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MODELLING AND OPTIMIZATION OF WIRE EDM PROCESS PARAMETERS

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ABSTRACT

Machining of Composite material creates demand for low weight to strength ratio for exclusive application in automobile and aerospace industries. The present work is aimed to optimize the Surface roughness and material removal rate of Magnesium and its composites addition considerably 5%,10% and 15% of Silicon carbide has been studied by drilling the composite plates under different parameters of Wire EDM process by considering the effect of input parameters viz. Wire Speed, Wire feed, Pulse time on and Pulse time off. Experiments have been conducted with these parameters in three different levels data related to process responses viz. Optimum machining condition for maximizing metal removal rate and minimizing the surface roughness is determined using desirability function approach. A comprehensive mathematical model for correlating the interactive and higher order influences of various machining parameters using Taguchi method with an L_9 fractional factorial design selected for the study. Grey relation theory is adopted to determine the best process parameters that optimize the response measures. The experimental results confirm that the proposed method in this study effectively improves the machining performance of WEDM process.

Keywords: GRA, Mg/SiC$_p$, Surface Roughness (R_a), Wire EDM, MRR,

I. INTRODUCTION

WEDM process involves the complex erosion effect by rapid repetitive and discrete spark discharges between the wire tool electrode and work piece immersed in a liquid dielectric medium. As research work even in WEDM much standard references are not available for the selection of the parameters and the level for optimizing the performance characteristics. Hence it is necessary to conduct an extensive experimental investigation to study the effect of different process parameters for the accuracy and surface finish of WEDM machined components. An attempt is also made to obtain machinery performance with the RSM. GRA is employed along with taguchi method, the percentage error between experimental values and predicted results are found separately. Mathematical models are developed to correlate the process parameters and performance measures. The objective of the study is to minimize the surface roughness and maximize the MRR.

1.1 Literature Review

The magnesium and silicon carbide composite are selected for the process. These metals have good mechanical strength and are conductive (Neera Sharma, N., et al.,2013, Gao,C., et al.,2012). Due to their high mechanical strength and high corrosion resistance properties, these are used in Marine, automotive and other applications (Kamal jangra, D.,et al .,2013).

These metals are cast by stir casting at 10% and 20% wt ratios of silicon carbide. The increase in strength of the composite relatively to the percentage of SiC present (Muthu Kumar, V., et al., 2010). The project involves optimization of machining parameters of WEDM on magnesium silicon carbide composite. This study focused on machining of magnesium silicon carbide using WEDM, in order to satisfy production and quality requirement (Saurav Datta, D., et al.,2010).

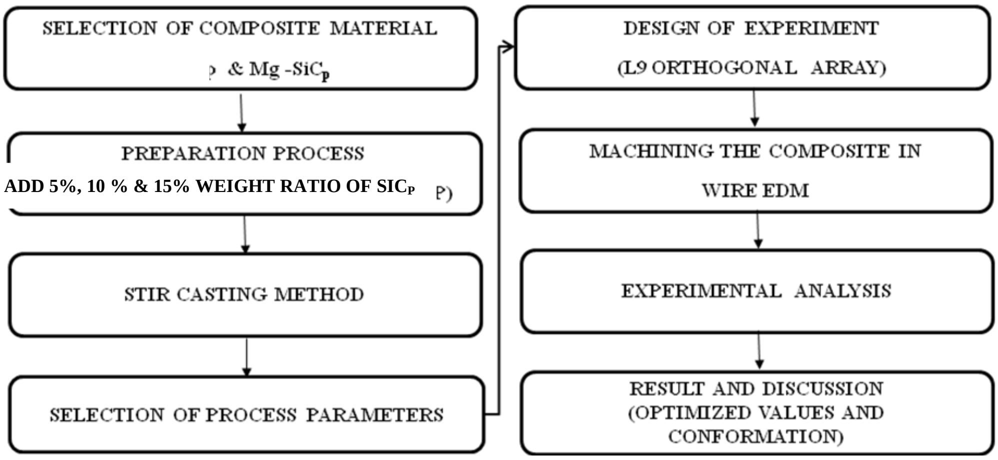
The selection of optimum machining parameters in WEDM is an important step. Improperly selected parameters may result in serious problems like short-circuiting of wire, wire breakage and work surface damage which is imposing certain limits on the production schedule and also reducing productivity. The Material Removal Rate and Surface Roughness are most important responses in WEDM (Kuo-WeiLin&Che-ChungWang.,2010).For the optimal selection of process parameters, the Taguchi method has been extensively adopted in manufacturing to improve the processes with single performance characteristic. However, traditional Taguchi method cannot solve multi-objective optimization problem (Kamal Jangra, et al., 2011).To overcome this, the Taguchi method coupled with Grey relational analysis has a wide area of application in manufacturing processes. A grey relational grade is obtained to evaluate the multiple performance characteristics (Singh, H., & Garg, R., 2009).As a result, optimization of the complicated multiple performance characteristics can be converted into the optimization of a single grey relational grade.

