Magnesium Metal Matrix Composite And Its Application: A Review

R. Ram Kumar[1], N. Rajasekar[2], M. Ramprasath[3],S. Selventhiran[4], M. Vethashiva[5]
[1, 2, 3, 4, 5] Dept of Mechanical Engineering
[1, 2, 3, 4, 5] K. Ramakrishnan College of Technology, Trichy-621112.

Abstract- *Magnesium matrix composites are potential materials for various applications of aerospace and defence organisations due to their low density,good mechanical and physical properties. Magnesium metal compare to aluminium metal is low density and low weight so most are used for aerospace application and automobile industries. This paper over review about the effect of the different type of reinforced particles on magnesiummatrix and the reinforced particles on the microstructure, hardness, impact, tensile strength and wear properties.*

Keywords- Mg alloy,Zirconium oxide,Nanopowder, Stir casting.

I. INTRODUCTION

Magnesium alloy used in aircraft and missile component, aircraft engine mounts, control hinges, fuel tanks, wings, housings, transmission cases, engine blocks, Bicycles and other sporting equipment, Equipment for material handling, Ladders, Laptops, televisions, cell phones, Luggage, Portable power tools, chainsaws, hedge clippers, weed whackers, Printing and textile machinery, Steering wheels and columns, seat frames [1-5].Magnesium metal matrix composites have been receiving attention in recent years as an attractive choice for aerospace and automotive application because of the low density and superior specific properties.It is the most abundant material in the earth.It is found in large deposits in minerals such as magnesite and dolomite. The sea contains trillions of tonnes of magnesium, and this is the source of much of the 850,000 tonnes now produced each year. This is 2% of the Earth's crust by weight, and it is the third most plentiful element dissolved in seawater. It’s also found in seawater, underground brines and salty layers [6].stir casting is a liquid state method for the fabrication of composite materials, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. It is the simplest and the most cost effective method, flexible, economical and suitable for mass production [7]. Good matrix-reinforcement interface and near net shapes.Zirconiumdioxide (ZrO_2) most naturally occurring form, with a monoclinic crystalline structure, is the mineral baddeleyite. A dopant stabilized cubic structured zirconia, cubiczirconia, is synthesized in various colours for use as a gemstone and a diamond simulant[8]. The main use of zirconia is in the production of hard ceramics, such as in dentistry, with other uses including as a protective coating on particles of titanium dioxide pigments, as a refractory material, in insulation, abrasives and enamels [9].

II. MAGNESIUM MATRIX COMPOSITES

Yousef Mazaheri et al.,has employed to treat the surface of AZ31 magnesium alloy and the addition of ZrO_2 nanoparticles to produced surface nanocomposite by FSP [10]. The wear performance of the samples was evaluated against AISI 52100 steel counterpart. Microstructural investigations indicated that FSP leads to significant grain refinement. By adding ZrO_2 nanoparticles and also increasing pass number this refinement intensifies in such a way that after four passes of FSP, the average grain size of the nanocomposite decreased to about 2μm. The SEM micrographs showed that ZrO_2nanoparticles were dispersed regularly in the AZ31 without any agglomerates or clusters after four passes of FSP.To increased ZrO_2 nanoparticles, as well as increasing the FSP pass number, hardness values of the sample increased significantly. The micro hardness of nanocomposite fabricated by four passes of FSP improved nearly 90%. Wear resistance is affected by the presence of ZrO_2 nanoparticles and increasing pass number. The wear rate of the four passes FSPed nanocomposite (4-pass NC) was about half of the as-received AZ31. The worn surface, wear track cross-section, counterpart tip and wear debris indicated that the wear mechanism changed from severe abrasion and adhesion for AZ31 base metal to mild abrasion for the 4-pass FSPed AZ31/ZrO_2 nanocomposite.

Sarita et al., wasused to synthesis Nano-ZrO_2 particulates containing magnesium composites by stir casting method [11]. Microstructural characterization shows significant grain refinement, non-uniform distribution of reinforcement particulates. The results of mechanical characterization revealed the presence of Nano ZrO_2 particulates in magnesium matrix lead to significant improvement in UTS value but adversely affect ductility. Mohsen Hajizamaniet al., has developed Al-alloy based composites reinforced with Al_2O_3-10% ZrO_2 nanoparticles were fabricated by stir casting at 850˚C [12]. It was concluded that by increasing the reinforcement content, density decreased while yield, ultimate tensile strength and compressive strength increased. Ductility's of the composites were low because of high porosity content, early void formation at low strains during tensile elongation and heterogeneous particle distribution.

