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Physical and Thermal Properties of Quarry Dust Reinforced A356 Metal Matrix Composites

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Abstract

The present investigation has been focused on the utilization of abundantly available industrial waste quarry dust in a useful manner by adding it into aluminium alloy to produce composites by stir casting method. The composite specimens are fabricated in different quarry dust weight percentage (0, 5, 7.5 and 10) by the modified stir casting set up in argon atmosphere. The density and porosity of different weight percentage of composites and monolithic alloy have been calculated by Archimedes principles. The density of the composite was gradually decreased by increasing quarry dust weight percentage. The porosity was increased by increasing weight percentage of quarry dust in the matrix alloy. The fabricated disc specimens are used to find the thermal conductivity using guarded hot plate method. The presence of porosity decreases the thermal conductivity of reinforced A356 composite. The value of thermal conductivity of metal matrix composite is 13% lesser than the aluminium alloy. A scanning electron microscope is used for study the micro structural characterization of aluminium composites.

Keywords: Aluminium alloy, Quarry dust, Density, Porosity, Thermal Conductivity.

1. Introduction

In the environment, large quantities of artificial and natural wastes in different forms are generated and disposed at water ways or landfills which causes environmental and health problems. Many of these cities lack of solid waste regulations and proper disposal facilities, including for harmful waste. Such waste may be infectious, toxic or radioactive. Across the countries, many of the organization come forward to research on reusing the solid waste. Reuse is the natural problem solving techniques [13]. All over the world, a plan has to be enforced for the final disposal of solid waste, in order to end the random open waste dumping. Speedy activation and implementation of such plans have been developed so far is needed [5]. The quarry dust is obtained as solid wastes, during crushing of stones to obtain aggregates. The annual production of quarry dust is roughly around 200 million tones. A limited research is available regarding the utilization of this waste for stabilization of expansive soil [4].Quarry dust is a by-product generated from quarrying activities involved in the production of crushed coarse aggregate [3].Aluminium Metal matrix composites (MMCs) possess significantly improved properties including high specific strength, hardness, tensile strength and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements [12].

2. Experimental Work

2.1 Material

In this study, commercial grade A356 alloy was taken to prepare the composite by adding quarry dust using stir casting method. In the light metal chart A356 has good casting properties due to presence silicon and magnesium. Silicon and magnesium which present in the metal matrix gives good fluidity and good corrosion resistance. Quarry Rock Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 200 mesh size.

2.2 Specimen Preparation

Stir casting is the widest method used to prepare the metal matrix composites. Stir casting method is the simplest and cheap among the liquid state production [12]**.** In the stir casting method the A356 alloy is completely melted at 750^0C and the solid form particulate is added to the alloy. The quarry dust particulates were mixed thoroughly with a stainless steel stirrer at 350 rpm [11]**.** The composite specimens are fabricated at different weight percentage (0, 5, 7.5 and 10) of quarry dust. The fabricated specimens are used to study the physical and thermal properties of composites.

2.3 Density

The theoretical value of density was obtained using rule of mixture (ROM). The theoretical density of the composites can be calculated by using the formulae [2], $\rho_{th} = \rho_m v_m + \rho_r v_r$,Where, ρ_{th}, ρ_m and ρ_r are the density values of theoretical , matrix and reinforcement, v_m, v_r are volume fraction of metal matrix and reinforcement. The density of the samples were measured using Archimedes principle. Fabricated composite specimens are taken and immersed in the water. The volume of the submerged portion equals the volume of water it displaces. By measuring the weight of the water and weight of the specimen density of the specimen was calculated.

2.4 Porosity

Porosity is the defect formation which is largely due to gas entrapment during stirring, air bubbles entering in to the slurry [9] .The porosity is the defect in cast metal matrix composites which is formed due to poor wetting of reinforcement particulates into the molten alloy and also the atmospheric gases dissolved into the molten metal during casting processing [1]**.** The percent of porosity presence in the composites was measured by comparing the theoretical and experimental densities determined by the Archimedes principle.

