Investigations on Wear Behaviour of Micro B₄C Particulates Reinforced Al7010 Alloy Composites

Dr. B Adaveesh¹, Raghukumar J², Madeva Nagaral³

¹Associate Professor, Department of Industrial Engineering & Management, Siddaganga Institute of Technology, Tumkur-587102, Karnataka, India
²PG Scholar, Department of Industrial Engineering & Management, Siddaganga Institute of Technology, Tumkur-587102, Karnataka, India
³Design Engineer, Aircraft Research and Design Centre, HAL, Bangalore-560037

E-mail: badaveesh@yahoo.co.in

Abstract. The work is done to research the dry sliding wear behaviour of B₄C strengthened Al7010 alloy metal composites. Here Al7010 was used as matrix material and B₄C as particulate to get MMC by vortex technique. For MMC the reinforcement was varied from 3% to 12 wt.% in venture of 3 wt %. The micro structural characterization was done by using scanning electron microscope and energy dispersive spectrographs to reveal the uniform distribution of particles and also to confirm the B₄C particulates. The wear resistance of metal matrix composites was reported by experimenting wear test using a pin on disc apparatus. The experiments were carried out at a constant sliding speed of 300rpm and sliding distance of 2000m over a varying load of 2, 3 and 4Kg. Similarly experiments were conducted at a constant load of 3Kg and sliding distance of 2000m over a varying sliding speed of 200, 300 and 400rpm. The results showed that the wear loss in microns found to increase with the load and sliding speed. To concentrate the dominant sliding wear component for different test conditions, the worn surfaces were analyzed using SEM.

1. Introduction
Metal matrix composites (MMCs) have been made to meet requests of lighter materials particularly suited for applications requiring high quality to weight proportion with high particular quality, dimensional dependability, auxiliary inflexibility, and solidness for various applications like car, space, flying machine, barrier, and in other building divisions [1-3]. Aluminum is the most broadly utilized grid material for the planning metal framework composites. Aluminum combinations are comprehensively ordered into thrown composites and fashioned compounds. Major alloying components in aluminum combinations are copper, manganese, silicon, magnesium and zinc. Aluminum has been utilized as a network material because of its light weight, high quality, magnificent wear resistance properties, high temperature, simple to set up the composite and accessibility in plenitude [4]. From quick couple of year’s aluminum lattice composites are broadly utilized as a part of various auxiliary, non-basic and practical applications. The significant advantages of aluminum based composites in transportation area are low fuel utilization, less air borne outflows and lower commotion.

Numerous artistic materials like particulates of SiC, TiC, graphite, boron carbide are generally utilized fortifications in aluminum compound [5-6]. Aluminum amalgam based particulate fortified composites have a more number of designing applications, strengthening aluminum combinations with various hard clay particles is for the most part because of wide accessibility. The most normally utilized aluminum composite networks are 2024, 2014, 2219, 5083, 5052, 6061, 6068, 7010 and 7075 compounds.

Particulate fortified aluminum composites are manufactured by strong or fluid state forms. These composites are more affordable as contrast with persistent fiber strengthened composites. Mechanical and tribological properties of particulate strengthened composites are in accordance with short fiber or consistent fiber fortified composites. The primary favourable circumstances of particulate fortified
aluminum composites over different materials are their cost preference, formability, enhanced consumption and seizure resistance [7]. Subsequently, these aluminum based composites are utilized as barrel squares, circle brakes, callipers, interfacing bars and structures for space applications. In the greater part of these administrations the segments are subjected to tribological stacking conditions [8]. A few scientists have investigated the wear conduct of Al based composites. Baradeswaran et al. [9] contemplated on mechanical and wear properties of Al7075-Al₂O₃-graphite composites. Demonstrated hardness, rigidity and pressure quality of the composites are observed to be expanded. The wear properties of mixture composites having graphite displayed the predominant wear resistance properties. Suresh et al. [10] have detailed wear conduct of Al-TiB₂ composites utilizing response surface strategy. Yuhai et al. [11] have investigated the contact and wear conduct of Al6061-B₄C composites. Composites were contemplated by considering the impact of sliding time, connected load, sliding speed and warmth treatment. Umanath et al. [12] led investigates dry sliding wear conduct of Al6061-Al₂O₃-SiC hybrid metal network composites.

