STUDY ON INFLUENCE OF CRYOGENIC TREATMENT ON MECHANICAL PROPERTIES OF AlSi10Mg ALLOY

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Abstract

Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal skinned aircraft. Aluminium-magnesium alloys are both lighter than other aluminium alloys and much less flammable than alloys that contain a very high percentage of magnesium. Hence, nowadays Al-Mg alloys are being utilized in many engineering applications. In the current study, an attempt was made to investigate the influence of cryogenic treatment on mechanical properties such as tensile strength, compressive strength, toughness & hardness of AlSi10Mg alloy. It was found that there was increase in tensile properties and rest of the properties increased drastically. There was also ductile to brittle transition in between 12 hour to 24 hour cryogenic treatment. It was also found that the transition was mainly due to the precipitation of second phase particles.

Keywords: *Al alloys, Al-Mg alloys, Cryogenic Treatment, Mechanical Properties.*

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1. INTRODUCTION

Cryogenics [2] is the science of production and effects of very low temperatures. Generally, the temperature referred is below 120 K (-153°C). The cryogenic treatment system developed by Ed Busch in the late 1960s and later improved by Peter Paulin with a temperature feedback control on cooling and heating rates allows to perform effective and crackles. CT until very low temperatures subsequently, the research about CT has been validated during the 1980s by the first request in machine tools [6, 7]. Since World War II era it is utilized on steel and other metals to improve the strength and wear resistance of the material. It is known that almost all steels at 193 K transform the austenite into martensite. The use of cold treatment has been initially developed on martensitic tool steels in order to remove retained austenite with benefits on hardness [12].

Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal skinned aircraft. Aluminium-magnesium alloys are both lighter than other aluminium alloys and much less flammable than alloys that contain a very high percentage of magnesium. Junwei et al. [22] has concluded that cryogenic treatment has induced the precipitation of second phase particles, which is one of the important factor influenced on the strengthening of AZ91 Mg Alloy during deformation process. Wang [23] depicts that when deep cryogenic treatment was performed on Mg-alloy its tensile strength and elongation increased by 4.4% and 5.1%. Chen and Li [24] have investigated the effect of cryogenic treatment on the microstructure and properties of Al alloys at -193 deg celsius for 24 hr has revealed the improvement of strength at room temperature and the reduction of the ductility. Zhirafar [25] has studied the effect of cryogenic treatment on mechanical properties on Al alloy by the impact and hardness experiments has concluded that the hardness of the cryogenically treated Al alloy were a little higher than those performed by the experiments at room temperature. Based on the above literature review, it can be infer that there is a scope to study the effect of cryogenic treatment on non-ferrous alloy characteristics. Hence, an attempt was made to study the influence of cryogenic treatment on mechanical properties of AlMg10Si alloy.

2. MATERIALS AND EXPERIMENTATION

2.1 Material

AlSi10Mg is a non ferrous aluminium alloy, it consist of 90% of aluminium and 10% of silicon. The composition of alloy used in the current study is indicated in Table 1. It has good machinability, castability characteristics combination. It also exhibits better corrosion resistance even against sea water.

Table-1: Composition of AlSi10Mg alloy

Component Elements	Metric(%) by weight
Aluminium	85.8-90.6
Copper	<=0.60
Iron	<=1.3
Magnesium	0.40-0.60
Manganese	<=0.35
Nickel	<=0.50
Silicon	9-10
Tin	<=0.15
Zinc	<=0.50
Others	<=0.25

2.2 Cryogenic Treatment

The 3 groups of AlSi10Mg specimen were machined, in which two of the groups were cryogenically treated with liquid nitrogen at 77K in an insulated chamber for 12h and 24h and then kept at room temperature for 24 hours, the other group of specimen were kept untreated. The main aim of our experimentation is for comparing the mechanical properties of the specimen at room temperature with that of the cryogenically treated specimen to determine the variations in properties that occurs due to cryogenic treatment.

