Mechanical and Wear Properties of Cold Extruded Al6063 Metal Matrix Alloy Reinforced with Silicon Carbide, Alumina and Cerium Oxide

Abdul Nazeer, Mir Safiulla

Abstract: Metal matrix composite is considered in various engineering fields like Automobile, medical, electronics aerospace, marine, recreational sectors, of which Aluminum metal matrix composite is considered mostly because of its high strength to weight ratio, easy of fabrication, corrosion resistance, good aesthetic appearance and high resistance to wear etc. This paper concentrates on the effect of secondary processing (Cold Extrusion) on mechanical and wear properties of Al6063 reinforced with SiC, Al_2O_3 and CeO_2 particles. Here composite systems prepared by varying reinforcement from 0% to 8% in steps of 2%. Stir casting route adopted for casting composite systems after casting the composite is made to pass through extrusion process with an extrusion ratio of 1.93 with a total strain of 1.45. All composite systems tested for mechanical properties as per ASTM and ISO standard. Wear test was conducted on pin on disc setup for different loads, reinforcement, sliding distance and sliding speed. Results reveals that due increase in reinforcement the mechanical properties have improved further improvement observed when subjected to extrusion process, similar observation was made for wear studies which conclude the wear rate is improved for extruded composite as compared to cast composite systems observed by various researchers.

Keywords: Aluminum 6063 matrix composite, Silicon Carbide, Stir Casting, Pin on disc and Mechanical Tests.

I. INTRODUCTION

Metal matrix composite have replaced many conventional materials due to its superior properties light weight with good resistance to corrosion and wear, due to these properties this materials are widely accepted in many engineering sectors like Marnie, Aerospace, Electrical, Automobile etc. Aluminum matrix composite have universally accepted due to its excellent friction and wear resistance, good corrosion resistance high elastic modulus, high specific strength, low coefficient to thermal expansion. Particulate reinforced metal matrix composite has widely accepted in last few decades, addition of ceramic particles in aluminum alloy has significantly improved mechanical and wear properties., the major problem associated with fabrication of metal matrix reinforcing with ceramic particles was poor wettability due to which agglomeration of reinforcement formed, the issue overcome with the development of different production techniques also optimizing the different production technique helps to fulfill the industry requirement at larger extent[18].
In liquid metallurgy route stir casting technique is widely used due to its easy of production and economical [17]. The present trends of potential applications is to improve the temperature effect, tribological properties and mechanical properties. Researchers identified number of reinforcement for aluminum based metal matrix composite like TiB_2, SiC, TiO_2, Al_2O_3,TiC, Gr to improve the properties of composite [4,6,7].It is also found that with reinforcing the fly ash with 5% and 10% by weight in Al6063 Hardness, Tensile and wear properties have improved [2].
Hybrid composite have also made a greater impact to replace the conventional materials. Reinforcement like SiC/Gr a hybrid reinforcement in aluminum matrix have improved significantly the tensile strength and reinforcement are evenly distributed as resulted [1].
Aluminium Based Silicon Carbide Particulate Metal Matrix Composite has identified for power transmitting product like manufacturing of Spur Gear [3], Aluminium composite systems exhibits good wear and friction properties when proper proportion of reinforcement added [7].
Researcher worked to study the effect of particle size which made them to involve with reinforcing the nanoparticles in multiwall carbon nanotubes [11] which resulted a very good output but the process of fabrication is very tedious and very expensive. A lot of work on primary processed composite done with various combination researcher are now focused on secondary processing of primary processed composite, it has found larger difference in hardness was observed at the surface compared to the core area due to severe deformation that occurred at the dead metal zone surface during extrusion. [16] Due to extrusion process the grain refinement improves which in turns improve the mechanical properties of composite [5].
The present work aims to study the effect of secondary process (Cold extrusion) on mechanical and wear properties for aluminum matrix reinforced with SiC, Al_2O_3 and CeO_2 particles of varying weight percentage from 0% to 8% instep of 2%.

