Influence of Extrusion Process on Mechanical and Tribological Properties of Aluminium A356-Al_2O_3 Stir Cast MMC

Ashok Kumar M.S.[1], Honnaiaha C.[2] and Ajit Prasad S.L.[3]

[1,2]Mechanical Engineering, P.E.S. College of Engineering, Mandya, Karnataka–571403, India
(Dayananda Sagar Academy of Technology & Management, Bangalore)
[2]Mechanical Engineering, A.P.S. College of Engineering, Bangalore, Karnataka–560082, India
E-mail: [1]ashok_2066@rediffmail.com

Abstract—Aluminium alloys are most commonly used MMCs because of their light weight, anticorrosive properties and large scale availability. However, aluminum alloys have poor wear resistance properties and fail to perform at high temperatures, these alloys are reinforced by harder particles to improve the properties. Among many types of MMCs, the most popular types are aluminum alloys reinforced with SiC or Al_2O_3 particles since they provide favorable properties with only a minimum increase in density over the base alloy. Out of the available methods of producing these composites, stir casting route is most promising and economical for synthesizing the particle reinforced MMCs. Alumina (Al_2O_3) particles mixed with Aluminium matrix in appropriate proportions are reported to exhibit improved mechanical properties because of the higher modulus of elasticity and strength of the reinforcement particles. The MMC materials processed by Stir casting and powder metallurgy technique contain defects like porosity, blow holes and irregular grain structure. Secondary processing like extrusion can reduce these defects and enhance the structural features.

The present work is a preliminary investigation of mechanical and tribological properties of Aluminium A356 reinforced with Al_2O_3 and MoS_2 for both cast and extruded conditions with varying extrusion ratio.

INTRODUCTION

Composite materials are increasingly replacing traditional engineering materials because of their beneficial characteristics over homogeneous materials. The application of Metal Matrix Composites (MMCs) as structural engineering materials has received growing concentration in latest years. Their excessive strength and durability at increased temperatures coupled with low-density makes them compatible for use in engineering materials. MMCs show off significantly better stiffness and mechanical force in comparison with matrix alloys, however generally suffers from cut back ductility and inferior fracture durability[1]. The mechanical properties of the composite material are strongly dependant on the microstructural parameters of the system. In particular, the shape, size, volume fraction and the orientation of the reinforcing particles, as well as the matrix composition play vital role in deciding the mechanical properties of MMCs[2]. The particulate reinforced composites can be prepared by injecting the reinforcing particles into the liquid matrix through liquid metallurgy route by casting. The problem associated with the stir casting process is the non-uniform distribution of particulates due to poor wettability and gravity related segregation[3].

The MMC materials processed by primary processes like Stir casting and powder metallurgy technique contain defects like porosity, blow holes and irregular grain structure that lead to reduction in mechanical and tribological properties of composite materials. Secondary processing like extrusion can reduce these defects and enhance the properties; Extrusion is defined as the process of shaping material, by forcing it to flow through a shaped opening in a die. The main factors that influence the properties of extruded component are Extrusion temperature, Extrusion pressure, Extrusion ratio and Extrusion speed[4,5]. The effect of extrusion ratio has a greater influence on the microstructure and mechanical properties of extruded material[6].

e-ISBN: 978-93-86256-19-5

Many of the components made out of MMCs are operated in applications, where they are subjected to relative sliding and rolling motion with respect to the surfaces of the mating components. The friction and wear characteristics of these components are important with respect to the efficiency, maintenance, operating cost and life of the total system. The sliding wear of the composites is a complex process involving not only mechanical but also thermal and chemical interactions between the surfaces in contact. Particulates of Graphite and MoS_2 (Molybdenum Di Sulphide) are added to improve the tribological behaviour of MMCs[7,8,9]. These particulates, which act as solid lubricants have the capacity to achieve low friction and wear of the contact surfaces.

EXPERIMENTAL DETAILS

WORK MATERIAL DETAILS

Aluminum (A356) with α- aluminum oxide with average particles sizes of 23 µm as reinforcement with volume fraction of 10%. Particulates of aluminum oxide are selected for the present investigation. Small amount of MoS_2 (Molybdenum Di Sulphide) with particle size of 5 µm with an volume fraction of 3% are also added to composite materials which helps in extrusion process. Table 1 shows the percentage composition of A356.

