Dry Sliding Wear Behavior of B_4C Particulates Reinforced Al7020 AlloyComposites

[1]SHARMILI ROUTRAY,
Gandhi Institute of Excellent Technocrats, Bhubaneswar, India
[2]SANDEEP KUMAR NAYAK,
Jagannath Institute of Engineering and Technology, Cuttack, Odisha, India

Abstract

The work is carried out to investigate the dry sliding wearbehaviorofB_4CreinforcedAl7020alloymetalmatrixcomposites. In the present work Al7020 alloy was taken as thebase matrix and B_4C particulates as reinforcement material toprepare metal matrix composites by stir casting method. Formetalmatrixcompositesthereinforcementmaterialwasvaried from 0to4wt. % in steps of 2wt. %. Thewearresistanceofmetalmatrixcompositeswasstudiedbyperforming dry sliding wear test using a pin on disc apparatus.The experiments were conducted at a constant sliding speed of300rpm and sliding distance of 4000m over a varying load of1, 2 and 3Kg. Similarly, experiments were conducted at aconstant load of 3Kg and sliding distance of 4000m over avarying sliding speed of 200, 300 and 400rpm. The resultsshowed that the wear resistance of Al7020-2% B_4C and 4%B_4C composites were better than the unreinforced alloy. Thewear in terms of height loss found to increase with the loadandslidingspeed.Tostudythedominantslidingwearmechanism for various test conditions, the worn surfaces wereanalyzedusingscanningelectron microscopy.

Keywords: Al7020 Alloy, B_4C Particulates, Microstructure,Wear,WornSurface

INTRODUCTION

Metalmatrixcomposites(MMCs)havebeenacceptingextraordinaryconsiderationbecauseoftheirhighrigidity,hardness andmodulus, andalso their high wear resistancecontrasted with the framework. The tribological properties ofaluminumcompoundscanbealtogetherupgradedbytheaddition ofadispersedceramicparticlephase[1,2].Thesubsequent material is all around known as aluminum matrixcomposites (AMCs). The improved properties of AMCs, forexample, high particular quality, lessened wear rate and lowerwarmextensionhaspulledintheconsiderationofthematerialsdesigninggroup.AMCsarereplacingregularaluminum alloys in a few applications including aviation, car,shipbuildingandatomicdesigning[3].Amongdifferentceramic particles B_4C is progressively favored as support forAMCsbecauseofitsthermodynamicdependability,highdissolving point, high hardness, high flexiblemodulus andremarkablewear resistance.

AMCs could be delivered either by solid state or fluid (liquid)state preparing [4, 5]. Liquid state systems are for the mostpart utilized in light of the fact that these are economicallyviable,simpleandapplicableinlargequantityproduction.Melt stirring techniques are of two sorts in particular ex situandin-situ.In'ex-situ'procedureartisticfortificationsareadded remotely to the liquid metal though 'in-situ' handle thegeneration of support happens inside the network accordinglyof compound response. The in-situ composites represent a fewfocal points over ex-situ, for example, uniform dispersion offortificationparticles,grainrefinement,clearinterface,improvedwarmsteadinessand prudentpreparing[6-8].

Al-ZnbasedAl7020alloyisheattreatablealuminumcomposite, which offers high quality at low particular weightand are broadly utilized as basic segments, especially in theaerospace industry. B_4C strengthened Al7020 composites aretherefore be consideredto havemore application potential. ItishoweveratestingundertakingtocreatehomogeneousAl/B_4CAMCsutilizingthesestrategies.Regularimperfections, for example, porosity, agglomeration, isolationand slag consideration are for the most part unavoidable. Ahomogeneous dispersion of B_4C particles is fundamental toaccomplishupgraded propertiesand execution.

Over the last decade, a lot of studies have been carried out toovercometheseinsufficienciesandplentyofexperimentalpreparations have been performed. Several efforts have beenmade to improve the interface bonding between aluminiumandceramicparticlesbyexploringsurfacecoatingoftheceramicparticles.InthepresentstudyAl7020-B_4Ccompositeshavebeenfabricatedbyusingnoveltwostepmixing process of reinforcements, to improve thewettabilityofB_4CparticulateswithAlalloymatrix.

