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Analysis of Micro structure, Hardness and Wear of Al-SiC-TiB_2 Hybrid Metal Matrix Composite

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ABSTRACT
Goodmechanicalandthermalpropertiesofhybridmetalmatrixcompositesmakethemmoredemandinginvariousfieldssuch as automotive, aerospace and structural applications.In this paper an effort has been made to fabricate a hybridmetal matrix composite, silicon carbide and titanium diboride reinforced in Al 6061 matrix using stir casting method.Microstructure and mechanical properties such as micro hardness and wear are studied for various compositions ofreinforcements, 10% SiC and 2.5%, 5% and 10% TiB_2. The results indicate that the hardness value increases with theaddition of the SiC and TiB_2 reinforcements to matrix Al6061, while the wear resistance increases up to certain amountandreduces drasticallywhencrossed the transitionload.
Keywords: Al 6061, HybridMetalMatrix composite, HardnessSiC, StirCasting,TiB_2, °Wear Resistance.

I. INTRODUCTION

Since aluminium has lesser density than steel, goodcorrosionresistance,goodmechanicalandrecyclingprop-erties,aluminiumanditsalloyshavebeenwidelyusedinvarioussectorssuchasautomotiveandaerospace.Alu-miniummetalmatrixcompositesreinforcedwithceramicparticlesaregainingwidepopularityashighperformancematerialbecauseoftheirimprovedstrength,highelast-ic modulus and increased wear resistance, their abilitytoexhibitsuperiorstrength-to-weightandstrength-to-cost ratio over conventional base alloy[1,2]. Al alloybased metal matrix composites are presently used inseveralapplicationssuchaspistons,pushrods,cylinderlinersandbrakediscs. Themanufacturingtechniquesofthealuminiummetalmatrixcompositesareclassifiedintothreetypesnamely

1. Liquidstatemethods,
2. Semisolidmethodsand
3. Powdermetallurgymethods[3]

Inliquidstatemethods,theceramicparticulatesareincorporated into a molten metallic matrix and casting ofthe resulting MMC is done. Stir Casting is a liquid statemethod of composite materials fabrication, in which aceramicparticleismixedwithamoltenmatrixmetalby means of mechanical stirring. The liquid compositematerial is then cast by conventional casting methods[4].Aluminium6061isametalalloywithlowdensityandhighthermalconductivity,butithaspoorwearresistance.Toovercomethisdrawback,Alalloyisreinforcedceramic materials so that its hardness, young's modulusand abrasion wear resistances are increased[5]. Ceramicmaterials generally used to reinforce Al alloys are SiC,TiC,TiB_2,ZrB_2,AlN,Si_3N_4,Al_2O_3andSiO_2.Amongthesereinforcing ceramic particles, titanium diboride (TiB_2)which exhibits high Young's modulus (345-409 GPa),lowdensity(4.5g/cm^3),superiorVickershardness(3400HV), high melting point (3225Cº ± 20), superior wearresistanceandgoodthermalstability,andSiliconCarbide(SiC)whichexhibitshighelasticmodulus(410GPa),low density (3.2 g/cm^3) and high Vickers hardness (2600HV)areveryattractive[6,7].

Ramesh et al.[8] investigated the mechanical propertiesof Al 6061-TiB_2 in-situ composites fabricated by liquidmetallurgy route using Al 6061 as the matrix materialand Al-10% Ti and Al-3% B as reinforcements. Thedevelopedin-situcompositesexhibitedconsiderableimprovement in the mechanical properties as comparedtothebasemetal.

Jayashreeetal.[9]reportedthatmechanicalpropertiesof aluminium metal matrix are improved by addingreinforcementofSiC.Devietal.[10]studiedmicrostructural behaviour of Aluminium with SiC (grit size60)byvaryingmassfractionsof5%,10%,15%,and2

0%.Theyobservedthatthereisauniformdistribution of metal. Al6061 is selected as a matrix material becauseof its properties such as high strength to mass ratio,moderatestrengthandlowdensity.Siliconcarbideandtitanium diboride are used as reinforcement materials.SiCisaceramicmaterialwithaveryhighhardnesswhileTiB_2isusedbecauseoftheveryhighwearresistanceandthermalstability.ThemeangritsizesforSiCandTiB_2are30and12micronsrespectively.Preheatedreinforcementparticle SiC and TiB_2 is added to the molten form ofAl6061 and stirred with the stirrer at the speed of 450rpm for duration of 15-20 mins and cast. Samples areprepared for the microstructure, micro hardness andweartest.

