IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE)
ISSN : 2278-1684 Volume 1, Issue 5 (July-August 2012), PP 17-20
www.iosrjournals.org

Effect of Heat Treatment on the Coefficient of Thermal Expansion of Aluminium 7075alloy-Sic_p (5wt %) Composites

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Abstract: *This paper describes the study of coefficient of thermal expansion (CTE) of as-cast and heat treated Aluminium 7075/ SiC_p composites. The content of silicon carbide particulates is used as 5wt% to prepare the castings. These composites were subjected to different aging durations. The stir casting technique is used to prepare the castings. Castings were machined in accordance with ASTM standards followed by heat treatment process. All the castings were aged to different periods of 1hr, 3hr, 5hr at an aging temperature of 175 ^oC. Coefficient of thermal expansion tests were performed in both as-cast and heat treated conditions. In each case the coefficient of thermal expansion values were found to increase with increase in aging durations. Solution heat treatment at 530 ^oC followed by artificial aging at 175 ^oC found to increase in dimension change of every specimen tested. The coefficient of thermal expansion curves exhibited some residual strains, which were decreased with the increase in aging durations.*

Keywords*: Alloys, Coefficient of thermal expansion (CTE), Heat treatment*

I. Introduction:

Al 7075 is widely used for construction of aircraft structures, such as wings and fuselages. Its strength and light weight are also desirable in other fields. Rock climbing equipment, bicycle components, and hang gliders are commonly made from 7075 aluminium alloys. Aluminium 7075 alloy is chosen as testing material owing to its superior strength and excellent corrosion resistance among all available aluminium alloys. Aluminium based metal matrix composites have been emerged as an important class of materials for structural , wear, thermal, transportation and electrical applications, primarily as a result of their ability to exhibit superior strength to weight and strength to cost ratios when compared to equivalent monolithic commercial alloys. Among all variable types of aluminium composites, particulate reinforced composites are considered as one of the advanced engineering materials which have attracted more and more interests. The incorporation of hard ceramic phase to a relatively soft matrix alloy like Aluminium improves the strength, creep performance and wear resistance of the alloy. Moreover, they exhibit light weight which make these materials suitable for many applications such as automotive and space applications. They are widely used as pistons, connecting rods, brake motors and drive shafts. Many techniques were developed for producing particulate reinforced MMC's, such as powder metallurgy, insitu, and squeeze casting. Besides that each of these methods has its own advantages and disadvantages, they are all relatively expensive. The stir casting technique is used to prepare the specimens owing to its easiness to manufacture.

Further the addition of ceramic reinforcements (e.g.SiC, E-glass fiber) has raised the performance limits of the Aluminium 7075 alloys . Ceramic materials are employed for high-temperature structural applications because of their high melting point, high temperature strength, stiffness and oxidation resistance . However, ceramics have limited fracture toughness. Owing to high strength, high stiffness and high resistance to wear, ceramic reinforced MMCs have attracted considerable attention in the past two and half decades. Composite materials are widely used because the qualities of two or more constituents can be combined without seriously affecting their short comings.

In the light of the above, the present investigation is aimed at development and characterization of aluminium 7075 and silicon carbide particulates composites. The developed alloy will be subjected to heat treatment. As cast and heat treated alloy will be characterized in finding the coefficient of thermal expansion under varying heat conditions.

II. Experimental Procedure:

2.1. Preparation of composites

The material used for producing the specimens in this study is aluminium 7075 alloy. This alloy is best suited for mass production of lightweight castings. The content of silicon carbide particulates is used as 5wt% to prepare the castings. The liquid route technique is employed to fabricate the specimens. Using this method the vortex created in the melt by the use of alumina coated stainless starrier. The coating of an alumina to the blades of the stirrer is essential to prevent the migration of ferrous ions from the stirrer into the molten metal. The stirrer was rotated at 550 rpm and the depth of immersion of the stirrer was maintained about two-thirds the depth of the molten metal. The system was degassed using pure nitrogen for about 3-4 minutes. The resulting liquid was tilt poured into the preheated permanent metallic moulds.

