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EXPERIMENTAL ANALYSIS OF FRACTURE TOUGHNESS AND MICROSTRUCTURE ANALYSIS OF ALUMINIUM6061 REINFORCED WITH ROCK DUST PARTICULATES

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Abstract – *For the last few years there has been a rapid increase in the utilization of aluminium alloys, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, and high strength, wear resistance. Among the materials of tribological importance, Aluminium metal matrix composites have received extensive attention for practical as well as fundamental reasons. Aluminium alloys and aluminium- based metal matrix composites have found applications in the manufacture of various automotive engine components.*

In our study, a stir casting process is used to fabricate aluminum composites reinforced with various volume fractions of rock dust (0, 4, 8, 12 & 16wt %) particulates. Mechanical properties of unreinforced MMCs were examined. Optical microscope is used to study the micro structural characterization of the composites. It is observed that the fracture toughness of the MMCs increased the reinforcement volume fraction. It is observed that compare to that of base aluminium alloy, the casted composite gives the better mechanical properties 16%rock dust is the best.

Key Words: **mechanical properties, Fracture Toughness, Aluminum 6061, automotive engine components, stir casting technique, etc.**

1. INTRODUCTION

A composite material is defined as a structural material created synthetically or artificially by combining two or more materials having dissimilar characteristics. The constituents are combined at macroscopic level and are not soluble in each other. One constituent is called as Matrix phase and the other is called Reinforcing phase. Reinforcing phase is embedded in the matrix to give the desired characteristics.

Ironically, given the growing knowledge with synthetic products and the ever-increasing range of applications, the term defines a clear definition. Loose words such as components composed of two or more clearly identifiable components are used to describe real composites such as wood, organic components such as facial fabric, plant aggregates, minerals, and rock.

Reinforcing phase: fibers, flakes, particulates, whiskers etc.

Matrix phase: continuous phase two ions.

2. OBJECTIVES

The goals of the proposed work are to:

- Investigation of Fracture toughness.
- Investigation brief microstructure analysis.

3. MATERIAL USED AND PROPERTIES

Composite material is made of Al6061-rock dust. The mechanical properties and chemical composition of Al6061 as shown in the tables.

TABLE.1 Material Properties.

Properties	Aluminium-6061 Alloy
Melting point (°C)	720
Density (g/cm³)	2.7
Linear thermal expansion (k^{-1})	$2.32*10^{-5}$
Poisson's Ratio	0.33
Modulus of elasticity (GPa)	68.9
Thermal Conductivity (W/mK)	151-202

TABLE.2 Chemical Composition

Element	Cr	Cu	Mg	Zn	Fe	Mn	Si	Ti	Al
Wt%	0.14	0.23	0.88	0.08	0.24	0.03	0.65	0.1	97.65

4. EXPERIMENTAL WORK

The simplest and the most cost effective method of liquid state fabrication is stir casting. In this work stir casting technique is employed to fabricate, which is a liquid state method of composite materials fabrication, in which a dispersed phase (reinforcement particulates) is mixed with a molten metal by means of stirring. The base metal Al6061 was melted at 720^{0}C in an induction furnace. An appropriate amount (4 wt% of the base metal) of rock dust powder was added slowly to the molten metal. Simultaneously, the molten metal was stirred thoroughly at a constant speed with a stirrer. The high temperature molten metal was poured into the pre-heated (600^{0}C) cast iron molds to get the required specimens. Figure 1 shows the induction furnace setup. The same procedure is followed to produce 8%, 12%, and 16%.

Fig 1: Induction Furnace.

5. TESTINGS

The specimens were machined as per ASTM E399 standards. Test was carried out on a computerized SENB specimen CNC wire cut EDM .The toughness test specimens are shown in fig.3

Fig 2: Toughness Test Specimen

6. RESULTS AND DISCUSSION

A. Fracture toughness Test

The fracture toughness test results are given the linear strain fracture toughness (K1c) of metal was investigated using pre-cracked fatigue specimens. The specimens were prepared and tests performed as per ASTM E399 standards. CNC wire cut Electronic discharge machine (EDM) used to form notch on the specimen. Single edge notch bending (SENB) specimen employed in performing K1c test. Total 5 specimens were prepared for 5 different compositions of aluminium 6061 and rock dust (0%, 4%, 8%, 12%, and 16%).

Table 3: Maximum cyclic load for pre-cracking the specimen

Sl no	Composition	Yield strength	maximum Cyclic load (P_f) N	a/w
1	Al6061	81	430.92	0.4627
2	Al6061-4%rock dust	89	473.48	0.4541
3	Al6061-8%rock dust	95	505.4	0.4662
4	Al6061-12%rockdust	103	547.96	0.4558
5	Al6061-16%rock dust	112	595.84	0.4561

Table 4: Experimental results of critical Fracture toughness (Kq) and maximum fracture Toughness (Kmax)

Sl no	Composition	a/w	f(a/w)	Pmax (kN)	Pq (kN)	Kmax mpa√m	Kq mpa√m
1	Al6061	0.4627	2.37	2.073	1.892	16.5388	14.5669
2	Al6061-4%rock dust	0.4541	2.31	2.276	2.115	17.6344	16.3658
3	Al6061-8%rock dust	0.4662	2.4	2.489	2.172	19.2699	17.5686
4	Al6061-12%rock dust	0.4558	2.32	2.552	2.357	19.5611	18.2126
5	Al6061-16%rock dust	0.4561	2.33	2.577	2.468	19.9396	19.0125

