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RESEARCH ARTICLE OPEN

Matrix Al-Alloys for Alumina Particle Reinforced Metal Matrix Composites

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The mechanical properties of different metal matrix compositeshave been determined. Al 6061, Al 6063 and Al 7072 matrixalloysarereinforcedwithaluminaparticulates.Theyieldstrength,ultimatestrength,andductilityofAl/Al2O3metal matrix composites are in the downhill order of Al 6061, Al6063and Al 7072 matrix alloys. Alumina is highly reactive to the Mgcontentinthematrixalloys.Thefracturemodeispredominantlyductilein nature.

I. INTRODUCTION

A composite is a material that is produced throughaphysicalcombinationofmaterialstoobtainanewmaterialwithuniquepropertieswhencomparedtothemonolithicmaterialproperties.Thisdefinitiondistinguishesacompositefromother multiphase materials. Composite materialshave been of interest to aerospace and defensemarketsformanydecadesastheysoughttoobtaincontinuousperformanceimprovements.Thematerialselectioncriteriainvolvetherequirement of high strength, and good corrosionresistancealuminumalloysforthematrixmaterials.

Inthepresentwork,Al-alloybasedmatrixmaterialshavebeenconsideredforalumina(Al_2O_3)particulatereinforcedmetalmatrixcomposites. Three Al-alloys namely Al 6061, Al6063andAl7072alloyswerechosen.Theeffectof matrix materials on the mechanical propertiesandfracturebehaviorhasbeeninvestigated.

Table-1:Chemicalcompositionofmatrixalloys

Alloy	Compositiondeterminedspectrographically,%								
	Al	Si	Fe	Cu	Ti	Mg	Mn	Zn	Cr
6061	97.6	0.68	0.61	0.021	0.053	0.92	0.044	0.072	0.0051
6063	98.8	0.271	0.325	0.0047	0.0376	0.52	0.0076	0.076	<0.0005
7072	97.8	0.387	0.464	0.013	0.0053	0.396	0.0082	0.85	0.012

II. EXPERIMENTAL PROCEDURE

Thematrixalloysandcompositeswerepreparedbystircastingprocessin TapasyaCastingPrivateLimited–Hyderabad.Thechemicalcompositionofalloysisgiven inTable-1. The properties of the matrix materials are giveninTable-2.Thevolumefractionandparticlesize ofAlO reinforcementare20%and10 m
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TheelementsofSi,Fe,Cu,Mn,andMginAl-alloys are known to increase tensile properties byforming precipitates such as Al_2Cu, Fe Al_3, Mg_5Al_8,andMg_2Siduringthefabricationprocess(Seleznev et al., 1998). Alumina is known to bestableinpurealuminum,butreactswithmagnesium to form $MgAl_2O_4$ (spinel). MgO mayformathighmagnesiumlevelsandlowertemperatures whereas the spinel will form even atvery low magnesium levels (Lioyd et al., 1990). Inthe as-cast conditions, the matrix is multiphase.Evensmallquantitiesofbrittlesecondphases,particularly if these are located along the matrix-reinforcement interface, affect the toughness andtensile ductility of metal matrix composites [Duttaetal.,1994andReddy2003).SomeAl_2O_3particles aggregated to form coarse clusters in thematrix.

According to a previous study (Manoharan,andLewandowski,1990),iftheagglomerationappearstobewellbondedtothematrix,theagglomeration can contribute to the strengtheningofthecomposites. respectively.

Table-2:Mechanicalpropertiesofmatrixmaterials

MatrixMaterial	Density,g/cc	ModulusofElasticity, GPa	UltimateTensilestrength, MPa	Elongation, %
Al6061	2.7	68.9	241	22
Al6063	2.7	68.9	172	22
Al7072	2.72	68.0	168	15

PreparationofMeltandMetalMatrixComposites

Al alloys were melted in an oil-fired furnace.Themeltinglossesofalloyconstituentsweretakenintoaccountwhilepreparingthecharge.The charge was fluxed with coverall to preventdressing.Themoltenalloywasdegasifiedbytetrachlorethane(insolidform).Thecruciblesweremadeofgraphite.Thepreheatedreinforcement particles were added to the liquidmelt.Themoltenalloyandreinforcementparticles are thoroughly stirred using a mixer tomake the melt homogenous. The temperature ofthemeltwasmeasuredusingadiptype thermocouple. The dross removed melt was finallygravitypouredintothepreheatedcastironmould.

