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Critical Review on Microstructure, Mechanical & Wear Study of MMC And Al6082 / Granite Particles for Light Weight Structural Applications

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Abstract

The majority of industrial applications use Metal Matrix Composites (MMCs) because of their strength-to-weight ratio and temperature endurance. The specimens' tensile strength, impact strength, shear strength, hardness, and wear rate are crucial factors in the composite. Al6082/granite particles wear rate is affected by the applied stress, sliding distance, sliding velocity, and weight percentage of the reinforced composite. The granite dust-reinforced material may be employed in engineering applications requiring low strength and weight. Wear is faster for Al6082/granite dust than MMC. Compared to MMC, Al6082/granite dust is less robust. The MMC density reduced by reinforcing Fly ash (FA) and Graphene Nanoplatelets (GNPs). Increasing the wt.% of GNP will increase the hardness of the MMC sample. The impact strength and shear strength increase from MMC 1 to MMC 3.

Keywords: Shear Strength, Tensile Strength, Hardness, Wear Resistance

Introduction

Aluminum alloys are highly ductile, castable, wear- and corrosion-resistant and strong. Aluminum alloy majorly used in aerospace and automotive industries as a result of its accomplished properties [1]. The composite performs improved distribution of graphite, according to an analysis of aluminum graphite composites' microscopic structure.

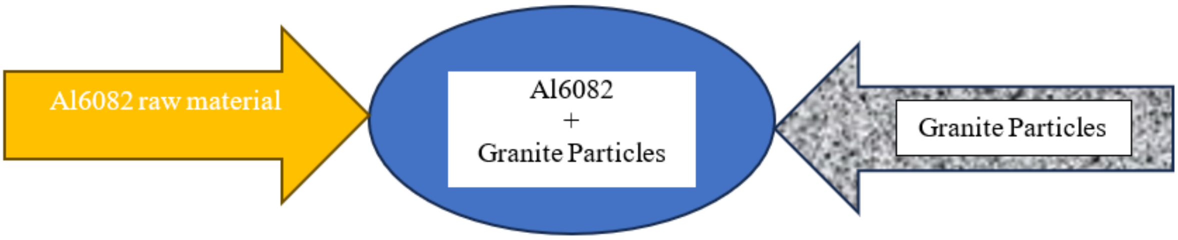

Fig.1. Basic composition of Al6082+granite materials

Figure 1 shows the basic idea for the selection of two materials to be a composite material with the different weight percentage (wt.%). Here the fig.1 mentioning that, the Al6082 is a raw material and the granite particles are the reinforcing materials as per the selection of different wt.%.

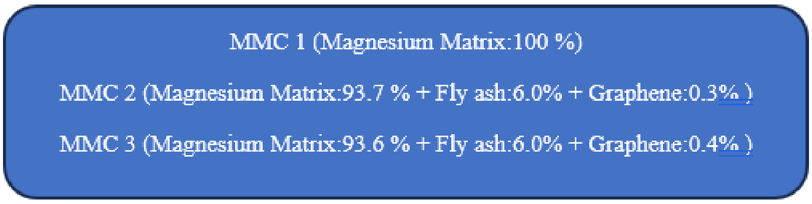

Fig.2. Basic composition of MMC materials

Figure 2 represents the MMC materials composition with different wt.% of Magnesium (Mg), Fly ash (FA) and Graphene Nanoplatelets (GNPs). The selection of two different composites like MMC and Al6082+granite particles has been selected to study the microstructure, mechanical properties and wear behavior for the test samples. Figure 3 shows that the conversion of raw material to test samples.

