# IMPACT OF STRONTIUM, MAGNESIUM AND NICKEL ON MECHANICAL PROPERTIES OF Al-5 Si-3 Cu (A319) ALUMINIUM ALLOY

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**Abstract -** *Aluminium and its alloys have number of applications, mainly, in the field of aerospace and automobile industry. A319 (Al-Si) based alloys are used in cylinder heads, engine blocks, suspension etc. The major drawback for this alloy is that of low tensile strength (180 - 220MPa). Porosity also is a major problem in high pressure and gravity die casting process used for the manufacturing of components. In the present work the major aim is to study the effects of alloying elements Strontium, Magnesium and Nickel in the mechanical properties ofA319. Development of porous free castings using Stir casting technique is also an objective of this work. Six castings were developed for this study (A319, A319 – 0.04Sr, A319 - 0.05 Ni, A319 –0.5Mg - 0.04Sr and A319 – 0.5Mg – 0.5Ni – 0.04Sr). The microstructure and EDAX analysis were done to identify the phases present. Different mechanical tests were carried out to study the effect of these alloying elements on basic A319 alloy. The results showed that these alloying elements have a positive influence on A319 alloy. It is seen that the tensile strength of the material has improved for each alloy composition and maximum tensile strength is obtained as238 MPa for A319 – 0.5Mg –0.5Ni – 0.04Sr alloy.*

***Key Words*: Aluminium, A319 (Al-Si) based alloys, Stir Casting, EDAX.**

## 1. INTRODUCTION

Aluminium is an element in the boron group with symbol Al and atomic number 13. It is a silvery- white, soft, nonmagnetic, ductile metal. Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials [6]. This work is based on aluminium silicon alloys. The aluminium silicon alloys have wide range of applications in the automobile industry. A319 (Al- 5Si- 3Cu) is the mostly used aluminium silicon alloy. Castings manufactured from this alloy can be heat treated to improve the mechanical properties. The machining properties are better than the high silicon aluminium alloys and considerably improve with heat treatment [5]. Engine blocks, engine cover and suspension parts are manufactured using A319 alloy. When these parts need to be heavy loaded conditions, the weight of the component should be increased to have higher strength which leads to reduced mileage of automobiles. High pressure die casting, which is used for manufacturing A319 components, is found to have porosity [6]. The objective of this project is to develop a new alloy based on A319 aluminium alloy system without porosity having high tensile strength by optimizing alloying compositions with different additives which are explained in the literature survey. Now days, the need for materials having high strength to weight ratio is increasing.

It is seen that the A319 alloy which is used in suspensions systems has only a low tensile strength (only having a peak tensile strength of 220MPa). This lack of strength is a major problem and the industry has been looking at improved materials with higher tensile strength. Many research studies are going on around the world to create newer materials with improved properties. Three possible solutions for increasing the tensile strength of A319 without compromising on other properties are,

**1**. Development of a new alloy

**2**. Addition of Nano or micro particles to improve strength

**3**. Alloying A319 with different elements and optimizing the percentage addition for obtaining maximum tensile strength for the alloy

In this thesis, the effect of alloying elements Strontium, Magnesium and Nickel on A319 alloy are studied. Stir casting techniques is used to study the effect of these alloying elements.

### 1.1 A319 ALLOY

A319 (Al- Si- Cu) aluminum alloy is widely used for a range of engineering applications where moderate stress is envisaged. Its casting characteristics make it ideal for castings of varying section thickness as it can cope with heavy and moderately thin sections. Castings manufactured from this alloy can be heat treated to improve the mechanical properties. The machining properties are better than the high silicon aluminum alloys and considerably improve with heat treatment. They are used in automotive cylinder heads, internal combustion engine crankcases, suspensions, engine mountings, gearboxes, etc;

| ALLOY | DENSITY Kg/m$^3$ | MELTING RANGE ($^0$C) | TENSILE STRENGTH (MPa) | YIELD STRENGTH (MPa) | BRINELL HARDNESS (BHN) |
|---|---|---|---|---|---|
| 319.0 | 2800 | 516- 604 | 220 | 105 | 80- 110 |

**Table 1.2** Properties of A319 alloy

## 1.2 Objectives

The main objectives of this project are to
**1**. To develop a new alloy based on A319 aluminum alloy system having high strength by optimizing the alloy composition.
**2.** To study the effect of magnesium, and nickel, strontium when alloyed with Al- Si- Cu alloy (A319).
**3.** To study the differences in mechanical properties of As-cast alloys
**4.** To develop porous free alloy by using stir casting.

## 2. LITERATURE REVIEW

## 2.1 Aluminum

Aluminum is the second most plentiful element on earth's crust. First commercial applications of aluminum included mirror frames, cooking utensils etc. But towards the end of 19th century aluminum grew so as to influence common life in different ways. Most important characteristic of aluminum is its versatility. The range of mechanical properties that can be developed through alloying is remarkable. The properties of aluminum that makes it attractive for wide usage today are its light weight, fabricability corrosion resistance and mechanical properties [1]. Aluminum surfaces can be highly reflective. Radiant energy, visible light, electromagnetic waves etc. are efficiently reflected. Aluminum has excellent electrical and thermal conductivity. Aluminum is non-ferromagnetic, which makes it a suitable material for electrical and electronics industry.

The reason why aluminum alloys has attracted worldwide attention is due to its high strength to weight ratio. With a density one third to that of steel, the fuel efficiency is considerably improved with the use of aluminum components in the automotive industry. A319 alloy is mostly used in the transport industry. A319 is a cast aluminum alloy with silicon as its major alloying element, about 5.5- 6.5 %. The alloy is heat treatable and hence is strengthened by precipitation hardening. Excellent mechanical properties of A319 alloy enable it to be used in automotive applications.

