International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Stir Casting Process Optimization for Enhanced Mechanical Properties of Metal Matrix Composites

Dr U.Sudhakar[1], K.Yuvaraju[2], K.Shanmukha Rao[3], M.Shiva Krishna[4], M.Kula Sekhar[5]

Department of Mechanical Engineering, Grandhi Mallikarjuna Rao Institute of Technology (GMRIT), Rajam 532127,India

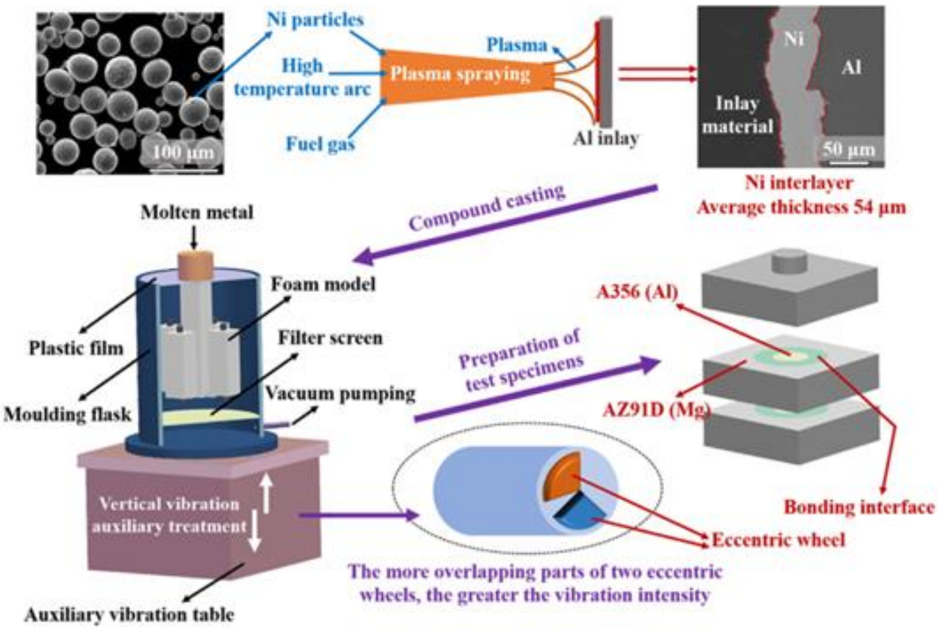
ABSTRACT :

Mechanical as well as biocompatible properties of AZ31B magnesium alloy are enhanced through the reinforcement process with nano-hydroxyapatite (nHA) and nano-alumina (Al2O3) using the stir casting process. AZ31B-0.5(Al2O3)-0.3nHA attained the highest compressive strength of 171 MPa, along with hardness of 95 BHN, significantly higher than the base alloy. The biocompatibility evaluations revealed a relatively safe profile for biological applications, but the corrosion resistance was found to be lower for the nHA-reinforced samples than that of the unreinforced samples, thus requiring further optimization. The nanocomposites in the magnesium-based type hold tremendous promise as biodegradable implants where the implant provides mechanical support where necessary but requires minimal surgical interventions. Future research directions are proposed to refine the composition and processing techniques to make these materials more effective in biomedical applications.

Keywords: Stir casting, Mechanical properties, Biocompatibility, Compressive strength, Hardness, Corrosion resistance, Biodegradable implants, Composition optimization, Biomedical applications, Nanocomposites

1.INTRODUCTION:

