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Production of high strength Al-Si Alloy with Various Compositions of Alloys

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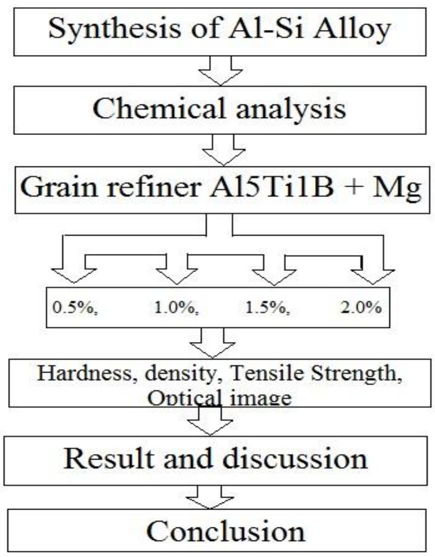
ABSTRACT: Within the last few years there has been a rapid increase in the utilization of aluminum-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application make the study of their hardness and tensile behavior of utmost importance. In this present investigation, Aluminum based alloys containing 12% weight (eutectic range) of Silicon were synthesized using casting method. Compositional analysis and tensile studies of same amount of samples in different composition have shown near uniform distribution of Si in the prepared alloys. The idea behind this work was to see the effect of addition of immiscible alloys for the refinement of microstructure.

Keywords: Al-Si Alloy, microstructure, grain refinement, casting, high strength alloy

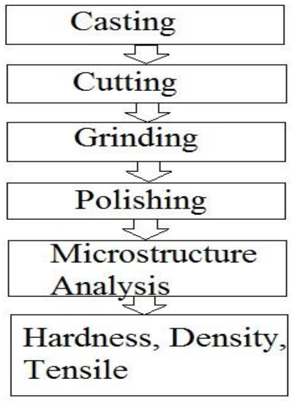
I. INTRODUCTION

Aluminum is a metal having atomic number 13 having FCC structure. The properties of aluminum which chiefly dedicate its use as an engineering material are its low relative density coupled with a reasonability high tensile strength when used in one of its alloyed forms. Since its relative density is only about one third of steel its alloys are widely used in aero, automobile and constructional engineering. A combination of suitable alloying and heat-treatment can produce alloys which, suitable for many engineering applications.

II. METHODOLOGY



III. EXPERIMENTAL METHODS



3.1 preparation of al-si, master alloys

Grain refiners were prepared with two different compositions (Al-3Ti-1B &Al-5Ti-1B) using halide salt route in a stir cast furnace. Then the grain refiners were added to the aluminum- silicon alloy (eutectic) at different compositions. Spectroscopic analysis has done on the sample for chemical composition of alloys. Samples of different dimensions were cut for different tests. Optical microscope was used for micro structural analysis. Scanning electron microscope (SEM) was used for higher magnification microstructure. The hardness was measured with the Vickers hardness testing machine. The tensile properties were obtained by conducting tensile test on tensometer. Effectiveness of grain refiners with different compositions on the mechanical properties of eutectic Al-Si alloy studied.

3.2 Preparation Grain Refiner (Al-Ti-B)

Materials and equipment required
1. Commercially pure Al (99.7% Al)
2. Halide salts **:**
a. Potassium hexafluorotitanate (K2TiF6), &
b. Potassium tetrafluoroborate (KBF4)
3. Resistance furnace
4. Stir – zirconia coated iron
5. Etchant- Keller's reagent
6. Poulton's reagent
7. SEM analysis
8. Degassing agent – Hexachloroethane
9. Flux- 45%NaCl+45%KCl+10%NaF
While the simultaneous addition of both the salts results a synergic reaction with molten aluminum and also both $TiAl_3$ and TiB_2 particles forms, which the most favorable condition for grain refinement.

$$12\ Al + 3\ K_2TiF_6 + 2\ KBF_4 \xrightarrow{\text{Exothermic reactions}} TiB_2+TiAl_3+K_3AlF_6+KAlF_4$$
$$Al+Ti+KBF_4 \xrightarrow{\text{Exothermic reactions}} TiB_2+TiAl_3+K_3AlF_6$$

3.3 Process parameters

Table 3.1 process parameters for the preparation of grain refiner

Master Alloy	**Melting temperature (^0c)**	**Holding time (min)**	**Stirring (sec)**
Al-5Ti-1B	800	30	30

3.3.1 Casting:

It is the process of producing metal parts by pouring metal into the mould cavity of the required shape and allowing the metal to solidify. The solidified metal piece is called as "casting".

Fig 3.2 Electric furnace Fig 3.3 molten metal pouring to the die

3.3.2 Die Casting:

The process of producing near net shape casting by pouring molten metal in metallic cavities.

Table 3.2 Process parameter for casting of samples

Temperature	700^0C
Holding time	20 -30 min
Degassing agent	Hexachloro-ethane (1%wt)
Stirring	30 sec
Die dimension	Length -14 mm Diameter- 35 mm
Temperature	1000°C
Voltage	230
Power	6 KW(3-Phase)

Fig 3.4 showing grinded sample

The sample was then polished on a fine polishing machine using Alumina/diamond polishes.

