Effect of Cryogenic treatment on Compression Strength of Al-Cu alloys

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Abstract — *It is well known that the cryogenic treatment enhances metallurgical properties of most of the metals, which in turn improve various strengths of the treated parts. It creates denser molecular structure of the metals and alloys resulting in a larger contact surface area that reduces friction, heat and wear. Now a day's mostly the Mechanical properties of the Materials are significantly varied by changing percentage composition of Alloy materials present in it. In this work, the effect of Cryogenic treatment on Compression Strength of Aluminium-Copper Alloy is studied by varying the percentage of copper for different durations of Cryogenic Treatment. The specimens were fabricated by varying the copper percentage in the Al-Cu Alloy for 1.5%, 3.0%, and 4.5% by metal casting process and then turning them to obtain an l/d ratio of 3:2. Then these fabricated Metal Alloy specimens are cryogenically treated by using liquid nitrogen for different durations of Six, Eight and Ten hours for all specimens for which the copper percentage has been varied. Both untreated and Cryogenic treated specimens are tested for the Compression Strengths on Universal Testing Machine. The experimental results show that as the duration of cryogenic treatment increases the Compression Strengths also increases, but as the percentage of Copper increases in the Alloy the Compression Strength increases to some extent and then decreases.*

Keywords — *cryogenic treatment, compression Strength, metal casting, Al-Cu Alloy.*

I. INTRODUCTION

A typical Metal Alloy is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale. An alloy may be a solid solution of metal elements (a single phase) or a mixture of metallic phases (two or more solutions). Mechanical properties of alloys will often be quite different from those of its individual base components. When designed properly a prefect ratio of mixed components yields optimal nature of the mechanical property at that particular percentage of composition.

J. Hashim [1] narrated that the multifunctional material systems that provide key characteristics are not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition, characteristics and sometimes also in different phases. Kelly [2] very clearly stresses that the alloy composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength or resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

By the work of Panchakshari H.V [3], he reveals that the microstructure of alloys changes due to the cryogenic treatment which influences of different process parameters on micro-hardness of Al alloy were compared and the results showed that cryogenic treatment could improve hardness of Al/Al2O3 composites. Experimental investigations showed that as the percentage of reinforcement increases corrosion resistance has further improved by cryogenic treatment [4]. Pavan K M [5] by probing in the field of cryogenics stated that cryogenics improves the resistance to stress corrosion which is plays a vital role in designing the aerospace components.

K.K.Padmanabhan [6] investigation revealed that aluminium 6063 properties will be enhanced by cryogenic treatment but the trend of enhancement is not revealed. Hence an available base material chosen in this work is aluminium 6063 alloy and pure copper to from different Aluminium-copper alloys. The alloy composition of aluminium 6063 alloy is as shown in the Table 1

TABLE I

The alloy composition of Al 6063

Element	%Weight
Si	0.2-0.6
Fe	0-0.35
Cu	0-0.10
Mn	0-0.10
Me	0.45-0.9
Zn	0-0.1
Other's	0.05-0.25
Al	97.5-99.3

The main controllable process parameters affecting the strengths of the alloys are the percentage variation of alloying material and the cryogenic treatment time. Hence these parameters are chosen as primary and secondary parameters respectively. In the current context, traditional casting is performed for manufacturing the Aluminium-Copper alloy and then they are subjected for the cryogenic treatment for different ageing durations. The levels of the both primary and secondary parameters are as shown in the Table 2.

TABLE II

Process parameters

S.No	Process parameters	Levels		
		1	2	3
1	% Copper Variation	1.5%	3.0%	4.5%
2	Cryogenic Time	6hrs	8hrs	10hrs

II. EXPERIMENTAL WORK

In the present work Aluminium-Copper alloys are prepared by using aluminium 6063 and by varying copper (Cu) in three different percentages (1.5%, 3%, 4.5%). For preparing 1.5% copper alloy, 800 grams of aluminium 6063 is taken in one crucible and heated till the aluminium in the crucible is liquefied. In other crucible 12 grams of copper (for 1.5%) is taken and heated separately until it gets liquefied. Now both are mixed by manual stirring so that a uniform aluminium-copper solution is attained in one crucible. Fig 1 shows the furnace used in preparing the composite.

