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Comparison of metal removal rate in the machining of Nickel Chromium Composite

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Abstract
Comparison of metal removal rate (MRR) in the machining of synthesized composite is playing an essential role in advanced manufacturing industries. Machinability behaviors synthesized composites are act as a vital role in metal forming process. The present article is used to analyze the machining behaviors of the synthesized nickel chromium composite using various unconventional machining processes such as Spark Erosion Machining (SEM) and Laser Beam Machining (LBM). Comparison of metal removal rate under different input constrains is also conducted. In SEM process, the different input actors are used such as voltage, current and pulse on time. In LBM process, the various input factors have been considered such as cutting speed, laser power and standoff distance. The parameter contribution is found by variance analysis. The selection of optimal parameters is decided by Taguchi optimization.

1. Introduction

The selection of composite materials is depending on the particular applications and its material properties. The rate of machinability is depending on the composition of various alloying elements, weight percentage of the reinforced particles, and fabrication methods. Nickel chromium composite is used in medical equipment, automobile parts, feed water heaters and evaporators. The different unconventional machining processes is used to machining of nickel copper composite and its MRR is evaluated by different level of input factors [1-2].The rate of metal removal is depending on the spark intensity and applied current. It is increased with increase of current [3]. The effect of various factors is investigated in the machining of different grade of steels. The current is the powerful factors and its developed major effect on MRR [4-5]. The process operates by creating sparks between an electrode and the workpiece. This innovative technique involves immersing the workpiece in a dielectric fluid, which effectively insulates electrical energy and facilitates meticulous control of the spark. The resulting spark discharges vaporize the workpiece, expertly removing excess material to achieve the desired shape [6-9]. Laser beam is focused for melting and vaporizing the unwanted material from the parent material. It is suitable for geometrically complex profile cutting and making miniature holes in sheet metal [10-12]. The power of the laser beam, typically measured in Watts, is a critical factor in laser machining. Higher power levels allow for quicker material removal but can also increase the heat affected zone, potentially affecting precision [13-15].

The present paper is deals with machinability comparison of synthesized nickel chromium composite through spark erosion and laser machining processes. The selection of optimal parameters is decided by Taguchi optimization.

2. Machining experimentation

Electrical discharge machining (EDM) is capable of machining complex shapes in hard materials. The process includes an electrode and a workpiece, both submerged in dielectric fluid. Electrical current flows between the workpiece and electrode, repeatedly creating tiny plasma zones that instantaneously melt and remove the material. The spark erosion or electrical discharge behaviors are evaluated by PE-250/PNR 35 EDM. The different control factors such as current, voltage and pulse on time are used to found the MRR. The synthesized composite is machined through MDF 300W type of laser beam machining process. The MRR is depending on laser power, cutting speed and Standoff Distance (SOD). The carbon dioxide laser is used for this experimental work. The fig.1 and fig.2 was shown SEM and LBM processes respectively.

Fig.1 EDM process

Fig.2 LBM process

3. Results and discussion

3.1. Spark erosion machining process

The peak current of 20 -30 A, pulse on time of 150-200 μs and voltage of 20-30V has been considered for SEM process. The silver tungsten is act as a tool material. The mineral oil is used as the dielectric fluid. Titanium carbide (6 weight percentage) is added to the nickel chromium composite and its synthesized by stir casting technique. The experimental results are shown in table 1. The drilled hole with 6mm diameter is produced in the composite. The metal is removed from the work piece through high intensity of spark developed between the tool and workpiece. The metal removal rate is increased with increase of peak current and pulse on time. The MRR has been gradually increased with increase of pulse on time.

Table 1.SEM Experimental results

Ex. No.	Peak current (A)	Pulse on Time (μs)	Voltage (V)	MRR (mm^3/min)
1	20	150	20	3.32
2	20	175	25	4.14
3	20	200	30	3.11
4	25	150	25	5.45
5	25	175	30	6.23
6	25	200	20	6.16
7	30	150	30	7.22
8	30	175	20	8.83
9	30	200	25	9.87

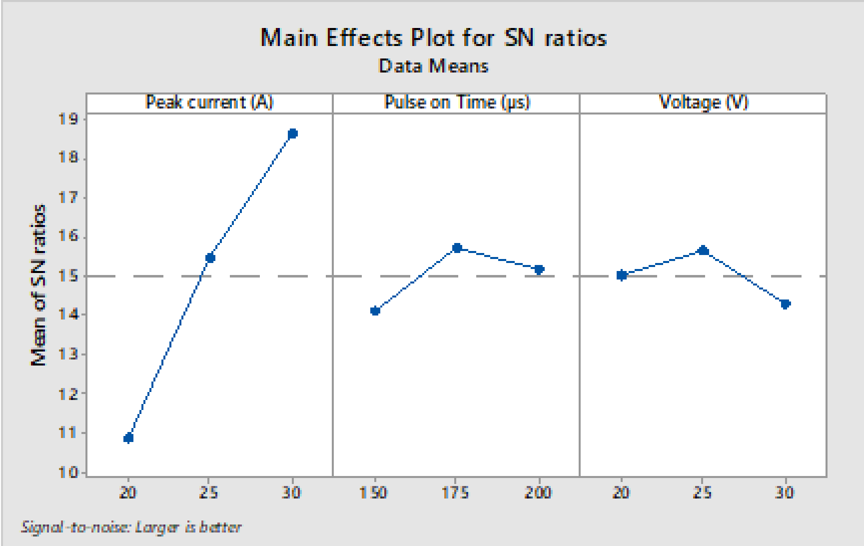

Fig.3. Main effect plot for SEM

Main effect plot for SEM is shown in fig.3. From the plot, the optimal parameter is selected based on the larger the better criterion. It is observed that optimal MRR is achieved at peak current of 30 A, pulse on time of 175 µs and voltage of 25V. The variance analysis for SEM was shown in table 2. From variance analysis, the peak current has provided the maximum effect on metal removal rate. In this experimental investigation, less error was observed (1%). The peak current (78%) has produced the high amount spark erosion on the work piece.