In this study, an attempt has been made to prepare Al7020alloy composites by adding 2 & 4 wt. % of B_4C particulatesinto matrix by using a novel two stage reinforcement additionmethod. Further, the prepared Al7020 – B_4C composites werestudiedforeffectofloadandslidingspeedonthewearpropertiesbyusingpin-on-discweartesting machine.

EXPERIMENTALDETAILS

Metal matrix composites containing 2 and 4 weight rates ofB_4Cparticleswerecreatedbyliquidmetallurgycourse.For the generation of MMCs, an Al7020 alloy was utilized as theframeworkmaterialwhileB_4Cwereutilizedasthefortifications. The theoretical density of grid material Al7020amalgamis2.80g/cm^{3}andsupportparticulatesB_4Cis2.52g/cm^3.ThechemicalsubstanceofAl7020compositeutilized asapartoftheworkisgiveninthetable 1.

Table1. ChemicalcompositionofAl7020alloy

Elements (symbol)	Zn	Cu	Mn	Mg	Fe	Cr	Si	Ti	Al
Wt.per centage	5	0.2	0.5	1.2	0.4	0.3	0.35	0.1	Bal

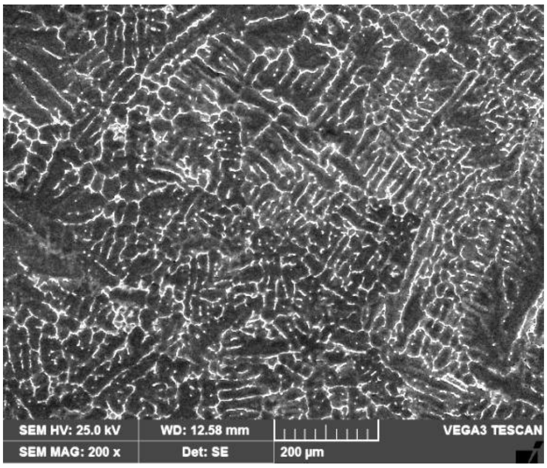
TheB_4CparticlereinforcedAl7020alloymetalmatrixcomposites have been produced by using a vortex method.Initially calculated amount of Al7020 alloy was charged intoSiC crucible and superheated to a temperature 730˚C in anelectricalresistancefurnace.Thefurnacetemperaturewascontrolled to an accuracy of ±10 degree Celsius using a digitaltemperaturecontroller.Oncetherequiredtemperatureisachieved,degassingiscarriedoutusingsolidhexachloroethane (C_2Cl_6) to expel all the absorbed gases. Themeltwasagitatedwiththehelpofazirconiacoatedmechanical stirrer to form a fine vortex. A spindle speed of300 rpm and stirring time 3-5 min. were adopted. The B_4Cparticulates were preheated to a temperature of 500 degreeCelsius in a pre-heater to increase the wettability. The pre-heated B_4C particles introduced into melt in steps of two atconstant feed rate of 1.2-1.4 g/sec. After holding the melt for aperiod of 5 min., the melt was poured from 710 degree Celsiusinto a preheated cast iron mould having dimensions of 120mmlength x15mmdiameter.

Metallographictestspecimensof5mmthicknesswereprepared by cutting the as cast and B_4C strengthened Al7020combinationcomposites.Testsampleswerepolishedaccordingtothestandardmetallographicmethodology andetched with Keller's reagent. The microstructure was viewedutilizingscanningelectronmicroscopeinstrument.

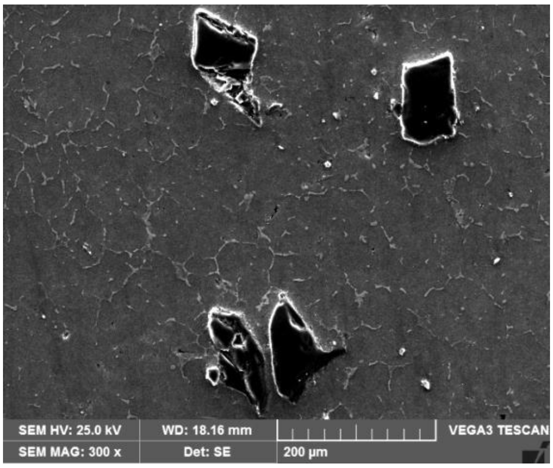
The dry sliding wear behavior of as cast Al7020 alloy andAl7020-B_4C composites were evaluated using a pin-on-discwear apparatus at room temperature according to ASTM G99standard.Pinsoflength25mmanddiameter8mmwerepreparedfromthecastsamples.Theexperimentswereconducted at a constant sliding speed of 300rpm and slidingdistance of 4000m over a varying load of 1Kg, 2Kg, and 3Kg.Similarly experiments were conducted at a constant load of3Kg and sliding distance of 4000m over a varying slidingspeed of 200, 300 and 400rpm. The polished surface of the pinwas slide on a hardened chromium steel disc. A computeraided data acquisition system was used to monitor the loss ofheight.Wearvalueispresented intermsofheightloss.

