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Optimization of Process Parameters in Drilling of Al6063/B_4C Composites Using AHP-TOPSIS Method

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Abstrat: The selection of drilling parameters like drill bits, speed, feed, material and coolant is vital role while drilling of Aluminium Metal Matrix Composites (AMMCs). Taguchi L27 orthogonal array is designed based on the drilling parameters. This research work is performed drilling on Al6063/B_4C composites and observed the output responses like power, thrust force, torque, temperature, amplitude and surface roughness. Selection of optimal output responses in drilling of Al6063/B_4C composites using Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method and optimal parameters combination is identified.

Key words: Al6063/B_4C composites, Taguchi, AHP-TOPSIS, technique, temperature, amplitude

INTRODUCTION

Aluminium based composites find the wide applications in the aerospace and automotive parts and marine particularly those reinforced composites offer many advantages and exhibiting the good mechanical behaviours. The growing industrial applications demands a structured study of their drilling characteristics as it is an important metal removal process for the final fabrication stage prior to application.

Particles are ensuring great hardness is commonly used to strengthen the aluminium alloy (Chennakesavrao *et al*., 2000). The combinations have investigated on AMMCs through altered cutting tool and described that the hollow wear is not significant in k 10 tools and is having grander wear resistance and produce continuous chips. Outcome of speed, feed, depth of cut, cutting fluid, rake angle, surface roughness and wear resistance have been studied (Davim, 2003; Chennakesavrao *et al*., 2000; Hocheng *et al*., 1999). Normally the machining constraints are picking established on the machinist's practice, information and denoting to usual guidebooks (Dabade *et al*., 2007; Joshi *et al*., 1995). The designated machining parameters may not be the optimum result which clues to greater price of the product (Thakur *et al*., 2009). Great machining performance is gained by the selection of finest machining parameters (Yang and Tang, 1998; Thirumalai and Senthilkumaar, 2013). Optimization methods help as to choice the best blend of machining parameters (Zuperl *et al*., 2005; Gadakh, 2012; Potluri *et al*., 2016).

The cutting conditions which influence the machining parameters are tool type, speed, coolant, feed, and depth of cut, out of which coolant is an important factor largely, affects the machining parameters (Prabhakaran *et al*., 2006; Rai *et al*., 2013). The innovative industries are looking for a cooling system to provide near dry or dry, clean and pollution free machining. Machining under Minimum Quantity Lubrication (MQL) condition is performed favourable machining over flood cooling condition in which 5 L of fluid can be dispensed per minutes (Kelly and Cotterell, 2002; Nouari *et al*., 2003).

From the available literature, it was understood that not enough work has been done on decision making associated with the drilling of composites. Current effort is engrossed on the optimization of constraints in drilling of AMMCs. For minimizing the power consumption, thrust force, torque, temperature, surface roughness and vibration amplitude using AHP-TOPSIS method.

Experimental setup for drilling of AMMCs: For lessening the experiments and charge, Taguchi DOE orthogonal array L27 has been used. By considered influences and their stages (levels) developed experimental layout using OA L27 and are shown in Table 1. Drilling tests have been

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Fig. 1: Drilled Al6063/B4 C composite

Fig. 2: Drill bits (HSS, SN and TAN)

Table 1: Input parameters and their levels

Input parameters/influential factors	Level 1	Level 2	Level 3
Reinforcement percentages (RFP)	2	3.5	5
Speed (S) in rpm	450	500	560
Feed (F) in mm/rev	0.15	0.2	0.3
Tool Material (TM)	HSS	SN	TAN
Coolant (C)	SO	VO	MO

conducted on Al6063/B_4C composites using radial drilling machine (Fig. 1) and three drill bits (Fig. 2) such as HSS, SN, TAN under Minimum Quantity Lubrication (MQL).

MATERIALS AND METHODS

Methodology-multi objective parameters optimizations: The Multi Criteria Decision Making Methods (MCDM) are widely accepted in manufacturing domain for the selection of optimal solution from a finite number of alternatives. AHP-TOPSIS is hybrid methodology found by adding the AHP by means of TOPSIS and is one of the multi criteria decision making methods for resolving several measures. Technique for order Preference by Similarity to Ideal Solution (TOPSIS) technique was initially introduced in 1995 by Hwang and Yoon and is convert the multi responses to a single response. In TOPSIS technique weightages/priorities required for each

Fig. 3: Radial drilling machine

output responses to optimize the process parameters of drilling on Al6063/B_4C composites. The weightages allocated to each response is very important in the TOPSIS method. This weightages has been conditioned that all weight must be sum up to 1 and this weightages may vary from hand to hand. So, these weightages/priorities are determined using Analytical Hierarchy Process (AHP) method for each response of drilling. Analytical hierarchy process has been developed by Thomas L. Saaty in 1980 and Fig. 3 gives AHP-TOPSIS flow chart and it describes the detailed view of this technique.

