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Use Of L27 Orthogonal Array With Grey Taguchi Technique To Optimize MRR And SR In EDM Machining For Al -6082, Al -6061, Al -2014 And Mild Steel

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Abstract: The new engineering materials are innovated by adapting advanced technologies in manufacturing industry. These materials are very difficult to machine by conventional machine tools as material properties of these materials are better thanordinarymaterials in terms of its strength, hardness, high resistance to temperature etc., and machining these materials on conventional machines results poor surface finish. To overcome these problems advanced non-conventional machines are introduced to machine difficult to machine materials. EDM is one of the innovative non conventional machining processes that can be easily adapted to machine conductive engineering materials. In the present research work, the effect of process parameters of EDM on material removal rate & surface roughness is studied on Al-6082, Al-6061, Al-2014, and Mild steel. The MRR& SR are optimized through various process parameters. The resultant values are then validated with experimental results.

Keywords: Electrical Discharge Machining, L27 Orthogonal Array, MRR, and SR, Grey Taguchi method.

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I. INTRODUCTION

The EDM is an advanced machining process where the material removal takes place from the work-piece by continuous electrical sparking between the work-piece and tool electrode. These electrical sparks are generated by creating voltage difference between electrode and the work-piece. EDM is widely used in variety of manufacturing industries including die industries, injection molding,prototype parts, aerospace, automobile and electronic industries. The present work-pieces are Aluminium-6082, Aluminium-6061, aluminium-2014, and Mild steel has been machine by using Copper tool electrode, Brass tool electrode, and Graphite tool electrode of 10x10 mm^2 cross section area and 75mm length to carry out experiments by using the input parameters as discharge current , pulse on time, and duty cycle. The output parameters are MRR and SR will be determined by each experimental runs. By implementing the Taguchi L27 orthogonal array using commercial tool Minitab 17 response to the variation of input parameters and an output was investigated with the number of experimental runs. The Grey Taguchi method is used for multi optimization. The Grey Taguchi method will convert the single objective function into multi-objective function thatprovide best optimized results and these results are compared with experimental test results.

II. SELECTION OF WORK-PIECES,TOOLS, AND PROCESS PARAMETERS

Material selection

Four different types of work pieces are used to do this experiment materials are Al-6082, Al-6061, Al-2014 and Mild Steel. The three different types of tool materials arecopper, brass, and graphiteare usedfor machining process.

Al-6082: The Aluminium-6082 is used at high stress areas at

Construction of bridges. This type of Aluminium is mainly used mad of Crane parts and transportation sections.

Al-6061: The aluminium-6061 is mainly used at aircraft, aerospace components, and make for bicycle frames, drive shafts, electrical fitting and connectors.

Al-2014: The Aluminium-2014 is mainly used at aerospace industry, Military vehicle bodies and manufacturing weapons.

Mild steel: the Mild steel material is mainly used in making of pipes, transporting the water & natural gas, machine parts manufacture, building of frames and making gates.

The above said materials are easily available, with less cost in the market.

Tools: Copper, Brass, Graphite

Copper: Copper and copper alloys have better EDM wear resistance than brass, but are more difficult to machine than either brass or graphite. It is also more expensive than graphite. Copper is, however, a common base material because it is highly conductive and strong. It is useful in the EDM machining of tungsten carbide, or in applications requiring a fine finish. Copper can produce very fine surface finishes, even without special polishing circuits. With development of the transistorized, pulse-type power supplies, Electrolytic (or pure) Copper became the metallic electrode material of choice. This is because the combination of Copper and certain power supply settings enables low wear burning. Also, Copper is compatible with the polishing circuits of certain advanced power supplies.

Brass: Brass was one of the first EDM electrode materials. It is inexpensive and easy to machine. Today, however, brass is seldom used as an electrode material in modern sinker EDMs, due to its high wear rate. In certain applications or in older machines with RC power supplies for which wear is not a primary concern, brass still has limited use, since it exhibits a higher degree of stiffness and is easier to machine than copper. Brass, however, is one of the most commonly used materials for High Speed Small Hole Machines.

Graphite: Graphite has an extremely high melting point. Actually, graphite does not melt at all, but sublimes directly from a solid to a gas (just as the Carbon Dioxide in dry ice) at a temperature thousands of degrees higher than the melting point of Copper. This resistance to temperature makes graphite an ideal electrode material. Graphite has significantly lower mechanical strength properties than metallic electrode materials. It is neither as hard, as strong, nor as stiff as metallic electrode materials. However, since the EDM process is one of relatively low macro mechanical forces, these property differences are not often significant.

Chemical compositions of the four different work pieces are as follows. Below table shows the chemical composition of Al-6082, Al-6061, Al-2014, and Mild Steel.

