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A study on effect of cryogenic treatment on Tensile and Hardness behaviour of Al6061alloy

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Abstract

The Synthesis of aluminum alloy is getting significant importance to meet the needs of industry requirement. Due to high strength to weight ratio, enhanced mechanical properties Al6061 are gaining more importance than the conventional engineering materials. The researchers are doing experiments to know the effect of cryogenic treatment of various steels. The present investigation is to study the effect of cryogenic treatment on mechanical on AL6061 alloy. The stir casting technique is used to fabricate the Al6061 alloy. The specimens are prepared as per ASTM standards. EDS and XRD were carried out to know the composition and phase identification of the al6061 alloy. Optical microstructure setup is used to study the microstructure of Al6061 alloy with and without cryogenic treatment Mechanical properties like ultimate tensile strength, yield strength, percentage elongation and hardness on AL6061 alloy has been studied with and without cryogenic treatment.

Keywords: AL6061, Cryogenic treatment, Stir casting

1. Introduction

The utilization of thermal treatments to enhance mechanical properties of metal components is an antiquated craftsmanship from the previous eras and is used till date. The treatments that are applied to metals to enhance mechanical properties are in a choice of temperature higher than the room temperature. Since few decades, attention has been shown in the cause of sub-zero treatment on the performance of metals. Sub-zero treatment is generally classified as either cold treatment down to dry ice temperature 193k or deep cryogenic treatment at near liquid nitrogen temperature 77k.

Cryogenics is the science and technology deals with production and effects of very low temperature. The significant improvement was observed after cryogenic treatment for 2 hours and decrease in hardness was observed after 48 hours of cryogenic treatment [1]. Nickel-titanium shows no improvement in microstructure and elemental composition after cryogenic treatment [2]. Farhani et al. [3] have concluded that results are improved due to soaking time and soaking temperature. Austenite transformed to martensite structure for steels on deep cryogenic treatment [4]. AISI M35 HSS material showed improved hardness and wear resistance after cryogenic treatment for 24 hours [5]. Wen-da ZHANG et al. [6] have concluded that 3104 aluminum alloy specimens processed by Deep cryogenic treatment (-196ºC) for 24 hours followed by heat treatment exhibited higher tensile properties. AA6061 alloy exhibits higher tensile strength and yield strength compared to AA6082, AA5052, and AA5086 alloys [7]. The Al6061/Al_2O_3 composites showed improved microstructure and mechanical properties on deep cryogenic at -196ºC [9]. G Elango et al., showed that the improvement of microstructure and hardness upon cryogenic treatment on LM25 alloy and MMCs reinforced with SiC [10].

2. Experimental Procedure

2.1 Preparation of Al6061 specimens

Al6061 alloy ingots are purchased from reputed producer. The bottom pouring automated stir casting equipment is used to fabricate the AL6061 alloy. The furnace is pre-heated to a temperature of 800ºC. The Al6061 alloy ingots are placed inside the furnace of stir casting equipment. The flux is added to remove the slag from the material. The stirrer is done for 5 minutes. The molten Al6061 alloy is poured in to the mould cavity and allowed it to solidify. The solidified Al6061 alloy is taken out from the mould cavity and the specimens are prepared using lathe machine as per ASTM standards. Figure 1 shows the Al6061 ingots purchased from manufacturer and Figure 2 shows bottom pouring stir casting machine.

Figure 3 and figure 4 shows mould box and Al6061 casts respectively.

Fig.1. Al6061 ingots

Fig.2. Bottom pouring stir casting equipment

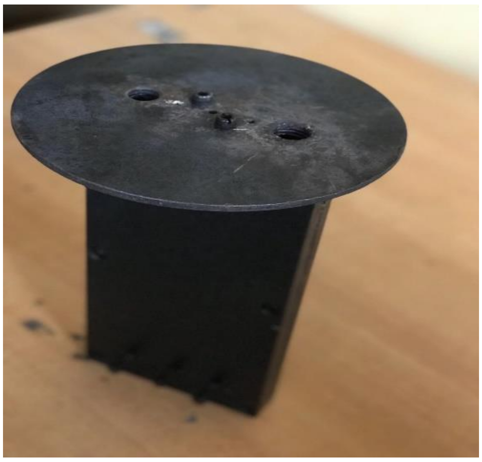

Fig.3. Mould box

Fig.4. Al6061 casts

2.2 Cryogenic treatment

The cryogenic treatment consists of cooling the specimens to liquid nitrogen temperature (-196ºC) , followed by soaking the specimens for 24 hours and finally warming of specimens to bring down to room temperature. Figure 5 shows the cryo treatment cycle. Figure 6 and 7 shows cryogenic chamber and cryotreated specimens respectively.

