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Estimation of fracture parameters for Al-SiC and Al-Fe_2O_3 metal matrix composites

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Abstract. In this paper silicon carbide and iron oxide is reinforced with aluminum matrix. The prepared composite provide high strength than the commercial composite. It provides high elastic properties and high service temperature. Since this material have great scope in space application it has been chosen for estimation of fracture toughness. Hence grain size of the samples increased this is due to the effect of reinforcement bonding with aluminum matrix. The CMOD test has been carried out for this Purpose. Microscopic examination has shown that with increase in of reinforcement test confirmed that with increase in reinforcement ratio the fracture toughness also increased. In this work specimens have been preferred with and without addition of SiC and Fe_2O_3 to compare the influence. The results are compared and it has been studied that Fracture Toughness increased significantly by addition of inclusions.

1.Introduction

Metal matrix composites offer the ameliorated concrete properties as well as incremented elevated temperature performance relative to their unreinforced alloys. These are critical impute for many aero engine applications, making composites alluring contempt their higher cost. For brittle matrix systems such as inter-metallic, reinforcement can withal be utilized as an expedient of ameliorating toughness. In this paper, a wide range of long fiber and discontinuously reinforced composite systems are considered from an aero engine perspective predicated on Aluminium, titanium, and inter-metallic matrices peregrinating from moderate-temperature systems towards sultry ones. Processing methods felicitous to each type are described [2]. Properties such as concrete stiffness, strength, creep, and fatigue performance are considered. Another paramount aspect is the predisposition to engender residual stresses as a function of the discrepancy in thermal expansion between the phases [3]. In the final section a range of potential aero engine applications is examined. In this paper, stir casting process was adopted for preparing Aluminum matrix composite which is reinforced with various weight fractions (1% and 3%) and investigations are carried out by using SEM, EDAX, and CMOD [4]

2.Methodology

In this work stir casting is been followed for preparing the composites. In stir casting process uniform distribution of reinforcing particles is ensured by adding 5gms of reinforcement with 1 kg of Aluminum. The Aluminum is melted in a crucible by heating it in a muffle furnace at 800°C for one hour. The grain size of the Aluminum oxide particles used is 150 µm. The furnace temperature was first raised above the liquidus temperature of Aluminum near about 950 ºC to melt the Al alloy thoroughly [6].A pink colored powder (Scum powder) Hexochloroethane is added to the melted Aluminum to remove the Slag from the melt. A degassing flux is added to remove the bubbles from the melt. Then the melted Aluminum is cooled down just below the liquidus to keep the slurry in Semi solid state.Automatic stirring was carried out with the avail of radial stirrer operated for about 10 minutes at stirring rate of 125 rpm. In order to minimize gas stored in the molten matrix during stirring, the stirring speed and the stirrer location was placed at a concrete location [7]. At this stage, the preheated SiC and Fe_2O_3 particles were integrated manually to the vortex. In the final commixing processes the furnace temperature was controlled within 700 ± 10ºC. After stirring process the melt was poured in the sand mould to get desired shape of specimen in Figure 1.