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II. EXPERIMENTAL PROCEDURE

A. Materials

Aluminum 6063 is used as metal matrix, Silicon Carbide, Aluminium oxide and cerium oxide as reinforcement in lab grade powder form.

Table I: Composition of Al6063

Elements	Si	Fe	Cu	Mn	Mg	Al
% (max.)	0.2%-0.6%	0.35% 3	0.10% 4	0.8	0.10%	Balance

Table II: Mechanical properties of Matrix and reinforcement

Material/ Properties	Density gm/cc	Hardness	Strength (Tensile/ Compressive) (MPa)	Elastic modulus (GPa)
Matrix – 6063 Al	2.7	73	130	68.9
SiC	3.02	2800	3900(C)	410
Al_2O_3	3.9		282-551	380
CeO_2	7.215		155	180

B. Preparation of Composites

Liquid metallurgy route stir casting technique adopted for preparation of Al6063- Sic, Al_2O_3 and CeO_2 composite systems, reinforcement powder of lab grade is first preheated about 300^0C and the molten matrix, which is maintained at a constant temperature of 700ºC, the reinforcement is induced 0-8% in steps of 2% and gradually mix in liquid matrix to a constant stirring time was 10min for all set of composite. The prepared composite is poured in mould of predefined shape and size and kept for solidification process at room temperature. The cast specimen were machined to require dimensions. Fig 1a-1b shows the preparation of composite and prepared samples. Here the mould used for casting is made of cast iron and the tool used machining the specimen is High speed steel (HSS).

Fig 1.a Pouring of molten material into mold

Fig 1.b Samples prepared for various tests

C. Cold Extrusion

Al6063 and its composites were cold impact extruded with a deformation rate of 130 mm/sec and a punch pressure of 1.06 KN/mm2 .The extrusion ratio of the process was 1.93 with a total strain of 1.45 using a mechanical crank forging press of 800T capacity, at Klass Technology Ventures Pvt.Ltd, Bangalore.The photograph of the press is shown in Fig.2.

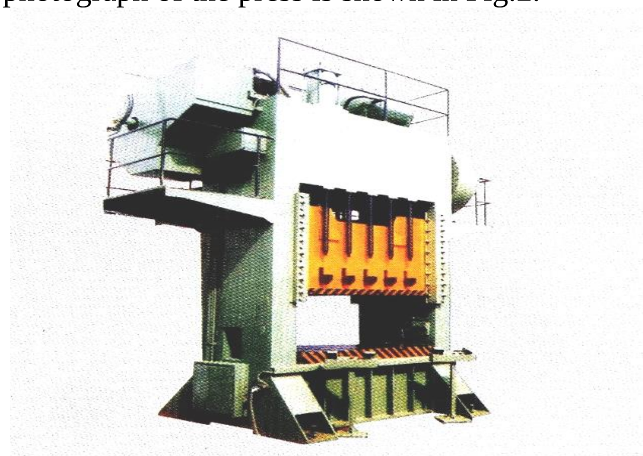


Fig.2 Photograph of Mechanical press used in the present work

Fig.3 Photograph of Slug and extruded tube

III. MECHANICAL AND WEAR TESTING

A. Tensile Test

Specimen of Al6063 matrix and its composite systems prepared according to ASTM B557M were tested for tensile test under 40 ton hydraulic universal testing machine of FIE (Fluid Instruments and Engines) made in M/s Bharat Technical Lab. The behavior of material under tensile test reveal lot information about prepared composites.

Fig 4 Specimen attached in UTM for tensile test

B. Charpy Impact Test

The specimen prepared as per IS: 1757 standard. The specimen is cut into 10 mm × 10 mm cross section area and a length of 55 mm and a notch of 2 mm from top in the center of the specimen and test was conducted.

The specimen of size 55×10×10 mm3 is clamped in a support at the bottom of the machine. The notch is situated in bottom facing apposite to hammer of the arm.

C. Hardness Test

Vickers micro hardness tests were performed on matrix and its composite systems the micro hardness tests was conducted on the polished samples. The polished samples were subjected for micro hardness tests on Shimadzu Micro hardness tester.

