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Multi Objective Optimization of Aluminium (AA6061-SiC-Flyash) Metal Matrix Composites using TOPSIS Method

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Abstract

Metal Matrix Composites (MMCs) have significant interest due to their superior mechanical properties, including improved strength, hardness, and fracture resistance. This study investigates the optimization of the mechanical and fracture behaviour of casted AA6061-SiC-Fly Ash (FA) MMCs using the TOPSIS method. Silicon carbide(SiC) and fly ash (FA) reinforcements, with different weight percentages of 5%, 10%, and 15% were fabricated through sand casting method. Total 10 combinations of composites are prepared to understand the impact of reinforcements and their percentages on the mechanical properties. The specimens were evaluated through a series of mechanical characterization tests like Ultimate Tensile Strength (UTS), Impact Strength (IS), and Vickers Hardness (MVH), to evaluate the influence of reinforcement composition on the composite's strength, toughness, and failure mechanisms. The TOPSIS optimization technique was applied to rank the specimens based on their mechanical performance, facilitating the identification of the optimum composite composition. The results revealed that specimen C9 with FA 5% and SiC 15% exhibited the highest impact strength (86 J) and a favorable combination of UTS (115.2 MPa) and hardness (67.5 Kgf), with 1st rank. The study highlights the critical role of SiC and FA reinforcements in improving the mechanical properties of AA6061-based MMCs, and it offers valuable insights for tailoring the composites for advanced engineering applications.

Keywords: Metal Matrix Composites, TOPSIS, AA6061 Aluminium Alloy, Optimization, hybrid composites

INTRODUCTION

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Metal matrix composites are a popular type of advanced materials that are preferred for their excellent strength to weight ratios, their increased mechanical strength, and their increased resistance to wear and heat [1]. Because MMCs typically consist of a metallic base, like aluminum, that is reinforced with metal powders, ceramic particles, short fibres, or waste from industry, engineers can tailor the properties and characteristics of the composites to suit the most challenging applications [2][1].

Ralph *et al.* provided an overview of processing routes for polymer, ceramic, and metallic matrix composites, emphasizing solid and molten state techniques for MMCs [3]. Kaczmar *et al.* discussed various MMC reinforcement forms and manufacturing techniques, highlighting their applications in aerospace and automotive sectors [4]. Harrigan Jr *et al*. reviewed commercial production methods for discontinuously reinforced MMCs, focusing on cost-effective techniques like CIP–sinter and powder metallurgy [5]. Rawal *et al*. outlined the evolution and potential of MMCs in space applications due to their high stiffness and low thermal expansion [6]. Casati *et al*. examined nanoparticle-reinforced MMCs, detailing synthesis challenges and strengthening mechanisms for improved mechanical performance [7]. Hooker *et al*. emphasized the role of Al and Ti MMCs in aeroengine components, discussing processing control and cost-performance optimization [8]. Bahl *et al*. reviewed fibre-reinforced MMCs, their properties, applications, and interfacial behaviour assessed through push-out tests [9]. Ozden *et al*. studied the impact behaviour of Al-SiC hybrid composites under varying temperatures, noting the effects of particle size [10][2], [11] Shen *et al*. analyzed the disconnect between tensile strength and hardness in MMCs, attributing it to matrix flow and particle fracture under different loadings [12]. Ramnath *et al*. fabricated and tested Al-Al_2O_3-B_4C composites via stir casting, evaluating their mechanical properties and internal microstructure [13]. Hawk *et al*. investigated the wear resistance of eight TiC-reinforced metal matrix composites fabricated via powder metallurgy with varying TiC volume fractions (0.35–0.45), and characterized their microstructures using SEM, optical microscopy, and XRD under diverse wear conditions [14]. Scudino *et al*. enhanced Al-based composites with glassy Zr powder via powder metallurgy, boosting strength while preserving plasticity [15]. Avikal *et al*. used Fuzzy AHP and TOPSIS to select AA7075 as the optimal AHMMC matrix [16]. Bhuyan *et al*. optimized EDM of Al–SiC composites using Box-Behnken design, RSM, and TOPSIS [17]. Prabhuram *et al*. optimized EDM of FGMMCs (Al–SiC) using Taguchi and TOPSIS, identifying pulse-on time as critical [18]. Senthil *et al*. applied TOPSIS for EDM parameter optimization of Al–$CuTiB_2$ MMCs [19]. Tamiloli *et al*. used RSM and Fuzzy-TOPSIS to optimize milling of AA6082–SiC–fly ash, finding feed rate most influential [20]. Jatinder Kumar *et al*. optimized WEDM of Al hybrid composites using Taguchi, TOPSIS, and microstructural validation [21]. Satpathy *et al*. used PCA–TOPSIS for EDM of Al–SiC, supported by SEM analysis [22]. Basavarajappa *et al*. analysed drilling in Al–SiCp and Al–SiCp–Gr composites, highlighting feed rate as dominant [23]. Kalita *et al*. proposed MOALO–MODA ensemble for robust MMC machining parameter optimization [24]. Sharma *et al*. optimized laser cutting of Al–SiC MMCs using RSM, confirming thermal effects via SEM and XRD [25]. Devanathan *et al*. used firefly algorithm to optimize FSW parameters of Al–B_4C using TiN/DLC tools [26]. Udaya Prakash *et al*. applied grey relational analysis to optimize WEDM of AMCs, improving MRR [27]and SR. Sahu *et al*. used grey Taguchi to optimize cold upsetting of Al–TiC composites, validating results with ANOVA [28]. Jamwal *et al*. optimized Cu–SiC–Graphite hybrid composites using stir casting and TOPSIS, reporting improved strength and wear resistance with increased reinforcement [29]. Senapati *et al*. applied PCA–TOPSIS to optimize EDM of Al–SiCp MMC, identifying key process parameters affecting MRR, TWR, DOC [30], and SR. Aruri *et al*. used RSM and TOPSIS for EDM optimization of Al7075/B_4C/Gr composites, finding Ip and Toff most influential [31]. Haq *et al*. employed Grey Relational Analysis to optimize drilling of Al/SiC MMC, improving surface roughness, force, and torque [32]. Palani Kumar *et al*. used Taguchi and RSM to model and optimize surface roughness in turning of LM25 Al/SiC composites, achieving high predictive accuracy [33].

