International Journal of Research and Development in Engineering Science
ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/
Regular Issue, Vol. 5, Issue.3 (May – June) , 2023 , Pages: 18 - 25
*Received*: 18 October 2022 ; *Accepted*: 03 May 2023 ; *Published*: 28 May 2023
https://doi.org/10.63328/IJRDES-V5RI3P4
Original Paper : Applied Research – Theoretical Research Paper

# Magnesium Metal Matrix Composites On Dry Sliding Weat Behaviour Through Stir Casting: A Review

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**Abstract:** An extensive investigation is conducted on Mg-based composites reinforced with various sorts of particles, which are manufactured by stir casting. The materials under examination include AZ31, AZX915, and AZ91 alloys, which have been strengthened with fly ash, TiC, Gr, (B4C), and carbon nanotubes. The wear behavior, mechanical characteristics, and microstructural properties of these composites are analyzed under different loads and circumstances. The findings indicate that the choice and concentration of strengthening significantly impact WRs, COF, and mechanical strength. Multiple wear mechanisms, including as abrasion, tribo-oxidation, and delamination, are acknowledged. The investigation is currently focused on the application of advanced techniques, including as vacuum SCTand ultrasonic-assisted solidification processing, to enhance the characteristics of materials. In addition, research investigates the synergistic benefits of different strengthenings, such as the combination of hard particles (TiC, B4C) and soft particles (Gr), to enhance WR. It emphasizes the significance of tribological elements, such as load, velocity, and SD. Decision trees have demonstrated effectiveness in predictive modeling when employed in machine learning models. The study contributes valuable insights to the progress of MMC that exhibit enhanced mechanical and tribological properties. The automotive and aerospace engineering sectors may find use for these composites.
Keywords:

## 1. Introduction

Mg and its alloys they have drawn countless pact of consideration because of their exceptional lightweight qualities., making them indispensable in weight reduction-focused applications. Mg (Mg) is recognized as the least heavy metal used for structural purposes, because of its special blend of low density and beneficial mechanical properties. However, it does have disadvantages, particularly in terms of its comparatively low WR. Due to this constraint, researchers have been looking into cutting-edge methods to advance the WP of Mg and related alloys. An effective approach is utilizing (MMMCs) produced via the SCT method, aiming to improve their performance in situations involving frictional wear without lubrication.

Wear is a common occurrence in engineering applications and refers to the progressive erosion of material from a solid surface caused by the movement of two surfaces in contact with each other. Wearing of this item can result in costly repairs, reduced operational effectiveness, and safety issues in certain situations. As a result, there is a strong emphasis on finding materials that have improved resistance to wear in various industries. Dry sliding wear, which happens when there is no lubrication, is especially important in engineering systems where typical lubrication solutions are neither viable or too expensive. This form of wear is commonly found in various applications, such as automotive components, aircraft systems, manufacturing equipment, and other similar contexts. Although Mg and its alloys have significant potential for use in lightweight structural applications, their limited WR has hindered their widespread use in conditions where wear is a crucial consideration. Integrating reinforcing components in the form of composites has emerged as a viable technique to overcome this constraint. (MMMCs) are a type of materials where Mg or its alloys act as the main component, while other elements with high strength and resistance to wear, such as ceramics, carbides, or metallic particles, are spread throughout the main component. The aim of this work is to advance knowledge of MMMC and their potential to advance the dry sliding WP of Mg alloys. The project aims to provide significant insights for the creation and deployment of lightweight, wear-resistant materials in engineering applications across multiple industries by

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 3, 2023 , https://doi.org/10.63328/IJRDES-V5RI3P4

analyzing the composition, microstructure, mechanical characteristics, and wear performance of these materials.

## 2. Literature Review

In their study, Dinaharan et al. (2019) investigated the application of classic SCT to successfully improve the AZ31 Mg alloy by using 10 vol.% FA particles. The WRs of the AZ31 Mg alloy, supplemented with 10% FA particles, were found to differ between the friction stir processed (FSP) and stir cast composites. The stir-cast composite exhibited a WR of 420x10-5 mm3/m. In their study, Nagaraj M. Chelliah et al. (2020) examined the SCT for enhancing the strength of the magnesium alloy AZX915 by including 12 wt % titanium carbide (TiC) particles.