Table 1: Chemical compositions of work piece material

Element	Al-6082	Al-6061	Al-2014	Mild
Si	0.740	0.480	0.594	0.171
Mg	0.790	1.28	0.499	--
Mn	0.839	0.059	0.768	0.608
Zn	0.076	0.083	0.095	--
Cr	0.0020	0.036	0.002	--
Ti	0.002	0.080	-	--
Cu	0.0049	0.199	4.56	--
Fe	0.082	0.283	0.264	98.69
Al	97.44	97.53	93.15	--
C	--	--	--	0.223
S	--	--	--	0.036
P	--	--	--	0.030

Process Parameters

The selection of input parameters are Discharge current, Pulse on time, Duty cycle and the output parameters are MRR and SR

III. EXPERIMENTAL SETUP:

Experimentation is done on Electronica SE-35die sinking EDM machine is shown in fig1. In EDM at first an ignition voltage around 200V is applied between the electrodes. The electrode is moved near the work piece which causes break down of the dielectric fluid (EDM oil of grade SAE450) due to the

Fig 1: EDM Machine

TABLE 2: Machine Specifications

Manufacture and Model	Electronica SE-35
Axes	X-500mm, Y-300mm
Operating Voltage	115/230V
Servo head movement	Min70mmtoMax300mm
Supply frequency	50-60 HZ
Maximum power consumption	20 W
Operating temperature	32- 113 F
Tool holder capacity	Dia 30 mm Max
Storage temperature	-40 to 131 F

Levels of process parameters: They are three parameters and three levels. They can be controlled to obtain a desired output.

Table3: Levels of process parameters

Symbol	Factors	Level 1	Level 2	Level 3
D	Current	6	8	10
E	Pulse on time	100	150	200
F	Duty cyle	10	11	12
X4	Tool	Copper	Brass	Graphite

***a. Design of experiments**:* They are four types. (1) One factor (2) Factorial design (3) Response surface method designs (4) Reliability DOE.

(1) One factor: These are the designs where only one factor is under investigation, and the objective is to determine whether the response is significantly different at different factor levels. The factor can be qualitative or quantitative. In the case of qualitative factors no extrapolations can be performed outside the tested levels, and only the effect of the factor on the response can be determined

(2) Factorial designs: In factorial design, multiple factors are investigated simultaneously during test.

(a) General Full Factorial Design: In general full factorial designs where the number of levels for each factor is restricted to two. Restricting the levels to two and running a full factorial experiment reduces the number of treatments and allows for the investigation of all the factors and all their interactions

(b) Plackett-burman designs: this is a special of two levels fractional factorial designs, proposed by R.L. Plackett and J,P. Burman, where only a few specifically chosen runs are performed to investigate just the main effects.

(c) Taguchis Orthogonal Arrays: Taguchi Orthogonal arrays are highly fractional designs, used to estimate main effects using only few experimental runs. These designs are not only applicable to two level factorial experiments, but also can investigate main effects when factors have more two levels. Designs are also available to investigate main effects for certain mixed level experiments where the factors included do not have the same number of levels.

(3) Response Surface Method Design: These are special design that is used to determine the settings of the factors to achieve an optimum value of the response.

(4) Reliability DOE: This is a special category of DOE where traditional designs, such as the two level designs, are combined with reliability method to investigate effects of different factors on the life of a unit. In Reliability DOE, the response is a life metric , and the data may contain censored observations. One factor designs and two level factorial designs are available in DOE ++ to conduct a reliability DOE analysis.

L27 Orthogonal Array (OA): In L27 orthogonal array there are 13 columns that can be used to assign test factors and their interaction. For a 3 factor-3 level setup the total number of experiments to be conducted is given by 3^3=27. In L27 OA the total number of the experiments to be conducted is 27. However, as a few more factors are to be added for further study with the same type of material, it was decided to utilize the L27 setup.

Table 4: L27 OA table of experiments

S.NO	I(amp)	Ton (µs)	Duty cycle	Tool material
1	6	100	10	Copper
2	6	100	11	Brass
3	6	100	12	Graphite
4	6	150	10	Brass
5	6	150	11	Graphite
6	6	150	12	Copper
7	6	200	10	Graphite
8	6	200	11	Copper
9	6	200	12	Brass
10	8	100	10	Copper
11	8	100	11	Brass
12	8	100	12	Graphite
13	8	150	10	Brass
14	8	150	11	Graphite
15	8	150	12	Copper
16	8	200	10	Graphite
17	8	200	11	Copper
18	8	200	12	Brass
19	10	100	10	Copper
20	10	100	11	Brass
21	10	100	12	Graphite
22	10	150	10	Brass
23	10	150	11	Graphite
24	10	150	12	Copper
25	10	200	10	Graphite
26	10	200	11	Copper
27	10	200	12	Brass

Material removal rate (MRR) and Surface roughness (SR): In today's competitive world to reach the market demand, production is to be increase. The material removal and surface roughness are plays a crucial role in manufacturing process. EDM machine is used to produce high material removal and better surface finish. When increase the material removal rate the production is to be increased. When production is to be increased the factory will get more profits. The profits are depends on the material removal rate and surface finish of the product. When the material removal rate is increased, the production time is decrease and labour cost also reduced and increase the machine life. The cost of production rate is reduced, and it consumes less operating time.