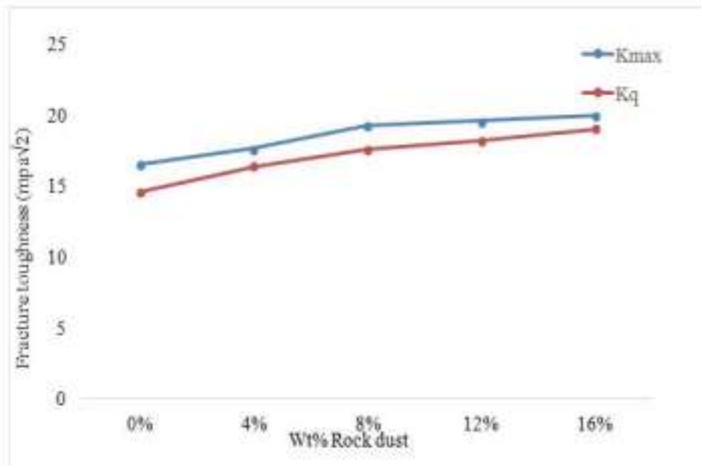

Fig 4: Experimental results of critical Fracture toughness (Kq) and maximum fracture toughness (Kmax)

The charts shown in figures are K1c Load V / s COD curves for all 5 compositions of aluminium 6061 and rock dust composite. 5 percent of the linear secant row is traced to the P-COD curve and at junction we can find out the Pq fracture charge. The base metal fracture charge (Pq) is 1,829 KN and the largest fracture charge (Pmax) is 2,073 KN and the fracture charge (Pq) is 2,357 KN and the maximum fracture charge (Pmax) is 2,552 for Al6061-12 percent rock dust. Experimental evaluation of peak fracture toughness (Kmax) is 19.5611 and critical fracture toughness (K1c) is 18.2126 for 12 percent rock dust weight. Obviously, the results show that the fracture's toughness increases with a maximum weight proportion of rock dust. From the outcomes, it is recognized that the material's brittleness improves with a rise in weight percentage of rock dust. The sudden fracture happens with 16 percent rock dust for the Al-6061.

B. Microstructure Analysis

The Figures shows microstructure of the casted specimens. The microstructure of the specimens is investigated by optical microscope with different zooming conditions. These micrographs confirm that there was a uniform distribution of rock dust particles in the base matrix; and it clearly shows that voids and discontinuities are reduced as increase in rock dust percentage.

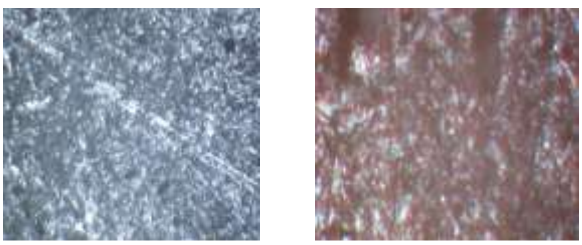

Fig 5: AL6061-ROCK DUST (0%) at 10X and 40X

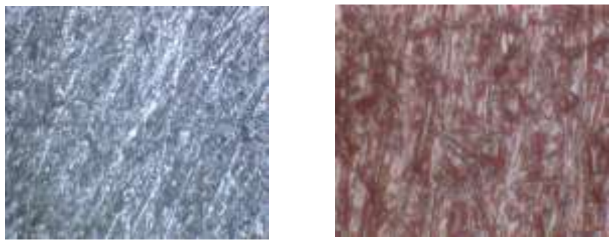

Fig 6: AL6061-ROCK DUST (4%) at 10X & 40X

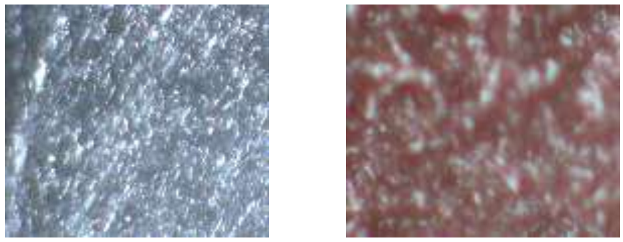

Fig 7: AL6061-ROCK DUST (8%) at 10X & 40X

Figure highlights the almost uniform distribution of rock dust particles in a matrix alloy. The rock dust's average particle size is 150 meshes. Most rock dust particle shape is in nature angular and sub-angular. It is discovered that the area fraction also improves as the proportion of strengthening rises as shown in the optical micrograph. It also observed that owing to enhanced interfacial bonding of reinforcement with aluminum matrix alloy this can be attributed to enhanced hardness and wear resistance. By preheating particles of rock dust before adding them to the matrix material, good interfacial bonding can be achieved. From the microstructures shown in the figures above, we can say that all Microstructures consist of fine precipitates of alloy elements dispersed in the aluminum matrix along the grain boundary. The tough particles in the rock dust help with the material's wear resistance. The microstructure of the products is heavily influenced by various mechanical characteristics such as hardness, strength, toughness, etc. Microstructure assessment is commonly used in the materials quality control sectors.

7. CONCLUSIONS

1. The aluminium alloy composites containing different amounts of rock dust particles were produced by stir casting method successfully.

2. Rock dust particles distribute evenly in the matrix phase.

3. The experimental and theoretical results of critical fracture toughness (kq) and maximum fracture toughness (Kmax) results are increases with increase of reinforcement in metal matrix composite.

4. Maximum fracture toughness (Kmax) experimental assessment is 19.9396 and critical fracture toughness (K1c) is 19.0125 for 16% rock dust weight.

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