The alloy is mainly used in the fabrication of cylinder heads and engine blocks. 319 is also used for manufacturing crank cases, piano plates, type writer frames etc… due to its good casting characteristics, low cost component production and energy efficiency. The major alloying elements in 319 are Silicon and Copper. The primary role of silicon in the alloy is to improve its casting characteristics. Silicon does not form any compounds or phases with aluminium. It forms a solid solution with eutectic point at 12.5% Silicon at 5770 C. 319 alloy is a hypoeutectic aluminium- silicon system with 5.5-6.5% silicon content. The addition of silicon to aluminum is found to improve its fluidity dramatically. In addition to fluidity, hot tear resistance and feeding characteristics are also improved. The Al- Si cast alloys belong to 3XX.X group. As per the designation system, first digit '3' indicates that its primary alloying is silicon addition. The next two digits identify the particular alloy (eg. 319, 356 etc) and the digit after the dot indicates whether it is cast or ingot form. [3] 319.0 is cast whereas 319.1 is an ingot. 3XX.X alloys are non-heat treatable. But they can be heat treated upon additions of Cu, Mg etc. 319 alloy contains Cu in the range of 3- 4%. The addition of Cu enhances the strength of the alloy by precipitation of Al2Cu phase after heat treatment. It can be formed either as block like Al2Cu or as eutectic Al+Al2Cu. [3]. the major alloying elements and effects on properties of aluminum is shown in figure 2.1.


**Fig. 2.1** Common alloying elements and their effects in aluminium

Aluminum casting alloy with silicon as major alloying element are most important commercial casting alloy because of their superior casting characteristics, Al- Si alloy have comparatively high fluidity in molten state, excellent feeding during solidification, comparative freedom from hot shortness. Silicon does not reduce good corrosion resistance of pure aluminum and in some cases increases corrosion resistance in mild acidic environment [4]. Among these aluminum cast alloys, the 319- type alloys have become the object of extensive investigation considering their practical importance to the transport industry.

## 3. PROBLEM AND METHODOLOGY

## 3.1 Problem Definition

Aluminum and its alloys have a number of applications, mainly, in the field of aerospace and automobile industry. A319 (Al-Si) based alloys are used in cylinder heads, engine blocks, suspension etc. The major drawback for this alloy is that of low tensile strength (180 - 220 MPa). Porosity also is a major problem in high pressure and gravity die casting process used for the manufacturing of components. This lack of strength is a major problem and the industry has been looking at improved materials with higher tensile strength. Many research studies are going on around the world to create newer materials with improved properties. The possible solutions for increasing the tensile strength of A319 without compromising on other properties are,

1. Addition of alloying elements
2. Varying the casting techniques
3. Strengthening by secondary processes
4. Addition of nano or micro particles

This project work is based on addition of alloying elements (Strontium, Magnesium and Nickel) and studying its effects on the mechanical properties of A319 alloy. In this work usage of stir casting is implemented. The main objective of this project is to increase the tensile strength of A319 alloy without much variation in its density.

### 3.2 Fixing Composition and Casting

First step was to fix the compositions to be casted. While doing the literature review, it was identified the maximum amount of strontium that have positive influence in A319 alloy is limited to 0.04 percentage. So the first casting was set to a composition of Al- 5Si- 3Cu- 0.04Sr[8]. These castings can be further used to study the influence of strontium in A319 alloys by different testes. The second casting is fixed to have a composition of Al- 5Si- 3Cu- 0.5Mg- .04Sr, this can be used to study about the effects of magnesium and strontium in A319 alloy. The percentage of magnesium was test according to finds from literature survey that 0.5 % Mg can provide maximum strength to A319 alloy [5]. Next is two casting can be used to identify the effect of nickel only on A319 alloy when alloyed at 0.5%. Next two casting can be used to study the combined effect of 0.04 % strontium and 0.5%Ni, 0.04 % strontium and 0.5%Ni, 0.5%Mg respectively [13- 14].

### 3.3 EDAX and Density Measurement

After casting the very next stage is to take EDAX analysis of the casted samples. This is to ensure that the composition or new alloy contains all alloying elements in required percentage. The density measure can provide the exact mass of the new alloy developed. Each alloy should be casted using stir casting methods.

### 3.4 Microstructure Analysis

All examinations of microstructure have begun with the use of scanning electron microscope, starting at low magnification, followed by progressively higher magnifications for efficient assessment of basic characteristics of the microstructure. Microstructures are taken for different magnifications 50x, 100x, 200x, 500x for as cast samples.

### 3.5 Mechanical Testing

The required mechanical testes for tensile, hardness and density are to be performed for identifying the various properties of the alloys casted and to reach in a conclusion. Corrosion test has to be conducted for studying corrosion behaviour of the newly developed alloys.

### 3.6 Methodology Flowchart

The master alloy used for the experiments was A319 i.e. Al- 5Si- 3Cu. The additions included 0.5% Mg, 0.04% Sr and 0.5% Ni. This alloy was casted using stir casting technique. The specimens were cut from the castings to perform various studies for both of these conditions. Once the specimens from as cast conditions were ready, testing was carried out on them. Figure 3.1 shows the entire methodology of the project.

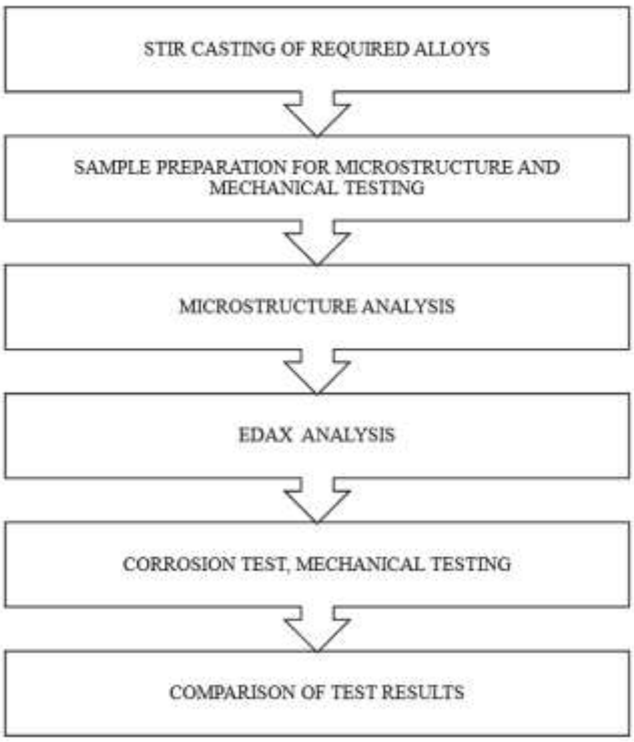


**Fig. 3.1** Methodology flowchart

## 4. EXPERIMENTATION

### 4.1 Alloy Preparation

The first step in the experimental procedure is casting of required alloys. For casting first, the alloys should be prepared by measuring its weights cleaning etc. The following ingots were used for preparation of the alloys required for experiments 319 ingot.