3.4 Characterization:

3.4.1 Micro Structural Analysis

The well-polished samples were then observed under an optical microscope. Micrographswere taken with the help of CCD camera attached tothe optical micro-scope and are furtherviewe d on computerwith optical image analyzer software at magnification of 200X and 400X for all the different samples.

3.4.2 Optical Microscopy

Microstructures of the alloy samples were observed under computerized optical microscope. The Al-Si samples of different composition of grain refiner mechanically polished using standard metallographic techniques before the examination. Characterization is done in etched conditions. Etching was done using the Keller's reagent (1 volume part of hydrofluoric acid (48%), 1.5 volume part of hydrochloric acid, 2.5 volume parts of nitric acid and 95 volume parts of water).

Fig 3.4.1 Optical microscope for micro structural analysis

Table 3.4 Specifications of microscope

Experiment set up data	
Magnification	400x
Objective magnification	40x
Resolution	0.0005
Measuring distance	0.23 m
Objective specification distance	0.9 mm

3.4.2 Vickers Hardness Test

The micro hardness tests of all the samples have been done using a Vickers's hardness testing machine. The applied load during the testing was 0 .3 kg, with a dwell time of 30 s. It has a square-base diamond pyramid indenter. The Vickers hardness number (VHN) is calculated from the following equation:

$VHN = 1.854\ P/D^2$

Where,
P- Applied load, kg
D-Average length of diagonals, mm

Fig 3.4.2 Vickers hardness testing machine (Zwick 3212 hardness test)

3.4.3 Density Measurement

Density of sample measured in density measuring instrument (HT/HTR 220E). It worked on the tuning fork technology. Weight of samples has taken in air and water respectively in the instrument (VIBRA-HT/HTR 220E) and the density has calculated for every samples.

Fig.3.4.3 Density measuring instrument

3.4.4 Tensile Test

Tensile properties of the alloys were analyzed by carrying out test on the tensometer. Tensile tests were carried out with a load of 20 KN and cross-sectional area of 63.23mm^2, gauge length was 36 mm and gauge diameter was 9 mm. During the tests, the load elongation data is captured in a digital screen, whose data is used for further analysis.

Table 3.4 Specifications of tensile samples and motor specification of tensometer

Standard specimen specification	
Gauge length- 36 mm	
Gauge diameter- 9 mm	
Load	20 KN
Cross-sectional area	63.23 cm2
Motor specification	
Speed	1440
HP	¼ KW
Frequency	50 cycles
Current	2 Amp
Voltage	220 V

Fig 3.4.4 Tensometer (TIMER3) for tensile test

IV. RESULT AND DISSCUSION

4.1 Microstructure

Micro structural investigation of different sample will be analyses in this section at different magnification captured by optical microscope.

4.1.1 Microstructure of Base Alloy

Microstructure obtained from optical microscope for Al-Si alloy containing 12.6%Wt Si in fig.4.1 for different magnification.

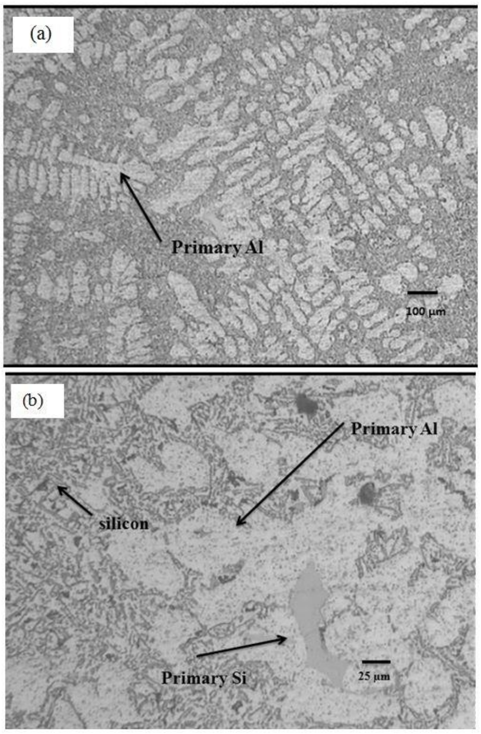


Fig 4.1 Microstructure of Al-Si alloy a) at 100x, b) at 400x

Microstructure of hypo-eutectic Al-Si captured in optical microscope gives information about the presence of α-Al, primary silicon and eutectic silicon in the alloy.

4.2 Hardness:

It embraces many different properties such as resistance to wear, scratching, deformation and machine ability etc. Hardness can be defined as the resistance of a metal to attempts to deform it.

Table 4.1 showing for Vickers hardness number for different samples.