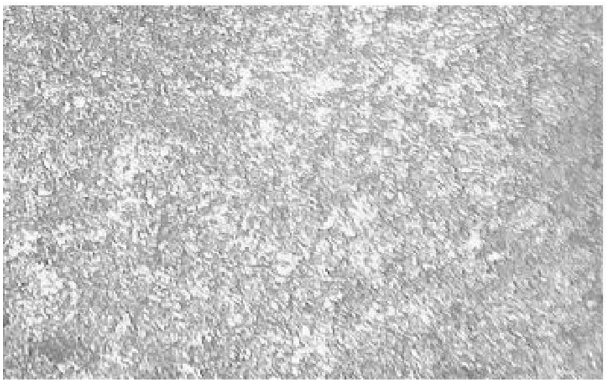
Figure 1. Fabrication of composites

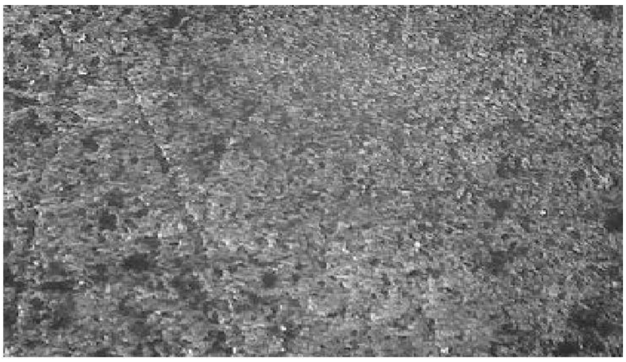
3. Results and Discussion

3.1. Optical Microscopic Examinations

Sample: 1 Al

Imported model in ANSYS workbench

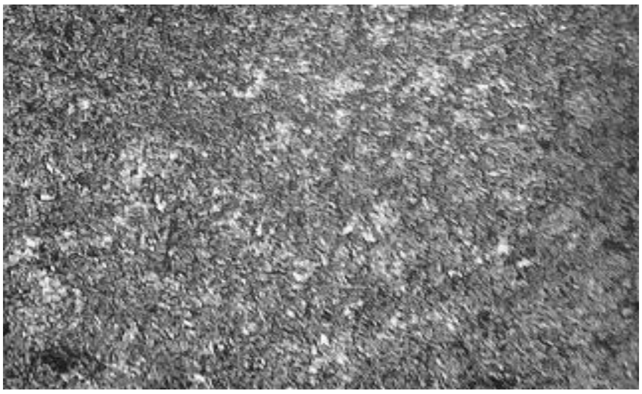




Magnification: 100X Etchant: H.F. soln

The metal matrix shows fine grains of Al-Si eutectic in aluminum solid solution. The constituents of phases present in the matrix are $Mg_2Si$and some $Cu\text{-}Al_2$ phases that are present in random distribution. As it is chill cast, the dendritic pattern of the grains is cored towards the direction of the chilled plate. No directional orientation could be seen in castings. The scanning of the plate in cross-section shows freedom from casting defects like shrinkage and micro porosities. The grains are finer due to the additives used and being a small area volume casting.

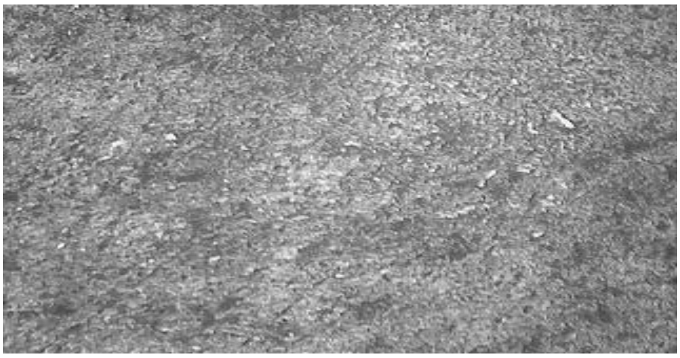
Sample:2 Al-SiC (1%)



Magnification: 100X Etchant: H.F. soln

The metal matrix shows fine grains of Al-Si eutectic in aluminium solid solution. The constituents of phases present in No directional orientation could be seen in castings. The scanning of the plate in cross-section shows freedom casting defects like shrinkage and micro porosities. The grains are finer due to the additives used and being a small area /volume casting. The presence of SiC in the matrix is uniform and present as dark particlesthe matrix are $Mg_2Si$and some $Cu\text{-}Al_2$ phases that are present in random distribution. As it is chill cast, the dendritic pattern of the grains is cored towards the direction of the chilled plate

Sample: 3 Al-Fe_2O_3 (1%)



Magnification: 100X Etchant: H.F. soln

The metal matrix shows fine grains of Al-Si eutectic in aluminium solid solution. The constituents of phases present in the matrix are $Mg_2Si$and some $Cu\text{-}Al_2$ phases that are present in random distribution. As it is chill cast, the dendrite pattern of the grains is cored towards the direction of the chilled plate. No directional orientation could be seen in castings. The scanning of the plate in cross-section shows freedom casting defects like shrinkage and micro porosities. The grains are finer due to the additives

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used and being a small area /volume casting. The presence of Fe_2O_3 could be seen but cannot be confirmed. The microstructure by using SEM followed by EDAX can give the composition of the particles.

