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RESEARCH

Reciprocating Wear Behaviour of 7075Al/SiC and 6061Al/Al_2O_3 Composites: A study of Effect of Reinforcement, Stroke and Load

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A B S T R A C T

The wear behaviour comparison of Al/SiC and Al/Al_2O_3 composites prepared by stir casting technique is investigated to find out the effects of weight percentage of SiC/Al_2O_3, load and the number of strokes on a reciprocating wear testing machine. The MMC pins are prepared with different weight percentage of SiC and Al_2O_3 (10, 15 and 20 %). The tests are carried out with different load conditions (25, 50 and 75 N) and different number of strokes (420,780 and 1605 strokes). Wear surfaces of tested samples are examined in Scanning Electron Microscope (SEM). Hardness test and impact test are also carried out on the MMC samples. The experimental results shows that hardness of composites increases with increase in SiC and Al_2O_3 particle and the impact strength decreases with increase in SiC and Al_2O_3 content. The volume loss of MMC specimens are less than that of the matrix alloy. The temperature rise near the contact surface of the MMC specimens increases with increase in wt% of SiC and Al_2O_3, load and number of strokes. The coefficient of friction decreases with increase in the number of strokes. The WVAS (Wireless Vibration Acquisition System) interfaced with MAT Lab software is used to record the amplitudes during the test.

1. INTRODUCTION

Metal matrix composites are mainly used to provide advantageous over monolithic metals such as steel and aluminium. MMC’s have several advantages such as higher elastic properties, higher service temperature, insensitivity to moisture, higher electric and thermal conductivities and better wear, fatigue and flaw resistances. Metal matrix composites are widely used in automotive engines because of their high strength and low weight. A variety of metals and their alloys can be used as matrix materials, but aluminium alloys are widely used because of their low density and excellent strength, toughness and resistance to corrosion. Applications of aluminum matrix composites are space shuttle, military, transportation. Particle reinforced MMC’s have become very important because they are inexpensive and they have relatively isotropic properties compared to fiber reinforced composites.

Generally AMC's are employed in moving or sliding applications, therefore investigation of the tribological properties of these materials is essential to reflect the behaviour of these materials in real situations.

Many investigators demonstrated the effect of reinforcement size, volume fraction, applied load, sliding distance and temperature on dry sliding wear behaviour of aluminium matrix composites. The reinforcing particles benefit the wear behaviour delaying the transition to higher normal loads [1].Significant improvement in wear resistance achieved by the addition of SiC particles [2]. The crack density increases with increase in the quantity of reinforcement. Also they reported that the specific wear rate increases with decrease of reinforcement size for a certain volume percentage of SiC [3]. The wear rate and coefficient of friction varies based on the sliding velocity [4]. Addition of SiC reduces the plastic deformation and increases the wear resistance [5]. Wear rate of composite decreases with increase of SiC [6]. The increase of volume fraction of reinforcement increases the wear resistance [7].

From the literature review, it was understood that the most of the experiments were conducted on pin–on disc machine. To the best of our knowledge, very few researches are carried out by reciprocating wear test method. In the present work an attempt is made to correlate the dry sliding wear behaviour of cast alloy and the composites by reciprocating test method using reciprocating wear testing machine.

2. EXPERIMENTAL SETUP AND PROCEDURE

2.1 Materials

The matrix material selected for the present studies is Al 7075 and Al 6061 alloy and is procured from Jindal Aluminium limited, Bangalore, in the form of ingots. The chemical composition of Al7075 T6 alloy and Al6061 T6 is shown in Table 1 and Table 2. The SiC and Al_2O_3 of 36 micron size is selected as reinforcement material, which is supplied by M/s Snam Abrasives Pvt. Ltd, Hosur, TamilNadu, India.

Table 1. Composition of Al 7075 –T6 alloy.

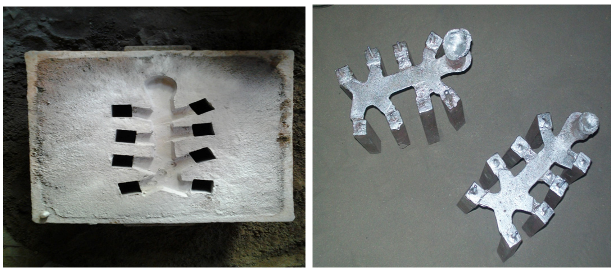
Chemical composition [%]					
Element	%	Element	%	Element	%
Fe	0.21	Mg	2.4	Cr	0.19
Cu	1.5	Zn	5.7	Si	0.11
Mn	0.07	Ti	0.05	Al	89.77

Table 2. Composition of Al 6061 –T6 alloy.

Chemical composition [%]					
Element	%	Element	%	Element	%
Fe	0.209	Mg	0.86	Cr	0.069
Cu	0.274	Zn	0.42	Si	0.7
Mn	0.28	Ti	0.14	Al	97.8

2.2 Processing

The composite specimens are prepared by stir casting method. The photograph of the mould used for casting and the castings are shown in Fig. 1. From the obtained composites, specimens are prepared for various tests.



(a) (b)

Fig. 1. Photograph of (a) Mould and (b) Castings.

2.3 Hardness test and Impact test

The hardness of cast alloy and their composites containing 10 %, 15 % and 20 % (wt.%) of SiC and Al_2O_3 are found using Brinell hardness tester having a steel ball indenter with a load of 5000 N. The impact strength of matrix alloy and their composites are found using Izod and Charphy test.

2.4 Wear test

The reciprocating wear tests are conducted using fabricated reciprocating wear testing machine. The Fig. 2 shows the schematic diagram of experimental setup used for wear tests. The wear tests are performed at a normal load of 25 N, 50 N and 75 N corresponding to vertical movement of 1 mm, 2 mm and 3 mm.