Roughness of surface is a measure of texture of surface. It is counted by the vertical non conformities of the real surface from its perfect surface. It is more important inaccuracy by tolerance. If the tolerance is high, the surface roughness of a work piece is not in a good condition. In moulding or stamping industry, surface roughness values are more important considerations to increase the quality of the product. Surface roughness can reduce the friction between the two mating parts. Surface finish can also give the appearance of the parts.

a) *Calculation of MRR and SR*:

Material removal rate: It is the ratio of weight loss of the work piece plate before machining and after the machining of the plate to be machining time.Material removal rate can be calculated using following formula

$$\frac{(W_I - W_F)}{T} = \text{gm/minute}$$

W_I: Initial wt of the work piece
W_F: Final wt of the work piece
T: Machining time in minute

Surface roughness: It is a quality of the machining surface related to the geometric irregularities of the surface. Surface roughness R_a arithmetic average height of surface above and below the central line. It is measured by using Mitutoyo SJ-201 Talysurf is shown inbelow.

Fig. 2: Mitutoyo SJ-201 Talysurf.

Experimentation result of Al-6082 steel is shown in the below.

Table5: Experimentation result for Al-6082

S.NO	I amp	Ton (µs)	Duty cycle	Tool material	MRR gm/min	SR µm
1	6	100	10	Copper	0.01421	4.693
2	6	100	11	Brass	0.1196	3.74
3	6	100	12	Graphite	0.08237	3.853
4	6	150	10	Brass	0.09259	3.14
5	6	150	11	Graphite	0.05213	4.413
6	6	150	12	Copper	0.009966	4.92
7	6	200	10	Graphite	0.012048	2.973
8	6	200	11	Copper	0.008191	2.22
9	6	200	12	Brass	0.139664	3.913

10	8	100	10	Copper	0.03785	4.266
11	8	100	11	Brass	0.24875	3.906
12	8	100	12	Graphite	0.14285	4.65
13	8	150	10	Brass	0.16447	4.16
14	8	150	11	Graphite	0.09469	5.833
15	8	150	12	Copper	0.030731	5.433
16	8	200	10	Graphite	0.030395	3.54
17	8	200	11	Copper	0.024715	4.11
18	8	200	12	Brass	0.15723	4.666
19	10	100	10	Copper	0.06858	4.896
20	10	100	11	Brass	0.50000	3.66
21	10	100	12	Graphite	0.21097	3.916
22	10	150	10	Brass	0.34013	4.89
23	10	150	11	Graphite	0.21551	5.616
24	10	150	12	Copper	0.11160	5.556
25	10	200	10	Graphite	0.10964	4.666
26	10	200	11	Copper	0.11737	6.133
27	10	200	12	Brass	0.24875	4.53

Experimentation result of Al-6061 steel is shown in the below

Table6: Experimentation result for Al-6061

S.NO	I amp	Ton (μs)	Duty cycle	Tool material	MRR gm/min	SR μm
1	6	100	10	Copper	0.013116	3.32
2	6	100	11	Brass	0.121359	4.32
3	6	100	12	Graphite	0.091407	4.846
4	6	150	10	Brass	0.11627	4.3
5	6	150	11	Graphite	0.05452	4.00
6	6	150	12	Copper	0.008431	3.983
7	6	200	10	Graphite	0.010838	3.446
8	6	200	11	Copper	0.008333	3.55
9	6	200	12	Brass	0.117096	4.8
10	8	100	10	Copper	0.02359	4.173
11	8	100	11	Brass	0.233644	5.063
12	8	100	12	Graphite	0.193798	5.553
13	8	150	10	Brass	0.197628	4.176
14	8	150	11	Graphite	0.11737	4.403
15	8	150	12	Copper	0.010384	4.15
16	8	200	10	Graphite	0.040290	3.996
17	8	200	11	Copper	0.010328	4.123
18	8	200	12	Brass	0.16077	4.566
19	10	100	10	Copper	0.04409	4.996
20	10	100	11	Brass	0.454545	5.64
21	10	100	12	Graphite	0.023584	6.006
22	10	150	10	Brass	0.318471	4.643
23	10	150	11	Graphite	0.206611	5.756
24	10	150	12	Copper	0.020807	3.816
25	10	200	10	Graphite	0.113895	5.846
26	10	200	11	Copper	0.015938	4.22
27	10	200	12	Brass	0.20242	6.216

Experimentation results of Al-2014is shown in the below.

