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Comparative Study of Mechanical and Tribological Properties of Aluminium with Silicon Carbide and Aluminium with Alumina Composites Produced By Powder Metallurgy

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Abstract : Aluminium alloys have been gaining greater importance as structural materials, but for many applications it is necessary to improve their wear resistance. In particularly, uses of Aluminium alloys in automotive applications has been limited due to their inferior strength, rigidity and wear resistance, as compared as of ferrous alloys. Particle reinforced Aluminium composites; nevertheless, offers reduced mass, high stiffness and strength and improved wear resistance.

Recently, particle reinforced Aluminium composites are made especially with the reinforcement of Aluminium (Al) with silicon carbide (SiC) and Alumina (Al_2O_3) i.e. mainly with the process of powder metallurgy. The powder metallurgy method has better matrix-particle bonding, easier control of matrix structure, uniform dispersion of the reinforcement and low manufacturing temperature compared with other MMCs production methods. The present investigation is focused on the comparative study of Aluminium (Al) based metal matrix composites with the addition of Al_2O_3 and SiC are manufactured with the help of Powder metallurgy method.

The effects of ceramic reinforcement $Al_2O_3$and SiC in Al have been analyzed with tribological and mechanical properties. The interaction of SiC with Al shows the better results in terms of wear behaviour and hardness than the individual Al. From the comparative analysis, Al with SiC composites improves the strength, hardness and showed reduced wear loss than Al with the reinforcement of Al_2O_3.

Keywords : component; formatting; style; styling; insert (key words)

I. Introduction

Aluminium alloys plays a major role in automobile industry due to high strength, stiffness to weight ratio, good formability, good corrosion resistance, and recycling potential for use in automobile industries as components of internal combustion engines but it has reduced wear resistance, inferior strength, rigidity which really has made a significant effect and limited its application [1].This has created a great need to improve the wear resistance to widen the application. Ceramic reinforcement with the Aluminium alloy, offer a great change in the properties such as high stiffness, reduced mass and improvement wear resistance. Specifically, there is a possibility of substituting iron-base materials for Al metal–matrix composites (MMCs), in automotive components, provides the potential for considerable weight reduction. Significant developments have been achieved in the system SiC/Al MMCs[2].The strength is increased by increasing the volume percentage of ceramic phase, by increasing the strength of the Al matrix and by decreasing the size of the ceramic reinforcement; ductility, nevertheless, diminishes Ceramic materials have excellent mechanical properties: high-hardness, high-temperature strength and chemical stability[3]. Metal matrix composites reinforced by Sic and Al2O3 particles, whiskers and short fibers, have performed well in the frictional and wear region for its super wear resistance, high strength, low density[4]. Alumina is one of the frequently used ceramic reinforcement; it does not react with the matrix at high temperatures and does not create undesired phases [3].The method of production of metal matrix composites has a strong influence on the mechanical and tribological properties of these composites via its effects on the matrix grain size, porosity and distribution of reinforcing particles [6]. A wide range of production techniques have been developed for Aluminium matrix composites, such as the accumulative roll bonding (ARB) method, anodizing and ARB processes, stir casting [7][8] and compo-casting [9]procedures vacuum infiltration [10]and also, by P/M[11]. Among others; however, the PM method is the most attractive due to several reasons. The powder metallurgy method has better matrix-particle bonding, easier control of matrix structure, and uniform dispersion of the reinforcement and low manufacturing temperature that prevents strong interfacial reactions, deduces the undesirable reinforcement/ matrix reactions and also, ensures uniform distribution of reinforcement particles in the matrix as compared with other MMCs production methods. Of all the metals, Aluminium is used commonly as a matrix for its light weight and high strength to weight ratio [12]. Alumina and silicon carbide are used for tribological applications such as seal rings, draw-cones, guides, bearing parts, cutting tools or medical prostheses. Aluminum matrix composites are widely used in automobile, mining and mineral, aerospace, defense and other related sectors. In the automobile sector, Al composites are used for making various components such as brake drum, cylinder liners, cylinder blocks, and driveshaft[13][14][13]. Using Al composites in aerospace industries is supported by the structural applications of such engineering materials making them widely used in helicopter parts (parts of the body, support for rotor plates, drive shafts), rotor vanes in compressors and in aero-engines. In general, these materials are developed for the production of high wear resistant components. Metal matrix composites are obtained by adding hard particles such as Al2O3and SiC into Al alloys to have good mechanical properties. Aluminium alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. These properties have made particle-reinforced metal matrix composites (MMCs) an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, transportation and industrial sectors [16][17][18]..These composites are used as cutting tools, bearing parts, and medical rigs. The development in the production of the composite material increased the use of al material and it had widened the area of usage [19][20]. Al being a soft phase structure which can be made harder with the reinforcement of hard particles (Al2O3 and SiC) and with the addition of solid lubricants the material can exhibits good potential for resistance to wear and consequently becomes more suitable for tribological application. In this study, an effort has been made to study the wear behaviour on the addition of ceramic material such as silicon carbide and alumina in the percentage of 3 and 10 % which is produced by the method of powder metallurgy.