RESULTSANDDISCUSSION

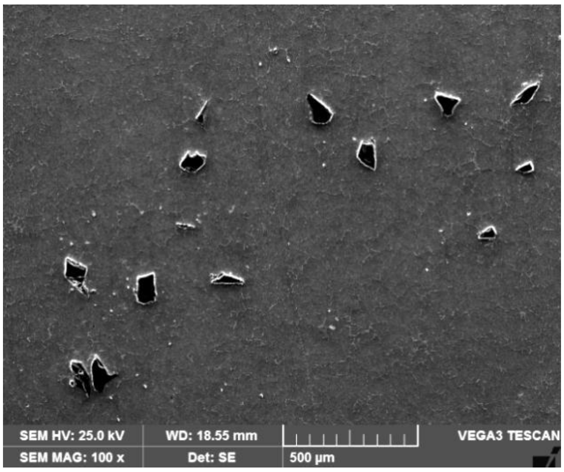
Microstructurestudy



(a)



(b)

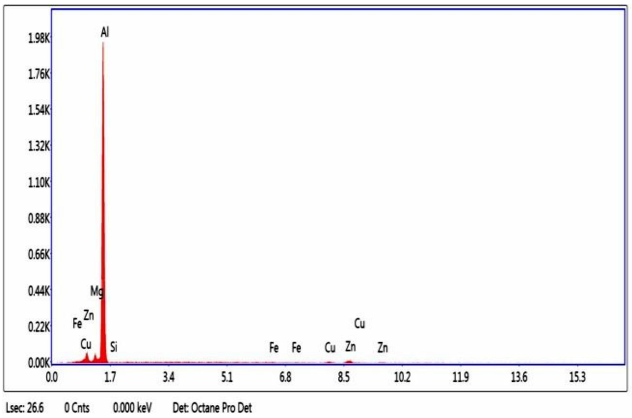


(c)

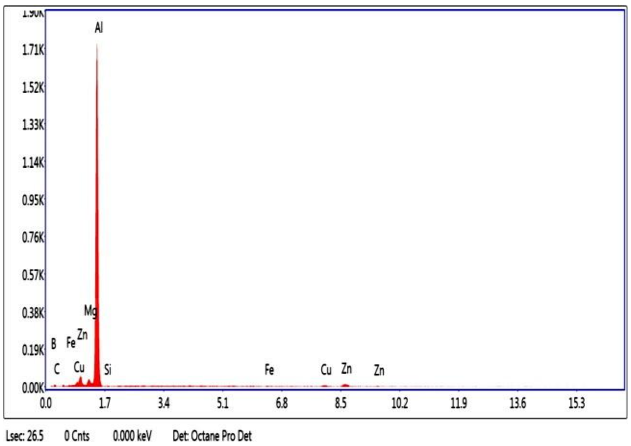
Fig. 1. a-c Showing the scanning electron microphotographsof (a) as cast Al7020 alloy (b) with 2 wt.% of B_4C & (c) with4wt.% ofB_4C

Figure 1 (a-c) shows the SEM microphotographs of Al7020alloyascastandAl7020with2and4wt.%ofB_4Cparticulate composites. Thisreveals theuniform distributionof B_4C particles and very low agglomeration and segregationofparticles, andporosity.

Fig. 1 b-c clearly show and even distribution of B_4C particlesin the Al7020 alloy matrix. In other words, no clustering ofB_4C particle is evident. There is no evidence of casting defectssuch as porosity, shrinkages,slag inclusion and cracks whichis indicative of sound castings. In this, wetting effect betweenparticlesandmoltenAl7020alloymatrixalsoretardsthemovement of the B_4C particles, thus, the particles can remainsuspendedforalongtimeinthemeltleadingtouniformdistribution.



