DETAILED STUDY OF ALUMINIUM METAL MATRIX COMPOSITES PROCESSED BY STIR CASTING METHOD

Neerja Parmar[1] , Mr. Rajkumar Duhan[2], Ashish[3]
[1]Student, M.Tech (Mechanical Engineering) Department of Mechanical Engineering, UIET, MDU Rohtak-124001
[2] Professor Department of Mechanical Engineering, [3]Research Scholar, UIET, MDU Rohtak-124001

Abstract—- **The shift of research work from solid aluminum to composite materials like Metal Lattice Composites (MMC's) is a result of world– wide stipulation for prudent and predominant quality materials. The main aim is to improve the process parameters for producing the aluminium metal composites. Metal matrix composites particularly aluminum matrix composites (AMC's) because of their amazing quality as for their weight, prevalent wear protection, temperate and high consumption protection are broadly created and used in a few applications like, building parts, auxiliary applications, aviation, vehicle industry, deliver building and many games things what's more, electrical and electronic parts. The reinforcements like SiC, B4C, Al2O3, TiB2, Red mud, Graphite, Fly ash remains, and Coconut ash and so forth can be effortlessly joined as fortification operators in the liquid soften by utilizing the conservative and generally utilized by stir casting system, which enhances quality, solidness, fatigue, hardness, wear and creep properties of the AMCs. This paper gives a view of mechanical, microstructural and wear exhibitions of aluminum focused metal matrix composites created by stir casting process reinforced with single and numerous sorts of reinforcements. The issues like support metal lattice holding, dispersion of particles, wettability of fortifying particles and agglomeration wonder are examined in this paper. The impact of different fortification particles on aluminum metal matrix composites on mechanical properties like uts, ys, stiffness, hardness, fatigue, % E, wear and on coming about microstructure is talked about. The Modified and double step stir casting method for the creation of AMCs is likewise talked about in this paper.**

keywords: Aluminum matrix composite (AMC), stir casting, reinforcement, mechanical properties, wear behaviour.

I.INTRODUCTION

Metal based matrix composites augmented with ceramic agents have a wide range of applications in aerospace, automobile, structural components and defence sector. There occur some constrains for monolithic aluminium alloy to achieve mechanical properties like stiffness, toughness, strength, density and wear resistance . To prevail over these deficiencies encountered in metallic alloy metal based matrix are prepared to meet the global demand

For light weight materials with properties like high specific resistance, corrosion resistance, higher stiffness and excellent wear resistance properties [1-2]. Aluminium alloys were chosen to be a matrix material in MMC's because they possess different characteristics such as low density, light weight, easy processing techniques and fine engineering charactericts. [3]. The aluminum matrix series like AA2xxx, AA5xxx, AA6xxx, and AA7xxx have abundant utilizations in aerospace, defence instrument, architectural and structural components, automobile, sport goods and ship building [1-4]. There are various methods that can be emplyed to produce the metal based matrix alloys. The resulting composite microstructure will majorly depend on the type of method used for fabrication and there can be alterations in the dispersion of ceramic agents, interfacial bonding between the matrix phase and reinforcement particle and mechanicalperformances [5]. The fabrication method that has to be used will depend on the type of metal and reinforcement. There lies many drawbacks in the manufacturing of aluminium based MMC's due to costly fabrication and reinforcement material.There is a great need for finding out economical ways of fabricating AMC's for elaborating their applications and properties. Two methods which are economical and easy are Stir casting and modified stir casting techniques and are highly attracting researchers. There arE many other different manufacturing processes available such as in-situ casting, powder metallurgy and squeeze casting these techniques are higly economical and easy. This paper depicts an outline of fabrication of aluminum based metal matrix composite (AMC's) with the help of stir casting method and presents the scope of

Improving the wear performance, mechanical and microstructure.

