Abstract- This paper aims to study the effect of Ce addition on mechanical properties of Al-12%Si Alloy. Ce was added in three different percentages (2%, 4%, & 6%). The alloy were prepared by induction furnace under Arargon atmosphere and poured into a sand mold then with the casting machined by Turning, next chemical analysis by X Ray Fluorescent (XRF) for the alloys and optical microscope for microstructure, the mechanical testing compression test and Vickers Micro hardness test were performed on the specimens, results showed an increase in mechanical properties and in decrease in hardness, the alloy with 6% Ce addition gave the best results in mechanical properties, while The Microstructure showed the Braking of the Si Dendrite into a coarse grains of Si with the increase of Ce Percentages.

Keywords: Al-Si Alloys, Mechanical Properties, Microstructure, Rare Earth Elements

I. INTRODUCTION

Aluminum-Silicon alloys are one of the most widely used alloys in the industry, the 413 alloy has applications in Miscellaneous thin-walled and intricately designed castings[1], since Al-Si Alloys are non-heat treatable [2] so adding alloying elements is the best alternative way to improve their properties and make them treatable in some cases. The most important Mechanical properties are Maximum Stress (σmax), Hardness (HV), and Elongation (%)[2] with The increasing demands for Rare earth element has increased in the last decade to improve the mechanical properties of Al-Alloys that is found in the works of Aiqin et al. 2013[3] also with other elements such as Phosphors or La added as (Elgallad et al. 2016)[4] or the addition of Ce in hypereutectic alloys Li et al. 2016 [5]. Ranajit et al. 2012[6] Studies on rare-earths as micro-alloying elements showed that they had beneficial effects on the mechanical properties of aluminum alloys. It was reported that addition of Ce to Al-Cu-Mg-Ag alloy improved the thermal stability of the Ω phase thus raised the service temperature of this alloy[5], Anasuya et al. 2009 [7] found that The increase of cerium content in the alloy led to higher wear resistance behavior for as-cast alloys. WhileAl-Uqaily et al. 2016 [8] found that addition of cerium led to decrease micro-hardness, increase corrosion resistance of Al-Si Alloys, Nogatta et al. 2004 studied the eutectic Modifications of Al-Si Alloy by Adding rare earth elements this study examine the effect of Ce Addition in three different percentages on mechanical properties and microstructure of Al-13%Si alloy, in this study the aim is to study the effect on mechanical Properties and microstructure.

II. EXPERIMENTAL WORK

2.1. Materials and Procedures

Pure Al foil (99.99%) Purity was provided by India Foils and Pure powder (Si 99.99%) purity were provided by RDH Chemical (UK) and Cerium (99.99%) purity was provided also RDH Chemical (UK), these were all melted at 700 °C in graphite crucible at induction furnace with an inert gas(Ar) atmosphere and mixed mechanically by stirring, then the molten metal was poured into a 34 steel mold, then the alloys re-melted with addition of Ce as a rare earth element in (2%, 4% and 6%) in the same conditions and poured into the same mold. The Alloys were cut be a Lethe into two types of specimens the first was (20mm diameter, 0.5 mm height) for Optical Microscope and XRF and the second specimen for compression test as ASTM E-9 (21mm diameter, 42 mm height).

2.2. Thermal Fatigue Test

XRF test was done at the Materials Research Labs at science and technology department for the Base Alloy, and The Metallurgy Laboratory at The Materials Engineering Department for the Modified Alloys by a NitonXLT alloy analyzer. The specimens were grinded in grinding device with sand paper (500, 600, 800, 1000, 1200) grading and polished with diamond paste and Al₂O₃ at speed 300-500 rpm, Then the specimens were etched by (H₂SO₄+HCl) and examined by bell Optical Microscope, after that Microhardness test was performed by Larray 600 device with 3 Kg load, finally compression test was performed by a computer controlled electronic universal testing machine type Larray 800 on the Specimens with using graphite as a lubricant.