1. Aluminum block
2. Srpowder
3. Mg powder
4. Ni powder
5. Cu powder
6. Si powder

**Fig. 4.1** Ingot

## 4.2. Preheating of mould and ingots

Ingots are preheated by keeping it upon the induction furnace. Plate mould were preheated to a temperature of 2500C in the preheating oven. Preheating of stir cast die was carried out using heat extracted from melt of scrap metal. The preheating furnace is shown in following figure. Figure 3.3 shows the preheating oven.

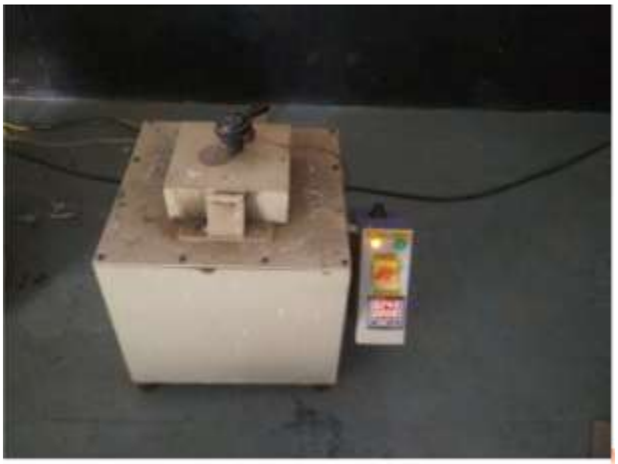

**Fig. 4.2** preheating oven

### 4.3 Furnace

Electrically operated induction furnace was used to melt the alloy. The heat is transferred to the metal through convection and radiation. When the crucible kept in the furnace attains 700- 750°C, the preheated ingots were charged into the crucible. The temperature of the melt was measured and monitored using thermocouple. Figure 3.5 shows the induction furnace and it temperature control set up.

**Fig. 4.3** Induction Furnace

### 4.4 Crucible

Clay crucibles are used to prepare the melt. They are preheated using oven for 8 hours up to 800 °C. The temperature is raised in steps of 100°C in each 1 hour. Crucible used for melting of ingots.

### 4.5 Pouring of metal

The molten metal was poured into the moulds at 710°C. The molten metal is poured into plate mould. Then the melt was allowed to solidify. After solidification the casting is removed from the mould. Moulds used were made of cast iron.

**Fig. 4.4** Pouring of molten metal to solidified the alloy

## 5. CASTING

### 5.1 Casting details

1. Temperature range of induction furnace : 0 to 1200°C
2. Preheating temperature of mould : 250°C
3. Size of cast : 100mm x100mm x10 mm

### 5.2 Casting Procedure

The Al ingots & Cast iron moulds, which are used for casting, is preheated to a temperature of $250^0$C for avoiding moisture. Then moulds are place on wise. The furnace (Induction type) was switched on and the crucible containing Al ingots was placed into furnace. The tongs and skimmer are kept above the furnace for preheating. The remaining alloy (other than master alloy) is in powder form. When the temperature of the melt reached around 7000C, then stirring is started with the help of crucible and remaining alloy according to the required wt% was added. Then crucible containing Al alloy again heated to 5-10min.Then the crucible is taken out and slag is removed by using skimmer. Then with in 5min the melts was poured at 7000- 7100C into the preheated mould and allowed to solidify. After solidification the casting was taken out. The dimension of the plate was 100mm x100mm x10 mm.

**Fig. 5.1** Cast sample

### 5.3 EDM MACHINING

In wire EDM machining process, a thin metallic wire is fed on to the work piece.which is submerged in a tank of dielectric fluid such as deionized water. The process can also cut metal plates with accurate measures. , which are difficult to machined with other methods. The wire which is constantly fed from a spool, is held between upper and lower diamond guides. The upper guide can moved independently in z- u- v axis, giving a flexibility to cut tapered and transitioning shapes.

**Fig. 5.2** Wire EDM cutting machined sample

### 5.4 List of Alloy Composition

The table below shows the list of different alloy composition used for studying the effects of strontium, magnesium and nickel on determining the mechanical properties of the alloy.

The composition of basic A319 is Al – 5Si – 3Cu. All the six castings taken were of different combinations

| Sl.No. | Composition |
|---|---|
| 1 | A319 |
| 2 | A319 – 0.04Sr |
| 3 | A319 – 0.5Mg – 0.04Sr |
| 4 | A319 – 0.5Ni |
| 5 | A319 – 0.5Ni – 0.04Sr |
| 6 | A319 – 0.5Mg – 0.5Ni – 0.04Sr |

**Table. 5.1** List of Alloy composition

## 6. TESTING

### 6.1 MECHANICAL TESTING

#### 6.1.1 Density

Density is an important physical characteristic of matter. All objects have density and that density can increase or decrease as the result of actions taken on the object. The effects of density are important for the workings of the universe and for our daily lives. It is simple to find the density of an object and see the effect of density. The Archimedes principle is used to found the density from the following equation. The apparatus used to calculate density is shown in figure.

$$\text{Density} = \frac{DRYWEIGHT}{DRYWEIGHT - WETWEIGHT}\ g/cm^3 \ \ldots\ldots$$

Dry weight is the weight which is measured keeping the test specimen in dry stage. Wet weight is measured by the weigh balance kept under water.