The powders used were: Aluminium powder with an average particle size of 40μm (commercial D grade Al, 99% purity), copper powder with an average particle size of 30μm and magnesium powder with an average particle size of 60μm as a matrix and silicon carbide powder purity that exceeds 99.3% with an average particle size of 30μm and flake Graphite powder with an average particle size of 33μm.

Aluminium was used as the basis for obtaining composites. Chemical composition of the alloy is given in Table 1.The composites were produced by powder metallurgy process. The amount of powder particles was 3 and 10 wt. % for Al_2O_3 and SiC particles. After weighing the powders, they were milled using a ball mill for an hour, with the speed of 42 rpm. The powders were pressed in the hydraulic Press with 22 ton to form a cylindrical shape with 10mm diameter and height of 30mm in the carbide die. The compacted specimen were taken out then coated with silica powder to prevent the oxidation from the atmosphere and the specimens were sintered at 380oC for 90min in a controlled furnace with a rate of temperature increase of 3oC/min. All the specimens were then cooled in the furnace and were machined to the exact size 8mm diameter and 20mm length for taking the wear test. Hardness test were carried using an indentor 3mm steel ball with 300kgf load. The brinell hardness values of the prepared composite specimen were measured and show in the table 3 along with the average sintered density. The experiments were repeated in order to identify the mean value.

Sliding wear test were carried out as per ASTM G9903 (reapproved 2010) test standards on pin-on-disc equipment. The counter disc material was of EN31 steel. Prior to testing, the pins and disc surface are clean with acetone. The pin was weighted before and after testing to an accuracy of 0.0001g to determine the amount of wear. All the test were carried out using hybrid composites pins of various compositions with an applied load of 3 to 30N,sliding speeds of 1 and 3 m/s for a varying sliding distance of 300 and 3000m. At the end of the each experiment, the specimen and the counter face disk were cleaned with organic solvents to remove traces. The experimental procedure was repeated in order to obtain the average value.

III Result and Discussion

3.1 Hardness Test

The effect of ceramic reinforcement on the hardness value is shown on the fig 3.1. It can be seen that the hardness value of the composite is higher than its base alloy. This really shows that the reinforcement, i.e. hard or soft plays a major role in the hardness value of the composites. The hardness of the material embraces many different properties such as resistance to wear, scratching; deformation etc.., .hence the hardness value is very important factor for the material .In this case, Al with 10% SiC has better hardness compared to the other reinforcement