The alloy used for this work AA6061, is unique among aluminum alloys due to its excellent weldability, good corrosion resistance, and balanced mechanical properties. When SiC and FA are added to the AA6061 matrix, they will increase hardness, tensile strength, and fracture toughness, using aluminium's lightweight advantages. SiC is a strong ceramic phase and maintains thermal stability and mechanical durability at high temperatures, while FA is a cheap, indestructible waste material that adds strength and weight. Combining these reinforcements to AA6061 will produce a hybrid composite system that can be deployed in thermal management, aerospace, defence, and structural applications. SiC and FA reinforcements, with varying weight percentages of 5%, 10%, and 15%, were fabricated through sand casting. Total 10 combinations of composites are prepared to understand the impact of reinforcement percentages on the mechanical properties There are optimization methods that regulate these values and achieve the desired material behaviour. The mechanical properties of cast AA6061 composites containing various combinations of Sic and FA: tensile strength, impact toughness and hardness are utilized in this research. The multi criterion optimization method named TOPSIS which ranks options by how close they are to the ideal solution is utilized in the study to identify the optimum combination of reinforcements to achieve best mechanical properties.

MATERIALS

AA6061 is a widely used aluminium alloy, with balanced mechanical strength, corrosion resistance and easy lubrication. This makes it suitable for usage in transportation, aerospace and structural applications. It has low density with good thermal conductivity, which makes it compatible with wide range of ceramic reinforcements. This is ideal for its usage as a base material while making Metal Matrix Composites (MMC's)[34-36]. The usage of SiC and FA as reinforcements further enhance its mechanical characteristics. SiC is a ceramic with high hardness, thermal stability and wear resistance. This improves the tensile strength and stiffness significantly while also reducing thermal expansion. It achieves uniform particle distribution within the matrix due to its perfect interfacial bonding with the molten aluminium alloy. Fly ash, a by-product of thermal power stations, is an economical and environmentally beneficial reinforcing material that mostly consists of silica, alumina, and iron oxides. It enhances hardness and wear resistance while lowering composite density. Combining AA6061 with SiC and FA creates a composite that is ideal for demanding engineering applications in a variety of industrial sectors because it provides an exceptional blend of strength, durability, and lightweight properties.Table1 gives the information about the material composition and properties.

Table 1. Material composition and properties from the spectroscopy results

Materials	**Composition**	**Mechanical Properties**
AA6061	Mg (0.8-1.2%), Si (0.4-0.8%), Fe (0.7%), Cu (0.15-0.4%), Mn (0.15%), Ti (0.15%), Al (95.8-98.6%) Cr (0.04-0.35%), and Zn (0.25%)	UTS – 310MPa Yield Strength (YS) -276MPa %Elongation – 12% Vickers Hardness-106Kgf/mm^2
Silicon Carbide (SiC)	SiC (98%), Si (0.29%), Fe (0.09%), C (0.29%) SiO_2 (0.39%) and Al (0.09%),	Compressive Strength –130 MPa Density (D)value 3.0 gm/cc,
Fly Ash (FA)	Al_2O_3 (26%), SiO_2 (55%), SO_3 (1%),CaO (9%), Fe_2O_3 (7%) and MgO (2%)	Density (D) – 2.1 g/cm^3, FA Melting point is 1000°C

DESIGN OF EXPERIMENTS

The effect of modifications in reinforcement on the mechanical performance of the composites was examined using a systematic experimental technique. The aluminium alloy AA6061 was chosen as the matrix material. Fly ash (FA) and silicon carbide (SiC) were selected as reinforcement materials with varying percentages (5%, 10%, and 15%) .Total 10 composites are planned by varying the combination of reinforcement percentages. The following describes the reinforcement combinations used in each experimental trial. Table 2 represents the composition of 10 different composites used for experimentation.