The Grey Taguchi method was established for combining both grey relational analysis and the Taguchi method. This study investigated the multi-response optimization of WEDM process for machining of magnesium silicon carbide using combination of Grey Relational analysis and Taguchi method to achieve higher Material Removal Rate (MRR), lower surface roughness (Ra) and necessary confirmation tests were conducted to validate the experimental results (Rao, R. V., & Pawar, P. J., 2014).

1.2 Problem Identification

The machining of magnesium silicon carbide is difficult in ordinary conventional method. The hardness of the metal will damage the tool and creates the tool wear. Due to the friction, magnesium silicon carbide gets fired. Wire cut edm is suitable for machining this type of composite material. So, SPRINT CUT 734 DI WATER CUT WEDM is used in this work. Selection of process parameters in wire EDM is also another problem.

II. METHODOLOGY



III. EXPERIMENTAL WORK

Experiments are conducted in Mg Sic_P composites with three levels of control factors. Experimentation is developed using DOE with input parameters as shown in table 1.

TABLE 1 Process Parameters and Levels

SYMBOL	CONTROL FACTOR	UNIT	LEVEL 1	LEVEL 2	LEVEL 3
A	WIRE SPEED	rpm	500	1000	1500
B	WIRE FEED	mm/min	1.0	1.1	1.2
C	PULSE-ONTIME	µs	120	124	128
D	PULSE-OFFTIME	µs	42	44	46

Holes of 5 mm diameter are drilled on 10 mm thick Mg-sic plate. WEDM using molybdenum wire of diameter 0.18 mm. The influence of process parameters on the machining of drilled hole is also analyzed. The average surface roughness (R_a) value of drilled hole is determined using surface roughness tester. The material removal rate (MRR) is evaluated as the average volume of material removed over the machining time in mm^3/sec. The experiments were performed on SPRINT CUT 734 DI WATER CUT WEDM is shown in fig.1. The experimental set up is shown in figure. 2. The workpiece is shown in fig.3.The molybdenum wire as tool electrode with flushed type dielectric fluid pressure 0.2 kgf/cm^2 (distilled water) bath between work piece and electrode. Electrical power and controlling system is controlled with servo controlled resistance capacitance (Rc) circuit which ensures low discharge current with high frequency to control input process parameters.

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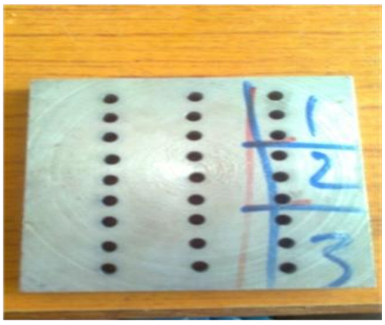

Fig.1. Sprint Cut 734 Di Water Cut Wedm **Fig. 2. Machining Setup** **Fig. 3. Work Piece**

IV. RESULT

TABLE2 Experimental Results of Mg Sic$_P$ 5%

EXP.NO	CONTROL FACTORS				RESPONSES	
	A	B	C	D	MRR (mm^3/sec)	R_a(µm)
1	1	1	1	1	6.68	3.8025
2	1	2	2	2	6.76	3.753
3	1	3	3	3	6.73	3.796
4	2	1	2	3	7.09	3.7095
5	2	2	3	1	7.56	3.7085
6	2	3	1	2	7.46	3.6575
7	3	1	3	2	7.76	3.6295
8	**3**	**2**	**1**	**3**	**7.84**	**3.7855**
9	3	3	2	1	7.43	3.908