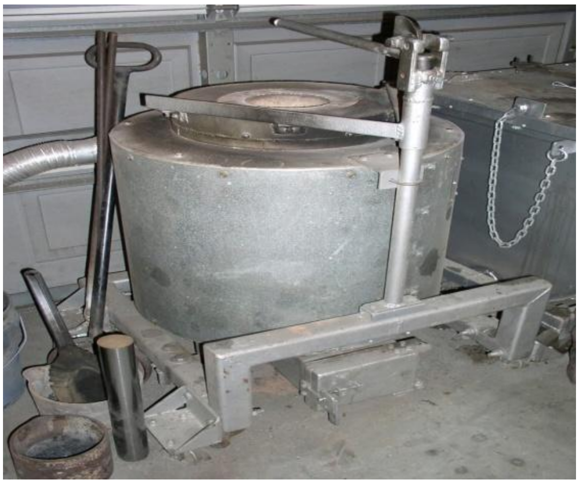


Fig 1: Furnace

Then the molten metal alloy is ready to pour into the mould and allowed it to solidify for a definite period and the required casting is obtained by breaking the sand mould. The above procedure is repeated for the remaining two percentages of copper i.e., 3% and 4.5% and corresponding alloys are obtained. The castings that are prepared from the above procedure are machined on the CNC lathe (Fig. 2) to the required dimensions by facing the edges of the specimen followed by turning the surface of the specimen to achieve exact dimensions.

Fig 2: CNC Lathe

To get homogenous deformation, the specifications of the specimens are taken so that the L/D=1.5, Where ‘L’ is Length of the Specimen and ‘D’ is the effective Diameter of the Cross Section of the Specimen. In the present experimentation work we have adapted the specimen specifications as D =20 mm and L=30 mm. Now fabricated specimens are cryogenically treated for different time duration levels. The time for which the specimens are subjected to cryogenic treatment is called soaking period in a cryogenic container as shown in Fig 3.

Fig 3: cryogenic container

The alloy samples obtained by varying the percentage of copper are subjected to different soaking periods i.e., Three samples each from 1.5%, 3%, 4.5% of Cu were stored in the liquid nitrogen container for 6 hours, 8 hours and 10 hours. After storing for the required time period samples are taken out and kept separately. The experimental plan is as shown in the table 3.

TABLE III

Experimental plan

Expt. No.	% Copper	Cryogenic Time
1	1.5%	0hrs
2	3.0%	0hrs
3	4.5%	0hrs
4	1.5%	6hrs
5	3.0%	6hrs
6	4.5%	6hrs
7	1.5%	8hrs
8	3.0%	8hrs
9	4.5%	8hrs
10	1.5%	10hrs
11	3.0%	10hrs
12	4.5%	10hrs

Hence finally the fabricated test specimens were subjected for compression tests. The Load vs Elongation curves for all specimens are shown in the Fig 4.

III. RESULTS AND DISCUSSIONS

From the results it is observed that as the cryogenic treatment time increases, the load bearing capacity i.e., the strength of the Aluminium-Copper Alloy increases. Hence the result is in coincidence with [3] and [4]. The measured compressive load is plotted against the Cryogenic treatment time and as shown in the Fig 5.