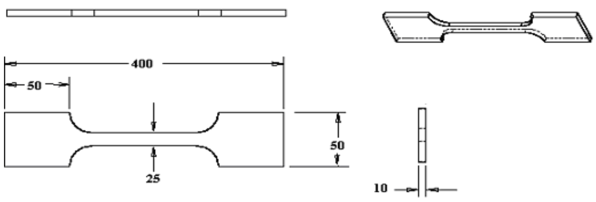

Figure1:Tensilespecimen,alldimensionsareinmm

3.1EffectofMatrixAlloyontheMechanicalProperties

Figure 3 shows the influence of matrix alloy onthe yield strength (YS) of Al/Al_2O_3 composites. Itcan be seen that the Al 6061 matrix alloy displayslarger YS than Al 6063 and Al 7072 matrix alloys.TheYSofAl6063matrixalloyissuperiortothatofAl7072matrixalloy.

TensileTest

The samples were machined to get dog-bonespecimenforthetensiletest.Theshapeanddimensions of the tensile specimen are shown inFigure 1. The computer-interfaced UTM (UniversalTestingMachine)wasusedforthetensiletest.The loads at which the specimen has reached theyieldpointandbrokenwerenoteddown.Theextensometerwasusedtomeasuretheelongation.

Optical and Scanning Electron Microscopic AnalysisMicroscopicanalysisofthecastcompositesamples was performed by the opticalmicroscopy.Animageanalyzerwasusedto

Matrixalloy

examinethedistributionofthereinforcementparticles within the aluminum matrix. The polishedspecimenswereringedwithdistilledwaterandetchedwith5%HFsolution.

Fracturesurfacesofthedeformed(undertensile loading) test samples were examined in ascanning electron microscope (SEM) to determinethe macroscopic fracture mode and toestablishthe microscopic mechanisms governing fracture.Samples for SEM observation were obtained fromthe tested specimens by sectioning parallel to thefracture surface and the scanning was carried inIICT(IndianInstituteofChemicalTechnology-Hyderabad).

III. RESULTS AND DISCUSSION

Thetestedtensilespecimensareshowninfigure2.Threesamplesweretestedforeachtrial.

Matrixalloy

Theaveragevaluesofyieldstrength,ultimatetensile strength, and ductility in terms of tensileelongation.