(a)



(b)

Fig.2: EDSspectrumof(a) ascastAl7020 alloy (b) Al7020-4%B_4Ccomposites

In order to confirm the presence of B_4C energy dispersivespectroscope analysis was carried out at the edge of the B_4Cparticle and Al alloy matrix. The EDS spectrum reveals thepresence of Al, Zn, Cu, Mg, B and C in the interface reactionlayer (fig. 2-b).

EffectLoadonWear

The variation of wear loss at steady 300rpm sliding speed andchanging loads of 1Kg, 2Kg and 3Kg is as appeared in fig. 3.Applied load influences thewear ofAl7020 compound andthe composites fundamentally and is the most overwhelmingcomponent controlling the wear conduct. The wear misfortunechanges with the typical load and is altogether lower if thereshould arise an occurrence of composites. With increment inloads there is higher wear misfortune for matrix alloy and thecomposites.Howeveratalltheloadsconsideringwearresistanceofthecompositesisbetterthantheframeworkcombination. At higher loads and the transition to sever wearthe surface temperature exceeds a critical value. So as appliedload increases ultimately there is an increase in the wear lossfor both the reinforced and unreinforced composite materials.Thevariationofwearlossofthematrixalloyanditscomposites with 2 and 4 wt. % of B_4C content is shown in fig.3.

The improvement in the wear resistance of the compositeswith B_4C reinforcement can be attributed to the improvementinthehardnessofthecompositesandimprovedhardnessresults in the decrease in the wear loss of the composites [9,10].

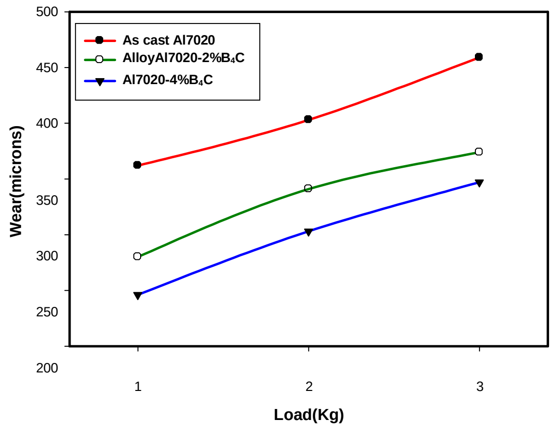


Fig. 3: Showing wear of Al7020 alloy and its composites atvaryingloadsand sliding speed of300rpmand 4000mslidingdistance

EffectSlidingSpeedonWear

Fig. 4 shows the variation of wear loss of Al7020 matrix alloyand Al7020-2% & 4% B_4C composites at constant 3Kg loadand varying sliding speeds. With an increasing speed i.e. 200,300, and 400 rpm, there is an increase in thewear loss forbothmatrixalloyanditscomposites.Howeveratallthesliding speeds studied, the wear loss of the composite wasmuch lower when compared with the matrix alloy. Furtherincreasedwear ratewith increasedsliding speedis duetothermal softening of the composite. On the other hand theincreasedtemperatureathigherslidingspeedscancausesevere plastic deformation of the mating surfaces leading toformhighstrainratesub-surfacedeformation[11,12].The increasedrateofsub-surfacedeformationincreasesthecontactareabyfracture,andfragmentationofasperities.Therefore this leads to enhanced delamination contributing toenhancewearrate.Further,4wt.%ofB_4Cparticulatesreinforced Al7020 alloy composites shown more resistance towear.

