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Work Hardening Characteristics of Non-Heat Treatable Aluminium Alloys

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ABSTRACT

Aluminium is the most widely used material for applications such as cooking utensils, food processing equipment, storage tanks, aircraft components, pressure vessels, ladders, railings, frames, tool boxes, truck bumpers components in truck and automobile industries, which requires strength and good formability. In this study, it is aimed to present the experimental results of studies conducted on strain hardenable characteristics of non-heat treatable casted and forged aluminium alloys using tensile test.. Pure aluminium, Aluminium alloy 5052 and Aluminium alloy 3003 are the chosen materials for the work. Strain hardening conditions selected are H12 and H14 on specimens as per ASTM standards. This paper involves graphs of true stress v/s strain as per the results obtained from tensile test on different heat treatment conditions.

Keywords : Strength, Formability, Characteristics, Strain Hardening, Aluminium alloy, H12-Half hardened, H14- Quarter hardened

I. INTRODUCTION

Non-heat treatable aluminium (NHT) alloys are utilized in all of the main industrial markets for aluminium flat-rolled products. Transportation, packaging and the building/construction sectors have represented the greatest utilization of NHT sheet all through the last phase of the 20th century. Higher performance non-heat treatable alloys have been developed for new and present applications ranging from foil to high electricity structural products. Work hardening, also known as strain hardening, is the strengthening of a metal by plastic deformation. This strengthening occurs because of dislocation movements and dislocation generation within the crystal structure of the material. Most non-brittle metals with a reasonably high melting point as well as several polymers can be strengthened in this fashion. Alloys not amenable to heat treatment, including low-carbon steel, are often work- hardened. Some materials cannot be work-hardened at normal ambient temperatures, such as indium, however others can only be strengthened via work hardening, such as pure copper and aluminium. Work hardening or cold working is an important industrial process that is used to harden metals or alloys that do not respond to heat treatment.

The chosen materials consist of following chemical composition. The composition of pure aluminium has not illustrated here.

Table 1. Chemical composition of Al-3003 alloy

Element	% Present
Manganese (Mn)	1.10 - 1.50
Iron (Fe)	0.0 - 0.70
Copper (Cu)	0.05 - 0.20
Magnesium (Mg)	0.0 - 0.05
Silicon (Si)	0.0 - 0.60
Zinc (Zn)	0.0 – 0.1
Others	0.0 – 0.15
Aluminium	Balance

Table 2. Chemical composition of Al-5052 alloy

Element	% Present
Manganese (Mn)	0.0 - 0.9
Iron (Fe)	0.0 - 0.39
Copper (Cu)	0.0 - 0.10
Magnesium (Mg)	2.20 - 2.80
Silicon (Si)	0.0 - 0.25
Zinc (Zn)	0.0 - 0.9
Chromium (Cr)	0.15 - 0.24
Others (Total)	0.0 - 0.14
Aluminium (Al)	Balance

II. METHODOLOGY

A. Preparation of castings

In the present study castings of pure Al, Al-3003 alloy and Al-5052 alloys are produced using sand casting process. The shape of moulds is cylindrical sand moulds. Green sand used in the study has following ingredients:

Silica (SiC2) Sand - AFS: 25

Clay Binder - Bentonite : 11.2%

Moisture content : 3.25

Additives - Coal dust : To improve Surface Finish.

In the present study three materials have been selected which are procured in the form of ingots.

Pure Aluminium

Al – 3003 alloy &

Al – 5052 alloy

These materials are kept in a crucible of 5 kg capacity, and heated at different temperatures for their melting. The melting temperatures are shown below.

Pure Aluminium 700oC

Al – 3003 alloy 800 oC

Al – 5052 alloy 800 oC

Molten metal obtained from crucible is poured into the cylindrical moulds prepared and allowed it to solidify. Finally we have produced 6 castings from each material.

Fig.1 Casting

Fig.2 Casted specimens

The three (3) castings of each material are kept in a forging furnace at 450 oC for 1 hour. The heated specimens are then hand forged using hammers and then the forged specimens are cooled to atmospheric temperature. In total, 9 casted and 9 forged specimens are produced from three materials. The forged specimens are further subjected to stress relieving to remove internal stresses.