II. MATERIALS AND METHODS

1.Stir casting

Stir casting is an economical and conventional process to manufacture AMC's , in the aluminium matrix melt micron sized particles of SiC, Al2O3, TiC, MgO, B4C etc are taken as reinforcement material and are incorporated in the aluminium matrix melt with the help of forced vortex stiring action. In order to attain an defect free microstructure the key challenge is that the reinforcement agent should be dispersed homogeneously in the matrix melt.The reinforcement composite used may either have particulate form or fiber form and what should be choosen depends on the size. Particle form of reinforced composites are choosen over fiber form of reinforced composites because particulate reinforced composites are economical and are have suitable fabricating techniques. In beginning period detailed writing of stir casting was first presented in 1968 by S.Ray.Ray fused Al2O3 particles into aluminum liquefy by mixing liquid al-alloy conveying the support (reinforcement) particles [6]. Mechanical vortex mixing of thick metallic liquefy in the furnace is the main key constituent of this procedure. The charged al-alloy dissolve containing strengthening operators would then be able to be prepared by using any technique like mold casting ,sand casting or die casting and so on. Stir casting technique is fitting to deliver composites upto 30 vol. % part of particles fortification [7-8]. Numerous aluminum framework composites with different lattice arrangements, for example, AA6061 [9], AA6063 [10], Al-Si-Fe amalgams [11], AA1070 and AA6063 [12], AA356 [13], AA6061 [14] have been created effectively utilizing stir casting system. A homogeneous dispersion and solid holding of optional particles in the composite matrix is basic for executing a high quality. The uneven dissemination and feeble holding can prompt untimely disappointments in fortification rich and support free zones. In support free regions under a connected load, slip of disengagements and starts of microcracks can happen effectively, in the long run bringing about failure of the material. Agglomeration or grouping of strengthening particles causing a feeble bond development, which can bring to decrease the mechanical properties. The homogeneous scattering of the artistic specialists in the subsequent throwing depends on the power of blending, wettability between the liquid soften and support particles cementing time. Two stage mixing is the current and intriguing development in stir casting system [17]. In this procedure, initially the matrix alloy is warmed over its liquidus temperature to guarantee finish melting. The temperature of the liquid metal is then drops down in the middle of the liquidus and solidus focuses with the end goal that the liquid slurry remains in a semi-solid state. The preheated support particles are blended into the semi-strong slurry by manual mixing at this stage. The slurry containing the support particles is again warmed recently over its fluids temperature and at this stage blending is finished with the assistance of a reasonably outlined mechanical stirrer. The acquired microstructure of the composite made by two stage blend throwing process is more uniform than that created with customary stirring mechanism. The primary preferred standpoint of double step stir casting process is essentially attributed to its capacity to split the layer of gas around the surface of the support particles. The wettability between the liquid soften and strengthening particles is decreased because of the retention of thin layer ofgas around the surface of support particles. The blending of the strengthening operators in the gooey state helpsmore viably to break the layer of gas as a result of the grating activity of the high consistency of the liquid melt.The expansion of reasonable mixing component like mechanical mixing, divergent mixing, and electromagnetic mixing upgraded the utilization of mix throwing method for metal composite handling[18].

B.Wettability.

Wettability in matrix alloy and fortifying particles is a standout amongst the most urgent factor in fluid metal dealing with and preparing. In stir casting method when the wettability is less the mechanical mixing push is essential to beat the surface vitality obstruction to make a capable bond between the fortification stages and the fluid metal. The surface vitality of support and grid material and the surface condition of the earthenware particles are the two critical factors on which the wettability between the network material and fortification stage to a great extent depends [19]. Wettability between metal network and clay stage can be upgraded by diminishing the surface strain of the liquid metal, expanding the surface vitality of the strong and diminishing framework molecule interface vitality through adding added substances to dissolve, covering of particles, subjecting the liquefy to ultrasonic light and warming and cleaning of the particles [20-21]. The expansion of Mg metal powder enormously improved the scattering of Silicon carbide particles in the composite just before the presentation of the strengthening specialists or ahead of time expansion of the fortifying particles with a blend of magnesia and zirconia of appropriate structure [22]. Wettability can likewise be expanded by cleaning the fortification surface on the grounds that the presence of firm layer of oxide on the earthenware performs block the wetting and penetration [23]. To overcome the issue of wetting amongst B4C and liquid aluminum dissolve, titanium having transition (K2TiF6) was utilized when the composite was created by blend throwing course. The microstructural examination of both as-cast and warmth treated examples with or without the presentation of titanium was completed utilizing SEM investigation. The arrangement of response layer was additionally analyzed with EDS examination and X-beam mapping. It was discovered that the microstructural perception by high determination field discharge firearm SEM (FEG-SEM), wetting enhanced by the development of thin TiC and TiB2 response layers [12].