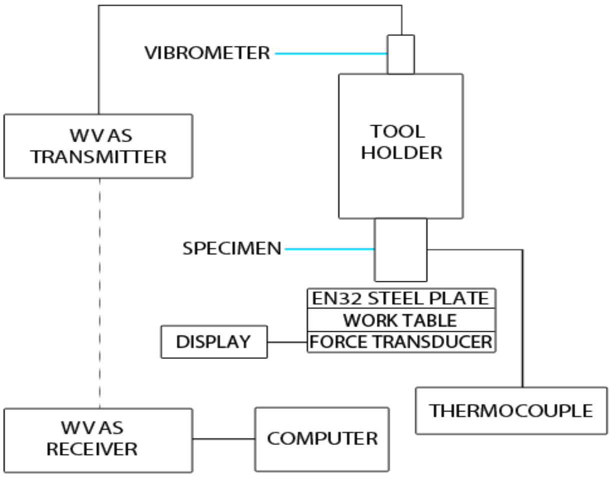


Fig. 2. Schematic diagram of experimental setup used for wear tests.

Initial weight of the specimen is weighed using electronic balance (Model: 200DX) having an accuracy of 0.1 mg. The k type thermocouple is attached in the specimen near the contact surface. A vibrometer is fitted on top of the specimen, who is connected to the transmitter and the receiver is connected with the computer. This WVAS integrated with MATLAB software are used to record the time versus amplitude plot during the test. Friction forces are measured from force transducer which is placed under the steel plate. After the test the final weight of the specimen is measured. The mass loss of the specimen is calculated by finding the difference between initial and final weight. The measured values of mass loss for all the specimens tested were converted in to volume loss using measured density of the alloy. The mass loss of the specimen was used to study the effect of SiC addition, load and number of strokes on the wear resistance of the composite materials. The worn surfaces of the samples were examined using SEM.

3. RESULTS AND DISCUSSION

3.1 Hardness studies

The Brinell hardness of cast Al7075 T6 and Al6061 T6 matrix alloy and its composites containing 10 %, 15 % and 20 % SiC and Al_2O_3 are found using a steel ball indenter at an applied load of 5000 N. The hardness results of 7075Al/SiC and 6061Al/Al_2O_3 composites are shown in Figs. 3 and 4. It is observed that the hardness of the 7075Al/SiC composites is higher than that of 6061Al/Al_2O_3 composites.

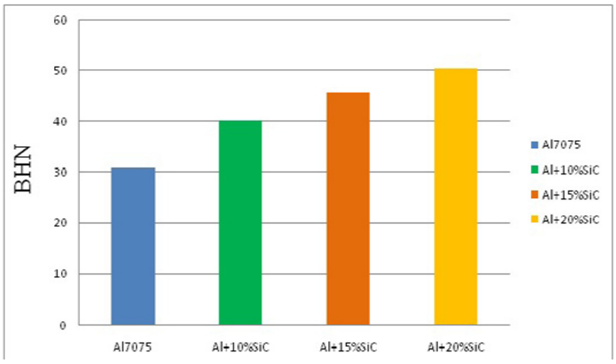


Fig. 3. Brinell hardness of Al7075-SiC composite with different composition of SiC.

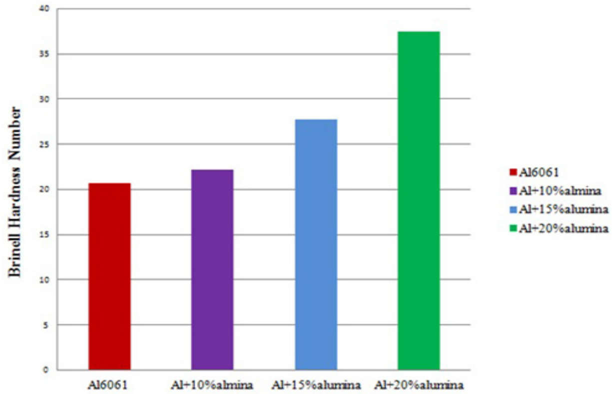


Fig. 4. Brinell hardness of Al6061-Al_2O_3 composite with different composition of Al_2O_3.

3.2 Impact strength

The impact strength of 7075Al and60661 alloy and its composites containing 10 %, 15 % and 20 % SiC and Al_2O_3 are found using charphy and Izod test. The Figs. 5 and 6 shows that the impact strength decreases with increase of wt% of SiC and Al_2O_3.

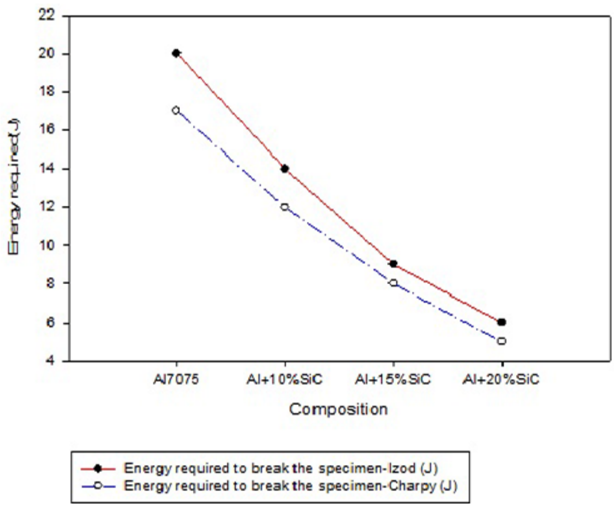


Fig. 5. Impact strength of Al7075-SiC composite with different composition of SiC.