In this examination, an attempt has been made to prepare Al7010 amalgam composites by including 3%-12 wt. % of B₄C particulates into framework by using a novel two stage stronghold development system. Further, the orchestrated Al7010-B₄C composites were mulled over for weight quality and besides to know the effect of load and sliding speed on the wear properties by using pin-on-disc wear testing device.

2. Experimental Details

2.1 Materials Used

MMC containing 3, 6, 9 & 12 weight %ages of B₄C particles were made by fluid metallurgy course. For the era of MMCs, an Al7010 compound was used as the system material while B₄C were used as the fortresses. The hypothetical density of framework material Al7010 alloy is 2.80g/cm³ and particulates B₄C is 2.52g/cm³. The compound substance of Al7010 composite used as a piece of the work is given in the table 1.

Table.1 Shows the Chemical Composition of the Al7010 alloy used in the present study.

| Elements | Si | Fe | Cu | Mn | Mg | Cr | Zn | Al |
|----------|----|----|----|----|----|----|----|----|
| Percentage | 0.12 | 0.15 | 1.5 | 0.10 | 2.1 | 0.05 | 6.5 | Balance |

2.2 Synthesis of composites

The B₄C constituent part braced Al7010 composites have been made by using a vortex procedure. At first processed measure of Al7010 compound was surged into SiC cauldron & heated to a temperature 730°C in an electrical furnace. The heater temperature was inhibited to a precision of ±10 degree Celsius utilizing a moved temperature controller. Once the necessary temperature is capable, removing gasses is done utilizing strong hexachloroethane (C₂Cl₆) to clear all the ingested gasses The break down was exasperates with the help of a zirconia secured mechanical stirrer to shape a fine vortex. A speed of 300 rpm and mixing time 3-5 min. were grasped during stirring. The B₄C particulates were preheated to a temperature of 500 degree Celsius in a pre-warmer to improve the wettability. The pre-warmed B₄C particles brought into the liquid Al framework at the rate of 1.2-1.4 g/sec. Ensuing to holding the condense for a period of 5 min., the mellow was purged from 710 degree Celsius into a preheated cast iron mould having dimensions of 120mm length x 15mm diameter.

2.3 Testing

Metallographic test specimens of 5mm thickness were prepared by cutting the as cast and B₄C strengthened Al7010 combination composites. Test samples were polished according to the standard
metallographic methodology and etched with Keller's reagent. The microstructure was viewed utilizing scanning electron microscope instrument. The dry sliding wear experiment of as cast Al7010 matrix and Al7010-B₄C composites were assessed utilizing a pin on-disc wear contraption at room temperature as indicated by ASTM G99 standard. Pins of length 25 mm and diameter 8mm were prepared from the cast samples. The experiments were conducted at a constant sliding speed of 300rpm and sliding distance of 2000m over a varying load of 2Kg, 3Kg, and 4Kg. Similarly experiments were conducted at a constant load of 3Kg and sliding distance of 2000m over a varying sliding speed of 200, 300 and 400rpm. The cleaned surface of the stick was slide on a solidified chromium steel circle. A computer aided data acquisition system was utilizes to monitor the loss of tallness. Wear value is presented in terms of height loss. Figure 1 shows wear test specimen used in the present work.

![Figure 1. Specimen used in wear test](image)

3. Results and Discussion

3.1 Microstructural Studies

Figure 2 (a-e) demonstrates the SEM microphotographs of Al7010 composite as cast and Al7010 with 3, 6, 9 and 12 wt. % of B₄C particulate composites. This shows the uniformity of B₄C particles and low agglomeration of particles, and porosity. From the scanning electron photographs figure 2a-e, it is revealed that there is uniform distribution of secondary phase particulates in the Al7010 alloy matrix. All the photographs showing the good interfacial bonding between the B₄C and Al alloy matrix, which further enhances the properties of Al7010 alloy. In the case of Al7010-12 wt. % B₄C composites, there are more particulates in the Al7010 matrix, which shows good castability and wettability of Al7010 alloy with ceramic reinforcements.