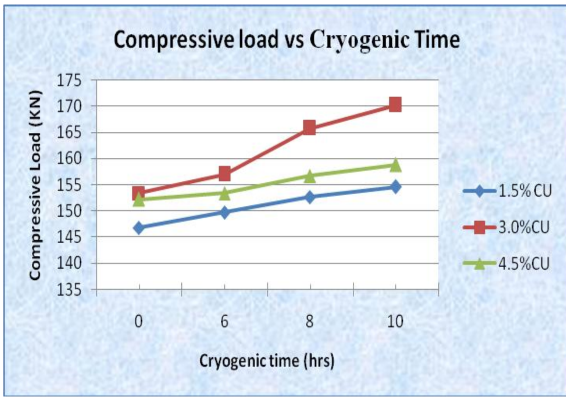


Fig 5: Load vs Elongation curves for all the specimens

S Takamori [7] in his investigation stated that mould temperature also plays a key role in enhancing the material properties. Thus the Compressive strength of the Aluminium-Copper Alloy upon cryogenic treatment should enhance because the cryogenic temperature can effectively strain harden with higher dislocation density of samples. The variation of compressive stress for cryogenically treated Al-Cu Alloys with respect to cryogenic time for different percentage composition of copper is shown in Fig 6 (a,b,c). The plots show that, the compressive strength of Al-Cu alloy increases with increase in cryogenic time.

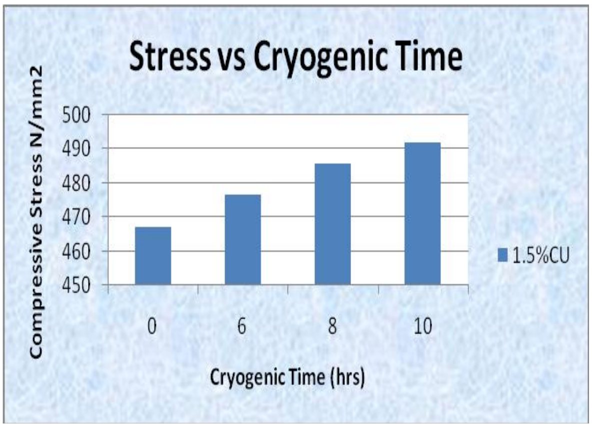


Fig 6(a):CompressiveStress vs Cryogenic time for 1.5%Cu specimens

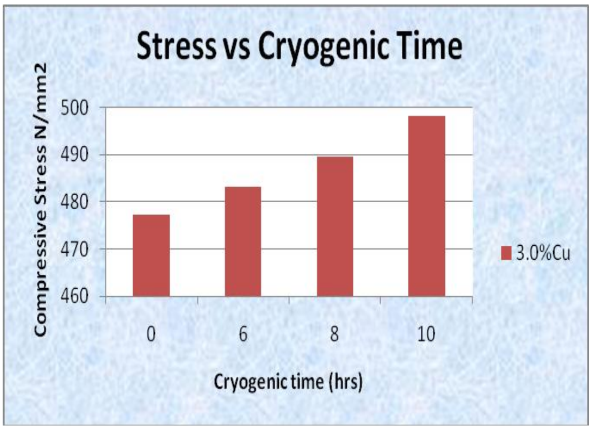


Fig 6 (b): Compressive Stress vs Cryogenic time for 3.0%Cu specimens

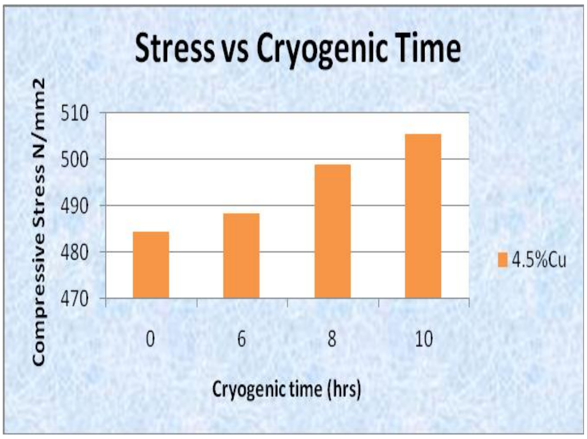
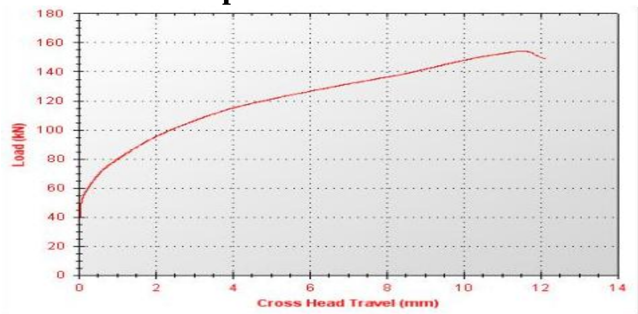