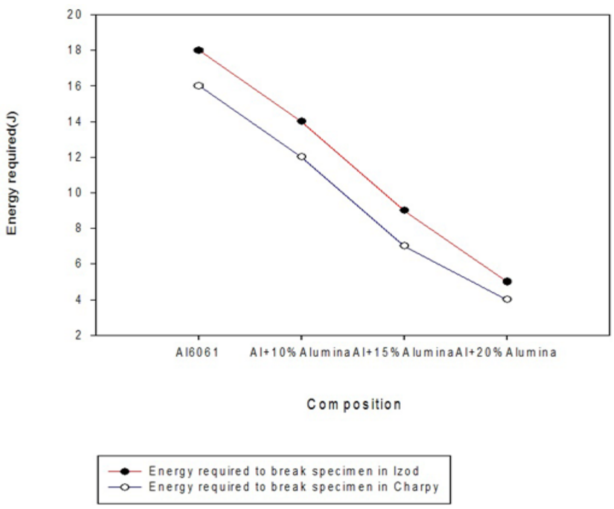


Fig. 6. Impact strength of Al6061-Al_2O_3 composite with different composition of Al_2O_3.

When the hardness increases the brittle property of the material increases this reduces the impact strength of the composites in both cases. These results are in agreement with those reported by [8,9].

3.3 Wear behaviour

The Figs. 7-9 shows that the volume loss of composites for different load at 420,780 and 1605 strokes. It can be observed that the volume loss decreases with increase of weight percentage of SiC. The volume loss of matrix alloy is more than that of composites. Increasing the weight percentage of reinforcement improves the hardness of the composites which improves the wear resistance of the composites [10]. It can be noted that when the number of strokes increases the volume loss increases. Also it can be seen that when the load increases the volume loss increases [11]. The same tendency can be observed for Al 6061 alloy and its Composites (Figs. 10-12). But the volume loss is more in the case of Al6061 alloy and its composites compare to Al7075 and its composites. Composite with 20 % SiC exhibits better wear resistance compared to the matrix alloy and other compositions in both cases. The previous studies carried out by [11,12] showed that wear resistance of the alloy is improved by the addition of SiC particle. The wear rate increases with increase in sliding speed and applied load [13].

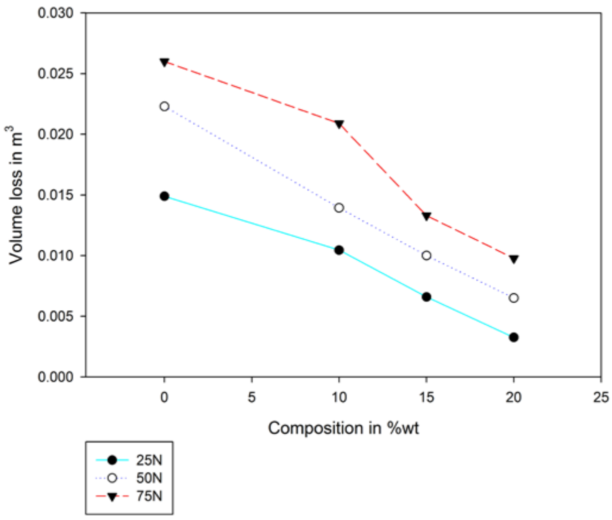


Fig. 7. Volume loss of Al7075 alloy and its composites at 420 strokes.

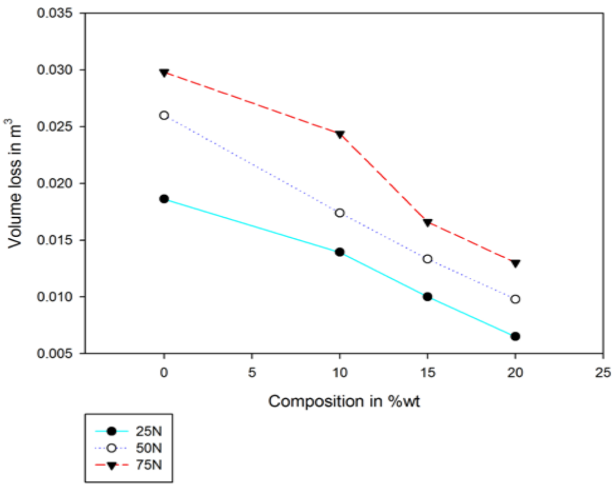


Fig. 8. Volume loss of Al7075 alloy and its composites at 780 strokes.

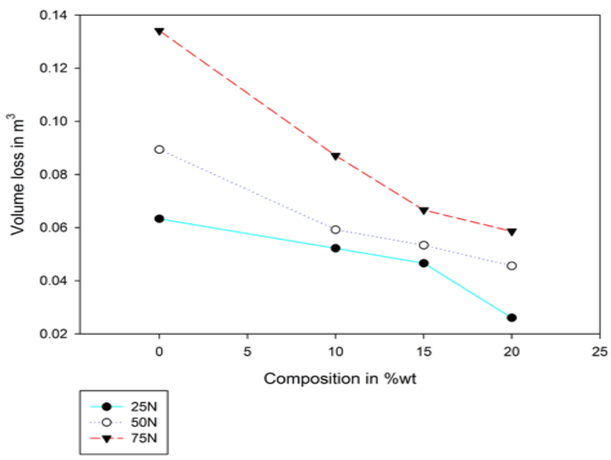


Fig.9. Volume loss of Al7075 alloy and its composites at 1605 strokes.

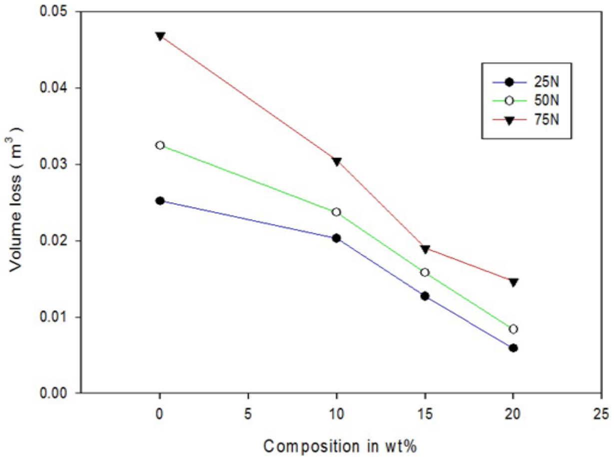


Fig. 10. Volume loss of Al6061 alloy and its composites at 420 strokes.