III. RESULTS AND DISCUSSIONS

1.*Mechanical and Microstructural examination*

The examination of mechanical conduct of a composite material is especially relies upon a few components for example, sort of strengthening particles, measure of fortification, size and state of particles and so forth. Composite materials have a few applications in various ranges, so an appropriate comprehension of mechanical and microstructural conduct of composite materials is exceptionally indispensable. In 1989 Kamat et al.[24] inspected the mechanical properties of AA2024 fortified with alumina (Al2O3) particles and broke down that with increment in % vol. division of alumina particles the UTS and YS of the subsequent composite expanded. Azim et al.[25] inspected that the YS of threw composite expanded while the UTS and % prolongation of the composite diminished with the expansion in the % vol. division of strengthening material when AA2024 was fortified with Al2O3 particles. Tee at al.[[26] fabricated aluminum-TiB2 composite material by using in-situ mix throwing procedure. They have dissected that the yield quality and extreme rigidity of the subsequent composite was two times that of ascast unreinforced framework compound yet the malleability of the composite was diminished. Amirkhanlou and Niroumand[13] has delivered AA356/5 % SiCp composites by differing the measure of Silicon carbide particles (sizes of around 3μm and 8μm) by consolidation of different types of the support particles into the semi-strong exceptionally thick slurry and completely fluid liquid liquefy of AA356. The creators watched that incorporation of SiC particles as composite powder and throwing in semi-strong state diminished the SiCp molecule estimate, upgraded the wettability and enhanced the scattering of strengthened particles in coming about composite network. There was an expansion in the hardness esteems and effect vitality of the composite material with a lessening in porosity. Aigbodion and Hassan[11] has examined the impacts of SiC support on microstructure and mechanical conduct of as-cast aluminum network composite (AMC's) created by twofold mix throwing method. The outcomes uncovered that, expansion of SiC particles from 5 to 25 wt. %, swelled the hardness and obvious porosity by 75% and 39 %, separately, and a reduction in thickness and effect vitality by 1.08% and 15 % individually was watched. The 20 wt. % expansion of SiC particles expanded YS and UTS by 26.25% and 25 % individually. The 20 wt. % expansion of SiC particles expanded YS, UTS and hardness esteems upto a maximumvalues of 79.98N/mm2, 106.12N/mm2 and 67.0HRB, separately. They examined that the uniform scattering of hard and weak fortification particles was ascribed to the expansion in quality and hardness of the malleable metallic framework. The minute examination uncovered a dim and white metal stages, which happened into increment in disengagement thickness at the lattice molecule interfaces. The fig. beneath indicates variety of properties and circulation of artistic particles in the subsequent composite material.

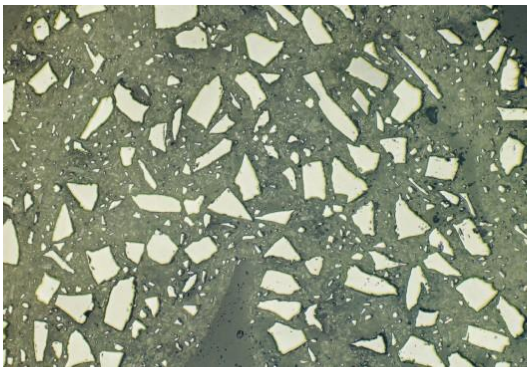

Fig -Metallography for SiC in Aluminium metal matrix composites

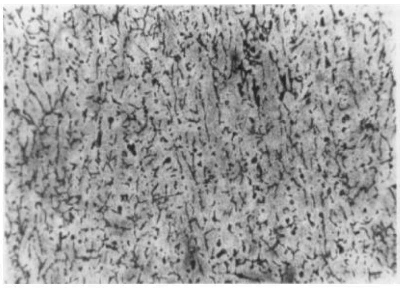

Fig 2-Micrograph of reinforced alloy with 5% SiC.

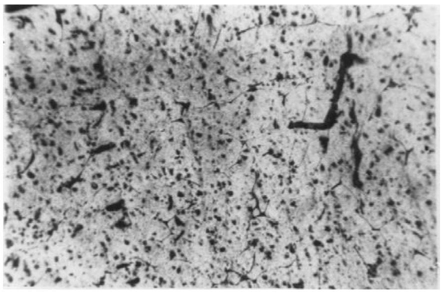

Fig 3-Micrograph of reinforced alloy with 10% SiC.