Figure2:TestedtensileAl/SiCCompositespecimens

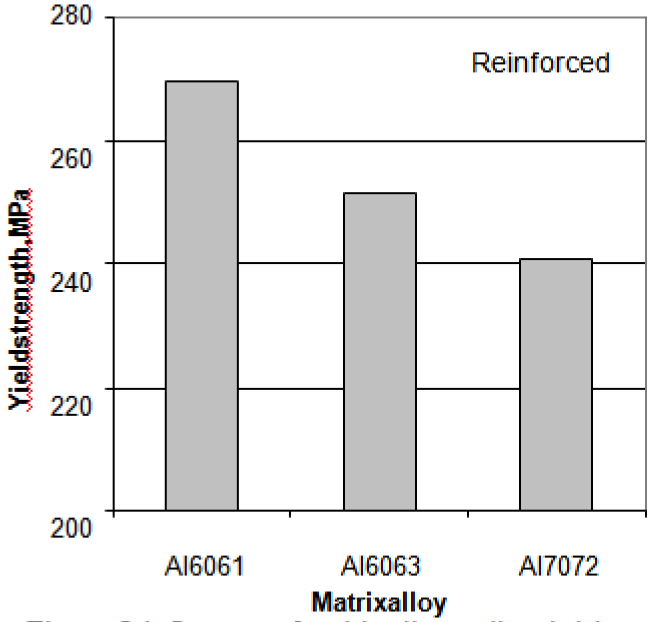

Figure3:Influenceofmatrixalloyontheyield strengthofAl/Al_2O_3composite

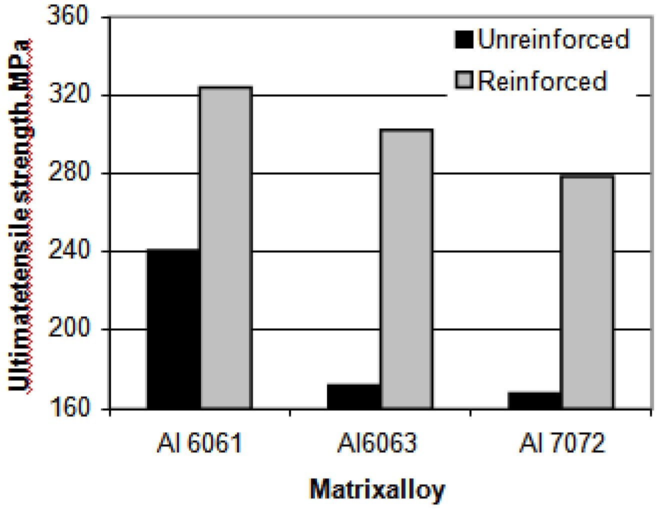

Figure4:InfluenceofmatrixalloyontheUTSof Al/Al_2O_3composite

Figure4:InfluenceofmatrixalloyontheUTSof

The influence of matrix alloy on the ultimatetensile strength (UTS) of metal matrix compositesand unreinforced alloys is shown in Figure 4. It isobservedthattheAl6061matrixalloyexhibitslarger UTSthanAl6063andAl7072matrixalloys.TheUTSof Al7072matrixalloyisinferiorto that of Al 6063 matrix alloy. The UTS of metalmatrixcomposites isverymuchprivilegedthantheunreinforcedAl-alloys.

Figure5showstheeffectofmatrixalloyontheductility(measuredintermsoftensileelongation)ofmetalmatrix compositesandunreinforced alloys. The variation in the ductility ofcomposites is largely influenced by the change inmatrixalloy.Theductility of$Al-Al_2O_3$ compositesis much lesser than that of un-reinforced Al-alloy.The ductility is in the downhill order of Al 6061,Al6063andAl7072matrixalloys.
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also seen along the grain boundaries. The phasesAl_2Cu, Mg_2Si, $Al_5Cu_2Mg_8Si_6$ and $Al_4CuMg_5Si_4$ arealsoobservedinthemicrostructures.Thepercentag eofintermetallicsinAl7072/Al_2O_3ishigher to that in Al 6063/Al_2O_3 and Al 6061/Al_2O_3metalmatrixcomposites.