Table 1: Percentage Composition of Aluminium (A356)

Elements	Percentage
Al	91.1-93.3
Cu	< = 0.2
Iron	< = 0.2
Mg	0.25-0.45
Mn	< = 0.1
Silicon	6.5-7.5
Titanium	< = 0.2
Zinc	< = 0.1
Other each	< = 0.05

Table 2: Extrusion Ratios

Diameter (mm)	Extrusion Ratio
35 to 10	12.25
40 to 10	16
45 to 10	20.25

STIR CAST PROCESSING DETAILS

The casting unit consists of a graphite crucible of 5 kg capacity, which is heated by electrical resistance type heating coils. A motor operated stirrer is provided at the top for mixing the particulate reinforcement with the molten metal. The mechanical stirrer used for stirring the molten alloy during fabrication of composites is made of steel blades coated with Alumina powder and sodium silicate mixture to withstand high temperature and to avoid iron pickup by the melt. Pre heated reinforcement particles with known quantity are added to the matrix material and stirring is carried out for uniform mixing of the particles, the prepared molten material are then poured into the dies of required shapes.

Fig. 1: Electrical Heating Furnace

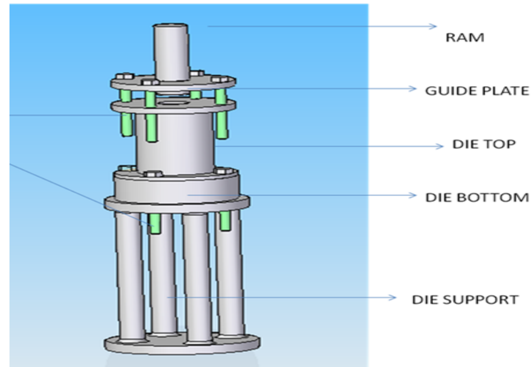

Fig. 2: Extrusion Die Assembly

EXTRUSION PROCESS

Cast specimens are subjected to secondary process of Extrusion where in the aluminum composite are extruded from bigger diameter to smaller diameter with varying extrusion ratio. Band heaters are used around the die area to maintain the required temperature (320°C) for carrying out the extrusion process. Table 2 shows the extrusion ratio used in the present investigation, Fig. 2 shows the extrusion die assembly.

MECHANICAL PROPERTIES

Hardness Test

Evaluation of hardness test are carried out in Brinell hardness tester where in a steel ball of diameter (D) is forced under a load (F) on to a surface of test specimen. Mean diameter (D_i) of indentation is measured after the removal of the load (F).

Tensile Test

Figure 3 shows the tensile test specimens prepared as per the ASTM B557 standard.

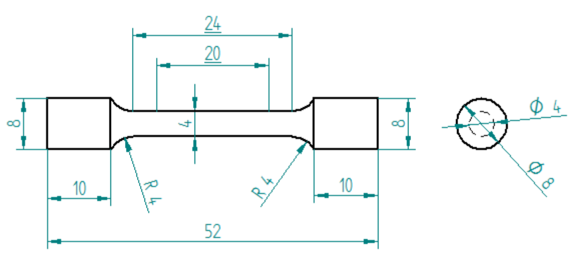

Fig. 3: ASTM B557 Tensile Specimen

Fig. 4: Wear Testing Pins

TRIBOLOGICAL PROPERTIES

Abrasion wear test were conducted for the prepared mmc material using tribometer test apparatus conforming to ASTM G99 standards with electronic data acquisition system. The wear test specimens of 28 mm length and 10 mm diameter are prepared as per the ASTM G99 standard as shown in the Fig. 4. The wear tests are conducted at varying load conditions with constant sliding velocity.

RESULTS AND DISCUSSION

MICROSTRUCTURAL STUDY: SCANNING ELECTRON MICROSCOPY

Figure 5 shows the SEM image of alumina reinforcement with particle size of 23 µm (average), Fig. 6 shows the SEM image of composite material (A356 + 10% Al_2O_3 + 3% MoS_2) for as cast condition, it can be seen that the reinforcement particles are non uniformly distributed in the matrix material. Fig. 7 indicates the SEM image of Extruded hybrid composite specimen (Extrusion ratio of 16) where in the reinforcement particles are uniformly distributed over the matrix material. The presence of reinforcement particles in the matrix material yields in higher strength of the composite materials.