D. Adhesive wear test

The wear test for cold extruded of both the matrix alloy and its composites system were studied on the standard pin on disc wear test rig for samples of different reinforcement studied under different loads, speed and distance. The photograph of the wear test rig is shown in Fig 5. The samples subjected for wear test was grinded with silicon carbide abrasive paper of 320 grit size. The loss of height of the samples were recorded at different intervals of time ranging from 5mins to 30mins. The test was carried at constant speed of 100rpm and constant track radius of 0.20m for different loads from 10N to 60N insteps of 10N.

Fig 5: Computerized Pin on disc setup

IV. RESULT AND DISCUSSION

A. Vickers micro hardness

The below represents the variation of vicker's microhardness value for all reinforcement with different weight percentage. The variation of micro hardness of cold extruded matrix alloy and its composites with increased contents of reinforcement of all systems studied are shown in Fig 6. The increase in hardness of cold extruded matrix alloy and its composites can be attributed to that during cold extrusion process the existing minor flaws and porosity in the casting was recovered during cold extrusion.

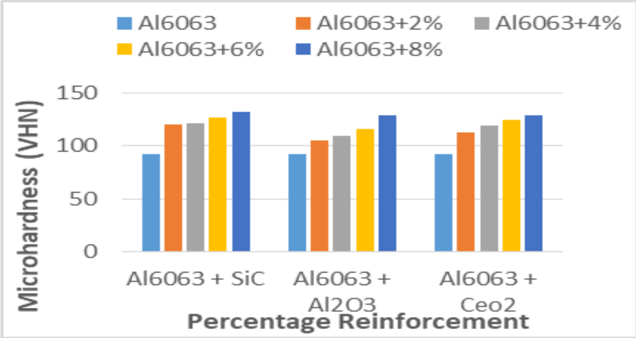


Fig 6: Variation of micro hardness with increased content of reinforcement for Cold Extruded matrix alloy Al6063 & its composites.

Further the increased hardness of cold extruded composites may be due to higher strain hardening effect of cold extrusion. Increased contents of reinforcement leads to increase in hardness for a given composite systems reinforcement studied. The hardness of matrix alloy Al6063 enhanced by 15.6% on cold extrusion. Where an improvement in micro hardness of 42.1% is observed for Al6063 + 8Wt%SiC. The improvement in micro hardness after cold extrusion of 39.7% is observed for Al6063 + 8Wt%Al_2O_3. Whereas Al6063 + 8wt% CeO_2 exhibited an improved by 38.9% on cold extrusion when compared with cast composites.

B. Tensile Strength

Fig 7 represents the variation of ultimate tensile strength of matrix alloy and its composite systems under cold extruded process for different wt% reinforcement and reinforcing material. The increased in tensile strength of cold extruded matrix alloy and its composites systems due to some of the existing minor flaws in the casting gets healed up.

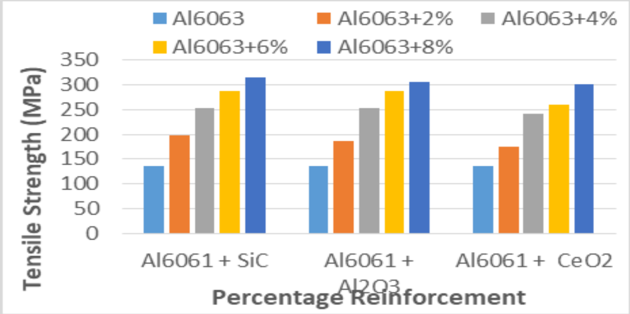


Fig. 7 – Variation of tensile strength with increase contents of reinforcement for cold extruded matrix alloy and its composites

From above figure it is observed that an improvement in ultimate tensile strength of cold extruded composites is appreciably high, when compared with matrix alloy, This drastic improvement in tensile strength value of cold extruded composites may be due the inherent brittleness exhibited by cold extrusion due to high level of residual stress that remains after cold extrusion of the matrix alloy and all the composite systems studied. The improvement in the tensile strength on cold extrusion composite with matrix alloy is about 57% for Al6063-8wt%SiC, where as 55.7% for Al6063-8wt% Al_2O_3 and 55.1% for Al6063-8wt% CeO_2 showed an improvement of 51.22% in tensile strength values on cold extrusion when compared with their cast counter parts.