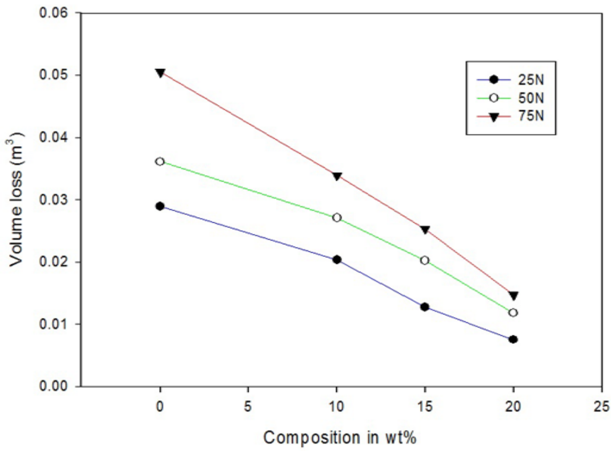


Fig. 11. Volume loss of Al 6061alloy and its composites at 780 strokes.

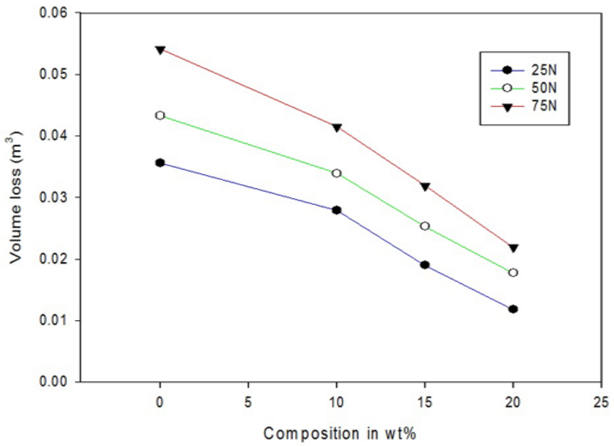


Fig. 12. Volume loss of Al 6061alloy and its composites at 1605 strokes.

3.4 Increase in contact temperature as a function of number of strokes

The increase in contact surface temperature near the contact surface is recorded during the test. From the Figs. 13-15 it is noted that when the number of strokes increases the contact temperature increases. Compared to matrix alloy the temperature rise is more in composites.

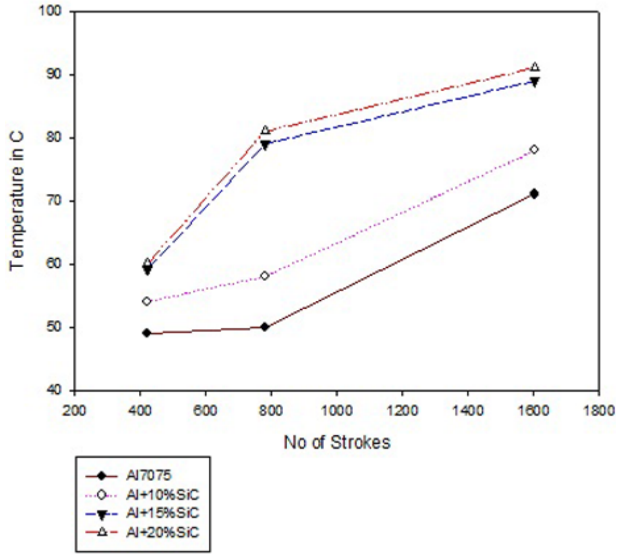


Fig. 13. Increase in contact temperature of Al7075 alloy and its composites at 25 N.

Also it can be observed that the temperature near the contact surfaces increases with increase in applied load.

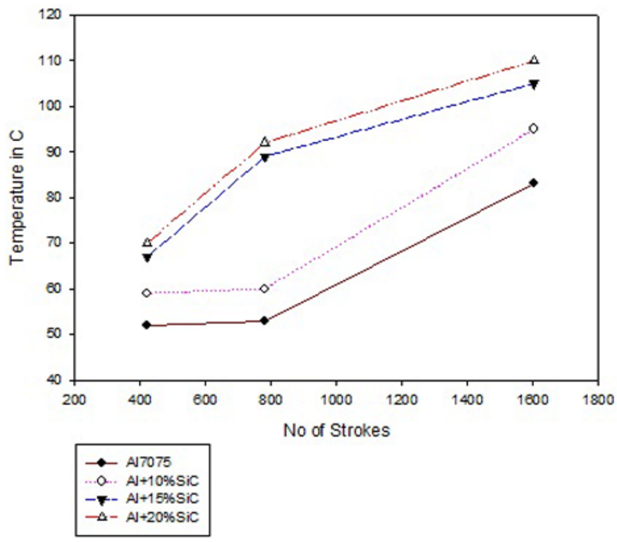


Fig. 14. Increase in contact temperature of Al7075 alloy and its composites at 50 N.

The amount of SiC particles presence in the composites, the number of strokes and the applied load attributes to the more frictional heating thus causes the more heat generation. These results are in agreement with those reported by [14].

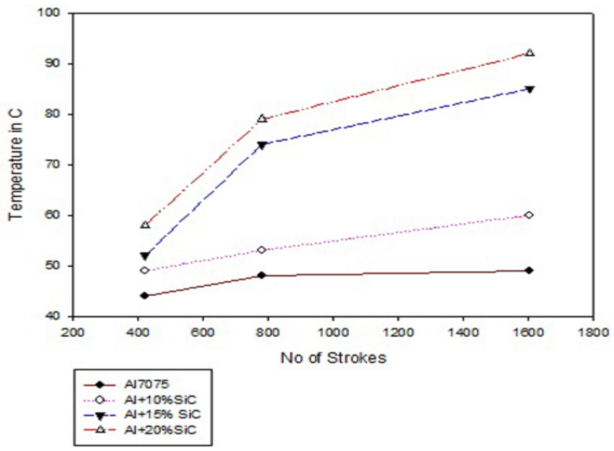


Fig. 15. Increase in contact temperature of Al7075 alloy and its composites at 75 N.