The cast AZX915–12TiCp composite's WR r. Tribo-oxidation and delamination synergistically regulate wear in the heat-treated AZX915–12TiCp composite. in dry sliding conditions is mostly influenced by delamination wear. Tribo-oxidation and delamination synergistically regulate wear in the heat-treated AZX915–12TiCp composite The composite AZX915–12TiCp after heat treatment demonstrates a substantial 4.5-fold reduction in COF when related to the as-cast composite. The enhanced oxidation propensity of the heat-treated composite, which is caused by the breaking down of the $\beta$-$Mg_{17}Al_{12}$ phase acting as a barrier against oxidation, is the reason for the decrease in oxidation.

Apratim Khandelwal et al. (2017) investigated the application of ultrasound-assisted solidification processes altered the mechanical attributes of AZ31/$Al_2O_3$ Mg metal matrix nanocomposites. The study focused on the utilization of ultrasonic treatment (UST) on the molten material in two distinct scenarios: isothermal UST conducted within the furnace, and external UST implemented during the process of air-cooling. The tests utilized alumina nanoparticles at varying weight % of 0.5 wt %, 1.0 wt %, and 2.0 wt % . Romana Syeda and her colleagues (2022) examined the development of innovative materials, specifically composites made of Mg, zirconium, Gr, and garnet. The aim was to reduce vehicle costs and fuel consumption. The SCT was used to create the composites, and their tribological and microstructural properties were investigated.

The WR was mostly influenced by the applied load, but the COF was affected by the % of composite strengthening. The optimal WR was determined under the following conditions: 0.6% composite strengthening, 10N applied stress, 0.5 m/s SV, and 500 m SD. Conversely, when a 10N force was applied, the SV was 1.5 m/s, the applied load was 2500m, and the composite strengthening was 0.3%, the COF decreased. Increased loads and higher %s of strengthening led to enhanced wear performance, whereas surfaces with lower Gr content exhibited more plastic deformations and accumulation of debris. 30N applied load, 2.5 m/s SV, 500 m SD, and 0.60 percent composite strengthening were determined to be the best COF and WR.

Sutan Paulo Hang Jutanaiman et al. (2020) investigated the underlying process responsible for the enhanced hardness of composites reinforced with B4C. They attributed this improvement to the increased development of interfaces between B4C particles and pure Mg. The enhanced interfaces have a vital function in inhibiting the migration of dislocations, thereby strengthening the material. The increased abundance of B4C particles enhances the material's resistance to wear by raising its hardness, in accordance with the principles of the Archard equation, which stipulates that the rate of wear is contrariwise related to the hardness of the material. The presence of B4C particles as load-restraining components leads to a rise in the impact value, resulting in enhanced toughness and requiring greater force for material deformation. On the other hand, when the composition is 4%, a significant level of porosity results in a decrease in the impact value.

Aatthisugan et al. (2017) examined the utilization of SCT to manufacture Mg-based hybrid composites that are strengthened with (B4C) and (Gr) particles. By examining the mechanical and tribological properties, it was noted that the Gr-reinforced composites shown lower wear in comparison to both the AZ91D alloy without strengthening and the AZ91D-B4C composites. Although the UTS decreased, the WR was improved by growing the B4C content. The incorporation of both soft (Gr) and hard (B4C) strengthening's significantly enhanced the abrasion resistance of Mg composites. The results emphasize the promise of hybrid Mg composites, especially in fields such as aerospace and automotive engineering where high strength, UTS, and WR are crucial.

