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Turning Process Parameters optimization of Al7075 Hybrid MMC's using Standard deviation method coupled with VIKOR

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Abstract. This research article elaborates the processes involved in optimization studies in turning process with multi-response features on the basis of Multi-Criteria Decision Making (MCDM) Methodology by utilizing the integrated approach of Standard deviation method and VIKOR approaches. In the study, the researchers optimized the cutting speed, feed and depth of cut with multi-response characteristics which are inclusive of Material Removal Rate (MRR) as well as a surface roughness (Ra). When using a combination of the turning process parameters such as cutting speed of 115 m/min, the feed of 0.16 rev/m, and depth of cut of 0.8 mm, the approach was able to achieve high MRR and low Ra. The study results inferred that the proposed method can be used to enhance the multi-response characteristics of the Al7075/FA/SiC MMC used during the turning process.

Keywords: Turning, Surface Roughness, MRR, MCDM, VIKOR

1. INTRODUCTION

Aluminium alloys reinforced with ceramic materials are the new breed of engineering materials with improved properties like specific strength, superior resistance to corrosion and wear, higher hardness when compared to the unreinforced alloys [1, 3-4]. Aerospace and automotive industries demand for materials with lightweight and improved mechanical properties. Hence researchers focused on production and characterization of Aluminium metal matrix composites (AMMCs) with ceramic particulates reinforcement [1-2, 5-6]. Existence of tough ceramic reinforcements in the AMMCs, which makes them complex to machine and make the surface rough leading to higher tool wear rate [7-9, 11]. Automobile parts like engine blocks, cylinders, and pistons justify the importance of optimal machining process parameters. It was reported that feed rate is the mainly influencing parameter followed by the depth of cut and cutting speed for characteristics like surface roughness (Ra) and material removal rate (MRR) on turning of A356/5 wt.% SiCp, [8]. Pradhan and Sahoo [10] reported that the most considerable parameter for the surface finish is feed, followed by cutting speed and depth of cut, during turning of SiC reinforced AMMCs with uncoated carbide inserts. Ciftci et al. [11] observed uncoated carbide tools produced improved surface roughness values when compared to the coated carbide tools, through turning of Al 2014/SiC MMCs in dry machining condition. The present investigation is focused on turning performance of Al 7075/Fly ash/SiC AMMC in terms of Ra and MRR under dry machining condition with uncoated carbide tipped tool inserts.

Among various MCDA/MCDM strategies created to understand genuine choice problems, VIKORS keeps on working attractively in altered use areas. As an outstanding old style MCDA/MCDM technique, VIKORS has gotten much enthusiasm from specialists and experts. The worldwide enthusiasm for the

VIKORS technique has exponentially developed, which we wish to record in this paper.

Opricovic had created VIKOR's basic concept. Visekriferijumska optimizacija Kompromusno Resenje, which means: Optimization of multi criteria and compromise solution with Pronunciation: VIKOR. Opricovic introduced the real applications. The paper by Opricovic and Tzeng [12] led to the VIKOR method's international recognition. In this paper, Marching's multi-criteria decision-making is carried out using the VIKOR approach coupled with standard deviation method. The cutting parameter on MRR and Ra during CNC turning was optimized by Raman et al . [13] using the method of VIKOR and AHP. In MCDM during electroplating of various materials in an industry, Kaoser et al . [14] Proposed VIKOR and AHP methods.

Subjective and objective are the two well-known methods of weight assignment. The system of subjective weight assignment is based on professional judgment, and pair-wise comparison AHP and SMART are the most common techniques used [15]. While the objective weight assignment methodology collects data from requirements data and calculates weights accordingly without the decision-maker's involvement [16]. Entropy, CRITIC, and the standard deviation approach are the most common techniques used [17]. The choice of the expert is not applicable, as in the present study, so an objective form of weighting is applied. So The SD method, integrated with the VIKOR method, is used in the present study to assess the response weights.

This paper is paying attention on optimizing the process parameter by VIKOR and standard deviation weight measurement method during turning of Al 7075 MMC based on the above literature review. The aim is to get a single numerical index known as the VIKOR index and an optimal level of process parameter setting for complex machining of multi characteristics.