Porosity percentage (%P)=1 – (ρ_{exp}/ρ_{th})

2.5 Thermal conductivity

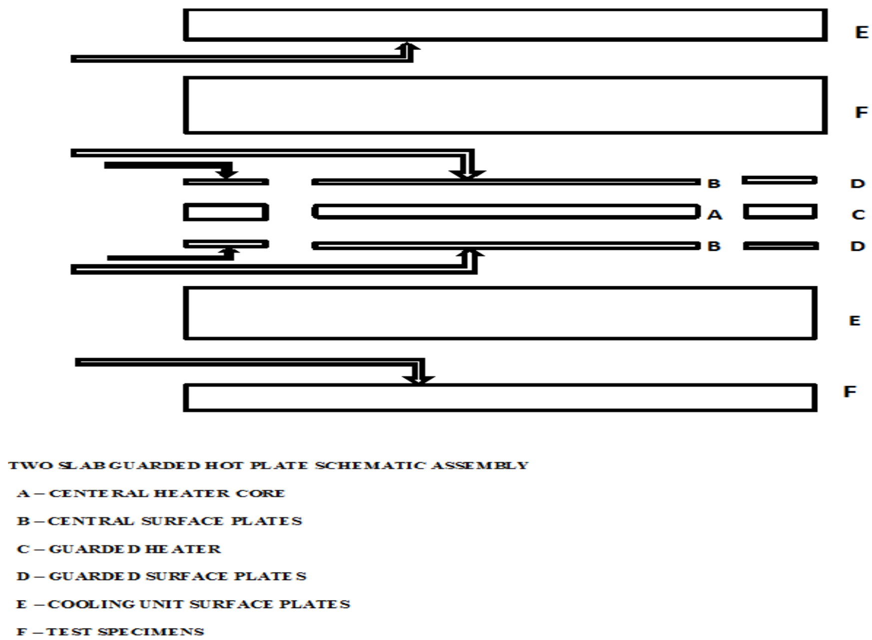

Fig. 1: Guarded hot plate specimen arrangement.

Guarded hot plate method is used to find the thermal conductivity of the composite specimens. The specimens are casted in the circular disc with the diameter of 180mm and a thickness of 12mm. The guarded hot plate testing machine consists of ring guard and central heat core assemblies to heat the test specimen. Set of thermocouples are attached in the assemblies to find the temperature distribution in the specimen and cooling water. Heat is supplied from the central heater core to both the specimens placed in the assembly as shown in fig.1.The specimens are placed above and below the heater core which has central and guard surface between them. Cooling unit was attached in the top and base of the stack of specimens in the machine. The flow of heat transfer is constant and the assembly is insulated to ensure negligible loss of heat. The thermal conductivity of the specimen was calculated using k =q/2a { $L/T_h - T_c$ }; where, q = Heat Flow Rate (w), a = Metering Area (sq. m) ,T_h = Hot Plate temperature (k), T_c = Cold Plate temperature (k) and L = Specimen Thickness (m).

2.5 Scanning electron microscope

The physical properties of the composites are mainly influenced by the microstructure, particle size, shape and distribution of the reinforcement [11]. JSM-6610LV Scanning electron microscope (SEM) is used for study the microstructure characterization at low vacuum mode. The composite specimens are etched using Keller's reagent before characterization

3. Results and Disscussion

The graph of theoretical and experimental density of the composites according to the weight fractions of quarry dust particulates is shown in Fig.2. It shows that the density values of the composites decrease linearly.

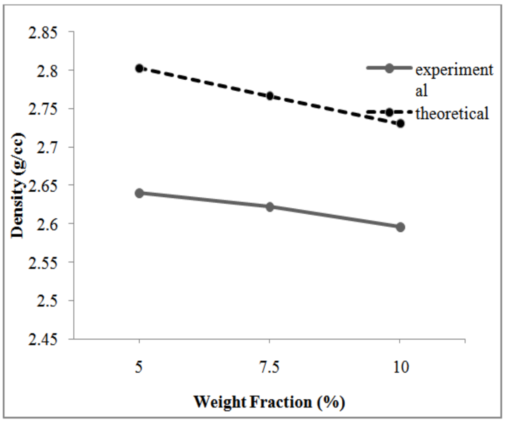

Fig. 2: Variation of experimental and theoretical density of the composites.

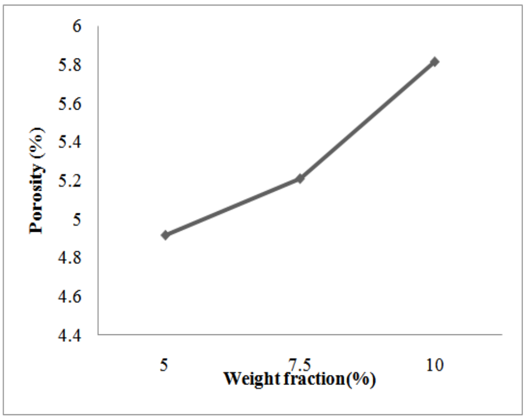

Fig. 3: Variation of porosity with weight fraction of the Composites.