In their study, S. Harish Kruthiventi et al. (2023) explored the impact of wear factors on the (WR) of Mg (AZ91) composites that were supplemented with stir-casted graphene and $Al_2O_3$. The study employed the Taguchi technique to investigate the tribological parameters, including load, velocity, and SD, along with the material type (MT). The wear mechanisms, including abrasion, delamination, adhesion, and oxidation, were assessed using scanning electron micrographs. Predictive modeling, utilizing machine learning models such as ANN, ANFIS, and DT, demonstrated the decision tree exhibited the highest level of accuracy in confirmation tests.

Vida Khalili et al. (2020) investigated a cost-effective liquid state method for producing Mg/HA

(Mg/HA SMMnC) using centrifugal casting and stirring. The wear behavior was evaluated using a CSM Nano-Scratch Tester equipped with a 20 μm diamond stylus. The load (Fn) applied ranged from 3 mN to 100 mN. The scratch parameters consisted of a loading/unloading rate of 6.06 mN/min, a length of 4.5 mm, and a lateral speed of 0.25 mm/min. The microstructure analysis technique involved the utilization of (OM), (SEM), and (XRD). The (XRD) technique, employing CuK$\alpha$ radiation, and (SEM) analysis of the longitudinal surfaces of the (HIP) cylinder, provided information about the composition of the phases present.

In their study, Yashar Behnamian et al. (2021) investigated ZK60 alloy matrix composites produced through SCT . These composites contained 10 wt % boron car (B4C) and different weight concentrations of (MWCNTs) ranging from 0 to 1% by weight. Alternatively, they also examined composites with 0.5 wt% MWCNTs combined with varying amounts of 5 to 20 wt % B4C. Wear behavior was evaluated at room atomsphere using a pin-on-disk setup, applying loads of 40 N and 80 N, and sliding at a speed of 0.5 m/s. An examination of the worn surfaces and tribo-layers was conducted using SEM and EDS techniques. When subjected to low levels of stress, samples that were reinforced with multi-walled carbon nanotubes (MWCNTs) exhibited decreased friction coefficients. The WRs decreased when the MWCNT content was up to 0.5 wt %, but increased with greater B4C content. The composite having 10% B4C and 0.5% MWCNTs exhibited the highest level of WR.

Karuppusamy et al. (2019) investigated the possible positive effects of combining (DCT) with hard particle strengthening on the WR of (MMNCs). The study employed a factorial design to consider variables such as cryogenic treatment, applied stress, sliding speed, and reinforcing %. The technique of SCT was employed to fabricate WC-reinforced metal matrix nanocomposites (MMNCs), and deep cryogenic treatment (DCT) was conducted at a temperature of -190°C. Experimental results indicate that the incorporation of WC strengthening substantially enhances WR through its ability to absorb load and dissipate frictional heat during dry sliding conditions. The application of DCT resulted in the formation of a precipitate, which significantly improved the WR, particularly under high loads. The presence of precipitates and WC was verified using SEM analysis, resulting in enhanced friction coefficient, reduced adhesion, and increased WR.

Anand et al. (2020) examined the utilization of vacuum SCT for manufacturing a Mg nanocomposite. They used Mg-4Zn alloy as the base material and reinforced it with Si3N4 nanoparticles. The cost-effective technique of SCT was utilized to manufacture metal matrix composites. The microstructural evaluation demonstrated a even diffusion of $Si_3N_4$ nanoparticles within the Mg matrix. Wear experiments done at different levels of RPM revealed wear processes included abrasion and plastic deformation.
The study concludes that vacuum SCT is an effective method for producing a Mg matrix nanocomposite with desirable mechanical and wear characteristics. In their study, Avtar Singh et al. (2022) investigated the application of SCTas a method for producing Mg matrix composites containing 4% and 7% SiC. Particle distribution was analyzed using microscopy methods. The composites displayed a notable improvement in hardness when compared to pure Mg, with increases of 26.67% and 35.56%, respectively. Wear tests performed under different loads demonstrated the exceptional WR of the 7% SiC composite. Although oxide surfaces and plowing marks were present in all samples, pure Mg exhibited more pronounced ploughing marks at a force of 30 N. Furthermore, the surface of the pure Mg in its as-cast state had a greater amount of visible debris and clumping compared to the Mg-SiC composites.