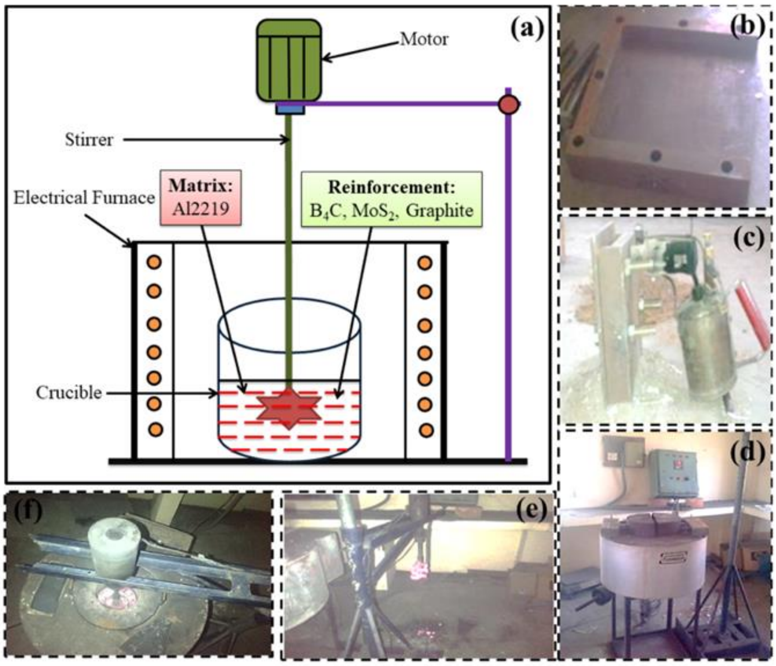
This study investigates further in the MMC development and optimization using stir casting, with emphasis on Al/Mg bimetallic composites and copper-based hybrid composites. While Al/Mg bimetal materials show much potential, the limitation of their wide application lies in the brittle Al-Mg intermetallic compounds and the coarse primary dendritic structures at the Al/Mg bimetallic composite interface, thereby being restrained from bonding



Experimental schematic diagram for preparing Al/Mg composite interface.

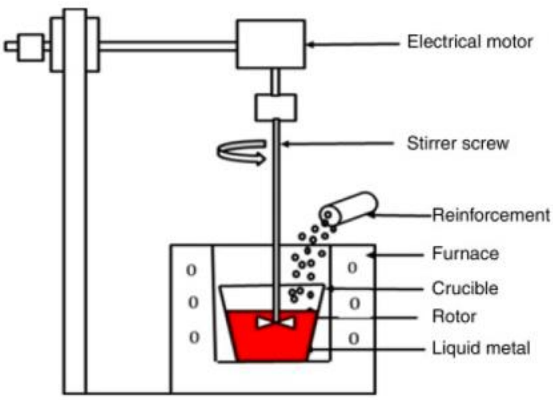
performance. Recent researches focus on interface alloying, external force fields, and metal interlayers; among them, nickel interlayers have especially implied potential in preventing the diffusion of Al and Mg atoms and the growth of IMCs. However, the quality of the nickel interlayer tends to varies with preparation processes, which may lead to oxidation and poorer bonding with the base metals. To this end, this study examines the impact of vibration-assisted processing combined with a pretreated nickel interlayer on the microstructure and bonding performance at the Al/Mg bimetallic composite interface to guide the development and application of Al/Mg bimetal materials.

The aluminum metal matrix composites (AMMCs) offer strength, stiffness, corrosion resistance, and durability in excess amounts that make them suitable for aerospace and automotive applications. Specifically, AA2219 alloy reinforced with hard B4C and self-lubricating Gr and MoS2 particles shows promise because of its lightweight, resistance to stress corrosion cracking, and high fracture toughness. However, machining of AMMCs involves problems arising from the abrasive nature of hard reinforcement particles, which leads to the increase in friction , cutting forces, and tool wear. To mitigate this, researchers studied optimization of stir casting and drilling process parameters with respect to the AA2219 alloy hybrid composites focusing on the aspects of hardness, wear properties, hole quality characterization, such as burr height, material removal rate, and thrust force. Employing the Taguchi method and the Data Envelopment Analysis Ranking (DEAR) method, the work aimed at fabrication of a lightweight structural material with excellent properties, giving industry personnel valuable insights in improving performance in aerospace as well as automotive applications.



a. Schematic representation of Stir casting set-up, b. Slab die c. Preheating the dies d. Electrical resistance furnace, e. Stirrer, f. Stir casting.

Copper-based composites have good wear resistance, corrosion resistance, mechanical properties, and electrical properties. It widely finds applications in the electronics and automotive industries. However, force transfer becomes challenging due to poor wetting characteristics between copper and ceramic reinforcements, affecting mechanical properties. To improve that, hybrid composites made of stainless steel and ceramics were incorporated within a copper matrix, taking benefits from the wettability as well as desirable properties of ceramics. The study is focused on Cu-HSSS-WC hybrid composites containing highly strained stainless steel (HSSS) and tungsten carbide (WC) as reinforcements. HSSS, an industrial waste, is found to possess highe r strength due to its fine microstructure, whereas WC possesses high strength, wear resistance, and hardness. This research aimed at synthesizing Cu-HSSS-WC composites through stir casting followed by the evaluation of their mechanical properties and corrosion behaviour in 0.1M NaCl solution by investigating the concentrations of HSSS. The findings are against pure copper, in which enhancements achieved through HSSS and WC reinforcements help to develop copper-based hybrid composites with improved properties for varied engineering applications.