The overall density of quarry dust reinforced composites was decreased because the density of quarry dust was 1.86 g/cc. By adding the quarry dust reinforcement of 5wt. % with matrix alloy; the experimental density was reduce up to 8.3% [6]. The values of the experimental densities are lower than that of the theoretical densities.Because of presence of porosity in the composite specimens. The porosity percentage was calculated using the theoretical and experimental density values of the composite specimens. The theoretical and experimental values of varying reinforcement weight fraction are compared in the table1.

Table 1: Density and Porosity of Al-quarry dust base composites

Specimen	Experimental density	Theoretical density	Porosity (%)
Al+5%qd	2.640	2.803	4.917
Al+7.5%qd	2.622	2.766	5.211
Al+10%qd	2.596	2.730	5.818

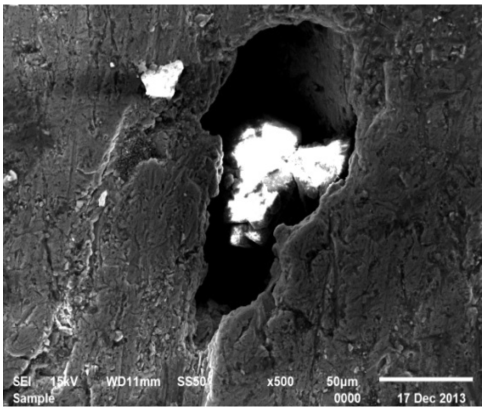

Fig. 4: Microstructure of A356 alloy with 7.5% quarry dust rein force composites.

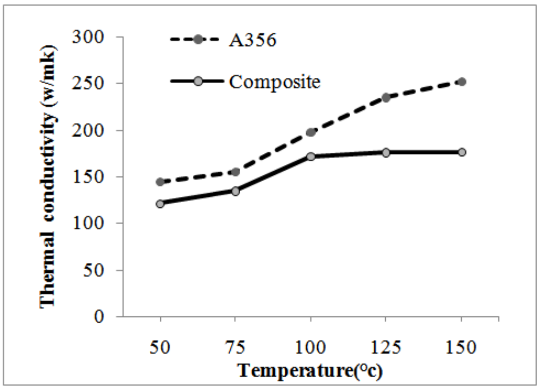

Fig. 5: Variation of thermal conductivity of A356 and composite with temperature

The graph of porosity values of the composites according to the weight fraction of the reinforcement is shown in fig.3. From the graph it is observed that the porosity of the composite specimens are increased with increase in weight percentage of the quarry dust. Because of operating the stirrer with a constant speed will form a vortex on the surface of the molten metal. The development of the vortex is causes the pressure difference between the inner and the outer surface of the melt .This pressure difference disperse the quarry dust particle into the molten metal. During this gas entrapment is created in to the specimens. For the 5 wt. % of the quarry dust reinforcement composite has the porosity level of 4.9% [9]. Fig.4 shows the SEM micrograph of A356 alloy with 7.5 wt. % of quarry dust reinforced composites. The quarry dust particle of various sizes was dispersed in the alloy. There is a presence of porosity around the quarry dust particle was clearly seen in the micrograph.

The thermal conductivity of the A356 and quarry dust reinforced composite according to the varying temperature is shown in fig.5.In the graph thermal conductivity of the composite increase with increase in temperature. Thermal conductivity of the composite specimen is lesser than the alloy. Addition of the quarry dust decreases the thermal conductivity value due to the scattering of the heat-carriers, such as electrons from metal alloy and phonons from non-metal reinforcement. Also the quarry dust added to the alloy is not sieved, it contains varying particle size .Because of the different particle size added to the alloy degrades the thermal conductivity value. S.Okumus said in his paper that thermal conductivity varies with different particle size. Thermal conductivity of the 7.5% weight fraction of the composite specimen shows the 13.4% decreased than monolithic alloy value. The thermal conductivity reduction is due to the presence of 5.2% of porosity in the composite. The porosity reduces the conduction between the matrix and reinforcement materials. Also the quarry dust particle has lesser conductivity than the A356 alloy [7].

4. Conclusions

Castings of A356 alloy by adding different weight percentage of quarry dust composites have been produced using stir casting method.

The following conclusions are drawn from the experimental investigations:

1. Quarry dust is the waste product which is used as better reinforcement for the A356 alloy.
2. Increasing in the weight percentage of the reinforcement in the alloy decreased the density value.
3. Composites fabricated using the stir casting process has obtained minimum percentage of the porosity. The porosity percentage increases with increased in weight fraction of quarry dust.
4. Thermal conductivity of the composite with 7.5 wt. % of quarry dust is lesser than that of the A356 alloy. Aluminium alloy reinforced with quarry dust composite can be used in low thermal conductivity applications.

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