**Fig. 6.1** Density measuring apparatus

### 6.1.2 Hardness

Hardness measurements were carried out using INDENTEC Universal hardness testing machine. The BHN was measured using indenter ball diameter of 2.0 mm and a load of 50kgf. The diameter of the impression made on the test piece is subsequently measured by means of a microscope the order of accuracy being ±0.01mm. The surface of the specimens has been machined and polished to 600 grit size on which the impression was made. The distance between the centers of indentation from the edge of specimen or edge of another indentation is shows the Brinell hardness testing machine.

**Fig. 6.2** Hardness testing machine

### 6.1.3 Tensile testing

Tension test was conducted to evaluate Ultimate tensile strength. The tests were conducted in as cast state. The specimens were prepared as per the standard size ASTM E8M04. During this test, the force applied to the test piece and the amount of elongation of the test piece was measured. Simultaneously. The applied force is measured by the test machine. Universal Testing Machine model (CUTM 50 KN) was used for tensile testing. Figure shows the tensile testing specimen after breaking, 4.16b shows the tensile specimen and figure shows the tensile testing machine.


**Fig.6.3** Tensile testing machine

**Fig. 6.4** Tensile specimen after breaking

## 7. RESULTS AND DISCUSSION

This chapter deals with result and its interpretations for studying the effects of Strontium, Magnesium and Nickel on mechanical properties of A319 alloy. EDAX, Microstructure analysis were done to confirm the presence and percent of

required alloying elements. Microstructure of all six castings were studied to understand the changes happened to it. It also reports about the density values, hardness, tensile and corrosion behavior of
all six castings.

### 7.1 EDAX ANALYSIS

EDAX analysis was done to identify the main elements of Al alloy. It indicate percentage of each elements in alloy. The first casting is conducted with Al- 3Cu- 5Si, and second and third casting contained 0.04% Sr. Third and fifth casting contains 0.5%Mg.Fourth, Fifth and Sixth castings contains 0.5%Ni. The fig

