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Study of Mechanical Properties of As Cast and Cast Aged Al-21%Si Alloy

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Abstract The purpose of this work was to study the mechanical properties of hypereutectic Al-21%Si with impurities (0.243%-Fe, 1.84%-Cu, 0.008%- Mn, 0.001%-Mg) such as Tensile test, Hardness test and Wear properties for fixed load (2kg) with varying speed of 2000m sliding distance for As cast and Castaged condition of the alloy for 1 Hour, 3 Hour and 5 Hour heat treatment. In this work we investigate the effect of different heat treatment time (1,3,5 Hours).In present investigation, Aluminium based alloys containing 21% weight of silicon were synthesized using casting method. Compositional analysis and tensile studies of different samples of same composition have show near uniform distribution of Si in the prepared alloys. Tensile tests were carried out with universal testing machine. Tensile strength is slightly decreases with increase in heat treatment rate. Wear behaviour was studied by using computerized pin on disc wear testing machine. The volumetric wear gradually decreases with increase in heat treatment rate but it is observed that at 3 hour it volumetric rate is gradually increased. Hardness test were carried out in Brinell Hardness Tester. The heat treatment was not contributed much to the improvement of the hardness strength of the alloy . Instead the hardness strength is reduced slightly from (BHN 69.1)of as cast to (BHN 59.4) of 1 hour heat treated and slight improved further for 3 hour (BHN 67.5) and 5 hour (BHN 63.1) heat treated as compared to 1 hour heat treated.

Keywords: hypereutectic, mechanical properties, Brinell Hardness Test

1. Introduction The important factors dictating the mechanical properties of cast Al-Si alloys are divided into two groups: (a) those that are governed mainly by the casting process and (b) those influenced by the physical metallurgy of the alloy . Tighter controls currently applied during the casting process as well as the advancements in the casting processes have resulted in reduction of structural defects in castings, such as pores and oxide bifilms, which seriously degrade mechanical properties. On the other hand, better understanding of the physical metallurgy background of the age-hardened cast aluminum alloys indicated that chemical composition, solidification rate and heat treatment are the key parameters to improve the 'quality' of the investigated material, as expressed through the mechanical properties. Dwivedi et al found that an increase in the silicon content from 4 to 20% influences the tensile strength, ductility and hardness of Al-Si-Mg alloys. The ductility of the alloy reduces monotonically while hardness increases over the range of Si increase.Furthermore, tensile strength increases up to 16% Si, but reduces at higher silicon contents. Al–Si alloys are well-known casting alloys with high wear resistance, a low thermal-expansion coefficient, good corrosion resistance, and improved mechanical properties at a wide range of temperatures. Such features make the application of these alloys particularly suitable for the automotive industry, especially in the manufacture of cylinder blocks, cylinder heads, pistons and valve lifters [1-3]. Silicon reduces the thermal expansion coefficient, increases corrosion and wear resistance, and improves castability characteristics of the alloy (especially fluidity and porosity formation) [2, 4]. Forged wheels have been used where the loading conditions are more extreme and where higher mechanical properties are required. Aluminium alloys have also found extensive application in heat exchangers. Modern, high performance automobiles have many individual heat exchangers, e.g. engine and transmission cooling, chargeair coolers (CACs),climate control ,made up of aluminium alloys.

Al-Si is an important alloy for many commercial automotive applications (pistons, cylinder liners, etc.) duo to its unique properties. Al-Si casting alloy are the most versatile of all common foundry cast alloys in the production of pistons

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for automotive engines. Commercial uses for hypereutectic alloys are comparatively limited because these are the most difficult Al alloys to cast and machine due to the high Si contents. Once high Si content is alloyed into Al, it adds a large amount of heat capacity that must be removed from the alloy to solidify it during the casting operation. Major variation in the sizes of the primary Si particles can be found between different areas of the cast structure, causing significant deviation in the mechanical properties forthe specimen. The primary crystals of Si must be refined so as to accomplish better hardness and wear resistance. Due to these reasons, hypereutectic alloys are not very cost-effective to fabricate because they have a broad range of solidification that results in poor castability and requires extra foundry processes to control the microstructure and the high heat of fusion.**2.**

2. Experimental Description

The purpose of the solution treatment of Al-Si alloys is to:

- Dissolve particles formed during solidification containing Cu and Mg,
- Spheroidise the eutectic silicon particles
- Homogenize the alloying elements in the matrix

The solution treatment also improves the distribution of eutectic silicon particles besides their spheroidisation. The solution treatment process needs to be optimized because too short solution treatment means that not all alloying elements added will be dissolved and made available for precipitation hardening, and too long solution treatment means usage of more energy than is necessary. The time needed for solution treatment is strongly dependent on the coarsenessof the microstructure. For a very fine microstructure a short solution treatment of 10 min is sufficient to achieve dissolution and homogenisation, while for a coarse microstructure more than 10 hrs is needed. A successful solution treatment depends on the as-cast microstructure (volume fraction, distribution, morphology and composition of phases, degree of modification of Si particles), in combination with the solution treatment parameters (temperature,time) choosen

Previous studies have been made to understand the solution treatment process of Al–Si–Cu alloys. The dissolution and homogenisation processes are found to be faster at high temperatures and more Cu and Mg can be dissolved in the matrix. The disadvantages of high solutionizing temperatures are higher thermal stresses induced during quenching and the risk of localised melting of Cu-rich phases. Dissolution and homogenisation of Al-Si-Cu(Mg) alloys need longer times than Al-Si alloys due to the lower temperature allowed and the slower diffusion of Cu atoms in the matrix.