Block diagram of stir casting process

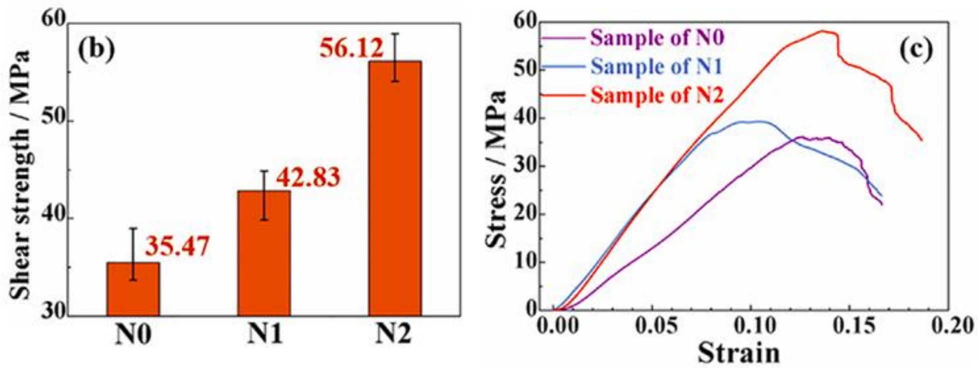
The biodegradable metallic biomaterial magnesia has great promise for bone tissue engineering because of its biocompatibility, biodegradability, and mechanical properties. However, its rapid corrosion in bodily fluids presents a challenge. In that regard, research has taken different approaches such as alloying, coating, and compositing methods. This current research is on the improvement of biocompatibility and further enhancement of bioactivity, corrosion resistance, and the mechanical properties of AZ31B magnesium alloy with reinforcement from nano-hydroxyapatite (nHA) and nano-alumina (Al2O3). AZ31B's zinc and aluminium alloying elements are the reasons for its enhanced properties. The paper studied the consequences of nHA and Al2O3 reinforcement to the microstructure and mechanical properties of Mg metal matrix nanocomposite made by stir casting in order to optimize magnesium compounds for biomedical purposes specifically implant orthopedics, where the biodegradability and bioactivity of magnesium can be worthwhile.

2.METHODOLOGY:

2.1: Strengthening of composite casting Al/Mg bimetallic interface with Ni interlayer by vibration assisted treatment:

1. SEM Scanning Electron Microscopy: observed microstructure and fracture morphology at the Al/Mg bimetallic composite interface.
2. EDS Energy-Dispersive Spectroscopy: determined composition and distribution of elemental bonding interface distribution, incorporating:
- Line scans
- Area scans

Sample Testing Procedure:
Shear Strength Testing:
1. Cutting samples to a thinness of about 3 mm using a wire cutting machine.
2. Measured bonding strength in a material performance testing machine:
- Peak load: 20kN
  Load speed: 0.5 mm/min
3. Calculation of shear strength by applying a particular formula.
4. Calculation of average values of three shear strengths obtained for each sample.



Hardness Tests:
1. Vickers hardness tester:
- Load: 200 g
  Pressure holding time: 15 s
2. Average hardness distribution of the Al/Mg composite interface was tested.

3. Morphology analysis of fracture:

1. Analyzed fracture morphology of samples to understand failure mechanisms.

2.2: Optimization of stir casting and drilling process parameters of hybrid composites:

The step-by-step procedure for fabricating AA2219/B4C/Gr/MoS2 hybrid composites using the stir casting method

●**Preparation of Material**

○AA2219 ingots of 99.5% purity were procured by the researchers.

○The AA2219 ingots were further cut into pieces with the use of a hacksaw power saw.

○The researchers also procured B4C reinforcement material with average 85 µm size, graphene having 99% purity, and a particle size of 35 ± 5 nm, and MoS2 with 99% purity and a particle size of 35 ± 5 nm.

○A set amount of reinforcements (15 wt% of B4C and 0.5 – 2.5 wt% of Gr and MoS2) was dehydrated at 400 °C in an electric resistance muffle furnace to remove moisture, dampness, agglomeration, and foreign particles.