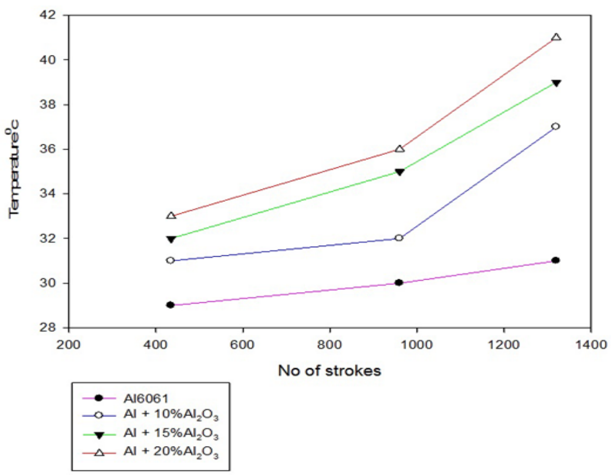


Fig. 16. Increase in contact temperature of Al 6061 alloy and its composites at 25 N.

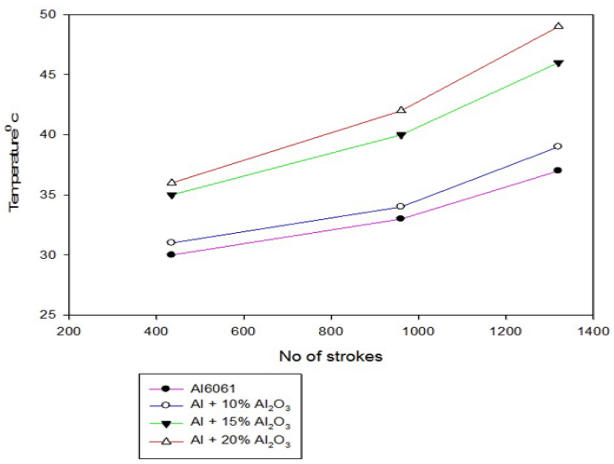


Fig.17. Increase in contact temperature of Al 6061 alloy and its composites at 50 N

From the Fig (16-18) it can be observed that the temperature rise near the contact surface in the case of Al6061 and its composites is less than that of the Al7075 and its composites.

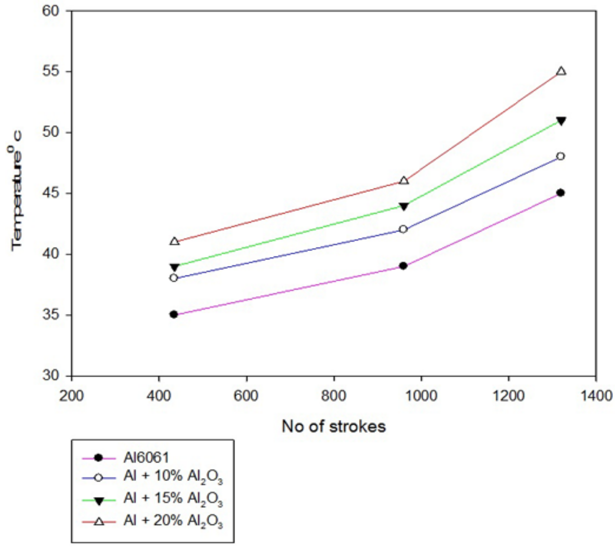


Fig. 18. Increase in contact temperature of Al6061 alloy and its composites at 75 N.

3.5 Coefficient of friction as a function of number of strokes

The Figs. 19 and 20 shows the effect in number of strokes at the load of 75 N on the coefficient of friction. It can be understood that the coefficient of friction decreases with increase in the number of strokes also increases with increase in SiC and Al_2O_3 content. The amount of reinforcement particles present in the composites attributed to higher coefficient of friction but increase in number of strokes reduces the coefficient of friction. When the number of strokes increases, the sliding distance increases with increase in contact temperature, leads to the softening of the surface and thus more slipping action occurs between the contact surfaces there by reduces the coefficient of friction [15-18]. The coefficient of friction of composites is higher than that of the matrix alloy.

