EFFECT OF QUENCHING MEDIA ON THE MECHANICAL PROPERTIES OF Al 6061-TiO_2 METAL MATRIX COMPOSITE

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Abstract

In recent years aluminum alloy based metal matrix composites are gaining importance in several aerospace and automobile applications. Aluminum 6061 which has excellent mechanical properties, good formability and wide applications in industrial sector has been used as matrix material.TiO2 which possess high hardness, modulus and corrosion resistance has been chosen as the reinforcement. In the present investigation Al6061-TiO2 composites were fabricated by the stir casting route with the percentage of TiO2 kept constant at 10 wt % .The specimens have been subjected to solutionizing heat treatment in a muffle furnace at a temperature of 530oc for 1.5 hrs followed by quenching in different media i.e. air, water, aqueous polymer solution and ice. Hardness and tensile tests were conducted on the as cast and heat treated Al 6061-TiO2 composites. It was observed that the quenching has significant effect on hardness and tensile strength, exhibiting significant improvement as compared to as cast composites.

Keywords: Aluminum Matrix Composites, Heat Treatment, Solutionizing, Quenching, Hardness. Tensile strength.

1. Introduction:

Metal matrix composites are gaining importance in several sectors due to its improved mechanical properties and light density when compared with metals and alloys, especially in applications where weight and strength are of prime importance .Presently, Al alloy based metal matrix composites are being used in several applications like Cylinder, piston, pushrods and brake discs. Al 6061 is a popular matrix material owing to its good corrosion resistance and good mechanical properties coupled with good formability. Al 6061 is heat treatable and as a result further increase in strength is expected by adopting optimal heat treatment [1]. Use of TiO_2 as reinforcement in aluminum metal matrix composites has received little attention even though it possesses high hardness used for hardening aluminum alloys [2].Heat treatment is an operation in the fabrication of an engineering material system .The main objective of heat treatment is to make the material system structurally and physically fit for engineering applications [3]. Solution heat treatment of aluminum alloys allows maximum concentration of hardening solute to dissolve into solution. The process is carefully carried out by heating the alloy to a temperature at which one single, solid phase exists. By doing so, the solute atoms originally part of two phase solid solution dissolve into solution and create one single phase. Once the alloy has been heated to the recommended solutionizing temperature, it is quenched at a rapid rate such that the solute atoms don’t have enough time to precipitate out of the solution .Due to quenching a super saturated solution now exists between solute and aluminum matrix. Quenching is the process of rapid cooling of material systems to room temperature to preserve the solute in solution .The cooling rate needs to be fast enough to prevent solid state diffusion and precipitation of the phase. The rapid quenching creates a saturated solution and allows for increased hardness and mechanical properties of the material system [4-5].

Although the combined effect of heat treatment and type of reinforcement plays a key role in dictating the final mechanical properties of composites, limited information is available regarding heat treatment of Al based composites that too with TiO_2 as the reinforcement.

In light of the above, the investigation was aimed at studying the effect of solutionizing and quenching media on mechanical properties of Al6061-TiO_2 composites.

2. Materials:

2.1 Matrix:

Al6061 was selected as the matrix material. This aluminum alloy contains Silicon, Magnesium, Copper, Manganese and some minor alloying elements. Silicon and Magnesium are the principal alloying elements. Among Al alloys, Al 6061 has high machinability, hardness and also light weight. It is a heat treatable aluminum alloy. Al 6061 alloy in the form of ingots were procured from reputed Metallurgical Manufacturing Company.

2.2 REINFORCEMENT:

Titanium Dioxide (TiO_2) powder of laboratory grade purity of particle size 10–20 micron was chosen as the reinforcing material. The various reinforcements that have been tried out to develop the metal matrix composites were graphite, silicon carbide, titanium carbide, Boron carbide, Al_2O_3, fly ash, ZrO_2, TiB_2, etc. On the other hand, TiO_2 which is very hard and possess low density, high fracture toughness and exhibits excellent wear resistance, but has not gained much importance as reinforcement in aluminum alloy [2].Laboratory grade TiO_2 powder was procured from reputed Scientific Company.