C. Cold Extrusion of matrix alloy Al6063 and its composites

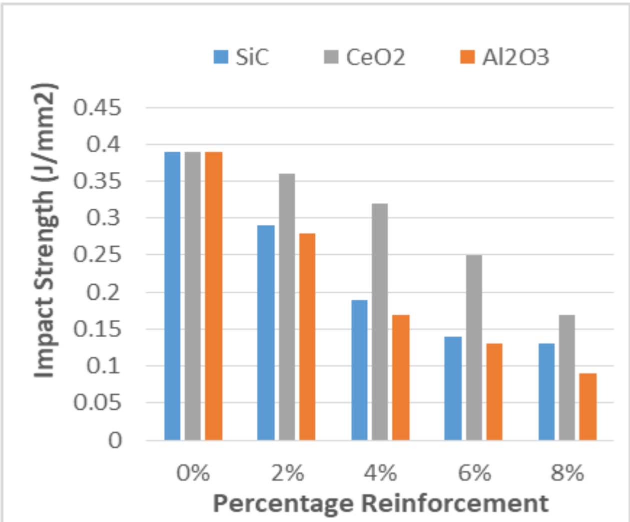


Fig 8 Variation of Impact Strength with increased contents of reinforcement of cold extruded matrix Al6061 alloy & its composite systems.

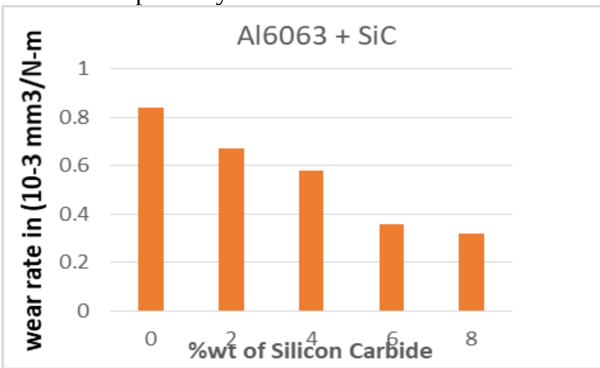
It is observed that there is a significant reduction in the impact strength of cold extruded matrix Al6063 alloy and all the composite systems studied.

The decrease in impact strength on cold extrusion of matrix alloy is 4.8%, and cold extruded composites impact strength is decreased by 25.28% for Al6063 8Wt %SiC, 24.77% for Al6063 -8Wt%Al_2O_3 and 34.33% for Al6063 -8Wt%CeO_2. Matrix alloy exhibits the least reduction in the impact strength values after cold extrusion (4.6%).

D. Adhesive wear analysis

- *Effect of Reinforcement*

From the fig 9 represents the wear rate variation for cold extruded matrix alloy and its composite systems. With increase in content of reinforcement the wear rate is decreased for all the composite systems studied under cold extruded process. As hard particulate reinforcement are introduced in matrix alloy the wear resistance have improved as compared to matrix alloy and cold extruded composite systems possess low wear rate as compared to primary processed composite systems.



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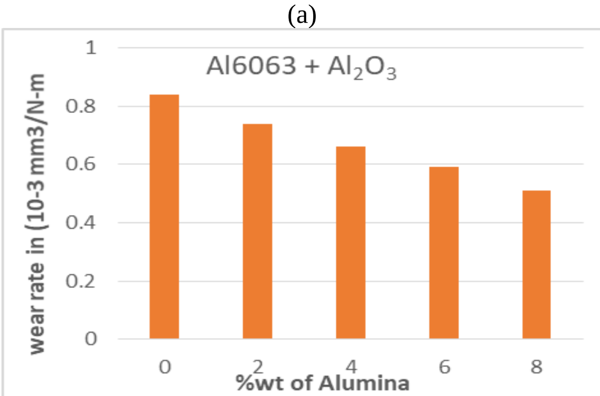