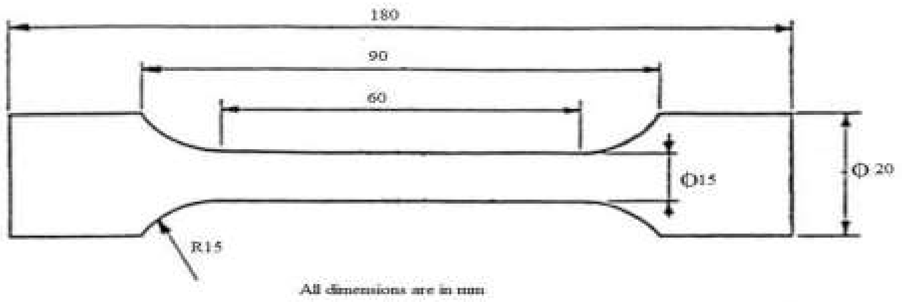

Fig.1 Tensile Test Specimen drawing

Hence, the choice of solution treatment temperature depends on the Cu concentrations of the alloy. However, if the solution temperature is too low, a reduction of mechanical properties will result. Standard T6 treatment specifies that the solution heat treatment of 319 alloys should be carried out at approximately 505ºC and maintained for4 - 12 hours depending on the casting method. Shorter periods of time are recommended for permanent mould castings and longer times for sand castings

3. Methodology Samples of Aluminium alloy that have been machined into tensile test specimen were subjected to tensile tests with the aid of an universal testing machine. The test is carried out to determine the response of samples under the application of increasing stresses. The properties studied are as follows; yield stress, percentage elongation, reduction in area and ultimate tensile stress. The samples and cast alloys are subjected to the hardness test using Brinell hardness test & the corresponding Brinell hardness number is then calculated using the formula shown in the Equation.

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$$BHN = \frac{2P}{\pi D\{D-\sqrt{(D^2 - d^2)}\}}$$

Where P = applied load;

D = diameter of the indentor,

d = diameter of the indentation.

Testing is performed to Brinell – ASTM E10 specifications,

4. Results and discussion

The chemical composition of the alloy under study is tested on the following machine SPECTROMAXx made in GERMANY and the composition is as given in Table.1 below

Table No 1 Chemical Compositions

Element	Si	Fe	Cu	Mn	Mg	Ni	Zn	Ti	Pb	Al
%	21.47	00.243	01.840	0.008	0.001	0.005	0.001	0.013	0.010	73.100

Fig.3 Tensile Test Specimen

Fig.4 Tensile Test Specimen

Specification of UTM Machine

Machine : FIE MAKE UNIVERSAL TESTING MACHINE

Model : UTE-40

Max capacity : 400KN

Table No 2 Test Results

Sample Identification	Al-21% Si Alloy As cast	Al-21% Si Alloy 1 Hour HT	Al-21% Si Alloy 3 Hour HT	Al-21% Si Alloy 5 Hour HT
Diameter,mm	15	15	15	15
Gauge Length,mm	62	60.6	61.8	60.6
Area,mm^2	176.786	176.786	176.786	176.786
Maximum Force (Fm),KN	18.680	18.680	18.920	18.520
Tensile strength (Rm),kN/mm^2	0.106	0.108	0.107	0.105

Brinell Hardness Test

The hardness tests of all the samples of hypereutectic Al Sl alloy were conducted using a Brinell hardness testing machine with applied load of 500 kgf (P) during the tests. For each composition, five indentations were taken and average value is reported.

Table3. Brinell hardness test result

Parameters	Observed Values(BHN)
As cast	69.1
1 hour	59.4
3 hour	67.5
5 hour	63.1

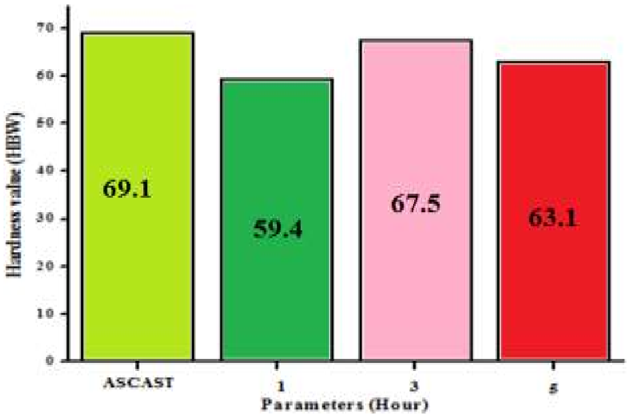

Fig.10.2.1 Hardness test result

5. Conclusion

From tensile test it is observed that the the ultimate tensile strength is not effected by heat treatment.From the hardness test it is observed that the BHN values are 69.1 for as cast alloy,59.4 for 1 hour heat treated alloy,67.5 for 3 hour heat treated,63.1 for 5 hour heat treated alloy

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