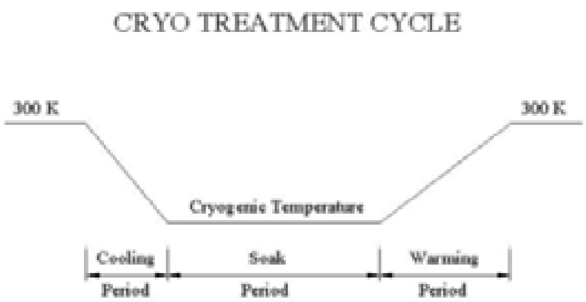

Fig.5. Cryo treatment cycle

Fig.6. Cryogenic container

Fig.7. Cryo treated specimens

2.3 Tensile test

The tensile test was conducted on a computerized Universal testing machine. The tensile properties like ultimate tensile strength, yield strength, percentage elongation was studied to know the effect of cryogenic treatment. The tensile specimens prepared as per ASTM standards is shown in Figure 8. The servo controlled UTM machine of capacity 50 kN is shown in Figure 9.

Fig.8. Tensile specimens

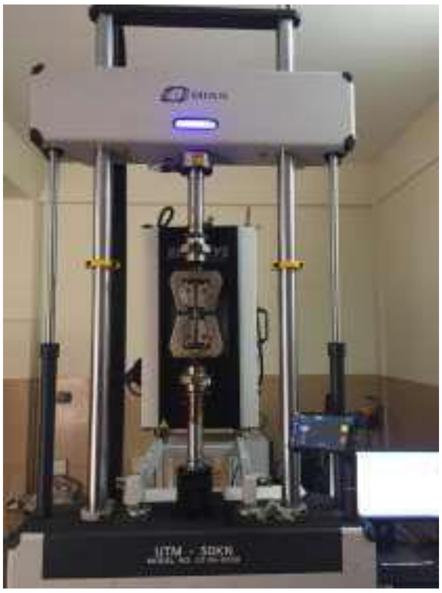

Fig.9. UTM machine

2.3.1 Ultimate Tensile Strength (UTS)

Ultimate Tensile Strength (UTS) is plotted for Al6061 alloy with and without cryogenic treatment. The bar graph of Al6061 for UTS with and without cryogenic treatment is shown in Figure 10. From the graph, it is seen that UTS for Al6061 alloy without cryogenic treatment is 102.72 N/mm^2 and 111.87 N/mm^2 with cryogenic treatment. The Al6061 alloy showed improved tensile strength after cryogenic treatment.

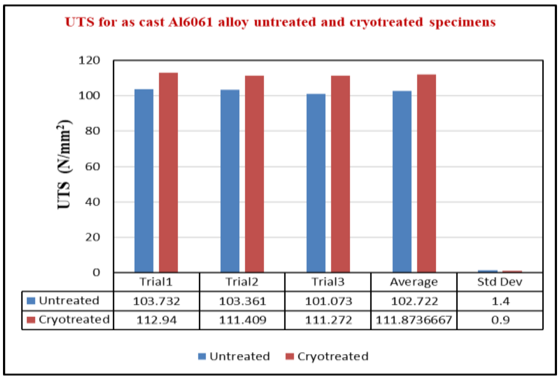

Fig.10. UTS (N/mm^2) of Al6061 with and without cryogenic treatment

2.3.2 Yield strength

Yield strength is plotted for Al6061 alloy with and without cryogenic treatment. The bar graph of Al6061 for UTS with and without cryogenic treatment is shown in Figure 11. From the graph, it is seen that yield strength for Al6061 alloy without cryogenic treatment is 46.61 N/mm^2 and 55.05 N/mm^2 with cryogenic treatment. The Al6061 alloy showed improved yield strength after cryogenic treatment.