![SEM microphotographs of Al7010](image)

(a)  (b)
Figure 2. Scanning electron micrographs of (a) as cast Al7010 alloy (b) Al7010-3 wt. % B₄C (c) Al7010-6 wt. % B₄C (d) Al7010-9 wt. % B₄C (e) Al7010-12 wt. % B₄C

Figure 3. Energy dispersive spectrographs of (a) as cast Al7010 alloy (b) Al7010-12 wt. % B₄C composites
Figure 3a shows the energy spectrographs of as cast Al7010 alloy, which contains Zn and Mg are the major alloying elements. Further, figure 3e shows EDS analysis of Al7010-12wt.% B\textsubscript{4}C composites, presence of B\textsubscript{4}C is confirmed in the form of B and C elements.

3.2 Wear Properties
Wear test was conducted on the fabricated as cast alloy and B\textsubscript{4}C reinforced 3, 6, 9 and 12 wt.% composites. And they are machined according to the ASTM G99 standard for wear test. For each composition test was conducted for 3 specimens by varying load with constant speed and another 3 specimens with varying speed with constant load.

Effect of Load on Wear Loss
The load is the parameter in wear test which expect a basic part in wear. A couple of experts have guided wear examinations to watch the effect of average load on wear rate of aluminum. To focus the effect of load on wear, charts were plotted for wear loss in microns against fluctuating loads of 2kg, 3kg and 4kg at an unaltering velocity of 300 rpm. Correspondingly for wear loss of the graphs were plotted in figure 4.

![Figure 4. Shows wear loss of Al7010 and its composites at varying loads and 300rpm constant speed](image)

Higher wear loss is observed for alloy and the composites at higher loads. At maximum loads the temperature of sliding surface and pin exceeds the essential value. So as weight increases on the pin finally there is an increase in the volumetric wear loss of both the matrix alloy and B\textsubscript{4}C composites. The variation of wear loss of the matrix alloy 7010 and its composites with 3, 6, 9 and 12 wt.% of B\textsubscript{4}C reinforcement contain are shown in figure 5. It is noted that the wear loss of the composites decreases with wt.% B\textsubscript{4}C reinforcements in the matrix alloy. The upgrading in the wear resistance of the composites with 12 wt.% of B\textsubscript{4}C reinforcements can be attributed to the high hardness of B\textsubscript{4}C particulates which acts as the barrier for the material loss [13-15].
Effect of Sliding Speed on Wear Loss

Figure 5: Shows wear loss of Al7010 and its composites at varying speeds and 3kg constant load

Figure 5 demonstrates the variation of wear loss with the variety of speed. The test was led with differing disc speed of 200rpm, 300rpm and 400 rpm at consistent load of 3 kg. From the figure, it is presumed that wear loss in microns shows increments with the expansion of sliding speed. For base compound the impact is more contrasted with B₄C fortified composite.

Figure 5 shows the dependence of all the wear loss of Al7010 matrix alloy and B₄C composites on sliding speed. With an increasing speed from 200rpm to 400rpm, the wear loss is increased for both Al7010 matrix alloy and fabricated composites. However for all sliding speeds, the wear is less for the composites compared to Al7010 matrix alloy & is much lesser in the case of Al7010-12 wt. % B₄C composites compared to Al7010 alloy matrix and 3, 6 and 9wt. % B₄C composites. Further, as sliding speed increases there is increase in wear due to softening of the composite at high temperature [16-18]. The increased temperature causes the severe plastic deformation in the specimen at higher sliding speeds can leading to form high strain rate sub-surface deformation. Therefore this leads to enhanced delamination contributing to enhance wear rate.