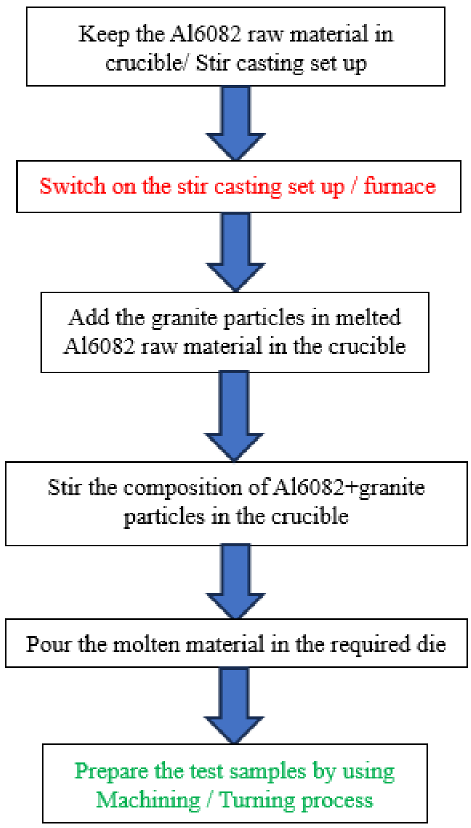

Fig.3. Conversion of raw material to test samples

The composite specimen prepared at 600 rpm stirrer speed performs, good surface hardness, an outstanding compression and tensile strength. The increased sliding distance result that, weight and wear volume loss tend to rise [2]. The porosity of stir cast LM6 aluminum alloy reinforcement, which has the composition Al+2Mg+0.5Ti+2.5Cu+7SiC, is calculated to be 4.59%. Compressive yield strength is decreased by heat treatment and is controlled by the geometry of the composite specimen, whereas malleability and energy dissipation are significantly increased [3].

The dendritic microstructure with intermetallic eutectics was observed in as-stir cast AA6082 MMC with 2.5 & 5 wt.% of SiC reinforcements [4]. MMC produced by Al, result greater mechanical properties and tribological behavior. The composite exhibits a low weight to strength ratio, a low wear rate, a low coefficient of friction, and also exhibits a low level of corrosion resistance [5]. Magnesium & corrosion are inextricably linked. When casting magnesium alloys, the presence of inclusions or impurities in the melt is a significant problem. The structural uses of Mg alloy in the aerospace and automotive industries, as well as its future potential and restrictions, have been examined [6]. The mechanical fragmentation of reinforcements brought on by the vigorous material flow during stir processing significantly reduced the lateral size of graphene oxide (GO) nanoplatelets. In comparison to friction stir processed (FSPed) AZ31 alloy, the reinforced composite containing 1.6 vol% of GO was both stronger and more plastic. [7]. Milled granite filler is added to reduce total pore volume, water absorption, and water penetration. In comparison to unground granite, samples with finely ground granite added to them have greater compressive strength [8].

Graphene nanoplatelets (GNPs) have much higher in-plane strength than they do out-of-plane strength. A genuinely homogenous distribution of GNPs and between GNPs and metal matrices cannot be achieved in a realistic manner [9]. As the amount of filler added increases, the thermal expansion coefficient decreases, as seen in composites filled to 50% volume versus composites filled to 20% volume. The thermal insulating and stability properties of waste granite scrap material reinforced composites are excellent [10]. Granite's thermal conductivity ranges from 2.87 to 3.75 W/mK, limestones from 2.82 to 3.17 W/mK, and marbles from 2.86 to 3.02 W/mK [11]. Test results shows that engineering properties of granitic rocks vary significantly. The unconfined compressive strengths (UCS) for dry samples ranges from 120 MPa to 175 MPa and from 119 to 170 MPa for saturated samples [12]. The use of red mud is a pressing issue in India, despite the fact that many applications established on a laboratory rule [13].