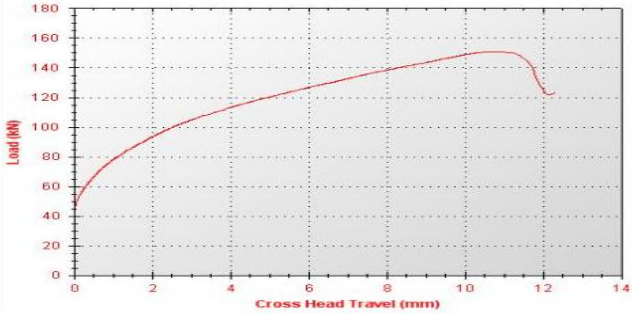
Fig 6 (c): Compressive Stress vs Cryogenic time for 4.5%Cu specimens

1.5% Cu-6hrs-Specimen-1

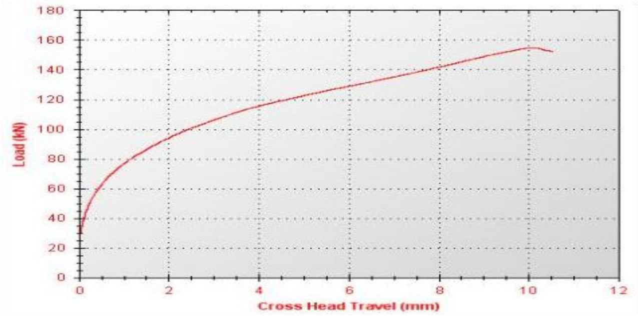


1.5% Cu-6hrs-Specimen-2

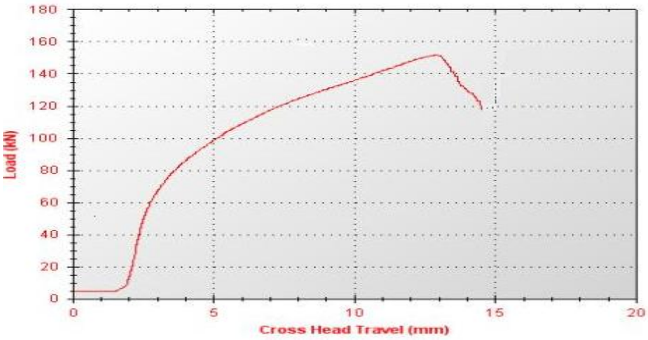
1.5% Cu-8hrs-Specimen-1



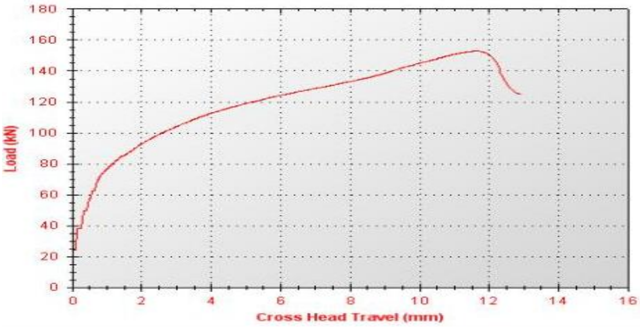
1.5% Cu-8hrs-Specimen-2



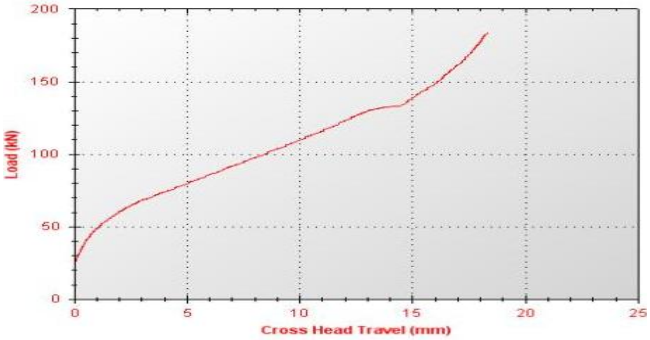