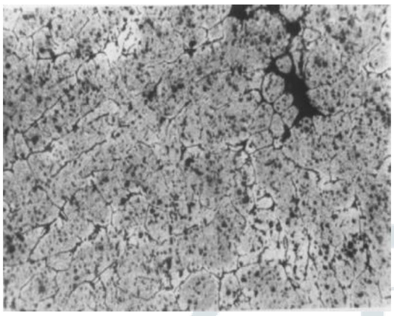

Fig 4-micrograph of reinforced alloy with 15% SiC.

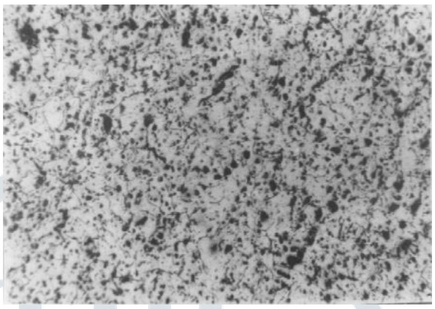

Fig 5-micrograph of reinforced alloy with 20% SiC.

Saravanakumar et al. (2014) effectively orchestrated hybrid composites of AA6063/0, 3, 6, 9 12 wt. % of Al2O3 particles+1 wt. % of Gr. particles by utilizing stir casting system. The microstructural examination demonstrated the effect of support particles on the grain measure, scattering of particles and agglomeration of support particles in the grid. They watched that upto 6 wt. % expansion of alumina particles the mechanical properties viz. hardness, pressure quality, affect quality, and flexural quality of the half and half composite in as-cast and age-solidified condition demonstrated an expanded conduct. The creators found that AA6063/6 wt. % alumina-1 wt. % Gr. half and half composite indicated most extreme estimations of mechanical properties (Refer fig. 7, 8, 9, 10).

Kalaiselvan et al. created AA6061-T6/B4C aluminum metal lattice composite by improved stir casting course by the consideration of K2TiF6 as transition into the liquid liquefy. The creators examined the homogeneous dissemination of B4C particles in the metal grid stage. The Vickers' microhardness of the subsequent composite material was expanded from 51.3HV to 80.8HV and brinell hardness from 34.4BHN to 58.6BHN by the incorporation of wt % of B4C support particles. The rigidity expanded from 185MPa to 215MPa.

Niranjan and Lakshminarayana detailed that hardness and extreme rigidity for in-situ stir castingof Al356/TiB2 expanded with the expansion in mass part of TiB2 from 2% to 6%. The most extreme UTS 261.84MPa and hardness 70.88HV were accounted for by the creators. K.K Alaneme and A.O Aluko [10] has examined the elastic conduct and crack sturdiness (K1c) for the as-cast and age solidified AA6063 strengthened with SiCp particles (3, 6, 9 and 12 vol. % of SiCp) created by utilizing double step mix throwing system. The creators inspected that the rigidity and yield quality expanded with an expansion in SiCp vol. % for both as-cast also, age solidified composites. The crack durability (K1c) has expanded essentially for both as-cast and age solidified composites. Zhang et al.[29] created TiB2 grid composites by utilizing high vitality ball processing in-situ stir casting process and inspected the microstructure and tractable conduct of the subsequent composite. The microstructural examine uncovered that no interfacial outgrowth was seen at the interface between AA6063 compound and TiB2 support particles. The elasticity for the composite was discovered [191 MPa] 1.23 times as high as the as-cast unreinforced network. Habibur Rahman and Mamur Al Rashed[30] detailed that most extreme hardness and elasticity were acquired at 20 wt. % of SiC particles fortified with aluminum framework, when aluminum framework was prepared with changing rate (0, 5, 10 and 20 wt. %) of SiC particles by means of stir casting procedure.