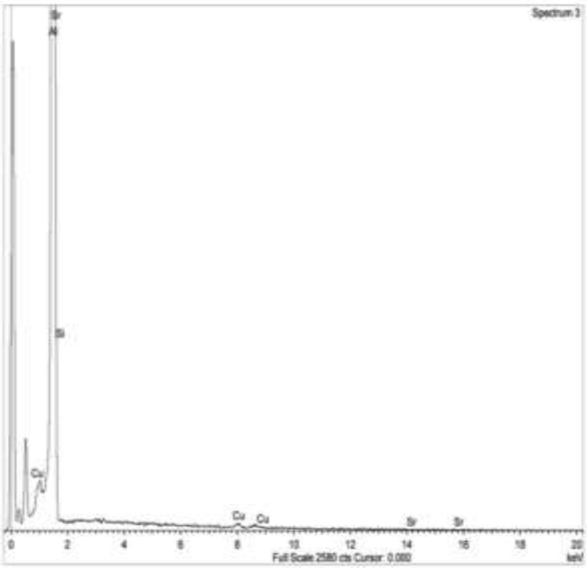

**Fig. 7.1** EDAX analysis of Sample V11 ( A319 – 0.04Sr)

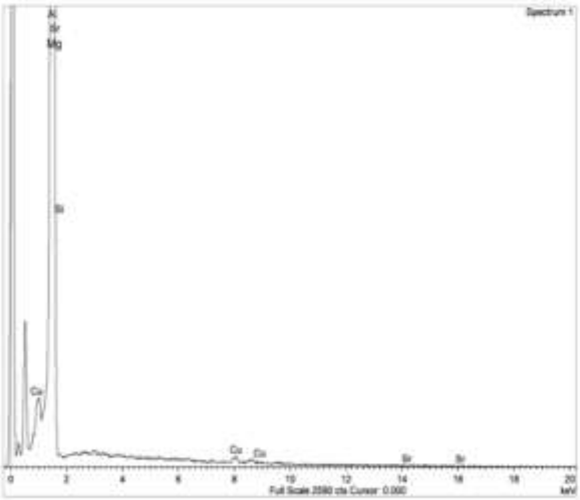

**Fig.7.2** EDAX analysis of Sample V12(A319 – 0.5Mg – 0.04Sr)

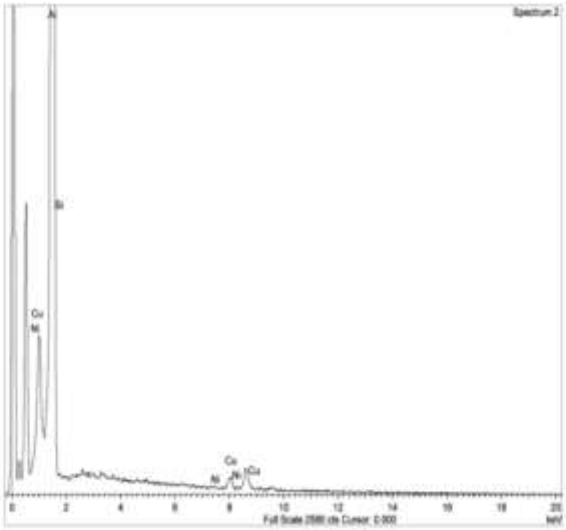

**Fig. 7.3** EDAX analysis of Sample V13 (A319 – 0.5Ni)

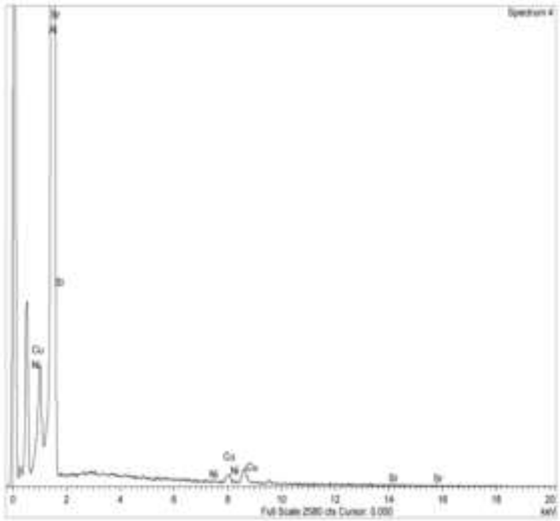

**Fig. 7.4** EDAX analysis of Sample V14(A319 – 0.5Ni – 0.04Sr

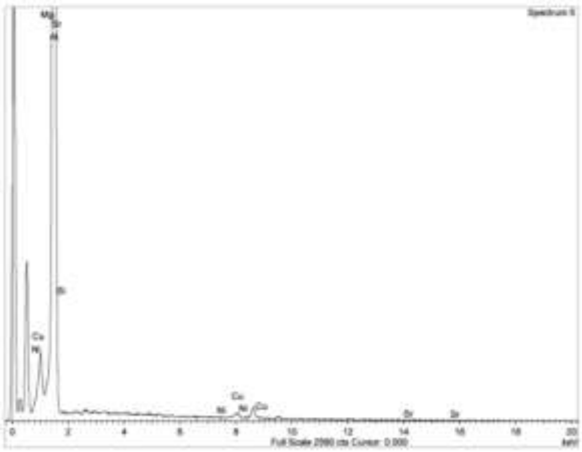

**Fig. 7.5** EDAX analysis of Sample V15(A319 – 0.5Mg – 0.5Ni – 0.04Sr)

### 7.3 EDAX Analysis Results

The chemical composition of the alloy castings was analyzed using Optical emission spectrometer, and the results are given in Table

| Elements | Si | Cu | Mg | Sr | Ni | Al |
|---|---|---|---|---|---|---|
| V11 (wt%) | 4.82 | 2.98 | 0 | 0.04 | 0 | 92.16 |
| V12 (wt%) | 4.78 | 2.78 | 0.53 | 0.04 | 0 | 91.87 |
| V13 (wt%) | 4.88 | 2.86 | 0 | 0 | 0.48 | 92.67 |
| V14(wt%) | 4.91 | 2.84 | 0 | 0.04 | 0.54 | 91.67 |
| V15(wt%) | 4.91 | 0.45 | 0.48 | 0.04 | 0.47 | 91.4 |

**Table 7.1** Chemical composition of castings

The alloy V11 with composition Al – 5Si – 3Cu- 0.04 Sris taken as base alloy without Mg content. 0.04% Sr is added for modifying silicon. In the second compositonV12 A319 – 0.5Mg–0.04Sr. In the third composition V13 A319 – 0.5Ni, 0.5%Ni is added to base alloy with obtaining the required composition. In fourth composition V14 A319 – 0.5Ni 0.04Sr and in fifth composition A319 – 0.5Mg – 0.5Ni – 0.04Sr. The composition analyses confirm that main alloying elements are present within the specified limits. From the table above it can be seen that the casting was obtained in the required combination. Even though there are small deviations from the exact percentage needed it can be neglected.

### 7.4 MICROSTRUCTURE STUDY

Microstructures analysis obtained for all six castings in the as cast condition is given below It can be used to identify phase's present, soundness of the casting. Tensile properties and other mechanical properties like wear and hardness depend strongly on the microstructural features such as size, and shape etc. Also it can be used to study the difference in grain size and grain boundary in stir cast.

### 7.4.1 Microstructure of A319

Figure shows microstructure of unmodified A319 alloy which consists of aluminum network and eutectic silicon. The morphology of silicon is plate like structure (acicular structure).It also shows the Al2Cu phase appears in blocky form and distributed very non- uniformly.

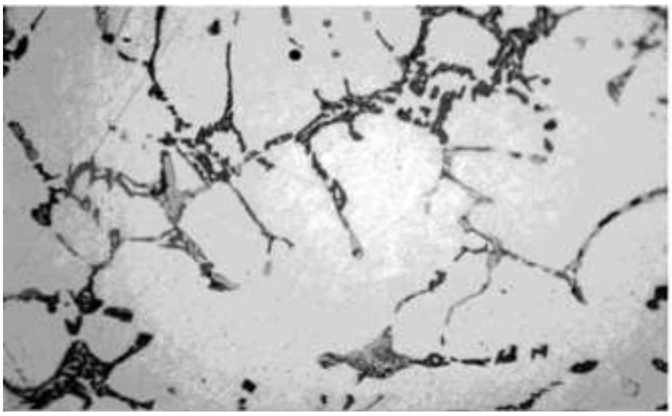

**Fig. 7.6** Microstructure of A319

### 7.4.2 Microstructure of A319 – 0.04Sr

The fig shows microstructure of A319 with addition of 0.04%Sr. The Al2Cu appears in a non uniform structure. Due to the addition of Sr, Cu atoms was distributed very effective to some extent.It also indicates the needle shape eutectic silicon and its size and shape play an important role in the mechanical properties.

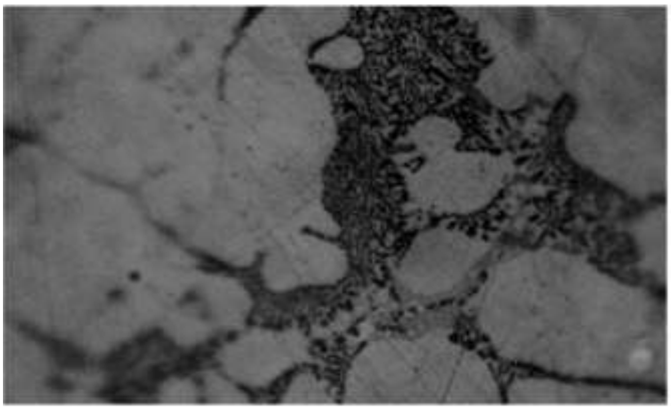

**Fig.7.7** Micro structure of A319 with addition of 0.04%Sr

### 7.4.3 Microstructure of A319 – 0.5Mg – 0.04Sr

Figure shows the addition of 0.5% Mg to A 319 compositions. Additional phases such as Mg2Si may be present in this alloy. But optical microstructure does not reveal these features since the Mg content is much less. Microstructure indicates that addition of strontium modifies silicon which is in the form of coarse and acicular in to finer fibrous structure.