II. METHODOLOGY

Stircastingmethodisusedforthemanufacturingof metal matrix composites. This method helps to getuniform distribution of reinforcement in the matrixmaterialbycreatingthevortexconditionin molten

III. EXPERIMENTAL DETAILS

siliconcarbideinaluminiummetalmatrix.Suresh etal.[11] prepared Al6061 reinforced with TiB_2 particlesby stir casting method. Experiments were conductedby varying weight fraction of TiB_2 (0%, 4%, 8% and12%), while keeping all other parameters constant. Thisstudy revealed that the addition of TiB_2 improves thewear resistance of aluminium composites. The resultsshowedthatincreaseinthemechanicalproperties,such as wear resistance and hardness were caused bythepercentageofTiB_2presentinthesamples.Prashantetal.[12]investigatedtheeffectofSiCreinforcementparticles.Thehardnessofmetalmatrixcompositeincreaseswithincrease in reinforcement content and the wear rate ofthe Al6061-SiC composite decreased with increasingSiCcontent.Thereviewofliteratureshowsthatcurrentlythere is a lot of interest in fabricating hybrid MMC.ReinforcementofSiCandTiB_2withaluminiummatrixformsahybridmetalmatrixcomposite.TheadditionofTiB_2tometalmatrixcompositeshasbeenobservedto exponentially enhance stiffness, hardness and wearresistance[13].Inthisstudy,reinforcementofSiCand TiB_2forvariouscompositionswithaluminiummatrixiscarriedout.Themicrostructuresofcompositeswere investigatedby optical microscope and the mechanical propertieslikehardnessandwearresistancewereanalyzed.

Microstructure

Samplesarepreparedformicrostructurestudybyusing standard metallographic procedure. Samples aregrinded on belt grinder followed by polishing on emerypaper. Further polishing using alumina powder is doneformirrorfinish.Keller'sreagentisappliedtothesamplesandobservedunderopticalmicroscope.

Hardness

Microhardnessofthemetalmatrixcompositesistakenforthespecimenswithvariousreinforcementproportions of 10% SiC and 2.5%, 5% Tib_2 particles inAl6061.Test is conducted on Vicker's Micro hardnesstester(Matsuzawa MMT-X) with 200 gram force fordurationof10susingadiamondindenter.

Wear Test

WearresistanceoftheAl-SiC-TiB_2compositesisstudied.Thereciprocatingtypepinonplatewearconceptisusedforweartesting.Inthisstudy,pinismadeupofmild steel with the dimensions of 8 mm diameter and25mmlengthandspecimen sampleisof30×30×10mm of metal matrix composite. Reciprocating typepinonplateweartestiscarriedoutwiththestrokeofreciprocatingsteelpinas17mmandisheldagainstthefixedspecimenplate.Theslidingdistance is 1.2kmwithslidingvelocityof0.33m/s.Readingsaretakenat50N and 70 N load for each proportion for one hour.Analysis of wear Vs time and coefficient of frictionVstimeiscarriedoutforeachspecimen.

IV. RESULTS AND DISCUSSION

Microstructure

TheMicrostructuresofsamplesareshowninFigures1-3.Figure1showsmicrostructureof10%SiCreinforcementsample. SiC is present in inter dendritic structure andisuniformlydistributedinthealuminiummatrix. Figure 2 shows microstructure of 10% SiC and 2.5%TiB_2 reinforcement sample. TiB_2 is present in hexagonalcrystal form. These crystals are surrounded by interdendritic structure of SiC uniformly distributed in theAl matrix. Figure 3 shows microstructure of 10% SiCand 5% TiB_2reinforcement sample. Hexagonal crystal ofTiB_2aresurroundedbyinterdendriticstructureofSiCuniformlydistributedinAlmatrix.

