Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

# Aluminium Metal Matrix Composites: A Quick Review

Hemant Rathore [1*], Mukesh Kumar Singh **

*( Research Scholar, Department of Mechanical Engineering, RSR Rungta college of Engineering and Technology, Bhilai, CG, India, hemant.rathore057@gmail.com)

** (Assistant professor, Department of Mechanical Engineering, RSR Rungta college of Engineering and Technology, Bhilai, CG, Inda, mks20387@gmail.com)

----------------------------------------************************----------------------------------

## Abstract:

Aluminum is widely used in the aerospace and automotive industries due to its light weight and other properties such as excellent strength and formability. Due to special properties such as low weight, low cost, wear resistance, corrosion resistance, and high strength, aluminium metal matrix composites are promising advanced materials when compared to conventional materials. Stir casting is one of the most cost-effective and popular methods of producing aluminium matrix composites. Because aluminium metal matrix is used in a variety of applications, it is critical to comprehend and investigate its capabilities. For this purpose, attempts have been made by researchers for investigation of characteristics of aluminium metal matrix composites (AMMC) based on various matrices and reinforcements. This review focuses on the processing techniques and characteristics of AMMCs wherein, factors influencing the properties of composites are also discussed. This study also provides research gaps from the past literature.

*Keywords* — ***Aluminium, Aluminium Metal Matrix Composites (AMMCs), Matrix, Reinforcements.***

----------------------------------------************************----------------------------------

## I. INTRODUCTION

The term composite is used for describing materials which are semi-homogeneous and have superior mechanical and physical properties than those of their components. The matrix of a composite can be a metal, ceramic or polymer. Furthermore, composites can be grouped on the basis of the reinforcements provided.

In automotive sector, the requirement of material is mandatory to offer its functional characteristics. Monolithic metals do not have the required quality which leads to more material cost. Such a material requires expensive manufacturing cost and cannot possess good strength to weight ratio and enhanced stability. To avoid these difficulties, composite materials play a vital role to replace the existing one. Composites are manufactured from two or more elements with dissimilar chemical and physical properties which yield to get significant improvement in properties of resulting materials. There are mainly two phases of constituents namely matrix phase and reinforcement phase. The reinforcements are either in the fiber form or particles which are entrenched into continuous matrix phase. So, the combined matrix and reinforcement material offer required property and mechanical behavior. In the current scenario, MMCs have focused their significant consideration in automotive industry, aerospace industry and marine applications due to its good mechanical and corrosion characteristics. In the recent decades, extensive work has been attained in the fabrication of MMCs to familiar in their applications. But developing the suitable characteristics of ceramics and metals catches the appropriate area to utilize the required property of the composite. Due to unique properties, particle reinforced MMCs unveil greater strength, wear and corrosion resistance. But the chemical compatibility among the matrix and reinforcement fetches some concern during the fabrication process. It is then expensive and challenging for production of MMCs due to lack of wetting amid matrix material and reinforcement. Hence, a lot of research is dedicated to fabricate MMCs with least expense. During this investigation, AA 6062-TiC composite has been fabricated by stir casting route. Mechanical characteristics of composite were evaluated to suit the industry requirements. Machining performance of AMC has been evaluated during the later part of research.

## II. FABRICATION TECHNIQUE

The fabrication method used to manufacture MMCs can be clustered based on temperature of the matrix material during dispersion. So, the processing methods can be categorized into different groups. They are

(a) Liquid metallurgy route (Stir casting)[6]
(b) Solid state processes [6]
(c) Semi Solid state processes [7]

In all the above processing technique stir casting technique is widely used for fabrication of aluminium and magnesium based composite[8].The Figure 1.4 shows the general setup of stir casting. There are two main parts of stirrer impeller and a rod which is cylindrical in shape the one end of cylindrical rod is connected to the impeller and another is connoted to the shaft of motor in vertical position when motor is rotated to its own axis the rod is also rotate at vertical position.