2. EXPERIMENTAL SETUP

AMMCs having 10 % by weight SiC and Fly ash particles of size 53μm were fabricated by stir casting route are taken as reference for machining as at this percentage, better mechanical properties were observed by Venkata Reddy et al. [2]. The composites were prepared by stir casting route. Melting of Al 7075 ingots was performed in an electric furnace with graphite crucible. At 770°C, the molten metal pool is stirred in the middle of the crucible using a mechanical stirrer at 500 rpm. SiC and fly ash particulates are preheated and dropped uniformly into the melt. To avoid the agglomeration, smooth, and continuous flow of the particles is ensured during stirring. Then, molten metal is poured into cast iron moulds which is preheated to 200 0C. The fabricated ingots were kept in a muffle furnace at 110 0C for 24 hours to remove any residual stresses induced in the castings and to reduce the chemical in homogeneities. Uncoated tungsten carbide inserts are used as the cutting tool. Rough turning on fabricated ingots is first performed on the lathe machine to make specimens of uniform diameter as shown in figure 1. Initially, based on the available feeds, and speeds on the Lathe, pilot experiments were conducted to find the range of feeds and speeds for good surface finish and material removal rate. After identifying the levels for cutting speed, feed and depth of cut, Taguchi's L16 orthogonal array is selected for the design of experiments. Factors and their levels selected are given in Table 1.

Average surface roughness (Ra) of 16 specimens was measured with Surface Roughness measuring instrument Mitutoyo's Surftest SJ-210. Mathematic average of the roughness profile of the surface Ra of all sixteen specimens is presented in Table 2. Surface roughness is measured at three different locations, and the average value is taken. Material Removal rate (MRR) was determined by utilizing the weight loss technique i.e. material removal weight over period of time in seconds.

Table 1.Factors and levels selected.

S.No	Factor	Unit	Levels of Factors			
			L-1	L-2	L-3	L-4
1	Cutting speed, v	m/min	20	50	75	115
2	Feed, f	mm/rev	0.05	0.10	0.16	0.20
3	Depth of cut, d	mm	0.2	0.4	0.6	0.8

Figure 1. Specimens of Al 7075

Table 2. Surface roughness and MRR values.

Exp. No.	v	f	d	Ra(μm)	MRR
1	20	0.05	0.2	1.52	0.020
2	20	0.1	0.4	1.78	0.038
3	20	0.16	0.6	2.48	0.066
4	20	0.2	0.8	3.00	0.170
5	50	0.05	0.4	1.72	0.042

6	50	0.1	0.2	1.50	0.038
7	50	0.16	0.8	2.28	0.220
8	50	0.2	0.6	2.32	0.174
9	75	0.05	0.6	1.36	0.070
10	75	0.1	0.8	1.51	0.210
11	75	0.16	0.2	2.14	0.112
12	75	0.2	0.4	2.24	0.162
13	115	0.05	0.8	1.31	0.140
14	115	0.1	0.6	1.39	0.220
15	115	0.16	0.4	1.71	0.250
16	115	0.2	0.2	2.00	0.122

3. METHODOLOGY

3.1 STANDARD DEVIATION METHOD:

Standard deviation applies to the measurement of impartial weight allocation. The technique comprises the following steps.

Step 1: Initially, the performance responses relevant to different parameters were standardized. For all the output response parameters, the measurement of the normalized value was performed using the following operations:

$$S_{ij} = \frac{S_{ij} - S_i^{min}}{S_i^{max} - S_i^{min}} \text{ (Formaximization)} \quad (1)$$

$$S_{ij} = \frac{S_i^{max} - S_{ij}}{S_i^{max} - S_i^{min}} \text{ (For minimization)} \quad (2)$$

Where: S_{ij} is the experimental value of output response 'i'.

Step 2: The Standard Deviation Method (SDM) weight of each attribute will be determined in the second stage. The objective weights are determined using the following equation for the attributes:

$$SD_j = \sqrt{\frac{\sum_{i=1}^{k}(S_{ij} - \mu_j)}{k}} \quad (3)$$

Where μ_j is the mean of the S_{ij} for each output response and k is the number of experiments.

Step 3: using Eq.(4), calculate the weights for each response

$$\omega_j = \frac{SD_j}{\sum_{j=1}^{n} SD_j} \quad (4)$$

Where n is the number of output response.

The weights are calculated using the Eq. (1), (2) and (3) for MRR and Ra and are shown in Table 3. The weight is 0.54 for MRR and 0.46 for surface roughness.

Table 3: Normalized values and standard deviation of output responses.