Table 2. Specimen Composition from the Taguchi L9 Array

Composite composition	**Code**
AA6061 + FA (0%) + SiC (0%)	C1
AA6061 + FA (5%) + SiC (5%)	C2
AA6061 + FA (10%) + SiC (10%)	C3
AA6061 + FA (15%) + SiC (15%)	C4
AA6061 + FA (10%) + SiC (5%)	C5
AA6061 + FA (15%) + SiC (5%)	C6
AA6061 + FA (5%) + SiC (10%)	C7
AA6061 + FA (15%) + SiC (10%)	C8
AA6061 + FA (5%) + SiC (15%)	C9
AA6061 (500g) + FA (10%) + SiC (15%)	C10

EXPERIMENTAL WORK

Sand casting was chosen as the fabrication technique in this study to create the metal matrix composites based on AA6061. Melted metal is shaped in sand moulds in the age-old and incredibly versatile process of sand casting. For casting the specimens, standard moulds with dimensions of 200 mm by 40 mm were utilized. Figure 1 represents the CAD model of the casting specimen.

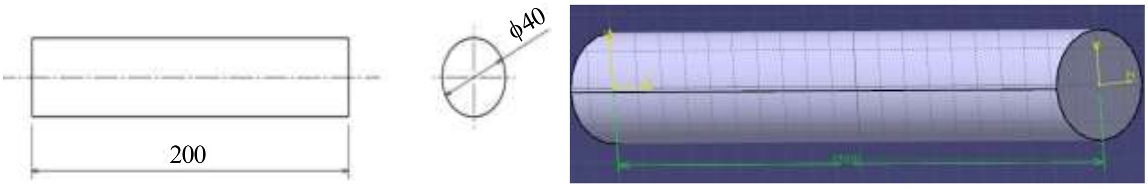

Figure 1. Specifications of sand mould casting specimen

Prior to addition, the reinforcements Fly Ash (FA) and Silicon Carbide (SiC) were preheated at 300°C to eliminate moisture and enhance their wetting behaviour with the molten aluminium. AA6061 alloy was melted in a crucible furnace at approximately 720°C. Once fully molten, the preheated reinforcements were gradually introduced with continuous stirring to promote uniform dispersion throughout the matrix. The composite slurry was poured at a controlled temperature of 680°C into the sand moulds and allowed to solidify naturally. Post-casting, the solidified specimens were removed and machined down to final dimensions of 180 mm × 20 mm.Figure 2 represents the casted cylinders.

Figure 2. Sand casted specimens after machining

Mechanical and microstructural characterizations were conducted on the fabricated samples. Tensile properties were evaluated using a RATNA K-210 UTM, following ASTM B 557:2016 and ASTM E8M standards. All fractured composite specimens displayed a brittle failure mode. Impact strength was determined through the Izod impact test using a Charpy testing machine, adhering to IS 1598:1977 specifications with samples sized at 12 mm × 12 mm × 55 mm and featuring a 45° V-notch according to ASTM D7205 guidelines. Surface hardness was assessed using Micro Vickers Hardness Testing (MVHT) equipment, suitable for detecting hardened surface layers and evaluating conditions like carburization or thermal damage. Figure 3 represents the ten tensile test specimens and figure 4 represents the impact specimens. Figure 5 represents machine for measuring hardness.