3. Experimental Details:

3.1 Composite Fabrication:

For the preparation of composite the stir casting procedure was adopted. The stir casting was carried out in the R&D lab, MSRIT, Bangalore. The Al6061 alloy was melted at 750ºc in the graphite crucible in electrical melting furnace. The stainless steel mechanical stirrer was introduced into the melt after effective degassing. The molten alloy was stirred at 220 rpm for 1 min, until a vortex was formed. Titanium Dioxide (TiO_2) particles preheated at 250ºc were added into the formed vortex slowly and steadily while continuing stirring for 3-4 min in a maneuvering way to ensure the complete dispersion of particles across the metal matrix. After the stirring, the stirrer was removed and the molten composite was poured into the pre-heated, pre-coated permanent finger mould die and allowed to cool. The addition of TiO_2 particles in the matrix alloy was kept at 10 wt. %.

Fig. 1: Fabrication of Al6061-TiO_2 Composite

3.2HEAT TREATMENT:

The cast composite specimens were subjected to heat treatment in a muffle furnace. The specimens were introduced in the furnace and solutionizing was carried out for 1.5 hrs at a temperature of 530ºc. After solutionizing the specimens were then rapidly quenched in different quenching media i.e. air, water, aqueous 20 % vol. polymer (PEG) solution and ice.

Fig 2: Specimens kept in Muffle Furnace

Fig 3: Solutionizingof Composite at 530ºc

Fig 4: Air quenched Specimens

Fig 5: Water quenched Specimens

Fig 6: Preparation of Aqueous Polymer Solution

Fig 7: Aqueous polymer Solution (PEG) quenched Specimens

Fig 8: Ice quenched Specimens

3.3Hardness Test:

Samples were machined and tests were carried out as per ASTM E18 standard. Rockwell hardness tester was used to test the hardness.

- Surface of the specimen to be tested was polished, cleaned and kept on anvil.
- The location on specimen where indentation is to be made was selected.
- The specimen was positioned on anvil in such a way that its surface is normal to the direction of applied load.
- Anvil was raised by means of elevating screw till pointer reaches red dot on the dial. This indicates minor load of 10 kg applied, by the indenter.
- Later major load of 100 kg was applied as per the B scale for duration of 30 seconds to ensure complete acting of the load on the specimen by the indenter.
- After 30 seconds load was removed and the final position on B scale was noted which directly indicates the Rockwell hardness number.
- The indentations were made at three different locations on the specimen and the average was considered as the hardness value.

Fig 9: Rockwell Hardness Tester

Fig 10: Rockwell Hardness Specimens

3.4Tensile Test:

Samples were machined and tested as per ASTM E8 standard. Bench tensometer was the device used to test the tensile strength. The electronic tensometer is a compact and bench model horizontal tensile testing machine of capacity 20 KN. PC 2000 model series of tensometer was used to test the tensile strength.

- Suitable pair of shackles were chosen to fix the shoulder. Specification of the specimen i.e. gauge length and its outer diameter were noted.
- The sample was laid in the cradle before stretching it and the pivoted arm was moved to the right slide.
- The right slide was locked for carrying out the test.
- The test graphs of load v displacement, True Stress v Strain and Engg. Stress v Strain, were obtained.

Fig 11: Bench Tensometer

Fig 12: Tensile Specimens

4. Results and Discussion:

4.1 Hardness:

The effect of different quenching media on the hardness is presented in fig.13. It was observed that solutionized and quenched Al6061-10% TiO_2 composites exhibit higher hardness as compared to as cast samples.

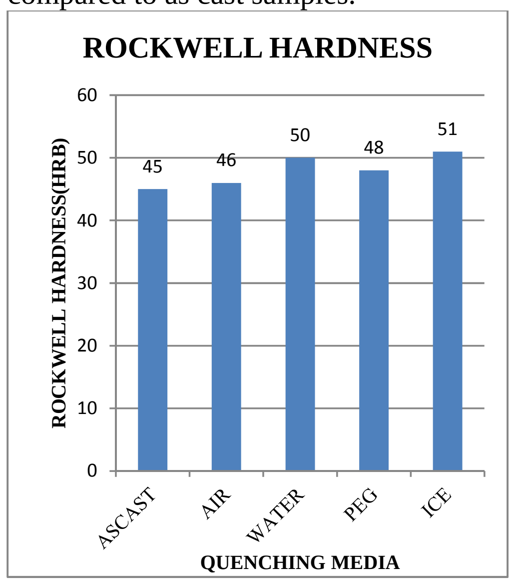

Fig 13: Variation of Hardness under Different Quenching Media

The air quenched specimen showed an increase of 2.17% compared to the as cast samples. Water quenching displayed an improvement in hardness of 10%. Quenching in PEG solution showed an improvement in hardness of 6.25% over the as-cast composite. The ice quenched samples show an increase of 11.76% in hardness compared to as-cast specimens.

