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Study the Influence of Cu% on the Mechanical Properties of Aluminium-Copper Alloys

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Abstract: Quality improvement is one of the most important requirement to strengthen a competitive position in our markets. This research aims to study the effect of Cu addition on the behavior of mechanical properties of Aluminum-Copper (Al-Cu) alloy, especially, the value of yield and tensile strength determined by tensile tests. Fatigue tests were also conducted on Al-Cu samples with various copper additions. Al-Cu samples were first cast with different percentages of copper (2, 4 and 8 wt.%) and then machined by a CNC milling to prepare samples for tensile and fatigue tests. The experimental result showed the clear influence of increasing copper percent. It was observed that the increase in Cu% increase the value of tensile strength.

Key words: Mechanical properties, aluminium-copper alloys, quality improvement, sample, position, Iraq

INTRODUCTION

The most common added alloying element to aluminum is copper, since, the commencement of Al production and various alloys with Cu as major addition were produced. Majority of such alloys include:

Cast alloys having deferent% copper, from 5-14, 85-94% iron and not more than 1.5|% of magnesium. Wrought alloys having 5-6% copper with small amounts of Mn, Si, Cd, Bi, Sn, Li, V and Zr. Such types of alloys contain Pb, Bi and Cd and are easy to machine. Dural's of 4-4.5% copper, 0.5-1.5% magnesium, 0.5-1.0% manganese and with added Si. Cu alloys with Ni % which are divided into two types of alloy, the first is Y type containing 4% copper, 2% nickel, 1.5% magnesium and second is the Hyduminiums which normally possess less Cu% and in which Fe is changed by 30 me of the Ni.

In majority of such alloys, Al is the principal element and in cast alloys, the structure contains cored dendrites of Al solid solution with several elements at the grain boundaries or inters the dendritic spaces, resulting in a brittle continuous eutectic network.

When using high-temperature applications of cast alloys and aluminum-copper-nickel alloys, creep resistance is important. The resistance of wear is promoted by the high hardness and the existence of hard elements. Alloys ether having 10-15% copper or heat treated to the peak hardness possess greater resistance of wear. Alumina (Al_2O_3) is pure aluminum which obtained from the electrolytic reduction is a relatively weak material. Therefore, for applications requiring greater mechanical strength, aluminum is alloyed with metals, such as copper, zinc, magnesium and manganese and the combinations of two or more of these elements together with iron and silicon make the alloy more strong (Oguocha, 1997). Because of the desirable chemical, physical and mechanical properties, the aluminum is the second widely used metal and becomes a significant type of technological materials. Al and its alloys are utilized in a broad range of industrial applications for various aqueous solutions because of the high strength to weight ratio in addition to other preferred features, for example preferred appearance, non-magnetic, non-toxic, non-sparking, high electrical and thermal conductivities, easy of fabrication and high corrosion resistance. Such characteristics lead to relate Al and its alloys with various transportation applications, especially with aircraft and space vehicles, containers and packaging, electrical transmission lines and construction and building (Al-Rawajfeh and Al-Qawabah, 2009). Esabna stated that numerous Al alloys utilized industrially more than 400 wrought alloys and more than 200 casting alloys are presently recorded with the aluminum association. The most significant consideration faced aluminum welding is assignment of the kind of aluminum base alloy required to be welded. When kind of the base material of the workpart to be welded is not available by a source that may be relied upon, it is hard to choose a proper welding approach. Certain general guidelines exist for highly probable types of Al utilized in various applications, like the abovementioned ones. Nevertheless, it is too