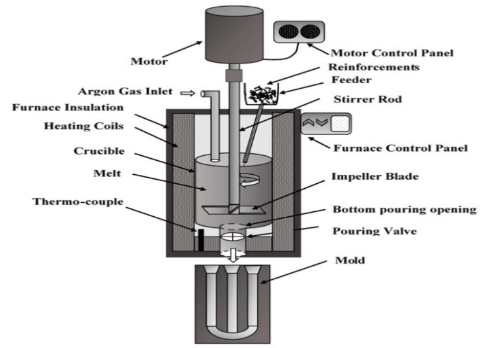


Figure 1:-Stir casting setup[9]

In the aluminium matrix, reaction process is done to form refractory reinforcements. This reactive process is called in-situ processes. Coating of fibers with matrix material to mould the composite is termed as deposition technique. Spray forming, spray deposition, electro plating and immersion bonding are some of the deposition techniques. Two phase processes comprise of blending reinforcements and matrix followed by heating in a solid and liquid transition phase. Compo casting involves two phase processes. A thorough mixture of fine grain powders is reinforced in the metal matrix to fabricate composites. Powder metallurgy and diffusion bonding are solid state fabrication process. In liquid state processing, the ceramic reinforcements are amalgamated into a molten metal matrix. This is followed by blending and subsequent casting of composite into billets for secondary forming methods. Squeeze casting, Stir casting is commonly adopted liquid phase processing techniques.

## III. LITERATURE REVIEW

***Acharya S R et al. (2022)*** fabricated and investigated the micro structural behavior of AA7075 aluminium composite fabricated by stir casting process with varying reinforcement (SiC wt % 2 to 10). It was observed that from XRD result the distribution of SiC particle is homogenous.

***Sinha et al. (2021)*** investigated the sliding wear characteristics of as-cast AMC by response surface method (RSM) and fuzzy logic approach to study the impact of quantity of reinforcement, applied load, rubbing distance and rubbing velocity on wear rate. Wear resistance of hybrid composites increases with the increase in wt.% of abaca.

***Gudipudir et al. (2020)*** conducted experiment to study of wear characteristics of aluminium 6061 alloy incorporated with 10% of $SiC_p$ against tempered AISI 4340 steel under combined sliding-rolling environment. They carried out investigation to realize the impact of rubbing speed, rubbing duration and contact stress on wear. The outcomes have exposedthatRSMisanefficientmethodtopredictthe wearperformanceunder combined effect of rolling and sliding environment. It was observed that the wear loss of MMC was greatly influenced by rolling speed.

***Bhat et al. (2019)*** performed experiments to observe the impact of heat-treatment parameters on the wear performance of SiC (10%) and graphite (2%) reinforced Al 6061 composite. The heat treated AMC exhibited decrease in wear volume with increase in ageing time. SEM micrographs of AMC indicated different wear mechanism like adhesion, abrasion and delamination.

***Mazarbhuiya et al. (2018)*** conducted machining study on aluminum work piece with copper tool as electrode to predict the optimal process parameters of EDM. An experimental layout was carried out based on Taguchi method and influence of input parameters on response was analyzed by ANOVA method. Maximum MRR was attained for optimal settings of discharge current at 16A, pulse- ON time at 463µs, flushing Pressure at 10 kgf/$cm^2$ with normal polarity. Also, 8A discharge current with reverse polarity by maintaining constant values of pulse ON time and flushing pressure as 463 µs and 10 kgf/$cm^2$ respectively resulted better surface roughness. It was witnessed that the polarity followed by current influenced most on MRR, while the surface roughness was significantly influenced by the current.

***SaeedDaneshmand et al. (2017)*** studied the impact of input process variables of EDM such as voltage, pulse current, pulse on time and pulse of time on machining performance like surface roughness, metal removal rate and tool wear rate for both environments of the rotary tool and stationary tool with powder mixed dielectric EDM. The variance analysis was used to predict the optimal process variables by Taguchi design. Outcomes exposed that the powder mixed dielectric accompanied by rotary tool exhibited minimum tool wear loss and surface roughness and enhanced the metal removal rate due to flushing action. Pulse current and pulse in time influenced more on machining performance of Al/7.5 %$Al_2O_3$.

***Ravikumar et al. (2017)*** fabricated TiC reinforced AMC processed by stir casting process. Experiments were performed on AMC to assess the mechanical properties. Phase identification and fracture mechanism were examined by XRD pattern and SEM analysis. Increase in addition of TiC minimized the percent elongation and impact strength of AMC to a maximum of 35% and 31% respectively. However, the density, tensile strength and hardness of AMC increased to a maximum of 7.8%, 19.55 % and 20 % respectively while adding TiC particles. Particle fracture, ridges, dimples, voids and cracks are observed in the microstructures of the ruptured composite specimen.

***Saravanan et al. (2017)*** studied the mechanical characterization and corrosion behavior of AA6063 composites by incorporating TiC particles with different weight fraction processed through stir casting. They observed the existence of TiC particles and uniformly distributed throughout the matrix. The corrosion study revealed that the existence of 9% of TiC particles by weight enhanced the mechanical characteristics than other combination of reinforcements.