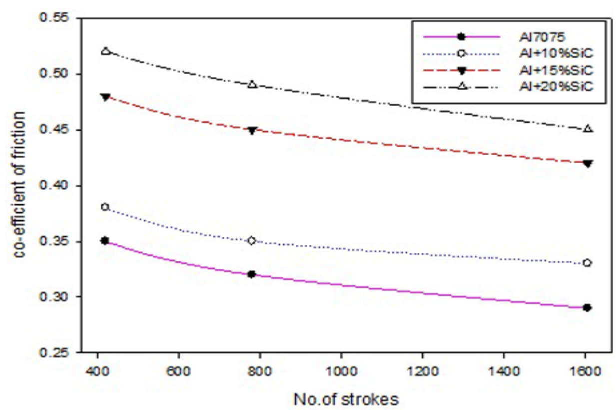


Fig.19. Coefficeient of friction of Al 7075 alloy and its composites at 75N

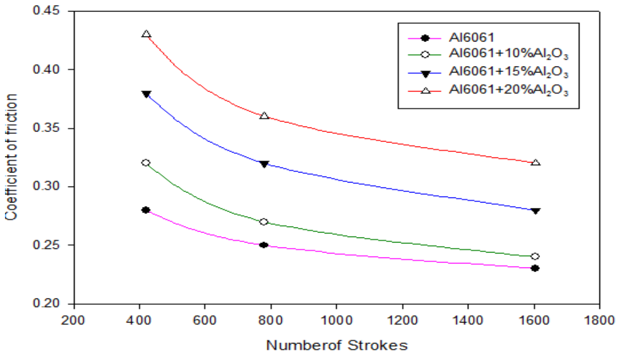
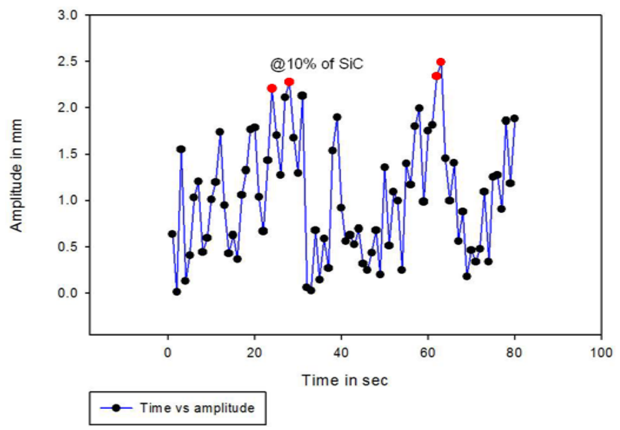


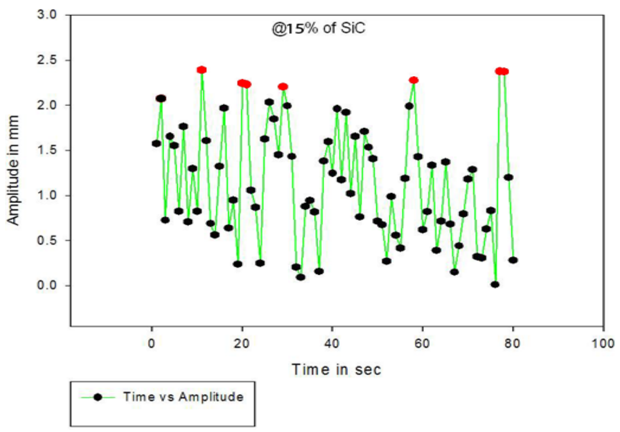
Fig. 20. Coefficeient of friction of Al6061 alloy and its composites at 75 N.

3.6 WVAS (Wireless Vibration Acquisition System)

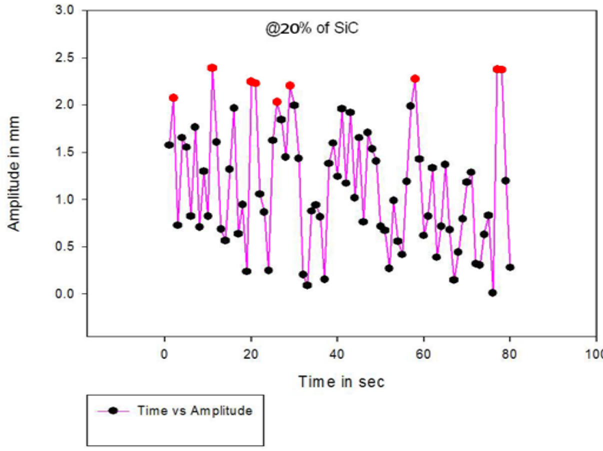
WVAS is used to observe the asperities contacts in between the two contacting surfaces. WVAS interfaced with MATLAB software are used to record the amplitudes during the test. The amplitude plots are obtained for maximum strokes (1605) and the maximum load (75 N) for different composition of SiC. From the Figs. 21(a-c) it can be noted that based on the amount of reinforcement particle, the number of peak amplitude observed.



(a)



(b)



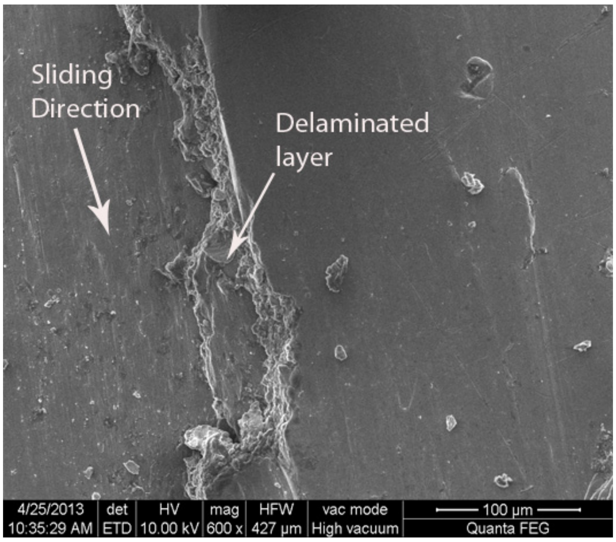
(c)

Fig. 21. Amplitude Vs Time graph at max.load and max.storkes (a) Al with 10%SiC; (b) Al with 15%SiC and (c) Al with 20%SiC.

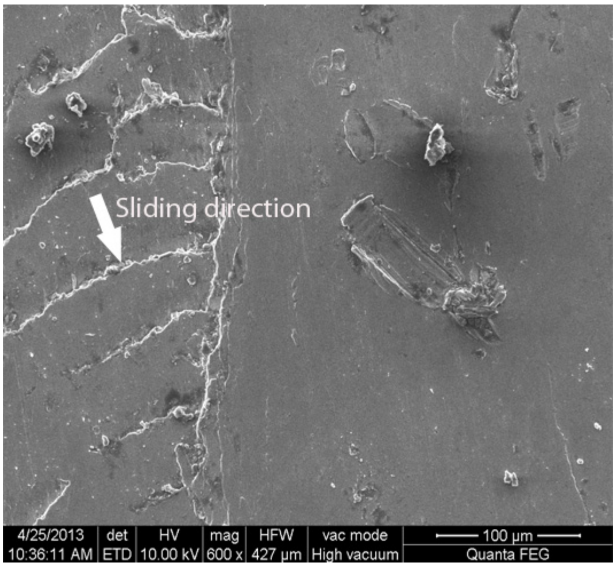
It is due to the more number of reinforcement particles comes in contact between the two contacting surfaces. It can be clearly observed from the Figs. 21(a-c) for the matrix alloy with 10 % SiC has less number of peak amplitudes compared to Al+15%SiC and Al+20% SiC. Due to the more number of strokes and the maximum load the more wear debris generated in between the mating surfaces which is evidently shown by the more number of peak amplitudes in composites with 20%SiC. The similar observation is recorded for Al6061 composites. The previous work carried out by [19] presented the LVDT records with sliding distance.