Microstructure Study

Mg-4Zn was employed as the matrix alloy and Si3N4 nanoparticles were used as reinforcement in a magnesium nanocomposite that was created by the stir casting technique. The micrographs display an equiaxed dendritic microstructure. The semi-continuous interdendritic networked phases seen at grain boundaries are most likely intermetallic compounds (IMCs) [14]. To confirm the microstructure, modified A356 was subjected to microstructural examination. It is made up of a rounder, less angular interdendritic network of eutectic silicon particles and Mg2Si particles dispersed throughout the structure in an aluminum solid solution matrix [15]. Composite materials were created by reinforcing cerium oxide with a magnesium matrix. The reinforcement wt.% is varied by 3, 6, 9 & 12. The SEM pictures of the worn surface exhibit fine-grained ceramic oxide in the matrix [16]. Using AA6061 as the matrix material and a new combination of SiC, Fly Ash & Graphite (Gr) as reinforcing elements, stir casting is used to generate hybrid composites made of aluminum and metal. Compared to cast aluminum alloy, the composite material has finer grain structure [17].

Mechanical Performance

Aluminum Copper used as base matrix and reinforcement used as fly ash and B_4C to develop the composite. An Al-4.5 wt% Cu matrix was used to strengthen a composite made of 3 wt% and 5 wt% fly ash and 2, 4 and 6 wt% of B_4C. Compared to stir casted composite samples with 50 mm & 75 mm diameters, those made with a 25 mm diameter performed better mechanically [18]. Aluminum alloy AA2014, which has a density of 2.80 g/cm^3, served as the matrix material. The B_4C material used as reinforcement with a 2.52 g/cm^{3}density. Inside the AA2014 matrix material, boron carbide was found to be distributed uniformly. A reinforced B_4C composite weighted at 10% produced the highest hardness and tensile strength. By raising the weight percentage of B_4C, toughness, ductility, and density are decreased [19]. The composite of AA6063 Al alloy prepared with the reinforcement of fly ash (FA) wt.% of 0-9 with 3% steps. The mechanical properties improved up to 6 wt.% of FA content addition, further it is decreasing [20].

Utilizing the stir casting technique, SiC, FA, and Coconut Coir Ash were employed as reinforcement to create the AA6061 hybrid metal matrix composite (HMMC). As the weight proportion of coconut Ash in HMMC grows, hardness improves. As the weight percentage of coconut ash increased, the tensile characteristics declined [21]. Fly ash and basalt ash were used as reinforcement in the preparation of Al6061 MMC. The incremental value of fly ash in wt.% increased the tensile and impact strength. With the weight fraction of basalt ash wt.% growing, the composite sample's hardness is likewise rising [22]. Alumina is reinforced with a hybrid reinforcement of as received fly ash. It has low density & better mechanical property [23]. Al-Si alloys are made-up with the reinforcement of zinc oxide as 0.05, 0.1 & 0.2 wt.%. The maximum tensile strength & hardness values for the 0.2 wt.% reinforced zinc oxide sample were 23.9 kg/mm^2 and 134.4 HV, respectively [24]. Evolution of thermal loading-induced damage within granite was investigated. Angle between the loading direction, microstructural surfaces, and microcracks all have an impact on granite's bearing capacity and other mechanical characteristics [25].

Mechanical behavior of granites under tension & compression was investigated using 178 different granites. The database was expanded and a trial campaign on granite from southern France was presented. The compressive strength of this rock is 158 MPa, which is 15% more than the average value for all the granites in the database 138 MPa [26]. Aluminum alloy AA6061 reinforced with different concentrations of fly ash particles with 0, 4, 8 & 12 wt.% was created using the compocasting technique. In the Al matrix, homogeneous FA particle dispersion with excellent bonding was achieved. Microhardness and UTS improved with the addition of FA [27]. In the study of granite, the thresholds of 15 MPa pressure and 200^{0}C temperature were used. [28]. LM25 aluminum alloy reinforcement samples made with FA at a fly ash content of 3 weight percent and varied Al_2O_3 wt.% of 5, 10 & 15. Composite materials' tensile strength and hardness increased as the wt.% of Al_2O_3 increases up to a certain limit. Because the reinforced material with the metal aluminum matrix has low wetability, tensile strength declines when reinforcement is increased. Charpy test demonstrated that increasing the reinforcement wt.%, reduces impact load absorption. Microstructure analysis produced homogeneous distribution of FA and Al_2O_3 particles in the matrix [29]. To investigate compressive behavior of granites and sandstones porosity is an important factor. Porous rocks have a visibly reduced compressive strength and a larger strain at maximum stress [30].