Fig.3 Forging

Fig.4 Forged specimens

B. Preparation of Testing specimen

All the materials, 9 casted and 9 forged materials are machined to produce tensile specimens. And specimens have been prepared as per ASTM standards.

Fig.5 tensile specimens

C. Tensile

Tensile strength is among the most important properties of engineering materials. Universal Testing Machine (UTM) was used to conduct tension test and to find the ultimate tensile strength of 18 specimens.

III. RESULTS AND DISCUSSION

The tensile test has been conducted on different specimens with different hardened conditions. From testing, a good relation has been obtained between strength and various parameters such as work hardening effect, manufacturing process effect, work hardening rate. The true stress v/s true strain curves for all specimens are plotted for different conditions and are shown below.

A. Effect of work hardening on Strength

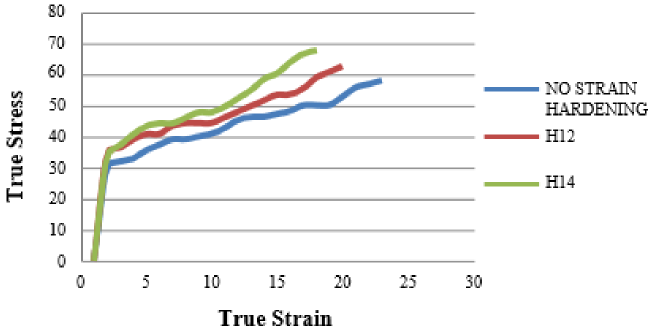

Fig.6 Graph shows effect of work hardening on strength of pure Al

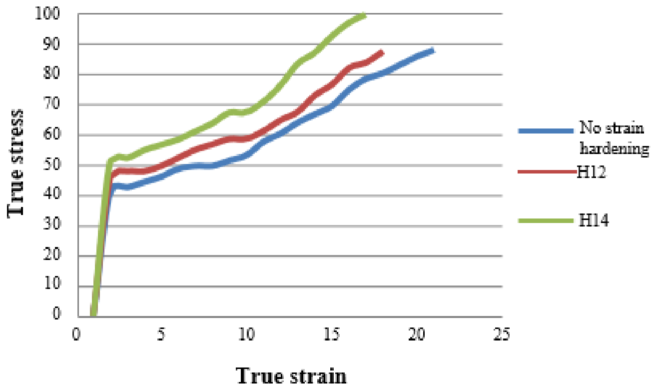

Fig.7 Graph shows effect of work hardening on strength of Al-3003.

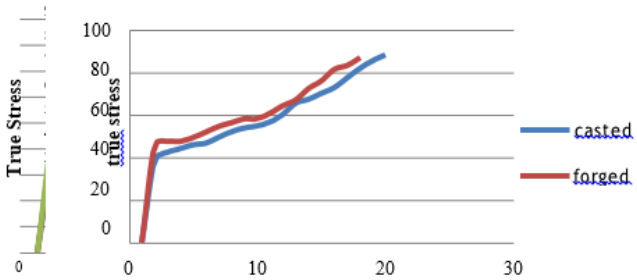

Fig.8 Graph shows effect of work hardening on strength of Al-5052

From the above graphs, it is clear that the strength of the material has increased with strain hardening for forged specimen of pure aluminum, Al-3003 and Al-5052 than the specimen without strain hardened (casted). This is due to increase in stress required for dislocations to move as the material is unloaded and reloaded with strain hardening.

B. Effect of manufacturing process on work hardening.

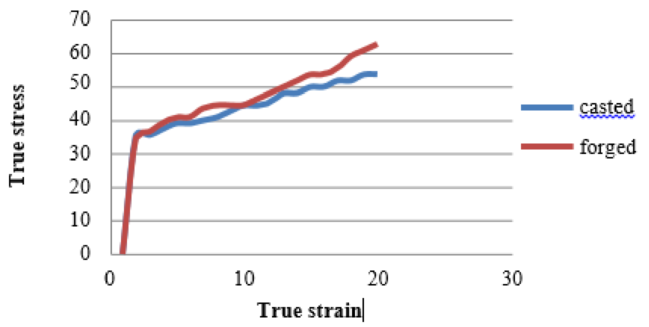

Fig.9 Graph shows effect of manufacturing process on Pure Al for H12 work hardened condition