3.7 Worn surfaces of alloy and composites

The worn surfaces of alloy and composites with 10 %, and 20 % SiC and Al_2O_3 at load of 75 N with 1605 strokes observed using SEM. Figure 22(a) shows the SEM graph of Al6061-10%Al_2O_3. It indicates the more fragmented particles and damaged regions. Figure 22 (b) shows the SEM graph of worn surface of Al7075-10 % SiC. It shows narrow grooves and minimum removal of material in the wavy form. Figure 22(c) shows the SEM micrograph of Al6061-20%Al_2O_3. It indicates the deep grooves and wear regimes. The worn surface of composite Al7075- 20% SiC is shown in Fig. 22 (d). It shows very less fragmented particles and very small wear grooves. The incorporation of SiC and Al_2O_3 improves the hardness, strength and Young's modulus of composite material as compared to the alloy. The high temperature resistance, hardness and modulus of elasticity of composite increase with increase of reinforcement content [20-22]. As a result, the volume loss of the composite is noted to be significantly lower than that of the alloy.



(a)



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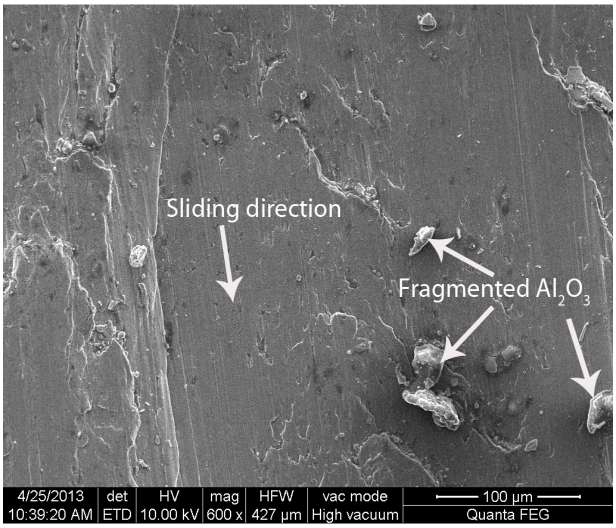
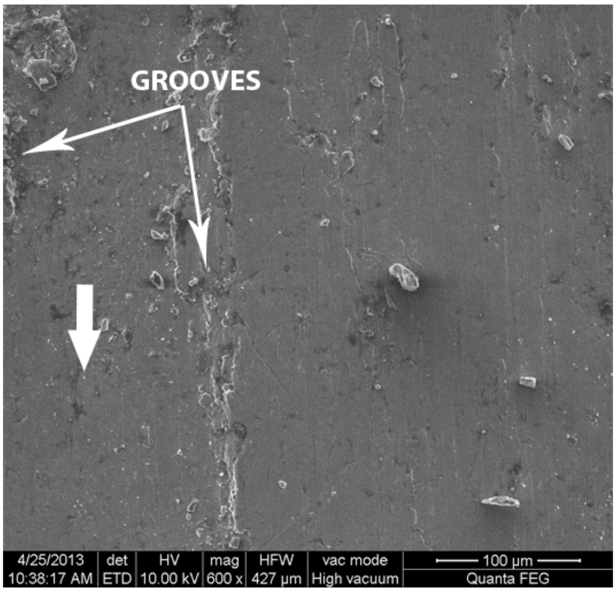


(c)



(d)

Fig. 22. SEM micrograph of the worn surfaces: (a) Al6061-10%Al_2O_3; (b) Al7075-10%SiC; (c) Al6061-20%Al_2O_3; (d) Al7075-20% SiC.

4. CONCLUSIONS

Tribological behaviour of Al 7075 T6, Al 6061 T6 alloy and its composites containing 10 %, 15 % and 20 % (wt %) SiC and Al_2O_3 has been experimentally analysed using reciprocating wear test method, leading to the following conclusions.

Hardness of composites increases with increasing of SiC and Al_2O_3 content. Al7075-20 % SiC exhibits maximum hardness of 50 BHN where as 37 BHN for Al6061-20%Al_2O_3. Impact strength of composite is decreasing with increase in wt.% of SiC and Al_2O_3 reinforcement. Composite with Al7075-20%SiC and Al6061-20%Al_2O_3 reinforcement shows better wear resistance compared to its matrix alloy and other compositions. But the wear resistance is more for Al7075-SiC composites compared to Al6061- Al_2O_3.

Increase in number of strokes, the volume loss increases. Also increase in number of strokes and wt.% of reinforcement, the contact temperature increases. The temperature rise in Al6061-Al_2O_3 composites is minimum when compared to the Al7075-SiC composites.

The coefficient of friction reduces with increase in number of strokes. Coefficient of friction for composite is higher than that of the matrix alloy in both composites. But the magnitude of the coefficient of friction is minimum for Al6061-Al_2O_3 composites compare to the Al7075-SiC composites for the identical test conditions.

The amplitude versus time graph was recorded using WVAS. More number of peak amplitude observed for Al-20 % reinforcement composite. The formation of wear grooves and fragmented particles observed at maximum number of strokes and maximum load. Composite with 20 % SiC shows less wear regime compared to alloy and other compositions.