Mahamani et al. considered the mechanical and wear conduct of AA6061-TiB2/ZrB2 in-situ metal framework composite. Trial examination uncovered that expansion of clay particles expanded the mechanical properties. Crack surface examinations were likewise done to watch the method of disappointment. Bosi et al.[32] created metal framework composites fortified with AA6061/10% Al2O3, AA6061/20% Al2O3 and AA2618/20% Al2O3. The microstructural and weariness investigation was done utilizing SEM/OM and EDS. The creators reasoned that in high cycle weakness administration; the composite material showed preferred protection over unreinforced grid combination at low anxiety. They likewise watched that composite protection from low cycle exhaustion was less attractive because of coarser support. Gurusamy and Balasivanandha parbu[33] considered the mechanical conduct of AA356/SiC composite produced by crush throwing process utilizing the mix throwing course. Microstructural examination demonstrated homogeneous scattering of Silicon carbide particles into the framework compound what's more, grain refinement of the subsequent composite material. They watched that crush throwing at weight of 100MPa created sound aluminum lattice composite with astounding elastic and hardness properties. G.M Vecchia et al.[34] did the break system and tractable conduct of aluminum framework composite fortified with 30 vol. % of SiC. They watched that break durability and tractable conduct of the composite expanded with the high vol. % of the fortification particles when contrasted with the unreinforced aluminum amalgam lattice. Nourouzi et al.[35] manufactured Al-Al2O3 composites by infusing the Al2O3 particles in four distinct structures into the liquid metal lattice. The SEM and OM examination of the composite demonstrated a homogeneous scattering of Al2O3 fortification operators into the al lattice composite. The mechanical testing uncovered that greatest estimations of hardness, yield quality and effect vitality were seen with estimations of 78.7BHN, 142MPa and 8.2J separately. Das et al.[36] examined the mechanical conduct of al-lattice fortified with precise and circular formed fortification particles. The creators contemplated that the consideration of both circular what's more, rakish formed particles essentially improved the UTS, versatile modulus and 0.2% proof anxiety yet diminished the flexibility contrasted and the unreinforced grid amalgam. Vedani et al.[37] explored that the incorporation of 10 vol. % SiC particles to AA6061 grid expanded the youthful's modulus and pinnacle recurrence by 24.898% and 7.38% individually for the subsequent composite.

B. Tribological Examination.

The matrix composites of aluminium alloy reinforced with various ceramic materials like SiC, B_4C, TiC, AL_2O_3, and TiB_2 etc. Have been widely used in many applications (semiconductor industry, bearings, heat exchangers, brushes and contact strips etc.) due to their specific strength and superior wear resistant properties. The interfacial bond strength, normal load, sliding distance, surface finish, environmental conditions, shape and size of ceramic particles and wt% of the reinforcement are the various parameters which influence the wear behaviour of the metal matrix composites. Wilson and Alpas[38] tested unlubricated dry slippery wear behaviour sat high temperature of AA356/SiC AA356/(SiC+ graphite) and AA6061/Al203 composite. They examined that the mixing of reinforcement particles enhance the wear property of the composite material significantly at elevated temperature compared to aluminium matrix alloy. The authors observed that SiC being more effective than Al_2O_3. They found that at higher temperature (SiC+graphite) hybrid composite have shown better resistance to severe wear compared to AA356- SiC and AA6061-Al203 composite material. Tee at el. [26] investigated the tribological behaviour of insitu stir cast Al-Tib2 and Al-4.5% Cu-Tib2 composites by using pinion-disc wear tester and analysed the rate of wear for both the composite material lowered with increase in % vol. Fraction of Tib2. They found that Al-Tib_2 composite has shown higher resistance to wear than the Al-4.5% Cu-Tib_2 composite material. the authors have noted that the volume loss with increase in sliding distance in composite material increases at slower rate as compared to pure aluminium matrix alloy. Kok[39] fabricated AA2024 composite reinforced with alumina (Al_2O_3) particles by vortex method and studied the wear properties. He found that wear properties were very much affected by the sliding distance, wt% of Al_2O_3, size of ceramic particles and abrasive grit size. The volumetric loss lowered with increase in wt% of Al_2O_3 , size of ceramic particles and abrasive grit size. The volumetric loss for composite material was very low as compared to pure aluminium alloy. The author found that the volumetric loss lowered with increase in wt% of Al_2O_3 and particle size and the wear losses increased with increase in both sliding distance and grit size.

Natrajan et al. Studied the pin-on-disc dry slippery wear behaviour of fabricated in-situ AA6063/Tib_2 composite material at applied loads of 9.8N, 19.6N & 29.4N at different temperatures (100,200 and 300 deg, Celsius) and at room conditions for comparison. The author studied that wear rate lowered with increase in wt% of Tib_2, while the wear rate increased with increase in the applied load at elevated temperature the test revealed that the resistance to wear of composite material was greater than those for the unreinforced Al-alloy matrix at all test temperatures.