Melting and Addition of Reinforcement

The cut AA2219 alloy was melted in a 3 kg capacity graphite crucible

The preheated reinforcements were packed in aluminium foil with a steel rod and were introduced at the bottom of the melted AA2219 alloy at 700 °C.

Stirring

○A mechanical stirrer driven by a 1 HP DC motor was used to ensure homogenous reinforcement dispersion within the AA2219 matrix.

○Researchers controlled the stirrer speed utilizing the dimmer stat of the DC motor.

A screw operator lift was used for controlling the stirrer position.

○The stirrer rotated at a preset speed for 3 minutes to create a vortex in the melt.

●**Degassing and Cleaning**

○ Powdered hexachloroethane (C2Cl6) tablets were packed in aluminium foil with a steel rod and introduced to the bottom of the melt to remove absorbed or dissolved gases.

○Cover flux was used to clean the molten metal, remove impurities, and eliminate slags on the surface.

●**Pouring and Solidification**

○The cleaned molten metal was poured into a 140 × 70×10 mm slab die.

Post Casting Processing

The pre-formed composite prepared was milled to create a horizontal flat surface.

The specimens were cut into two pieces, each measuring 140 × 35 × 10 mm.

Characterization

The Researchers conducted mechanical (hardness) and tribological (wear rate) characterization of the composites as per ASTM standards.

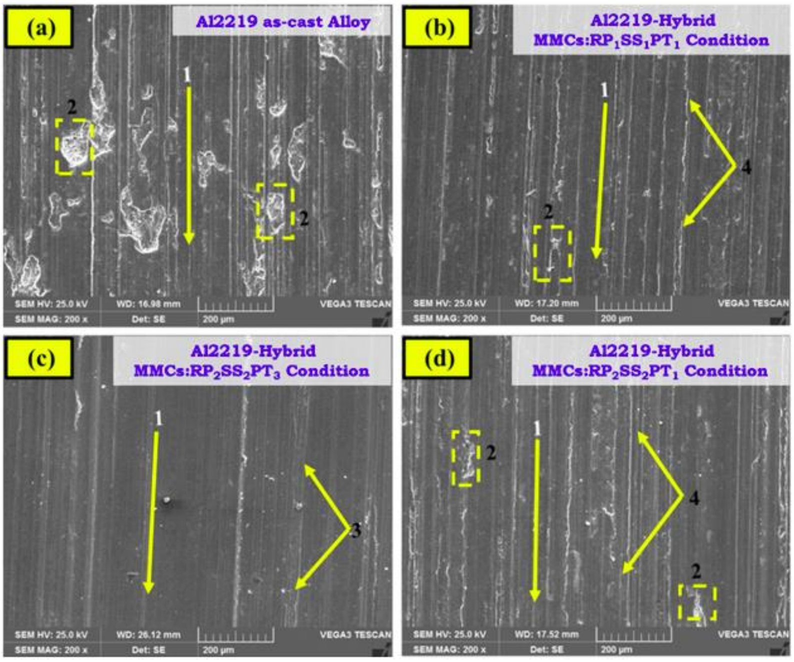
■Hardness Measurement: A Vickers hardness tester was used to measure the hardness of composite samples of dimensions 20 × 20 × 10 mm as per ASTM E384 standards.

■Wear Rate Measurement: A pin-on-disc wear test rig was used to investigate wear examination of machined specimens sized at 6 mm in diameter and 30 mm in height against the surface of a 60 HRC EN-32 steel disc with a diameter of 160 mm and 8 mm thick.

■Surface Roughness Measurement: The surface roughness of the cylindrical wear samples was checked on a surface roughness tester. The average surface roughness (Ra) value was maintained at 0.8 ± 0.06 µm.

■Microstructural Analysis: Metallographic studies were carried out using the scanning electron microscope (SEM) for stir casting and the wear samples. Stir-cast samples were etched with Keller's reagent.

The variables affecting the quality of the composite were created with stir casting such as the percent reinforcement of Gr and MoS2, stir speed, and pouring temperature.



Wear surface morphology

3.CONCLUSION:

In conclusion, the results show a successful strategy to highly strengthen the bonding performance of the Al/Mg bimetallic composite interfaces. The introduction of a Ni interlayer in an appropriate proportion, followed by vibration-assisted treatment, indeed overcame the inherent weakness related to the brittle AleMg IMCs, thereby providing a more robust and high-strength composite interface. This innovative method holds great promise for promoting the development and application of Al/Mg bimetallic materials in various engineering fields.