3.2. Crack mouth opening displacement test

In the CMOD test the specimens are proportional. If the thickness is represented by 'A', then the depth will either be 'A', for a square cross section, or, '2A' for a rectangular cross section with the standard length being '4.6A'.To prepare a specimen for a CMOD test, a incision on the surface is machined in the centre of the specimen and then an authentic fatigue crack is conscientiously induced at the base of the notch. The crack must be long enough to pass through any area showing plastic deformity caused by the machining process

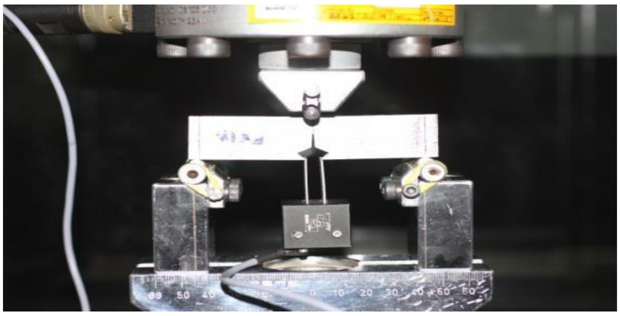

Figure 2.CMOD Test Specimen

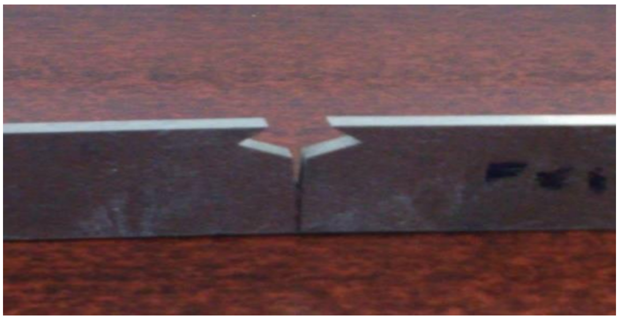

Figure.3.CMOD Testing Sample

3.3. EDAX Test

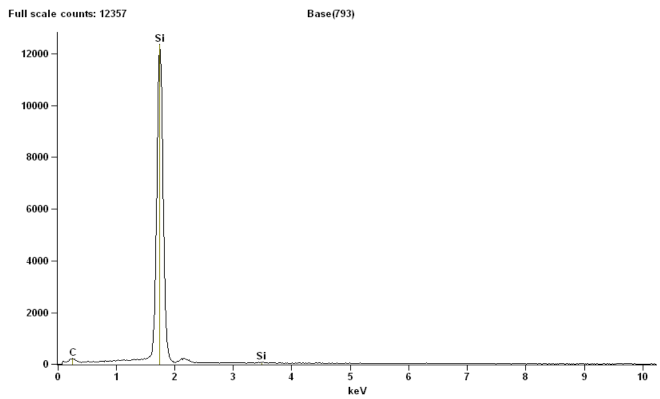

Figure 4. Quantitative Results for: Base(793)

EDAX Test Results For Fe_20_3

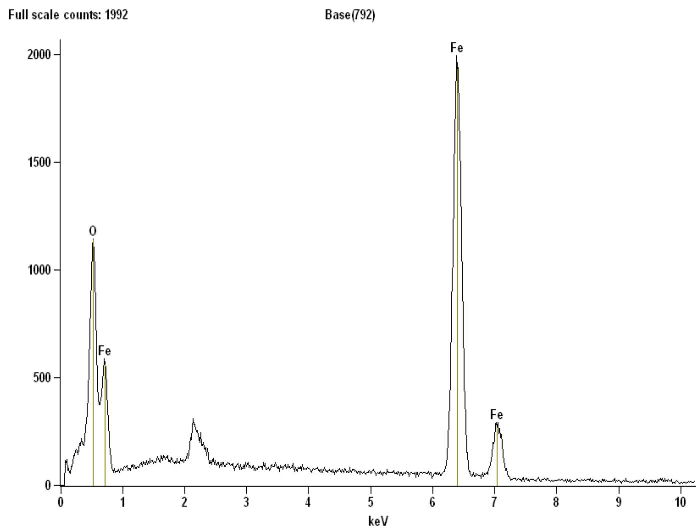

Figure.5. Quantitative Results for: Base(792)