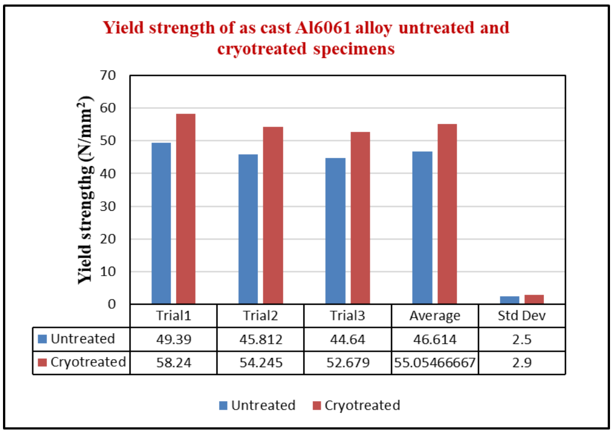

Fig.11. Yield strength (N/mm^2) of Al6061 with and without cryogenic treatment

2.3.3 Percentage elongation

Percentage elongation is plotted for Al6061 alloy with and without cryogenic treatment. The bar graph of Al6061 for percentage elongation with and without cryogenic treatment is shown in Figure 12. From the graph, it is seen that percentage elongation for Al6061 alloy without cryogenic treatment is 11.89 and 8.31 with cryogenic treatment. The Al6061 alloy showed decrease in percentage elongation after cryogenic treatment.

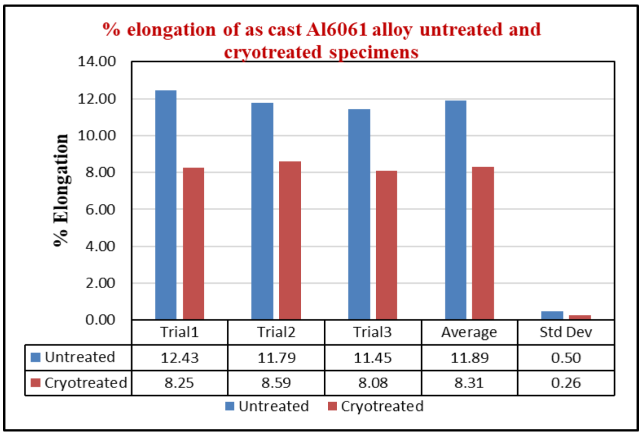

Fig.12. Percentage elongation of Al6061 with and without cryogenic treatment

2.3 Hardness test

The Vickers Hardness number (VHN) measurement was done by using computerised hardness tester. The Computerized hardness tester machine is shown in Figure 13.

VHN is plotted for Al6061 alloy with and without cryogenic treatment. The bar graph of Al6061 for VHN with and without cryogenic treatment is shown in Figure 14. From the graph, it is seen that VHN for Al6061 alloy without cryogenic treatment is 95.6 and 104.4 with cryogenic treatment. The Al6061 alloy showed increase in VHN after cryogenic treatment.

Fig.13. Computerized hardness tester

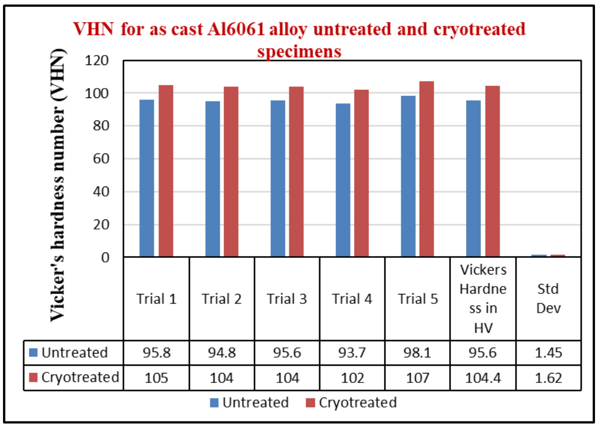

Fig.14. VHN of Al6061 with and without cryogenic treatment

3. Scanning electron microscope and Optical microscope

The SEM were carried out to know the microstructural change of Al6061 alloy after cryogenic treatment. Figure 15 and 16 shows the SEM images of Al6061 alloy without and with cryogenic treatment respectively. The cryotreated specimens shows decrease in residual stress. SEM images showed that Al6061 will become harder and brittle after cryogenic treatment.