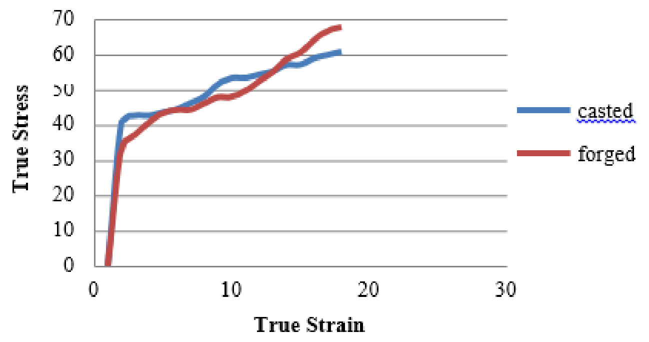

Fig.10 Graph shows effect of manufacturing process on Pure Al for H14 work hardened condition

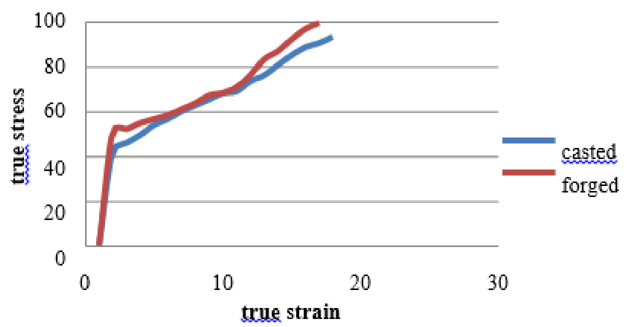

Fig.11 Graph shows effect of manufacturing process on Al- 3003 for H12 work hardened condition

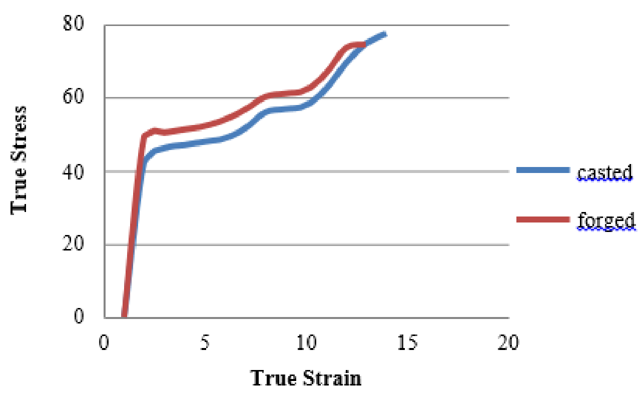

Fig.13 Graph shows effect of manufacturing process on Al-5052 for H12 work hardened condition

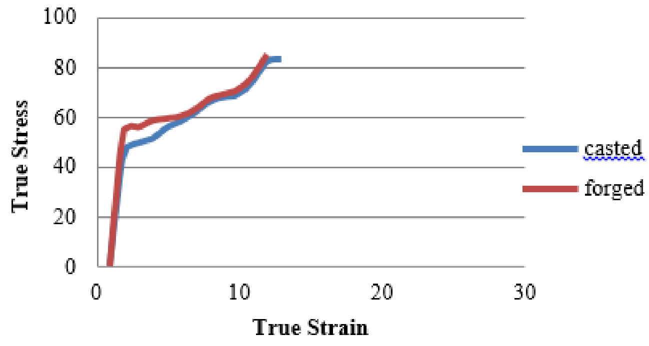

Fig.14 Graph shows effect of manufacturing process on Al- 5052 for H14 work hardened condition

From the above graphs, it is evident that forged specimens of pure aluminium have shown better work hardening characteristics than casted specimens under all strain hardening conditions.

V. Conclusion

Based on the experimental data obtained and observations made in the present study, it is concluded as below. Strain Hardening increases the strength of non- heat treatable alloys considerably. Forged specimens have shown greater work hard enable characteristics and greater strengths than casted specimens. H14 and H12 conditions show greater characteristics than without strain hardened condition. Strain hardening rate and strength are inversely proportional to each other.

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