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significant to know that improper assumptions for the chemical content of an Al alloy can cause too serious influences upon performance of the weld. It is highly recommended that the positive assignment of the kind of Al be made and that the welding approaches are evolved and tested for verifying the performance of weld. Dobrzanski *et al.* (2006) showed that the AC $AlSi_9Cu$ aluminum alloy has been widely used in the engineering applications. In the design of cast automotive products, it is necessary to gain closely acquainted awareness of the way that alloy solidifies various cross sections of the casting and the way that this effects on the mechanical properties. This awareness helps the designer to make ensure that the casting will perform the preferred characteristics for its required purpose. Polmear (1995) found that the aluminum alloys are the predominant alloys. The typical alloying elements are of two main types, cast alloys and wrought alloys which are more classified into heat-treatable and non-heat-treatable. Al wrought products makes about 85% such as foils, extrusions and rolled plates. Cast Al alloys provide less cost products because of their low melting point and less ultimate tensile strengths than the wrought types. Al alloys are much utilized in engineering frames and mechanical parts because of their light weight and resistance to corrosion. Girisha and Sharma (2012) presented that Cu addition (usually 3-6 wt.%) as a principal alloying constituent with or without Mg (0-2%) as an alloying element increases strength of the alloy by precipitation hardening, making the alloys very strong with very good fatigue properties. If Cu is present, nevertheless, the resistance to corrosion is very bad, since, it precipitates at the grain boundaries, resulting in very susceptible material to intergranular corrosion, pitting and stress corrosion. The rich Cu regions are more noble/cathode than the surrounding Al matrix and work as the desired positions for corrosion by the galvanic coupling, also Cu is not good for the anodizing process. Smith and Danielou (Lequeu *et al*., 2010) discussed the Al-Cu-Li 2050 alloy that made, qualified and manufactured by Alcan (Aluminum Company of America), the low density and high corrosion resistant aerospace plates. AA2050 alloy offers alternative to incumbent medium to alloys with thick plate such as AA2024 or tolerant versions with higher damage. The principles beyond the selection of Al-Cu-Li chemical structure are described in addition to the generation of property balance in a broad thickness range from 12-127 mm (0.5-5. Drits *et al.* (1983) studied the widely disseminated utilization currently for critical force components in aviation and space engineering (alloys based on the Al-Cu-Mg), especially in the shape of pressed semi-finished components depicting better characteristics that enhance the reliability and the needed working life of products. Higher levels of strength properties, fatigue strength and fracture toughness with almost low resistance to corrosion are utilized in the supersonic-aircraft designs. Greater attention has been concentrated on the design process "increased viability" (increased size) and extended life span of aircraft. So, there is a need to raise the broad use of methods of fracture mechanics in the calculations and a need of large degree of increasing the normal characteristics of static strength and plasticity, such measures are fracture toughness (KC and KIC), the rate of crack propagation and fatigue life.

Accordingly, the goal of present paper is to study influence of various percentages of Cu addition on mechanical properties of aluminum-copper material which are obtained by tensile and fatigue tests.

MATERIALS AND METHODS

Experimental work

Alloy preparation: Experimental work was carried out at (State Company for Inspection and Engineering Rehabilitation (SIER) and in this research, Al-Cu alloys with different percentages (2, 4 and 8%) of Cu were investigated to study their mechanical properties. In order to cast the Al-Cu alloy, certain casting tools were prepared as shown in Fig. 1. The aluminum ingots were first melted in a graphite crucible as depicted in Fig. 2 and then copper was added with the required percentage. Finally, the Al-Cu was cast as revealed in Fig. 3 and then cleaned to be ready for further finishing operations.

Tensile tests: Prior to tensile test, all Al-Cu samples were first milled on a CNC milling machine shown in Fig. 4 to prepare them according to the standard test dimensions as illustrated in Fig. 5. Then, all tensile experiments were conducted by a tensile testing machine type "United" as manifested in Fig. 6. Tensile test was achieved on specimens of aluminium-copper with different added

Fig. 1: Alloy preparation tools

Fig. 2: Melting the aluminium with added copper

Fig. 3: (Al-Cu) alloy as cast

Fig. 4: CNC Milling machine used to prepare all test samples

copper percentages. The dimensions of tensile sample are G: Gage length = 75 mm, W: Width = 12.5 mm, T: Sheet Thickness = 3 mm, R: Fillet Radius = 20R, L: Overall Length = 165 mm, B: Grip section length = 35 mm and C: Grip section width = 20 mm.