The study concludes that the reinforcement of nano-hydroxyapatite (nHA) and nano-alumina (Al2O3) in AZ31B magnesium alloy significantly enhances its mechanical properties and biocompatibility, thus becoming a suitable candidate for biomedical applications. The best composition, AZ31B-

0.5(Al2O3)-0.3nHA, achieved the highest compressive strength of 171 MPa because of a well-distributed reinforcement; the hardness of the composites increased with addition of nHA and reached its maximum value of 95 BHN. The corrosion resistance, however, was a bit compromised by this specimen, being in the AZ31B-nHA sample. Besides, cytotoxicity tests showed only slight reactivity; this means that the material is quite secure in use in biologic media. In general, the results demonstrated the possibility of magnesium-based nanocomposites as biodegradable implants providing enough mechanical support with a minimum degree of additional surgical interventions. The next step should be the adjustment of composition and processing technology to improve the properties of these materials.

The work concludes that nano-hydroxyapatite (nHA) and nano-alumina (Al2O3) reinforcement of AZ31B magnesium alloy through the stir casting process significantly improves its mechanical properties and biocompatibility, thus making it a promising candidate for biomedical applications. The optimal composition, specifically AZ31B-0.5(Al2O3)-0.3nHA, revealed the highest compressive strength of 171 MPa, which was attributed to the uniform distribution of reinforcements in the metal matrix. Composites showed an increase in hardness with the incorporation of nHA, and reached 95 BHN. Although promising mechanical performance was demonstrated by the composites, corrosion resistance of the corrosion sample was the lowest in AZ31B-nHA, which requires further optimization work. In vitro cytotoxicity tests demonstrated a rather mild response and indicates that the material is relatively non-toxic for biological use. The results indicate that magnesium-based nanocomposites are good biodegradable implants, capable of yielding the necessary mechanical strength without causing increased surgical intervention. The future study should aim at refining composition and processing to make the materials better suited for biomedical applications.

The study of AZ31B magnesium alloy, strengthened with nano-hydroxyapatite (nHA) and nano-alumina (Al2O3), has shown that this material has remarkable mechanical properties, including a maximum compressive strength of 171 MPa and hardness of 95 BHN. Although the biocompatibility investigations proved its certain safety of application for biomedical purposes, the corrosion resistance improvement is necessary. Overall, these results place magnesium-based nanocomposites as potential biodegradable candidates for transient implants and deserve further research on the refinement of their composition and processing, to greatly improve their performance in the clinic.

REFERENCES :