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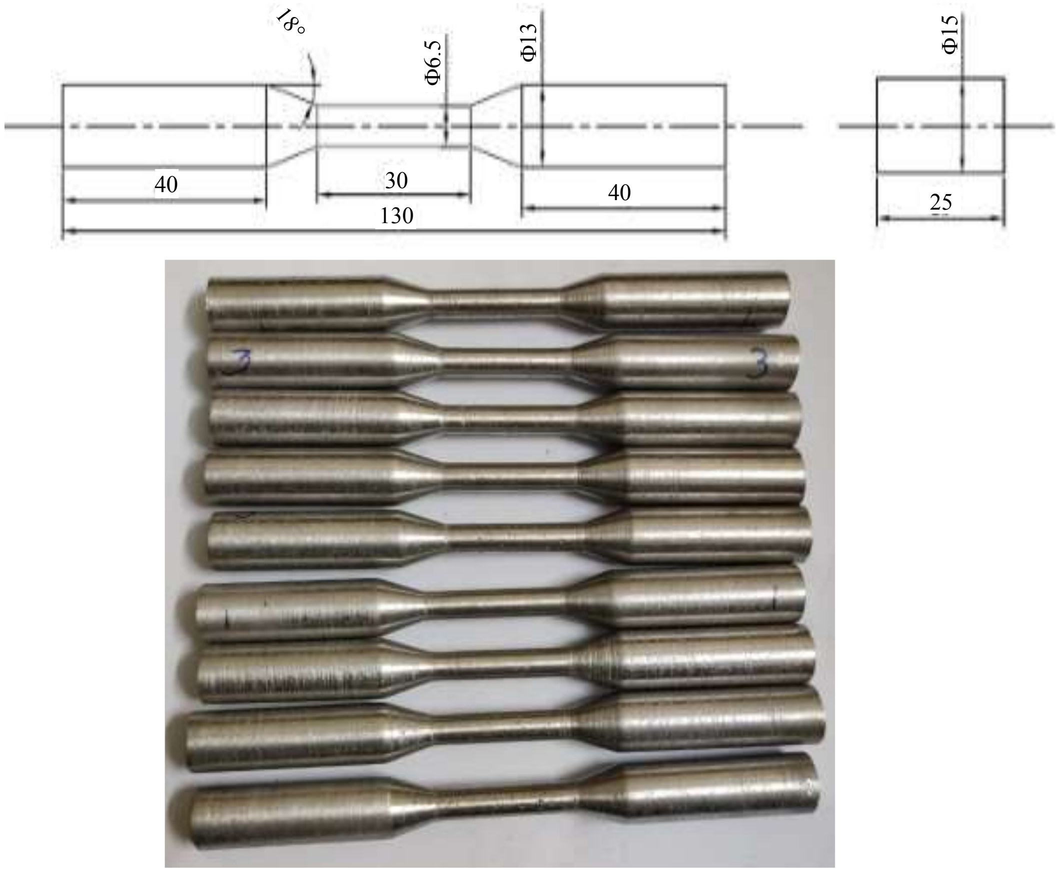

Figure 3. Drawing of tensile test specimen and Samples of tensile tests

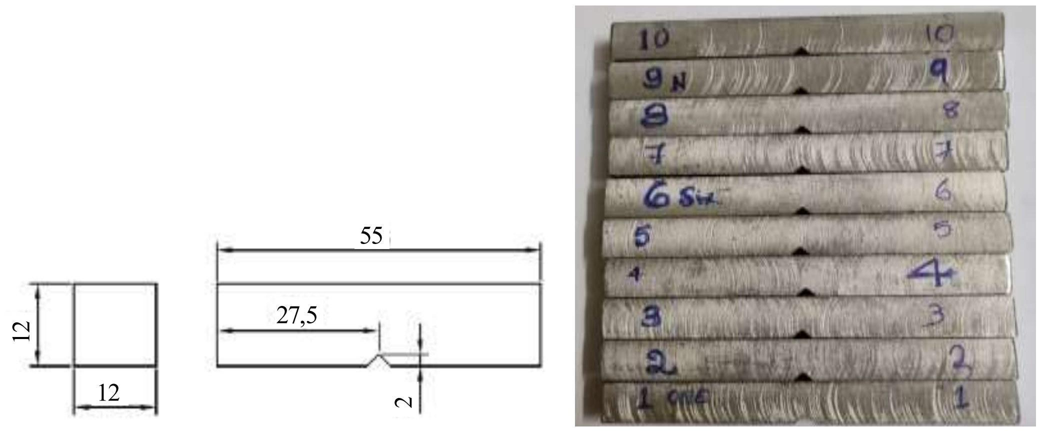

Figure 4. specifications of impact test specimen and Samples of impact specimens

TOPSIS OPTIMIZATION

TOPSIS Optimization is a widely used MCDM method designed to rank solutions according to their relative nearness to an optimal solution. In this study, TOPSIS was employed to optimize the mechanical properties specifically, Ultimate Tensile Strength (UTS), Impact Strength (IS), and Micro Vickers Hardness (MVH) of AA6061-based hybrid MMC reinforced with SiC and FA. By applying TOPSIS, the multi-response optimization challenge is effectively transformed into a singular decision index that enables the identification of the best reinforcement combination.

The optimization procedure began with the normalization of the experimental data to eliminate units and ensure comparability across different mechanical properties. For performance characteristics such as UTS, IS, and MVH where higher values indicate better performance the "higher-the-better" normalization was performed using the below formula. Table 3 is considered as matrix $(x_{ij})_{A\times B}$. Here A and B represents rows and columns respectively. Formulae 1-7 explains the logic involved in TOPSIS algorithm.