TABLE 3 Experimental Results Of Mg SicP 10%

EXP.NO	CONTROL FACTORS				RESPONSES	
	A	B	C	D	MRR(mm^3/sec)	R_a (µm)
1	1	1	1	1	6.33	4.1295
2	1	2	2	2	6.48	3.769
3	1	3	3	3	6.58	3.7145
4	2	1	2	3	6.81	3.6605
5	2	2	3	1	6.73	3.607
6	2	3	1	2	6.99	3.7475
7	**3**	**1**	**3**	**2**	**7.28**	**3.9875**

8	3	2	1	3	7.14	4.026
9	3	3	2	1	7.13	4.161

TABLE 4 Experimental Results of Mg Sic$_P$ 15%

EXP.NO	CONTROL FACTORS				RESPONSES	
	A	B	C	D	MRR(mm³/sec)	R_a (μm)
1	1	1	1	1	6.33	3.562
2	1	2	2	2	6.56	3.711
3	1	3	3	3	6.23	3.765
4	2	1	2	3	6.76	3.888
5	2	2	3	1	6.58	4.081
6	2	3	1	2	6.88	3.928
7	3	1	3	2	6.93	3.698
8	**3**	**2**	**1**	**3**	**7.14**	**3.832**
9	3	3	2	1	7.03	3.758

4.1. Optimization Steps to Find Grey Relational Grade

TABLE 5 Grey Relational Co-Efficient and Grey Relational Grade of Mg 5%

Exp.no	Control factors				Grey relational co-efficient		Grey grade
	A	B	C	D	MRR (mm³/sec)	RA (μm)	NO UNIT
1	1	1	1	1	1	0.37	0.4535
2	1	2	2	2	0.916	0.549	0.413
3	1	3	3	3	0.954	0.395	0.4505
4	2	1	2	3	0.628	0.705	0.4285
5	2	2	3	1	0.228	0.709	0.5495
6	2	3	1	2	0.311	0.896	0.487
7	3	1	3	2	0.065	1	0.6085
8	**3**	**2**	**1**	**3**	**0**	**0.43**	**0.7685**
9	3	3	2	1	0.336	0	0.799

TABLE 6 Grey Relational Co-Efficient and Grey Relational Grade of Mg Sic_P 10%

Exp.no	Control factors				Grey relational co-efficient		Grey grade
	A	B	C	D	MRR (mm³/sec)	RA(μm)	NO UNIT
1	1	1	1	1	1	0.053	0.6185
2	1	2	2	2	0.833	0.693	0.397
3	1	3	3	3	0.724	0.794	0.395
4	2	1	2	3	0.494	0.896	0.430
5	2	2	3	1	0.607	1	0.392
6	2	3	1	2	0.291	0.732	0.518
7	**3**	**1**	**3**	**2**	**0**	**0.298**	**0.813**
8	3	2	1	3	0.139	0.231	0.7325
9	3	3	2	1	0.149	0	0.885

TABLE 7 Grey Relational Co-Efficient and Grey Relational Grade of Mg Sic_P 15%

Exp.no	Control factors				Grey relational co-efficient		Grey grade
	A	B	C	D	MRR(mm³/sec)	RA(μm)	NO UNIT
1	1	1	1	1	0.884	1	0.347
2	1	2	2	2	0.622	0.699	0.431
3	1	3	3	3	1	0.593	0.395
4	2	1	2	3	0.402	0.357	0.568
5	2	2	3	1	0.6	0	0.727
6	2	3	1	2	0.273	0.281	0.643
7	3	1	3	2	0.219	0.725	0.551
8	**3**	**2**	**1**	**3**	**0**	**0.463**	**0.759**
9	3	3	2	1	0.114	0.607	0.6850

4.2 Optimum Levels of the Factors

Since the experimental design is orthogonal, it is possible to separate out the effect of each machining parameter on the grey relational grade at different levels. The mean of the grey relational grade for each level of the other machining parameters can be computed in a similar manner. The mean of the grey relational grade for each level of the machining parameters is summarized and shown in Tables.