Table-2: Cryogenic Fluids

FLUID	TEMP in K	TEMP in °C
Methane	111.7	-161.5
Hydrogen	20.3	-252.9
Oxygen	90.3	-183
Nitrogen	77.4	-195.8
Helium	4.2	-269

Fig. 1: Liquid Nitrogen

2.3 Mechanical Properties Characterization

The mechanical properties of specimen were characterized through different test followed in accordance to ASTM standards. Tensile, compression, hardness and impact tests were employed to investigate the mechanical properties of material. Tensile test, compression test, Vicker's hardness test and Charpy impact was done in accordance to ASTM E8, E9, E92 and E23 respectively. Each test was repeated for 5 specimen in order to keep the error minimum and average readings were considered for the evaluation.

3. RESULTS AND DISCUSSION

3.1 Tensile Behavior

Tensile test was conducted 0h,12h,24h, cryogenically treated specimen and it was found that ultimate strength increased as the number of hours increased, Proof stress increased from 0h to 12h and reached maximum then decreased at 24h. Young's modulus decreased from 0h to 12h then increased and reached maximum at 24h. Fig. 1 illustrates the comparison of different tensile characteristics of specimen. After cryogenic treatment for 12h, and 24h the tensile strength increased to 5% & 8%. After cryogenic treatment for 12h and 24h the proof stress increased to 40% &16.6%. After cryogenic treatment for 12h, and 24h the young's modulus (tensile) decreased in 11.1%and then increased to 11.16%

Fig. 2: Material after tensile test

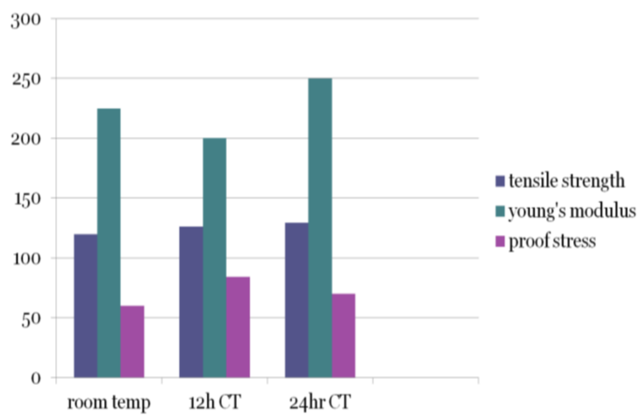

Fig. 3: Comparison of different tensile characteristics of specimen

3.2 Compression Behavior

Compression test was conducted 0h,12h,24h, cryogenically treated specimen and it was found that ultimate strength increased as the number of hours increased, and reached maximum then decreased There was minor increase in young's modulus from 0h to 12h then increased and reached maximum at 24h. . Fig. 2 illustrates the comparison of compressive strength and Young's modulus of different specimen. After cryogenic treatment for 12h, and 24h the compressive stress increased to 22.8%, & 27.81%.

Fig.4: Material after Compression test

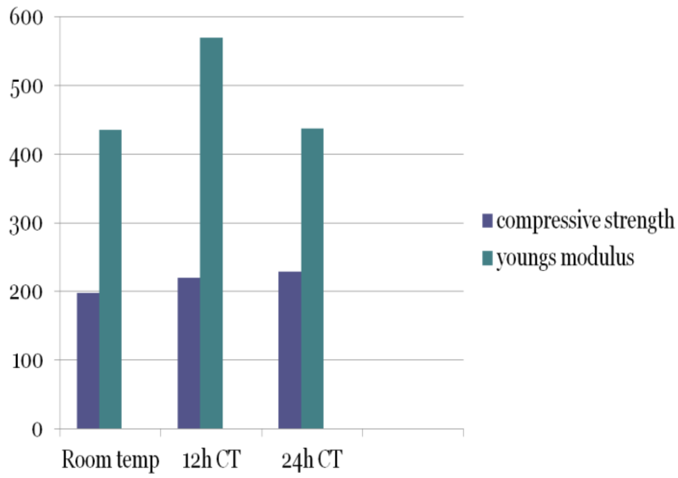

Fig.5: Comparison of compressive strength and Young's modulus of different specimen.