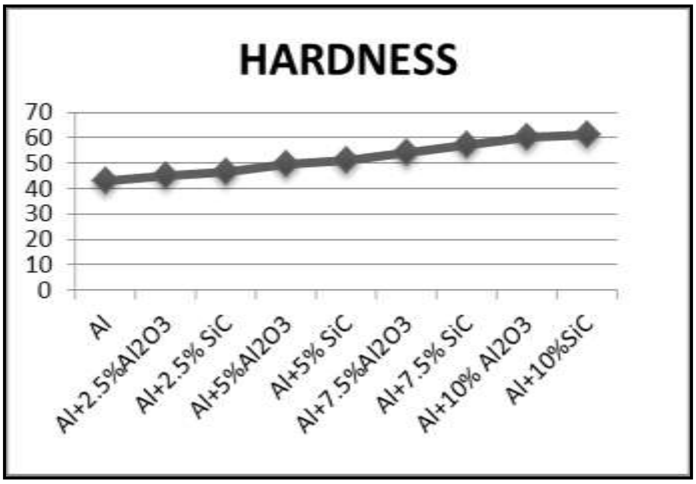


Fig.3.1. Variation of hardness

3.2 Theorectical Density

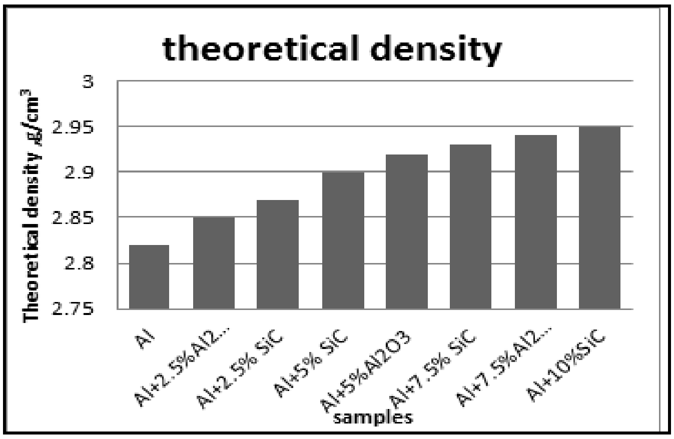


Fig.3.2. Variation of theoretical density

The fig 3.2.gives the theoretical density value of the composite with different reinforcement. It can be seen that the densities of composites are higher than that of their base alloy, further the density increase with increasing percentage of reinforcement content in the composites. From the fig, comparing all composites Al with Al_2O_3 has higher density values.

3.3 Sliding Wear Loss and Wear Rate Performanceo the Different Samples with Reinforcement and Base Material under Dry Sliding Condition

Pin on disc wear tester is used to perform the wear test under dry sliding wear condition. For conducting wear test three condition are selected by varying the load from 1 to 3kg, sliding distance in range of 1000 to 3000 m and the sliding velocity varying from 1 to 3 m/s and they are shown in the table 3.1

Table 3.1 variation in wear conditions

Wear Conditions	Sliding velocity m/s	Sliding distance , m	Load, kg
1	1	1000	1
2	2	2000	2
3	3	3000	3

3.3.1 **Wear loss in terms of micrometer for the wear condition 1**

In this experiment , wear test is carried at a load of 1 kg , sliding velocity of 1m/s and sliding distance of 1000m. This result shows the effect of reinforcement on the wear behaviour of the sample. In this case, the wear loss in micrometer is high for the base material compared to all the composites. The addition of ceramic reinforcement improves the hardness of the composites which made an impact on the wear loss of the composites. Here the composites with reinforcement of silicon carbide have low wear loss compared to the entire specimen.