Table 8 Main Effects of the Factors on the Grey Relational Grade for Mg SiC_P 5%

SYMBOL	CONTROL FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
A	SPEED	0.439	0.488	0.7253*
B	FEED	0.496	0.577	0.588*
C	PULSE ON	0.496	0.5888*	0.521
D	PULSE OFF	0.592*	0.496	0.521

*Optimum level

Table 9 Main Effects of the Factors on the Grey Relational Grade for Mg SiC_P 10%

SYMBOL	CONTROL FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
A	SPEED	0.4702	0.447	0.8102 *
B	FEED	0.6207 *	0.5072	0.5995
C	PULSE ON	0.6095 *	0.5072	0.5905
D	PULSE OFF	0.5072	0.6207 *	0.521

*Optimum level

Table 10. Main Effects of the Factors on the Grey Relational Grade for Mg SiC_P 15%

SYMBOL	CONTROL FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
A	SPEED	0.391	0.6462	0.6478 *
B	FEED	0.489	0.639 *	0.5568
C	PULSE ON	0.4432	0.6278*	0.5598
D	PULSE OFF	0.439	0.6282 *	0.5468

*Optimum level

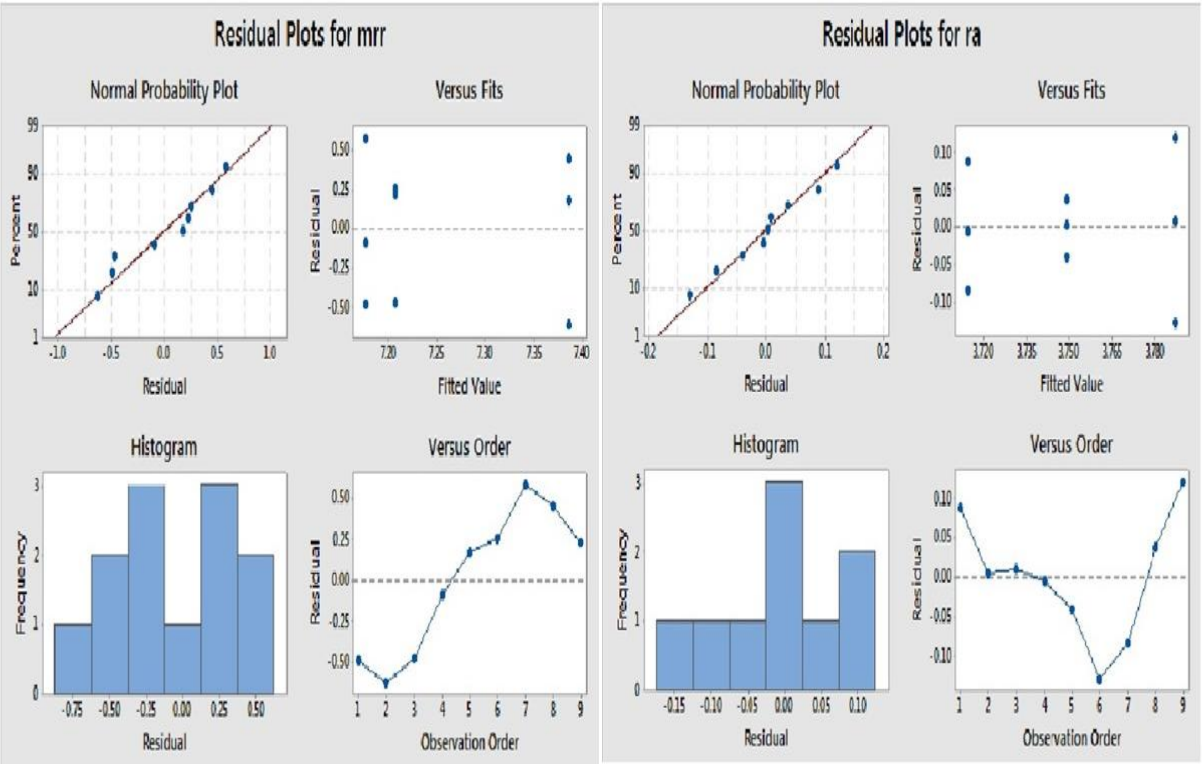

Fig.4. Residual plot for output parameters of Mg Sic$_P$ 5%

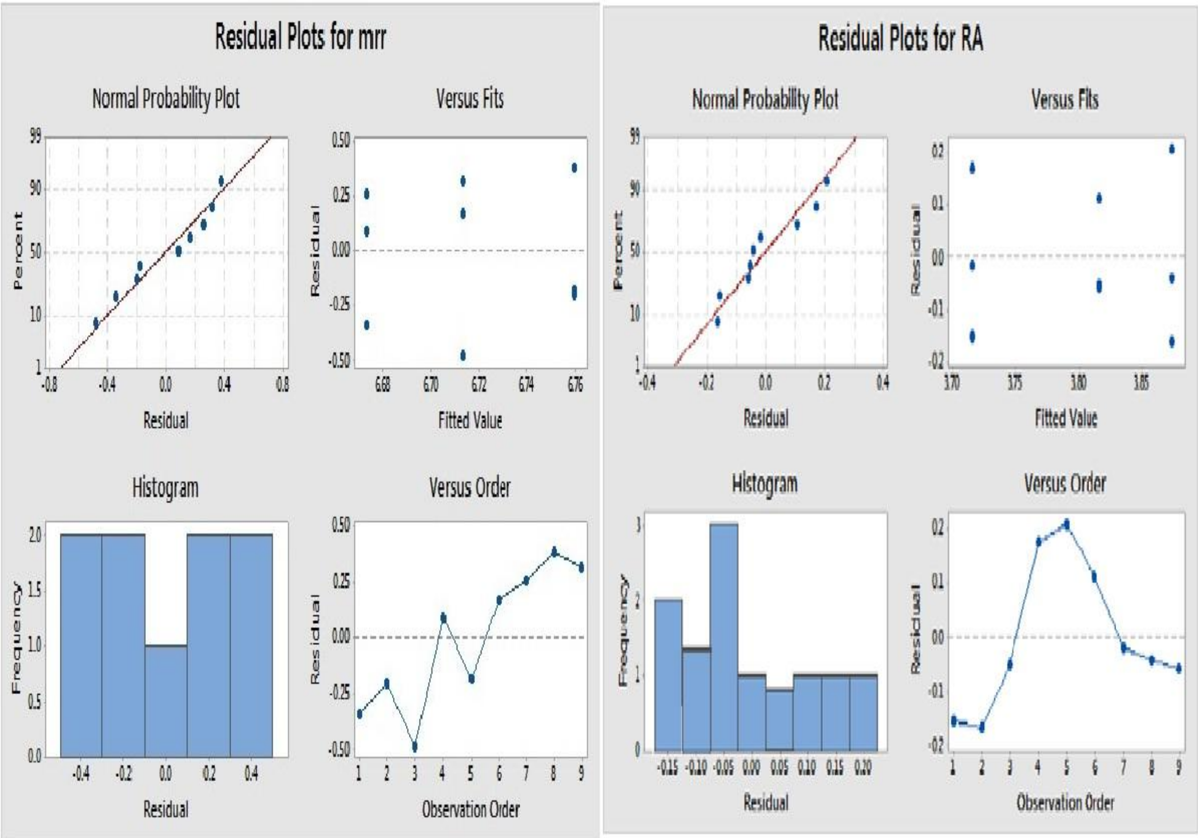

Fig. 5. Residual plot for output parameters of Mg Sic$_P$ 10%

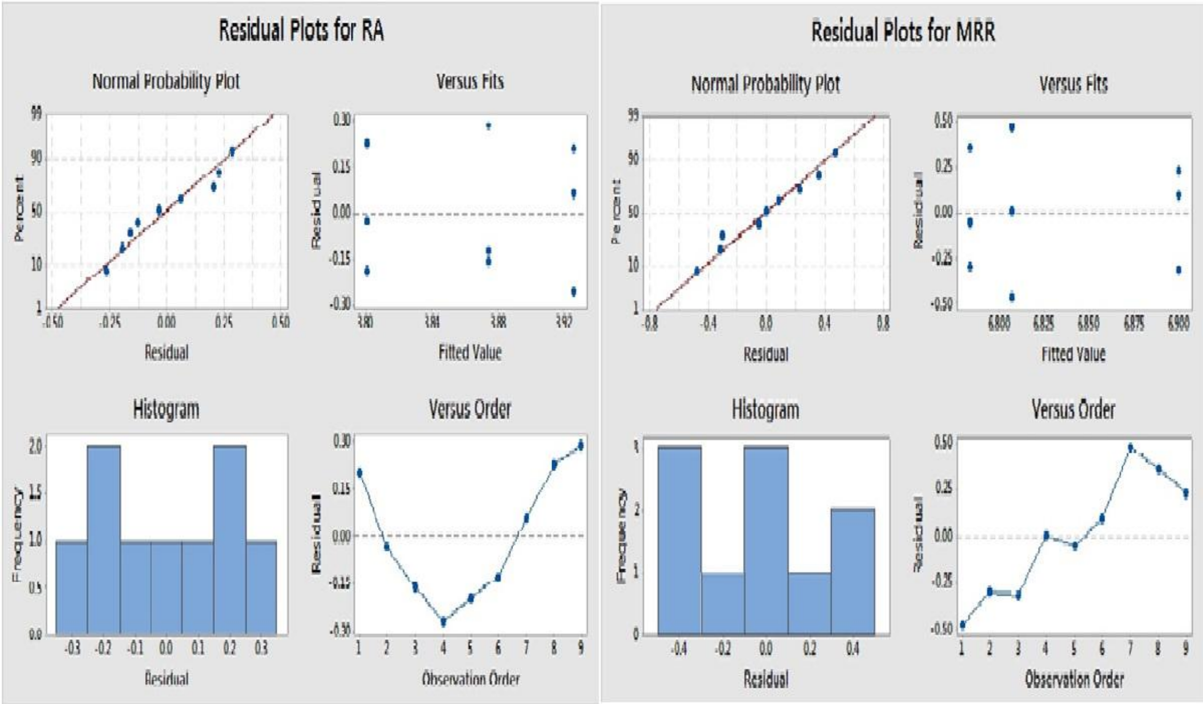

Fig. 6. Residual plot for output parameters of Mg Sic_P 15%

V. DISCUSSION

The confirmation test for the optimal parameter setting with its selected levels was conducted to evaluate the quality characteristics for Wire EDM of Mg Sic_P5 **%**, Mg Sic_P10 **%** & Mg Sic_P 15**%**