	Normalized Values			
EXP.No.	Ra	MRR	Ra	MRR
1	0.876	0.000	0.048	0.222
2	0.722	0.078	0.004	0.154
3	0.308	0.200	0.121	0.074
4	0.000	0.652	0.430	0.033
5	0.757	0.096	0.010	0.141
6	0.888	0.078	0.054	0.154
7	0.426	0.870	0.053	0.159
8	0.402	0.670	0.064	0.039
9	0.970	0.217	0.099	0.064
10	0.882	0.826	0.051	0.126
11	0.509	0.400	0.022	0.005
12	0.450	0.617	0.043	0.021
13	1.000	0.522	0.118	0.003
14	0.953	0.870	0.088	0.159
15	0.763	1.000	0.012	0.280
16	0.592	0.443	0.004	0.001
Standard Deviation			0.276	0.320

Table 4: Objective weights of each response

Ra	-0.1667	0.46
MRR	1	0.54

3.2 VIKOR METHOD:

In a complex decision making problem, the VIKOR approach is applicable to multi-criteria decision making. The basic principle of this VIKOR strategy is to refine multi-criteria and compromise the approach to find a final solution. Basically, finding the solution similar to the optimal and negative ideal solution is an aggregate statistical process. This approach focuses on rating the collection of alternatives from the various criteria for problems that assist decision-makers to reach a final solution. The result corresponding to the smallest VIKOR indexed value is the most optimal solution. The following steps are used to measure the VIKOR Index as per the literature.

Step1. Normalize the decision matrix, The Normalized matrix may be defined as

$$k = (k_{ij})_{lxm} \quad (5)$$

$$\text{Where } k = \frac{p_{ij}}{\sqrt{\sum_{i=1}^{l} p_{ij}^2}} \quad (6)$$

$i = 1,2, \ldots l; j = 1,2 \ldots m;$ p_{ij} is the output response value for experiment 'j'.

Step 2: The positive and negative ideal solutions are determined by following equations.

$$k^* = \{(\max k_{ij} \ / \ j \in J)\} \text{ OR } (\min k_{ij} \ / \ j \in J') \}, \quad (7)$$

$k^{-} = \{(\min k_{ij} \ / \ j \in J)\}$ OR $(\max k_{ij} \ / \ j \in J')\}$ (8)

Where $J = \{j = 1,2, \ldots l\}, k_{ij}$ if preferred response is maximum

$J' = \{j = 1,2, \ldots l\}, k_{ij}$ if preferred response is minimum

Step 3: The utility and regret measures are determined using the following equation for each outcome.

$$D_i = \sum_{j=1}^{n} \omega_j \frac{(k^* - k_{ij})}{(k_j^* - k_j^-)'} \quad (9)$$

$$E_i = \max_j \left[\omega_j \frac{(k^* - k_{ij})}{(k_j^* - k_j^-)'} \right] \quad (10)$$

Where E_i is the regret measure and D_i is the utility measure and ω_j is the weight of response' j'.

Step 4: The VIKOR index is calculated as the relationship below.

$$F_i = \left[(v) \frac{(D_i - D^*)}{(D^- - D^*)} \right] + \left[(1 - v) \frac{(E_i - E^*)}{(E^- - E^*)} \right] \quad (11)$$

Where F_i is the VIKOR index and v is the group utility maximum weight generally taken as 0.5.

Step 5: To rank the alternatives decease value of the VIKOR index is consider and the smallest value is the highest rank order

Step 6: Propose the consideration weights of the given alternative as a compromise solution. The alternative R1 is considered by the measure F (minimum) as the first highest rank and R2 is the second highest rank in the VIKOR index list ranking order.

$$F(R^2) - F(R^1) \geq DQ = \frac{1}{(m-1)'} \quad (12)$$

Where $'m'$ is the number of alternatives.

Step 7: The primary aim is to rank the experimental outcome list and compromise the solution with its rate of advantage. The better outcome for the multi-responses problem is a smaller VIKOR Index.