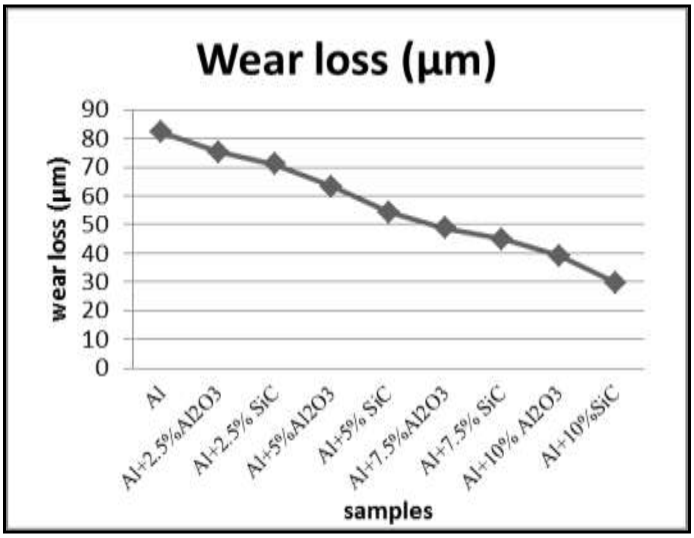


Fig 3.3 Wear in micrometer vs. samples for wear condition 1

3.3.2Wear loss in terms of micrometer for the wear condition 2

The effect of ceramic reinforcement on the wear loss of the composites is shown in the fig 3. In this case , wear test is carried out at a load of 2 kg , sliding distance of 2000 m and sliding velocity of 2 m/.The addition of hard phase really improves the wear behaviour of the composites formed. Hard phase like silicon carbide and alumina reduced the wear loss of the composites compared to the base material.in this condition, composite with addition of 10 % wt silicon carbide shows lower wear loss relative all the sample. This is due to the fact that distribution of the ceramic reinforcement in the base material is uniform and because of this proper distribution reduces the wear loss of the composites

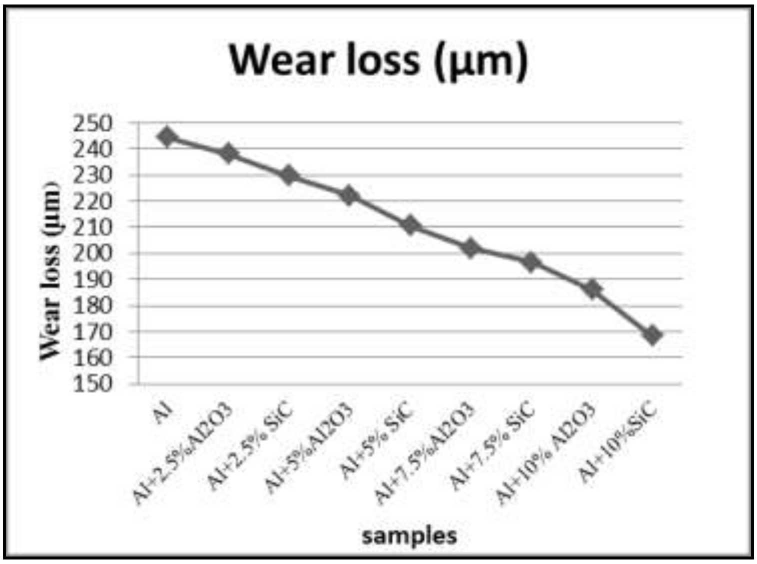
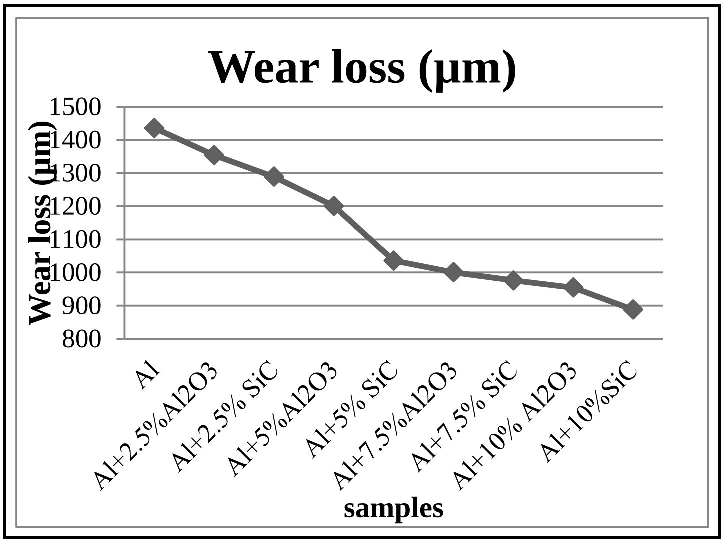


Fig 3.4 Wear in micrometer vs. samples for wear condition 2.