AZ31/ZrO_2 composites with various volume percentages of ZrO_2 have been successfully fabricated using stir casting method [13]. Micrograph of the produced composites confirms the uniform distribution of ZrO_2 particles and good bonding between reinforcement and the matrix alloy. Significant refinement in grain size from 70 µm to 20µm was observed in ZrO_2 reinforced composites. The mechanical properties of the composites increased with increase in ZrO_2 particles. The hardness, proof stress and tensile strength of the developed composites significantly improved by 65, 33 and 41% respectively compared the matrix alloy. However, the ductility of the composite sample decreased with increase in ZrO_2 addition. The tensile fracture surfaces of AZ31 alloy revealed the presence of ductile fracture, whereas the composites revealed the presence of cleavage fracture. Magnesium based metal matrix composites were successfully prepared by stir casting technique. The uniform distribution of B_4C reinforcement particles and good interface bonding between Mg/B_4C particles was observed in cast composites. The unreinforced Mg exhibits ductile type of failure, whereas the fracture surface of composites shows brittle failure.

Mohammadi et al., has the effects of B_4C addition on the microstructure, mechanical and wear properties of AZ91 magnesium alloy in the as-cast and extruded conditions [14]. The microstructural studies revealed that the amount of Mg17Al12 phase is reduced to some extent by adding B_4C particles the cast MMCs, showing good bonding between B_4C and matrix, appropriate distribution of B_4C in the matrix with no serious agglomerated particles. The extrusion process showed significant effects on the shape and size of Mg17Al12 intermetallic and grain size of the matrix. By increasing the B4C contents, not only the weight loss of the composite specimens was reduced, but also the friction coefficient was increased significantly. Worn surface observation suggested that the dominant wear mechanism for AZ91-xB_4C composites was oxidation assisted abrasiveSiC particle reinforced Magnesium MMCs have higher wear and creep resistance compared to Al_2O_3 reinforced Magnesium MMCs.The wear resistance of Al2O3 independently reinforced magnesium matrix composite is higher than that of the CNTs independently reinforced magnesium MMCs.Reinforcement of CNTs in the matrix of magnesium and its alloy improved the wettability and bonding strength of the composites [15]. Sliding wear resistance of Magnesium MMCs is betters compared to that of the base alloy. Dense B4C/Mg composites with homogeneously distributed B_4C particles within the magnesium matrix was processed by a processing condition at 993K for 120 minute with 6 vol.% or above of metal powder Ti is added into B4C ceramic preform.

The magnesium matrix composites reinforced by stainless steel (Fe–18Cr–9Ni), titanium alloy aluminium alloy (Al–5Mg–3Zn), were prepared by the pressure infiltration technology [16]. The reinforcements of the composites are interwoven with the matrix and have an integrated interface. The grain size and distribution in the as-cast magnesium matrix composites have the same characteristics, and their sizes are mainly concentrated at 200–300 µm, and the size distribution is random and does not obey normal distribution. The extrusion process, the grain size of magnesium matrix composite is more refined than that of the as-cast state, because of the dynamic recrystallization and the superposition of shear strain, and its size is mostly concentrated at 10–30 µm. Different MIMCs with different reinforcements exhibit different mechanical properties. Among the three composite materials, the tensile strength, yield strength, and elongation of MISC are 355 MPa, 241 MPa, and 13%, with an increase of 47.9%, 60.7%, and 85.7%, respectively; while for MITC, they are 340 MPa, 220 MPa, and 12%, with an increase of 41.7%, 46.7%, and 71.4%, respectively; and for MIAC, are 280 MPa, 175 MPa, and 8%, an increase of 16.7%, 16.7%, and 14.3%, respectively.