Gopalakrishnan and Murgan combined AA6061/TiCp composite by utilizing improved blend throwing method by fluctuating the volume divisions of TiCp. Their investigation discovered huge change in the particular quality and protection from wear of the composite material. The dry dangerous wear execution utilizing pin-on-circle wear and grating screen uncovered that wear misfortune expanded directly with ordinary load, yet expanded at an exceptionally bring down rate with expanded volume parts of TiC p. They found that the composites created by improved mix throwing strategy have less wear misfortune regarding volume misfortune when contrasted and tests led on AlTiC p created by in-situ method.

Suresh and Shenbag examined that the expansion in weight division (0%, 4%, 8% and 12%) of TiB2 in AA6061 enhanced the wear protection of composite material. Bharath et al.[33] delivered AA6061 composite fortified with Al2O3 particles (changing from 0-12 wt %) utilizing blend throwing procedure. The creators directed dry sliding wear trial of the composite examples and found that composite example with AA6061/12 wt% Al2O3 has least weight reduction when thought about as-cast unreinforced AA6061. Radha and Vijayakumarb[43] analyzed the wear conduct of AA6061 fortified with Silicon carbide and grapheme nano particles composite manufactured by blend throwing process. They found a surprising improvement in mechanical and tribological properties of the composite. The creators found that wear rate and contact coefficient diminished as needs be with the expansion in wt% of grapheme nano particles. Yogesh et al.[9] researched the dry dangerous wear examination of AA6061 based composites fortified independently with red mud, SiC and Al2O3 particles utilizing pin-on-circle tribometer. They analyzed that wear rate diminished with increment in wt% of SiC and Al2O3 in the framework, however the wear rate of red mud fortified composite diminished upto 7.5 wt% just and expanded past 7.5 wt%. This occurred because of expanded consistency of AA6061 composite and in light of agglomeration impacts in the composite framework. The 7.5wt% red mud strengthened composite about had steady wear rate all through the dry tricky wear examination. The creators additionally reasoned that AA6061composite with 7.5wt% had the greatest estimation of hardness among the diverse created composites with red mud as support.

IV. CONCLUSIONS

A lot of work has been given to the innovative work of aluminum network composites as of late. Different methods like blend throwing, powder metallurgy and in-situ arrangement have been created and connected to the handling of AMCs. Key components affecting the execution of the AMCs are the shape, measure, dispersion of the fortifications, holding quality at grid support interface and the financially savvy strategy for preparing. The present survey got from the earlier works did ranges to a number of results recorded here: (I) The fluid metal handling method known as Stir throwing system is appropriate, prudent and can be effectively utilized to deliver Al-network composite materials having wanted mechanical, microstructural and wear properties. (ii) Aluminum and its compounds strengthened with artistic operators showed huge change in microstructural, mechanical and tribological exhibitions. (iii) The mechanical properties, for example, UTS, YS, hardness, break strength expanded essentially while the malleability is lessened with the expansion of SiC, B4C, Al2O3, TiC, TiB2, red mud and so forth (iv) The protection from wear of created AMCs expanded with expanding wt% and diminishing the span of particles of artistic operators. (v) The above audit demonstrated that wear rate generally relies upon connected load, sliding rate and sliding separation and sliding remove is the most affecting parameter. (vi) For aluminum network composites strengthened with natural fortifications, exceptionally constrained measure of research work has been completed. Aluminum network amalgam fortified with natural fortifications have indicated noteworthy increment in mechanical and tribological properties. This gives extension to promote examination in the field of natural fortified metal grid composites. (vii) Nano estimated fired particles and half breed fired particles have astoundingly expanded the mechanical and wear properties of the composite material. A constrained measure of work has been accounted for in writing in this field. This broadens encourage open door for look into in this area. (viii) The altered double step blend throwing strategies for upgrading the scattering of clay particles into the network stage and limiting the odds of agglomeration in metal lattice composites has been accounted for by a couple of creators. This revamped system has required more work to be done in this space.

REFERENCES

[1] Tokaji, K,. 2005, "Effect of stress ratio on fatigue behavior in SiC particulate-reinforced aluminium alloy composite",Fatigue Fract. Eng. Mater. Struct., 28(6), pp. 539–45.

[2] Lopez, V.H., Scoles, A., Kennedy, A.R., 2003, "The thermal stability of TiC particles in an Al7 wt. % Si alloy", Mater. Sci. Eng.,A356,pp.316-25.
[3] Khan, K.B., Kutty, T.R.G., Surappa, M.K., 2006, "Hot hardness and indentation creep study on Al–5% Mg alloy matrix–B4C particle reinforced composites" Mater. Sci.Eng.,A 427pp. 76-82.