Fig. 5: Tensile test samples of Al-Cu alloy after milling

Fig. 6: Tensile test machine used for testing Al-Cu samples

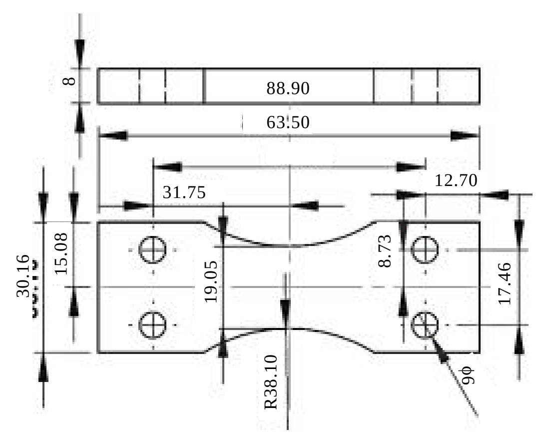

Fig. 7: Dimensions of fatigue specimen

Fatigue tests: All fatigue tests were conducted on a reversed-bending machine (Avery Denison Ltd.,) using 5 Hz frequency at room temperature and stress Ratio (R) equals to -1. Figure 7 reveals the shapes and dimensions of fatigue samples that were cut from rolled plates with a thickness of 2.1 mm such that the sample length direction is parallel to the direction of longitudinal rolling. Finally, all samples were fine ground and the average surface Roughness (Ra) of ground samples is 0.7-1.3 μm.

This research deals with the practical part of the project where the samples were prepared from various types as follows:

- Al-Cu alloys with thickness 2 mm contains 2% Cu was added
- Al-Cu alloys with thickness 2.5 mm contains 4% Cu was added
- Al-Cu alloys with thickness 3 mm contains 8% Cu was added

These models have been cut into fatigue test specimens with equal dimensions. The samples were made from cast Al-Cu alloy which were in form of sheets with the dimensions 30×20 cm) for 3 pieces.

The tools that are used for this purpose are holder, manual grinding tool containing a cutting dirk, grinding dirk for removing the sharp edges, special equipment that contains a circular dirk for smoothing and cleaning the samples and a CNC milling machine having a number of milling cutter to get precise measurements.

RESULTS AND DISCUSSION

Tensile results: After creating the sample according to standard specification, tensile tests were conducted on cast Al-Cu samples and the results of the yield and tensile stresses are shown in Fig. 8-13 and summarized in Table 1 for six samples of this alloy with three added copper percentages (8, 4 and 2 wt.%). Table 1, it can be seen that the addition of copper in the aluminium alloy increases the tensile stress of the resultant alloy. The tensile strength of sample 1 was 99.83 MPa with added 2% Cu, whereas the addition of 4% copper to sample 2 raised the tensile stress to 132.29 MPa. As copper was further increased in sample 3, the expected tensile stress would have been higher than that of sample 2 and it was 135.443 MPa. So, from the results, one can conclude that the best ultimate tensile stress is 135.443 MPa for the first specimen with (8% Cu).