III. RESULTS AND DISCUSSION

3.1. Chemical Analysis

Figure (1) shows XRF results in which the chemical Composition of the base alloy with Al, Si within range then the XRF analysis was done for the modified alloys by NitonXLT alloy analyzer Table (1) Shows the Results in which Ce is found within the Limits of the Alloy.
3.2. Microstructure

Figure (2) shows the microstructure of the base alloy while figure (3) shows the B1 alloy while figure (4) shows the B2 Alloy and figure(5) shows the B3 alloy. In figure (2) the typical microstructure of the Al-12%Si Al-Dentrate but in figure (3) and in figure (4) the dentrates are broken due to the addition of Ce as Li showed [8] that the microstructure the Si coarse shape is absent Ce dissolve the coarse Si Shapes (Needles, Paetelte) into the matrix the effect is also noticed in figure (5) the coarse Si has been dissolved into the Matrix. Addition of Ce causes particle coarsening at all concentrations studied. The present results on Ce are in contrast [3] just as this one also Ce. Moreover, the coarse acicular and plate-like eutectic, Si structure transformed into branched morphology, and the edges and corners of eutectic Si became smooth and round[4] eutectic silicon grains are refined gradually with the increasing of Ce content. [2].

Cerium will modify Si phase from acicular need. The addition of cerium resulted in the formation of (Al-Ce) and (Al-Si-Ce) intermetallic phases which led to the improvement of hardness and wear resistance. It has also been reported that (Ce) reduced
interdendritic spacing of the alloy which can resist the movement of dislocation. In addition, the strengthening effects of (Ce) atoms segregated at the grain boundary have the contribution of keeping the highest tensile properties. That is, to say, the main reason that makes the segregation of (Ce) atom at grain boundary increases the sliding resistance of the grain boundary increase the mechanical properties [7].

3.3 Mechanical Properties

Table(2) shows the Vickers Micro Hardness readings, the Hardness increased in the case of B3 and Decreased in the case of B2 this is similar to what (Joy Yii et al. 2012)[10] found in his study a low hardness with a big increase the hardness raised while in B2 it has a fine grain structure but in the case of B3 a coarse structure raised the Hardness Also (Al-Uqaily et al 2016) found the Addition of Cerium led to the decrease of microhardness[8]. Figure(6) shows the compression results of the Alloys with Table (2) shows the mechanical properties of the alloys, from the results yield stress increases with the rise of Ce percentage also the young modulus and the max. strain increased and Maximum Stress also increased with the increase of Ce because of the change of Morphology in the microstructure as(Aqin et al 2013) showed there are three reasons for that Firstly, the size of primary silicon crystal is refined and the stress concentration in the sharp corner is decreased. Secondly, the macrostructure of Al-Si Alloy is refined by the chemical compound of Ce. Lastly, Ce plays an important role of adsorbing gas and removing impurity in the smelting process.[3]

Table 2. Mechanical Properties Results for Base And Modified alloys refined by the chemical compound of Ce. Lastly, Ce plays an important role of adsorbing gas and removing impurity in the smelting process.[3]

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Yield Stress (MPa)</th>
<th>Ultimate Tensile Stress (MPa)</th>
<th>Young Median Stress (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>170</td>
<td>293.65</td>
<td>199.95</td>
</tr>
<tr>
<td>B2</td>
<td>195</td>
<td>353.65</td>
<td>225.95</td>
</tr>
<tr>
<td>B3</td>
<td>210</td>
<td>407.65</td>
<td>349.95</td>
</tr>
</tbody>
</table>

Fig 6 Stress-strain Diagram of the Alloys

IV. CONCLUSIONS

1. Cerium addition raised modulus of elasticity and Yield Stress in which increased the mechanical properties
2. Cerium addition increased the strain for all alloys
3. The addition of Cerium lowered the hardness and made the alloy tougher
4. The Addition of Ce Changed the microstructure to a coarse grain instead of Denterate.
5. The best results were with 6% Ce Addition.

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