International Journal of Material Science Innovations
Volume 03, Issue 03, Pages 74-86, 2015

ISSN 2289-4063

The Influences of Variation of Copper Content on the Mechanical Properties of Aluminium Alloy

Husain Mehdi[1,*], Shivam Sharma[2], Mohd Anas[2], Naman Sharma[2]

[1]Department of Mechanical Engineering, Meerut Institute of Technology, Meerut, India
[2] Graduate Student, Meerut Institute of Technology, Meerut, India
* Corresponding author. Tel: 9259361558
E-mail address: *husainmehdi4u@gmail.com*

A b s t r a c t

The aluminum-copper alloys typically contain between 9 to 12% copper, with smaller additions of other elements. The copper provides substantial increases in strength and facilitates precipitation hardening. The copper in aluminum can reduce ductility and corrosion resistance. The susceptibility to solidification cracking of aluminum-copper alloys is increased; consequently, some of these alloys can be the most challenging aluminum alloys to weld. These alloys include some of the highest strength heat treatable aluminum alloys. The main uses for aluminium alloy are in internal combustion engines. In this work we are interesting to investigate the mechanical properties of aluminium alloy to vary the percentage of copper. The results showed that with the increasing of copper content the solidification time increased, and increase of both the ultimate tensile strength and the hardness is obtained by the increase of the copper content

Keywords:

Copper,
Aluminium,
Aluminium Alloy,
Ultimate Strength.

Accepted:27 June2015

1. Introduction

The metallic atoms must dominate in its chemical composition and the metallic bond in its crystal structure. Commonly, alloys have different properties from those of the component elements. An alloy of a metal is made by combining it with one or more other metals or non-metals that often enhances its properties

Aluminium alloys with silicon as a major alloying element are a class of alloys, which are the basis of many manufactured castings. This is mainly due to the outstanding effect of silicon in the improvement of casting characteristics, combined with other physical properties, such as mechanical properties and corrosion resistance [1]. Silicon is present as a uniformly distributed fine particle in the structure. However, when the primary silicon appears as coarse polyhedral particles, the strength properties decrease with increasing silicon content, but the hardness goes on increasing because of the increase in the number of silicon particles [2]. Silicon is not only the most frequent impurity in commercial pure aluminium, but also the most common alloying element [3]. Al-Si alloys find wide application in the marine, electrical, automobile and aircraft industries because of high fluidity, low shrinkage in casting, high corrosion resistance, good wald-ability, easy brazing and low coefficient of thermal expansion [4].

The influence of the Si content of the aluminium alloys on their wear resistance has been well documented and eutectic alloys are reported to have better wear resistance than those of hypoeutectic and hypereutectic composition [5]. Manganese is also able to change the morphology of the iron-rich phases from platelets to a more cubic form or to globules. These morphologies improve tensile strength, elongation, and ductility [6].

I. N. Fridlyander et al 2004 has considerable experience in applications of cold-pressed sheet materials from heat harden able aluminium alloys of the magnesium group. However, the alloys of this group have rather low strength characteristics, especially the yield point. For example, the alloys with 4 – 5% Mg (domestic alloy AMg4 and foreign counterparts 5082, 5182) possess a yield stress of 20 – 40%, which is responsible for worsened processibility. Such metal is suitable for simple operations of drawing, bending, and flanging for fabrication of cold-pressed parts [7]. M. Elmadagli, T. Perry, A.T.Alpas et al 2007 reported that grain refinement leads to fine equiaxed grain structure, which in turn results in improved mechanical and wear properties. A number of investigations have been reported on the wear behaviour of aluminium alloys [8]. Karaaslan et al 2007 studied Alloy AA 7075-T6 after retrogression and re-aging. The retrogression heat treatment is performed at various temperatures and hold times, and subsequent aging is performed at 130°C for 12 h. The microstructure and mechanical properties of the alloy are studied depending on the temperature and the hold time of the retrogression heat treatment. Electron microscopic studies are preformed and mechanical characteristics are determined in tensile and impact tests [9].