Wear Performance

In order to create Al-based 6082 metal matrix composites (AMMCs) using the stir casting technique, 5 to 10 wt.% of graphite was employed as reinforcement. The surface hardness and tensile strength of the composite specimen decreased with an increase in the weight percentage of Gr [31]. Hardness of developed composite (AA6061 & AA6082) sample improved for the addition of ceramic particles [32]. Matrix and reinforcement phases are made of copper and Silicon Carbide (SiC)-Fly Ash by using powder metallurgy. A set of specimens made with two composites by 95 wt.% of Cu and 5 wt.% of SiC as set 1, 90 wt.% of Cu, 5 wt.% of SiC and 5 wt.% of FA as a set 2. Friction coefficient & wear rate are proportional to applied load [33].

Using the stir casting technique, Al-Si alloy (A356) is created with granite and graphite particle reinforcement. CoF for the hybrid reinforced graphite and granite A356 aluminum alloy composite decreased with an increase in the wt.% of the particle reinforcement and sliding time [34]. Aluminum 7075 Hybrid MMC developed by using stir casting process. Wear rate rises as Al_2O_3 content, applied stress and sliding distance all increase. As the applied load increases and the sliding distance reduces, the friction force increases. As the sliding distance and applied load decrease, CoF rises [35].

SiC and Ti were added to an Al matrix composite by the use of the stir casting technique. Composite with a 3 wt.% of silicon content results low wear rate. As the silicon content rises, the wear rate rises as well. Adding titanium beyond a certain limit reduces bond strength between the particles and it results lowering wear resistance at 10 to 30 N applied load. Wear rate and wear resistance behavior both increase with increasing load [36].

Wear rate increased as applied load increased, but it decreased as sliding speed increased [37]. Al alloy (A356) composite developed with FA particle reinforcement of 6 and 12 vol.%. Up to 80 N applied load, composites outperform unreinforced alloys in terms of wear resistance. The wear and friction properties of composites are significantly influenced by the size and volume fraction of FA particles [38].

Composite prepared by using vortex method via the liquid metal route. With the addition of 10% of fibers, the wear rate was lowered by 40%, the Copper-coated steel fibre wt.% ranged from 2.5 to 10. Composite exhibit an improved wear property when compared to base metal [39]. Al composite yielded with SiC particle reinforcement. With increasing abrasive size, applied stress, and sliding distance, the matrix and composite materials' wear rates increased [40].

Conclusions

Metal Matrix Composites (MMCs) are used in high-strength industrial applications because of their weight-to-strength ratio and tolerance to temperature. Applied stress, sliding distance, sliding velocity, and wt.% of composite with reinforcement all affect how quickly Al6082/granite sample wears out. The input parameters for Al6082/granite particles enhanced the abrasion resistance of aluminum alloys, and this granite dust-reinforced material could be used in engineering applications requiring light weight applications.

References

1. Dinesh Kumar, Satnam Singh, Surjit Angra., (2023). Dry sliding wear and microstructural behavior of stir-cast Al6061-based composite reinforced with cerium oxide and graphene nanoplatelets. *Wear,* 516–517. doi.10.3390/met13050943.
2. S. Arunkumar, Ch. Siva Ramakrishna, M.S. Alphin, R. Muraliraja, et al., (2023). Optimization of stirrer speed on mechanical properties of aluminium graphite stir cast. *Materials Today: Proceedings*. doi.10.1016/j.matpr.2023.03.379.