REFERENCES

[1] T. Gomez-del Rio, A. Rico, M.A. Garrido, P. Poza, J. Rodriguez: *Temperature and velocity transitions in dry sliding wear of Al-Li/SiC composites,* Wear, Vol. 268, No. 5-6, pp. 700-707, 2010.

[2] Adel Mahamood Hassan, Abdalla Alrashdan, Mohammed T. Hayajneh, Ahmad Turki Mayyas: *Wear behavior of Al-Mg-Cu-based compositescontaining SiC particles*, Tribol. Int, Vol. 42, No. 8, pp. 1230-1238, 2009.

[3] S.K. Ghosh, Partha Saha: *Crack and wear behaviour of SiC particulate reinforced aluminium based metal matrix composite fabricated by direct metal laser sintering process*, Mater. Des., Vol. 32, No. 1, pp. 139- 145, 2011.

[4] N. Jha, Anshul Badkul, D.P. Mondal, S. Das, M. Singh: *Sliding wear behaviour of aluminium syntactic foam: A comparison with Al-10 wt% SiC composites*, Tribol. Int , Vol. 44, No. 3, pp. 220-231, 2011.

[5] P. Rodrigo, M. Campo, B. Torres, M.D. Escalera, E. Otero, J. Rams: *Microstructure and wear resistance of Al-SiC composites coatings on ZE41 magnesium alloy,* Appl. Surf. Sci, Vol. 255, No. 22, pp. 9174-9181, 2009.

[6] Y. Sahin, V. Kilicli: *Abrasive wear behaviour of SiCp/Al alloy composite in comparison with ausferritic ductile iron*, Wear, Vol. 271, No. 11-12, pp. 2766-2774, 2011.

[7] G.B. Veereshkumar, C.S.P. Rao, M. Selvaraj: *Studies on mechanical and Dry sliding wear of Al6061-SiC composites*, Composites: part B, Vol. 43, No. 3, pp. 1185-1191, 2012.

[8] Bekir Sadik Unlu: *Investigation of tribological and mechanical properties Al2O3-SiC reinforced Al composites manufactured by casting or P/M method*, Mater. Des., Vol. 29, No. 10, pp. 2002-2008, 2008.

[9] Tamer Ozben, Erol kilickap,Orhan Cakir: *Investigation of mechanical and machinability properties of SiC particle reinforced Al-MMC*, J. Mater. Process. Technol., Vol. 198, No. 1-3, pp. 220-225, 2008.

[10] Ranjit Bauri, M.K. Surappa: *Sliding wear behaviour of Al-Li-SiCp composites, Wear,* Vol. 265, No. 11-12, pp. 1756-1766, 2008.

[11] S. Mitrović, M. Babić, B. Stojanović, N. Miloradović, M. Pantić, D. Džunić: *Wear Properties of A356/10SiC/1Gr Hybrid Composites in Lubricated Sliding Conditions,* Tribology in Industry, Vol. 35, No. 2 pp. 148-154, 2013.

[12] S. Mitrović , M. Babić , B. Stojanović , N. Miloradović , M. Pantić, D. Džunić: *Tribological Potential of Hybrid Composites Based on Zinc and Aluminium Alloys Reinforced with SiC and Graphite Particles,* Tribology in Industry, Vol. 34, No. 4, pp. 177-185, 2012.

[13] S. Kumar, V. Balasubramanian: *Effect of reinforcement size and volume fraction on the abrasive wear behaviour of AA7075 Al/SiCp P/M composites-A statistical analysis*, Tribol. Int, Vol. 43, No. 1-2, pp. 414-422, 2010.

[14] Adem Onat*: Mechnaical and dry sliding wear properties of silicon carbide particulate reinforced aluminium-copper alloy matrix composites produced by direct squeeze casting method*, J. Alloys and Comp, Vol. 489, No. 1, pp. 119-124, 2010.

[15] R.N. Rao, S. Das: *Effect of matrix alloy and influence of SiC particle on the sliding wear characteristics of aluminium alloy composites*, Mater. Des, Vol. 31, No. 3, pp. 1200-1207, 2010.

[16] R.N. Rao, S. Das, D.P. Mondal, G. Dixit: *Dry sliding wear behavior of cast high strength aluminium alloy (Al-Zn-Mg) and hard particle composites*, Wear, Vol. 267, No. 9-10, pp. 1688-1695, 2009.

[17] S.M.R. Mousavi, Abarghouie, S.M. Seyed Reihani*: Investigation of friction and wear behaviors of 2024 Al/SiCp composite at elevated temperatures,* J. Alloys and Comp., Vol. 501, No. 2, pp. 326-332, 2010.

[18] J.O. Agunsoye, E.F. Ochulor, S.I. Talabi, S. Olatunji: *Effect of Manganese Additions and Wear Parameter on the Tribological Behaviour of NFGrey (8) Cast Iron,* Tribology in Industry, Vol. 34, No. 4, pp. 239-246, 2012.

[19] Sudashan, M.K.surappa: *Dry sliding wear of fly ash particle reinforced A356 Al composites*, Wear, Vol. 265, No. 3-4, pp. 349-360, 2008.

[20] S. Das, D.P. Mondal, S. Sawla, N. Ramakrishnan: *Synergic effect of reinforcement and heat treatment on the two body abrasive wear of an Al-Si alloy under varying loads and abrasive sizes*, Wear, Vol. 264, No. 1-2, pp. 47-59, 2008.

[21] Rupa Dasgupta: *Sliding wear resistance of Al-alloy particulate composites*: An assessment on its efficacy, Tribol. Int., Vol. 43, No. 5-6, pp. 951-58, 2010.

[22] S.A. Alidokht, A. Abdollah-Zadeh, S. Soleymani, H. Assadi: *Microstructure and tribological performance of an aluminium alloy based hybrid composite produced by friction stir processing*, Mater. Des., Vol. 32, No. 5, pp. 2727-2733, 2011.