Kouichi Maruyama et al 2008 the high-temperature creep resistance of magnesium alloys was discussed, with special reference to Mg-Al and Mg-Y alloys. Mg-Al solid-solution alloys are superior to Al-Mg solid-solution alloys in terms of creep resistance. This is attributed to the high internal stress typical of an HCP structure having only two independent basal slip systems [10]. Aluminium and aluminium alloy are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear and seizure resistance, high stiffness, better high temperature strength, controlled thermal expansion coefficient and improved damping capacity [11].

Jing Li et al 2010 has several methods for estimating fatigue properties of wrought aluminium alloys from simple tensile data or hardness was discussed. Among them, Park-Song modified Mitchell's method provided the best estimation results in low fatigue life regime [12].

In this work we investigate the mechanical properties of aluminium alloy of to vary the percentage of copper, using specimens prepared with reference to ASTM D638-02 a [13].

The addition of copper as main alloying element (mostly range 3–6 wt. %, but can be much higher), with or without magnesium as alloying constituent (range 0–2 %), allows material strengthening by precipitation hardening, resulting in very strong alloys. Also the fatigue properties are very good for this series. Copper tends to precipitate at grain boundaries, making the metal very susceptible to pitting, intergranular corrosion and stress corrosion [14]. Up to 12 wt. % copper the strength of the alloy can increase through precipitation hardening, with or without the presence of Mg; Hardening is achieved through the precipitation of Al_2Cu or Al2CuMg intermetallic phases during ageing which leads to strengths second only to the highest strength 7xxx series alloys [15].

The aluminium alloy specimens obtained from casting were machined on a lathe machine so as to prepare the samples for tensile testing. The specifications of the machined samples were as

Table 1:-Dimensions of Test Specimen

Dimension	Type-I	Type-II	Type-III
W- Width	13	6	19
L-Length	57	57	57
WO-Width over all	19	19	29
LO Length over all	165	183	246
G-Gage length	50	50	50
D- grips Distance	115	135	115

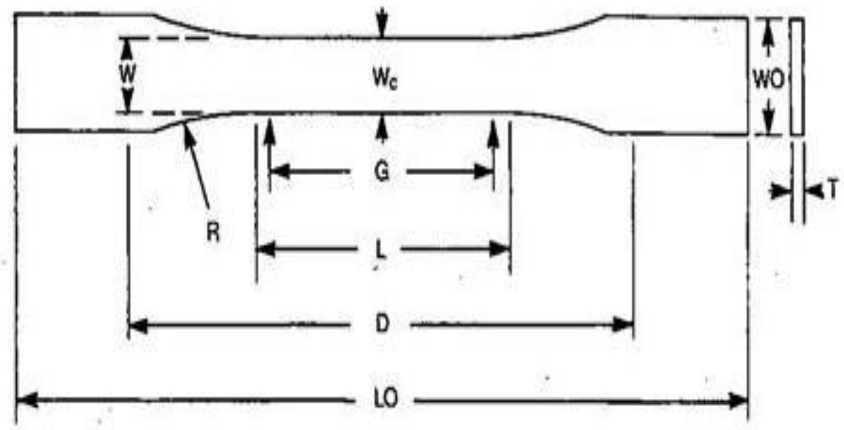


Fig.1: Drawing of Test Specimen

2. Experimental Procedure

In this process, the metal which has highest melting temperature is firstly poured in the crucible and allowed to melt on the furnace. The metal which posses low melting temperature is allowed to melt in the last because if it will allowed to melt with metal which posses highest temperature then lowest melting temperature metal will get burn.

Table 2: Chemical Composition of Aluminium Alloy

Alloying components	Al–Alloy Cu-11%)	Al–Alloy Cu-8.25%)	Al–Alloy Cu-5.5%)	Al–Alloy Cu-2.75%)
Copper	11	8.25	5.5	2.75
Magnesium	0.6	0.6	0.6	0.6
Manganese	0.6	0.6	0.6	0.6
Zinc	1	1	1	1
Lead	0.1	0.1	0.1	0.1
Tin	0.05	0.05	0.05	0.05
Aluminium	86.65	86.9	89.65	92.4

After pouring molten metal in the mould cavity allows to solidify into the mould cavity. The solidification time of the molten metal is given by Kornichov's Criterion.