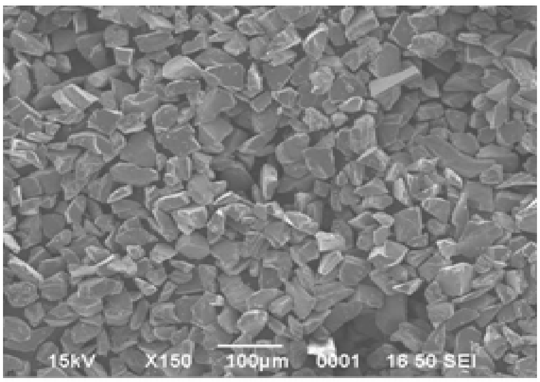

Fig. 5: 23 µm Al_2O_3 Particles

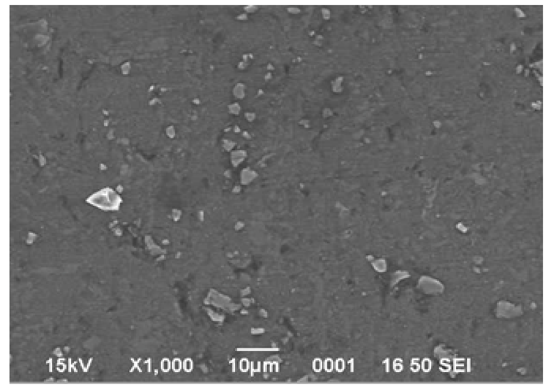

Fig. 6: A356 (As Cast)

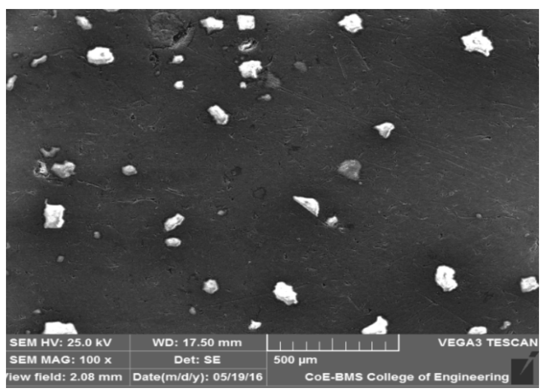

Fig. 7: A356 (Extrusion Ratio 16)

HARDNESS TEST

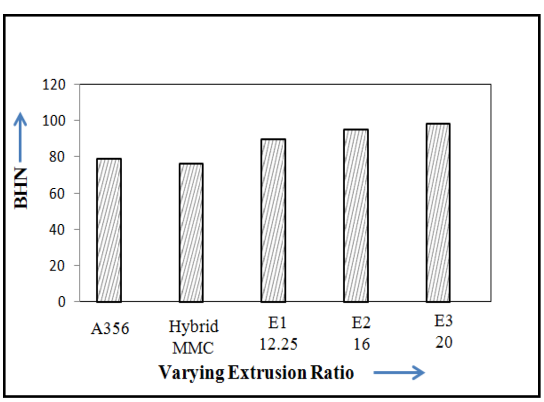

Fig. 8: BHN of Cast and Extruded Composites

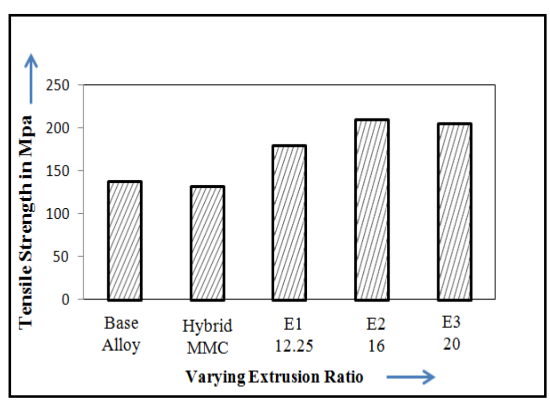

Fig. 9: Tensile Strength of Cast and Extruded Composites

Figure 8 illustrates the variation in Brinell Hardness Number (BHN) of composite test specimens with reinforcements for varying extrusion ratio. It can be observed that the addition of Al_2O_3 particulates has increased the hardness of the composite materials compared to that of the base alloy. Test results also indicate the progressive increase in hardness of the composite structure with increase in extrusion ratio. Increase in hardness is due to the increased number of hard alumina particles. Extrusion process helps in dislocation densification, grain refinement and lowering of porosity. Extrusion also helps in breaking down of agglomerates of the reinforcement particulates and their uniform distribution in the matrix phase. Results indicate that extrusion process has caused marginal increase in the hardness of composite material compared to the as cast specimens.