3.3.3 Wear loss in terms of micrometer for the wear condition 3

The wear condition in this case is with a load of 3 kg, sliding distance of 3000m, sliding velocity of 3m/s and its effect is shown in the fig 3.3 and table 3.4 shows the corresponding wear rate value. The wear loss is reduced due to the addition of the ceramic reinforcement. Sample with 10 % wt. sic show a lower loss and next to that Al_2O_3 with 10% wt. has lower wear loss.



Figs 3.5 wear in micrometer vs. samples for wear condition 3

3.3.4 Wear Rate of Samples with Addition of Reinforcemnt

Wear Calculation

1. Area
Cross sectional Area,
2. Volume loss
Volume loss = Cross sectional Area x Height loss
3. Wear rate
Wear rate = Volume loss / Sliding distance

3.3.4 Wear rate of the samples with the wear condition 1

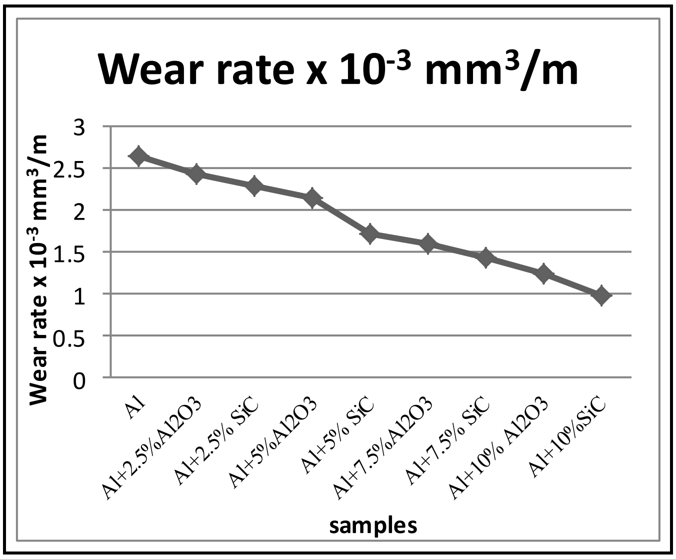


Fig 3.6 Wear rate in mm^3/m vs. samples for wear condition 1

The effect of ceramic reinforcement on the wear loss of the specimen is shown in the fig 3.4 and respective wear rate values are shown in the table 3.3. In this experiment, the wear test is carried out at a load of 1 kg, sliding velocity of 1m/s and sliding distance of 1000m .the rate of wearing in the samples with the reinforcement is low compared to the base material aluminum. This is due to the reason that the addition of reinforcement made an effective impact on the hardness which really reduces the wear rate of the samples. Composite with 10%wt silicon carbide has lower wear rate

3.3.3 Wear rate of the samples with the wear condition 2

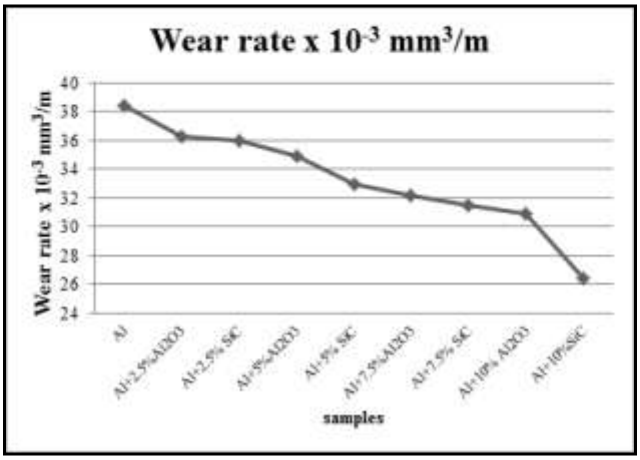


Fig 3.7 Wear rate in mm3/m vs. samples for wear condition 2

The wear test condition for this experiment is with a load of 2 kg, sliding velocity of 2 m/s, 2000m sliding distance and its effect is shown in the fig 3.3. and the corresponding values are shown in the table 3.6 .The wear rate of composites is very low compared to the base material . Al with 10% silicon carbide reinforcement shows a lower wear rate.