According the Kornichov's criterion, the solidification time of the molten metal in the mould cavity is directly proportional to the square of the ratio of volume to the surface area of the cavity.

$$T_s \ \alpha \ \left[\frac{V}{S.A}\right]^2 \qquad (1)$$

$$T_s = k \ \left[\frac{V}{S.A}\right]^2 \qquad (2)$$

T_s = Solidification Time

k = Constant of proportionality

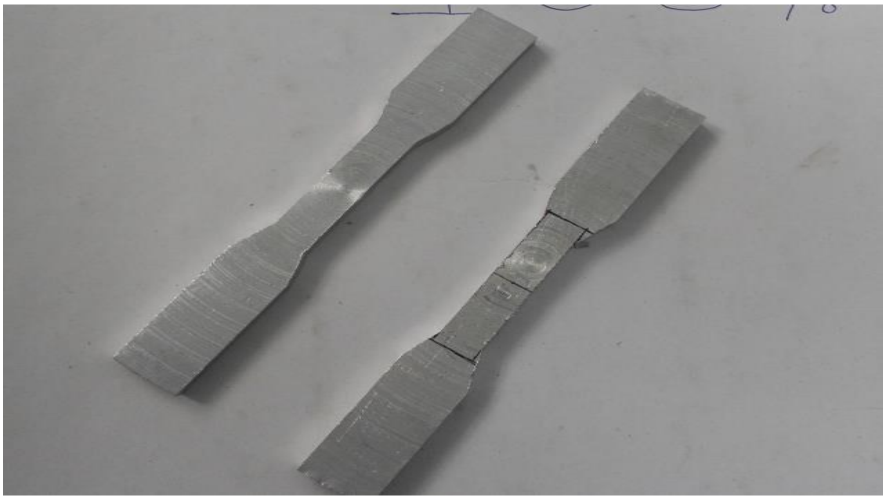
V = Volume of the cavity

S.A. = Surface area of the mould cavity

After destroying mould, the casted product is obtained. The mould used in this process is called temporary mould. As surface finishing of the casted product remain bad then it requires machining operation for finishing the product. The surface finishing of the casted product is done on the lathe machine.

(a)

(b)



(c)

Fig. 2: Casted product obtained after destroying the mould
(b) Machining of the Specimen (c) Finished Specimen

3. Result and Discussion

Figure 3 shows that the average ultimate strength of pure Aluminium is 56.55 MPa, to increase the strength of Aluminium we have added the different constituent in aluminium (Al) such as Copper (Cu), Magnesium (Mg), Manganese (Mn), Zinc (Zn), Lead (Pb), etc. but main aim of this research was to vary the percentage of copper. In those alloy, other elements were maintained in the same value.

Table 3: Ultimate strength and strain of aluminum and Al-alloy

Material	Specimen	Ultimate Strength (N/mm^2)	Mean Ultimate Strength (N/mm^2)
Aluminium	1	54.5	56.55
	2	58.6	
Copper 11%	1	114.5055	114.2803
	2	114.0551	
Copper 8.25%	1	89.3254	90.2912
	2	91.2547	
Copper 5.5%	1	72.851	71.221
	2	69.591	
Copper 2.755%	1	60.853	62
	2	63.147	