2.2 Specimen preparation

After casting the Aluminium 7075 based specimens by the stir cast method, CTE test specimens were prepared by machining in accordance with ASTM standard from the cylindrical bar castings. Each specimen was 10mm in diameter and 15mm in height. The specimen surfaces were polished with 1µm diamond paste. Each result presented is an average of five samples and each composite was tested under identical conditions. The samples for microscopic examination were etched with keller's reagents. The specimens were washed with distilled water followed by acetone and dried thoroughly.

2.3. Heat treatment

A T6 heat-treatment process called aging was carried out for the as-processed specimens. First, the specimens aere subjected to solution treatment for 12hr at 530 ^oC, then quenched in water at 80 ^oC. then after stabilizing for three hours, the aging is carried out at 175 ^oC for different intervals of time ranging from 1h, 3h, 5h. The heat treatment cycle is shown in Fig.1

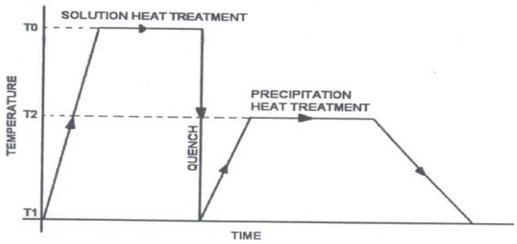

Fig.1 Heat Treatment Cycle

2.4 CTE measurement

Coefficients of thermal expansion tests were carried out at using a TMA Q400 Thermo-mechanical analyzer having a resolution of 10 significant decimal digits. CTE test specimens of size diameter 10 mm and height 15 mm were prepared, by machining a cylindrical bar castings of 20mm in diameter and 300 mm in length using a centre lathe. The specimen surfaces were polished with 1µm diamond paste to obtain fine finish. Specimens were subjected to a constant load of 0.5N and measurements were taken from room temperature to 400^{o}C for the heating part of the cycle and from 400^{o}C to room temperature for the cooling part of the cycle at a sweep rate of 5 ^{o}C/min. The specimen was positioned on a quartz base and a standard expansion probe was used to measure the changes in length. The whole experiment was carried out in a furnace whose temperature could be controlled and monitored. The data were noted in terms of linear dimension changes with respect to temperature. Each result noted was an average of five samples and each specimen was tested under identical conditions. Standard TMA data analysis software was used to compute the CTE of the as-cast and heat-treated specimens.

III. Results And Discussion:

3.1 Microstructure of composites

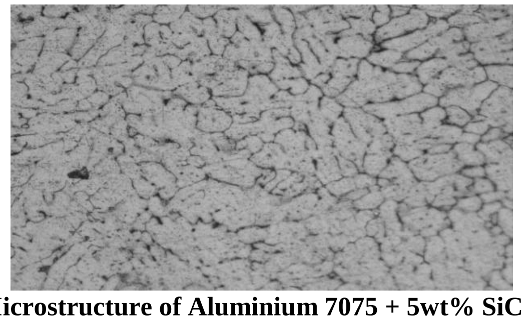

Figure 2 Microstructure of Aluminium 7075 + 5wt% SiC composite

Figure 2 shows the Microstructures of Aluminium 7075 alloy +5wt% SiC composite. Microstructures consist of fine precipitates of alloying elements along the grain boundary in the matrix of Aluminium solid solution. Particles are uniformly dispersed in the matrix.