Optical microscope images were carried out to know the grain structure of Al6061 alloy after cryogenic treatment. . Figure 17 and 18 shows the optical microscope images of Al6061 alloy without and with cryogenic treatment respectively Optical images show that finer grains were observed after cryogenic treatment for Al6061 alloy.

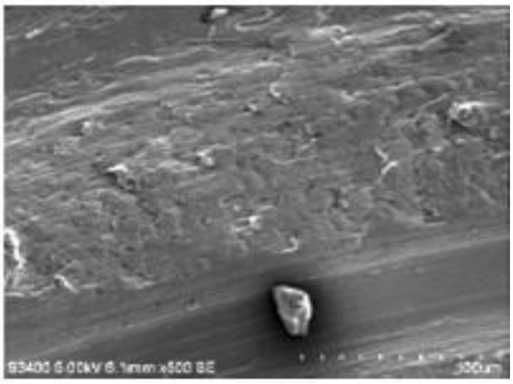

Fig.15. SEM of untreated Al6061 alloy

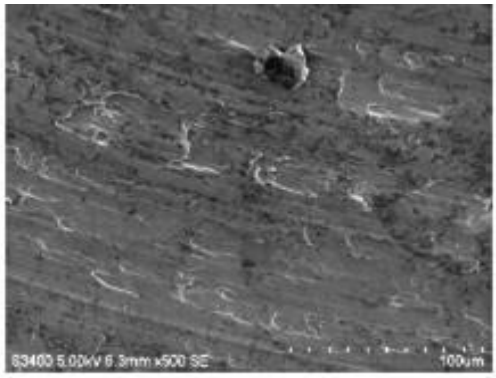

Fig.16. SEM of cryotreated Al6061 alloy

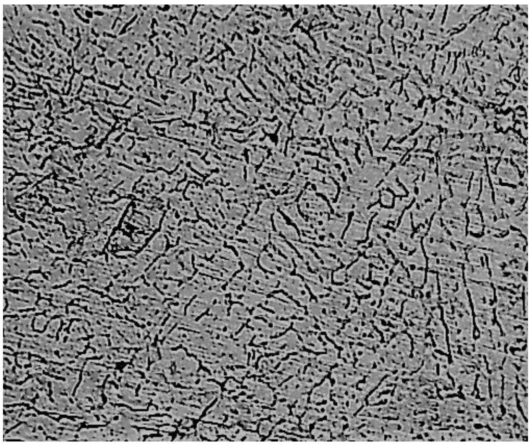

Fig.17. Optical microscope of untreated Al6061 alloy

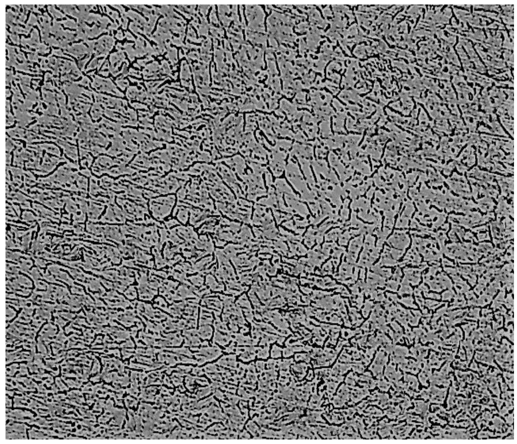

Fig.18. Optical microscope of cryotreated Al6061 alloy

4. Conclusions

- Al6061 shows 8.9% increase in UTS after cryogenic treatment
- Al6061 shows 18% increase in yield strength after cryogenic treatment
- Al6061 shows 43% decrease in percentage elongation after cryogenic treatment
- Al6061 shows 9.2% increase in VHN after cryogenic treatment
- SEM shows that Al6061 will become harder and brittle after cryogenic treatment.
- Optical microscope images reveals that the fine grain structure were observed after cryogenic treatment

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