Matrixalloy

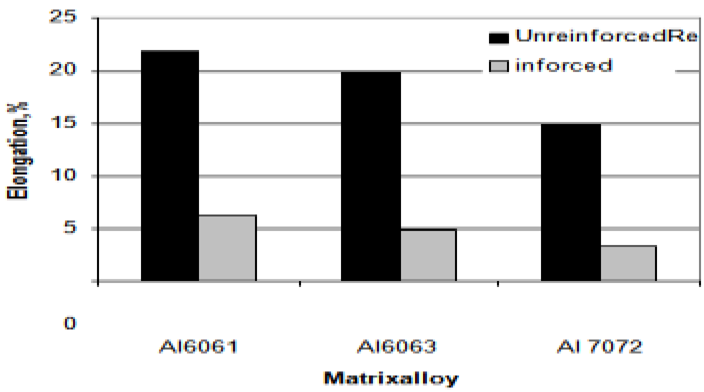

Figure 5: Influence of matrix alloy on the ductility ofAl/$A_{l2}O_3$composite

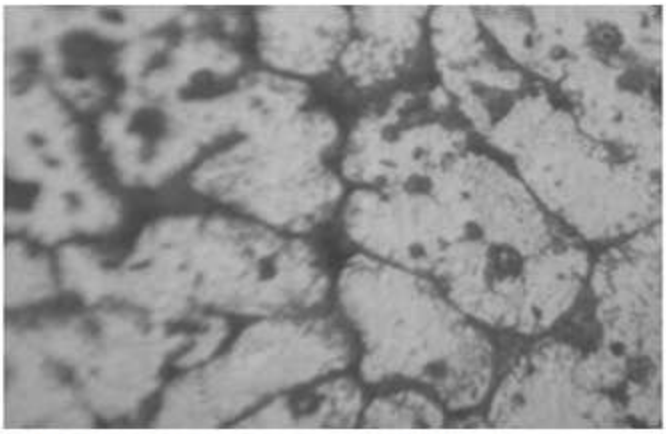

Figure 6: Microstructure of Al 6061/ Al_2O_3metal matrixcomposite,200X

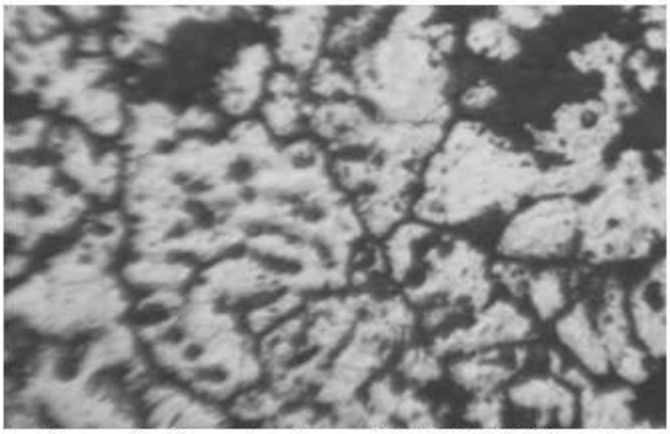

Figure 7: Microstructure of Al 6063/ Al_2O_3metal matrixcomposite,200X

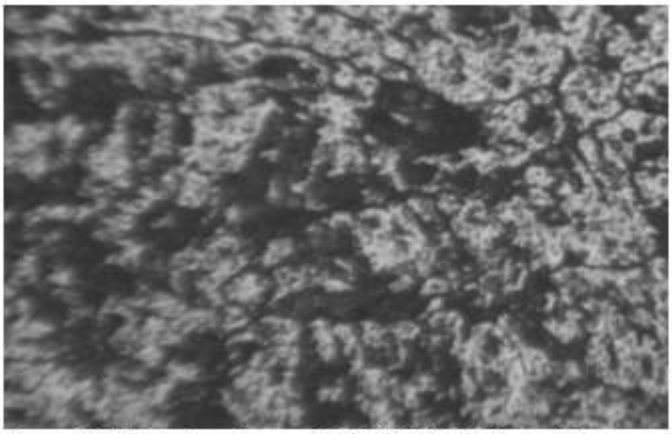

Figure 8: Microstructure of Al 7072/ Al_2O_3metal matrixcomposite,200X

Al_2O_3particlesaggregatedtoformcoarse clusters in the matrix. The agglomeration can addto the strengthening of the composites. Aluminareacts with magnesium to form MgO and $MgAl_2O_4$.Al_2O_3isnotthermodynamicallystableinmostaluminumalloys.Thereisalsopossibilityofforming intermetallics such as $Al_5Cu_2Mg_8Si_6$ and$Al_4CuMg_5Si_4$. These are brittle in nature. The MgcontentinAl6061,Al6063,andAl7072isrespectively0.920%,0.520%,and0.396%.TheYS and UTS of Al/Al_2O_3 metal matrix compositesarelargerthantheunreinforcedalloysinconsequenceoftheloadtransferredtothereinforcementAl_2O_3particles.

The various intermetallics can be revealed inthe microstructures shown in figures 6-8. In theas-cast conditions, the matrix is multiphase. Evensmallquantitiesofintermetallics,particularlyifthese are located along the matrix-reinforcementinterfaceaffect the YS, UTS and tensile ductilityof metal matrix composites.In the as-cast condition,Al is present both in solid solution with the matrixand precipitated as $Al_{12}Mg_{17}$ phase that is presentat and along the grain boundaries. A non-uniformdistribution of Al_2O_3 particulates through the Al-alloy metal-matrix with evidence of clustering, oragglomerationisobserved.MgOand$MgAl_2O_4$are

3.2FractureBehavior

Thefracturedsurfacesofthetensilespecimensareshowninfigures9–11.ThefractureofAl_2O_3particlesisnotseeninAl6061/ Al_2O_3 metal matrix composite (figure 9). Thefracture is only due to the matrix in Al 6061/Al_2O_3composites.ThefailuremodeinAl6063/Al_2O_3 metalmatrixcompositesisasaresultoftheparticle-matrix interfacecracking(figure10).TheruptureofAl_2O_3particlesandparticle-interfacecracking appear in the Al 7072/Al_2O_3 metal matrixcomposite.Theoverallfractureisductileinnature.

