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Experimental Testing & FEA Validation of High Temperature Tensile Test of Aluminum Alloy (A413) for Piston Material

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Abstract:

Generally the prediction of behaviour of material at high temperature is very difficult. During design of components which are subjected to or working at high temperature must consider the testing at elevated temperature. Hot tensile testing (HTT) is the method of tensile testing of material at elevated temperature. The materials used for automotive or aerospace applications are mostly subject to cyclic loading, high temperature and sometimes involve high frequency vibrations. High strength aluminium alloys are one class of materials that are widely used in the automotive and aerospace industries .In this work I test A413 material for HTT at different temperature and strain rate, which can be used for piston.

Keywords — **HTT, high temperature, strain rate, piston, automotive or aerospace.**

I. INTRODUCTION

Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties are frequently included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behaviour of a material under forms of loading other than uni-axial tension. The strength of a material often is the primary concern. The strength of interest may be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. These measures of strength are used, with appropriate caution (in the form of safety factors), in engineering design. Also of interest is the material's ductility, which is a measure of how much it can be deformed before it fractures. Rarely is ductility incorporated directly in design rather, it is included in material specifications to ensure quality and toughness. Low ductility in a tensile test often is accompanied by low resistance to fracture under other forms of loading. Elastic properties also may be of interest, but special techniques must be used to measure these properties during tensile testing, and more accurate measurements can be made by ultrasonic techniques.[1]

II. LITERATURE REVIEW:

WilfriedWunderlich et al [2012], this research was focused on thermal cyclic fatigue analysis of three aluminium piston alloys. In this research, thermo-cycle fatigue tests were performed on aluminium piston alloys ACA8, SC100 and A2618-T6 at elevated temperatures up to **400 ºC** (673 K). The aluminium piston Al 11wt% Si alloys SC100, ACA8, A4032 were tested together with A2618-T6 concerning their mechanical properties and their thermal fatigue behaviour. The alloy A2618 shows a better elongation to failure and higher yield stress compared to the other alloys by maintaining the low coefficient of thermal expansion (CTE). Alloy A2618-T6 has much longer thermal fatigue life times for maximum temperatures below 600K as compared to the two other alloys, only above 600 K the alloy ACA8 has a slightly longer life time, but the failure occurs suddenly.

J. O˜noroa, et al [2006]inthis paper High-temperature mechanical properties of aluminium alloys reinforced with boron carbide particles are studied. The tensile properties and fracture analysis of these materials were investigated at room temperature and at high temperature to determine their ultimate strength and strain to failure. The fracture surface was analyzed by scanning electron microscopy (SEM).

Amro M. et al [2006] investigated the High Temperature Tensile Response of Al 6061 Reinforced with Submicron Alumina Composite. Tensile tests of the composite were conducted at temperatures ranging from room temperature to 300 °C. Tensile strength of the composite decreases linearly with increasing temperature. The composite was able to retain over 35% of room temperature strength when tested at 300°C. Strain to fracture increases with temperature **up to 250 °C**.

AnirudhBiswas et al [2012] investigated that Aluminium-Silicon alloys are sought in a large number of automotive and aerospace applications due to their low coefficient of thermal expansion and high wear resistance. The present study focused on Mechanical properties of the silicon based aluminium alloys. This study aimed to investigate solidification and mechanical behaviour of Al- Si alloy against both the moulding conditions and silicon content (15%- 24% Si). Grain size analysis of mechanical properties and non destructive test of the alloys have been studied. The results showed that with the increasing of silicon content, the solidification time increased and also decrease of the liquids temperature was observed up to 12% and then increased with increasing Si%. However, an increase of both the ultimate tensile strength and the hardness is obtained by the increase of the silicon content. With the increase of silicon content the wear rate decrease and coefficient of friction increase.

W. Ozgowicz, et al [2008] the purpose of this paper is to determine the influence of temperature **(100ºC-700°C)** of plastic deformation on the structure and mechanical properties of copper alloy of the type CuCr1Zr during a tensile test. Copper alloys CuCr1Zr stretched statically at a rate of deformation **1.2×10^{-3} s^{-1}** show distinct minimum of plastic properties in a narrow range of deformation temperature about 550ºC - 600°C. The examined copper alloys showed after the tensile test in the temperature range 20ºC- 500°C transcrystalline ductile fracture. At 600°C, in the investigated alloy it is observed that brittle crystalline fracture with small areas of plastic deformation according to the minimum growths of the elongation and narrowing.

III. Hot tensile test set-up:

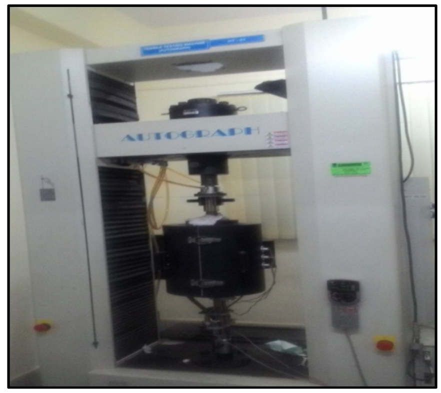

Fig. 1 Hot Tensile Testing Set-up machine "SHIMADZU" (ELCA LAB, Pune)

This test was perform as per ASME E-21:2009 using gauge diameter in the range 9.8 mm to 10 mm, gauge length 50 mm and overall length of specimen is 120mm. for this test, temperature of this specimen is maintain at 150^0C, 250^0C, and 350 ^{0}C throughout the test. For this test, strain rate on specimen is maintained at 0.05 per min, 0.1 per min.