1.5% Cu-10hrs-Specimen-1



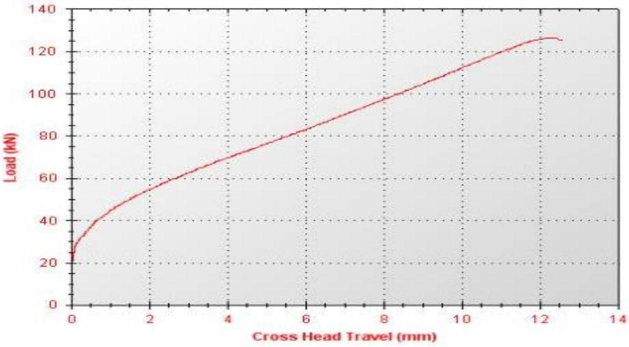
1.5% Cu-10hrs-Specimen-2



3.0% Cu-6hrs-Specimen-1

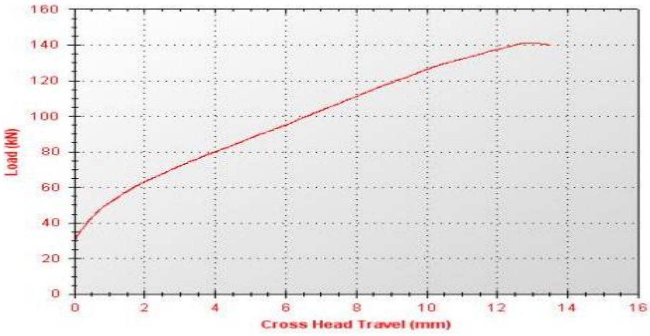


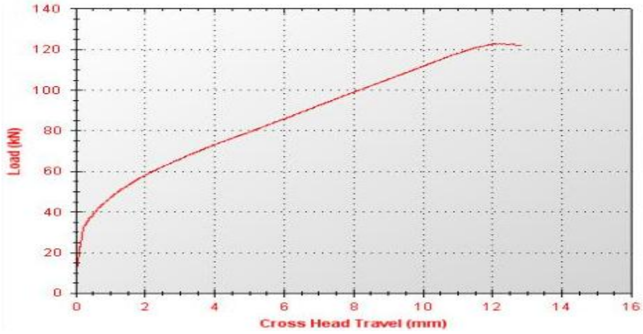
3.0% Cu-6hrs-Specimen-2



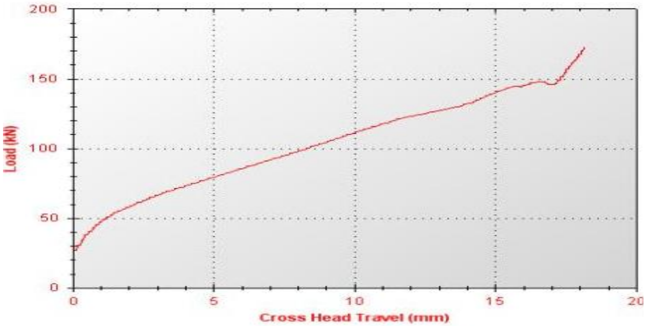
3.0% Cu-8hrs-Specimen-1

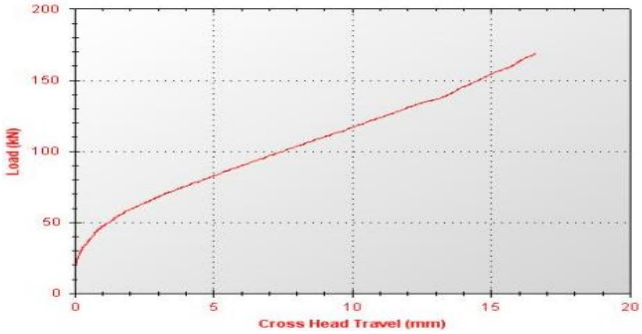
3.0% Cu-8hrs- Specimen-2