RESULTS AND DISCUSSION

Finding of priority values or weightage values for out responses by using analytical hierarchy process: First the weightages or priority values are calculated for output responses through articulating the pair-wise comparison matrix in demand to adopt the comparative importance of one measure versus alternative using Saaty's scale. Table 2 and 3 is shown the Saaty scale for pair wise comparison. In the current paper, the following steps of Analytical hierarchy process to assistance to extent the priority values or weighted values of numerous criteria:

- Outline the problem and decide the conditions
- Building the judgment hierarchy attractive into interpretation the objective of the conclusion
- Improve the pair-wise comparison matrix in which set of elements are compared with itself and size of the matrix is n×n by means of the essential rule of pair wise comparison which are revealed in Table 3

The hierarchy mixture is used to weight the eigen vectors by the weights of the criteria and the sum is taken over all weighted eigen vector entries corresponding to those in the next level of the hierarchy. Finding the consistency index by using Eq. 1:

Table 2: Experimental design/layout using OA L27 and output responses

	Input parameters					Output responses					
Exp. No.	Tool	Material (%)	Speed	Feed	Coolant	Power	TF	Torque	Temp.	Ra	Amplitude
1	HSS	2.00	450	0.15	SO	1000	49	0.90	32.5	0.32	0.089704
2	HSS	2.00	450	0.15	VO	750	33	1.20	34.0	0.31	0.300930
3	HSS	2.00	450	0.15	MO	800	59	2.20	30.8	0.33	0.527246
4	HSS	3.50	500	0.20	SO	900	51	1.30	32.7	0.26	0.474514
5	HSS	3.50	500	0.20	VO	1000	42	1.20	32.5	0.22	0.650737
6	HSS	3.50	500	0.20	MO	890	43	1.00	32.8	0.18	0.255962
7	HSS	5.00	560	0.30	SO	1050	47	1.60	33.5	0.14	0.479407
8	HSS	5.00	560	0.30	VO	1000	58	0.70	33.8	0.15	0.467954
9	HSS	5.00	560	0.30	MO	1050	68	1.00	34.9	0.16	0.766901
10	SN	2.00	500	0.30	SO	1000	128	2.70	30.1	0.26	0.654465
11	SN	2.00	500	0.30	VO	900	120	1.40	31.5	0.27	0.212675
12	SN	2.00	500	0.30	MO	1000	115	1.30	31.0	0.25	0.594424
13	SN	3.50	560	0.15	SO	1050	67	0.60	32.9	0.65	0.074177
14	SN	3.50	560	0.15	VO	1000	64	0.80	34.7	0.67	0.530499
15	SN	3.50	560	0.15	MO	1000	67	0.70	37.0	0.58	0.788743
16	SN	5.00	450	0.20	SO	1100	110	0.27	30.9	0.88	0.156855
17	SN	5.00	450	0.20	VO	700	114	3.60	37.9	0.82	0.425610
18	SN	5.00	450	0.20	MO	710	120	3.30	34.9	0.89	0.412530
19	TAN	2.00	560	0.20	SO	900	73	0.90	31.5	0.15	0.224539
20	TAN	2.00	560	0.20	VO	1000	79	0.60	32.0	0.16	0.116220
21	TAN	2.00	560	0.20	MO	1050	79	0.70	33.3	0.15	0.124188
22	TAN	3.50	450	0.30	SO	1200	136	3.30	32.0	1.58	0.135260
23	TAN	3.50	450	0.30	VO	1000	131	5.50	33.8	1.55	0.099176
24	TAN	3.50	450	0.30	MO	1000	140	4.50	34.9	1.53	0.743980
25	TAN	5.00	500	0.15	SO	700	66	0.50	33.8	0.55	0.697017
26	TAN	5.00	500	0.15	VO	1000	67	0.70	36.3	0.80	0.671990
27	TAN	5.00	500	0.15	MO	900	73	1.00	36.0	0.95	0.266719