3. Kumar Prakash, N.K. Singh., (2023). Behaviour of a stir casted aluminium hybrid composite under compressive and bending loads. *Materials Today: Proceedings,* 87(1), pp.215-220. doi.10.1016/j.matpr.2023.05.182.
4. Surendarnath S, Ramesh G, Ramachandran T, Dharma lingam R, et al., (2022). Dry sliding wear behaviour of aluminium alloy 6082-Sic composites through ex-situ casting process. *Proceedings of the Institution of Mechanical Engineers, PartJ: Journal of Engineering Tribology*, 237(8), pp.1-10. doi.10.1177/13506501221142651.
5. Dhananjay Pise, C. Shravankumar, T.V.V.L.N. Rao., (2020). An overview on aluminum metal matrix composite for automobile application. *Proceedings of Mechanical Engineering Research Day*, pp. 14-15. https://www3.utem.edu.my/care/proceedings/merd20/pdf/01_Automotive/007-p14_15.pdf
6. S V Satya Prasad, S B Prasad, Kartikey Verma, Raghvendra Kumar Mishra et al., (2021). The role and significance of Magnesium in modern day research-A review. *Journal of Magnesium and Alloys,* 10(1), pp.1-61. doi.10.1016/j.jma.2021.05.012.
7. M. Tahaghoghi, A. Zarei-Hanzaki, M.S. Jalali, H.R. Abedi., (2022). Improved strength and plasticity of magnesium matrix nanocomposites reinforced by carbonaceous nanoplatelets and micro-clusters. *Journal of Materials Research and Technology*, 21, pp.2797-2814, doi.10.1016/j.jmrt.2022.10.083.
8. Agata Stempkowska, Tomasz Gawenda, Adrian Chajec and Łukasz Sadowski., (2022). Effect of Granite Powder Grain Size and Grinding Time of the Properties of Cementitious Composites. *Materials*, 15(24), pp.1-14. doi.10.3390/ma15248837.
9. Meysam Tabandeh-Khorshid, P. Ajay Kumap, Emad Omrani, Chngsoo Kim et al., (2019). Synthesis, characterization, and properties of graphene reinforced metal-matrix nanocomposites. *Composites Part B: Engineering*, pp.1-67.doi.10.1016/j.compositesb.2019.107664.
10. Shujit Chandra Paul, Muhammed Yusuf Miah, Abdul Gafur and Rajib Chandra Das., (2017). Study of Thermal Properties of Granite Powder (Scrap) Reinforced Polyester Resin Composite. *Journal of Advanced Chemical Engineering*, 7(1), pp.1-5. doi.10.4172/2090-4568.1000159.
11. Paulo Amaral1, António Correia, Luís Lopes, Paula Rebola et al., (2013). On the Use of Thermal Properties for Characterizing Dimension Stones. *Key Engineering Materials*, 548, pp.231-238, doi.10.4028/www.scientific.net/KEM.548.231.
12. R. K. Yadav, Ajitesh Anurag., (2014). A Study on Variation in Mineralogical and Strength Characteristics of Some Granitic Rocks. *International Journal of Engineering Research & Technology (IJERT)*, 3(1), pp.505-511.
13. Sneha Samal, Ajoy K. Ray, Amitava Bandopadhyay., (2012). Proposal for resources, utilization and processes of red mud in India — A review. *International Journal of Mineral Processing,* 118, pp.43-55. doi.10.1016/j.minpro.2012.11.001.
14. N. Anand, K.K. Ramachandran, D. Bijulal., (2020). Microstructural, mechanical and tribological characterization of vacuum stir cast Mg-4Zn/Si3N4 magnesium matrix nanocomposite. *Materials Today: Proceedings*, 46(19), pp.9387-9391. doi.10.1016/j.matpr.2020.03.053.
15. Dhanasekaran R, Sathish kumar K., (2015). Microstructure, Mechanical properties of A356/Li aluminum alloy Fabrication by Stir Casting method. *International Journal of Applied Engineering Research*, 10(50), pp.416-419.
16. V Anand Babu, A Kumaravel, R Manikandan., (2022). Microstructure, mechanical and wear characteristics of CeO_2-Mg metal matrix composites. *Proceedings of the Institute of Mechanical*