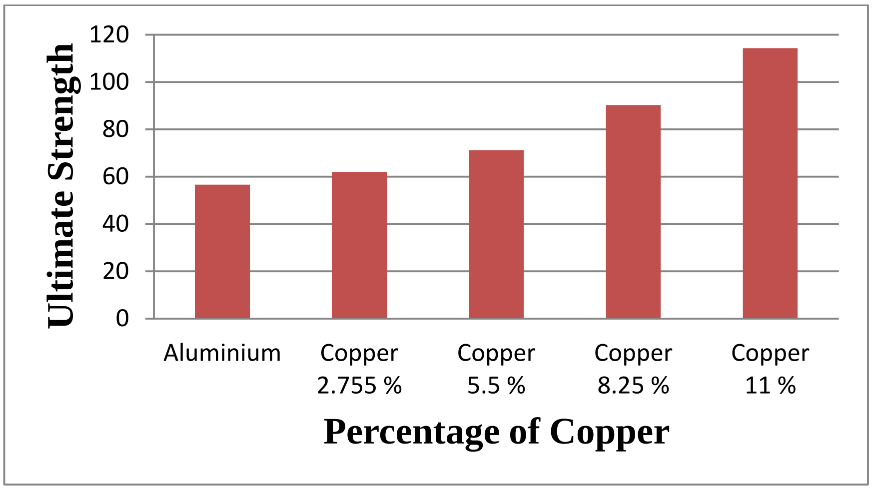
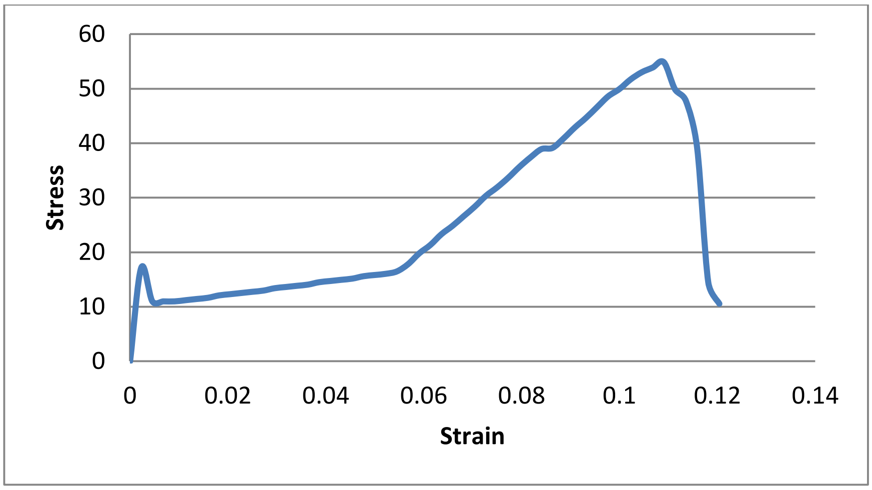


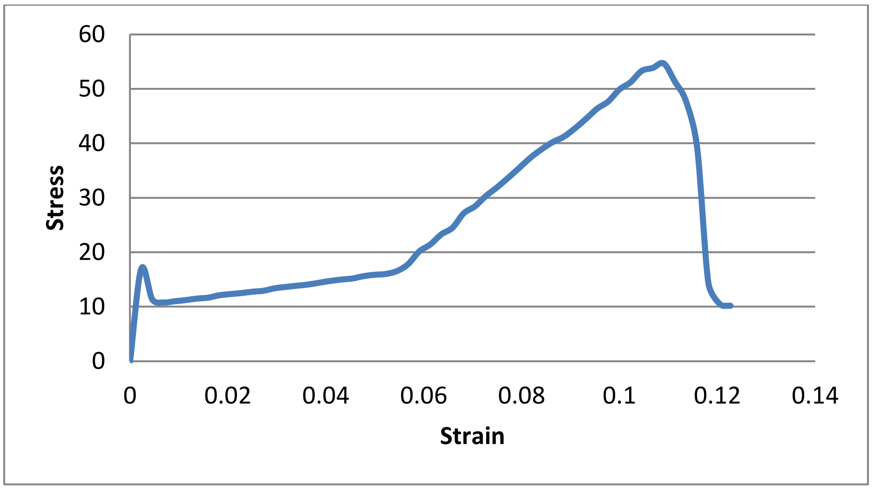
Fig. 3: Comparison of Ultimate Strength between Aluminium and Al- Alloys

After varying the percentage of copper, it was concluded that when copper increase in Aluminium alloy, the ultimate strength, hardness, and fatigue of alloy increased too. The highest value of ultimate strength (114.28 MPa) is at 11% of copper in alloy.