Table7: Experimentation result for Al-2014

S No	I Amp	T on μs	T off μs	TOOL MATERIAL	MRR mg/min	SR μm
1	6	100	10	COPPER	0.03720	5.46
2	6	100	11	BRASS	0.201612	4.273
3	6	100	12	GRAPHITE	0.119331	4.22
4	6	150	10	BRASS	0.122249	4.26
5	6	150	11	GRAPHITE	0.10989	4.64
6	6	150	12	COPPER	0.012716	5.563
7	6	200	10	GRAPHITE	0.054054	4.813
8	6	200	11	COPPER	0.019069	5.65
9	6	200	12	BRASS	0.14044	5.34
10	8	100	10	COPPER	0.061957	5.683
11	8	100	11	BRASS	0.205761	5.796
12	8	100	12	GRAPHITE	0.21834	5.053
13	8	150	10	BRASS	0.199203	4.536
14	8	150	11	GRAPHITE	0.159744	4.823
15	8	150	12	COPPER	0.033311	3.363
16	8	200	10	GRAPHITE	0.119904	6.176
17	8	200	11	COPPER	0.016661	4.876
18	8	200	12	BRASS	0.213675	5.13
19	10	100	10	COPPER	0.22727	6.056
20	10	100	11	BRASS	0.314465	5.57
21	10	100	12	GRAPHITE	0.205761	5.81
22	10	150	10	BRASS	0.23696	5.596
23	10	150	11	GRAPHITE	0.22624	6.413
24	10	150	12	COPPER	0.070422	6.326
25	10	200	10	GRAPHITE	0.16447	6.383
26	10	200	11	COPPER	0.02351	3.633
27	10	200	12	BRASS	0.24390	5.686

Experimentation results for Mild steel is shown in the below.

Table8: Experimentation result for Mild steel

S.NO	I amp	Ton (μs)	Duty cycle	Tool material	MRR gm/min	SR μm
1	6	100	10	Copper	0.08116	3.713
2	6	100	11	Brass	0.06506	3.89
3	6	100	12	Graphite	0.04651	3.87
4	6	150	10	Brass	0.06480	3.823
5	6	150	11	Graphite	0.02168	3.02
6	6	150	12	Copper	0.07610	3.96
7	6	200	10	Graphite	0.01487	1.93
8	6	200	11	Copper	0.04277	2.133
9	6	200	12	Brass	0.04894	4.56
10	8	100	10	Copper	0.12077	4.566
11	8	100	11	Brass	0.10582	2.506
12	8	100	12	Graphite	0.05730	3.583
13	8	150	10	Brass	0.07662	4.023

14	8	150	11	Graphite	0.04436	2.483
15	8	150	12	Copper	0.108108	3.586
16	8	200	10	Graphite	0.02061	1.89
17	8	200	11	Copper	0.05197	3.43
18	8	200	12	Brass	0.06915	3.39
19	10	100	10	Copper	0.18450	4.91
20	10	100	11	Brass	0.10952	2.053
21	10	100	12	Graphite	0.07072	3.926
22	10	150	10	Brass	0.09551	3.47
23	10	150	11	Graphite	0.04972	3.036
24	10	150	12	Copper	0.16638	3.166
25	10	200	10	Graphite	0.04508	2.346
26	10	200	11	Copper	0.0888	2.99
27	10	200	12	Brass	0.04690	2.96

Step 1: Normalization: Here the experimental data is to be normalized in the range of 0 to 1. As MRR is higher the better (HB) and SR is lower the better criterion is selected.

(1) Higher the better for MRR

$$Xi(k) = \frac{Yi(k) - \min Yi(k)}{\max Yi(k) - \min Yi(k)}$$

(2) Lower the better for SR

$$Xi(k) = \frac{maxYi(k) - Yi(k)}{\max Yi(k) - \min Yi(k)}$$

Table9: Normalization for Al-6082

S.NO	MRR (gm/min)	SR
1	0.01223	3.3680
2	0.22652	0.6115
3	0.1582	0.5826
4	0.17160	0.7646
5	0.08934	0.4395
6	0.003609	0.3099
7	0.007842	0.8075
8	0	1
9	0.267325	0.5673
10	0.06030	0.4771
11	0.481689	0.5694
12	0.27380	0.3789
13	0.31776	0.5042
14	0.17587	0.07666
15	0.04583	0.1788
16	0.04514	0.6626
17	0.03359	0.5169
18	0.30304	0.3749
19	0.12278	0.3161
20	1	0.6319
21	0.41231	0.5665
22	0.67493	0.3176
23	0.42154	0.1321
24	0.21026	0.1474
25	0.20627	0.3749
26	0.22199	0
27	0.48913	0.4548