Engineers, Part E: Journal of process Mechanical Engineering, 237(2). doi.10.1177/09544089221139592.
17. Prashant Chechi, Saurabh Kumar Maurya, Rabindra Prasad, Alakesh Manna., (2022). Microstructural and mechanical characterization of stir cast AlSiC/Flyash/Graphite hybrid metal matrix composite. *Materials Today: Proceedings*,64(1), pp.637-642. doi.10.1016/j.matpr.2022.05.150.
18. G.N. Lokesh, K.P. Prashanth, G.P. Prasad, B.K. Venkatesha., (2022). Mechanical and microstructure evaluation of stir cast Al-4.5%Cu alloy reinforced fly ash/boron carbide hybrid metal matrix composites. *Materials Today: Proceedings*, 54(2), pp.486-491. doi.10.1016/j.matpr.2021.11.131.
19. Shashi Prakash Dwivedi., (2019). Microstructure and mechanical behaviour of Al/B4C metal matrix composite. *Materials Today: Proceedings*, 25(4), pp.751-754. doi.10.1016/j.matpr.2019.08.244.
20. M Ravichandran, M Balasubramanian, C Anand Chairman, S Marichamy, et al., (2020). Mechanical properties of Fly ash reinforced Aluminium matrix composites. *IOP Conference Series: Materials Science and Engineering*, *988*, pp.1-6. doi.10.1088/1757-899X/988/1/012095.
21. R.Devanathan, J.Ravikumar, S.Boopathi, D.Christopher Selvam, et al., (2020). Influence in Mechanical Properties of Stir Cast Aluminium (AA6061) Hybrid Metal matrix Composite (HMMC) with Silicon Carbide, Fly Ash and Coconut coir Ash Reinforcement. *Materials Today: Proceedings*, 22, pp.3136–3144.doi.10.1016/j.matpr.2020.03.450.
22. Kumaravel S, Mohanraj D, Channankaiah., (2019). Production and Mechanical Properties of Fly ash and Basalt ash reinforced Al 6061 composites. *Indian Journal of Engineering, 16*, pp.276-283. https://api.semanticscholar.org/CorpusID:201797915.
23. S.G. Kulkarni, J.V. Meghnani, Achchhe Lal., (2014). Effect of Fly Ash Hybrid Reinforcement on Mechanical Property and Density of Aluminium 356 Alloy. *Procedia Materials Science*, 5, pp.746-754, doi.10.1016/j.mspro.2014.07.324.
24. Poppy Puspitasari, Okky Rachmadilla Soepriyanto, and Muhammad Ilman Nur Sasongko, Johan Wayan Dika et al., (2018). Mechanical and physical properties of aluminium-silicon (Al-Si) casting alloys reinforced by Zinc Oxide (ZnO). *MATEC Web of Conferences*, 204, pp.1-7. doi.10.1051/matecconf/201820405003.
25. You-Liang Chen, Su-Ran Wang, Jing Ni, Rafig Azzam et al., (2017). An experimental study of the mechanical properties of granite after high temperature exposure based on mineral characteristics. *Engineering Geology*, 220, pp.234-242. doi.10.1016/j.enggeo.2017.02.010.
26. N. Domede, T. Parent & A. Sellier., (2017). Mechanical behaviour of granite: a compilation, analysis and correlation of data from around the world. *European Journal of Environmental and Civil Engineering*, 23(2), pp.193-211. doi.10.1080/19648189.2016.1275984.
27. J. David Raja Selvam, D.S. Robinson Smart, I. Dinaharan., (2013). Microstructure and some mechanical properties of fly ash particulate reinforced AA6061 aluminum alloy composites prepared by compocasting. *Materials and Design* 49, pp.28–34. http://dx.doi.org/10.1016/j.matdes.2013.01.053
28. Wang Yu, Liu Bao-lin, Zhu Hai-yan, Yan Chuan-liang, et al., (2014). Thermophysical and Mechanical Properties of Granite and Its Effects on Borehole Stability in High Temperature and Three-Dimensional Stress. *Hindawi Publishing Corporation. The Scientific World Journal*, 2014, pp.1-11.doi.10.1155/2014/650683.
29. Mr.Sharanabasappa R Patil, Prof B.S Motgi., (2013). A Study on Mechanical Properties of Fly Ash and Alumina Reinforced Aluminium Alloy (LM25) Composites. *IOSR Journal of Mechanical and Civil Engineering*, 7(6), pp.41-46.