IV. EXPERIMENTAL RESULTS:

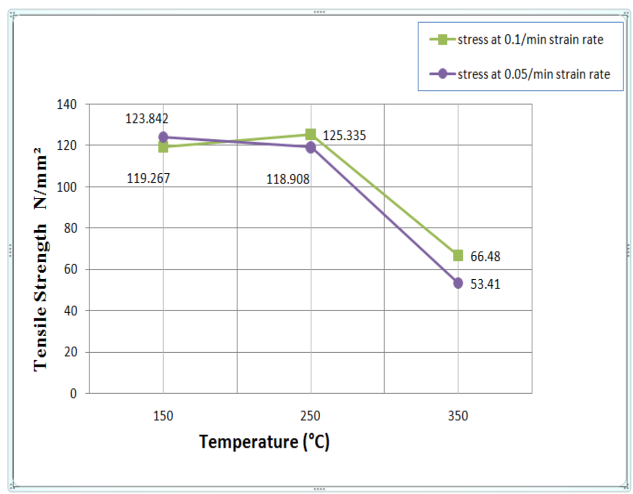

Fig.: 2: Tensile Strength Vs Temperature

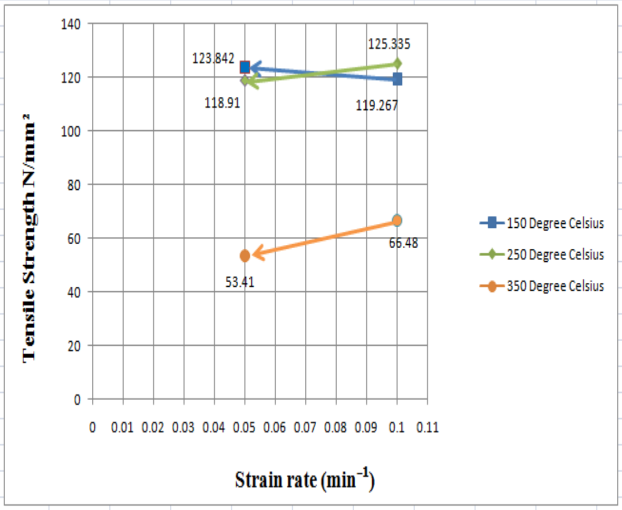

Fig.: 3: Tensile Strength Vs Strain rate

V. RESULTS

1. From fig. 2, at constant strain rate of 0.05 per min, the tensile strength of aluminium material is decreases continuously from 123.842 N/mm^2 to 53.37 N/mm^2. But for higher strain rate of 0.1 per min the tensile strength initially increases from 119.27 N/mm^2 to 125.34 N/mm^2 as temperature increases from 150 °C to 250 °C. Tensile strength decreases to 66.48 N/mm^2 for further increase in temperature from 250 °C to 350 °C. Generally, the true stress–true strain curve is always used to analyse the plastic deformation behaviours of materials. Obviously, the flow stresses are strongly dependent on the deformation temperature and strain rate. Also, the effects of deformation parameters on the peak stress. Increasing the deformation temperature or decreasing the strain rate can result in the decrease of peak stress. This is because the low strain rate provides long time for energy accumulation and high deformation temperature enhances the thermal activation process of the alloy, which accelerates the dislocation motion and annihilation, and thus the dynamic softening is enhanced and the peak stress are reduced.

2. From fig. 3, (a) At temperature of 150 ^{0}C, as strain rate increases from 0.05 per min to 0.1 per min, the tensile strength decreases from 123.84 N/mm^2 to 119.27 N/mm^2.

(b) But at temperature 250 ^{0}C, as strain rate increases from 0.05 per min to 0.1 per min, tensile strength of aluminium material increases from 118.91 N/mm2 to 125.34 N/mm^2.

(c) At 350 ^{0}C also, as the strain rate increases from 0.05 per min to 0.1 per min tensile strength of material is increases from 53.45 N/mm^2 to 66.48 N/mm^2. So it is concluded that as strain rate increases, tensile strength will also increases.

3. Comparison with other material: Piston is also subjected to fatigue stresses during working, so material must have good fatigue strength. From above comparison we can observe that proposed material had more fatigue strength & melting point. We can replace A4032 alloy by A413 material for better working of piston. In present work, tensile property of material A413 is tested by hot tensile test (HTT) at 350 ^{0}C; 0.05 per min is compared with FEA result of material A4032 at 357 ^{0}C studied by S. Bhattacharya et al. It is also observe that, for nearly same temperature range tensile property of A413 at 350 ^{0}C is 53.37 MPa, while for material A4032 at 357 ^{0}C is 21.4 MPa. So we conclude that tensile property of A413 at 350 ^{0}C is much higher than A4032 at 357 ^{0}C. Hence, new material A413 is best replacement for A4032 under same temperature range.

A] Current Material Used For Piston:

Hypoeutectic (0.25<% Si)	Eutectic (10-13%Si)	Hypereutectic (16-18% Si).
A2618, A2024-T6, A 201	A4032,	A390

Table no. 1[4]

VI. CONCLUSIONS:

1. From the test results we can conclude that as temperature increase the tensile strength decreases

2.In case of strain rate, as strain rate increases, the tensile strength is also increases.

3. In present work, tensile property of material A413 is tested by hot tensile test (HTT) at 350 ^{0}C; 0.05 per min is compared with FEA result of material A4032 at 357 ^{0}C studied by S. Bhattacharya et al. It is also observe that, for nearly same temperature range tensile property of A413 at 350 ^{0}C is 53.37 MPa, while for material A4032 at 357 ^{0}C is 21.4 MPa. So we conclude that tensile property of A413 at 350 ^{0}C is much higher than A4032 at 357 ^{0}C. Hence, new material A413 is best replacement for A4032 under same temperature range.

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