International Journal of Automobile Engineering

E-ISSN: 2707-8213
P-ISSN: 2707-8205
IJAE 2020; 1(1): 42-54
Received: 11-11-2019
Accepted: 15-12-2019

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Investigation of mechanical and thermal properties of strontium modified aluminum (AA7175) alloy

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Abstract
Aluminum exhibit many attractive properties like low weight to strength ratio, good corrosion resistance etc. but pure aluminum alloy has low strength properties. This can be overcome by adding some alloying elements like Nb,Sr etc. the addition of strontium has beneficial results which changes the morphology of silicon present in the aluminum thereby increasing strength however, only 0.2%Sr is limited as excess strontium form as impurities in castings. The strength of this alloy is better improved by treatment process called AGING with different time and temperature conditions these heat treated alloys have beneficial effects on strength and other properties.

Keywords: AA7175, strontium addition, age treatment

1. Introduction

In most of the Al-Mg-Si work hardening and precipitation hardening are important to strengthen the aluminum alloys. By combining both the process mechanical properties can be increased to great extent. Changes in mechanical properties are analyzed by examining microstructure taken under scanning electron microscope. Natural aging increases the volume fraction of the precipitated particles. Aluminium alloy is hardened by precipitation heat treatment. Cold working is done to get required shape then aged to get required microstructure [1]. Aging is done to increase the resistance to thinning and then formed. By increasing amount of cold working strength of the alloy increases. Cold working increases the density of dislocation thereby increasing strength of the alloy. If these cold worked specimens are subjected to aging strength further increases. Heavy reduction in area gives more nucleation sites leads to increase in strength of the alloy. Pre-aging reduces reduction in area and ZP zones increases as amount of cold working increases and beta precipitates could take place. These precipitated particles act as pin to dislocation and improves strength of the alloy and cold working upto 20% strength due to precipitation hardening is less than the decrease in strength due to restoration process. Strength is increases if heat treated followed by cold work and even if cold is increased beyond the limit corresponding to aging time and aging temperature therefore it is better to cold work within the limit in order to increase the strength of the alloy. Dissolution of precipitates gives suitable microstructure during cold working. T. Kobayashi [2], in aluminium alloy microscopic cracks are occurred due to inclusions and second phase particles. Delamination occurs when normal stress reaches some value at room temperature. When iron content in aluminium increased fracture toughness and fatigue strength decreases. Modification of eutectic silicon can be done with addition of Ca and harmful effect of iron is decreased and increase in silicon content improves fatigue strength of the aluminium alloy. Strength and fracture of aluminium alloy is very important in aerospace application and its related fields. Ductile fracture occurs during sequences of nucleation, growth and coalescence of voids. Ductile-brittle transition is not takes place in BCC structure metals this provides us to improve resistance to ductile fracture by modifying the alloy. Care should be taken during aging because toughness of the alloy decreases if metal is over aged during heat treatment process and unstable fracture becomes common this should be avoided to rely on the products. In fact, fracture toughness more important in many application like fatigue, impact strength of the alloy. Usually in aluminium alloy ductile fracture is of dimple type in nature and this might happened because of fracture of inside second phase particles. Second phase particles are main cause for ductile fracture. Nucleation of voids takes place by the mechanism of interference of grain boundaries and slip band.