Table10: Normalization for Al-6061

S.NO	MRR (gm/min)	SR
1	0.010725	1
2	0.253306	0.65469
3	0.186181	0.47306
4	0.241901	0.66160
5	0.103515	0.76519
6	0.00022634	0.77106
7	0.0056206	0.95649
8	0	0.92023
9	0.243752	0.48895
10	0.034198	0.70545
11	0.504944	0.39813
12	0.415647	0.22893
13	0.424230	0.70441
14	0.244366	0.62603
15	0.0046031	0.71339
16	0.071624	0.76657
17	0.0044776	0.72272
18	0.341629	0.56975
19	0.0801407	0.42127
20	1	0.19889
21	0.034185	0.07251
22	0.695048	0.54316
23	0.444362	0.15883
24	0.0279618	0.82872
25	0.236578	0.12776
26	0.0170500	0.68922
27	0.434969	0

Table 11: Normalization for Al-2014.

S.NO	MRR (gm/min)	SR
1	0.081140	0.3124
2	0.626003	0.7016
3	0.353323	0.7190
4	0.362993	0.7059
5	0.322035	0.5813
6	0	0.2786
7	0.136994	0.5245
8	0.021053	0.2501
9	0.423278	0.3518
10	0.163185	0.2393
11	0.639753	0.2022
12	0.681440	0.4459
13	0.618020	0.6154
14	0.487252	0.5213
15	0.068252	1
16	0.355222	0.0777
17	0.013073	0.5039

18	0.665980	0.4206
19	0.711034	0.1170
20	1	0.2763
21	0.639753	0.1977
22	0.743147	0.2678
23	0.707621	0
24	0.191238	0.0285
25	0.810197	0.00983
26	0.035771	0.9114
27	0.766146	0.2383

Table12: Normalization for Mild steel

S.NO	MRR (gm/min)	SR
1	0.39079	0.3963
2	0.29587	0.3377
3	0.18652	0.3443
4	0.29434	0.3599
5	0.04014	0.6258
6	0.36096	0.3145
7	0	0.9867
8	0.16447	0.9195
9	0.20084	0.1158
10	0.62429	0.1139
11	0.53616	0.7960
12	0.25013	0.4394
13	0.36402	0.2934
14	0.17384	0.8036
15	0.54965	0.4384
16	0.03383	1
17	0.23639	0.4900
18	0.31999	0.5033
19	1	0
20	0.55797	0.9129
21	0.32924	0.3258
22	0.47538	0.4768
23	0.20544	0.6205
24	0.89228	0.5774
25	0.17809	0.8490
26	0.43583	0.6357
27	0.18882	0.6635

Step 2: Grey Relational Coefficient: It is used to find the
Correlation between the ideal (best = 1) and normalized results.

$$\in(k) = \frac{\Delta min + \varphi \Delta max}{\Delta oi(k) + \varphi \Delta max}$$

Table13: Grey Relational Coefficient for l-6082

S.NO	MRR (gm/min)	SR
1	0.336073	0.441696
2	0.392624	0.562746
3	0.370595	0.545018
4	0.376392	0.680087
5	0.70533	0.471475
6	0.334137	0.420132
7	0.335085	0.722021
8	0.333333	1
9	0.405621	0.536020
10	0.347294	0.488806
11	0.491009	0.537287
12	0.407763	0.445990
13	0.422925	0.502108
14	0.377606	0.351286
15	0.343838	0.378443
16	0.343675	0.597086
17	0.340968	0.508595
18	0.417724	0.444404
19	0.363050	0.422332
20	1	0.575970
21	0.459689	0.535618
22	0.606009	0.422868
23	0.463624	0.365523
24	0.387675	0.369658
25	0.386479	0.444404
26	0.391233	0.333333
27	0.494623	0.478377

Table14: Grey Relational coefficient for Al-6061

S.NO	MRR (gm/min)	SR
1	0.335733	1
2	0.401660	0.591498
3	0.380569	0.486783
4	0.379425	0.596374
5	0.358041	0.680448
6	0.333383	0.685927
7	0.334587	0.919946
8	0.333333	0.862410
9	0.398010	0.494535
10	0.341110	0.629287
11	0.502484	0.453774
12	0.461104	0.393369
13	0.464783	0.628464
14	0.398205	0.572102
15	0.334359	0.635639
16	0.350047	0.681728
17	0.334331	0.643268
18	0.431640	0.537489
19	0.352147	0.463508
20	1	0.384287
21	0.341107	0.350265
22	0.621155	0.522553
23	0.473647	0.372808
24	0.339665	0.744845
25	0.395750	0.364367
26	0.337165	0.616690