1. C, G. M., Hiremath, P., Shettar, M., Sharma, S., & U, S. R. (2020). Experimental validity on the casting characteristics of stir cast aluminium composites. *Journal of Materials Research and Technology*, *9*(3), 3340–3347. https://doi.org/10.1016/j.jmrt.2020.01.028
2. Zhang, Z., Xiao, Y., Xu, J., He, M., Luo, Y., & Xiang, J. (2022). Understanding the influencing mechanism of CNTs on the microstructure and mechanical properties of semi-solid stir casting Al-Cu-Mg alloys. *Journal of Materials Research and Technology*, *18*, 3949–3960. https://doi.org/10.1016/j.jmrt.2022.04.087
3. Santhosh, N., Praveena, B., Jain, R., Hasan, M. A., Islam, S., Khan, M. A., Razak, A., & Daniyal, M. (2022). Analysis of friction and wear of aluminium AA 5083/ WC composites for building applications using advanced machine learning models. *Ain Shams Engineering Journal*, *14*(9), 102090. https://doi.org/10.1016/j.asej.2022.102090
4. Momeni, E., Sharifi, H., Tayebi, M., Keyvani, A., Aghaie, E., & Behnamian, Y. (2023). Tribological behavior of ZK60Gd alloy reinforced by SiC particles after precipitation hardening. *Journal of Magnesium and Alloys*, *11*(9), 3362–3381. https://doi.org/10.1016/j.jma.2023.09.006
5. Karthik, B., Sharma, S., Gowrishankar, M., & Hegde, A. (2023). Peak hardness stability analysis of Al7075 alloy dispersed with Ni coated duralumin powder during natural aging phenomena. *Journal of Materials Research and Technology*, *26*, 2219–2228. https://doi.org/10.1016/j.jmrt.2023.07.280
6. Chen, X., Xu, J., Zheng, K., Li, X., Wang, T., Han, S., Kang, Y., Feng, B., Yang, H., Zhou, N., Zhang, W., & Pan, F. (2023). Effect of Ti particles on microstructure and mechanical properties of Mg–9Al–1Zn based composite sheets. *Journal of Materials Research and Technology*, *27*, 1242–1257. https://doi.org/10.1016/j.jmrt.2023.10.024
7. Somasundaram, M., NarendraKumar, U., Annamalai, A. R., & Muthuchamy, A. (2023). High-temperature tribological performance of stir-cast and heat-treated EV31A magnesium alloy: Experiments and predictions. *Heliyon*, *9*(8), e19055. https://doi.org/10.1016/j.heliyon.2023.e19055
8. Singh, M. K., Gautam, R. K., & Ji, G. (2019). Mechanical properties and corrosion behavior of copper based hybrid composites synthesized by stir casting. *Results in Physics*, *13*, 102319. https://doi.org/10.1016/j.rinp.2019.102319
9. Hanizam, H., Salleh, M. S., Omar, M. Z., & Sulong, A. B. (2019). Optimisation of mechanical stir casting parameters for fabrication of carbon nanotubes–aluminium alloy composite through Taguchi method. *Journal of Materials Research and Technology*, *8*(2), 2223–2231. https://doi.org/10.1016/j.jmrt.2019.02.008
10. Ahmad, S., Tian, Y., Hashmi, A. W., Singh, R. K., Iqbal, F., Dangi, S., Alansari, A., Prakash, C., & Chan, C. K. (2024). Experimental Studies on Mechanical Properties of Al-7075/TiO2 Metal Matrix Composite and Its Tribological Behaviour. *Journal of Materials Research and Technology*, *30*, 8539–8552. https://doi.org/10.1016/j.jmrt.2024.05.227
11. Anuar, N. F. B. W., Omar, M. Z., Salleh, M. S., Zamri, W. F. H. W., & Ali, A. M. (2024). Effect of graphene addition on microstructure and wear behaviour of the A356-based composite fabricated by thixoforming process. *Journal of Materials Research and Technology*, *30*, 4813–4831. https://doi.org/10.1016/j.jmrt.2024.04.192
12. Balamurugan, K., Shanmugam, V., Palani, G., Sundarakannan, R., Sathish, T., Linul, E., Khan, S. A., & Asif, M. (2023). Effect of TiC/RHA on solid particle erosion of Al6061 hybrid composites fabricated through a 2-step ultrasonic-assisted stir casting process. *Journal of Materials Research and Technology*, *25*, 4888–4900. https://doi.org/10.1016/j.jmrt.2023.06.225
13. Hu, Z., Wu, Z., Luo, S., Wang, X., Nian, Q., Chen, Y., & Nagaumi, H. (2023). Large scale production of graphene aluminum composites by stir casting: Process, microstructure and properties. *Journal of Materials Research and Technology*, *27*, 681–691. https://doi.org/10.1016/j.jmrt.2023.09.298