Table 3: Saaty scale for pair-wise comparison

Rating	Preferences
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strongly importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between two adjacent judgments

$$CI = \frac{(\lambda_{max} - n)}{n-1} \quad (1)$$

Where:

λ_{max} = Principal Eigen vector

n = Number of criteria

Finally calculate the consistency ratio, it is defined as the ratio of CI and RI Consistency Ratio, CR = Consistency Index/Random Index. Saaty suggest that CR is does not exceeded, so in the present CR is <0.1. Then it is accepted to consider the obtained priority values.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): The following steps are used in this technique to get optimal value. Normalize the output responses by using priority values obtained from Analytical hierarchy process. Normalized values are obtained by Eq. 2:

$$N_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \quad (2)$$

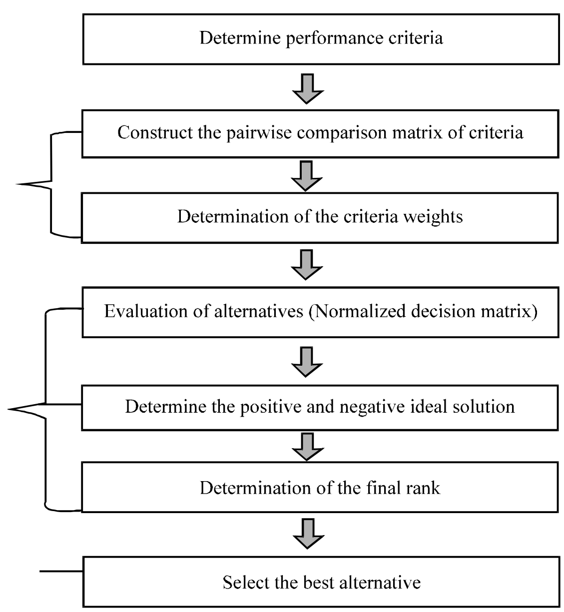

Fig. 4: Proposed integrated AHP-TOPSIS methodology

Determining the weighted regularized matrix which has been acquired by Eq. 3:

$$V_{ij} = W_i \times N_{ij} \quad (3)$$

Calculate Positive separation and Negative separation ideal solutions. Positive Ideal Solution (PIS) (Fig. 4).

Table 4: Pair-wise comparison matrix

		J				
Variables	Power (P)	Thrust Force (TF)	Torque (TQ)	Temperature (Temp)	Surface roughness (Ra)	Vibration Amplitude (Amp)
Power (P)	1	3	3	7	9	9
Thrust Force (TF)	0.333333	1	5	3	3	5
Torque (TQ)	0.333333	0.2	1	3	3	3
Temperature (Temp)	0.142857	0.333333	0.333333	1	3	3
Surface roughness (Ra)	0.111111	0.333333	0.333333	0.333333	1	3
Vibration Amplitude (Amp)	0.111111	0.2	0.333333	0.333333	0.333333	1

Table 5: Priority value in the Pair-wise comparison matrix

Varibles	P	TF	TQ	Temp.	Ra	Amp.	Eigen	Priority
P	1	3	3	7	9	9	4.149263	0.470670
TF	0.333333	1	5	3	3	5	2.053573	0.232946
TQ	0.333333	0.2	1	3	3	3	1.102924	0.125110
TEMP	0.142857	0.333333	0.333333	1	3	3	0.723020	0.082015
RA	0.111111	0.333333	0.333333	0.333333	1	3	0.480750	0.054534
AMP	0.111111	0.2	0.333333	0.333333	0.333333	1	0.306129	0.034726
Total, Ti	2.031746	5.066667	10	14.66667	19.33333	24	8.815658	1