Table 1. Quantitative Results for: Base(792)

Element	Net Counts	Weight %	Atom %
O	10354	14.66	37.49
Fe	35993	85.34	62.51
Fe	6387	---	---
Total		100.00	100.00

Table 2. J Integral test values for Al

Rec No	Max Load	Max Disp	Compliance	Crack Length	Kmax	Jmax	Jel	Jpl	Area Total	Area Elastic	Area Plastic
	kN	mm	mm/kN	mm	MPa/m	kJ/sq-m	kJ/sq-m	kJ/sq-m	kN-mm	kN-mm	kN-mm
1	0.278	0.089	0.220259	14.526	6.244	0.632	0.504	0.008	0.014	0.012	0.017
2	0.283	0.164	0.227537	14.684	9.256	1.935	1.256	0.666	0.034	0.034	0
3	0.256	0.242	0.254812	14.793	10.254	3.985	1.778	2.256	0.076	0.036	0.052
4	0.267	0.344	0.288645	15.251	11.235	5.325	1.987	4.985	0.112	0.054	0.089
5	0.281	0.432	0.342564	15.625	11.48	7.325	1.856	5.652	0.165	0.014	0.145
6	0.279	0.534	0.234561	16.234	10.825	9.365	1.652	7.562	0.152	0.016	0.15
7	0.269	0.634	0.477352	16.256	8.852	9.256	0.787	7.652	0.952	0.017	0.195
8	0.280	0.614	0.692652	17.679	7.765	10.462	0.658	9.762	0.298	0.013	0.215
9	0.258	0.802	0.820123	18.065	5.984	10.658	0.985	10.225	0.478	0.008	0.225