Figure 5. Samples of hardness tests and Micro-Vickers hardness machine

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

Following normalization, the weighted normalized decision matrix was constructed. If equal importance is assigned to each criterion, weights are uniformly distributed; otherwise, specific weights based on application needs can be used. The weighted normalized value is calculated as:

$$D_{ij} = \alpha_{ij} \times W_j \quad (2)$$

Subsequently, the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) were determined. For beneficial criteria ("higher-the-better"), PIS corresponds to the maximum value and NIS to the minimum value across alternatives. The Euclidean distances of each alternative from the PIS and NIS were then computed as:

$$V+ = Best_{i=1}^{M} \mathrm{Dij} \quad (3)$$

$$V- = Worst_{i=1}^{M} D_{ij} \quad (4)$$

$$Si+ = \sqrt{\sum_{j=1}^{N} (D_{ij} - V+)^2} \quad (5)$$

$$Si- = \sqrt{\sum_{j=1}^{N} (D_{ij} - V-)^2} \quad (6)$$

Finally, the Closeness Coefficient (P_i) for each alternative was calculated to rank the options. The Closeness Coefficient represents how close an alternative is to the ideal solution and is given by:

$$P_i = \frac{Si+}{(Si-)+(Si+)} \quad (7)$$

A higher Closeness Coefficient indicates a more favourable composite combination. Based on the computed CC values, the optimal set of reinforcement contents was identified to achieve the best overall mechanical performance.

RESULTS

The mechanical performance of the developed AA6061–SiC–Flyash hybrid metal matrix composites was assessed through three principal tests: Ultimate Tensile Strength (UTS), Impact Strength (IS), and

Micro Vickers Hardness (MVH). By using ASTM E8M criteria, tensile testing was performed on a Universal Testing Machine, UTS values obtained are in between 88.9 MPa and 119 MPa. The composites' capacity to stand with abrupt impact loads was highlighted by their impact strength, which ranging from 30 J to 86 J when measured using a Charpy impact tester in compliance with IS 1598-1977 requirements. Surface hardness was measured using the Micro Vickers Hardness test, which produced results oscillating from 57.8

Kgf to 67.7 Kgf (1kgf = 0.80665N). The information obtained from the experimentation makes it clearly evident how varying reinforcement amounts affect the strength, toughness, and surface hardness properties of the composites. Table 3 gives mechanical properties obtained from experimentation.

Table 3. Test results for specimens C1 to C10 (1kgf = 0.80665N)

S. No	UTS(MPa)	IS(J)	MVH(Kgf)
C1	119	36	57.8
C2	109.8	68	59.5
C3	94.5	80	61.8
C4	88.9	76	64
C5	108.1	48	62.4
C6	102.3	56	61.2
C7	112.1	74	65.3
C8	100.9	44	67.7
C9	115.2	86	67.5
C10	111.7	30	67.5

The ten composite specimens were analysed and ranked based on their mechanical characteristics using the TOPSIS Optimization method. Micro Vickers Hardness (MVH), Impact Strength (IS), and Ultimate Tensile Strength (UTS) were the mechanical factors considered. To enable direct comparability across all units and magnitudes, the raw experimental data were first normalized to convert all response values into a dimensionless form. The "higher-the-better" normalization criterion was used for all three attributes (UTS, IS, and MVH) since improved composite performance was intended by optimizing each attribute. Table 4 shows the calculations involved in TOPSIS technique.

Table 4. Normalised values for UTS, IS and MVH (1kgf = 0.80665N)

NORMALISED MATRIX			
S. No	***UTS***	***IS***	***MVH***
Units	*MPa*	*J*	*Kgf*
C1	0.352918	0.181725	0.287582
C2	0.325633	0.343259	0.29604
C3	0.280258	0.403834	0.307484
C4	0.26365	0.383643	0.31843
C5	0.320592	0.242301	0.310469
C6	0.303391	0.282684	0.304499
C7	0.332454	0.373547	0.324898
C8	0.299239	0.222109	0.336839
C9	0.341648	0.434122	0.335844
C10	0.331268	0.151438	0.335844

After normalisation, each criterion was assigned equal weight, which reflected its importance in the evaluation. A weighted normalised was then calculated by multiplying the normalised matrix using the respective weights. Then, the positive and negative ideal solution (V^+ and V^- respectively) were identified, which depicted the best and worst performance levels across all alternatives. Euclidean distance measures were used to find the separation distances (Si^+ and Si^-), between the ideal solutions and the alternatives. Table 5 represents the calculations involved in TOPSIS technique.