***Rao et al. (2017)*** investigated that the mechanical properties such as corrosion behavior and sliding wear behavior by using salt spray technique and pin disc method respectively of AA6061 aluminum alloy fabricated by friction stir casting technique. The Titanium di-boride is used as reinforce material where the percentage of reinforcement was varied in this research. It is found that with the increase of reinforcement higher than 8% corrosion resistance also increased. This paper concludes that the mechanical performance is comparatively high for Aluminum-based hybrid metal matrix nano composites as compare to the pure aluminum alloys.

***Dakarapu S R et al. (2017)*** studied process parameter optimization of fabricated AA6061/TiB2 composite using friction stir casting process. Aluminum-based hybrid metal matrix nano composites made with different percentage by weight of reinforce material (TiB2) and mechanical properties was optimized by GRA method. The effect of input parameters such as rotational speed, transverse feed, axial load, and wt. % reinforcement on microstructure and mechanical characteristics of AA6061/TiB2 aluminium alloy composites (AMCs) was investigated. The AA 6061/TiB2 metal matrix composite was effectively manufactured using friction stir processing, according to this paper. The mechanical qualities of the material, such as tensile strength and hardness, were assessed. The homogenous distribution of particles was revealed by microstructure observations.

***Mosleh-Shirazi et al. (2016)*** fabricated Al 6061 Nano-composite through powder metallurgy process to predict the significance of graphite on the dry sliding and corrosive wear. The addition of graphite content decreases the hardness of the AMC linearly and associated with minimum resistance to erosion at 90° particle impingement. Moreover, the graphite acts as the micro- cathodes that improved the galvanic effect and lead to growth of corrosion rate and resulted strong corrosive wear. Aluminium hybrid composite reinforced with nano-particles (SiC and Gr) exposed better wear characteristics.

***Monikandan et al. (2016)*** studied the dry sliding wear characteristics of stir-cast aluminium composite comprising 10% $B_4C$ along with graphite by weight fraction. The friction and wear characteristics were increased with increase in applied force and rubbing distance. While the rubbing velocity varies from 2-2.5 m/s range, the friction and wear characteristics were minimized with increased amount of graphite addition. A graphite tribolayer of worn pin was revealed from SEM and overlap distortion band was observed through transmission electron microscopy

***Neeraj Sharma et al. (2016)*** fabricated stir cast hybrid AMC incorporated with Nano-graphite and $Si_3N_4$ (3–15% by weight) which were mixed in ball mill to develop a sound composite. They carried out wear test to observe the wear performance of AMC against a steel disc using tribometer. The process variables were optimized by genetic algorithm (GA) and response surface methodology (RSM). ANOVA revealed that the rubbing distance plays a major dominant factor on the sliding wear rate followed by applied force, rubbing velocity and reinforcement particles. GA recommended 0.827 mg of wear at optimum process variables. Microstructure examination using SEM revealed fine grooves at optimal process variables and severe plugging was observed on the worn surface for rest of the combination of variables. The increase in rubbing speed produced evolution of wear mechanism from abrasive to adhesivewear.

***Radhika& Raghu (2016)*** investigated tensile strength and hardness on aluminium LM25/TiC (10 wt. %) composite fabricated by liquid metallurgy process. They studied tribological performance carried out by pin- on-disc tribometer based on RSM approach under the impact of process variables like applied force, rubbing distance and rubbing velocity. Microstructural analysis revealed the uniform distribution of reinforcement in the AMC which improves the mechanical characteristics. The wear characteristics exhibited that the increase in applied force increases the wear rate and decreases with increase in velocity. And the wear rate changes non- linearly with rubbing distance. TiC incorporation in to the matrix restricts material removal at all environments which are necessary in automotive applications like cylinder liner, piston and engine block.

***Satnam et al. (2015)*** analyzed AMC which are strengthened by alumina ($Al_2O_3$), graphite (Gr) and Boron Carbide ($B_4C$) to evaluate dry sliding wear performance by employing Taguchi design with orthogonal array (OA). The impact of process variables containing normal force, wear track diameter and rubbing distance on dry sliding wear performance was studied based on ANOVA. The outcomes explored that the composite amalgamated with Graphite (3%) and $B_4C$ (1%) and $Al_2O_3$ (10%) exhibited the greater Vickers hardness. ANOVA exposed that the normal force was the most dominant factor and contributed 65.05 % of weight loss of AMC. The rest of the variables were not offered any significant impact.