[4] Adamiak, M., 2006, "Selected properties of the aluminium alloy base composites reinforced with intermetallic particles", J. Achievements Mater. Manuf. Eng., 14 (1-2).

[5] Hashim, J., Looney, L., and Hashmi, M.S.J., 1999, J. Mater. Process. Technol. 92–93, 1.

[6] Ray, S., 1969, M.Tech Dissertation, (Indian Institute of Technology, Kanpur, 1969).

[7] LUO, A., 1995, Metall. Mater. Trans, A 26A (1995) 2445

[8] Saravanan, R.A., and Surappa, M.K., 2000, Mater. Sci. Engg. A 276 (2000) 108.

[9] Singla, Y.K., Chhibber, R., Bansal, H. and Kalra, A., 2015, "Wear Behavior of Aluminum Alloy 6061-Based Composites Reinforced with SiC, Al2O3, and Red Mud: A Comparative Study", JOM, vol. 67, pp. 2160-2169.

[10] Alaneme, K.K., Aluko, A.O., 2012, "Fracture toughness (K_{1c}) and tensile properties of as-cast and age-hardened aluminium (6063)- silicon carbide particulate composites" , Scientia Iranica A, 19 (4)pp. 992-996.

[11] Aigbodion, V.S., and Hassan, S.B., 2007, "Effects of silicon carbide reinforcement on microstructure and properties of cast Al–Si–Fe/SiC particulate composites" ,Materials science and Engineering A, 447, pp. 335-360.

[12] Toptan, F., Kilicarslan, A., Karaaslan, A., Cigdem, M., and Kerti, I., 2010, "Processing and microstructural characterisation of AA1070 and AA 6063 matrix B4CP reinforced composites", Materials and Design, 31, S87–S91.

[13] Amirkhanlou, S., and Niroumand, B., 2010, "Synthesis and characterization of 356-SiCp composites by stir Casting and compocasting methods" , Trans. Nonferrous Met. Soc. China, 20, S788-S793.

[14] Kalaiselvan, K., Murugan, N., and Parameswaran, S., 2011, "Production and characterization of AA6061–

B4C stir cast composite" , Materials and Design 32. Pp. 4004-4009.

[15] Harnby, N., Edward, M.F., and Nienow, A.W., 1985, Mixing in Process Industries, (Butterworths, London, 1985).

[16] Girot, F.A., Albingre, L., Quenisset, J.M., and Naslain R., 1987, J. Met. 39 (1987) 18.

[17] Zhou, W., and Xu, Z.M., 1997, J. Mater. Proc. Techn. 63 (1997) 358.

[18] Rohatgi, P., 1988, Modern Casting April (1988) 47.

[19] Laurent, V., Jary, P., and Regaiiond, G., 1992, J. Mater. Sci. 27(27) (1992) 4447.

[20] Mortensen, A., 1988, "Mechanical and Physical Behaviors of Metals and Ceramic Compounds", (Riso

Natioanl Laboratory, Roskilde, Denmark, 1988) 141.

[21] Pai, B.C., Satyanarayana, K.G., and Robi, P., 1992, J. Mater. Sci. Lett. 11 (1992) 779.

[22] Sundararajan, S., Mahadevan, R., and Dwarakadasa, E.S., 1995, "Tenth International Conference on

Composite material" , II. Metal Matrix composites (Woodhead Publishing Limited, 1995) p. 831.

[23] Cirakoglu, M., Toy, C., Tekin, A., and Scott, W.D., 1997, Ceram. Intern. (UK) 23(2) (1997) 115.

[24] Kamat, S.V., Hirth, S.P., and Mehrabin, R.M., 1989, "Mechanical properties of particulate-reinforced aluminum-matrix composites", Acta Metallurgy, 37,p. 2395.

[25] Abdel-Azim, A.N., Kassem, M.A., El-Baradie, Z.M., and Waly, M., 2002, "Structure and properties of short alumina fibre reinforced AlSi18CuNi produced by stir casting", Materials Letters 56, pp. 963– 969.

[26] Tee, K.L., Lu, L., and Lai, M.O., 1999, "Synthesis of in situ Al-TiB2 composites using stir cast route", Composite Structures 47, pp. 589-593.

[27] Saravanakumara, A., Sasikumar, P., and Sivasankaranc S., 2014, "Synthesis and mechanical behavior of AA 6063-x wt. % Al2O3- 1% Gr (x = 3, 6, 9 and 12 wt. %) hybrid composites", Procedia Engineering 97, pp. 951–960.