Table 5. Weighted normalised values along with PIS and NIS (1kgf = 0.80665N)

WEIGHTED NORMALISED MATRIX			
S. No	***UTS***	***IS***	***MVH***
Units	*MPa*	*J*	*Kgf*
Weight	0.34	0.33	0.33
C1	0.119992	0.059969	0.094902
C2	0.110715	0.113276	0.097693
C3	0.095288	0.133265	0.10147
C4	0.089641	0.126602	0.105082
C5	0.109001	0.079959	0.102455
C6	0.103153	0.093286	0.100485
C7	0.113034	0.12327	0.107216
C8	0.101741	0.073296	0.111157
C9	0.11616	0.14326	0.110829
C10	0.112631	0.049975	0.110829
V+	0.119992	0.14326	0.111157
V-	0.089641	0.049975	0.094902

For each specimen, the closeness coefficient (Pi) was calculated based on its proximity to the ideal solution. A higher Pi value indicated that the sample configuration is closer to optimal mechanical behaviour. The composites were ordered according to the computed Pi values, and the specimen with the greatest Pi value (sample C9) showed the best combination of mechanical properties. On the other hand, sample C10 with the lowest Pi value exhibited the least desirable mechanical performance. Among the evaluated specimens, this method offered a transparent, impartial foundation for choosing the best composite formulation. Table 6 present the ranks assigned to various experiments.

Table 6. Final ranks for each specimen

S.NO	Si+	Si –	Pi	Rank
C1	0.084862	0.031954	0.273543	9
C2	0.034153	0.066775	0.661613	5
C3	0.028356	0.08374	0.747041	3
C4	0.035151	0.077301	0.687414	4
C5	0.064835	0.036482	0.360079	7
C6	0.053804	0.045712	0.459342	6
C7	0.02153	0.077918	0.783507	2
C8	0.072306	0.030895	0.299371	8
C9	0.003846	0.098281	0.962344	1
C10	0.093576	0.027968	0.230104	10

CONCLUSIONS

Stir casting was used to create metal matrix composites of silicon carbide ,fly ash and aluminium alloy AA6061. Ten distinct material compositions were obtained using the Taguchi approach. After that, the samples underwent MVH, IS, and UTS testing. The test results were tabulated for additional analysis. The 10 composite specimens were analysed using the TOPSIS method, to evaluate and rank based on their performance. The data was first normalised and then weights were given to the three responses (UTS, IS and MVH) equally. Determination of positive and negative ideal solutions allowed for the calculation of separation measures. Using these, the Relative Closeness coefficients (Pi) was calculated for each sample, which allowed for ranking of the composites.

From the TOPSIS results:

- Sample C9 achieved the highest Pi value of 0.962344, securing Rank 1, indicating superior mechanical performance overall. So AA6061 + FA (5%) + SiC (15%) is the best composition to achieve the optimum mechanical performance.
- Increasing SiC content generally improves impact strength and hardness, with 15% SiC showing the best results. 5% FA with 15% SiC (C9) offers the highest overall performance in impact strength, tensile strength, and hardness.
- Sample C7 followed with a Pi value of 0.783507, earning Rank 2, mainly due to its strong UTS and balanced IS and MVH values.
- Sample C3 recorded a Pi of 0.747041, ranking 3rd, reflecting consistent mechanical behaviour across all parameters.
- Sample C10 exhibited the lowest Pi value of 0.230104, ranking 10th, primarily due to lower impact strength and hardness performance.
- Sample C1 also performed relatively weakly with a Pi of 0.273543, placing it at 9th position in the ranking.
- Higher FA content beyond 5% negatively affects impact strength despite increased SiC reinforcement.
- The balance between FA and SiC is crucial, with too much FA reducing the composite's ability to absorb impact energy.

Declaration of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

REFERENCES

1. Rasmi Ranjan Mishra, Amlana Panda, Ashok Kumar Sahoo, and Ramanuj Kumar, “Characterization and machinability analysis of aluminium-based metal matrix composites (MMC): A critical review,” *Proc Inst Mech Eng C J Mech Eng Sci*, vol. 239, no. 3, pp. 861–884, Oct. 2024, doi: 10.1177/09544062241290091.
2. C. Santulli, S. Palanisamy, and M. Kalimuthu, “Chapter 14 - Pineapple fibers, their composites and applications,” in *The Textile Institute Book Series*, S. Mavinkere Rangappa, J. Parameswaranpillai, S. Siengchin, T. Ozbakkaloglu, and H. B. T.-P. F. Wang their Composites, and Applications, Eds., Woodhead Publishing, 2022, pp. 323–346. doi: https://doi.org/10.1016/B978-0-12-824528-6.00007-2.
3. B. Ralph, H. C. Yuen, and W. B. Lee, “The processing of metal matrix composites — an overview,” *J Mater Process Technol*, vol. 63, no. 1–3, pp. 339–353, Jan. 1997, doi: 10.1016/S0924-0136(96)02645-3.
4. J. W. Kaczmar, K. Pietrzak, and W. Wlosiński, “The production and application of metal matrix composite materials,” *J Mater Process Technol*, vol. 106, no. 1–3, pp. 58–67, Oct. 2000, doi: 10.1016/S0924-0136(00)00639-7.
5. W. C. Harrigan, “Commercial processing of metal matrix composites,” *Materials Science and Engineering: A*, vol. 244, no. 1, pp. 75–79, Mar. 1998, doi: 10.1016/S0921-5093(97)00828-9.
6. S. P. Rawal, “Metal-matrix composites for space applications,” *JOM*, vol. 53, no. 4, pp. 14–17, 2001, doi: 10.1007/s11837-001-0139-z.
7. R. Casati and M. Vedani, “Metal matrix composites reinforced by nano-particles—a review,” *Metals (Basel)*, vol. 4, no. 1, pp. 65–83, 2014.
8. [8] J. A. Hooker and P. J. and Doorbar, “Metal matrix composites for aeroengines,” *Materials Science and Technology*, vol. 16, no. 7–8, pp. 725–731, Jul. 2000, doi: 10.1179/026708300101508414.