3.1 Stress Strain Diagram



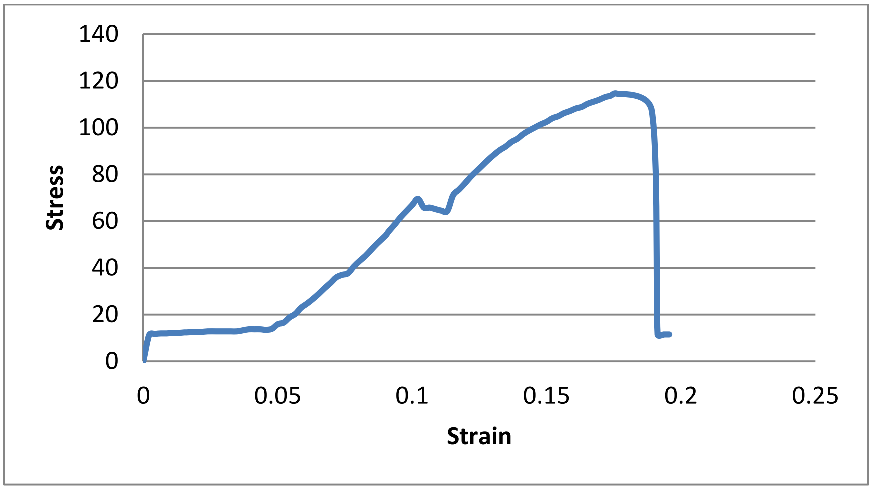
(a)



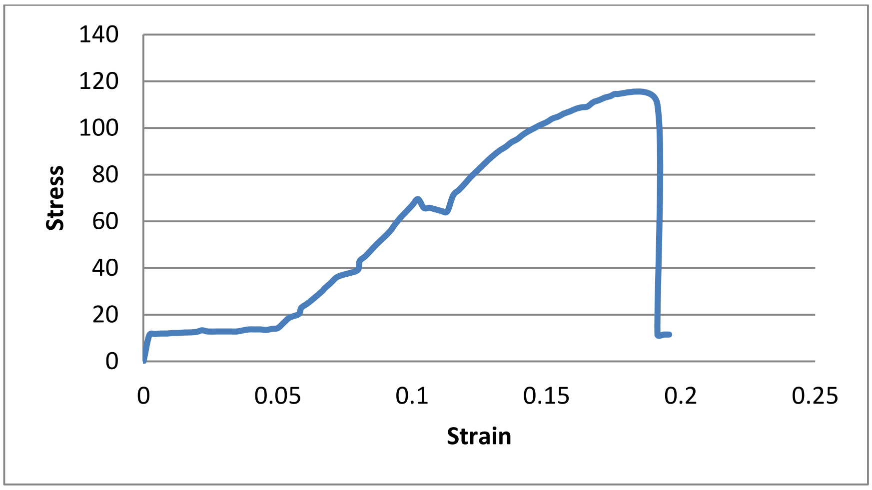
(b)

Fig.4: Stress Strain Diagram for Aluminium, (a) Specimen- I, (b) Specimen-II

Figure 4 shows the engineering stress-strain curve for pure Aluminium specimens with an enlarged scale, now showing strains from zero up to specimen fracture. Here it appears that the rate of strain hardening diminishes up to UTS (Ultimate Tensile Strength).Beyond that point, the material appears to strain soften, so that each increment of additional strain requires a smaller stress. [13]. The ultimate Stress for pure Aluminium is calculated by 56.55 N/mm^2.

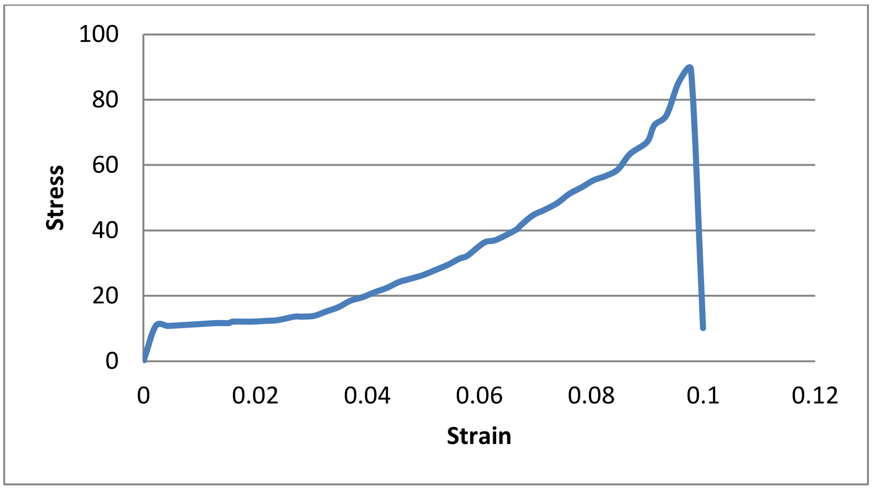


(a)