***Satnam et al. (2015)*** analyzed AMC which are strengthened by alumina ($Al_2O_3$), graphite (Gr) and Boron Carbide ($B_4C$) to evaluate dry sliding wear performance by employing Taguchi design with orthogonal array (OA). The impact of process variables containing normal force, wear track diameter and rubbing distance on dry sliding wear performance was studied based on ANOVA. The outcomes explored that the composite amalgamated with Graphite (3%) and $B_4C$ (1%) and $Al_2O_3$ (10%) exhibited the greater Vickers hardness. ANOVA exposed that the normal force was the most dominant factor and contributed 65.05 % of weight loss of AMC. The rest of the variables were not offered any significant impact.

***Nayak et al. (2014)*** produced copper hybrid composite reinforced with TiC and graphite different volume fraction through powder metallurgy process. Addition of graphite decreased the hardness of copper MMC. Conversely, the TiC particle addition increased the hardness of the composite. They studied the effect of volume fraction of graphite, applied force, rubbing velocity and rubbing distance on the wear characteristics of as-sintered hybrid MMC. The weight loss of MMC decreases from 0.1345 to 0.0830 gram while the volume fraction of graphite varied from 5 to 15%. The outcome of investigations exposed the better wear performance. The impact of process variables such as applied force, rubbing distance and volume fraction of graphite on the weight loss of MMC contributed 43.85%, 29.84%, 15.17% respectively. And the rubbing velocity contributed least significance of 1.83%. The tribological and mechanical characteristics of the copper hybrid composites were significantly enhanced by amalgamation of both TiC and graphite.

***Baskaran et al. (2014)*** investigated the sliding wear characteristics of as-cast AMC by employing Taguchi experimental design and to study the impact of quantity of reinforcement, applied load, rubbing distance and rubbing velocity on wear rate. The process variables of 4% of TiC by weight fraction, load 9.81 N, velocity 3 m/s and rubbing distance 1500 m were recognized as the optimal set of variables in order to attain minimum wear rate. Load and rubbing velocity contributed 50.09% and 31.26% respectively with R-Square value of 92.66% among the other parameters using ANOVA.

***Velmurugan et al. (2014)*** performed experiments to observe the impact of heat-treatment parameters on the wear performance of SiC (10%) and graphite (2%) reinforced Al 6061 composite. The heat treated AMC exhibited decrease in wear volume with increase in ageing time. SEM micrographs of AMC indicated different wear mechanism like adhesion, abrasion and delamination.

***BeleteSirahbizuYigezu et al. (2013)*** studied the abrasive wear characteristics of in situ synthesized Al-12Si/TiC composites to analyze the impact of applied load, rubbing distance and weight fraction of reinforcement using a pin-on-disk wear testing machine. The microstructure and worn surface characteristics of the experimental specimen were examined by utilizing SEM. The outcomes exposed that the hardness and strength were increased with increase in weight fraction of reinforcement. Nevertheless, the existence of porosity was comparatively more while the weight fraction of reinforcement was increased. The friction and wear characteristics were increased with increase in applied force and rubbing distance. In particular, the increase in weight fraction of TiC exhibited minimum friction and wear loss. Worn out fragments and small grooves were witnessed in the SEM micrograph of the rubbed surfaces of specimens.

***Ravi Kumar et al. (2012)*** fabricated Al-Cu-Si composite incorporated with distinct sizes of fly ash particles in different weight fractions using a stir-casting route. Wear studies were performed in pin-on- disc machine with different loads (20, 30 and 40 N) and rubbing velocity in the range of 2-4 m/s for a fixed time interval of 10 minutes. A mathematical model was established to evaluate the wear and friction characteristics of AMCs. Composites incorporated with larger size particles exposed superior wear and friction characteristics than composite with fine particles under the same load andvelocity.

***Velmurugan et al. (2012)*** produced SiC-graphite reinforced Al 6061 composite to investigate the wear characteristics under heat treatment process. AMCs were exposed to solution process at 803 K for one hour duration followed by water quenching. Then the AMCs were subjected to various ageing durations at a temperature of 448 K. It was witnessed that the increase in ageing time improves the wear resistance of AMC. Abrasion and delamination type wear mechanisms were found through microscopic examination.

***Uyyuru et al. (2007)*** investigated tribological characteristics of stir-cast Al–Si/$SiC_p$ composite as rotating disc against automotive brake pad. They reported that the increase in the applied force increases the wear loss and decreases the friction coefficient. Nevertheless, both the wear loss and friction coefficients were varied consistently with the rubbing speed. The tribo-layer formation affected the wear characteristics and found to be heterogeneous in nature. Worn surfaces and debris were analysed through SEM to study the topography and morphology of AMC.

