al 7075 3%SiC

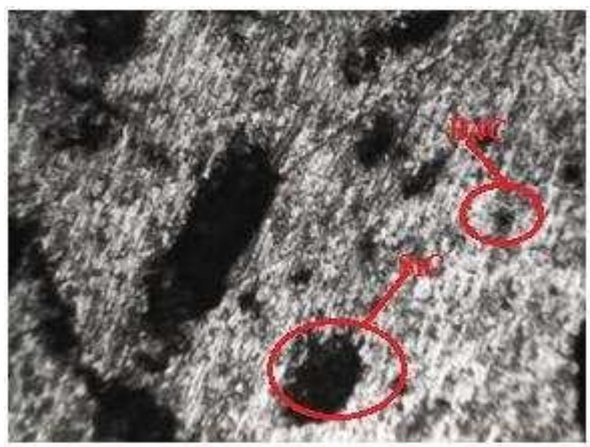


Fig b Al 7075 3%SiC 3%B4C

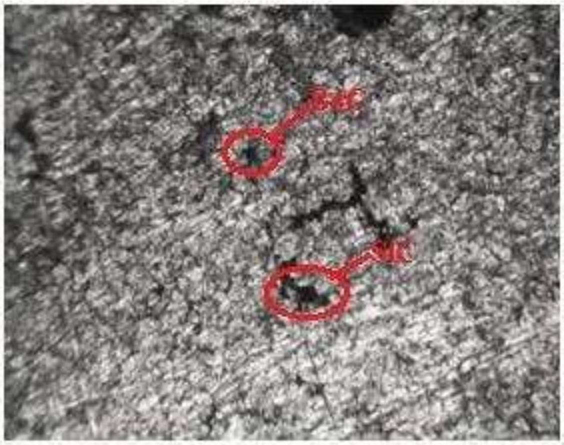


Fig c Al 7075 7%SiC 3%B4C

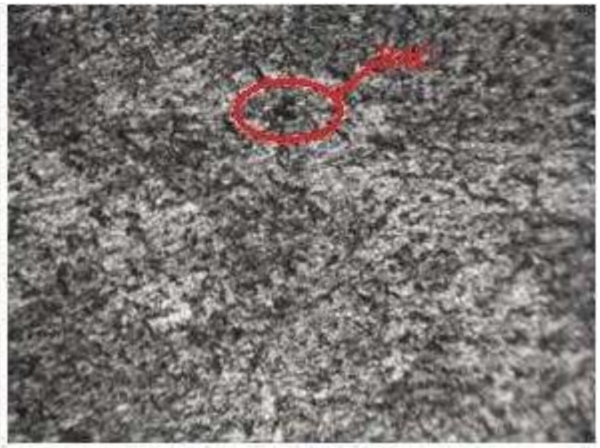
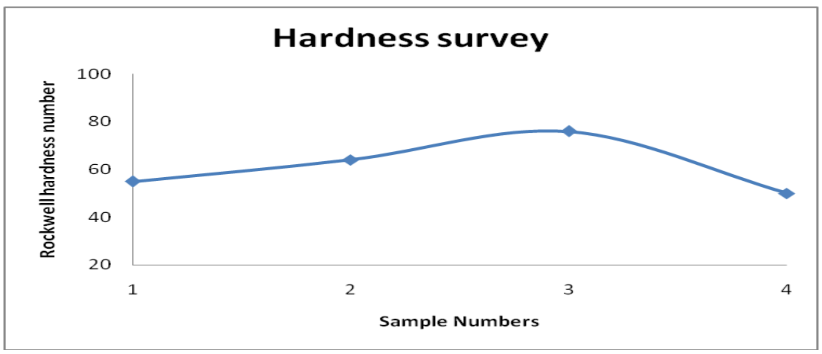


Fig d Al 7075 3%B4C

Fig 7(a-d)) Optical microscope images of MMC'S and HAMMC'S



From the fig 7(a-d) it has been revealed that the particle distribution are uniform throughout the matrix due to constant speed of the stirrer. Microstructure analysis of these specimens shows that the SiC and B4C particles are uniformly distributed in the matrix. Presence of porosity around the SiC particles was seen due to wetting behavior of aluminum alloy. The good bonding between the aluminum alloy and particulates was observed. The uniformly distributed particulates within the matrix and dendrites are also seen. Grain boundaries are clearly seen with some precipitates in the grains. Hardness test was carried out using Rockwell hardness tester with six indentations of each sample and then the average values were used to calculate hardness number. A considerable increase in hardness of the matrix was seen with the addition of SiC and B4C particles .The hardness of HAMMCs increases with the weight fraction of particulate in the alloy matrix.

Fig 8 Hardness survey for the composite materialsThe added amount of SiC and B4C particles enhances hardness, as these particles are harder than Al alloy, which render their inherent property of hardness to soft matrix. The hardness graph Fig 8 shows that the sample with 7 wt% SiC and 3 wt% B4C showed slightly high hardness and low toughness as compare to 3 wt% SiC and 3 wt% B4C. Higher the percentage of particulates in the matrix lesser is the toughness. Composites with higher hardness could be achieved by this technique which may be due to the fact that silicon carbide and boron carbide particles act as obstacles to the motion of dislocation. Therefore, from this study it is evidently indicated that 7wt% SiC and 3 wt% boron carbide composite sample have high hardness and good toughness. Hence this may be considered as the optimum weight percentage of the particulate to achieve better hybrid composite properties for heavy vehicle applications. Also the presence of harder SiC and B4C reinforcement increases the resistivity of the matrix.

4. Conclusion:

The results from the debate above are as follows.

- Stir casting was used to create Metal Matrix Composites and Hybrid Metal Matrix Composites with various reinforcing weight fractions.
- There was a consistent distribution of particles that were firmly bound to the metal matrix.
- Due to uniformly integrated hard phase silicon carbide and boron carbide particles in an aluminium 7075-based matrix, hybrid composites exhibit excellent hardness.
- A sample of a hybrid aluminium metal matrix composite with 7% SiC and 3% B4C displays good machining properties.
- The pulse on time, pulse off time, and current are the input parameters affecting the machining. Because silicon carbide and boron carbide reinforcement have been added to the composite materials, the rate of material removal has decreased, and the Ra value has increased.

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