Table 2.Variance analysis for SEM

Basis	DF	SS	MS	F	P	%
Peak current	2	90.462	44.7311	257.57	0.043	78
Pulse on Time	2	4.124	2.1363	20.14	0.142	08
Voltage	2	8.145	4.0861	16.48	0.175	13
Error	2	0.153	0.1324	--	--	01
Total	8	116.693	--	--	--	100
	R-sq = 98.86% R-sq(pred.) = 97.18%					

3.2. Laser beam machining process

The cutting speed of 10-20 m/min, laser power of 1000-1400 W and standoff distance of 1-3mm has been chosen for LBM process. The laser machining experimental results was shown in table 3. The monochromatic Co_2 laser beam is focused on the work piece. The material is removed from the work piece through melting and vaporized due to thermal energy of the laser beam was transferred to the surface of the work piece. The coherent and intensity of laser has been produced during high laser power. The more amount of material was removed when increase of laser power and cutting speed.

Table 3 Laser beam machining of cupronickel MMC

S.No	Cutting speed (m/min)	Laser power (W)	Standoff distance(mm)	MRR (mm^3/min)
1	10	1000	1	4.11
2	10	1200	2	5.23
3	10	1400	3	6.11
4	15	1000	2	5.78
5	15	1200	3	7.12
6	15	1400	1	8.34
7	20	1000	3	10.13
8	20	1200	1	11.90
9	20	1400	2	13.01

The variance analysis for LBM was shown in table 4. From variance analysis, the cutting speed has provided the maximum effect on metal removal rate. The second influential factor was laser power. The standoff distance between laser source and the work piece has produced less effect on material removal rate.

Table 4.Variance analysis for LBM

Basis	DF	SS	MS	F	P	%
Cutting speed	2	150.441	75.721	12.48	0.079	80
Laser power	2	30.425	15.712	2.88	0.404	12
SOD	2	10.168	5.879	0.79	0.634	06
Error	2	8.519	4.484	--	--	02
Total	8	193.793	--	--	--	100
	R-sq = 95.24% R-sq(pred.) = 92.18%					

The main effect plot for LBM was shown in fig.4. The maximum MRR was observed at laser power of 1400 W. The maximum MRR was achieved at laser power of 1200W. From the plot, the optimal parameter is selected based on the larger the better criterion. It is observed that optimal MRR is achieved at cutting speed of 20 m/min, laser power of 1400 W and SoD of 3mm.

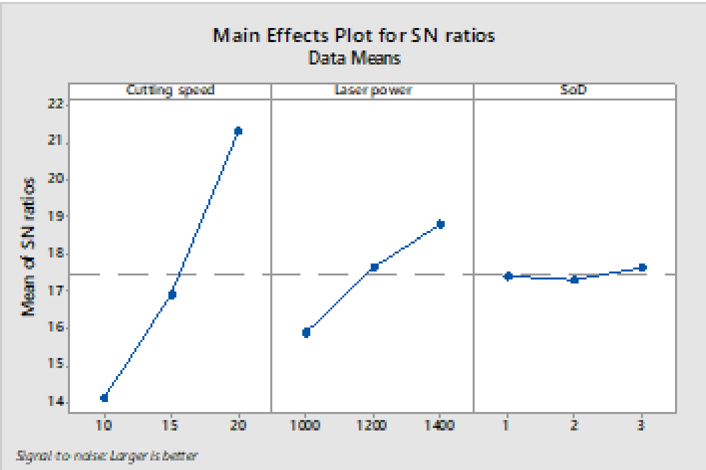

Fig.4. Main effect plot for LBM

Comparison of metal removal rate is shown in table 4. From the experimental investigations, the maximum metal removal rate is attained in laser machining process due to proper level of input constrains.

S.No	LBM-MRR (mm^3/min)	EDM-MRR (mm^3/min)
1	4.11	3.32
2	5.23	4.14
3	6.11	3.11
4	5.78	5.45
5	7.12	6.23
6	8.34	6.16
7	10.13	7.22
8	11.90	8.83
9	13.01	9.87

4. Conclusions

- The synthesized nickel chromium composite is machined through SEM and LBM processes.
- In spark erosion machining, the maximum MRR of 9.87mm^3/min was achieved at current of 30 A, pulse on time of 200μs and voltage of 25V.
- Optimal MRR is achieved at peak current of 30 A, pulse on time of 175 μs and voltage of 25V.
- From variance analysis for SEM, peak current was provided the maximum effect (78%) on MRR.
- In laser machining, optimal MRR is achieved at cutting speed of 20 m/min, laser power of 1400 W and SoD of 3mm.
- From variance analysis for LBM, cutting speed was provided the maximum effect (80%) on MRR.
- From the experimental investigations, the maximum metal removal rate is attained in laser machining process

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