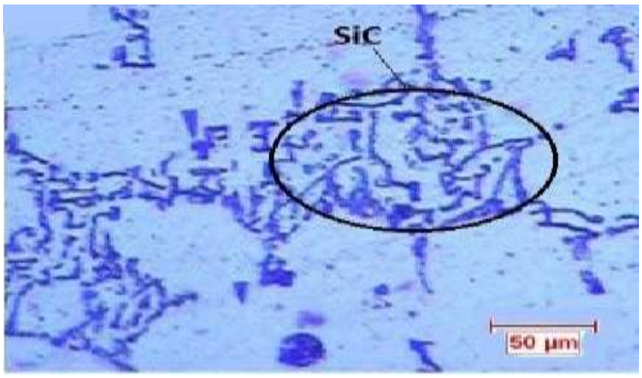

Figure1.10%SiCreinforcement.

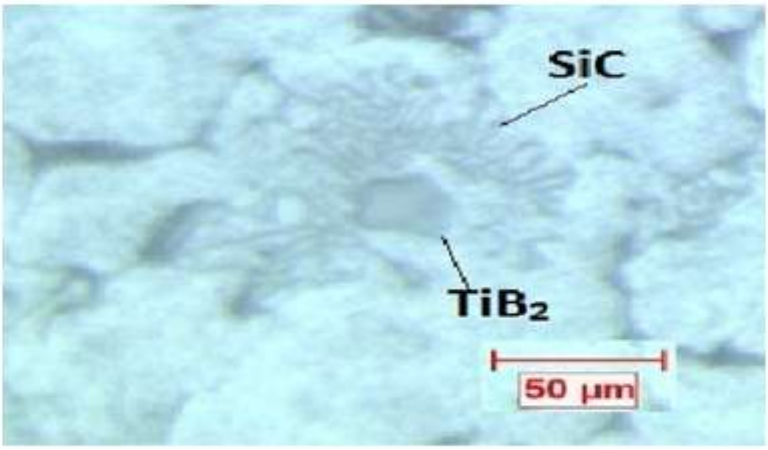

Figure2.10%SiCand2.5%TiB_2reinforcement.

Hardness

Table1showsthemicrohardnessreadingforcompositesampleswithdifferentreinforcementpercentage.Itisseenthat,withadditionofthereinforcement,hardnessofthecompositeincreaseswhencomparedtoAl6061.Siliconcarbide particle have very high hardness and when it isreinforced in the matrix material, it helps to improve thehardnesspropertiesofcompositebyconsiderableamount.Hardness of the composite depends on various factorslikeporosity,non-uniformdistribution,andpresenceof cluster formation. Hardness increases by 38% in thecaseofAl/10SiCpwhileinthecaseofAl/10SiCp/5TiB_2itis35.7%

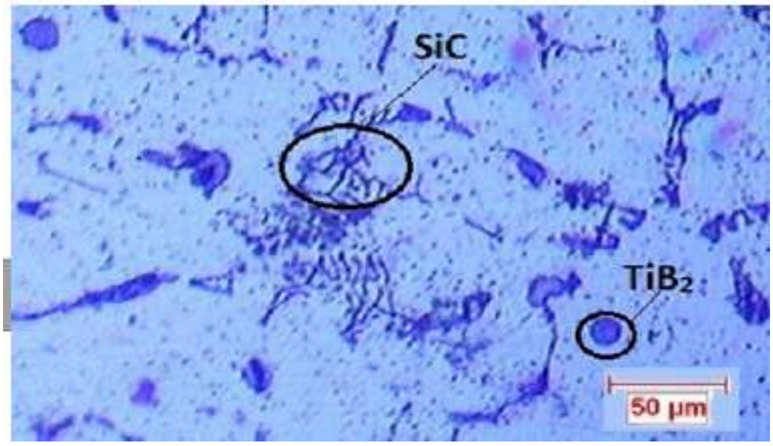

Figure3.10%SiCand5%TiB_2reinforcement

Table1. Microhardnessreading

Specimens	Hardness
Aluminium6061	45HV
Al with 10% SiCreinforcement	72.28HV
Alwith10%SiCand2.5%TiB_2 reinforcement	71.46HV
Alwith10%SiCand5%TiB_2 reinforcement	70.05HV