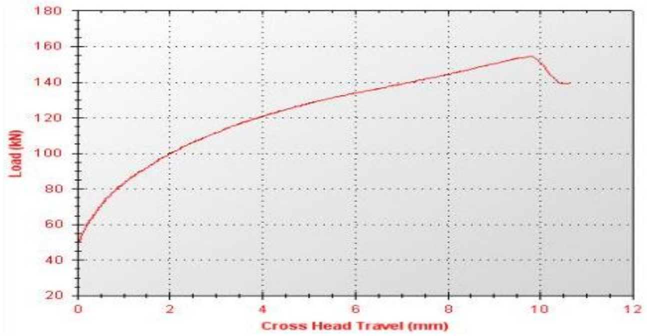


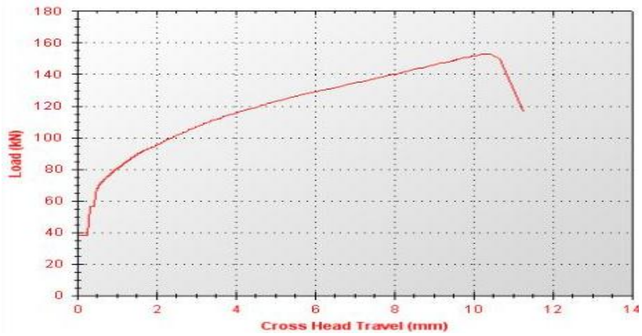
3.0% Cu-10hrs-Specimen-1 **3.0% Cu-10hrs-Specimen-2**



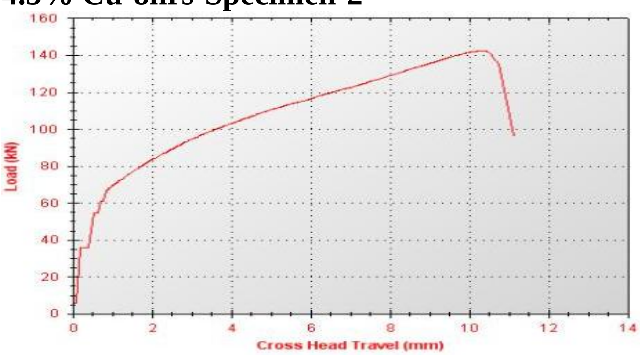


4.5% Cu-6hrs-Specimen-1 **4.5% Cu-6hrs-Specimen-2**

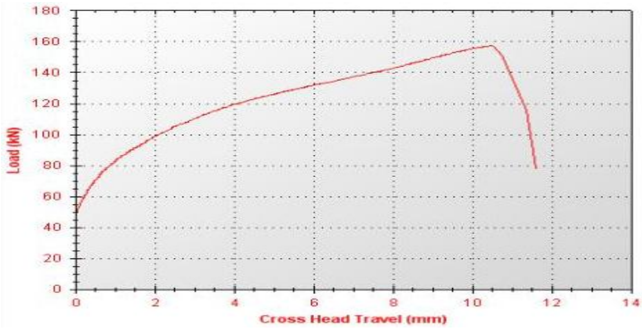




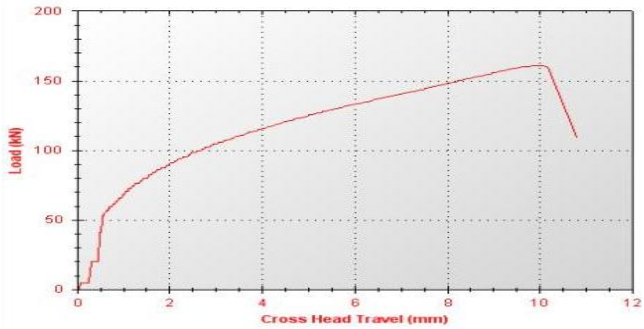
4.5% Cu-8hrs-Specimen-1 **4.5% Cu-8hrs-Specimen-2**