The wear test condition for this experiment is with a load of 2 kg, sliding velocity of 2 m/s, 2000m sliding distance and its effect is shown in the fig 3.3. and the corresponding values are shown in the table 3.6 .The wear rate of composites is very low compared to the base material . Al with 10% silicon carbide reinforcement shows a lower wear rate.

3.3.6 Wear rate of the samples with the wear condition 3

The effect of ceramic reinforcement on the wear loss of the composites is shown in the fig 3.6 In this case , wear test is carried out at a load of 3 kg , sliding distance of 3000 m and sliding velocity of 3 m/.The addition of hard phase really improves the wear behaviour of the composites formed. Hard phase like silicon carbide and alumina reduced the wear rate of the composites compared to the base material. In this condition, composite with addition of 10 % wt. silicon carbide shows lower wear loss relative all the sample. This is due to the fact that distribution of the ceramic reinforcement in the base material is uniform and because of this proper distribution reduces the wear loss of the composites.

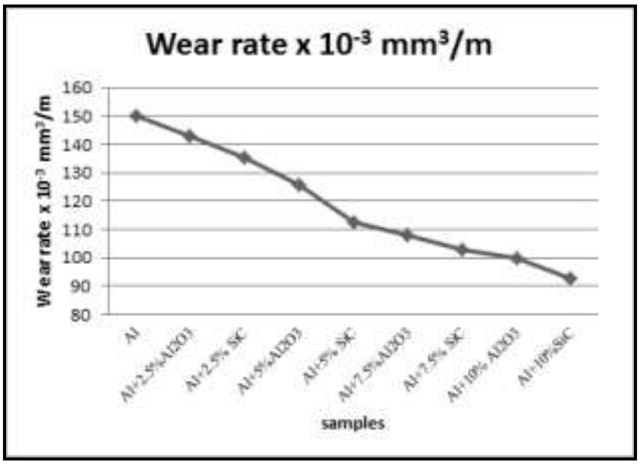


Fig 3.8 Wear rate in mm^3/m vs. samples for wear condition 3

3.4 Coefficient of Friction

3.4.1variation of Co-Efficient of Friction for the Wear Condition 1

Fig 3.9 shows the variation of coefficient of friction with constant sliding distance at 1000m, for a constant load of 1kg and for a constant sliding speed of 1 m/s.

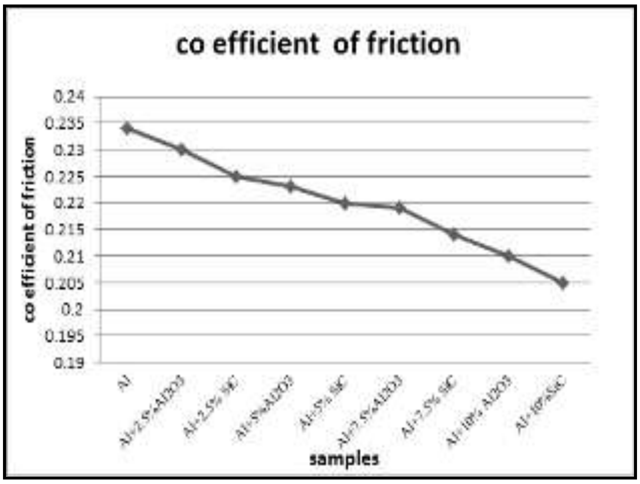


Fig.3.9 Variation of co-efficient of friction for the wear condition 1

The friction force in tribosystems usually results from the adhesion between counterparts and ploughing work. Similar trend for reduced friction coefficient of composites by increasing of hard reinforcing particles has also been reported by other researchers. Addition of SiC particles results in improvements in strength and hardness of composites. Moreover, the hard SiC particles, present on the surface of composites as protrusions, protect the matrix from severe contact with the counter surfaces. In this fig shows the hard ceramics materials can be used to reduce the coefficient of friction than the base alloy. The composite with 10% wt of silicon carbide has low co efficient of friction

3.4.2 variation of Co-Efficient of Friction for the Wear Condition 2

Fig 3.10 shows the variation of coefficient of friction with constant sliding distance at 2000m, for a constant load of 2 kg and for a constant sliding speed of 2 m/s.