In this study, Amandeep Singh et al. (2019) examined the use of automated SCTto produce Mg-based composites that include $Al_2O_3$ strengthening at varying wt %ages ranging from 3% to 12%. The composites exhibited a significant increase in hardness and resistance to wear, reaching their highest levels when the $Al_2O_3$ content was 9 wt %. However, the hardness and WR decreased when higher amounts of $Al_2O_3$ were added. The process of reducing the size of the grains and evenly distributing $Al_2O_3$ particles within the material resulted in a 32% enhancement in hardness. The adding of 9 wt % $Al_2O_3$ resulted in a 28% increase in WR under a 1-kilogram load and a 20% increase under a 5-kilogram load.

The researchers, Baljinder Ram et al. (2019), explored the effects of hot extrusion on the WP of stir-cast Mg and Mg/SiC composites. They found that the main reason of wear were oxidation and abrasion, but the use of lower COF helped reduce the severity of wear. A Mg composite was created, which was strengthened by the addition of 9% SiC (by weight). Wear experiments were performed on a disk made of EN31 steel, subjecting it to stresses varying from 1 kg to 5 kg. Optical microscopy revealed the presence of fine-grained microstructures as a consequence of the extrusion process. A comparative analysis of extruded SiC composite, as-cast Mg, Mg/SiC composite, and extruded pure Mg shown a notable improvement in WR and a reduction in friction coefficients in the extruded SiC composite. The results emphasize the crucial significance of the extrusion process in improving the durability of the composite material against wear.

In their study, S. Santhosh et al. (2022) investigated the utilization of bottom pouring SCT to

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 3, 2023 , https://doi.org/10.63328/IJRDES-V5RI3P4

improve the strength of pure Mg by using fly ash fillers at different of 2.5wt.%, 5wt.%, and 7.5wt.%. The wear test was performed at ambient temperature in agreement with the ASTM G99-04A standards. The findings demonstrated a decrease in WRs and friction coefficients with an increase in the wt %age of fly ash. Sample 4 demonstrated a WR reduction of 53% compared to pure Mg, while samples 2 and 3 showed reductions of 13% and 30%, respectively. The decrease in wear was ascribed to the rise in hardness, in accordance with Archard's wear rule, which states that there is an inverse correlation between the rate of wear and the level of hardness.

In their study, Aqeel Abbas et al. (2020) investigated the tribological properties of AZ31 Mg alloy strengthened with MWCNTs using the SCT. The specific focus of their research was on the impact of aging on these properties. The study revealed an inverse relationship between the proportion of MWCNTs and both WRs and friction coefficients. The improved microhardness and self-lubricating characteristics of MWCNTs accounted for this phenomenon. Wet sliding conditions were found to enhance WR. The microstructural investigation indicated that the primary causes of wear were oxidation, abrasion, and limited plastic deformation. The research highlighted that the incorporation of a graphitic layer at the interface resulted in the AZ31-CNT composites exhibiting a self-lubricating effect, hence reducing both wear and friction. These findings suggest that these composite materials have the potential to improve tribological performance.

The study conducted by Selvamani et al. (2017) examined the impact of varying concentrations (ranging from 2% to 4%) of CNTs on the SCT process of the Mg alloy AZ91D. By subjecting CNTto different loads (10N, 15N, and 20N), researchers saw a reduction in WRs during dry sliding tests. Conversely, the WR increased at a concentration of 4% due to localized pressures causing deformation of the matrix. The investigation revealed that increased material hardness resulted in reduced wear, while higher load exacerbated material loss by increasing pressure and friction. Ultimately, the study emphasized that when the concentration of CNT reaches 4%, the WRs may increase due to localized strains, particularly when subjected to higher loads. This is despite the initial reduction in wear observed with more CNT strengthening.