3.3 Wear Properties

Figure 6a-b demonstrates the worm surface morphology after wear testing on base compound Al7010 and 12 wt. % of B₄C composite case. The photo bolsters the debate that advancement of hard B₄C particles enhanced the wear resistance of composites. It is clear from the Figure 6 (a) that the wear tracks and surface delamination are plainly obvious. Wear track is found in the event of Al7010, demonstrates the glue wear portion. The wear resistance is an occurrence of (Al7010+ 12% B₄C) composites. Figure 6b demonstrates that wear has taken less aggregate. The result uncovered that the composites with B₄C particulates have better destroy resistance property remained from base blend. Because of high temperature and rubbing, just oxide wear has happened [19].
Figure 6. SEM Micro photographs of worn surface of (a) base alloy 7010 (b) Al7010 with 12 % B₄C

4. Conclusions

The present work on preparing and assessment of Al7010-B₄C metal network composite by liquid mixing has prompted taking after conclusions. Al7010 matrix based composites have been effectively created by stir casting strategy utilizing two phase expansion technique for fortification joined with preheating of particles. The SEM microphotograph of composites genuinely shows uniform dissemination of support particulates in the Al7010 alloy grid and EDS spectrographs affirmed the presence of B₄C particles. The reinforcement of B₄C particles to Al amalgam framework enhances the wear resistance of the composite. The wear loss is commanded by load consider and sliding speed. The expansion of loads and sliding speed prompts a critical increment in the wear loss. The Al7010-12% B₄C composites have demonstrated lower wear loss when contrasted with that seen in as cast Al7010 combination and 3, 6 and 9 wt. % B₄C fortified composites. Worn morphology demonstrated the impact of hard artistic particulates expansion on wear conduct of Al alloy and its composites.

References

1. Sourabh Garatte Rahul Upadhye Venkatesh Dandagi Shrikanth Desai and Bhimappa Waghamode 2013 *Journal of Minerals and Materials Characterization and Engineering* 1 p 8-14.
2. Ramkoteshwara Rao V Ramanaiah N and Sarcar M 2014 *Applied Mechanics and Materials* Vol 592-594 p 349-353.
3. Hamid Reza Ezatpour Seyed Abolkarim Sajjadi Mohsen Haddad Sabzevar and Yizhong Huang 2014 *Materials and Design* 55 p 921-928.
4. Srimant Kumar Mishra Sandyarani Biswas and Alok Satapathy 2014 *Materials and Design* 55 p 958-965.
5. Baskaran S Anandakrishnan and Muthukannan Duraiselvam V 2014 *Materials and Design* Vol 60 p 184-192.
6. RamPrabhu T Varma V K and Srikanth Vedantam 2014 *Wear* Vol 309 p 1–10.
7. Dora Siva Prasad and Chintada Shoba 2014 *Journal of Materials and Research Technology*, vol 3(2) p172–178.
8. Surendran R and Kumaravel A 2014 *Journal of Applied Mechanics and Materials* Vols 592-594 p 1352-1356.
9. Baradeswaran A and Elaya Perumal 2014 *Composites Part B* 56 p 464-471.
10. Suresh S Shenbaga Vinayaga Murthy Vettivel S C and Selvakumar N 2014 *Materials and Design* 59 p 383-396.
11. Lisheng Zhong Fangxia Ye Yunhua Xu and Jinshan Li 2014 *Materials and Design* 54 p 564-569.
12. Umanath K Palanikumar K and Selvamani S T 2013 *Composites Part B* 53 p 159-168.
13. Madeva Nagaral Auradi V and Kori S A 2014 *Applied Mechanics and Materials*, Vol.592-594 p 170-174.
14. Ravikiran A and Surappa M. K 1997 *Wear* 206 p 33-38.
15. Sudarshan and Surappa M K 2008 *Wear* 265 p 349-360.
16. G B Veereshkumar C S P Rao N Selvaraj 2012 *Composites Part B* 43 p 115-1191.
17. Madeva Nagaral Auradi V Kori S A 2014 *Applied Mechanics and Materials* Vol.592-594 p 170-174.
18. Ravikiran A Surappa M K 1997 *Wear* 206 p 33-38.
19. Surendran R Kumaravel A 2014 *Journal of Applied Mechanics and Materials* Vols 592-594 p 1352-1356.