4. RESULTS AND DISCUSSIONS

This study has chosen two performance characteristics such as minimization and maximization. In order to attain the optimal machining performance, the researcher took the maximization features for MRR and minimization features for surface roughness. With the help of equation (5) and (6), the two responses were normalized at the initial stage. Since the priority given to both output responses is based on standard deviation method, the responses weight criterion was taken as 0.46 for surface roughness and 0.54 for MRR. The output of the individual normalized response matrix is now analyzed by Eq.(9) and (10). D_i (utility measure) and E_i (regret measure) are measured by Eq. (11) and with Eq.(12) respectively, respectively. The VIKOR Index (F_i) is assessed on the basis of an Eq. (13) and ranked in accordance with the lowest $F_i$value shown in Table 5.

By using the Eq.(12), the appropriate advantage condition is applied to verify the stable position and advantage over other experimental outcomes. Table 6 shows that $F(R^1)$ and $F(R^2)$ are the first index and the second index values respectively. The corresponding VIKOR index values, respectively, are 0.0000 and 0.0674. As, per the condition the value of DQ is 0.0666. Therefore $F(R^2)$ - $F(R^1)$ is 0.0674, is greater than DQ and the condition is satisfied.

Table 5. Normalized, utility, regret measure and VIKOR index values

	Normalized Values		Measures		VIKOR index
EXP.No.	Ra	MRR	Di	Ei	Fi
1	0.057	0.560	0.6172	0.5600	0.8889
2	0.127	0.516	0.6441	0.5162	0.8639
3	0.318	0.448	0.7665	0.4480	0.8850
4	0.460	0.194	0.6548	0.4600	0.8142
5	0.111	0.506	0.6180	0.5064	0.8345
6	0.051	0.516	0.5679	0.5162	0.8072
7	0.264	0.073	0.3371	0.2640	0.3764
8	0.274	0.185	0.4600	0.2749	0.4791
9	0.013	0.438	0.4519	0.4383	0.6408
10	0.054	0.097	0.1518	0.0974	0.0674
11	0.225	0.336	0.5619	0.3360	0.6177
12	0.253	0.214	0.4674	0.2531	0.4623
13	0.000	0.267	0.2678	0.2678	0.3288
14	0.021	0.073	0.0948	0.0730	0.0000
15	0.108	0.000	0.1089	0.1089	0.0473
16	0.187	0.311	0.4995	0.3117	0.5462

The factor response results were taken into account by utilizing 'lower-the-better' expectation through MINITAB software. As per table 6, the role played by 'd' remains insignificant, whereas the contribution made by the parameters, 'v' and 'f', seemed to have significantly enhanced the VIKOR index value. Fig.2 depicts the main effects plots for S/N ratio and optimal settings are shows as $v_4f_3d_4$.

Table 6. Response means of VIKOR index

Level	v	f	d
1	1.285	4.030	3.080
2	4.578	8.853	9.012
3	9.545	10.059	3.773
4	13.806	5.033	10.840
Delta	12.521	6.029	7.760
Rank	1	3	2

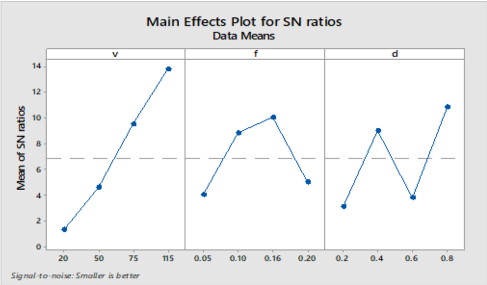

Figure 2. Main Effects plot for S/N ratios.

Table 7 shows a comparison of the assessment outcomes for beginning and best choice of turning process parameters for the expected as well as the test conditions. Once the best level parameters for machining were decided, the tests for confirmation were conducted in order to ensure the improvement in the multi response feature of turning. Using optimal level of turning parameters and using the equation [13], the forecasted response value ($\gamma_{predicted}$) can be calculated.

$$\gamma_{predicted} = \gamma_m + \sum_{j=1}^{n}(\gamma_0 - \gamma_m) \quad (13)$$

In which, the γ_m denotes the overall mean multiresponse value and γ_0 denotes the mean multiresponse value at the optimum level of factors. In the equation, n denotes the number of input process parameters. From the outcomes, it can be inferred that the VIKOR index value of the optimal parameter condition (v4f3d4) seems to be high when compared with the initial setting parameter condition (v1f1d1). In addition to that, the forecasted response value also seems to be closer to the experimental value.