In their study, Khatkar et al. (2021) examined how several parameters, including normal load, SD, speed, and the proportions of (Gr) and (SiC), affect the rate at which self-lubricating AZ91D-SiC-Gr Mg composites experience wear during sliding. The fabrication of these composites was carried out using the SCT with the aid of vacuum. Pin-on-disc tribometer studies were performed to investigate dry sliding wear. The trials involved applying weights ranging from 10 to 50 N, sliding at speeds of 1-3 m/s, and covering SDs of 1000-2000 m. The findings demonstrated that the hybrid composites, which incorporated both SiC and graphite strengthening, displayed improved resistance to wear. The statistical study identified SD and load as the most important variables, and found that the AZ91D/5SiC/5Gr composite showed the most favorable wear characteristics. The principal wear mechanism was revealed as delamination by SEM and EDS examinations.

In their study, Sudip Banerjee et al. (2020) discussed the specific qualities of abrasive wear in AZ31-WC that had different concentrations of nanoparticles. By employing SCT together with ultrasonic vibration aid, these nanocomposites demonstrated enhanced microhardness, density, and uniformly distributed WC nanoparticles. The use of WC nanoparticles significantly enhanced the durability and friction characteristics. Upon undergoing testing with 400 grit SiC paper, the Mg-2WC nanocomposite exhibited a significant When compared to the parent alloy, there is a 56% improvement in WR. Moreover, there was a direct correlation between larger grit sizes in the abrasive paper used in the composites and a decrease in wear. The main wear mechanisms observed were delamination, adhesion, and abrasion. Nanocomposites demonstrated improved WR and a reduced number of grooves.

In this study, Avtar Singh et al. (2019) investigated the performance of Mg matrix composites created via stir casting. These composites included 10 wt % of TiC, SiC, and FA strengthening's each. The results demonstrated that these composites exhibited better WR than pure Mg. Although all composites exhibited an improvement in hardness, the Mg-TiC composite exhibited the highest level of WR. WR increased as the load increased, ranging from 5 N to 30 N, across all materials. The primary wear mechanisms seen in both composites and pure Mg were oxidation, plowing, and abrasion. However, the degree to which each mechanism occurred varied depending on the applied stress. Delamination and deep plowing were most prominent in pure Mg when subjected to a high load of 30 N. These materials have the potential to be applied in the automotive and aerospace industries.

In their study, Huang et al. (2019) explored the addition of CNTto the AZ61 Mg alloy using the SCT. The concentrations of CNTs used ranged from 0% to 1%. Sliding wear experiments were executed utilizing a ring on block wear apparatus, where an S45C counterface was used. A force of 50 N was applied, with a speed of 140 rpm, and the testing lasted for 10 minutes. The samples with dimensions ranging from 12.2 mm x 12.5 mm x 12 were used, and the change in mass was evaluated using a photoelectric weight balance before and after each experiment. The volume loss was calculated by dividing

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the mass loss by the density of the composite material.

In their study, Thirugnanasambandham et al. (2021) investigated the characteristics related to the erosion of AZ91E Mg alloy nanocomposites produced using the stir-casting method, specifically under dry-sliding conditions. These nanocomposites were enhanced with the inclusion of SiC nanoparticles. The nanocomposites showed a substantial reduction in WRs at elevated sliding speeds and loads. The nanoparticle strengthening containing 7.5 wt % SiC had the highest level of WR. Despite the fact that the increased SiC content led to a higher COF (COF), the nanocomposite containing 7.5 wt % SiC exhibited a noteworthy 68% decrease in wear when compared to the cast AZ91E alloy. This nanocomposite material is believed to be a highly promising option for automotive brake discs due to its enhanced WR and COF, surpassing the performance of traditional grey cast iron.