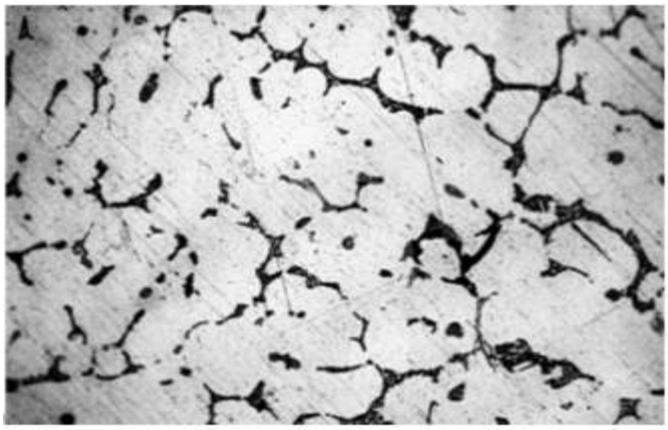

**Fig.7.8** A319 – 0.5Mg – 0.04Sr

### 7.4.4 Microstructure of A319- Ni

When nickel is added to A319 3 phases are found.Al3Ni2, Al7Cu4Ni, Al2 Cu. The creep features are mainly depend upon the copper content of phases. Here Al7CuNi is the high creep resistant phase. The phase of Al3 Ni consist of thin boundary .Hence which resist the slip process of Atoms during the deformation and increases the hardness.

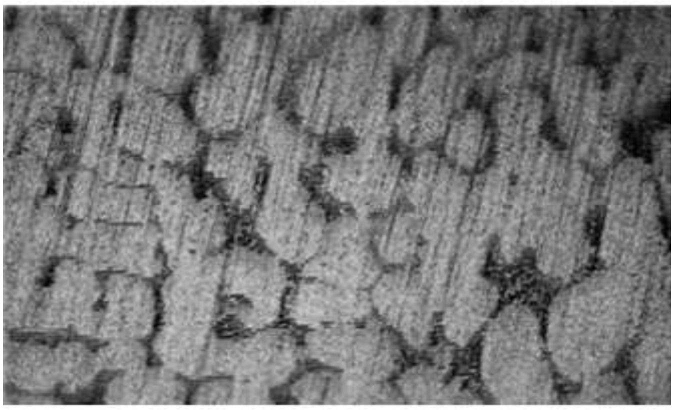

**Fig. 7.9** Microstructure of A319- Ni

### 7.4.5 Microstructure of A319 – 0.5Mg – 0.5Ni – 0.04Sr

Figure showing the microstructure of A319 with addition of 0.5Mg, 0.5Ni and 0.04Sr in as cast. Detailed micro structural investigations were carried out on the alloys. The addition of Ni refines the structure with a changes in intermetallic phase into fine fibrous Al3Ni.The Al3Ni displays as a lamellar or rod morphology.

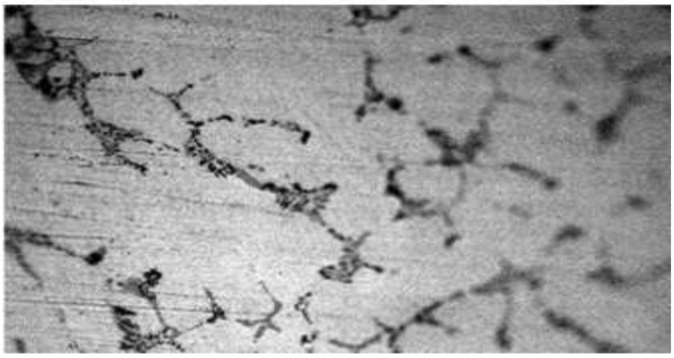

**Fig. 7.10** A319 – 0.5Mg – 0.5Ni – 0.04Sr

### 7.5 DENSITY VALUES

Density measuring equipment works based on Archimedes principle. The weight of the specimen is measured both under dry (dry weight)and wet(wet weight) conditions .And then using Archimedes principle the density is calculated. Table and figure shows the density comparison of castings to that of basic A319 alloy.

$$\text{Density} = \frac{Dryweight}{Dryweight - Wetweight}$$

| Alloy | Density (g/$cm^3$) |
|---|---|
| A319 (V0) | 2.74 |
| A319 - 0.04Sr(V1) | 2.749 |
| A319 - 0.5Mg - 0.04Sr(V2) | 2.752 |
| A319 - 0.05 Ni(V3) | 2.731 |
| A319 - 0.5Ni - 0.04Sr(V4) | 2.729 |
| A319 - 0.5Mg- 0.5Ni - 0.04Sr(V5) | 2.742 |

**Table 7.2** Density values of stir castings

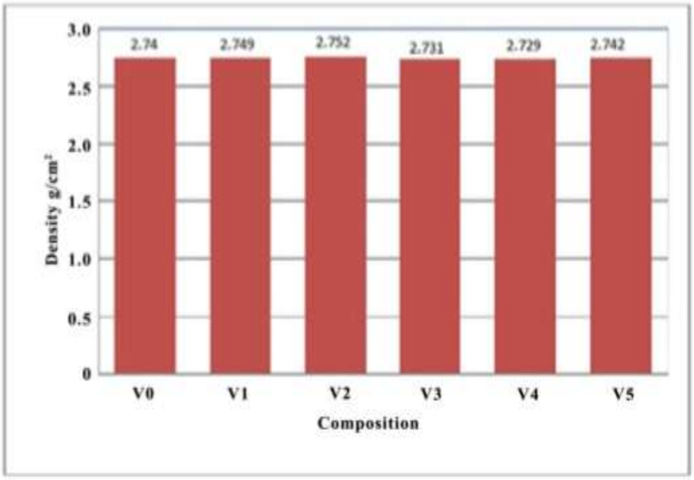


**Fig. 7.11**Graphical representation of density values

It is clear that V3 has produced the lowest density value.. And also the density of V5 is 2.733 which is obtained for A319 – 0.5Mg – 0.5Ni – 0.04Sr is also comparable to that of A319 alloy. The small increase in the density can be neglected.