27	0.469469	0.333333

Table15: Grey Relational Coefficient for Al-2014

S.NO	MRR (gm/min)	SR
1	0.352395	0.421017
2	0.572084	0.626252
3	0.436042	0.640204
4	0.439751	0.629643
5	0.424460	0.544247
6	0.333333	0.409366
7	0.366836	0.512557
8	0.338078	0.400032
9	0.464372	0.435464
10	0.374023	0.396605
11	0.581228	0.385267
12	0.610828	0.474338
13	0.566906	0.565227
14	0.493706	0.510881
15	0.349223	1
16	0.436765	0.351543
17	0.336263	0.501957
18	0.599506	0.463220
19	0.633740	0.361532
20	1	0.408596
21	0.581228	0.383936
22	0.660630	0.405778
23	0.631011	0.333333
24	0.382040	0.339789
25	0.724844	0.335532
26	0.341476	0.849473
27	0.681334	0.396290

Table16: Grey Relational coefficient for Mild Steel

S.NO	MRR (gm/min)	SR
1	0.450771	0.453021
2	0.415237	0.430181
3	0.380668	0.432638
4	0.414710	0.438558
5	0.342498	0.571951
6	0.438966	0.421762
7	0.333333	0.974089
8	0.374383	0.861326
9	0.384864	0.361219
10	0.570965	0.360724
11	0.518758	0.710227
12	0.400041	0.471431
13	0.440148	0.414387
14	0.377028	0.717978
15	0.526121	0.470987
16	0.341024	1
17	0.395691	0.495049
18	0.423725	0.501655
19	1	0.333333
20	0.530768	0.851643
21	0.427073	0.425821
22	0.487985	0.488663
23	0.386231	0.568504
24	0.822747	0.541946
25	0.378240	0.768049
26	0.469848	0.578502
27	0.381335	0.597728

Step 3: Grey Relational Grade: The Grey relational grade is calculated by averaging the grey relational coefficient of total responses.

$$Yi = \frac{1}{n}\sum_{k=1}^{n} \varphi i(k)$$

Table17: Grey Relational Grade for Al-6082

S.NO	Grade	Order
1	0.3888845	22
2	0.477685	10
3	0.4578065	14
4	0.528239	5
5	0.588402	3
6	0.377134	24
7	0.528553	4
8	0.666666	2
9	0.470820	11
10	0.41805	18
11	0.514148	7
12	0.426876	16
13	0.462516	13
14	0.364446	25
15	0.361140	27
16	0.470380	12
17	0.424781	17
18	0.431064	15
19	0.392691	21
20	0.787985	1
21	0.497653	8
22	0.514438	6
23	0.414573	20
24	0.378666	23
25	0.415450	19
26	0.362283	26
27	0.4865	9

Table18: Grey Relational Grade for Al-6061

S.NO	Grade	Order
1	0.667866	2
2	0.496279	11
3	0.433676	21
4	0.487899	13
5	0.519244	8
6	0.509655	10

7	0.627266	3
8	0.597871	4
9	0.446272	20
10	0485198	14
11	0.478129	18
12	0.427236	22
13	0.546623	6
14	0.485153	15
15	0.484999	16
16	0.515887	9
17	0.488799	12
18	0.484564	17
19	0.407827	24
20	0.692143	1
21	0.345686	27
22	0.571854	5
23	0.423227	23
24	0.542255	7
25	0.380058	26
26	0.476927	19
27	0.401401	23

Table19: Grey Relational Grade for Al-2014

S.NO	Grade	Order
1	0.386706	23
2	0.599168	3
3	0.538123	8
4	0.534697	9
5	0.484353	15
6	0.371349	25
7	0.439696	20
8	0.369055	26
9	0.449918	19
10	0.385314	24
11	0.483247	16
12	0.542583	6
13	0.566066	5
14	0.502293	13
15	0.674611	2
16	0.394154	22
17	0.41911	21
18	0.531363	11
19	0.497636	14
20	0.704298	1
21	0.482582	17
22	0.533204	10
23	0.482172	18
24	0.360914	27
25	0.530188	12
26	0.595474	4
27	0.538812	7

Table20: Grey Relational Grade for Mild Steel

S.NO	MRR (gm/min)	SR
1	0.451896	18
2	0.422709	25
3	0.406653	26
4	0.426634	23
5	0.457224	17
6	0.430364	21
7	0.653711	5
8	0.617854	6
9	0.373041	27
10	0.465844	15
11	0.614492	7
12	0.435736	20
13	0.427267	22
14	0.547503	9
15	0.498554	11
16	0.670512	3
17	0.44537	19
18	0.46269	16
19	0.66666	4
20	0.691205	1
21	0.426447	24
22	0.488324	13
23	0.477367	14
24	0.682346	2
25	0.573144	8
26	0.524175	10
27	0.489531	12