TENSILE STRENGTH TEST

Figure 9 illustrates the variation in tensile strength of composite test specimen with respect to varying extrusion ratio. It can be observed from the results that tensile strength of composites is higher than that of base alloy (A356) and also observed that there is in increasing trend in the tensile strength values of the composites with varying extrusion ratio. By the application of the extrusion process the matrix alloy tends to deform in a plastic manner, but the presence of the reinforcement clusters exerts constraints on the plastic flow within the ductile matrix resulting in a significant build up of stress concentration and triaxial stresses. Local shear stresses acting on particle clusters during extrusion cause them to break up, leading to a relatively more uniform particle distribution. Casted Hybrid composite specimen with an extrusion ratio of 16 experienced higher strengths than other specimens.

DRY SLIDING WEAR TEST RESULTS

Influence of Sliding Distance and Normal Load on Material Wear

Wear with respect to the sliding distance for varying load conditions [10 N to 60 N] are carried out for as cast, hybrid and for varying extrusion ratio [Fig. 10 (a)-(e)]. It can be observed that the slope of the curves is higher initially, indicating running-in wear, Later as the asperities get flattened, contact area increases decreasing contact pressure with reduction in wear rate. With the increase in sliding distance, the number of fatigue load cycles also increases resulting in localized failures of the asperities. This results in increased wear rate of the material with increase in sliding distance. Wear rate of extruded composite material at all loading conditions experiences lower wear rate than that of the as cast composites. It can be seen from the figure that the wear rate of extruded specimens are lower than the as cast specimens at all the loading conditions. As the sliding distance increase MoS_2 particles get crushed and form a protective layer between the pin and counterface surface thus reduces the wear rate in abrasive wear rate mechanism.

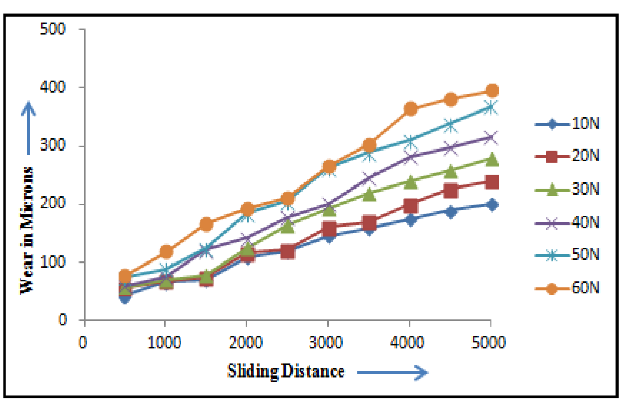

Fig. 10(a): Cast A356

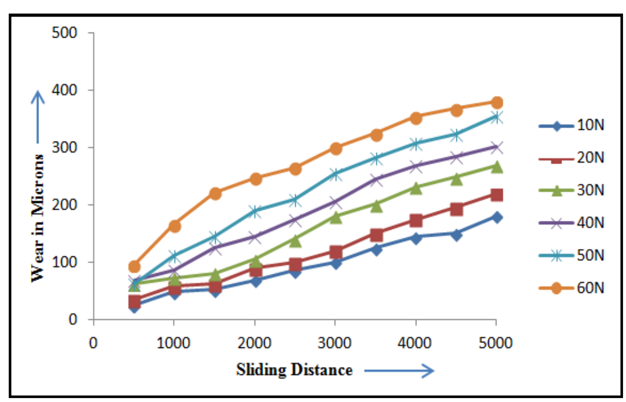

Fig. 10(b): Hybrid MMC [A356 + 10%AL_2O_3 + 3%MoS_2]

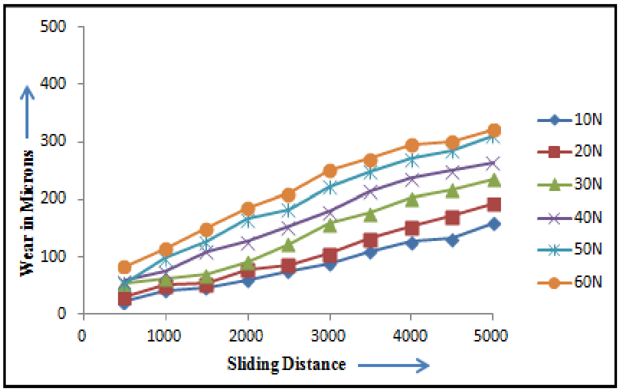

Fig. 10(c): Extrusion Ratio [12.25]