V0 – Al- 3Cu- 5Si (A319)

V1 - A319- 0.04Sr

V2 - A319- 0.5Mg- 0.04Sr

V3 - A319- 0.05 Ni

V4 - A319 - 0.5Ni – 0.04Sr

V5 - A319- 0.5Mg- 0.5Ni- 0.04Sr

### 7.6 MECHANICAL PROPERTIES

Mechanical properties are also used to help classify and identify material. The most common properties considered are strength, ductility, hardness, impact resistance, and fracture toughness. Most structural materials are anisotropic, which means that their material properties vary with orientation The main mechanical properties that are deal in this work are hardness, tensile and Corrosion..

#### 7.6.1 Hardness Results

Brinell hardness number can be defined as a number expressing Brinell hardness and denoting the load applied in testing in kilograms divided by the spherical area of indentation produced in the specimen in square millimeters called also Brinell number. In the experiment, Brinell hardness test was used in attempt to examine the relation of the deformation of metal specimen to the hardness property of a metal. Table indicates hardness value of casted aluminum alloys. Figure shows the graphical representation of hardness values of Stir casted samples in as cast condition..

| Alloy | Hardness (BHN) |
|---|---|
| A319 (V0) | 75 |
| A319 - 0.04Sr(V1) | 80 |
| A319 - 0.5Mg - 0.04Sr(V2) | 90 |
| A319 - 0.05 Ni(V3) | 77 |
| A319 - 0.5Ni - 0.04Sr(V4) | 76 |
| A319 - 0.5Mg- 0.5Ni - 0.04Sr(V5) | 75 |

**Table 7.3** Hardness values of stir cast samples

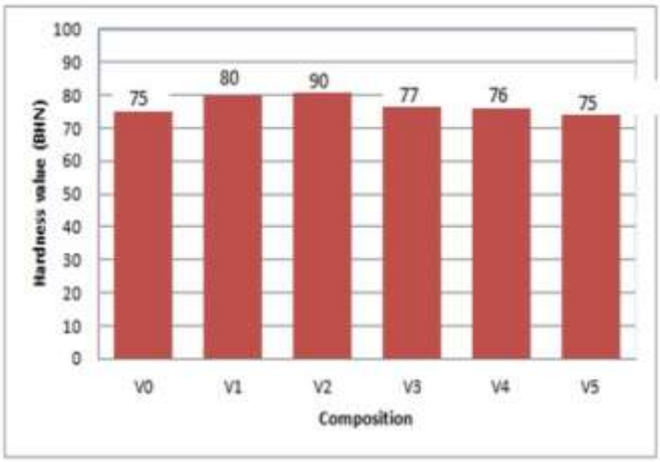


**Fig. 7.12** Hardness comparison of castings

From the results it is clear that A319 - 0.5Mg- 0.04Sr combination have the maximum hardness 90. When Ni is added with this combination (A319- 0.5Mg - 0.5Ni - 0.04Sr) hardness decreases to 75.

#### 7.6.2 Tensile results

For each alloy composition a plate casting of dimensions 100 x 100 x 10 mm cast. 6 tensile samples were taken. Ultimate tensile strength for each casting in as cast were given in table

| Composition | UTS Value (MPa) | | Average value |
|---|---|---|---|
| A319 | V0- 175.99 | V02- 173.98 | 175 |
| A319- 0.04Sr | V11- 184.99 | V21- 174.98 | 180 |
| A319- 0.5Mg- 0.04Sr | V12- 198.99 | V22 192.98 | 196 |
| A319- 0.05 Ni | V13- 213.98 | V23 220 | 217 |
| A319- 0.5Ni- 0.04Sr | V14 229.99 | V24 225.99 | 228 |
| A319- 0.5Mg- 0.5Ni- 0.04Sr | V15- 240 | V25- 235.99 | 238 |

**Table 7.4** Tensile properties samples.

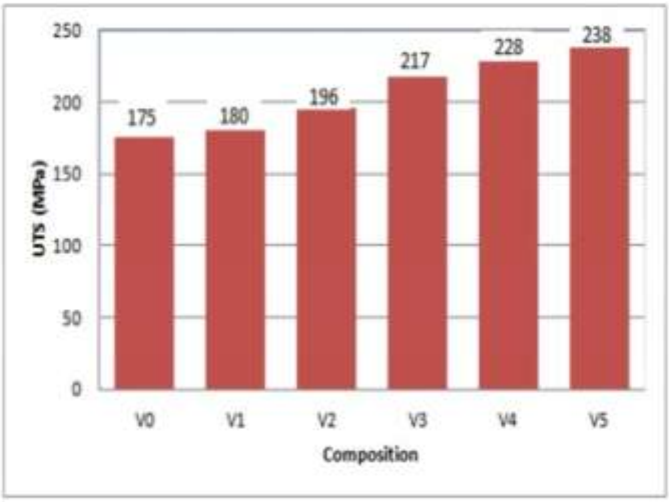


**Fig. 7.13** UTS comparison between basic A319 and developed alloys

From the plot it is clear that the objective of this project is attained. That is to increase the tensile strength of A319 alloys with addition of alloying elements Strontium, Magnesium and Nickel. The increased tensile strength is due to the formation different phases identified in micro structure analysis stage. By addition of 0.5Mg, 0.5Niand 0.04Sr to the base alloy we can derive a tensile strength of 238MPa without decreasing any of other properties.