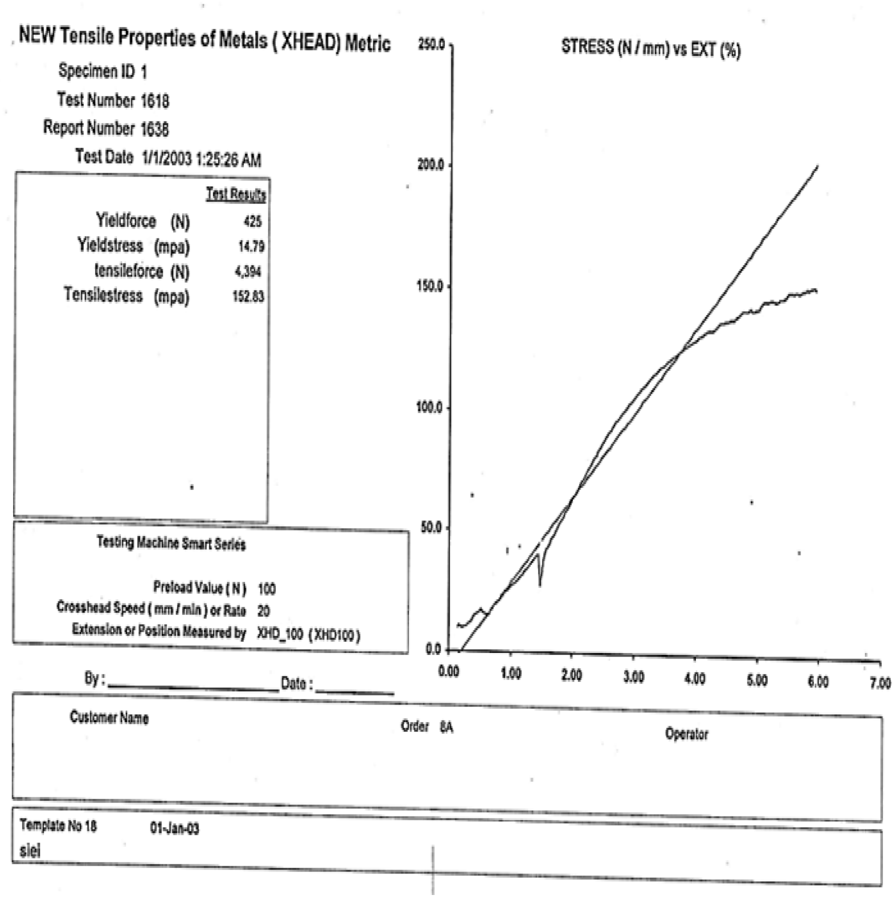

Fig. 8: Al-Cu alloy with 8% Cu (Sample 1)

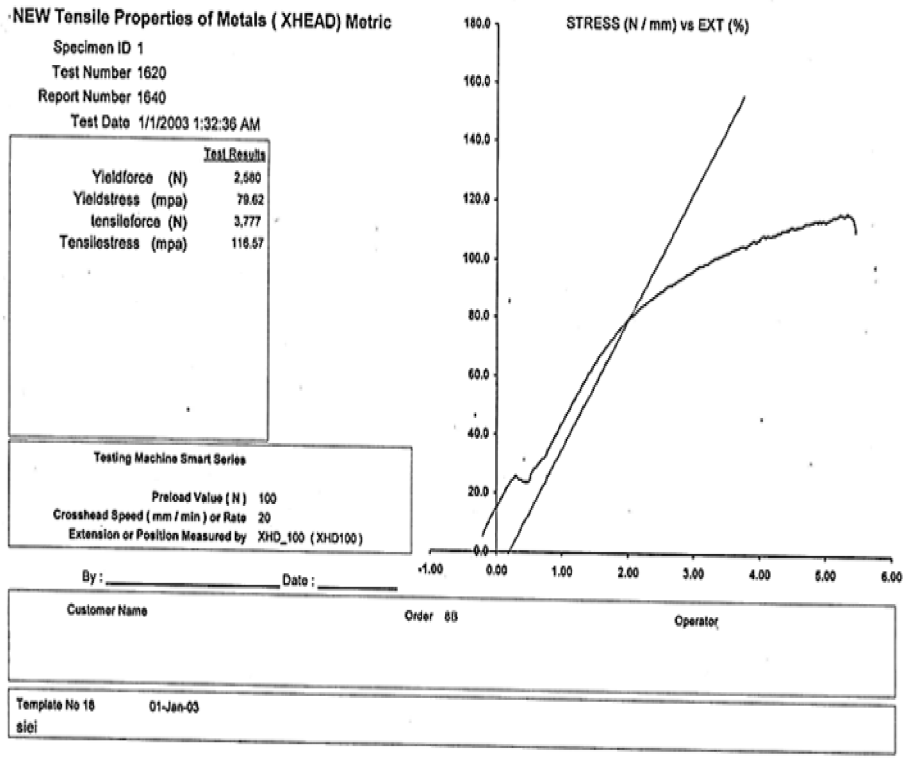

Fig. 9: Al-Cu alloy with 8% Cu (Sample 2)