14. Kumar, T. S., Thankachan, T., Giri, J., Makki, E., Dhanasekar, R., & Guru, A. (2024). Microstructural characterization of in-situ MgAl2O4 nanoparticles reinforced Al–2Mg–1Si composite produced using the ultrasonic assisted stir casting process. *Journal of Materials Research and Technology*. https://doi.org/10.1016/j.jmrt.2024.01.254
15. Motaharinia, A., Drelich, J., Goldman, J., Bakhsheshi-Rad, H., Sharif, S., Ismail, A., & Razzaghi, M. (2024). Current status and recent advances in magnesium-matrix syntactic foams: Preparation, mechanical properties, and corrosion behavior. *Journal of Materials Research and Technology*, *30*, 8316–8344. https://doi.org/10.1016/j.jmrt.2024.05.191
16. Ponhan, K., Jiandon, P., Juntaracena, K., Potisawang, C., & Kongpuang, M. (2024). Enhanced microstructures, mechanical properties, and machinability of high performance ADC12/SiC composites fabricated through the integration of a master pellet feeding approach and ultrasonication-assisted stir casting. *Results in Engineering*, 102937. https://doi.org/10.1016/j.rineng.2024.102937
17. Sun, J., Ding, D., Liu, W., Wu, G., Liu, H., Wei, G., & Liu, H. (2022). Strength and elastic modulus enhancement in Mg-Li-Al matrix composites reinforced by ex situ TiB2 particles via stir casting. *Journal of Magnesium and Alloys*. https://doi.org/10.1016/j.jma.2022.09.020
18. Thakur, B., Barve, S., & Pesode, P. (2022). Investigation on mechanical properties of AZ31B magnesium alloy manufactured by stir casting process. *Journal of the Mechanical Behavior of Biomedical Materials/Journal of Mechanical Behavior of Biomedical Materials*, *138*, 105641. https://doi.org/10.1016/j.jmbbm.2022.105641
19. Alfattani, R., & Yunus, M. (2024). Explorations of Mechanical and Corrosion Resistance Characteristics of AA6063/TiB2/Cr2O3 Hybrid Composites Produced by Stir Casting. *Journal of Science Advanced Materials and Devices*, 100790. https://doi.org/10.1016/j.jsamd.2024.100790
20. Aravindan, S., Rao, P., & Ponappa, K. (2015). Evaluation of physical and mechanical properties of AZ91D/SiC composites by two step stir casting process. *Journal of Magnesium and Alloys*, *3*(1), 52–62. https://doi.org/10.1016/j.jma.2014.12.008
21. Kantheti, P. R., Meena, K. L., & Chekuri, R. B. R. (2024). Experimental investigation on mechanical and tribological behavior features of gr/B 4 C reinforced AA7075 alloy matrix using induction stir casting. *Cogent Engineering*, *11*(1). https://doi.org/10.1080/23311916.2024.2380806
22. Kumar, A., Kumar, S., & Mukhopadhyay, N. (2018). Introduction to magnesium alloy processing technology and development of low-cost stir casting process for magnesium alloy and its composites. *Journal of Magnesium and Alloys*, *6*(3), 245–254. https://doi.org/10.1016/j.jma.2018.05.006
23. Kumar, J., Singh, D., Kalsi, N. S., Sharma, S., Mia, M., Singh, J., Rahman, M. A., Khan, A. M., & Rao, K. V. (2021). Investigation on the mechanical, tribological, morphological and machinability behavior of stir-casted Al/SiC/Mo reinforced MMCs. *Journal of Materials Research and Technology*, *12*, 930–946. https://doi.org/10.1016/j.jmrt.2021.03.034
24. Li, M., Guo, Q., Chen, L., Li, L., Hou, H., & Zhao, Y. (2022a). Microstructure and properties of graphene nanoplatelets reinforced AZ91D matrix composites prepared by electromagnetic stirring casting. *Journal of Materials Research and Technology*, *21*, 4138–4150. https://doi.org/10.1016/j.jmrt.2022.11.033
25. Li, M., Guo, Q., Chen, L., Li, L., Hou, H., & Zhao, Y. (2022b). Microstructure and properties of graphene nanoplatelets reinforced AZ91D matrix composites prepared by electromagnetic stirring casting. *Journal of Materials Research and Technology*, *21*, 4138–4150. https://doi.org/10.1016/j.jmrt.2022.11.033
26. Liu, G., Karim, M., Wang, S., Eskin, D., & McKay, B. (2022). Processing of SiC nano-reinforced AlSi9Cu3 composites by stir mixing, ultrasonication and high pressure die casting. *Journal of Materials Research and Technology*, *18*, 2384–2398. https://doi.org/10.1016/j.jmrt.2022.03.132
27. Mohanavel, V., Ali, K. A., Prasath, S., Sathish, T., & Ravichandran, M. (2020). Microstructural and tribological characteristics of AA6351/Si3N4 composites manufactured by stir casting. *Journal of Materials Research and Technology*, *9*(6), 14662–14672. https://doi.org/10.1016/j.jmrt.2020.09.128
28. Qie, X., Zhang, Z., Li, Q., Guan, F., Fan, Z., & Jiang, W. (2023). Strengthening of compound casting Al/Mg bimetallic interface with Ni interlayer by vibration assisted treatment. *Journal of Materials Research and Technology*, *26*, 1736–1742. https://doi.org/10.1016/j.jmrt.2023.08.016
29. Ramadoss, N., Pazhanivel, K., & Anbuchezhiyan, G. (2020). Synthesis of B4C and BN reinforced Al7075 hybrid composites using stir casting method. *Journal of Materials Research and Technology*, *9*(3), 6297–6304. https://doi.org/10.1016/j.jmrt.2020.03.043
30. Tharanikumar, L., Mohan, B., & Anbuchezhiyan, G. (2022). Enhancing the microstructure and mechanical properties of Si3N4–BN strengthened Al–Zn–Mg alloy hybrid nano composites using vacuum assisted stir casting method. *Journal of Materials Research and Technology*, *20*, 3646–3655. https://doi.org/10.1016/j.jmrt.2022.08.093
31. Alfattani, R., & Yunus, M. (2024). Explorations of Mechanical and Corrosion Resistance Characteristics of AA6063/TiB2/Cr2O3 Hybrid Composites Produced by Stir Casting. *Journal of Science Advanced Materials and Devices*, 100790. https://doi.org/10.1016/j.jsamd.2024.100790
32. Daneshmand, S., Vini, M. H., Basem, A., Mohammed, A. A., Wais, A. M. H., Salahshour, S., & Hekmatifar, M. (2024). Mechanical properties of aluminum /SiC bulk composites fabricated by aggregate accumulative press bonding and stir-casting process. *Journal of Materials Research and Technology*, *31*, 3509–3514. https://doi.org/10.1016/j.jmrt.2024.07.082
33. David, P., Gopathy, V., Ravichandran, M., Mohanavel, V., Barve, A., Raja, T., Soudagar, M. E. M., Obaid, S. A., & Salmen, S. H. (2024). Fabrication and development of high temperature resisted bronze composites using 3D printed gate pattern through stir casting route. *Thermal Science and Engineering Progress*, *53*, 102710. https://doi.org/10.1016/j.tsep.2024.102710
34. Farajollahi, R., Aval, H. J., & Jamaati, R. (2022). Evaluating of the microstructure, texture, and mechanical properties of AA2024-Al3NiCu composites fabricated by the stir casting process. *CIRP Journal of Manufacturing Science and Technology*, *37*, 204–218. https://doi.org/10.1016/j.cirpj.2022.01.013