Song-Jeng Huang et al., has explained the micro hardness of 2 wt% SiC/AZ61 Mg MMC shows a higher ductile response at 12 h ageing time [17]. The ageing time increased to 36 h, the discontinuous secondary phases were changed to continuous laminar structures. For 12 h aged 5 wt% SiC/AZ61 Mg MMC the brittle Mg_2Si phase was revealed. XRD patterns of AZ61 magnesium alloy shows the formation of single crystal structure at homogenization heat treatment condition and the formations of Al12Mg17 secondary phase at 12 h ageing time. However, in the case of 2 and 5 wt% SiC the formations of heterogeneous phases were detected at different heat treatment conditions. Most importantly, a nanocrystal line 51.6% of ductile MgSiO3 phase was detected in the 12 h aged 2 wt% SiC/AZ61 Mg MMC. For 5 wt% SiC, the brittle phase Mg2Si was detected throughout the whole heat treatment processes. By using the Williamson-Hall method, the maximum average crystallite size and microstrain distributions were found to occur in the 12 h aged 2 wt% SiC/AZ61 Mg MMC.

Apratim Khandelwal et al., has explained the Microstructural observations revealed a reasonably uniform distribution of Al_2O_3 nanoparticles in the Mg matrix after ultrasound-assisted stir casting [18]. The addition of nanoparticles and introduction of UST resulted in significant improvements in mechanical properties of both types of composites. AC-UST composites exhibited animprovement in ductility with increasing alumina content. However, a considerable reduction in the ductility of Iso-UST composites was observed which can be correlated with a transition from quasi-cleavage fracture to a more advanced brittle fracture, as revealed by the fracture surfaces of the tensile specimens. The strengthening contribution due to the particles is significantly high and increases with an increase in the concentration of the Nano-alumina particles. The strengthening contribution due to CTE mechanism dominates over Orowan mechanism by a large factor, for any volume fraction of alumina nanoparticles used.

Pin-on-disc dry sliding wear tests of Mg9Al alloy and its 8vol.% SiC-reinforced composite pins against a steel counterface were carried out under loads of 10 and 30N, and over a range of sliding speeds from 0.2–5m/s [19]. The composite generally exhibits better wear resistance due to its superior load-bearing capacity and its ability to maintain a stable oxide film, which protects against metal-to-metal contact with the steel counterface during sliding. A transition from oxidation to delamination and abrasion occurs with an increase in applied load to 30N. The wear resistance of the composite deteriorates as the presence of a second phase promotes delamination wear. A gradual transition from delamination and abrasion to adhesion takes place with a rise in sliding speed under the higher load. The composite once again shows slightly improved wear resistance due to its higher load-bearing capacity. At even higher speeds, increased frictional heating leads softening and melting. The massive plastic deformation experienced by the pin under 30N and 5m/s limits the use of the MgAl alloy and its composite to milder sliding conditions.

The presence of SiC does not appear to be beneficial in reducing wear rates or delaying such thermally activated processes.Jiang et al., was explained magnesium matrix composites reinforced with TiC particles can be fabricated by adding a TiC–Al master alloy processed via SHS reaction into molten magnesium and using the semi-solid slurry stirring technique [20]. TiC particles in the master alloy are fine, spherical, and since TiC particles are surrounded by aluminum, the particle surfaces are uncontaminated, which makes the wetting of TiC particles in the magnesium alloy significantly improved. Also by stirring, a PRMMC with dispersed homogenously clean fine TiC particles embedded in a magnesium alloy matrix can be obtained. The properties of the PRMMC prepared such as UTS, hardness, and wear resistance are higher than those of the unreinforced magnesium.

Magnesium AZ31B alloys filled with micron sized tungsten carbide composites were remarkably prepared through low cost stir casting process. SEM photographs display the almost homogeneous distribution of WC in the Mg matrix [21]. The macro-hardness and UTS of AZ31B/WC MMCs enhances with augment in wt% of WC. The mechanical properties of the developed composites are improved with the augment in filler content when compared to the plain Mg matrix alloy. The manufactured composites are widely suitable for various renewable energy applications like wind mill blades and solar panels based components.

A uniform and continuous Si coating was obtained, and the effective fabrication of CNT-reinforced metals depends on the homogenous dispersion of CNTs in the metal matrix and the interfacial adhesion between them [22]. Silicon powder has been effectively coated on the surface of MWNTs and well covered and continuous. The solid reaction method for the Si-coat MWNT nanocomposite has made very simple, inexpensive and high mass. TEM observations show that the interface between MWNTs and matrix is wettability and in good adhesion. The analysis results of Raman spectroscopy and structure properties of MWNT, SEM images of MWNTs suggest that after solid reaction, the smooth MWNTs surface become rough, and the surface defects of Si-coat MWNTs are enhanced, but the integrity of the MWNTs patterns is not damaged.

