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Effect of Addition of Copper and Nickel on Microstructure and Mechanical Properties of Al-18Si Alloy

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***Abstract*— Today automotive engines need to operate at elevated temperature and higher pressure to maximize efficiency and reduce pollution. The engine elements such as piston, cylinder liners must be able to meet these challenging conditions. And also with faster growth in these sectors there is enormous demand of material light in weight and having acceptable mechanical and tribological properties. The prime objective of the study is to produce an alloy by using stir casting method. Further to study the effect of addition of copper and nickel on morphology, mechanical and tribological properties of Al-18Si alloy. Later as per standards specimens were prepared and tests are conducted for microstructure, tensile, hardness and wear properties. From these experiments it is found that effect of strengthening by addition of copper is very prominent compared to effect of addition of nickel to base alloy.**

Keywords*— Piston, Cylinder liner; stir casting; Al-18Si, Al-18Si-2Cu, Al-18Si-2Ni and Al-18si-2Cu-2Ni.

INTRODUCTION

Aluminium is one of the most used metal in automotive sector now a days because it is abundantly available metal in earth crust. i.e. 8% of the earth crust in pure form of it is soft and ductile. By adding alloying elements to it a specific property can be alter. The engine components are working in such conditions where the temperature and stress levels are high. Materials from which the components are made should sustain these challenges. Aluminium to which the alloying elements are added to meet these challenging conditions. Al-Si based alloy are very well known with higher wear resistance, low thermal expansion coefficient, excellent cast ability with their low weight, good corrosion resistance and having enhanced mechanical properties.

Microstructure and mechanical properties of the alloys depend on its composition, melting condition, rate of solidification, casting process and additional heat treatment if any. The mechanical properties of these alloys are governed by silicon particles (size, shape and distribution) and aluminium dendrite parameters. Copper is very good strengthener of Al-Si based alloys.

Stir Casting

Stir casting method is one of the convenient methods to produce composites or alloys by mixing various alloying elements or reinforcements with molten metal by stirring process. For better properties stirring speed and melt temperature play vital role. Optimum condition of 300-600 rpm stirring speed and melt temperature 750-900^{0}C have been found by this. Stir casting setup is shown in the figure.

Methodology and Experimental Setup

Fig 1 shows stir casting setup consists of heating furnace with maximum temperature of 1100^o C with 2Kg capacity of aluminium and variable speed of 600rpm.

Figure 1: Stir casting setup

Al-18Si has been procured and commercially available copper and nickel were taken for the current study. Four alloys are produced Al-18Si, Al-18Si-2Cu, Al-18Si-2Ni and Al-18si-2Cu-2Ni.

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Figure 2: Cast Alloy

Microstructure of specimens were developed following for the usual metallographic procedures (grinding, polishing and etching) and observed size, shape and distribution of Si, Cu and Ni in the Al-18Si using inverted microscope.

Hardness's of samples for determine using Brinell hardness tester. .

Tensile test is performed using electronic tensometer, specimens for the test prepared according to ASTM E8.

Wear test is carried out with the help of ducom pin on disc type wear testing machine. Parameter such as run time, sliding distance, sliding speed and track diameter are kept constant and load is varied and wear rates are of the different alloys are compared.

RESULTS AND DISCUSSION

MICROSTRUCTURE EVALUATION: Microstructure of alloys melted cast under identical conditions as shown in figure 3-6. Sample are prepared to study the distribution of grains, strength of the alloy is influenced by presence of silicon samples are investigated with 100X magnification ranges.

Fig 3: Microstructure of Al-18Si

Figure 3 shows investigation of Microstructure Al-18%Si in 100X magnification. Because of rapid cooling primary silicon is somewhat coarse and partly modified while eutectic silicon is fully modified.