Signal to Noise (S/N) ratio: In Taguchi method S/N ratio is the statistical measuring process for predict the optimum factors to represented responses.
S/N Ratio equation

$$S/_{N_{NB}} = 10log_{10}\left[\frac{1}{S^2}\right]$$

Table21: S/N Ratio Grey Relational Grade for Al-6082

S.NO	Grade	S/N Ratio.
1	0.3888845	8.203587
2	0.477685	6.417167
3	0.4578065	6.786370
4	0.528239	5.543390
5	0.588402	4.606517
6	0.377134	8.470086
7	0.528553	5.538229
8	0.666666	3.521833
9	0.470820	6.542901
10	0.41805	7.575435
11	0.514148	5.778236
12	0.426876	7.393965
13	0.462516	6.697464
14	0.364446	8.767336
15	0.361140	8.846488
16	0.470380	6.551023

17	0.424781	7.436698
18	0.431064	7.309164
19	0.392691	8.118981
20	0.787985	2.069640
21	0.497653	6.061467
22	0.514438	5.773339
23	0.414573	7.647979
24	0.378666	8.434873
25	0.415450	7.629624
26	0.362283	8.819040
27	0.4865	6.258343

Table22: S/N Ratio Grey Relational Grade for Al-6061

S.NO	Grade	S/N Ratio
1	0.667866	3.506213
2	0.496279	6.085482
3	0.433676	7.256692
4	0.487899	6.233401
5	0.519244	5.692570
6	0.509655	5.854474
7	0.627266	4.050965
8	0.597871	4.467850
9	0.446272	7.008007
10	0485198	6.281619
11	0.478129	6.409098
12	0.427236	7.386643
13	0.546623	5.246241
14	0.485153	6.282425
15	0.484999	6.285183
16	0.515887	5.748908
17	0.488799	6.217393
18	0.484564	6.292977
19	0.407827	7.790480
20	0.692143	3.196083
21	0.345686	9.226364
22	0.571854	4.854296
23	0.423227	7.468532
24	0.542255	5.315928
25	0.380058	8.403002
26	0.476927	6.430961
27	0.401401	7.928430

Table23: S/N Ratio Grey Relational Grade for Al-2014

S.NO	Grade	S/N Ratio
1	0.386706	8.252381
2	0.599168	4.449027
3	0.538123	5.382368
4	0.534697	5.437845
5	0.484353	6.296760
6	0.371349	8.604354
7	0.439696	7.136949
8	0.369055	8.658178
9	0.449918	6.937332
10	0.385314	8.283704
11	0.483247	6.316616
12	0.542583	5.310676
13	0.566066	4.942658
14	0.502293	5.980857
15	0.674611	3.418931
16	0.394154	8.086681
17	0.41911	7.553439
18	0.531363	5.492173
19	0.497636	6.061764
20	0.704298	3.044870
21	0.482582	6.328577
22	0.533204	5.462132
23	0.482172	6.335960
24	0.360914	8.851925
25	0.530188	5.511402
26	0.595474	4.502743
27	0.538812	5.371254

Table24: S/N Ratio Grey Relational Grade for Mild Steel

S.NO	Grade	S/N
1	0.451896	6.899230
2	0.422709	7.479170
3	0.406653	7.815520
4	0.426634	7.398890
5	0.457224	6.797419
6	0.430364	7.323281
7	0.653711	3.692284
8	0.617854	4.182282
9	0.373041	8.564868
10	0.465844	6.635189
11	0.614492	4.229675
12	0.435736	7.215531
13	0.427267	7.386012
14	0.547503	5.232269
15	0.498554	6.045755
16	0.670512	3.471868
17	0.44537	7.025580
18	0.46269	6.694197
19	0.66666	3.521833
20	0.691205	3.207862
21	0.426447	7.402698
22	0.488324	6.225838
23	0.477367	6.422952
24	0.682346	3.319907
25	0.573144	4.834724
26	0.524175	5.610473
27	0.489531	6.204396

By using of Grey Taguchi Method machining conditions obtained for Al-6082 material is

Table25: Grey Taguchi optim value for Al-6082

Current (amp)	T on (µs)	Duty cycle	Mrr (mg/min)	Surface roughness(µm)
10	100	11	0.5	3.66

By using of Grey Taguchi Method machining conditions obtained for Al-6061 material is

Table 26: Grey Taguchi optim value for Al-6061

Current (amp)	T on (µs)	Duty Cycle	Mrr (mg/min)	Surface roughness(µm)
10	100	11	0.454545	5.64

By using of Grey Taguchi Method machining conditions obtained for Al-2014 material is