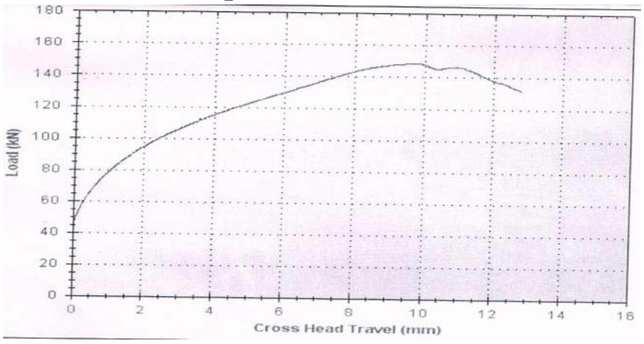
4.5% Cu-10hrs-Specimen-1 **4.5% Cu-10hrs-Specimen-2**



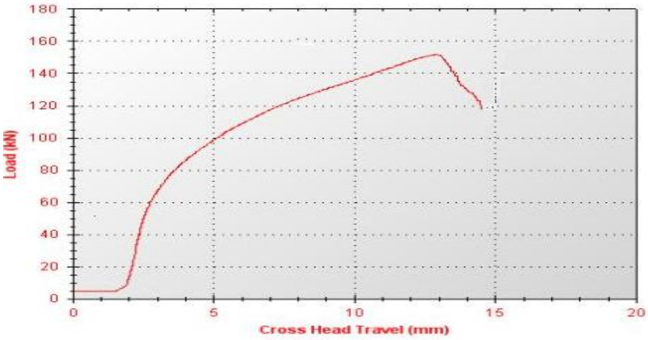
1.5% Cu-0hrs-Specimen-1



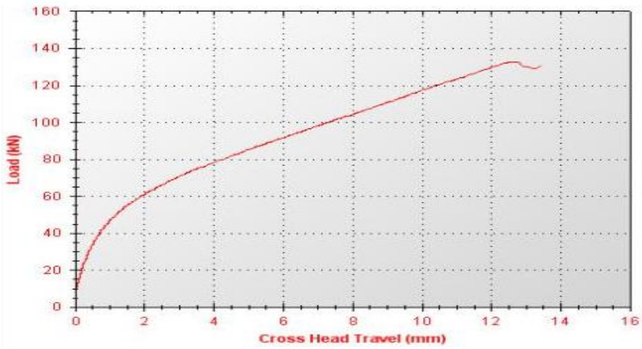
1.5% Cu-0hrs-Specimen-2



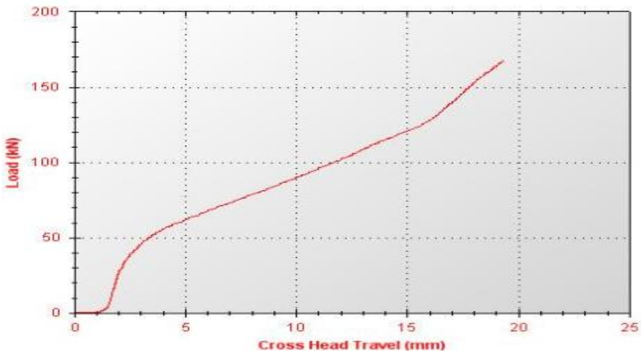
3% Cu-0hrs-Specimen-1



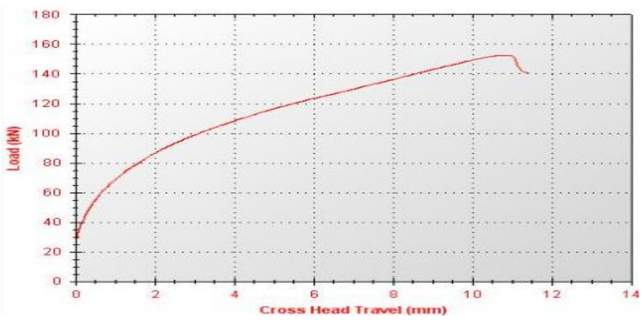
3% Cu-0hrs-Specimen-2



4.5% Cu-0hrs-Specimen-1



4.5% Cu-0hrs-Specimen-2



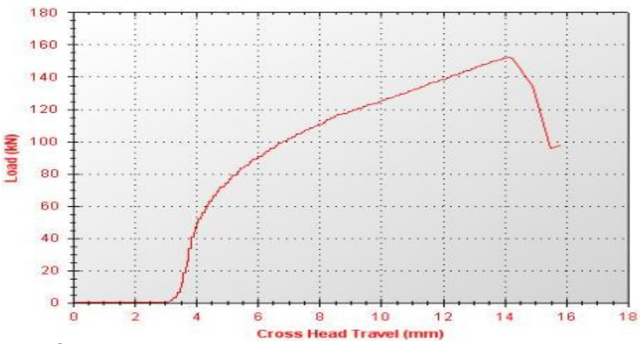


Fig 4: Load vs Elongation curves for all the specimens

It is also clear from the results that, as percentage of copper increases in the Aluminium, the strength of the Aluminium-Copper Alloy increases to an extent and then decreases. This is evident by Compressive load vs. % Cu plot as shown in Fig 7.

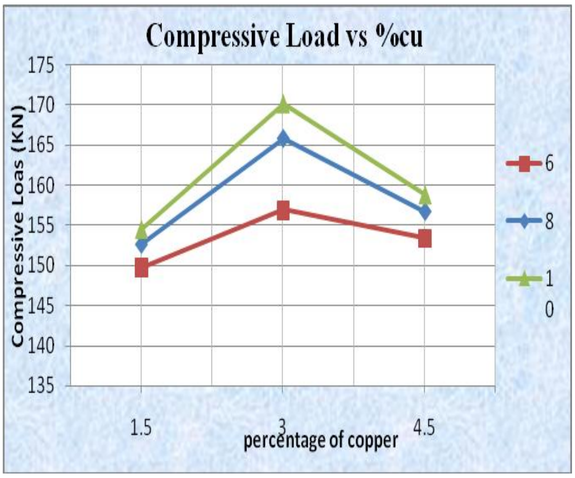


Fig 7: Compressive Load vs %Cu in the alloy

From the Fig 8 which is the variation plot between the % elongation vs cryogenic time it is obvious that, the ductile nature of the Al-Cu Alloy also increases with respect to the duration of the cryogenic treatment.