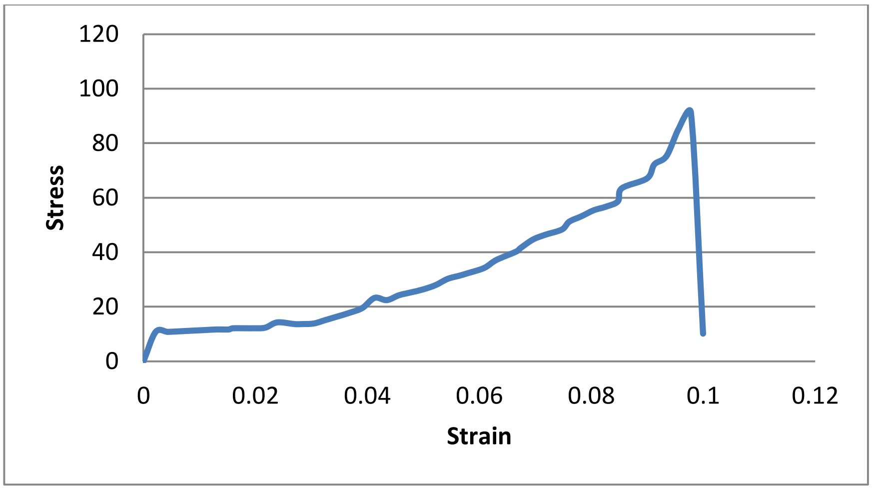


(b)

Fig. 5: Stress Strain Diagram for Al- Alloy with Cu- 11%
(a) Specimen- I, (b) Specimen-II

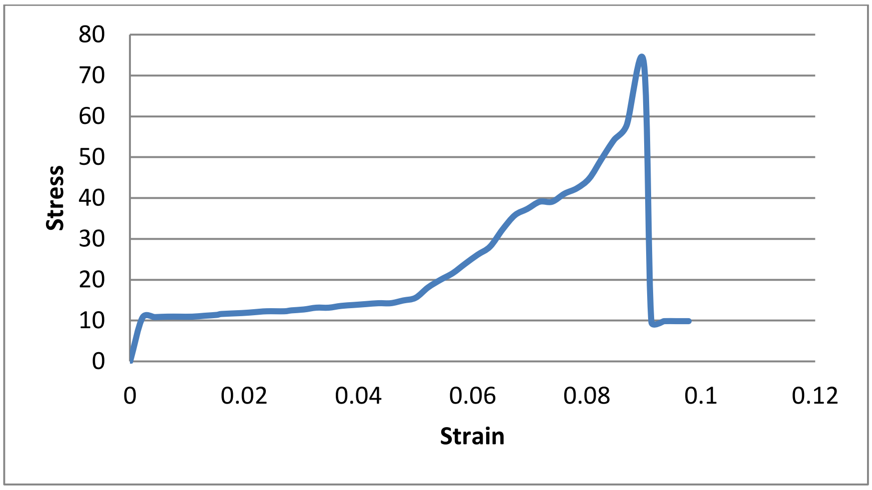


(a)