The solutionizing heat treatment resulted in the formation of intermetallic phase of Mg & Si which is harder than the aluminum alloy resulting in higher hardness. Of the heat treated composites the ice quenched composites displayed higher hardness compared to other quenching media, which may be due to combined effect of enhanced bonding between TiO_2 particles and matrix due to lower temperature and the formation and stabilization of Mg_2Si intermetallic phase with matrix.

4.2 Tensile Strength:

The variation of true ultimate tensile strength (UTS), Engg. UTS and peak load with different quenching media is shown in fig. 14.1, 14.2 and 14.3 respectively. It was be observed that the true UTS, Engg. UTS and peak load increased for the solutionized and quenched Al6061-10% TiO_2 composites as compared to as cast, except the specimens quenched in air which showed a decrease in UTS as compared to the as-cast samples.

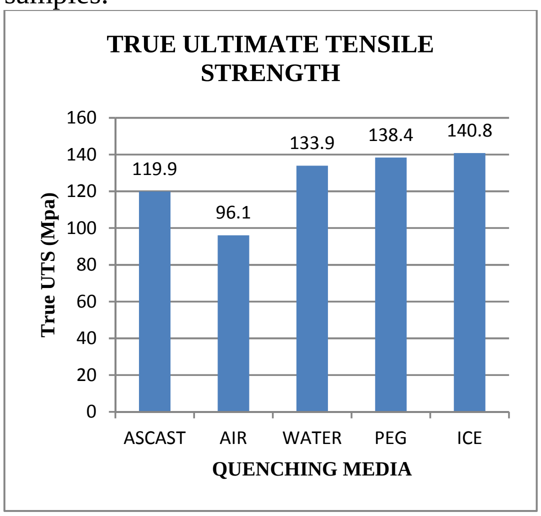

Fig 14.1: Variation of True UTS under Different Quenching Media

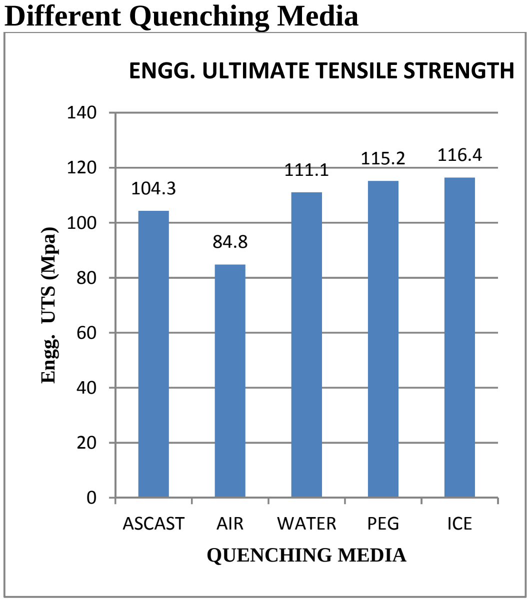

Fig 14.2: Variation of Engg. UTS under Different Quenching Media

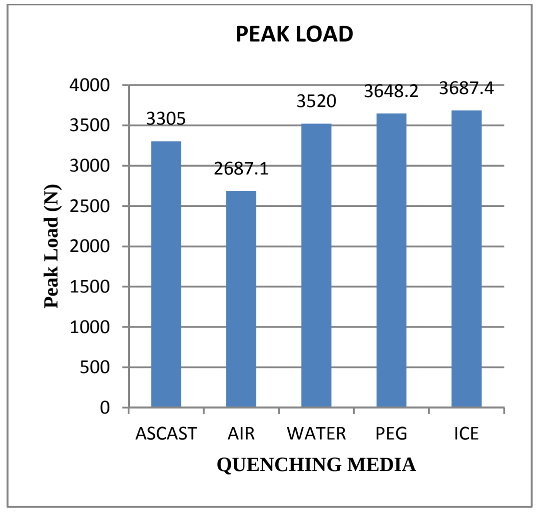

Fig 14.3: Variation of Peak Load under Different Quenching Media

The water quenched specimen showed an increase of 10.45 %, 6.12 % and 6.10 % in true UTS, Engg. UTS and peak load respectively over the as cast sample. Quenching in PEG solution showed an improvement in true UTS, Engg. UTS and peak load of 13.36%, 9.46% and 9.40 % respectively. The ice quenched samples displayed an increase of 14.84%, 10.39% and 10.37 % in true UTS, Engg. UTS and peak load respectively which is higher compared to the other quenching media. Only air quenching displayed a decrease in true UTS, Engg. UTS and peak load compared to the as-cast sample.

The improvement in tensile strength of Al6061-10% TiO_2composites on heat treatment can be attributed to a large extent on formation of intermetallic precipitates which act as obstacles for pinning down the dislocations. This curtails the mobility of dislocations, thereby reducing the extent of plastic deformation. This leads to significant improvement in UTS. The ice quenched samples showed higher UTS compared to other quenching media due to formation and stabilization of intermetallic phase of Mg_2Si and enhanced bonding between TiO_2 particles and matrix due to lower temperature. Due to presence of residual stresses in the as cast specimen, its tensile strength could have been more than the air hardened specimen. Air hardening could have relieved the internal stresses leading to lower value of tensile strength.

The graphs obtained from the tensile test conducted on the bench tensometer are displayed in the fig. 15.1 to 15.5.