35. Hu, Z., Wu, Z., Luo, S., Wang, X., Nian, Q., Chen, Y., & Nagaumi, H. (2023). Large scale production of graphene aluminum composites by stir casting: Process, microstructure and properties. *Journal of Materials Research and Technology*, *27*, 681–691. https://doi.org/10.1016/j.jmrt.2023.09.298
36. Jolokhani, A., Razaghian, A., Moharami, A., & Emamy, M. (2023). Microstructure and tribological properties of as-cast and multi-pass friction stir processed Mg-0.5Zn-0.5Zr/SiC composite fabricated by stir casting technique. *Journal of Materials Research and Technology*, *27*, 7823–7838. https://doi.org/10.1016/j.jmrt.2023.11.205
37. Khalili, V., Heidarzadeh, A., Moslemi, S., & Fathyunes, L. (2020). Production of Al6061 matrix composites with ZrO2 ceramic reinforcement using a low-cost stir casting technique: Microstructure, mechanical properties, and electrochemical behavior. *Journal of Materials Research and Technology*, *9*(6), 15072–15086. https://doi.org/10.1016/j.jmrt.2020.10.095
38. Kumar, A., Kumar, S., & Mukhopadhyay, N. (2018). Introduction to magnesium alloy processing technology and development of low-cost stir casting process for magnesium alloy and its composites. *Journal of Magnesium and Alloys*, *6*(3), 245–254. https://doi.org/10.1016/j.jma.2018.05.006
39. Liu, G., Karim, M., Wang, S., Eskin, D., & McKay, B. (2022). Processing of SiC nano-reinforced AlSi9Cu3 composites by stir mixing, ultrasonication and high pressure die casting. *Journal of Materials Research and Technology*, *18*, 2384–2398. https://doi.org/10.1016/j.jmrt.2022.03.132
40. Mourad, A. I., Christy, J. V., Krishnan, P. K., & Mozumder, M. S. (2023). Production of novel recycled hybrid metal matrix composites using optimized stir squeeze casting technique. *Journal of Manufacturing Processes*, *88*, 45–58. https://doi.org/10.1016/j.jmapro.2023.01.040
41. Selvan, C. P., Girisha, L., Koti, V., Madgule, M., Davanageri, M. B., Lakshmikanthan, A., & Chandrashekarappa, M. P. G. (2023). Optimization of stir casting and drilling process parameters of hybrid composites. *Journal of Alloys and Metallurgical Systems*, *3*, 100023. https://doi.org/10.1016/j.jalmes.2023.100023