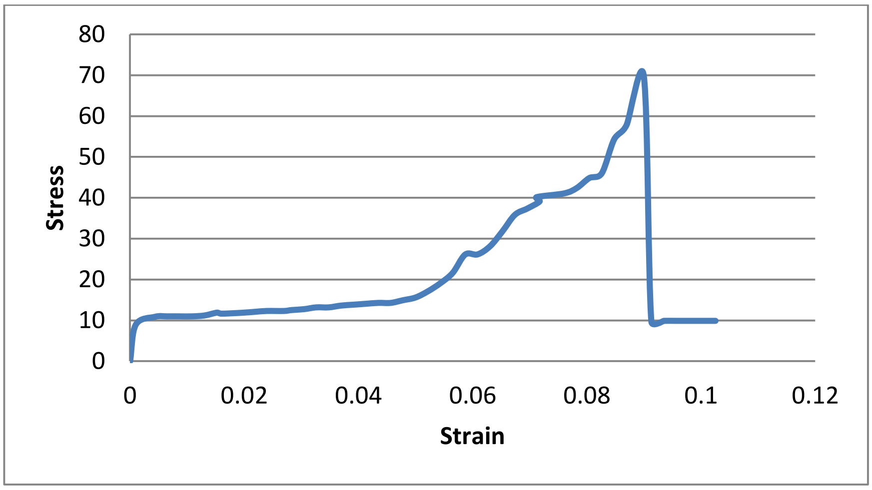


(b)

Fig. 6: Stress Strain Diagram for Al- Alloy with Cu- 8.25 %
(a) Specimen-I, (b) Specimen-II

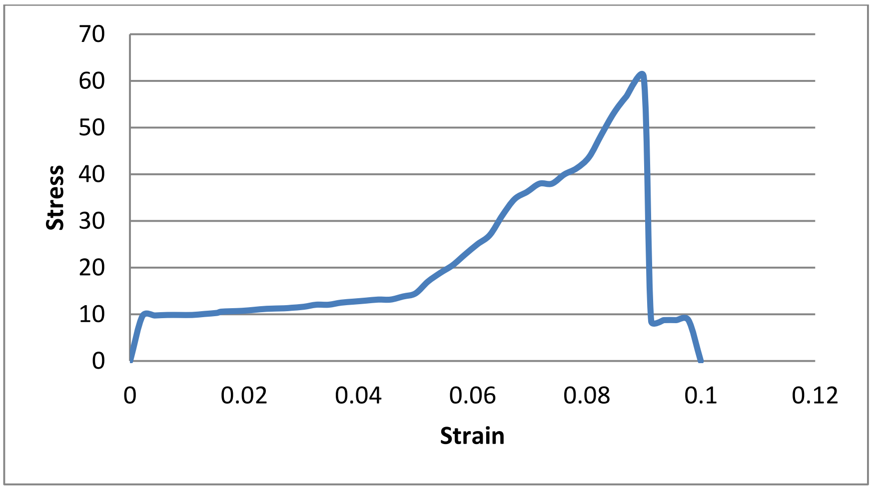


(a)

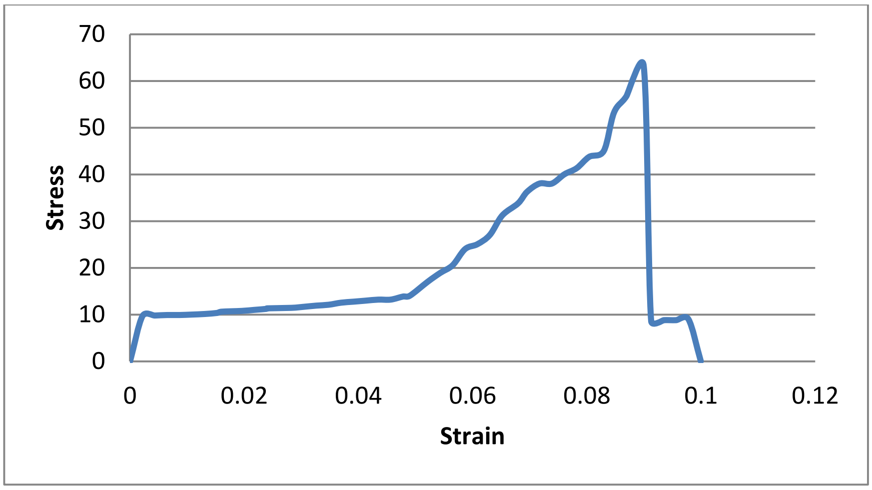


(b)

Fig. 7: Stress Strain Diagram for Al- Alloy with Cu- 5.5
(a) Specimen-I, (b) Specimen-II



(a)



(b)

Fig. 8: Stress Strain Diagram for Al- Alloy with Cu- 2.75 %
(a) Specimen-I, (b) Specimen-II

Figure 5 the graphs is based on testing of two specimens on UTM having copper as 11% as an alloying element in Aluminium. At a certain point stress and strain is directly proportional and on increasing the stress strain is increasing but after ultimate stress point stress decreases rapidly with a small change in strain this is because the elongation has reached its maximum stage and there can be no more elongation as the material gets softer and ultimately the specimen gets fractured and graph depicts the fracture point.