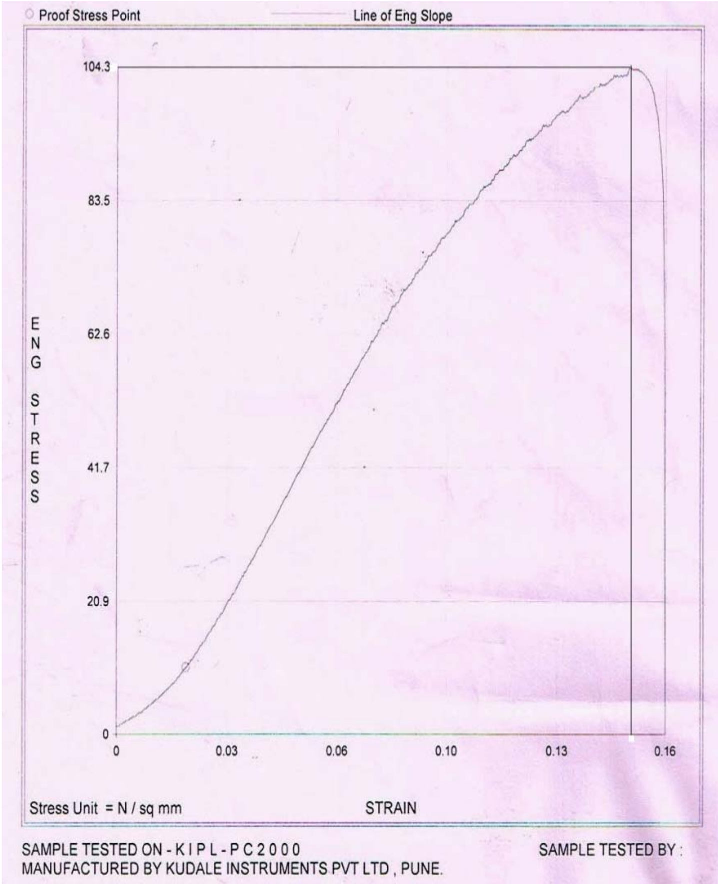

Fig 15.1: Plot of Engg. Stress v strain for ascast sample

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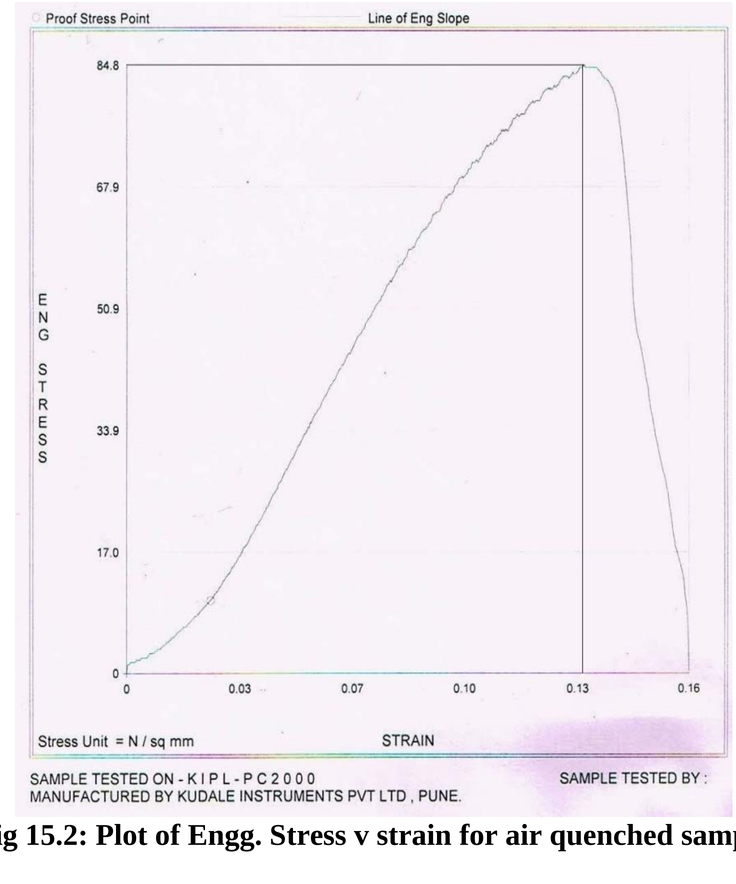