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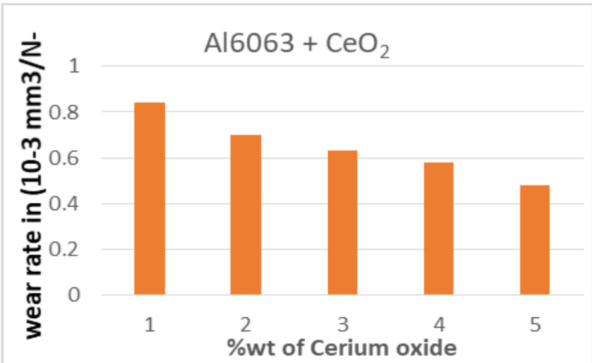

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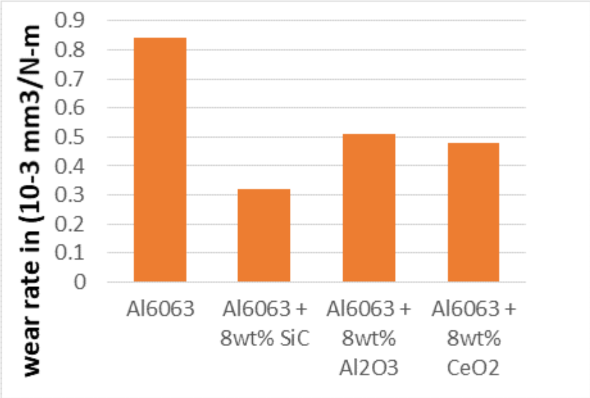


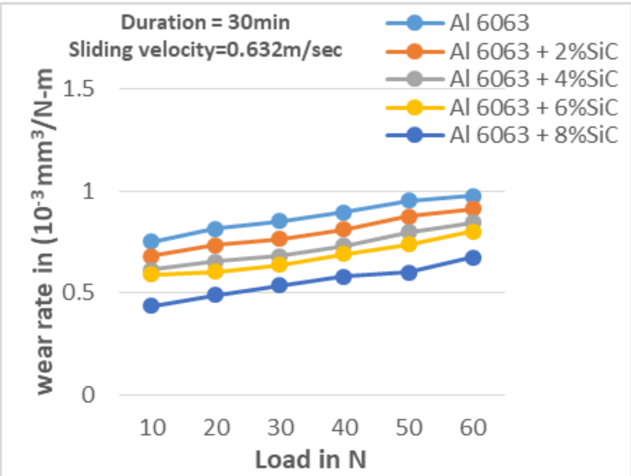
(d)

Fig.9 Effect of reinforcement on wear rate of cold extruded Al 6063 based composites

(a)Al6063+SiC (b)Al6063+ Al2O3 (c)Al6063+ CeO2 (d) Comparison of matrix alloy and 8wt% of Sic, Al2O3 and CeO2

- *Effect of load*

Fig 10 represents the wear rate variation all composite systems studied and Al6063 matrix alloy under cold extruded process. As the load is increased it can be observed from figure the wear rate is linearly increased for matrix alloy and its composite systems. From the obtained results as represented in graph the with as load is increased the friction between the surfaces increased due to which the plastic deformation takes place at larger extent. It can also be attributed that due larger friction higher temperature generated of which recrystallization and grain refinement takes place and also during cold extrusion grain refinement occurs.



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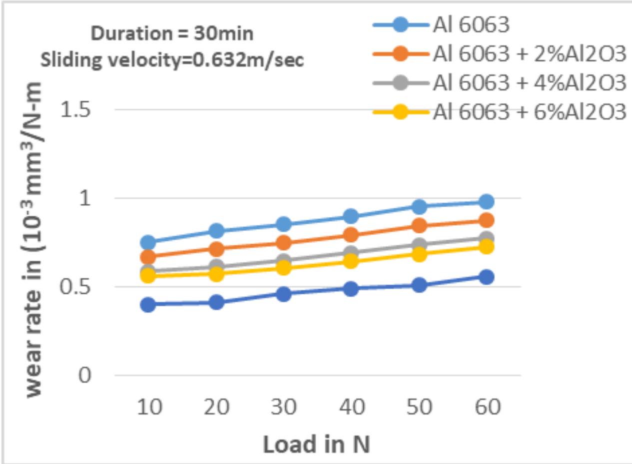