Copper as an alloying element increase the strength, hardness, fatigue, creep resistance and machinability in an aluminium-copper alloy. Strength and ductility are depending on how copper is distributed in the alloy. Copper is found dissolved in the dendrite matrix or as aluminium-copper rich phases. Alloys with dissolved copper in the matrix shows the most increase of strength and retains ductility.

As it is shown in figure 5 to 8, the ultimate tensile strength gives a higher result with increasing copper level. An interesting value is found in the 11 % of copper sample that is showing a higher value then all the aluminium alloy.

4. Conclusion

The effects of copper concentration on mechanical properties of Cu-Al- alloy mould casting have been studied. Based on Mechanical testing & examination conducted of the specimen, the following conclusion can be drawn:

- Ultimate tensile strength of the alloy improved as compared to LM 12
- Ultimate load of the alloys is increase & % Elongation decrease with increase in copper %.
- By addition of more copper , the solidifications temperature for Al- Alloy reduces and this is an important factor to consider which temperature the heat treatment not should exceed

References

[1] E.L. Rooy, Metals Handbook, Vol. 15, ASM International, Materials Park, Ohio, 1988; 743- 770.

[2] Torabian H., Pathak J.P., Tiwari S.N., Wear Characteristics of Al-Si Alloys, Wear, 1994;172(1): 49-58.

[3] M. Johnsson: Z. Metallkd.”Influence of Zr on grain refinement of aluminium”, 1994; 85: 781-785.

[4] S. A. Kori, B. S. Murty and M. Chakraborty: Mater. Sci. Eng. A, 2000; 283: 94-104.

[5] Singh M., Prasad B.K., Mondal D.P., Jha A.K., Dry sliding wear behaviour of an aluminium alloy-granite particle composite, Tribology International, 2001; 34(8): 557-567.

[6] S.G. Shabestari, M. Mahmudi, M. Emami, J. Campbell, Inter. J. Cast Metals Res., 2002; 15: 17–24.

[7] N. Fridlyander,1 O. E. Grushko,1 and L. M. Sheveleva1, Heat hardened alloy v1341 for cold pressing of sheets, 2004; 46: 9 – 10.

[8] M. Elmadagli, A.T. Alpas: Sliding wear of an Al-18.5wt. % Si alloy tested in an argon atmosphere and against DLC coated counterfaces, Wear, 2006; 261 (7-8): 823-834.

[9] A.Kara Karaaslan, I. Kaya and H. Atapek , Effect of aging temperature and of retrogression treatment time on the microstructure and mechanical properties of alloy 7075 , Metal Science and Heat Treatment, 2007; 49: 9 – 10.

[10] Kouichi Maruyama, Mayumi Suzuki, and Hiroyuki Sato, Creep strength of magnesium-based alloys, 2008; 42.

[11] Das, S., Mondal, D. P., Sawla, S. & Ramakrishnan, N.(). Synergic effect of reinforcement and heat treatment on the two body abrasive wear of an Al-Si alloy under varying loads and abrasive sizes. Wear. 2008; 264(1-2):47-59.

[12] Jing li, Zhong-ping zhang, Qing sun, Chun-Wang li, and Rong-sui li a modified method to estimate fatigue parameters of wrought aluminium alloys, july 31, 2010.

[13] Mehdi. H et al, Experimental Analysis of Mechanical Properties of Composite Material Reinforced by Aluminium-Synthetic Fibers” International journal of Mechanical Engineering, 2014; 1-2(2): 59-69.

[14] H. N. Girisha, K. V. Sharma, Effect of magnesium on strength and microstructure of aluminum, copper, magnesium alloys, International Journal of Scientific Engineering and Research, 2012; 3 (2).

[15] A. Zhu, B. M. Gable, G. J. Shiflet, E. A. Jr. Starke, Trace element effects on precipitation in Al–Cu–Mg–(Ag, Si) alloys: a computational analysis, Acta Materialia 2004; 52: 3671–3679.