Wear Test

TheFigures4-7showthereadingofweartesttakenforvarioussamplesofthecomposites.Figure4and5showsthe graph of wear vs time for load of 50 N and 70 Nrespectively while Figure 6 and 7 shows the graph ofcoefficientoffrictionvstimegraphfor50Nand70 Nrespectively. The blue, red and green colors represent 10%SiC, 10% SiC with 2.5% TiB_2 and 10% TiB_2 reinforcementsamplesrespectively.Samplesarecleanedwithacetonebeforeandafterthetests.

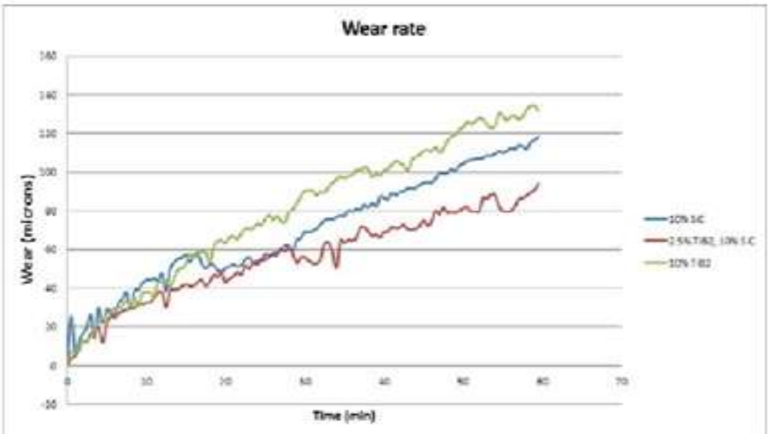

Figure4. GraphofWearvs.Time(50N).

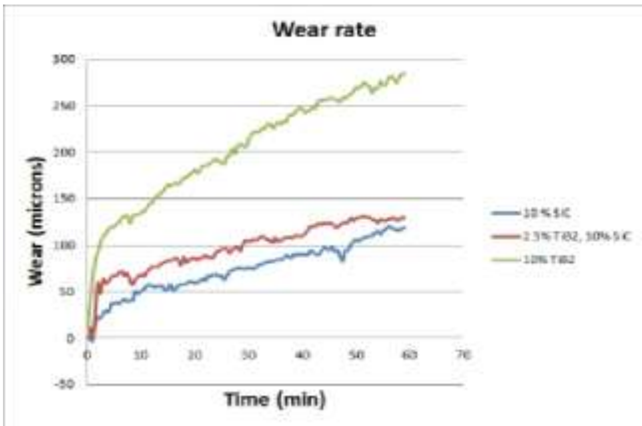

Figure5. GraphofWearvs.Time(70N).

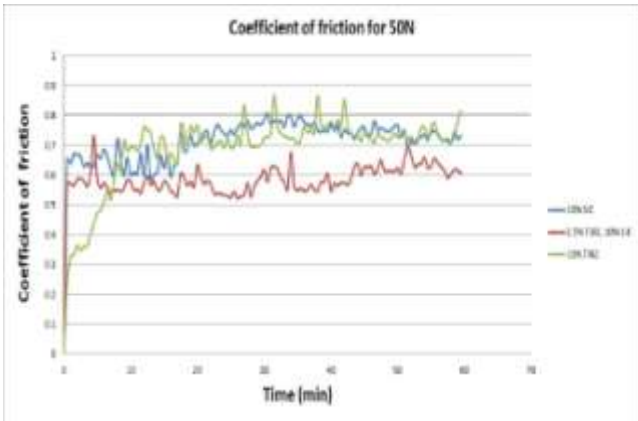

Figure6. Graphofcoefficientoffrictionvs.Time(50N).