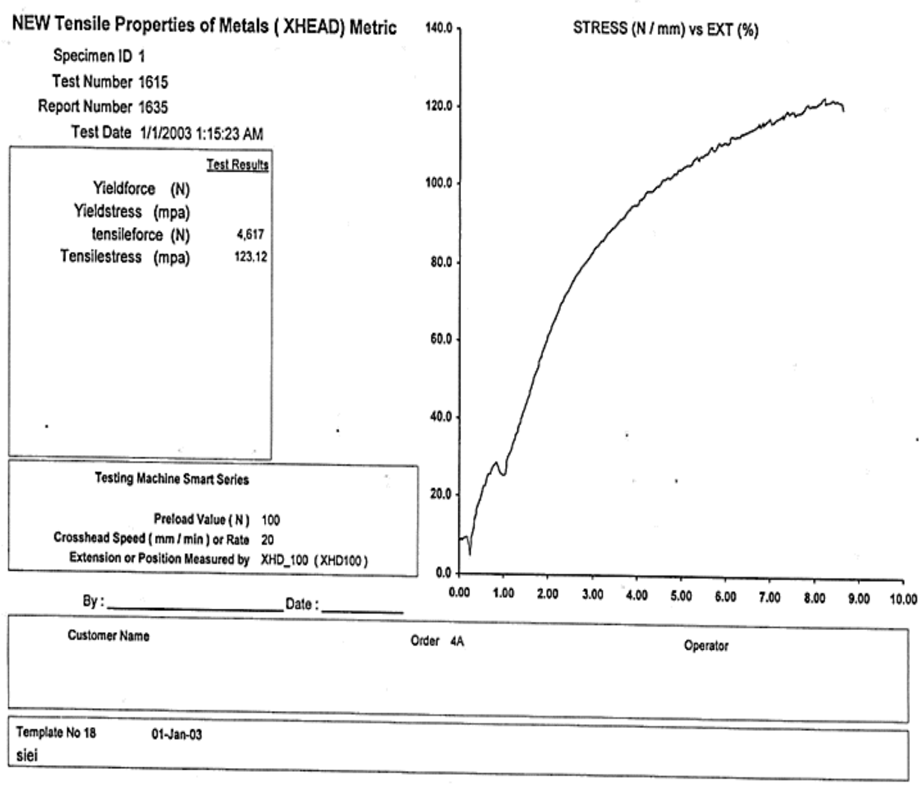

Fig. 10: Al-Cu alloy with 4% Cu (Sample 1)