Fig 15.2: Plot of Engg. Stress v strain for air quenched sample

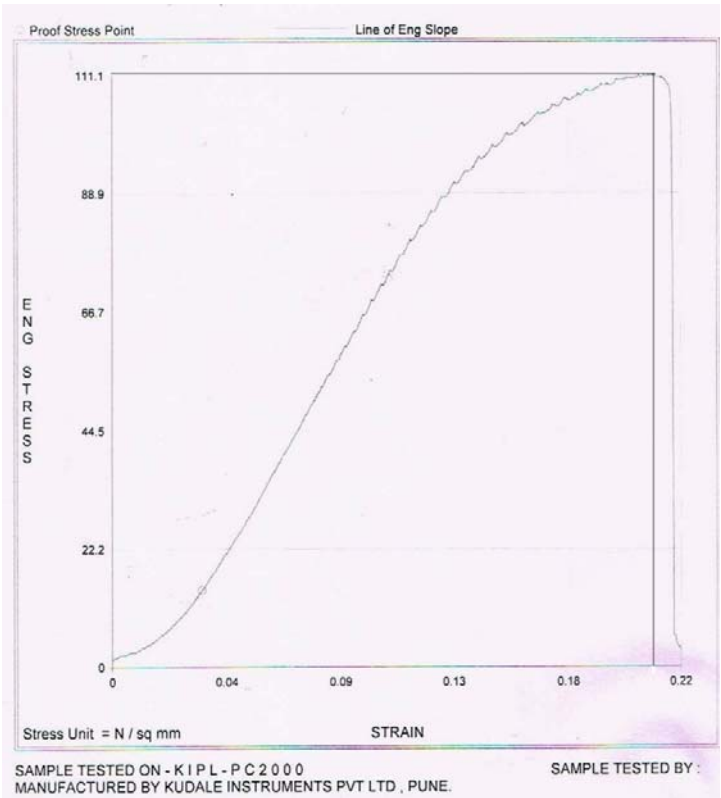

Fig 15.3: Plot ofEngg. Stress v strain for water quenched sample

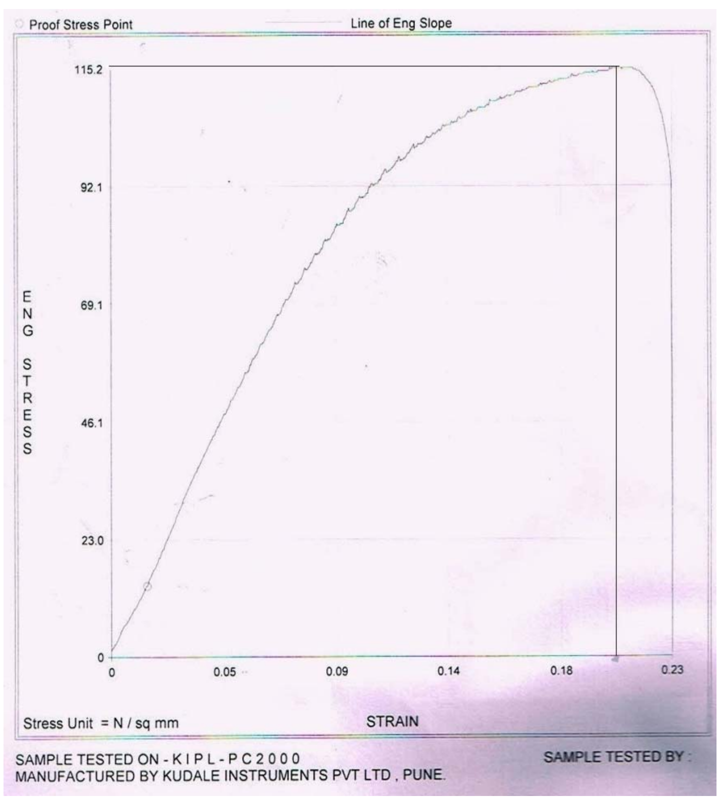

Fig 15.4: Plot of Engg. Stress v strain for PEG quenched sample

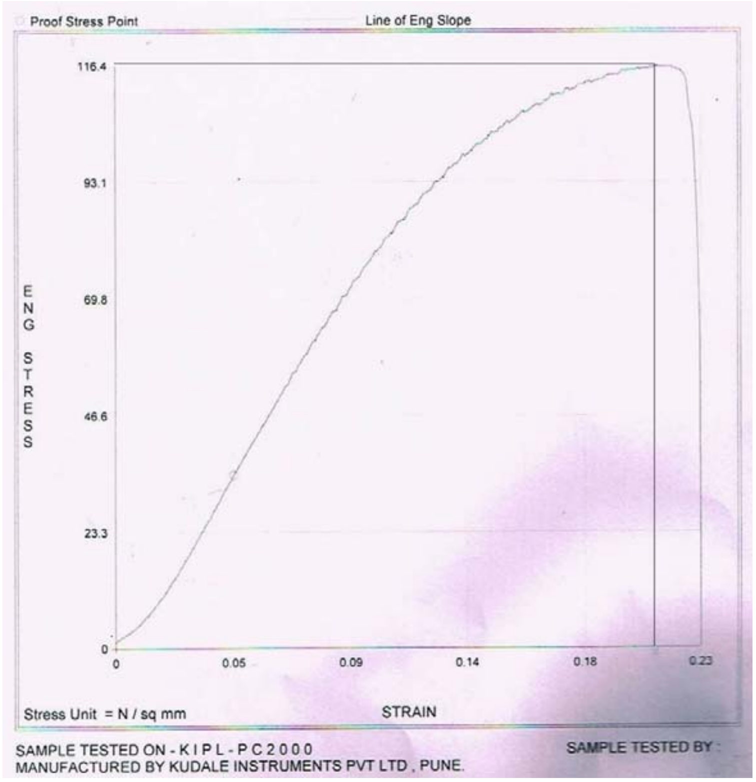

Fig 15.3: Plot of Engg. Stress v strain for ice quenched sample

5. Conclusions:

The conclusions drawn from the above research work are

- ✓ The aluminum metal matrix composite was successfully fabricated by stir casting technique.
- ✓ Solutionizing and quenching in different media were successfully carried out on machined specimens.
- ✓ Heat treated specimens showed enhanced hardness compared to as cast.
- ✓ Ice quenched specimen has higher hardness compared to other quenching media.
- ✓ Tensile strength of heat treated specimen was much higher compared to the as cast specimen, except for air quenching which showed a decrease in tensile strength.
- ✓ Ice quenching resulted in the maximum tensile strength among all the quenching media.

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