***Gurcan & Baker (1995)*** studied the wear resistance of SiC particle reinforced aluminium 6061 matrix with four diverse combinations. The outcomes exposed that the composites comprising of low weight fraction of reinforcements have poor wear performance. Superior wear resistance was witnessed for 20% of SiC particle reinforcement by weight fraction.

## IV. LITERATURE REVIEW

Stir casting is the most widely used commercial method for producing aluminum-based composites. Mechanical stirring is used to distribute powder form reinforcing phases into molten metals in this process. The main disadvantages of the stir casting process are non-uniform distribution and porosity in casted CMMCs, which can be removing while taking optimal process parameters.

- AMCs are the most effective way to increase mechanical property and uses mostly in aerospace industries, automobile now a day.
- From a review of the literature, it appears that the reinforcement of titanium carbide (TiC) is less common, but it has a lot of potential due to its high strength, hardness, and wear and corrosion resistance.
- No one has prepared/attempted TiC- aluminium (6082) Hybrid Metal Composite and tested mechanical behaviour

Following are the major research gaps identified from the overview of past literature:

1. To prepare TiC- aluminium (6082) using stir casting by varying weight percentage of TiC.
2. Investigate the mechanical property of hybrid AMMC and compare in different wt% of ceramics in AMCs. Optimize the performance parameters using Taguchi Method.
3. Compare the optimized experimental results available in the literature with optimized results

## References

**[1]** M. Imran and A. R. A. Khan, “Characterization of Al-7075 metal matrix composites: A review,” *J. Mater. Res. Technol.*, vol. 8, no. 3, pp. 3347–3356, 2019, doi: 10.1016/j.jmrt.2017.10.012.

  

**[2]** A. Sankhla and K. M. Patel, "Metal Matrix Composites Fabricated by Stir Casting Process – A Review Metal Matrix Composites Fabricated by Stir Casting Process – A," *Adv. Mater. Process. Technol.*, vol. 00, no. 00, pp. 1–22, 2021, doi: 10.1080/2374068X.2020.1855404.

**[3]** S. R. Sree, R. Sandeep, and M. I. Rani, "Experimental Study of Double Sided Friction Stir Welding of AA 6061 Plates Using Hexagonal Tool Tip," vol. 6, no. 1, pp. 32–37, 2018.

**[4]** A. Bhowmik, D. Dey, and A. Biswas, "Characteristics Study of Physical, Mechanical and Tribological Behaviour of SiC/TiB2 Dispersed Aluminium Matrix Composite," *Silicon*, pp. 1133–1146, 2021, doi: 10.1007/s12633-020-00923-2.

**[5]** N. Yuvaraj and S. Aravindan, "Fabrication of Al5083 / B 4 C surface composite by friction stir processing and its tribological characterization," *Integr. Med. Res.*, vol. 4, no. 4, pp. 398–410, 2015, doi: 10.1016/j.jmrt.2015.02.006.

**[6]** N. Sreedhar and S. Balaguru, "Mechanical and tribological behaviour of al 7075 hybrid mnc's using stir casting method," *Int. J. Mech. Prod. Eng. Res. Dev.*, vol. 10, no. 3, pp. 391–400, 2020, doi: 10.24247/ijmperdjun202036.

**[7]** R. Surace and L. A. C. De Filippis, "Investigation and Comparison of Aluminium Foams Manufactured by Different Techniques," *Adv. Knowl. Appl. Pract.*, 2010, doi: 10.5772/10353.

**[8]** R. K. Rathore, N. K. Singh, and J. F. Xavier, "Characterization of AA7075 Alloy Foam Using Calcium and Magnesium Carbonate as Foaming Agent," 2021, pp. 289–297.

**[9]** M. K. Sahu and R. K. Sahu, "Experimental Investigation, Modeling, and Optimization of Wear Parameters of B4C and Fly-Ash Reinforced Aluminum Hybrid Composite," *Front. Phys.*, vol. 8, no. July, pp. 1–14, 2020, doi: 10.3389/fphy.2020.00219.

**[10]** S. Acharya S R and P. M. Suresh, "Fabrication and micro structural characterization of Al 7075 reinforced with various proportions of SiC," *Mater. Today Proc.*, vol. 49, no. xxxx, pp. 638–643, 2022, doi: 10.1016/j.matpr.2021.05.162.