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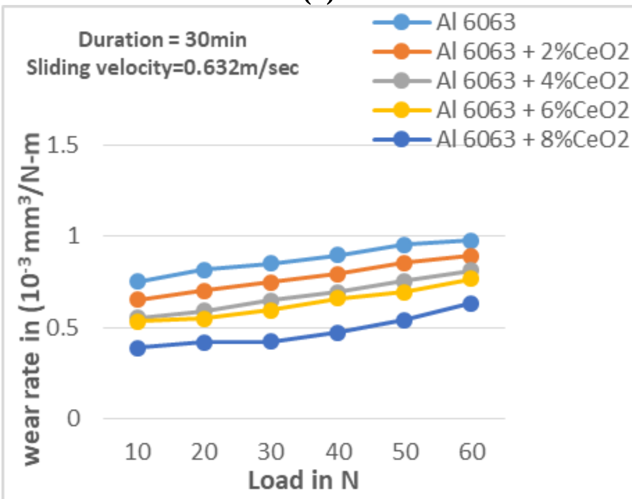

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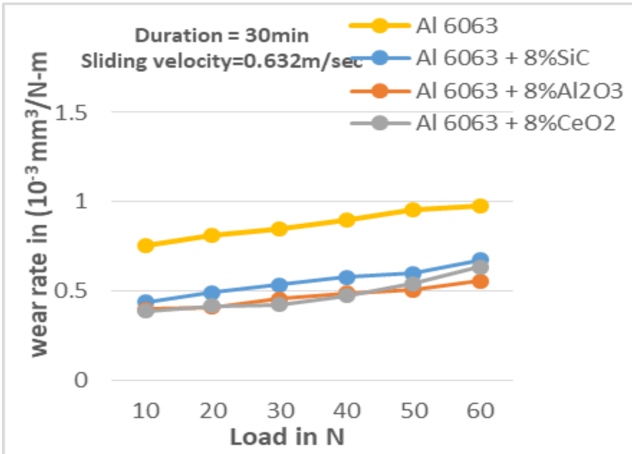


(d)

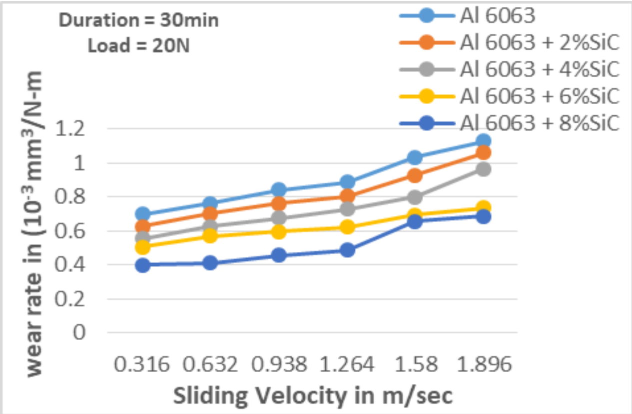
Fig.10 Dependence of wear rate of cold extruded Al 6063 matrix alloy and all its composite systems on load

(a)Al6063+SiC (b)Al6063+ Al2O3 (c)Al6063+ CeO2 (d) Comparison of matrix alloy and 8wt% of Sic, Al2O3 and CeO2

- *Effect of sliding velocity*

Fig 11 shows the wear rate variation for matrix alloy and its composite systems under cold extrusion process.

As the sliding speed increased the wear rate also increased as it can observed from below graph. As the content for reinforcement is increased the wear rate is decreased which can be attributed reinforcing of hard particulate in soft matrix alloy, with increase in sliding velocity the surface temperature increases which damages the surface and sub surface of matrix alloy and its composite systems. Among all reinforcement studied Al6063 +SiC possess lower wear rate as compared other two reinforcement and maximum wear rate is observed for matrix alloy.