[28] Niranjan, K., and Lakshminarayanan, P.R., 2013, "Optimization of process parameters for in situ casting of Al/TiB2 composites through response surface methodology", Trans. Nonferrous Met. Soc. China 23, pp. 1269−1274.

[29] Zhang, S.-L., Yang, J., Zhang, B.-R., Zhao, Y.-T., Chen, G., Shi, X.-X., and Liang, Z.-P., 2015, "A novel fabrication technology of in situ TiB2/6063Al composites: High energy ball milling and melt in situ reaction", Journal of Alloys and Compounds 639, pp. 215–223.

[30] Habibur Rahmana Md., and Mamun Al Rashedb H.M., 2014, "Characterization of silicon carbide reinforced aluminum matrix composites", Procedia Engineering 90, pp. 103–109.

[31] Mahamani, A., Jayasree, A., Mounika, K., Reddi Prasad, K., and Sakthivelan, N., 2015, "Evaluation of mechanical properties of AA6061-TiB2/ZrB2 in-situ metal matrix composites fabricated by K2TiF6-KBF4-K2ZrF6 reaction system", International Journal of Microstructure and Materials Properties Jan 2015, Vol. 10, Issue 3-4, pp. 185-200.

[32] Bosi, C., Garagnani, G.L., Tovo, R., and Vedani, M., 2002, "Effects of matrix and reinforcement properties on low- and high-cycle fatigue behaviour of particulate-reinforced MMCs", International Journal of Materials and Product Technology Jan 2002, Vol. 17, Issue 3-4, pp. 228-24.

[33] Gurusamy, P., and Balasivanandha Prabu, S., 2013, "Effect of the squeeze pressure on the mechanical properties of the squeeze cast Al/SiC p Metal Matrix Composite", International Journal of Microstructure and Materials Properties Jan 2013, Vol. 8, Issue 4-5, pp. 299-312.

[34] Vecchia, G.M., La and D'Errico, F., 2002, "Fracture mechanics behaviour of aluminium matrix composites reinforced with SiC", International Journal of Materials and Product Technology. Jan 2002, Vol. 17, Issue 3-4, pp. 261-274.

[35] Nourouzi, Salman, Esmaeil Damavandi, and Sayed Mahmood Rabiee., 2016, "Microstructural and mechanical properties of Al-Al2O3 composites focus on experimental techniques", International Journal of Microstructure and Materials Properties 11.5 (2016): pp. 383-398.

[36] Das, T., Munroe, P.R., and Bandyopadhyay, S., 2003, "Some observations on the mechanical properties of particulate-reinforced 6061 aluminium metal matrix composites", International Journal of Materials and Product Technology Jan 2003, Vol. 19, Issue 3-4, pp. 218-227.

[37] Vedani, Maurizio, and Elisabetta Gariboldi., 2002, "Creep damage behaviour of Al6061-Al2O3 particulate composites", International Journal of Materials and Product Technology 17.3-4, pp. 243-260.

[38] Wilson, S., and Alpas, A.T., 1996, "Effect of temperature on the sliding wear performance of Al alloys and A1 matrix composites", Wear, 196, pp. 270-278.

[39] Kok, M., 2005, "Production and mechanical properties of Al2O3 particle-reinforced 2024 aluminium alloy composites", Journal of Materials Processing Technology 161, pp. 381–387.

[40] Natarajan, S., Narayanasamy, R., Kumaresh Babu, S.P., Dinesh, G., Anil Kumar, B., and Sivaprasad, K., 2009, "Sliding wear behaviour of Al 6063/TiB2 in situ composites at elevated temperatures", Materials and Design 30, pp. 2521–2531.

[41] Gopalakrishnan, S., and Murugan, N., 2012, "Production and wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method", Composites: Part B 43, pp. 302–308.

[42] Suresha, S., and Shenbaga Vinayaga Moorthib, N., 2013, "Process development in stir casting and investigation on microstructures and wear behavior of TiB2 on Al6061 MMC", Procedia Engineering 64, pp. 1183 – 1190.

[43] Radhaa, A., Vijayakumarb, K.R., 2016, "An investigation of mechanical and wear properties of AA6061 reinforced with silicon carbide and graphene nano particles-Particulate composites", Materials Today: Proceedings 3, pp. 2247–2253.