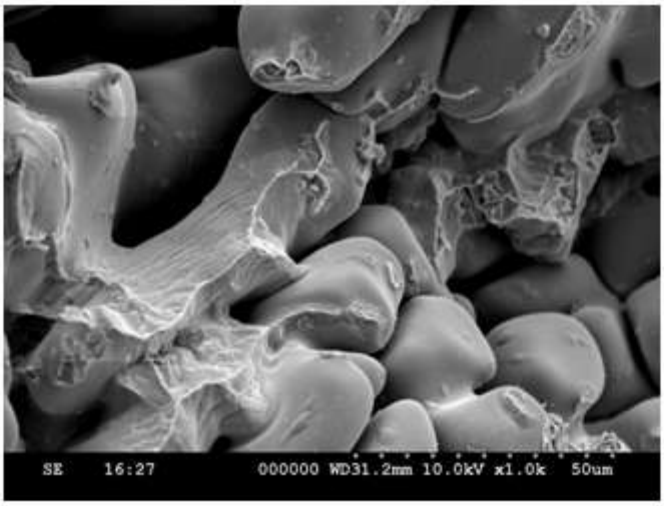

Figure 9: SEM of fracture surface of Al_2O_3/Al6061 metalmatrixcomposite,1000X

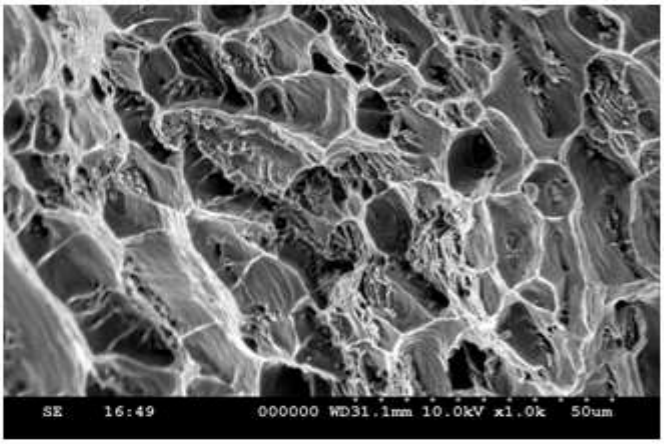

Figure 10: SEM of fracture surface of Al_2O_3/Al6063metalmatrixcomposite, 1000X

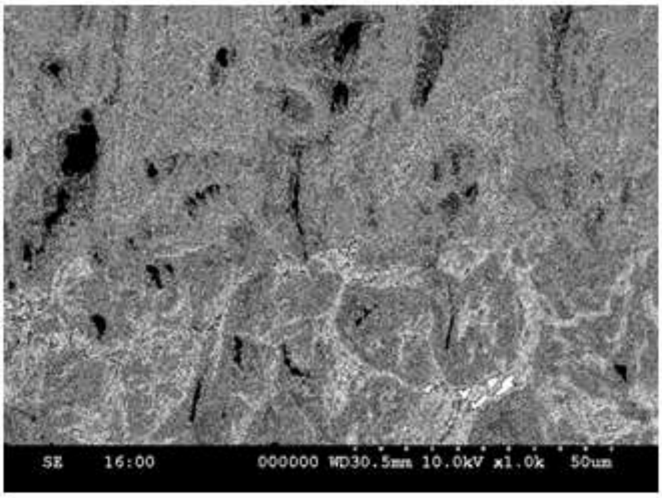

Figure 11: SEM of fracture surface of Al_2O_3/Al7072metalmatrixcomposite, 1000X

IV. CONCLUSIONS

The yield strength, ultimate tensile strength,and ductility of Al/Al_2O_3 metal matrix compositesare in the downhill order of Al 6061, Al6063 and Al7072 matrix alloys. In the as-cast condition, Al ispresent both in solid solution with the matrix andprecipitated as $Al_{12}Mg_{17}$ phase that is present atandalongthegrainboundaries.Theagglomeration can add to the strengthening of theAl/Al_2O_3metalmatrixcomposites.

The fracture of Al/Al_2O_3 particles is not seen inAl6061Al/Al_2O_3metalmatrixcomposite.Thefractureisonlyduetothematrixin Al6061Al/Al_2O_3 composites. The failure mode in Al6063Al/Al_2O_3 composite is on account of particle-interfacecracking.ThefailuremodeinAl7072Al/Al_2O_3 composite is the resultant effect ofparticleruptureandtheparticle-matrixinterfacecracking.

REFERENCES

1. Seleznev ML, Seleznev IL. Cornie JA, Argon AS, andMason RP (1998), Effect of Composition, Particle Size,and Heat Treatment on the Mechanical Properties of Al-4.5wt.%CubasedAluminaParticulateReinforcedComposites,SAEInternationalCongressandExposition, Detroit, MI, February pp.23-26, 1998, PaperNo.980700.
2. Lioyd DJ, Lagace HP and McLeod AD (1990), In:Interfacialphenomenainmetalmatrixcomposites,Controlledinterphasesincompositematerials,H.Ishida (ed.), pp.359-376, Elsevier Science PublicationsCo.N.Y.
3. Dutta L, Harper CP and Dutta G (1994), Role of Al2O3particulatereinforcementonprecipitationin2014Almatrixcomposites,MetallurgicalandMaterialsTransactions.25A, 1591-1602.
4. Chennakesava Reddy A (2003), Studies on fracturebehaviorofbrittlematrixandaluminatrihydrateparticulate composites, Indian Journal of Engineering &MaterialsSciences,9(5),365-368.
5. Manoharan M, and Lewandowski JJ (1990), Crackinitiation and growth toughness of an Al- MMC, ActaMetallurgica,38,489-496.