J integral vs Crack increment

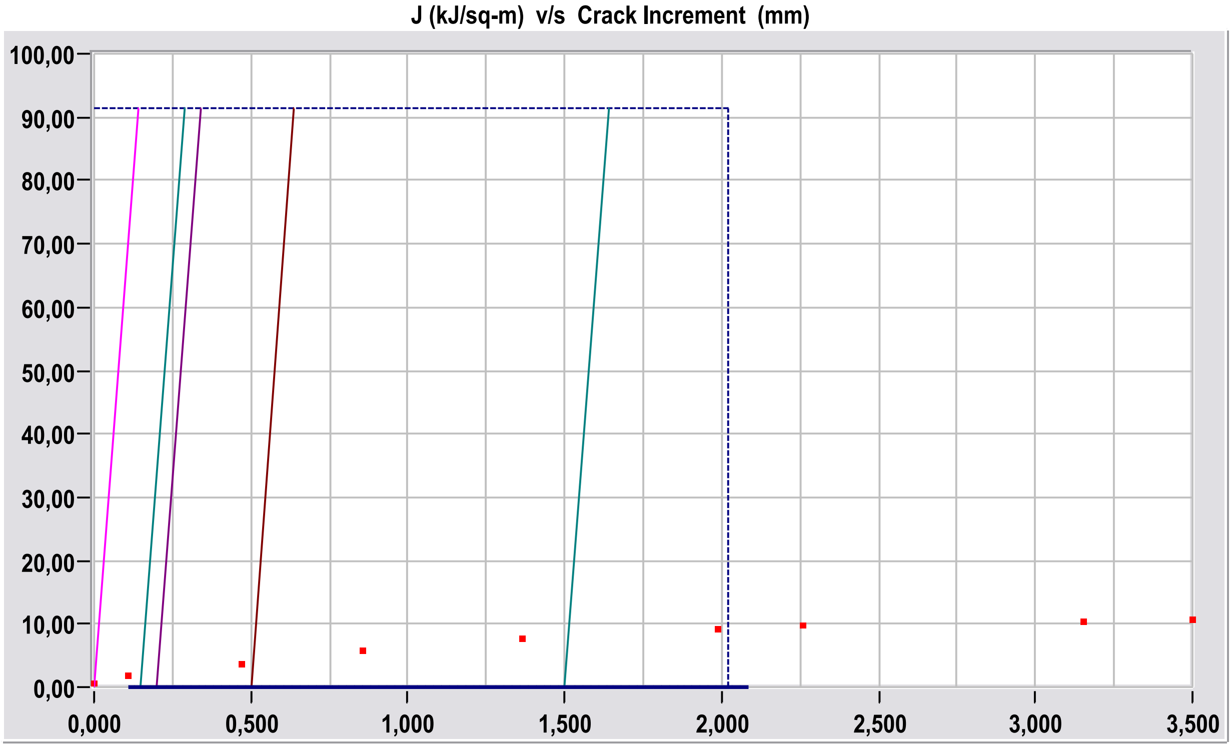

Figure 6. J integral vs Crack increment

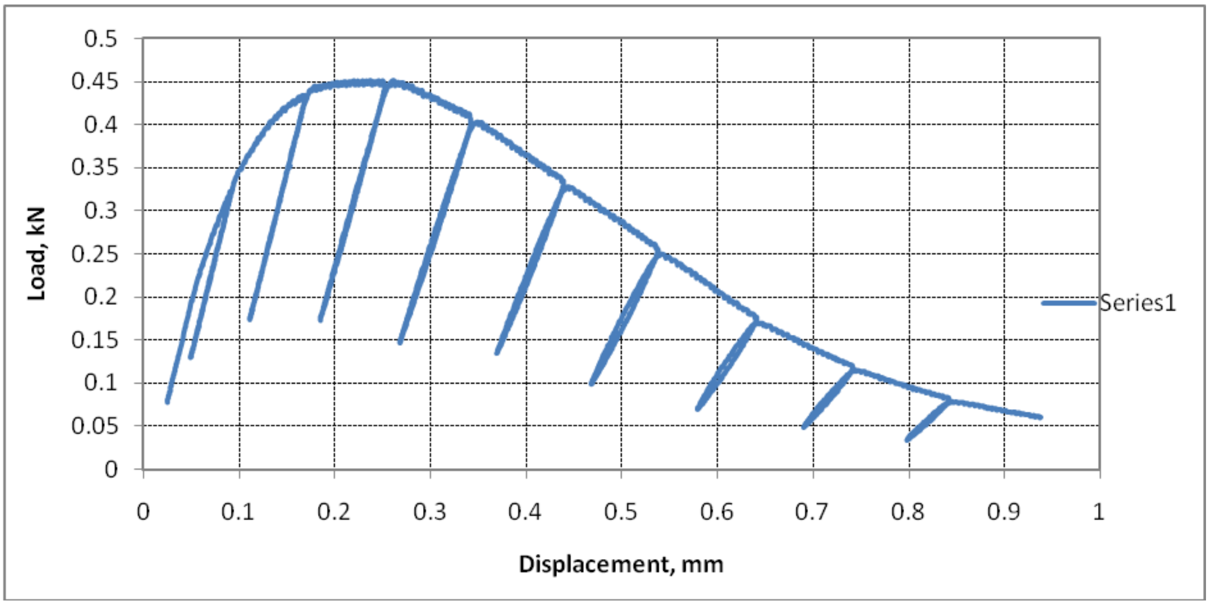

Figure 7. Load VS Displacement

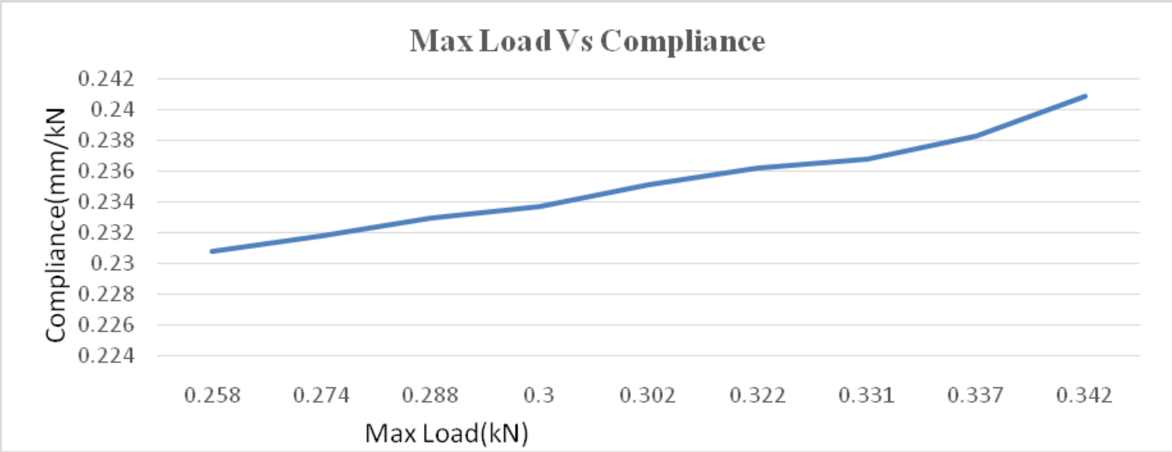

Figure 8. J- Integral test report for Al

Validation condition

1.Thickness, B>25*JQ/Yield stresses

2.Initial ligament,bo>25*JQ/Yield stresses

3.Slope of power law regression line,dj/da, evaluated at delta aQ is less than the yield stress.

Stress Intensity Factor

The stress intensity factor, K, is calculated to estimate the “stress intensity” near the tip of a crack generate by a distant load or leftover stresses. It is a theoretical construct conventionally applied to a homogenous, linear elastic material and is peripheral for providing a failure criterion for brittle materials. The concept can withal be applied to materials that exhibit minute scale yielding at a crack tip. The magnitude depends on sample geometry, the size and location of the crack and magnitude and modal distribution of loads on the material. Linear theory presages that the stress distribution (σij) near the crack tip, in polar co-ordinates(r, ϴ) with origin at the crack tip, has the form.It is denoted K_{Ic} and has the units of

K_{IC}=Y (3PS√a) / 2TW^2

Y=1.9-3.07 (a/w) +14.53 (a/w) 2-25.11 (a/w) 3+25.80 (a/w) 4

Where

P=Critical load for crack propagation S=Length of the span

a=Crack length T=Thickness , W=Width