**[11]** A. K. Sinha, H. K. Narang, and S. Bhattacharya, "Experimental Determination, Modelling and Prediction of Sliding Wear of Hybrid Polymer Composites Using RSM and Fuzzy Logic," *Arab. J. Sci. Eng.*, vol. 46, no. 3, pp. 2071–2082, 2021, doi: 10.1007/s13369-020-04997-3.

**[12]** S. Gudipudi, S. Nagamuthu, K. Subbu, S. Prakasa, and R. Chilakalapalli, "Engineering Science and Technology , an International Journal Enhanced mechanical properties of AA6061-B 4 C composites developed by a novel ultra-sonic assisted stir casting," *Eng. Sci. Technol. an Int. J.*, vol. 23, no. 5, pp. 1233–1243, 2020, doi: 10.1016/j.jestch.2020.01.010.

**[13]** A. Bhat and G. Kakandikar, "Manufacture of silicon carbide reinforced aluminium 6061 metal matrix composites for enhanced sliding wear properties," *Manuf. Rev.*, vol. 6, pp. 4–9, 2019, doi: 10.1051/mfreview/2019021.

**[14]** Abhishek, K, Gautam, RK &Rajnesh T 2016, „Dry sliding wear characteristics of in situ synthesized Al-TiC composites‟, Composite Interfaces, vol. 23, no. 6, pp. 469- 480.

**[15]** Daneshmand, S, Masoudi, B &Monfared V 2017, „Electrical discharge machining of Al/7.5% Al2O3 MMCs using rotary tool and Al2O3 powder‟, Surface Review and Letters, vol. 24, no. 2, pp. 1750018 (17 pages).

**[16]** Das, S 2004, „Development of aluminium alloy composites for engineering applications‟, Transaction of Indian Institute of Metals, vol. 57, no. 4, pp. 325-334

**[17]** Deuis, RL, Subramanian, C &Yellup, JM 1997, „Dry Sliding wear of aluminium composites - A review‟, Composites Science and Technology, vol. 57, no. 4, pp. 415-435.

**[18]** Doel, TJA, Loretto, MH & Bowen, P 1993, „Mechanical properties of aluminium-based particulate metal-matrix composites‟, Composites, vol. 24, no. 3, pp. 270-275.

**[19]** Du, J, Liu, Y, Yu, S & Li, W 2007, „Effect of heat-treatment on friction and wear properties of Al2O3 and carbon short fibers reinforced AlSi12CuMgNi hybrid composites‟, Wear, vol. 262, no. 11-12, pp. 1289-1295.

**[20]** El-Taweel, TA 2009, „Multi-response optimization of EDM with Al-Cu-Si-TiC P/M composite electrode‟, International Journal of Advanced Manufacturing Technology, vol. 44, no. 1-2, pp. 100-113.

**[21]** Hong, SH & Chung, KH 1995, „The effects of processing parameters of mechanical properties of SiCw/2124 Al composites‟, Journal of Materials Processing Technology, vol. 48, no. 1-4, pp. 349-355.

**[22]** Hourmand, M, Farahany, S, Sarhan AAD &Noordin, MY 2015, „Investigating the electrical discharge machining (EDM) parameter effects on Al-Mg2Si metal matrix composite (MMC) for high material removal rate (MRR) and less EWR–RSM Approach‟, International Journal of Advanced Manufacturing Technology, vol. 77, no. 5, pp. 831-838.

**[23]** Huda, D, El Baradie, MA &Hashmi, MSJ 1994, „Development of a hardness model for MMCs (Al/ Al2O3)‟, Journal of Materials Processing Technology, vol. 44, no. 1-2, pp. 81-90.

**[24]** Jang, H, Ko, K, Kim, SJ, Basch, RH &Fash, JW 2004, „The effect of metal fibers on the friction performance of automotive brake friction materials‟, Wear, vol. 256, no. 3-4, pp. 406-414.

**[25]** Jebeen Moses, J, Dinaharan, I & Joseph Sekhar, J 2016, „Prediction of influence of process parameters on tensile strength of AA6061/TiC aluminum matrix composites produced using stir casting‟, Transactions of Nonferrous Metals Society of China, vol. 26, no. 6, pp. 1498-1511.

**[26]** Rathore, R. K., Singh, N. K., & Xavier, J. F. Characterization of AA7075 Alloy Foam Using Calcium and Magnesium Carbonate as Foaming Agent. *Processing and Characterization of Materials*, 289.

  