The table.14. shows that the significant machining parameters for performance measures of surface roughness in the WEDM process. Factors like speed, feed, Time on and Time off have been found to play a significant role for MRR and surface roughness. Taguchi's method is used to obtain optimum parameters combination for maximization of MRR and minimization of surface roughness. The conformation experiments were conducted to evaluate the result predicted from Taguchi's Optimization.

TABLE 14 Optimal Process Parameters

MATERIAL	FACTOR	MRR (mm^3/sec)	R_a (μm)
Mg Sic_P5%	Orthogonal array	7.84	3.7855
	Grey theory design	8.72	3.803
Mg Sic_P10%	Orthogonal array	7.28	3.9875
	Grey theory design	7.93	4.234
Mg Sic_P15%	Orthogonal array	7.14	3.832
	Grey theory design	7.74	4.102

VI. CONCLUSION

In this project, an application of combined Taguchi Method and Grey Relational Analysis, to improve the multi-response characteristics of MRR (Material Removal Rate), Surface roughness in the Wire-Cut EDM (Electrical Discharge Machining) of pure Mg Sic_P 5%, Mg Sic_P 10% & Mg Sic_P15% has been done. As a result, this method greatly simplifies the optimization of complicated multiple performance characteristics and since it does not involve complicated mathematical computations, this can be easily utilized by the Manufacturing world.