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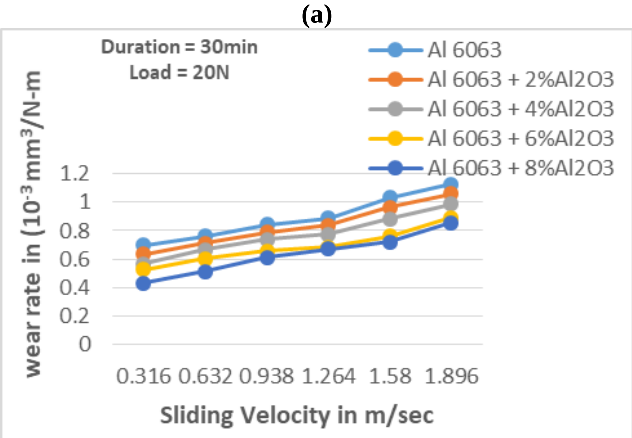

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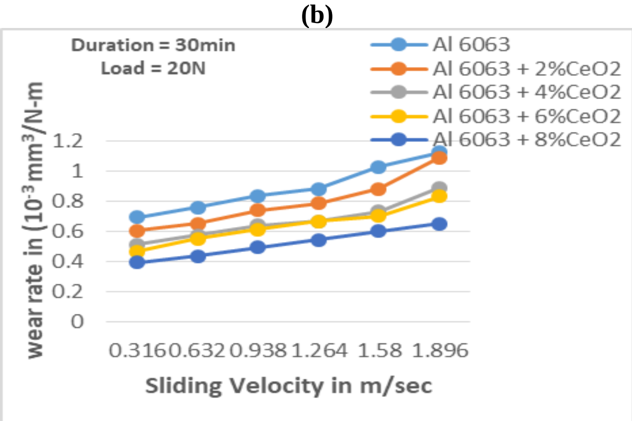

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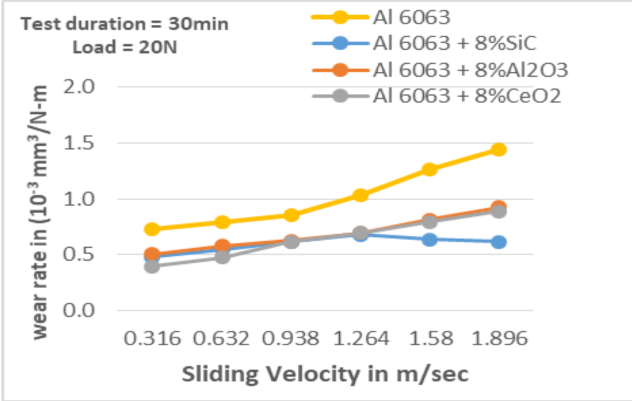


(d)

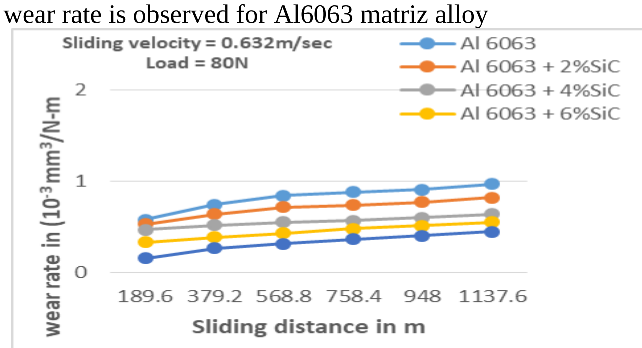
Fig.11 Dependence of wear rate of cold extruded Al 6063 matrix alloy and all its composite systems on sliding velocity

(a)Al6063+SiC (b)Al6063+ Al2O3 (c)Al6063+ CeO2 (d) Comparison of matrix alloy and 8wt% of Sic, Al2O3 and CeO2