Y=Non dimensional shear factor

J- Integral

The J integral is a line integral (path-independent) around the crack tip. It has huge consequentiality in elastic-plastic fracture mechanics.In materials science, fracture toughness is a property which describes the facility of a material containing a crack to resist fracture, and is one of the most paramount properties of any material for many design applications. The linear-elastic fracture toughness of a material is resolute from the stress intensity factor ( ) at which a thin crack in the material commences to grow. Plastic-elastic fracture toughness is denoted by JIC, with the unit of

J/cm2 or lbf-in/in2, and is a expression of the energy required to grow a thin crack.

JIC ⊐ K_{IC}^2 / E

Where

K_{IC} = Stress intensity factor

E = Young's modulus of the material

Table: 3 Stress intensity factor and J- Integral value of specimen

S. No	Samples	K_{IC} (MPa m)	J_{IC} (Pa m)
1	Al (pure)	4.18	249.61
2	Al+ 3%SiC	6.931	686.23
3	Al+3%Fe_2O_3	9.932	1409.23

4. Conclusion

The following are concluded from the above analysis

- It has been studied that Fracture Toughness increased significantly by addition of reinforcements
- The addition of Fe_2O_3 has more significant fracture toughness when compared to SiC.

So by all the tests carried out, it has been concluded that the specimen with 3% reinforcement is having superior properties.

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