Zheng et al., revealed therefined and uniform microstructure of Mg/2wt. SiCwas obtained; the SiC nanoparticles contribute to grain refinement bystimulating the dynamic recrystallization (DRX) nucleation [23]. A strong {0 0 0 2} basal texture formed in bothmonolithic Mg and Mg/2wt.%SiCp during ARB process,and the addition of SiC nanoparticles could weaken the basal plane. After fourteen ARB cycles,Mg/2 wt. SiC exhibited (0 0 0 2) ⟨1 1 −2 0⟩recrystallization texture. Nanocomposite exhibitsmuch better mechanical properties than raw magnesiumand monolithic magnesium. The UTS, YS,microhardness, and elastic modulus of nanocompositeare significantly increased by about 17.6%, 61%,72.7%, and 80.8% compared to those of raw material,respectively.

Monolithic AZ81 and the AZ81/Si_3N_4 nanocomposite can be successfully synthesized using the DMD technique followed by hot extrusion [24]. In tension, the AZ81/Si_3N_4nanocomposite stress strain curve was overlapping the AZ81 curve. In compression, the AZ81/Si_3N_4nanocomposite stress strain curve was above the AZ81 curve. This can be attributed to the AZ81-Si_3N_4nanoscale interface being relatively less adequate in tension but relatively more adequate in compression. In both cases, reduction in size of Mg-Al second phase supported hypothetical decrease in strength. The tensile failure strain increase in the AZ81/Si_3N_4nanocomposite compared to monolithic AZ81 can be attributed presence and reasonably uniform distribution of ceramic nanoparticles and Si_3N_4nanoparticle induced regulated precipitation of MgAl second phase. Within the structure of composites with a magnesium alloy AZ91 metal matrix strengthened with ZrO_2 particles [25]. Over grain boundaries conglomerates of ZrO_2 particles are present, and within the matrix there are particles of Mg17A12 intermetallic.Particles of ZrO_2 facilitate an increase in hardness and wear resistance of the composites studied.Wear mechanism for a composite is abrasive of AZ91/ZrO_2 composites was good wear resistance.

III. CONCLUSION

It is concluded that magnesium alloy with reinforcement is clearly better to base alloy. It improves the mechanical properties with their excellent quality of tensile strength,hardness and wear resistance. Tensile properties of magnesium cast alloy is also presents a better result has compare to matrix material, but sometimes presence of porosity may cause not so much desirable results. It is also concluding that after adding of reinforcement to the matrix material properties such as mechanical and thermal are also improving compare to matrix material.

REFERENCE

[1] Hong Yan, Mingfu Fu, Fayun Zhang, Guoxiang Chen, (2007),Research on Properties of SIC/AZ61 Magnesium Matrix Composites in Fabrication Processes.Trans Tech Publications.Vols 561-565.

[2] C. Badini a, M. Ferraris a, F. Marchetti, (1994).Interfacial reaction in AZ6 1 /AZ9 1 /P 100 Mg/graphite composite an Auger spectroscopy investigation. Elsevier.

[3] Muhammad Rashad, Fusheng Pan, Dong Lin, Muhammad Asif (2015),High temperature mechanical behavior of AZ61 magnesium alloy reinforced with graphene Nano platelets. Materials Design

[4] S. F. Hassan1, M. J. Tan*1 and M. Gupta, (2007),Development of nano-ZrO2 reinforced magnesium nanocomposites with significantly improved ductility.Maney on behalf of the Institute

[5] Xin Shu, YuxinWang, ChumingLiu, AbdullahAljaafari, WeiGao, (2014), Double Layerd Ni-P/Ni-P-ZrO2 electro less coatings on AZ31 magnesium alloy with improved corrosion resistance. Elsevier

[6] S.Jayalakshmi, S. Seshan, S.V. Kailas, K. Kumar and S. Srivatsan, (2004),Influence of processing and reinforcement on microstructure and impact behaviour of magnesium alloy AM100. S Jayalakshmi.

[7] Zhang Xiuqing, Wang Haowei, Liao Lihua, Teng Xinying, (2005), The mechanical properties of magnesium matrix compositereinforced with (TiB2 + TiC) ceramic particles. Elsevier.