Sample No	Aluminum-silicon in(gms)	Magnesium (wt %)	Master alloy (wt %)	Hardness VHN
1	250	0.5	0.5	95.32
2	250	0.5	1.0	101.3
3	250	0.5	1.5	91.83
4	250	0.5	2.0	117.38
5	250	1.0	0.5	115.4
6	250	1.0	1.0	119.87
7	250	1.0	1.5	102.54
8	250	1.0	2.0	118.28
9	250	1.5	0.5	108.27
10	250	1.5	1.0	124.57
11	250	1.5	1.5	117.57
12	250	1.5	2.0	119.57
13	250	2.0	0.5	129.29
14	250	2.0	1.0	111.81
15	250	2.0	1.5	113.43
16	250	2.0	2.0	106.7

Fig 4.4 samples Vs Hardness

4.3 Density:

The mass density of the material is the mass per unit volume. Unit-kg/m^3.

Table 4.3.2 showing for Density for different samples.

Sample No	Al-Si in(gms)	Mg (wt %)	Master alloy (wt %)	Density (gm/cc)
1	250	0.5	0.5	2.6948
2	250	0.5	1.0	2.6863
3	250	0.5	1.5	2.6876
4	250	0.5	2.0	2.7014
5	250	1.0	0.5	2.7008
6	250	1.0	1.0	2.7171
7	250	1.0	1.5	2.7106
8	250	1.0	2.0	2.7162
9	250	1.5	0.5	2.7498
10	250	1.5	1.0	2.7355
11	250	1.5	1.5	2.7200
12	250	1.5	2.0	2.6865
13	250	2.0	0.5	2.7210
14	250	2.0	1.0	2.6895
15	250	2.0	1.5	2.7112
16	250	2.0	2.0	2.6371

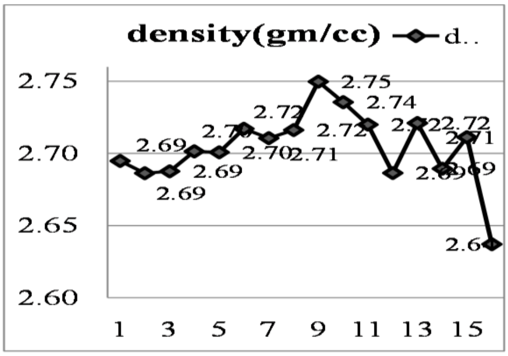


Fig 4.5 samples Vs density

4.4 Tensile Strength:

Table 4.4.1 showing for tensile strength for different samples.

Sample No	Al-Si in(gms)	Magnesium (wt %)	Master alloy (wt %)	TS (N/mm^{2})
1	250	0.5	0.5	335.1
2	250	0.5	1.0	356.75
3	250	0.5	1.5	323.31
4	250	0.5	2.0	415.35
5	250	1.0	0.5	409.07
6	250	1.0	1.0	421.43
7	250	1.0	1.5	361.4
8	250	1.0	2.0	417.61
9	250	1.5	0.5	382.39
10	250	1.5	1.0	438.99
11	250	1.5	1.5	415.45
12	250	1.5	2.0	420.74
13	250	2.0	0.5	458.71
14	250	2.0	1.0	395.04
15	250	2.0	1.5	400.34
16	250	2.0	2.0	376.21

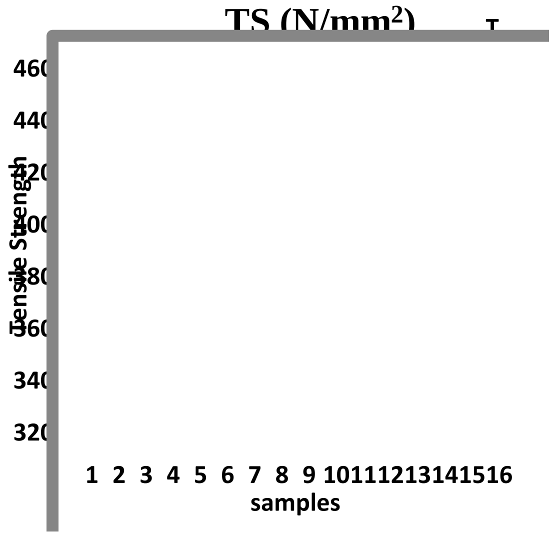


Fig 4.6 samples Vs Tensile Strength

IV. CONCLUSION

A conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest

- Eutectic aluminum silicon alloys were synthesized.
- Al5Ti1B Master alloy was prepared via Induction furnace (Reaction of K_2TiF_6+ KBF_4 with CP Al).
- The hardness, tensile property of Before and after Grain refinement of Eutectic Al-Si alloy with different addition level of Mg were studied.
- Mechanical properties are increased and best combination of alloys were noted that sample number 13 such as Eutectic Al-Si + 2.0 % Mg+ 0.5% Al5Ti1B.
- In future automobile piston parts are made up of like high strength alloy, based on this research work I conclude that the master alloy(Al-Ti-B) 0.5%, Mg 2.0% and eutectic Al-Si Alloy enhances better strength to alloy material.

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