1. For The pure Mg Sic_P 5%, the optimal value from the L_9 orthogonal array is (EX.NO.8) with (speed – 1500 rpm) , (feed – 1.2 mm/min) , (pulse on – 124µs) , (pulse off – 42 µs). where as the optimal value obtained from the Grey theory design is (speed – 1500 rpm) , (feed – 1.0 mm/min) , (pulse on – 120µs) , (pulse off – 46 µs) .
2. For Mg Sic_P10% the optimal value from the L_9 orthogonal array is (EX. NO7) with (speed – 1500 rpm) , (feed – 1.1 mm/min) , (pulse on – 124 µs) , (pulse off – 42 µs) .where as the optimal value obtained from the Grey theory design is (speed – 1500 rpm) , (feed – 1.2 mm/min) , (pulse on – 124 µs) , (pulse off– 42 µs) .
3. For Mg Sic_P 15% the optimal value from the L_9orthogonal array is (EX.NO 8) with (speed – 1500 rpm) , (feed – 1.2 mm/min) , (pulse on – 124 µs) , (pulse off – 46 µs), where as the optimal value obtained from the Grey theory design is (speed – 1500 rpm) , (feed – 1.1 mm/min) , (pulse on – 120 µs) , (pulse off – 46 µs) .
4. While applying the Grey Taguchi method, the Material Removal Rate shows an increased value.Thus, it can be concluded that the Grey Taguchi Method is suitable for the parametric optimization of the Wire Cut EDM process, when using the multiple performance characteristics such as Material Removal Rate (MRR), Surface Roughness(R_a) for machining the MgSic$_P$5%, MgSic$_P$10% & MgSic$_P$15%.

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