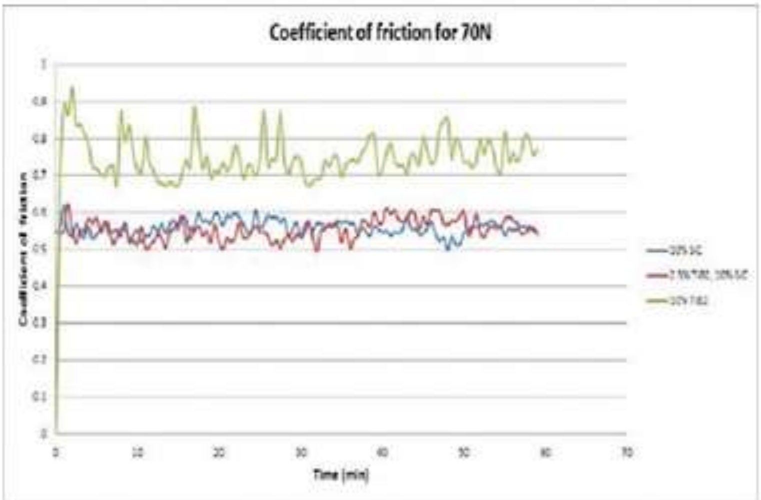

Figure7. Graphofcoefficientoffrictionvs.time(70N)..

Major portion of applied load is carried by SiC. Majorroleofreinforcementistocarrytheappliedload,stressesand to avoid plastic deformation which leads to decreaseinthewearrate.TiB_2hasverygoodwearresistanceand as it uniformly distributed with the Al matrix, ithelps to improve the wear resistance of the composites.Wettabilityisalsooneoftheimportantfactorsincomposites. Poor wettability can lead to weak interfacesbetween matrix and reinforcement. If bonding betweenmatrix and reinforcement is good, then wear

resistanceincreasesconsiderably.Butifbondingisnotgoodenough,then wear resistance increases up to certain amount andthendecreases.Anincreaseinapplied load increasesthe pressure on the pin resulting in an increase in theinterfacial temperature, leading to the softening of thematerialandanincreaseintheplasticflow.Whentheloadsaregreaterthantransitionload,severewearoccurs whichleads to seizure of material. From the various literaturesurvey carried out, it is found that the transition load forTiB_2 reinforced metal matrix composites is around 40 to50 N. Beyond this load, appliedloadfrom10to50N.Wearratedecreasedintherangeof19.46%foranadditionofTiB2pfrom
2.5 to 20% under tested conditions. This observeddecrease may be attributed to the increase in hardnessof TiB2p composites compared to the unreinforcedalloy.Similarresultshavebeenduring wearstudiesonAlSi17alloy[15].

V. CONCLUSION

Al6061reinforcedwithSiCandTiB₂hybridcompositesarefabricatedusingstircastingmethod.Themicrostructure and mechanical properties such as microhardness and wear of the Al-SiC-TiB_2 composites

iii. Wear rate and coefficient of friction decreases
onadditionofSiCandTiB_2 tothematrixmaterial.

iv. The hardness and wear values decrease up to
certainamountandthenremainunaffectedfurtherbecauseof dependence on various factors such as wettabil-
ityandbondingbetweenmatrixandreinforcement.Excess formation of Al_3Ti flakes may decrease thewearresistanceofthecomposite.

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severe wear occurs. This is veryevidentfromthefigures,wearrateincreasesconsiderablyfor load of 70 N. A higher degree of delamination wasobserved at lower applied loads, which reduces to minordelamination at higher applied loads. This may be due togreatercompactionofsubsurfaceleadingtoformationofdenselaminatedlayersathigherappliedloads.Similarly,resultswasreportedbyDwivedi[14]inhypereutecticAl-
Sialloy,thewearrategraduallyincreaseswithincreasing

arestudied.Themainconclusionsobtainedfromthepresentinvestigationsaregivenbelow.

i. Dendritic structure of the SiCand hexagonal
shaped crystal of the TiB2 are observed in the mi-crostructure. Microstructure shows uniform distribu-
tionofthereinforcementwithsomeamountofclusterformation.

ii. HardnessvalueincreasesonadditionofSiCandTiB_2 totheAl6061matrixbyconsiderableamount.
Hardnessincreasesby38%inthecaseofAl/10
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