**Table 7.5** Elongation properties samples.

| Composition | Elongation in mm | | Average value |
|---|---|---|---|
| A319 | V0- 25 | V02- 21 | 123 |
| A319- 0.04Sr | V11- 18 | V21- 19 | 18.5 |
| A319- 0.5Mg- 0.04Sr | V12- 24 | V22- 25 | 124.5 |
| A319- 0.05 Ni | V13- 23.5 | V23 - 23.5 | 23.5 |
| A319- 0.5Ni- 0.04Sr | V14- 21.5 | V24 - 22.5 | 22 |
| A319- 0.5Mg- 0.5Ni- 0.04Sr | V15- 26 | V25- 23.5 | 24.75 |

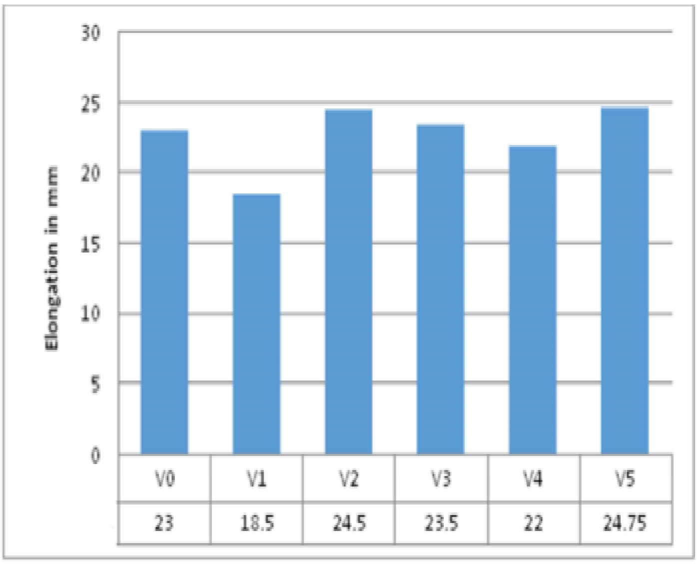


**Fig. 7.14** Elongation comparison between basic A319 and developed alloys

### 7.6.3 Corrosion Test

Two different corrosion tests were conducted for this studies (using different specimens). They are electro chemical test and immersion corrosion tests. Here immersion test is conducted for checking the corrosion rate of the alloys. For the study prepared sample immersed in the 3.5% of NaCl solution for 10 days. After the test the samples were taken out of the salt water and have to dip in the Nitric acids to remove the oxides form on the surface. The weight loss is calculated and the corrosion rate can be obtain by the equation:

$$\text{Corrosion rate} = \frac{K \times W}{(A \times T \times D)}$$

Where,

K = 87600 mm/yr (constant)

W = Weight loss in grams

A = Area in $cm^2$

T = Time of exposure in hours

D = Density in gm/cc

**Fig.7.15** Immersive corrosion test

| Alloy | Kvalue (constant) | Weight loss in grams (W) | Time (T) | Density (g/cc) | Corrosion rate(mm/yr) |
|---|---|---|---|---|---|
| A319 | 87600 | 0.0192 | 192 | 2.74 | 0.3197 |
| A319- 0.04Sr | 87600 | 0.0174 | 192 | 2.749 | 0.2887 |
| A319- 0.5Mg- 0.04Sr | 87600 | 0.0162 | 192 | 2.752 | 0.2685 |
| A319- 0.05 Ni | 87600 | 0.0187 | 192 | 2.731 | 0.3124 |
| A319- 0.5Ni- 0.04Sr | 87600 | 0.0176 | 192 | 2.729 | 0.2942 |
| A319- 0.5Mg- 0.5Ni- 0.04Sr | 87600 | 0.0153 | 192 | 2.742 | 0.2545 |

**Table 7.6** corrosion rate of aluminum alloys

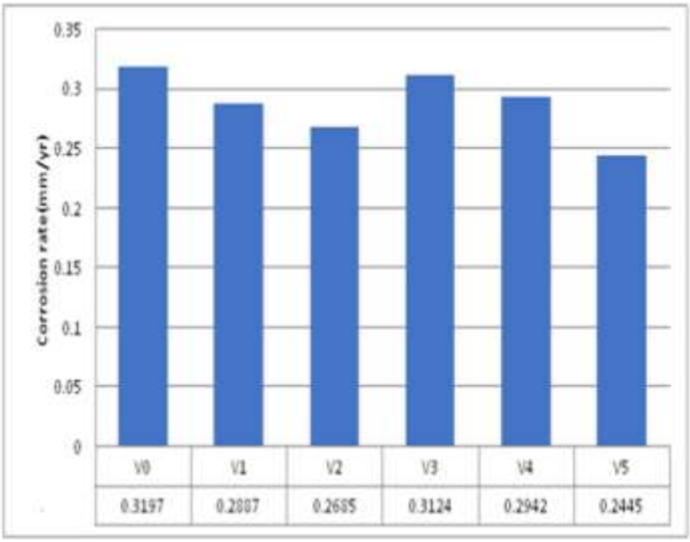


**Fig. 7.16** Corrosion rate comparison of each samples

## 6. CONCLUSION

After castings made, the EDAX analysis study was conducted and it shows the percentage composition of each alloy in acceptable limit. Then microstructure analysis were carried out to identify which all strengthening phases are present in the alloys. The results of mechanical experiments show that all alloying elements Sr, Mg and Ni found to have good effect on properties of A319 alloy expect for corrosion. The corrosion behavior analysis shows that, there is no much effect of Sr, Mg and Ni addition on A319 alloy. Similar for all alloys. The corrosion results show that there is no much impact for alloying elements. The density value of all compositions are observed in between 2.73 –2.75 which is very near to the base A319 alloy and thus the base alloy can be replaced with alloy having best mechanical properties. From the hardness results, it can be seen that the hardness value increased for Sr modified, Mg and Ni added alloys. Maximum hardness value observed is 90 A31- 0.5Mg – 0.04Sr alloy. When Ni is added to this alloy the hardness value reduced to 75, even though there is not much of a difference the resulting alloy is more ductile than Mg alone added alloy. Maximum tensile strength obtained is 238Mpa for A319 – 0.5Mg – 0.5Ni – 0.04Sr. Also other compositions are found to have good tensile properties than the basic A319 alloy. So from all the results obtained it shows A319 – 0.5Mg – 0.5Ni – 0.04Sr alloy is having much better properties than other alloys studied. The influence of Stir casting is clear from the result. Our objective was to increase the tensile strength of A319 alloy with minimum addition of alloying elements for suspension systems of vehicles. And from the results it is clear that the objective was achieved to a good extent.

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