30. Marco Ludovico-Marques, Carlos Chastre, Graça Vasconcelos., (2012). Modelling the compressive mechanical behaviour of granite and sandstone historical building stones. *Construction and Building Materials*, 28, pp.372–381. doi.10.1016/j.conbuildmat.2011.08.083.
31. R. Harikumar, A. Devaraju, Gopi Raji., (2022). An evaluation of corrosion & wear properties of AL6082 reinforced with graphite particles. *Materials Today: Proceedings*, 68, pp.1787–1792. doi.10.1016/j.matpr.2022.09.484.
32. Hartaj Singh, Kapil Singh, Sachit Vardhan, Sanjay Mohan., (2020). Study on the wear performance of AA 6061 and AA 6082 based metal matrix composites. *Materials Today: Proceedings*, 43, pp. 660–664. doi.10.1016/j.matpr.2020.12.585
33. A.Devaraju, P. Sivasamy, R. Gopi, A. Muthiah., (2020). Studies on wear behaviour of silicon carbide and fly ash reinforced copper-based metal matrix composites. *Materials Today: Proceedings*, 39, pp.888–891. doi.10.1016/j.matpr.2020.10.1006.
34. Tirlangi Satyanarayana, Putti Srinivasa Rao, M.Gopi Krishna.,(2019). Influence of wear parameters on friction performance of A356 aluminum – graphite/ granite particles reinforced metal matrix hybrid composites. *Heliyon 5*. doi.10.1016/j.heliyon. 2019.e01770.
35. T.S.A.Suryakumari, S.Ranganathan., (2017). Preparation and Study the Wear Behaviour of Aluminium Hybrid Composite. *Materials Today: Proceedings*, 5, pp.8104–8111. doi.10.1016/j.matpr.2017.11.497.
36. Godwin Antony, V.Vijayan, S. Saravanan, S. Baskar, M.Loganathan., (2018). Analysis of wear behaviour of aluminium composite with silicon carbide and titanium reinforcement. *International Journal of Mechanical Engineering and Technology*, 9(12), pp.681–691. http://iaeme.com/Home/issue/IJMET?Volume=9&Issue=12.
37. S. Suresha, B.K. Sridhara., (2010). Effect of silicon carbide particulates on wear resistance of graphitic aluminium matrix composites. *Materials and Design*, 31, pp.4470–4477. doi.10.1016/j.matdes.2010.04.053.
38. Sudarshan, M.K. Surappa., (2007). Dry sliding wear of fly ash particle reinforced A356 Al composites. *Wear*, 265(3-4), pp.349–360. doi.10.1016/j.wear.2007.11.009.
39. Durbadal Mandal Æ B. K. Dutta Æ S. C. Panigrahi., (2007). Dry sliding wear behavior of stir cast aluminium base short steel fiber reinforced composites. *Journal of Materials Science*, 42(7), pp.2417-2425. doi.10.1007/s10853-006-1271-5.
40. Y. Sahin., (2003). Wear behaviour of aluminium alloy and its composites reinforced by SiC particles using statistical analysis. *Materials and Design*, 24(2), pp.95–103. doi.10.1016/S0261-3069(02)00143-7.