3.3 Hardness

Fig. 3 depicts the comparison of hardness of different specimen and effect of cryogenic treatment on hardness value. After cryogenic treatment the specimen were compared using Vickers's hardness testing machine and then it was found that hardness increases drastically with treatment period due to precipitation of second phase particles. After cryogenic treatment for 12h and 24h the impact strength increased to 36.3%&39.4%.

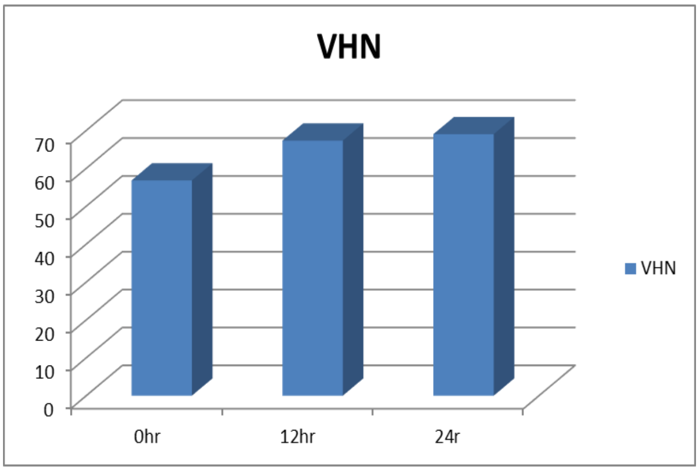

Fig.6: Comparison of hardness of different specimen.

3.4 Impact Strength

From the impact test of treated and untreated specimen it was found that the treated specimen absorbed more energy that untreated this is mainly due to increase in ductility of material due t0 partial precipitation of second phase elements. Fig. 4 illustrates the comparison of impact strength of different specimen and effect of cryogenic treatment on impact strength of Al alloy studied. After cryogenic treatment for 12h and 24h the hardness increased to 18.4% & 21.47%.

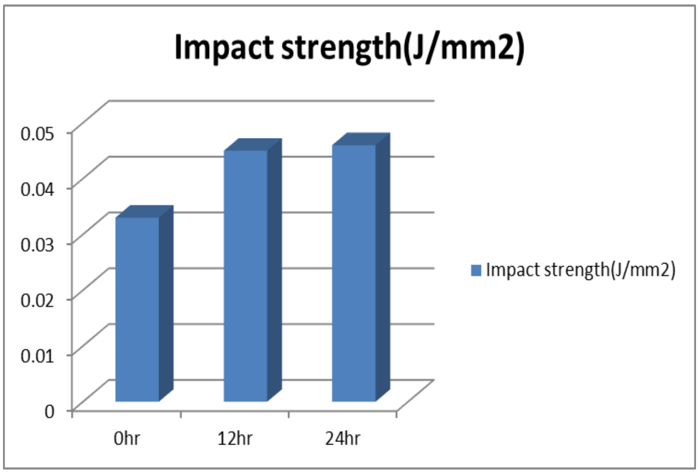

Fig.7: Comparison of impact strength of different specimen

4. CONCLUSION

From the above experimentation the following conclusion were drawn:

- After cryogenic treatment for 12h,and 24h the tensile strength increased to 5% & 8%, while proof stress increased to 40% &16.6% and young's modulus(tensile) decreased in 11.1%and then increased to 11.16%
- After cryogenic treatment for 12h,and 24h the compressive stress increased to 22.8%, & 27.81%
- After cryogenic treatment for 12h,and 24h the impact strength increased to 36.3%&39.4%
- After cryogenic treatment for 12h, and 24h the hardness increased to 18.4% & 21.47%.

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