[8] Aatthisugan, A. Razal Rose, D. Selwyn Jebadurai, (2016),Mechanical and wear behaviour of AZ91D magnesium matrix hybrid composite reinforced with boron carbide and graphite. Elsevier.

[9] S.C. Sharma, B. Anand, Krishna, (2000), Evaluvation of sliding wear behaviour of feldspar particle-reinforced magnesium alloy composite. Elsevier.

[10] Yousef Mazaheri, Mohammad Mahdi Jalilvand, Akbar Heidarpour, Amir Reza Jahani, (2019),Tribological behavior of AZ31/ZrO2 surface nanocomposites developed by friction stir processing. Elsevier

[11] Sarita, Ravindra m lathe, (2017),Synthesis, Mechanical and Microstructural Behaviour of AZ91/NANO ZrO2 Stir Casted Magnesium Metal Matrix Composites.IJITR,Volume No.5, Issue No.4,6951-6954.

[12] Mohsen Hajizamani, Hamidreza Baharvandi, (2011),Fabrication and Studying the Mechanical Properties of A356 Alloy Reinforced with Al2O3-10% Vol. ZrO2 Nanoparticles through Stir Casting.Sciencific Research, volume 1, pp 26- 30.

[13] T Satish Kumar, (2019),Characterisation of AZ31/ ZrO₂ composites produced via stir casting. Material Research Express.

[14] H. Mohammadi, (2019),The microstructure, mechanical and wear properties of AZ91x%B₄C metal matrix composites in as-cast and extruded conditions. Material Research Express.

[15] Amandeep Singh, Niraj Bala, (2017), Evaluation of Microstructural and Mechanical Behavior of Some Magnesium Metal Matrix Composites. Advance Material and Manufacturing characteristics. Vol. 7 Issue2

[16] Shuxu Wu ShourenWang, Daosheng Wen, Gaoqi Wang and Yong Wang, (2018), Microstructure and Mechanical Properties of Magnesium Matrix Composites Interpenetrated by Different Reinforcement. Applied science.

[17] Song-Jeng Huang, Addisu Negash Ali, (2017),Effects of heat treatment on the microstructure and microplastic deformation behavior of SiC particles reinforced AZ61 magnesium metal matrix composite. Elsevier.

[18] 18. Apratim Khandelwal, Karthick Mani, Neeraj Srivastava, Rahul Gupta, G.P. Chaudhary, (2017),Mechanical behaviour of AZ31/Al_2O_3magnesium alloy nanocomposites prepared using ultrasound assisted stir casting. Composites.

[19] C.Y.H. Lim∗, S.C. Lim, M. Gupta, (2003),Wear behaviour of SiCp-reinforced magnesium matrix composites, Elsevier.

[20] Q.C. Jiang,X.L. Li, H.Y. Wang, (2002),Fabrication of TiC particulate reinforced magnesium matrix composite. Scripta materialia.

[21] R.Praveenkumar,P. Periyasamy,V. Mohanavel,D. Chandra Mohan, (2018),Microstructureandmechanical properties of mg/wc composites prepared by stir casting method.Scopus Indexed, Volume 9, Issue 10, pp. 1504–1511

[22] Yongha Parka, Kyungmox Choa, Ikmin Parka, (2011),Fabrication and mechanical properties of magnesium matrix composite reinforced with Si coated carbon nanotubes. Elsevier.

[23] Yan Yan, Hua Zhang,a) Jianfeng Fan, Lifei Wang, Qiang Zhang, and Minjian Hou, (2016)Improved mechanical properties of Mg matrix composites reinforced with Al and carbon nanotubes fabricated by spark plasma sintering followed by hot extrusion. Crossmark

[24] MuralidharanParamsothy, Jimmy Chan, Richard wok and ManojGupta, (2011),TiCNanoparticleAdditiontoEnhancetheMechanical Responseof HybridMagnesiumAlloy. Research Article,Volume 2012, Article ID 401574, 9 pages

[25] Fatih Aydin and Yavuz Sun, (2019), Microstructure and wear of a sintered composite with magnesium alloy AZ91 matrix reinforced with ZrO_2Particles. Springer Science. Vol. 61, Nos. 5 – 6.