Table 27: Grey Taguchi optim value for Al-2014

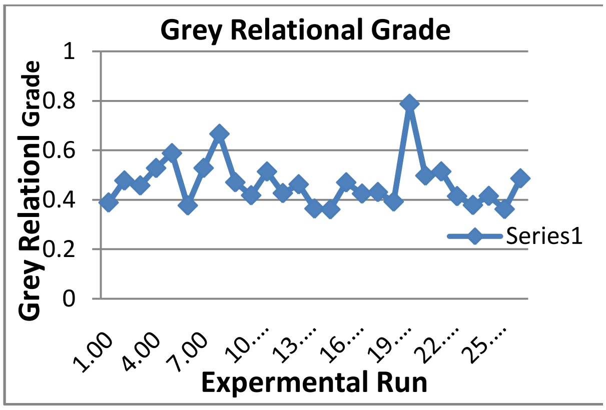
Current (amp)	T on (µs)	Duty Cycle	Mrr (mg/min)	Surface roughness(µm)
10	100	11	0.314465	5.57

By using of Grey Taguchi Method machining conditions obtained for Mild Stel material is

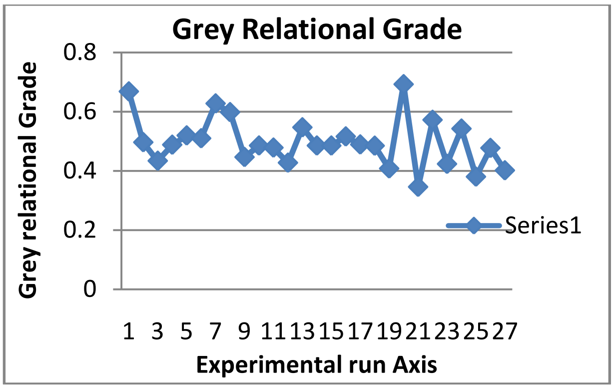
Table 28: Grey Taguchi optim value for Mild steel

Current (amp)	T on (µs)	T off (µs)	Mrr (mg/min)	Surface roughness(µm)
10	100	11	0.10952	2.053

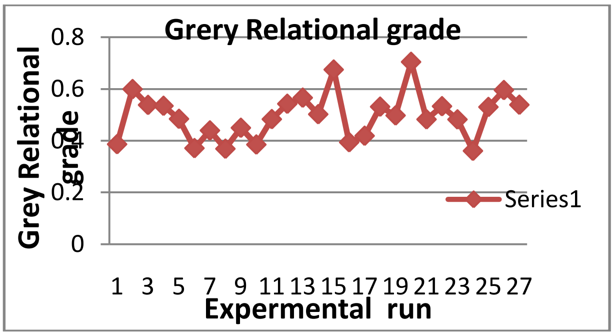
Grey Relational Gradefor Aluminum-6082



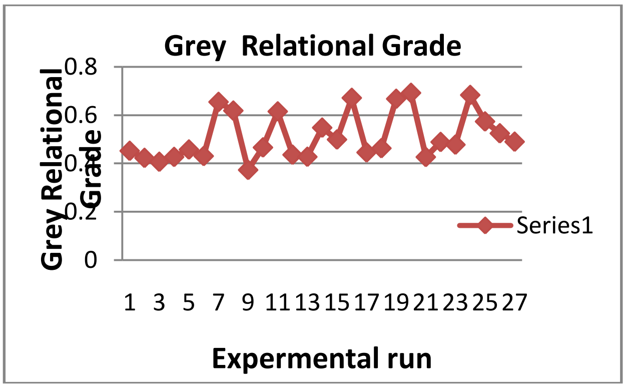
Grey Relational Grade for aluminium-6061



Grey Relational Grade for Aluminum-2014



Grey Relational Grade for Mild steel



IV. RESULT

The optimized results of four metals (i.e.Al-6082, Al-6061, Al-2014, and Mild steel) are obtained with some balanced work. It is off to do the confirmation test with the obtained output values and also find prediction error.

V. CONCLUSION

The four metals, Al-6082, Al-6061, Al-2014, and Mild steel are machined on electric discharge machine using copper, brass and graphite as cutting tools. Based on the L27 orthogonal array, current, pulse on time, duty cycleand tool materials are taken as input parameters. By using multi objective Grey Taguchi method, optimum values are obtained. The desired outputs for Al-6082: 10(A) I, 100(µs) T on, 11 Duty cycle), with 0.50 (gm/min) MRR, 3.66 (µm) SR are obtained Brass using as a tool. The desired outputs for

Al-6061: 10(A) I, 100(µs) T on, 11 Duty cycle, with 0.4545 (gm/min) MRR, 5.64(µm) SR are obtained Brass using as a tool. The desired outputs for Al-2014: 10(A) I, 100(µs) T on, 11 (µs) Duty cycle, with 0.3144 (gm/min) MRR, 5.57(µm) SR are obtained Brass using as a tool. The desired outputs for Mild steel: 10 (A) I, 100(µs) T on, 11 Duty cycle, with 0.1095 (gm/min) MRR, 2.053(µm) SR are obtained Brass using as a tool.

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