Table 6: Normalized decision matrix

Ex.No.	Power	TF	Torque	Temp.	Ra	Amplitude
1	0.200891	0.107646	0.083415	0.187665	0.087651	0.036902
2	0.150668	0.072496	0.111219	0.195172	0.084912	0.123796
3	0.160713	0.129615	0.203902	0.179158	0.090390	0.216897
4	0.180802	0.112040	0.120488	0.188666	0.071217	0.195204
5	0.200891	0.092268	0.111219	0.187665	0.060260	0.267698
6	0.178793	0.094465	0.092683	0.189166	0.049304	0.105297
7	0.210936	0.103252	0.148293	0.192669	0.038347	0.197217
8	0.200891	0.127418	0.064878	0.194171	0.041086	0.192506
9	0.210936	0.149386	0.092683	0.199676	0.043826	0.315485
10	0.200891	0.281198	0.250244	0.175654	0.071217	0.269232
11	0.180802	0.263623	0.129756	0.182661	0.073956	0.087490
12	0.200891	0.252639	0.120488	0.180158	0.068477	0.244532
13	0.210936	0.147189	0.055610	0.189667	0.178041	0.030515
14	0.200891	0.140599	0.074146	0.198675	0.183520	0.218235
15	0.200891	0.147189	0.064878	0.210185	0.158868	0.324471
16	0.220980	0.241654	0.025024	0.179658	0.241041	0.064527
17	0.140624	0.250442	0.333658	0.214689	0.224606	0.175086
18	0.142633	0.263623	0.305853	0.199676	0.243780	0.169705
19	0.180802	0.160371	0.083415	0.182661	0.041086	0.092370
20	0.200891	0.173552	0.055610	0.185163	0.043826	0.047810
21	0.210936	0.173552	0.064878	0.191669	0.041086	0.051088
22	0.241069	0.298773	0.305853	0.185163	0.432778	0.055643
23	0.200891	0.287788	0.509756	0.194171	0.424560	0.040799
24	0.200891	0.307560	0.417073	0.199676	0.419082	0.306056
25	0.140624	0.144993	0.046341	0.194171	0.150650	0.286737
26	0.200891	0.147189	0.064878	0.206682	0.219128	0.276441
27	0.180802	0.160371	0.092683	0.205180	0.260214	0.109722

$$A^{**} = \{(\max V_{ij}/jJ),\ (\min V_{ij}/jJ),\ (\max V_{ij}/jJ),\ i = 1, 2, 3, \ldots, m\} W_i \times N_{ij} \quad (4)$$

Negative Ideal Solution (NIS):

$$A^{*} = \{(\min V_{ij}/jJ),\ (\max V_{ij}/jJ),\ (\max V_{ij}/jJ),\ i = 1, 2, 3, \ldots, m\} \quad (5)$$

Positive Separation Ideal Solution (PSIS):

$$S_i^{+} = \sqrt{\sum_{j=1}^{m}\left(V_{ij}\text{-}A^{*}\right)^2} \quad (6)$$

Negative Separation Ideal Solution (NSIS):

$$S_i^{-} = \sqrt{\sum_{j=1}^{m}\left(V_{ij}\text{-}A^{*}\right)^2} \quad (7)$$

And also find out the closeness coefficient and is also obtained from Eq. 8 (Table 4-6):

$$CC_1 = \frac{S_i^{-}}{S_i^{+} + S_1^{-}} \quad (8)$$

The larger the CC_i value is the better performance of the alternatives. From Table 7 and 8, experimental

Table 7: Weighted Normalized matrix

Exp. No.	Power	TF	Torque	Temp	Ra	Amplitude
1	0.094553	0.025076	0.010436	0.015391	0.004780	0.001281
2	0.070915	0.016888	0.013915	0.016007	0.004631	0.004299
3	0.075643	0.030193	0.025510	0.014694	0.004929	0.007532
4	0.085098	0.026099	0.015074	0.015473	0.003884	0.006779
5	0.094553	0.021493	0.013915	0.015391	0.003286	0.009296
6	0.084153	0.022005	0.011596	0.015514	0.002689	0.003657
7	0.099281	0.024052	0.018553	0.015802	0.002091	0.006849
8	0.094553	0.029681	0.008117	0.015925	0.002241	0.006685
9	0.099281	0.034799	0.011596	0.016376	0.002390	0.010956
10	0.094553	0.065504	0.031308	0.014406	0.003884	0.009349
11	0.085098	0.061410	0.016234	0.014981	0.004033	0.003038
12	0.094553	0.058851	0.015074	0.014776	0.003734	0.008492
13	0.099281	0.034287	0.006957	0.015556	0.009709	0.001060
14	0.094553	0.032752	0.009276	0.016294	0.010008	0.007578
15	0.094553	0.034287	0.008117	0.017238	0.008664	0.011268
16	0.104009	0.056292	0.003131	0.014735	0.013145	0.002241
17	0.066187	0.058339	0.041744	0.017608	0.012249	0.006080
18	0.067133	0.061410	0.038265	0.016376	0.013294	0.005893
19	0.085098	0.037358	0.010436	0.014981	0.002241	0.003208
20	0.094553	0.040428	0.006957	0.015186	0.002390	0.001660
21	0.099281	0.040428	0.008117	0.015720	0.002241	0.001774
22	0.113464	0.069598	0.038265	0.015186	0.023601	0.001932
23	0.094553	0.067039	0.063776	0.015925	0.023153	0.001417
24	0.094553	0.071645	0.052180	0.016376	0.022854	0.010628
25	0.066187	0.033775	0.005798	0.015925	0.008216	0.009957
26	0.094553	0.034287	0.008117	0.016951	0.011950	0.009600
27	0.085098	0.037358	0.011596	0.016828	0.014191	0.003810