From Fig. 10 (d) it is evident that of all the composite systems studied Al 6061-CeO_2 composites exhibited better wear resistance for all the sliding velocities studied. This can be attributed to higher hardness of Al 6061-CeO_2 composites

- *Effect of sliding distance*

Fig 12 represents the dependence of wear rate of matrix alloy and its composite systems studied under cold extruded process with constant sliding velocity and load with varying sliding distance. From the below graphs it can be seen as the sliding distance increses the wear rate increases for all compsite systems studied. Among all composuite studied al6063+CeO_2 for 8wt% has lowest wear rate. The maximum wear rate is observed for Al6063 matriz alloy



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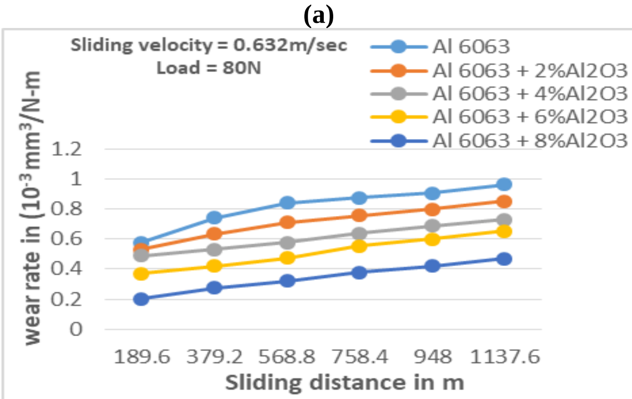

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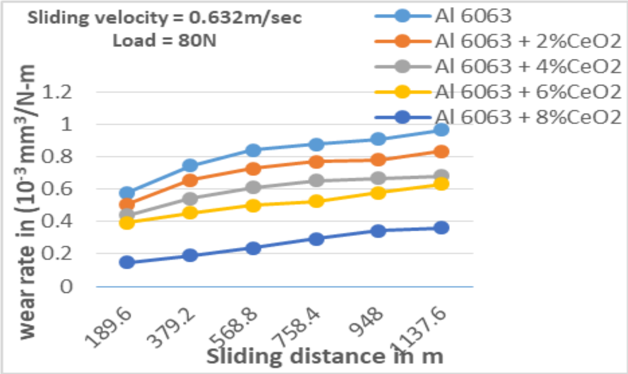

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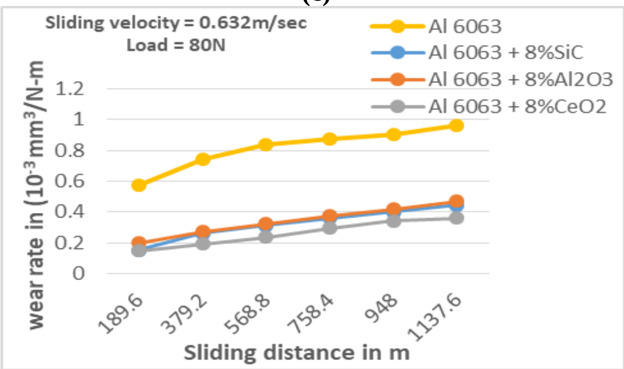

(d)

Fig.12 Dependence of wear rate of cold extruded Al 6063 matrix alloy and all its composite systems on sliding distance

(a)Al6063+SiC (b)Al6063+ Al2O3 (c)Al6063+ CeO2 (d) Comparison of matrix alloy and 8wt% of Sic, Al2O3 and CeO2

V. CONCLUSION

1. SiC, CeO_2, & Al_2O_3 have been successfully dispersed in the matrix alloy Al 6061 by liquid metallurgy route
2. Cast Al6063-SiC, Al6061-CeO2, & Al6061-Al_2O_3 have been successfully cold extruded
3. Cold extruded composites possess higher micro hardness, tensile strength and lower impact strength when compared with cast composites.
4. As the content of reinforcement increased the mechanical properties have increased
5. Cold extruded composites possess the lowest wear rates 4
6. Al6063-CeO_2 possesses lowest wear rates among all the composite systems studied under identical test condition

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