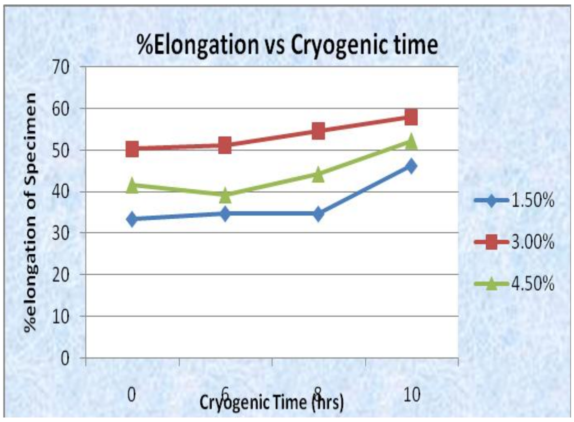


Fig8: % Elongation vs Cryogenic time alloy specimens

IV. CONCLUSIONS

The alloys produced by varying the percentage composition of different alloying materials will enhance the mechanical properties of the base materials up to some extent. But in order to improve the material characteristics every time varying the percentage composition of the alloy increases the production cost which as a consequence decrease the domestic applicability of the product. In present investigation, one such trail is successfully carried-out on Aluminium-Copper alloy which is a most significant domestic alloy. This study showed that, the cryogenic treatment, instead of varying the percentage composition to the base material, enhanced the material properties of Aluminium-Copper alloy. This accurate implementation of cryogenic treatment of alloys will help to save production time and hence production cost.

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