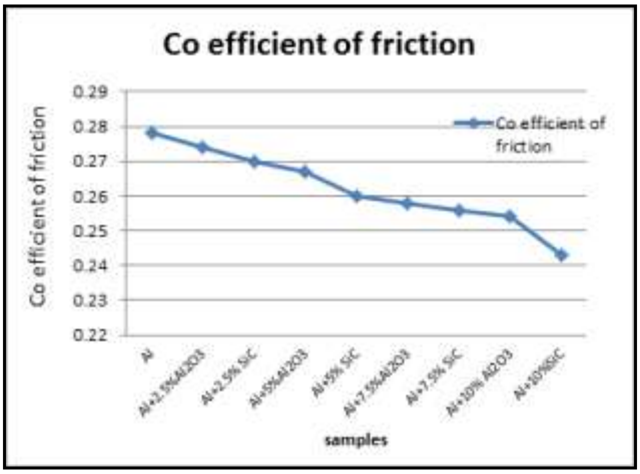


Fig.3.10 Variation of co-efficient of friction for the wear condition 2

In this case, sample with reinforcement has shown a decrease in the co-efficient of friction value compared to the base material. The hard phase present in the composites improves the strength and hardness which really reduces the co efficient of friction. Composites with 10% sic had shown a lower co efficient of friction.

3.4.3 variation of Co-Efficient of Friction for the Wear Condition 3

Fig 3.9 shows the variation of coefficient of friction with constant sliding distance at 3000m, for a constant load of 3 kg and for a constant sliding speed of 3m/s. In this experiment, the effect of load, sliding velocity and sliding distance showed an impact on the co- efficient of friction of the composites. Hard phase in the composites reduces the friction between the pin and counter disc. This really helps to reduce the wear occurring in the samples. However, the composites with 10% wt. of both the reinforcement shown an lower co efficient of friction.

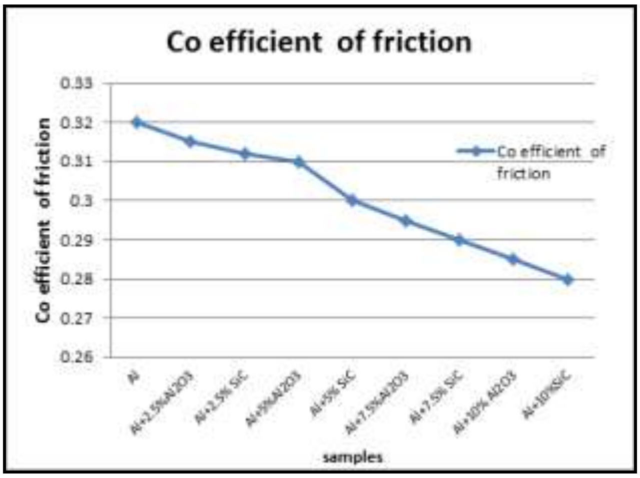


Fig.3.11.Variation of Co-Efficient of Friction for the Wear Condition 3

IV. Conclusion

In this present investigation, the wear behaviour of Aluminium matrix composites which was successfully fabricated by the powder metallurgy process. The hardness, wear test of the Aluminium metal matrix composites was evaluated. The obtained results can be summarized as follows:

- The composite displays higher hardness value compared with the base material, which is attributed due to the presence of hard SiC and Al_2O_3.
- The incorporation of SiC and Al_2O_3 reinforcement to Aluminium matrix increases the wear resistance of the composites.
- Wear test results shows that composites with reinforcement of 10% SiC has higher wear resistance compare to other combination.