Table 7. Predicted and Experimental values

Index	Optimal Settinngs	Predicted Values	Experimental Value	% Error
VIKOR	v=115 m/min, f=0.16 mm/rev, d=0.8 mm	0.0544	0.0526	3.3

5. CONCLUSIONS

The current study utilized the hybrid approach of Standard deviation – VIKOR method in addition to orthogonal array so as to best enhance the process parameters in the turning process of Al7075/FA/SiC hybrid MMC for multi response features. The researcher identified a best combination of turning parameters along with their levels when it comes to achieving the least surface roughness (Ra) value and a better Material Removal Rate (MRR). Based on the response noted from VIKOR index values, the researcher found out the optimum combination levels of input process parameters: Cutting speed 115 m/min, feed 0.16 mm/rev. and depth of cut 0.8 mm. Further, the study concluded with the proposed method showing efficiency in finding a solution for turning multi-response problems when compared to the methods used earlier.

References

1. Das, Diptikanta, et al. "Turning performance of Al 7075/SiCp MMC and multi-response optimization using WPCA and Taguchi approach." Materials Today: Proceedings 5.2 (2018): 6030-6037.
2. Venkata Reddy et al. “Studies on microstructure and mechanical behavior of A7075 -Flyash/SiC hybrid metal matrix composite” IOP Conf. Series: Materials Science and Engineering, 310 (2018) 012047.
3. Koli, Dinesh Kumar, GeetaAgnihotri, and Rajesh Purohit. "Advanced aluminium matrix composites: The critical need of automotive and aerospace engineering fields." Materials Today: Proceedings 2.4-5 (2015): 3032-3041.
4. Sarada, B. N., PL Srinivasa Murthy, and G. Ugrasen. "Hardness and wear characteristics of hybrid aluminium metal matrix composites produced by stir casting technique." Materials Today: Proceedings 2.4-5 (2015): 2878-2885.
5. Mishra, P., et al. "Multi-response optimization of process parameters using Taguchi method and grey relational analysis during turning AA 7075/SiC composite in dry and spray cooling environments." International Journal of Industrial Engineering Computations 6.4 (2015): 445-456.
6. M.Chandrasekaran, and SantoshTamang. "Desirability analysis and genetic algorithm approaches to optimize single and multi-response characteristics in machining Al-SiC MMC." 5th international & 26th all India manufacturing technology, Design and Research conference (2014) 653.1-653.6.
7. Das, D., et al. "Fabrication process optimization for improved mechanical properties of Al 7075/SiCp metal matrix composites." Management Science Letters 6.4 (2016): 297-308.
8. Gururaja, Suhasini, MamidalaRamulu, and William Pedersen. "Machining of MMCs: a review." Machining Science and Technology 17.1 (2013): 41-73.
9. Andrewes, Caroline JE, Hsi-Yung Feng, and W. M. Lau. "Machining of an aluminum/SiC composite using diamond inserts." Journal of materials processing technology 102.1-3 (2000): 25-29.
10. Sahoo, Ashok Kumar, and SwastikPradhan. "Modeling and optimization of Al/SiCp MMC machining using Taguchi approach." Measurement 46.9 (2013): 3064-3072.
11. Ciftci, Ibrahim, Mehmet Turker, and UlviSeker. "Evaluation of tool wear when machining SiCp-reinforced Al-2014 alloy matrix composites." Materials & design 25.3 (2004): 251-255.
12. Opricovic, S., &Tzeng, G. H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European journal of operational research, 156(2), 445-455.
13. Kumar, R., Kumar, R., Soni, G., &Chhabra, S. (2013). Optimization of process parameters during CNC turning by using AHP & VIKOR method. International Journal of Engineering Research & Technology, 2(12), 3478-3480.
14. Kaoser, M. M., Mamunur, R. M., & Ahmed, S. (2014). Selecting a material for an electroplating process using AHP and VIKOR multi attribute decision making method. In International Conference on Industrial Engineering and Operations Management (pp. 834-841).
15. Javed, S. A., Mahmoudi, A., Khan, A. M., Javed, S., & Liu, S. (2018). A critical review: shape optimization of welded plate heat exchangers based on grey correlation theory. Applied Thermal Engineering, 144, 593-599.
16. Li, L. H., & Mo, R. (2015). Production task queue optimization based on multi-attribute evaluation for complex product assembly workshop. Plos One, 10(9), e0134343.
17. Lotfi, F. H., &Fallahnejad, R. (2010). Imprecise Shannon’s entropy and multi attribute decision making. Entropy, 12(1), 53-62.