9. S. Bahl, "Fiber reinforced metal matrix composites - a review," *Mater Today Proc*, vol. 39, pp. 317–323, Jan. 2021, doi: 10.1016/J.MATPR.2020.07.423.
10. S. Ozden, R. Ekici, and F. Nair, "Investigation of impact behaviour of aluminium based SiC particle reinforced metal–matrix composites," *Compos Part A Appl Sci Manuf*, vol. 38, no. 2, pp. 484–494, Feb. 2007, doi: 10.1016/J.COMPOSITESA.2006.02.026.
11. M. Almeshaal, S. Palanisamy, T. M. Murugesan, M. Palaniappan, and C. Santulli, "Physico-chemical characterization of Grewia Monticola Sond (GMS) fibers for prospective application in biocomposites," *Journal of Natural Fibers*, vol. 19, no. 17, pp. 15276–15290, Dec. 2022, doi: 10.1080/15440478.2022.2123076.
12. Y. L. Shen, J. J. Williams, G. Piotrowski, N. Chawla, and Y. L. Guo, "Correlation between tensile and indentation behavior of particle-reinforced metal matrix composites: an experimental and numerical study," *Acta Mater*, vol. 49, no. 16, pp. 3219–3229, Sep. 2001, doi: 10.1016/S1359-6454(01)00226-9.
13. B. Vijaya Ramnath, C. Elanchezhian, M. Jaivignesh, S. Rajesh, C. Parswajinan, and A. Siddique Ahmed Ghias, "Evaluation of mechanical properties of aluminium alloy–alumina–boron carbide metal matrix composites," *Mater Des*, vol. 58, pp. 332–338, Jun. 2014, doi: 10.1016/J.MATDES.2014.01.068.
14. Ö. N. Doğan, J. A. Hawk, J. H. Tylczak, R. D. Wilson, and R. D. Govier, "Wear of titanium carbide reinforced metal matrix composites," *Wear*, vol. 225–229, no. PART II, pp. 758–769, Apr. 1999, doi: 10.1016/S0043-1648(99)00030-7.
15. S. Scudino *et al.*, "Mechanical properties of Al-based metal matrix composites reinforced with Zr-based glassy particles produced by powder metallurgy," *Acta Mater*, vol. 57, no. 6, pp. 2029–2039, Apr. 2009, doi: 10.1016/J.ACTAMAT.2009.01.010.
16. S. Avikal, A. Kumar Singh, K. C. Nithin Kumar, and G. Kumar Badhotiya, "A fuzzy-AHP and TOPSIS based approach for selection of metal matrix composite used in design and structural applications," *Mater Today Proc*, vol. 46, pp. 11050–11053, Jan. 2021, doi: 10.1016/J.MATPR.2021.02.161.
17. R. K. Bhuyan, B. C. Routara, and A. K. Parida, "An approach for optimization the process parameter by using TOPSIS Method of Al–24%SiC metal matrix composite during EDM," *Mater Today Proc*, vol. 2, no. 4–5, pp. 3116–3124, Jan. 2015, doi: 10.1016/J.MATPR.2015.07.272.
18. T. Prabhuram, S. Prathap Singh, J. Immanuel Durairaj, D. Elilraja, M. Chrispin Das, and D. Arthur Jebastine Sunderraj, "Optimization of operation parameters in machining of functionally graded metal matrix composite using TOPSIS," *Mater Today Proc*, vol. 62, pp. 429–433, Jan. 2022, doi: 10.1016/J.MATPR.2022.03.562.
19. P. Senthil, S. Vinodh, and A. K. Singh, "Parametric optimisation of EDM on Al-Cu/TiB2 in-situ metal matrix composites using TOPSIS method," *International Journal of Machining and Machinability of Materials*, vol. 16, no. 1, pp. 80–94, Jan. 2014, doi: 10.1504/IJMMM.2014.063922.
20. N. Tamiloli, J. Venkatesan, G. Murali, S. P. Kodali, T. Sampath Kumar, and M. P. Arunkumar, "Optimization of end milling on Al–SiC-fly ash metal matrix composite using Topsis and fuzzy logic," *SN Appl Sci*, vol. 1, no. 10, p. 1204, 2019, doi: 10.1007/s42452-019-1191-z.
21. J. Kumar, S. Sharma, J. Singh, S. Singh, and G. Singh, "Optimization of Wire-EDM Process Parameters for Al-Mg-0.6Si-0.35Fe/15%RHA/5%Cu Hybrid Metal Matrix Composite Using TOPSIS: Processing and Characterizations," *Journal of Manufacturing and Materials Processing*, vol. 6, no. 6, 2022, doi: 10.3390/jmmp6060150.
22. A. Satpathy, S. Tripathy, N. P. Senapati, and M. K. Brahma, "Optimization of EDM process parameters for AlSiC- 20% SiC reinforced metal matrix composite with multi response using TOPSIS," *Mater Today Proc*, vol. 4, no. 2, pp. 3043–3052, Jan. 2017, doi: 10.1016/J.MATPR.2017.02.187.
23. S. Basavarajappa, G. Chandramohan, and J. P. Davim, "Some studies on drilling of hybrid metal matrix composites based on Taguchi techniques," *J Mater Process Technol*, vol. 196, no. 1–3, pp. 332–338, Jan. 2008, doi: 10.1016/J.JMATPROTEC.2007.05.043.