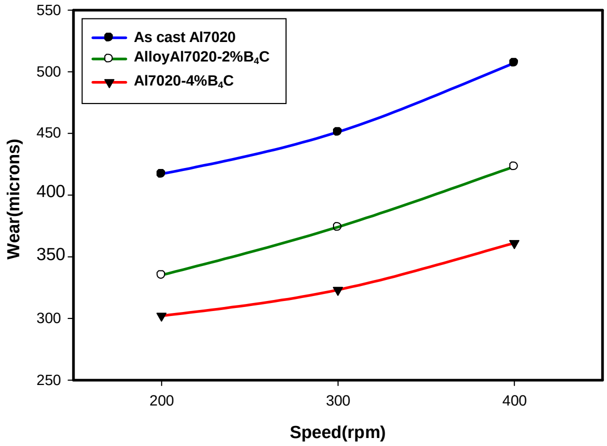
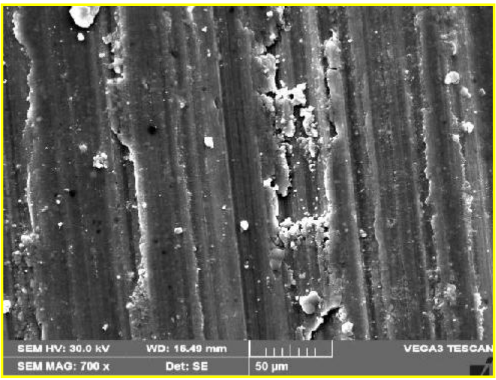
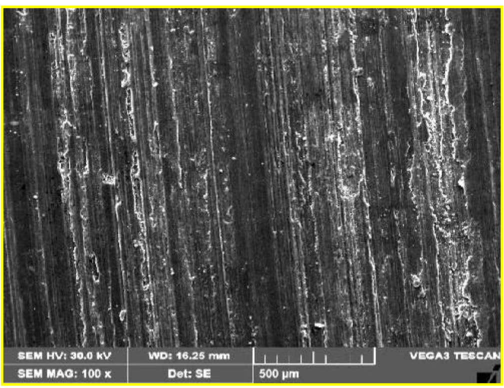


Fig.4: ShowingwearofAl7020alloyanditscompositesatvarying sliding speed, constant load of 3Kg and 4000mslidingdistance

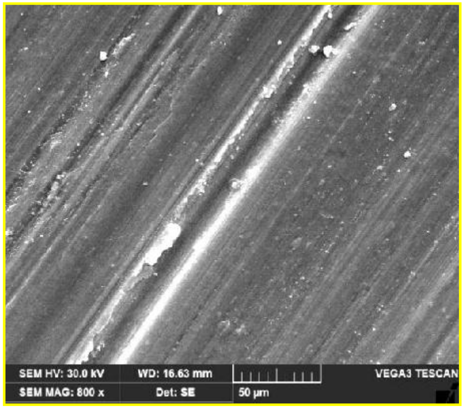
WornSurfaceMorphology



(a)



(b)



(c)

Fig.5: ShowstheSEM microphotographsofwornsurfaces of (a) ascastAl7020 alloy(b)Al7020– 2wt.%B_4C (c)Al7020–4wt.%B_4Ccompositesat3Kgload and300rpm

Wearsurfaceanalysisofcompositeswereexaminedbyscanning electron microscope. Fig.5a-c represents thewearsurface of as cast Al7020 alloy and specimens containing 2 &4 wt. % of B_4C particles reinforced composite at 3Kg load and300rpmslidingspeed.

The examination of worn surface as appeared in figure 4a, thatthewornsurfacesofbasecombinationareconsiderablyrougher thancomposites.Cavitiesandextensivefurrowedsurfaces are found on worn surface of Al7020 amalgam. Thesign of pits and scores underpins the way that delicate Alcomposite disfigured at higher load of 3kg and at 300rpmspeedandhauledoutfromthesurface.Theweartrackperceptiondemonstratesthatgripanddelaminationareprevailingwearinstrumentsseenathigherloads.Thisissupported by the large sized delamination flakes and severeadhesion resulting in bulk removal of material at higher loads[13].

Fig. 5b & c shows the SEM image of the worn surface ofAl7020-2 & 4wt.% of B_4C composite tested at applied loadof 3kg and 300rpm speed. The grooves are very small due tothe hard nature of B_4C reinforcement and poor wear losses. Astheceramicparticlesresistthedelaminationprocess,composites are found to have greater wear resistance [14].Worn surface shows less cracks and grooves mainly due to thepresenceofhardparticulates.