V. References

1. V. Daniel Jebin, D. Shivalingappa, J. Jenix Rino Wear behavior of AL6063-Alumina Metal Matrix Composite, International Journal of Science and Research (IJSR), India Online ISSN: 2319- 7064.
2. M.D. Bermúdez, G. Mart´ınez-Nicolás , F.J. Carrión,I. Mart´ınez-Mateo , J.A. Rodr´ıguez , E.J. Herrera Dry and lubricated wear resistance of mechanically-alloyed aluminium-base sintered composites, Wear 248 (2001) 178–186
3. Shinya Sasaki, John B. Pethic, Effects of surrounding atmosphere on micro-hardness and tribological properties of sintered alumina, Wear 241 _2000. 204–208.
4. A.R.I. Khedera, G.S. Marahleh, D.M.K. Al-Jameaa, Strengthening of Aluminum by SiC, Al2O3 and MgO, Jordan Journal of Mechanical and Industrial Engineering, Volume 5, Number 6, Dec. 2011 ISSN 1995-6665 Pages 533 – 541.
5. Gheorghe Iacob, Valeriu Gabriel Ghica, Mihai Buzatu, Traian Buzatu, Mircea Ionuţ Petrescu, Studies on wear rate and micro-hardness of the Al/Al2o3/Gr hybrid composites produced via powder metallurgy, Composites: Part B (2014)
6. S. Pournaderi , S. Mahdavi , F. Akhlaghi , Fabrication of Al/Al2O3 composites by in-situ powder metallurgy (IPM), Powder Technology 229 (2012) 276–284.
7. Jayashree P .K *a, Gowri Shankar M.C a, Achutha Kinia, Sharma S.Sa, and Raviraj Shettya ,Review on Effect of Silicon Carbide (SiC) on Stir Cast Aluminium Metal Matrix Composites
8. Y. Sahina,*, M. Acılarb, Production and properties of SiCp-reinforced aluminium alloy composites, Composites: Part A 34 (2003) 709–718.
9. Umit coen, kazim oriel, the production of Al- Sicp composites via compocasting some microstructural aspect, material science and engineering A221 (1996) 187-191.
10. Ramanpreet Singh, Tribological Characterization of Aluminium-Silicon Carbide Composite Prepared ByMechanical Alloying, International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012) .
11. Kim YW, Griffith WM, Fors HH. The break up and distribution of surface oxides through processing of PM aluminum a7091. ASM Cong 1983;October.
12. Y. Sahin* Wear behavior of aluminium alloy and its composites reinforced by SiC particles using statistical analysis, Materials and Design 24 (2003) 95–103.
13. Adel Mahamood Hassan, Abdalla Alrashdan, Mohammed T.Hayajneh, Ahmad Turki Mayyas Wear behavior of Al–Mg–Cu–based composites containing SiC particles Tribology International 42 (2009) 1230–1238.
14. Md. AminulIslam, Zoheir N.Farhat Effect of porosity on dry sliding wear of Al–Si alloys
15. Hassan Adel M, Abdalla Alrashdan Ahmad TM, Hayajneh Mohammed T. Wear behavior of Al–Cu and Al–Cu/SiC components produced by powder metallurgy. J Mater Sci 2008;43 5368–75.
16. Z. Hasan1, R. K. Pandey, D.K. Sehgal, Wear Characteristics in Al-SiC Particulate Composites and the Al-Si Piston Alloy, Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.14, pp.1329-1335, 2011 .
17. Sun Zhiqiang , Zhang Di , Li Guobin , Evaluation of dry sliding wear behavior of silicon particles reinforced aluminum matrix composites, Materials and Design 26 (2005) 454–458.
18. Kiran Kumar Ekka1, S. R. Chauhan2, Varun,study on the effects of ceramic particulates (SiC, Al2O3 and cenosphere) on sliding wear behaviour of aluminium matrix composites using taguchi design and

neural network, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

19. Ajit kumar Senapati, Saurabh Srivastava, Atmananda Ghadai, Ranjeet Kumar, Atul Kujur, Effect of reinforcement on abrasive wear of different aluminium based metal matrix composite-a review, International Journal of Engineering Trends and Technology (IJETT) – Volume 8 Issue 5- Feb 2014.
20. M. Delavari, A. Salarvand, A. Rahi, F. Shahri, The effect of powder metallurgy process parameters on mechanical properties of micro and nano-iron powder, International Journal of Engineering, Science and Technology Vol. 3, No. 9, 2011, pp. 86-94.

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