Table 8: Closeness coefficient value

Exp. No.	PIS	NIS	CC
1	0.076356	0.030550	0.2857630
2	0.087783	0.012576	0.1253070
3	0.070598	0.028589	0.2882310
4	0.075262	0.024943	0.2489230
5	0.076029	0.031818	0.2950280
6	0.080905	0.020710	0.2038100
7	0.070688	0.037681	0.3477080
8	0.075475	0.032049	0.2980630
9	0.068797	0.039869	0.3668960
10	0.043037	0.063514	0.5960920
11	0.060226	0.050195	0.4545800
12	0.057476	0.052595	0.4778290
13	0.071599	0.038366	0.3488910
14	0.070997	0.034682	0.3281810
15	0.071235	0.035884	0.3349930
16	0.064823	0.055739	0.4623300
17	0.055257	0.057861	0.5115100
18	0.055125	0.058054	0.5129420
19	0.073168	0.028896	0.2831160
20	0.071474	0.037074	0.3415460
21	0.069451	0.040945	0.3708890
22	0.027349	0.081926	0.7497230
23	0.021884	0.086276	0.7976728
24	0.022239	0.082069	0.7867980
25	0.085275	0.020280	0.1921290
26	0.070640	0.036178	0.3386860
27	0.069626	0.031751	0.3131960

number 23 is the higher value of CC_i. The S/N ratio of the closeness coefficient for individually parameter at changed stages is intended. The answer curve is used for exploratory the parametric belongings on the answer characteristics. From Fig. 5, it can be observed that the second level of tool, second level of reinforcement, first level of speed, third level of feed and third level of coolant result in the optimal values of output responses in drilling of Al6063/B_4C. The confirmation test is conducted for their combination and results are shown in Table 7-9 and Fig. 5.

Table 9: Confirmation test results

Influential parameters				Output responses						
Tool material	% of reinforcement	Speed	Feed	Coolant	P	TF	TQ	Temp	Ra	Amp
SN	3.5%	450	0.3	MO	1100	133	5.7	34.0	1.56	0.12486

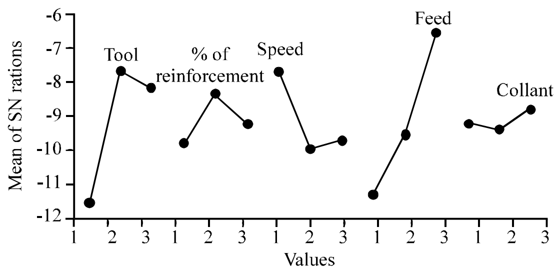

Fig. 5: Key things of plot for signal to noise ratios of CC_i

CONCLUSION

In the present research, according to the orthogonal array L27 drilling experiments are conducted on the Al6063/B_4C composite and output responses are observed. This data are analysed and influential parameters combinations have been identified using Hybrid Approach Method (AHP-TOPSIS). The Analytic Hierarchy Process (AHP) has been used to finding the priority values or weightage factors for each response in drilling.

The TOPSIS has been used to finding the optimal process parameters setting by integrating the AHP weightages in the TOPSIS. After identified the best grouping of significant influences, the validation trial is conducted and then outcomes are noted in Table 9. The Power consumed (P), Thrust force (TH), Torque (TQ), Temperature (Temp), Surface roughness (Ra) and Amplitude (Amp) are minimized successfully using AHP-TOPSIS method. It is evident that the material of tool or drill bit material and coolant are highly influencing the Power consumed (P), Thrust force (TH), Torque (TQ), Temperature (Temp), Surface roughness (RA) and Amplitude (Amp). Speed, feed, percentage of reinforcement are low influencing on Power consumed (P), Thrust force (TH), Torque (TQ), Temperature (Temp), Surface roughness (Ra) and Amplitude (Amp).

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