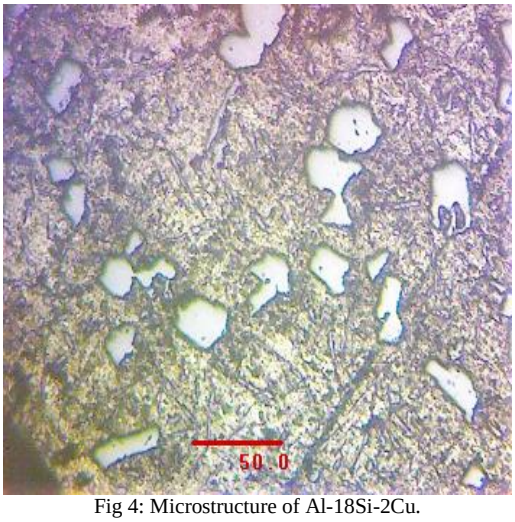

Fig 4: Microstructure of Al-18Si-2Cu.

Above 4 fig depicts addition of 2% copper to Al-18Si cast alloy as further modified the primary silicon and effected better distribution of primary silicon. Eutectic silicon remains totally modified.

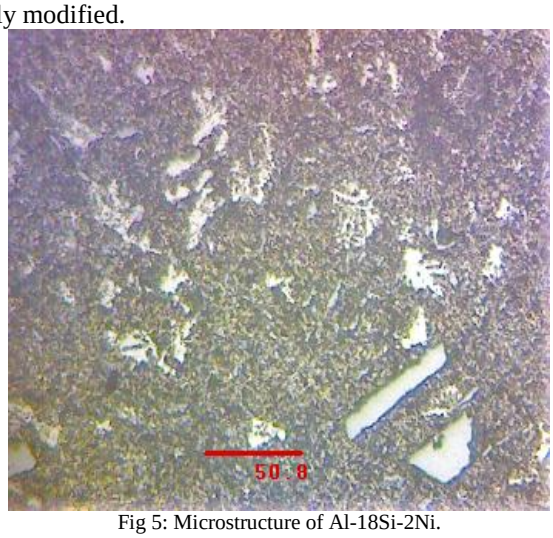

Fig 5: Microstructure of Al-18Si-2Ni.

The fig 5 shows the microstructure investigation of Al-18%Si-2%Ni in this case eutectic silicon is totally refined. Primary silicon shape is somewhat odd.

Fig 6: Microstructure of Al-18Si-2Cu-2Ni.

In this case combined addition primary silicon is tending to odd shapes and eutectic silicon modification seems to be less effective.

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HARDNESS TEST: Hardness test is carried out in Brinell hardness testing machine. The figure 7 shows the variation of hardness value.

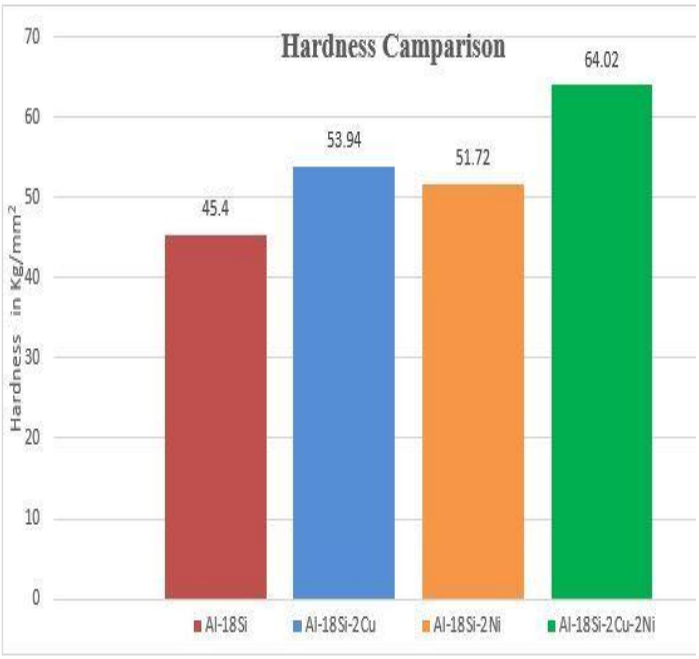

Fig 7: Hardness Comparison.

Hardness of Al-18%Si is found to be 45.4 BHN. Hardness of addition of copper cum nickel and both copper and nickel are found to be 53.94 BHN, 51.72BHN and 64.02BHN respectively. It means 41.01% increase in hardness value is found with combined addition.