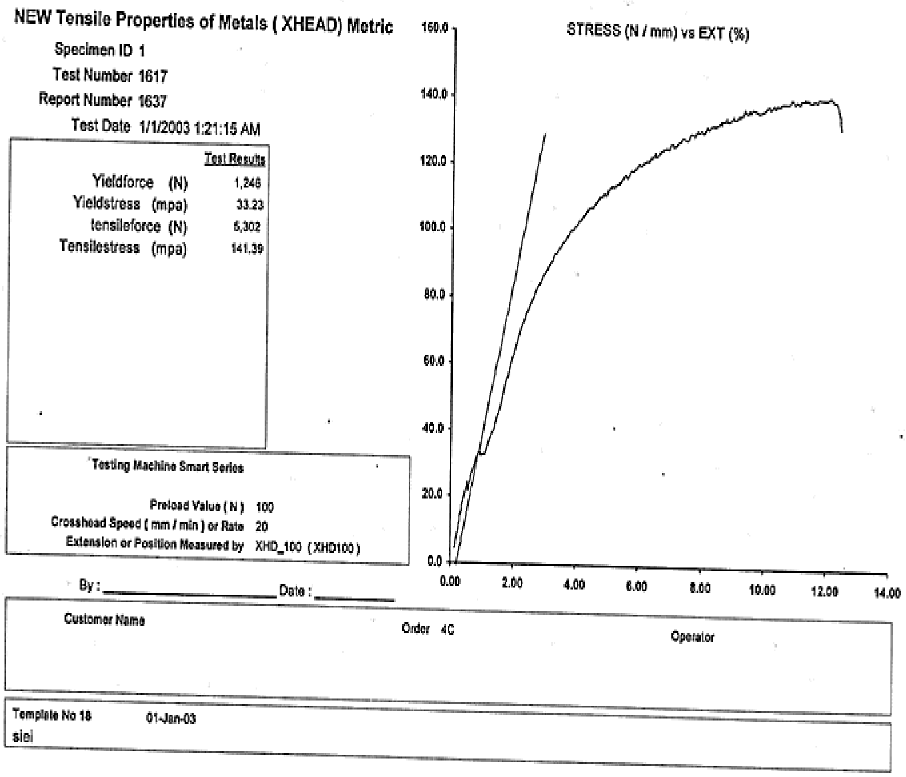

Fig. 11: Al-Cu alloy with 4% Cu (Sample 2)

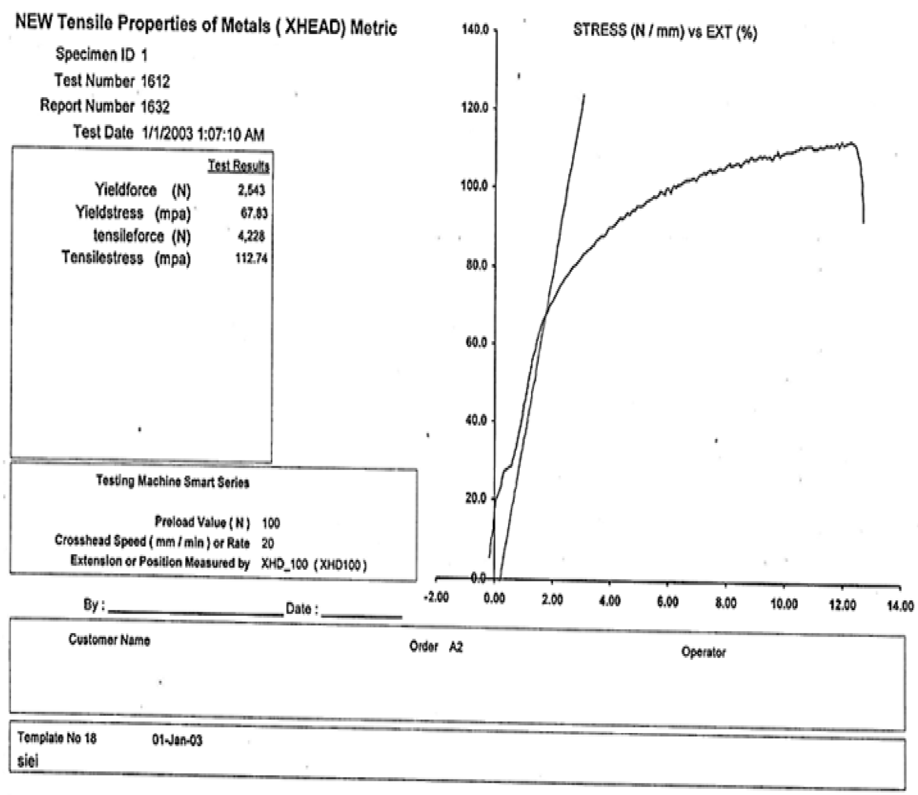

Fig. 12: Al-Cu alloy with 2% Cu (Sample 1)