CONCLUSIONS

The present work on processing and evaluation of Al7020-B_4Cmetalmatrixcompositebymeltstirringhasledtofollowing conclusions. Al7020 alloy based composites havebeen successfully fabricatedby meltstirringmethodusingtwo stage addition method of reinforcement combined withpreheatingofparticles.TheSEMmicrophotographsofcompositesrevealedfairlyuniformdistributionofreinforcementparticulatesintheAl7020metalmatrixandEDS spectrographs confirmed the presence of B_4C particles.TheadditionofB_4CparticlestoAlalloymatriximprovesthe wear resistance of the composite. The wear loss is dominatedby load factor and sliding speed. The increase of loads andsliding speeds leads to a significant increase in the wear loss.The Al7020-4% B_4C composites have shown lower wear lossascompared to that observed inascastAl7020 alloyand2 wt. %B_4Creinforcedcompositesmatrix.Wornmorphologyshowed the effect of hard ceramic particulates addition onwearbehavior of Alalloyand itscomposites.

REFERENCES

[1] HamidRezaEzatpour,SeyedAbolkarimSajjadi,Mohsen HaddadSabzevar,YizhongHuang,Investigationofmicro structureandmechanicalproperties of Al6061-nanocomposite fabricated by stircasting,Materialsand Design,55(2014),921-928.

[2] XianZhu,Yu-GuangZhao,MinWu,Hui-YuanWang,Qi-ChuanJiang,Fabricationof2014aluminiummatrixcomp ositesreinforcedwithuntreatedandcarboxyl-functionalizedcarbonnanotubes, Journal of Alloys and Compounds, 674 (2016),145-152.

[3] NarendraKumar,RakeshKumarGautum,SunilMohan,In-situdevelopmentofZrB_2particlesandtheireffectonmicro structureandmechanicalpropertiesofAA5052metalmatr ixcomposites,MaterialsandDesign,80(2015), 129-136.

[4] XiaoHuiChen,HongYan,Solidliquidinterfacedynamics duringsolidificationofAl7075-Al_2O_3based metal matrix composites, Materials and Design,94 (2016) 148-158.

[5] MeijuanLi,KakaMa,LinJiang,HanryYang,EnriqueJ.La vernia,LianmengZhang,JulieM.Schoenung,Synthesisa ndmechanicalbehaviorofnanostructuredAl5083/n-TiB2metalmatrixcomposites, Materials Science& Engineering A, 256(2016),241-248.

[6] G. Garces, K. Mathis, P. Perez, J. Capek, P. Adeva,Effect of reinforcing shape on twinning in extrudedmagnesium matrix composites, Materials Science&Engineering A, 666(2016),48-53.

[7] V. Vembu, G. Ganesan, Heat treatment optimizationfortensilepropertiesof8011Al/15%SiCpm etalmatrixcompositeusingresponsesurfacemethodolog y, Defence Technology, 11 (2015), 390-395.

[8] N.MathanKumar,S.SenthilKumaran,L.A.Kumaraswa midhas, Aerospace application on Al2618withreinforcedSi3N4,AINandZrB2insitucomp osites, Journal of Alloys and Compounds, 672(2016),238-250.

[9] N.Shivakumar,V.Vasu,N.Narasaiah,SubodhKumar, Synthesis and characterization of nano sizedAl_2O_3particlereinforcedZA27metalmatrix composites,ProcediaMaterialsScience,10(2015), 159-167.

[10] B.VIjayaRamnath,C.Elanchezhian,M.Jaivignesh, S. Rajesh, C. Parswajinan, A. Siddique Ahmed Ghias,Evaluationofmechanicalpropertiesofaluminiuma lloy alumina boron carbide metal matrix composites,MaterialsandDesign, 58 (2014) 332-338.

[11] R. Palanivel, I. Dinaharan, R. F. Laubscher, J. PauloDavim, Influence of boron nitride nano particles onmicrostructureandwearbehaviorofAA6082/TiB2hyb rid aluminium composites synthesized by frictionstirprocessing,MaterialsandDesign,106(2016), 195-204.

[12] T.S.Kiran,M.PrasannaKumar,S.Basavarajappa,B. M. Vishwanatha, Dry sliding wear behavior of heattreated hybrid metal matrix composite using Taguchitechniques,MaterialsandDesign,63(2014),294-304.

[13] A.Pramanik,Effectsofreinforcementonwearresistanceo faluminiummatrixcomposites,Transactions of Nonferrous Metals Society of China,26 (2016), 348-358.

[14] Jaswinder Singh, AmithChauhan, Overview of wearperformanceofaluminiummatrixcompositesreinfo rced with ceramic materials under the influenceof controllable variables, Ceramics International, 42(2016),56-81.