24. K. Kalita, V. Kumar, and S. Chakraborty, "A novel MOALO-MODA ensemble approach for multi-objective optimization of machining parameters for metal matrix composites," *Multiscale and Multidisciplinary Modeling, Experiments and Design*, vol. 6, no. 1, pp. 179–197, 2023, doi: 10.1007/s41939-022-00138-5.
25. V. Sharma and V. Kumar, "Multi-objective optimization of laser curve cutting of aluminium metal matrix composites using desirability function approach," *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, vol. 38, no. 4, pp. 1221–1238, 2016, doi: 10.1007/s40430-016-0487-9.
26. C. Devanathan and A. SureshBabu, "Multi Objective Optimization of Process Parameters by Firefly Algorithm during the Friction Stir Welding of Metal Matrix Composites," *Transactions of FAMENA*, vol. 45, no. 1, pp. 117–128, May 2021, doi: 10.21278/tof.451018520.
27. J. Udaya Prakash, P. Sivaprakasam, S. Jebarose Juliyana, S. Ananth, C. Sarala Rubi, and A. Divya Sadhana, "Multi-objective optimization using grey relational analysis for wire EDM of aluminium matrix composites," *Mater Today Proc*, vol. 72, pp. 2395–2401, Jan. 2023, doi: 10.1016/J.MATPR.2022.09.415.
28. Mohit K Sahu, A Valarmathi, S Baskaran, V Anandakrishnan, and Rupesh K Pandey, "Multi-objective optimization of upsetting parameters of Al–TiC metal matrix composites: A grey Taguchi approach," *Proceedings of the Institution of Mechanical Engineers, Part B*, vol. 228, no. 11, pp. 1501–1507, Feb. 2014, doi: 10.1177/0954405413519434.
29. A. Jamwal, R. Agrawal, and P. Gupta, "Application of Multi-Criteria Decision-Making Techniques in the Optimization of Mechano-Tribological Properties of Copper-SiC-Graphite Hybrid Metal Matrix Composites," in *Intelligent Manufacturing*, S. Pathak, Ed., Cham: Springer International Publishing, 2021, pp. 149–172. doi: 10.1007/978-3-030-50312-3_7.
30. N. P. Senapati, R. Kumar, S. Tripathy, and A. Rout, "Multi-objective Optimization of EDM Process Parameters Using PCA and TOPSIS Method During the Machining of Al-20 % SiCp Metal Matrix Composite," in *Innovative Design and Development Practices in Aerospace and Automotive Engineering*, R. P. Bajpai and U. Chandrasekhar, Eds., Singapore: Springer Nature Singapore, 2017, pp. 359–367.
31. D. Aruri, M. Kolli, S. Kosaraju, and G. Sai Kumar, "RSM-TOPSIS multi optimization of EDM factors for rotary stir casting hybrid (Al7075/B4C/Gr) composites," *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 2022, doi: 10.1007/s12008-022-00893-2.
32. A. N. Haq, P. Marimuthu, and R. Jeyapaul, "Multi response optimization of machining parameters of drilling Al/SiC metal matrix composite using grey relational analysis in the Taguchi method," *The International Journal of Advanced Manufacturing Technology*, vol. 37, no. 3, pp. 250–255, 2008, doi: 10.1007/s00170-007-0981-4.
33. K. Palanikumar and R. and Karthikeyan, "Optimal Machining Conditions for Turning of Particulate Metal Matrix Composites Using Taguchi and Response Surface Methodologies," *Machining Science and Technology*, Vol. 10, No. 4, Pp. 417–433, Dec. 2006, Doi: 10.1080/10910340600996068.