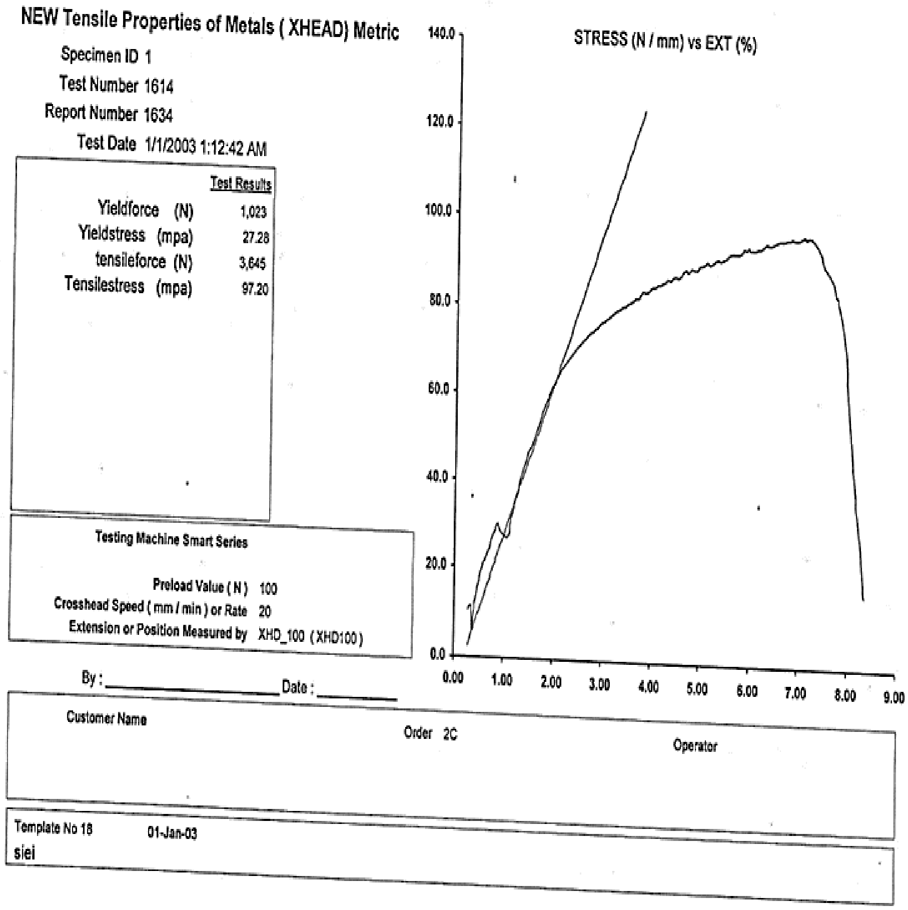

Fig. 13: Al-Cu alloy with 2% Cu (Sample 2)

Table 1: Tensile test results for the three samples

Sample (Cu%)	Average yield force (N)	Average yield stress (MPa)	Average tensile force (N)	Average tensile stress (MPa)
2	1652	44.06	3743.665	99.83
4	1246	33.23	4905.666	132.29
8	1115.666	34.616	4378.333	135.443

Also, from Fig. 8 till (13), one can see that the Cu % affected the yield forces, for example, for the first sample, the yield force was 1652 N while for the third sample it was 1115.666 N, this means the yield stress was also increased. The reason for increasing both yield and ultimate tensile strength is likely attributed to the increased Cu% that forms a hard intermetallic compound within the alloy structure leading to increase both yield and ultimate tensile strength. Figure 13 manifests the fractured tensile test of the Al-Cu samples with different added Cu%.

Regarding the fatigue tests of Al-Cu samples with different percentages of added copper, Table 2 depicts the results of number of cycles at different applied stresses. It can be noticed that as the applied stress increased, the no. of cycles decreased and this indicates that the fatigue resistance is reduced with the decreased of applied stress for different added copper percentages.

Table 2: No. of cycles to failure for fatigue test at different applied stress

Stress (MPa)	No. of cycles to failure
130	$3.2*10^6$
120	$4.1*10^6$
105	$4.7*10^6$
95	$5.03*10^6$

CONCLUSION

The addition of copper up to 8% increased both the yield and tensile strengths of cast Al-Cu alloy. Fatigue strength of cast Al-Cu alloy decreased with the increase of applied stress for different added copper percentages.

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