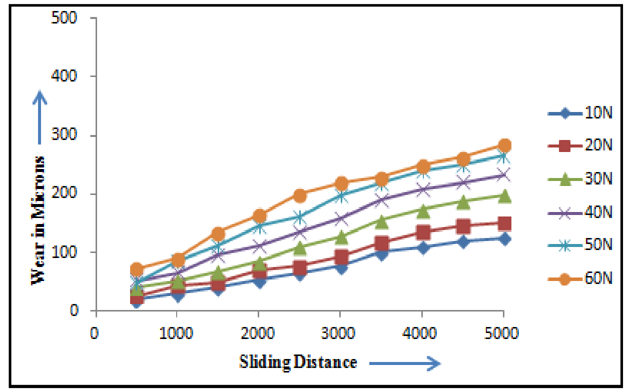

Fig. 10(d): Extrusion Ratio [16]

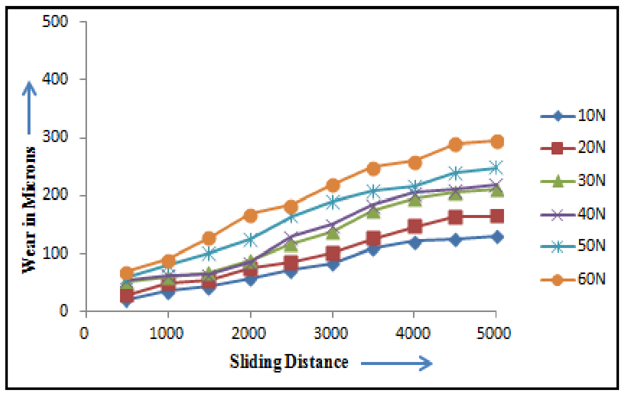

Fig. 10(e): Extrusion Ratio [20.25]

CONCLUSIONS

Experimental investigations conducted on the influence of extrusion ratio on mechanical and tribological properties of Al-Al_2O_3 MMCs provided the following conclusions.

- The micrographs reveal the presence of alumina particles (Clustered form) in the matrix material.
- SEM images indicate that extrusion process aids in uniform distribution of reinforcement particles over the matrix material.
- Graphs indicate that the hardness of the extruded composite samples for varying extrusion ratios are higher compared to that of as cast composite.
- Tensile strength of extruded composite experienced higher strength than the as cast.
- The wear properties of the A356 alloy were considerably improved by the addition of Al_2O_3 and MoS_2 particles, and the wear resistance of the composites was much higher than that of as cast composites.
- Presence of MoS_2 particles leads to the improvement in the wear resistance properties of the extruded specimens.

ACKNOWLEDGEMENT

The authors express gratitude and thank Principal and HOD, Mechanical Engineering, P.E.S. College of Engineering, Mandya, for providing the necessary equipments for carrying out the proposed work.

REFERENCES

[1] Veeresh Kumar G.B, C. S. P. Rao, N. Selvaraj, M. S. Bhagyashekar- "Studies on Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites" Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55, 2010.

[2] Sajjadi, Ezatpour, Torabi Parizi- "Comparison of microstructure and mechanical properties of A356 aluminium alloy/Al_2O_3 composites fabricated by stir and compo-casting processes" materials and design Vol. 34, page: 106-111, 2012

[3] Barath V, Mahadev Nagaral & V.Auradi- "preparation, characterization and mechanical properties of Al_2O_3 reinforced 6061 Al particulate MMC's". International journal of Engineering Research Technology, Vol.1, Issue6, August 2012.

[4] Kok, M. - "production and mechanical properties of Al_2O_3 particle-reinforced 2024 Al alloy composites". Journal of materials processing technology vol. 161, page: 381-387 2005.

[5] Mahadev Nagaral & V.Auradi- "preparation, characterization and mechanical properties of Al_2O_3 reinforced 6061 Al particulate MMC's". International journal of Engineering Research Technology, Vol.1, Issue6, August 2012.

[6] M. Ramachandra, K. Radhakrishna "Sliding wear, slurry erosive wear, and corrosive wear of aluminium A356- AL2O2 composite" Materials Science, Vol. 24, No. 2/1, 2006

[7] Evaluation of Mechanical properties of Aluminium Alloy (Al2024) reinforced with Molybdenum disulphide (MoS_2) metal matrix composites by Bhargavi Rebba and N. Ramanaiaha. 3rd International conference on materials processing and characterization (ICMPC 2014)

[8] Mechanical and Wear behavior of aluminium metal matrix hybrid composites. By Siddesh Kumar N.G, V.M. Ravindranath, G.S.Shivashankar. International conference on advances in manufacturing and materials engineering (AMME 2014).

[9] Mechanical and Tribological Characteristics of Stir Cast Al-Si10 Mg and Self Lubricating al-Si10Mg/MoS_2 Composites by Kannapan.S.V, Ramanathan.S, Somasundaram.D, Balu.A. Original Scientific Article ISSN 15580-2949.