TESION TEST:
Tension test have been carried out in electronic tensometer for all the specimens. Three specimens were prepared for each composition and average value of the ultimate tensile strength of these alloys shown in the table.

Table 1: Avg. UTS in MPa

Alloy	Avg. UTS in MPa
Al-18Si	94.8
Al-18Si-2Cu	133.1
Al-18Si-2Ni	110
Al-18Si-2Cu-2Ni	143

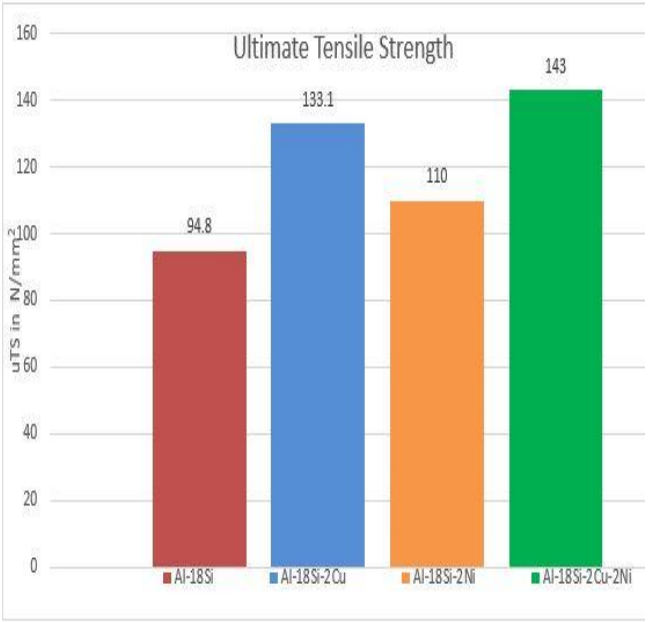

Fig 8: Avg. Ultimate Tensile Strength of All Alloys.

From the above graph it is clearly manifest that Ultimate tensile strength is being compared for all the alloys. The UTs are drawn from the test are 94.8 MPa, 133.1MPa, 110MPa and 143MPa for Al-18Si, Al-18Si-2Cu, Al-18Si-2Ni and Al-18si-2Cu-2Ni respectively. It has been observed that the UTS of addition of both copper and nickel found to be 143MPa. It is almost 51% more than the base alloy.

WEAR TEST: Wear test is conducted to know the amount of loss of material for an applied load.

The following table gives various parameters used for the test.

Table 2: Parameters Used for the Wear Test

Varying load	1kg, 2kg and 3kg.
Track diameter	100mm
Sliding distance	1000 m
Run time	9 minutes
Sliding speed	382 rpm

Specimens for wear test are prepared according to G99 standards. Wear test is performed for three specimens for each alloy. The following figure gives average wear rate.

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Fig 9: Comparison of wear test result,

It has been seen from the test results, copper addition improves hardness and also it increases wear resistances. And for the addition of both Cu and Ni wear decreases up to 31% compared to wear of base alloy.

CONCLUSIONS:

The experiments have been carried out for the Al-18Si, Al-18Si-2Cu, Al-18Si-2Ni and Al-18si-2Cu-2Ni alloys. Tests were conducted and results are compared. The conclusion drawn from the present work is as follows.

- Eutectic in all the investigated structure of alloys is very fine. Due to high rate of solidification structure is altered nicely. Addition of copper and nickel tends to coarsen the primary silicon and refine the primary silicon respectively.
- Hardness is improved to greater amount i.e. 41% more than the hardness of base alloy for addition of both Cu and Ni.
- Tension test results shown that the strengthening effect of copper addition is dominating compared to strengthening effect of addition nickel to the base alloy.
- The result revealed from the wear test is that addition of copper decreases wear by almost 28% but addition of nickel not greatly effect on wear.
- Effect of addition of copper on mechanical behaviour of Al-18Si is very strong but nickel addition alone improves slightly and also both combination of copper and nickel improves the mechanical properties to the largest amount.

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