Jayabharathy et al. (2019) investigated the composition and properties of stir-cast hybrid MMC incorporating TiO2 and graphene. These composites were fabricated using the Mg alloy AZ91. The hardness of the hybrid composite was 10% greater than that of the base metal. The hybrid composite exhibited superior WR in dry sliding testing as compared to the AZ91 alloy. It was observed that the WRs rose as the normal load increased. Micrographs of AZ91 at a load of 80 N revealed delamination and deeper grooves, whereas the reinforced hybrid composite exhibited shallower grooves. This can be attributed to the enhanced toughness provided by graphene and TiO2. The results indicate that composites have the potential to enhance WR in applications connected to transportation. In their study, Kumar et al. (2023) investigated the application of durable ultrasonic SCT to produce a Mg metal matrix composite, AZ91, with strengthening of TiB2.

This composite was specifically tailored for utilization in automotive and aerospace sectors. The dry sliding wear experiments were conducted using a pin-on-disc tribometer, using standard loads of 30-50 N and varying sliding velocities between 1-2 m/s. The SEM, XRD, and EDX investigations demonstrated enhanced WR, as well as a well-structured grain arrangement and homogeneous dispersion of strengthening particles. Elevated loads were correlated with heightened rates of wear, predominantly attributed to adhesion, oxidation, and delamination. Conversely, a protective layer that was mixed mechanically was observed when the sliding velocities were high. The composite exhibited superior performance compared to the base alloy due to its heightened hardness and enhanced interfacial adhesion between the matrix and strengthening.

Dash et al. (2020) explored the abrasion and mechanical properties of Mg/TiC composites in relation to the AZ91D Mg alloy. The composites were fabricated using the SCT method, with the TiC at various %s ranging from 0% to 20%. The addition of a higher amount of TiC greatly improved the Mg alloy's UTS, percent elongation, compressive strength, and microhardness. The fracture mechanisms in specimens subjected to compression and tension were examined using (SEM). The (WR) and (SWR) were evaluated using a (POD) tribotester under dry sliding conditions. The tests were conducted at different weights (10N, 30N, and 50N) while maintaining a constant SD and speed (1000 m and 1 m/s). The worn pin was subjected to surface analysis using SEM inspection.

## 3. Procedures And Techniques

The components were used as strengthenings or additives in the production of a variety of Mg matrix composites for a wide range of applications., including the automotive and aerospace sectors, in order to improve WR and mechanical qualities.

The creation of these composites commences with the preparation of the Mg matrix. Commercially pure Mg ingots are fragmented into smaller pieces, rendering them appropriate for the SCT procedure. The Mg is subsequently liquefied inside a regulated setting, commonly in a furnace with temperatures reaching up to 700°C.

The liquid Mg is agitated violently by a steel impeller moving at a speed of 450 revolutions per minute. Throughout the agitation procedure, the heated reinforcing materials (SiC, titanium carbide, or fly ash particles) are progressively added to the liquid Mg. The agitation persists for roughly 20 minutes to guarantee complete amalgamation, yielding a uniform composite material. The liquefied composite material is subsequently poured into a mild steel mold with a cube shape, typically measuring 80x80x80 mm, in order to form the intended composite structure.

Importantly, the entire SCT process is conducted within a protective atmosphere of shielding gases, such as SF6 and Argon gas. This environment inhibits the oxidation of the components during the casting procedure. Both pure Mg specimens and composites, which are strengthened with SiC, TiC, and FA, are fabricated into square cross-section pins for the purpose of conducting wear testing. This allows for the evaluation of WR. An analysis of the microstructure of the specimens is conducted to evaluate the distribution of reinforcing particles inside the composites. The approach entails sectioning 20x20 mm plates from the casting specimens, subjecting them to typical polishing techniques, and subsequently immersing them in an etching solution. The resultant microstructure

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is analyzed utilizing (SEM) and (EDS). This investigation offers a comprehensive understanding of the distribution of reinforcing particles within the Mg matrix.

Following that, Vickers hardness measurements are performed on polished samples of both pure Mg and composites. These measurements yield data on the material's hardness characteristics and aid in evaluating its durability against abrasion.

The WR of the composites and pure Mg is evaluated using a pin-on-disk testing machine. Wear tests are performed using varying loads on a revolving disk composed of EN31 alloy steel. Prior to testing, specimens undergo polishing using emery paper. The tests are then conducted under air circumstances, with a prescribed SD of 1800 meters. Weight measurements are conducted prior to and during the tests in order to determine the mass reduction (in grams) for each sample.