3.2 Dimension change

The coefficient of thermal expansion results were expressed as dimension change as a function of temperature. The dimension change as a function of temperature for as-cast and heat treated specimens are shown in Fig.3,4,5,6. It is observed that all the plots of dimension change versus temperature for the specimens with different aging times had similar characteristics and all the curves showed similar trends. During the heating part of the cycle, as the temperature increases so does the dimension change (µm). on the return (cooling) part of the cycle, there is invariably some hysteresis and dimension change and it is always more than that during heating. This hysteresis becomes less as the aging duration increases. There was invariably some residual strain at the end of each thermal (heating-cooling) cycle. An increase in aging durations plays a significant role in influencing the residual contractions seen in these MMCs upon cooling. The hysteresis is caused by the thermal stress relaxation in the matrix material. Thus stress relaxation causes plastic yielding in the matrix that causes the curves not to retrace their path on the return (cooling) part of the thermal cycle. The result is not only a hysteresis phenomenon, but also a final residual strain in each case.

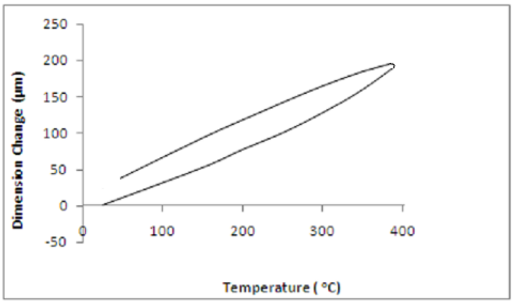

Fig 3. Dimension change as a function of temperature for as-cast condition

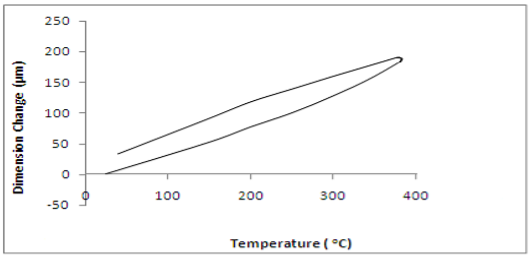

Fig 4. Dimension change as a function of temperature for heat-treated condition (1h)

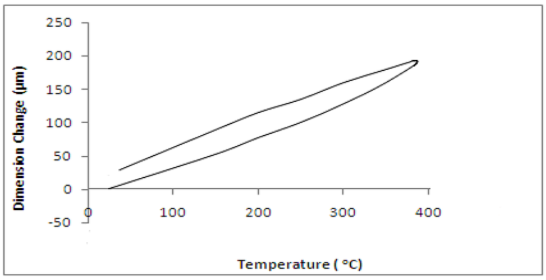

Fig 5. Dimension change as a function of temperature for heat-treated condition (3h)

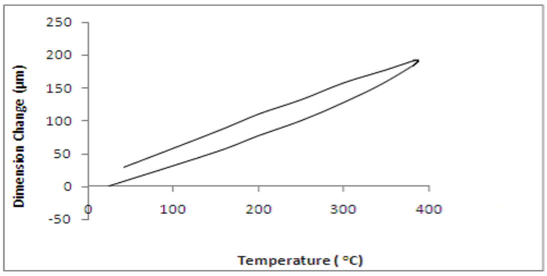

Fig 6. Dimension change as a function of temperature for heat-treated condition (5h)

The residual strain in the case of the as-cast condition is found to have a maximum value when compared to heat-treated one. The area of the hysteresis between the curves decreases with increase in the aging durations.

Authors M.M.Benal and Shivanand H.K observed similar effects when testing MMCs consisting of Al alloy 6061 reinforcements with SiC particles. The hysteresis seen was caused by viscoplastic deformation in the metal matrix. They explained that this deformation occurs by yielding followed by cavitation and also by time-dependent creep mechanism.

IV. Conclusions

The coefficient of thermal expansion of the as-cast and heat treated Aluminium 7075 based composites has been investigated over a room temperature to 400 ^{o}C both in the heating and cooling cycles. The thermal expansion study showed hysteresis residual strains. This study revealed the presence of the residual thermal stresses generated in the composites. This is due to the difference in the CTE between the as-cast and heat-treated composites.

The study of residual strains obtained is particularly useful in high-temperature applications of composites. Residual thermal stresses at the matrix reinforcement interface are induced by the CTE mismatch between the reinforcement and matrix, which are dependent on the properties of the matrix, reinforcements and aging durations.

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