Furthermore, the specimens' worn surfaces are studied utilizing SEM to get insight into the wear mechanisms that happened during testing. Measurements of the COF are also taken during the testing to evaluate the materials' frictional characteristics.

The data collected from hardness tests, wear loss measurements, and COF records is examined to assess the wear behavior and wear mechanisms of the various materials in different settings. This complete methodology enables a meticulous evaluation of the manufactured Mg metal matrix composites and their effectiveness in terms of their ability to withstand wear.

## 4. Findings and Analysis

Multiple studies have shown that determining the optimal strengthening or combination for Mg alloy is challenging. This is because the selection of the reinforcing material and its ability to enhance WR might vary depending on the unique applications and needs. Nevertheless, a comprehensive analysis derived from the data:

Boron Carbide Strengthening: The studies conducted by Sutan Paulo Hang Jutanaiman et al. (2020) and Ashashar Behnamian et al. (2021) have shown that the adding of B4C strengthening effectively increases WR. Some of the mechanisms that were examined include the development of robust interfaces and the enhancement of hardness.

Kumar et al. (2023) explored strengthening of AZ91 Mg composites with TiC. They discovered that the addition of TiC resulted in enhanced WR, particularly under high shear rates. Improved rigidity and bonding interfaces contribute to enhanced durability.

(SiC) is used as a reinforcing material. In their study, Thirugnanasambandham et al. (2021) examined the effects of incorporating SiC nanoparticles into AZ91E Mg composites. They observed a notable decrease in wear, particularly under conditions of high shear and stress.

According to a study by Aqeel Abbas et al. (2020), the inclusion of Multiwalled Carbon Nanostructures (MWCNT) in Mg alloy AZ31 resulted in an enhancement of its WR. (MWCNTs) have demonstrated inherent self-lubricating characteristics, resulting in a reduction in both wear and friction.

Enhancement of Graphene with Titanium Dioxide (TiO2): S. Jayabharati et al. (2019) examined the use of AZ91 Mg alloy together with Graphene and TiO2 are mixed to create hybrid composites. They found that these composites exhibited enhanced resistance to wear, resulting in narrower wear grooves. The efficiency of a particular strengthening is contingent upon several elements, such as the application, load conditions, shear rate, and environmental variables.

Moreover, the selection of strengthening can impact several characteristics, including rigidity and mechanical robustness, which could hold significance in particular use cases. Hence, the selection of the optimal fastening device should be predicated upon a comprehensive examination of the precise demands and circumstances of the planned use. Moreover, it is crucial to integrate the findings from many studies in order to arrive at a well-informed judgment regarding the optimal strengthening for a certain application.

## 5. Conclusion

The domain of metal matrix composites (MMCs) investigation encompasses a substantial and valuable corpus of research that examines the mechanical properties, WR, and prospective uses of these sophisticated materials. These studies offer crucial insights for the development and implementation of MMCs across many sectors. The subsequent are significant inferences to derive from this comprehensive investigation:

Enhanced Mechanical capabilities: Several tests have demonstrated significant enhancements improve the mechanical capabilities of metal matrix composites by adding various strengthening materials, such as nanoparticles, carbides, and oxides. The improvements encompass heightened hardness, tensile strength, and WR, resulting in significant advantages for the overall performance of MMCs.

Improved WR: Numerous research have prioritized the enhancement of WR in Metal Matrix Composites (MMCs), especially for components that are subjected to friction and abrasion. These discoveries have significant practical consequences, as they can help in developing MMCs are used in a variety of applications, such as automobile components and industrial gear.

Weight reduction is a critical goal, particularly in industries such as automotive and aircraft. Experiments involving Mg-based metal matrix composites (MMCs) have shown that they can significantly reduce weight without sacrificing mechanical performance. This channel has opportunities for enhancing fuel efficiency and promoting environmental sustainability, in line with global objectives.

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