Coalescence of voids is very difficult to recognize because it happens rapidly. L. Bolzoni *et al*. [3], Cast aluminum alloys have their own benefits in automobile industry but their properties are not so good due to lack of grain refinement. Addition of grain refiner like Nb will refine the grains thereby increasing mechanical properties hence strength of the alloy systems. These refiner acts as potent nucleation sites in aluminium alloy and this leads to significant refinement of grain structures causing increase in strength and resistance to corrosion in aluminium alloy. Many scientific concepts are their behind this to develop grain structures out of which one is based on "solute" this is a peritectic reaction which is derived from phase diagram or hypo nucleation theory. In aluminium alloys inoculation is very easy because particles are added during solidification of molten metal. Depending upon method of inoculation nucleation process can be controlled and also formation of columnar grains can be minimised and equiaxed grains are formed these equiaxed grains increase strength by converting needle like grains into spherical shape. Not only mechanical properties like yield strength, tensile strength also other properties like formability can be significantly increased and good surface finish also obtained by refining the grains but low resistance to hot tear is found due to second phase particles in matrix of aluminium alloy. All these advantages directly linked to that inoculated melt easily in molten metal and distributes uniformly in parent matrix material. Residual particles present in the metal leads to defects in metal and efficiency also fade, which is either because of dissolution of the potential nucleation substrates as a function of density difference in molten metal. Finally presence of secondary particles in molten metal leads to decrease in grain refining efficiency and, eventually lowering of refinement. E.J. Pickering *et al.* [4], High-entropy alloys are those which contain more than five elements with nearly equiatomic ratios. These are so called because they allow more entropy of mixing and it is realized that this high mixing entropy is sufficient to form solid solution. Alloying is required to avoid intermetallic formation. Dendrite FCC is found at low temperature and it is also found that variation bonding energy also influences reduces in rate of solid solution. Heat treatment is carried out at 1000 ^{0} C for 1000 hours prior quenching in water. Microstructure is examined under transmission electron microscope. Interdendritic material was not appear to be homogeneous and precipitates were present. STEM resulted that spherical microstructure in the dendritic material. From STEM it is found that precipitates possess FCC crystal structure similar to that of matrix and fine precipitates were observed in dark-field image. Generally precipitates present in interdendritic material are well defined shape. And these usually possess FCC crystal structure. Upon cooling from solidus which will have some solubility in Cu at higher temperature. Aging at 1000 degree celsius for 1000 hours led to form two FCC phases are likely to be stable at higher temperature. This precipitation does not include formation of Cu and Ni rich compositions. Here precipitates are present both in dendritic and interdendritic material. The decomposition of precipitates and spinodal were observed in in an alloy while cooling. R.G. Song *et al.* [5], for alumnium inserts surface properties are very important from application point of view. Combining different materials with another metal we can able to get different properties as we required. Wide range of technologies are used to join the aluminium with other metals like magnesium to increase the additional strength. In this case thermal treatment should be avoided interface layers are capable withstanding more load. Renju Cheng *et al.* [6], Addition of strontium (Sr) in the alloy promotes segregation of Al and Zn in liquid phase during solidification and leads to grain refinement of Al and Zn in AZ31 alloy. Effect of strontium (Sr) is to increase the coefficient of distribution of Al in AZ311 alloy and it also improves GRF value of an alloy. It is well known that grain refinement will enhance mechanical properties like strength, formability very precisely. Some experts propose that low solubility of strontium (Sr) in an alloy is the main reason for grain refinement during solidification. The solute redistribution process decides the uniformity of composition solidification structure and also it has effect on precipitation. One parameter is used to describe redistribution is "k" called redistribution coefficient. The coefficient k0 is used for equilibrium solidification and it is defined as the ratio of solute concentration in solid phase to liquid phase. It is observed that addition of strontium has an effect on liquid phase. With the addition of 0.04%wt of Sr under temperature of 850k, solid solubility decreased from 0.04%wt and 0.0198%wt to 0.003% and .0045%wt respectively. As we increase the Sr content solid solubility of Al and Zn decreases indicating that it promotes the segregation of Al and Zn in liquid phase. It is also known that dendrite boundary is the last zone of solidification. At lower content of Sr, concentration of Al and Zn decreases with increase of Sr and vice-versa. At an early, addition of Sr second phases are refined and their amount has been increased. It is well known that segregation of elements in alloy indicates more precipitation of second phase particles. Both segregated and precipitated particles will contribute to the grain refinement. And also Sr has more effect on solute concentration of aluminium. Solute addition has the effect both on nucleation and grain growth in aluminium alloy system. It is also found that influence of Sr on aluminium is more than Zn. It is concluded that the Sr itself contributed more for the grain refinement by improving the GRF value. Chengwei Liao *et al.* [7], due to outstanding properties of aluminium alloys, it is extensively used in many of the industry for manufacturing of automobiles parts and components like piston, body sheet etc. But due to high silicon (Si) content, the aluminium alloy contains coarse grain structure and it needs to modify the morphology of Si in an alloy in order to improve the properties of the aluminium alloy and also it is a common practice for the aluminium alloy to modify to get required properties like high strength and resistance to environmental attack like corrosion etc. Sr has good recovery rate, modification performance and long modification time and also it has no environmental problem. Modifying the aluminium microstructure by alkaline earth metals like Sr, Ca, Ba is very easy because they combine with parent matrix very easily. First Na element is used to modify the Al-Si alloy. But now it becomes obsolete due to its low solubility and poor recovery. Therefore other elements have been tried and addition of Sb reduces mechanical properties and also it react with other elements like Sr. Of all other modifier strontium (Sr) is the best solution because it has high recovery rate, good modification performance and long modification period. Because of this Al-Sr master alloys are widely used in many foundry and other industry. SEM with 15Kv is used to examine the microstructure and direct reading spectrometer is used to study the Sr content in the aluminium alloy. Modification is depends on the stability of phases which is very closely related to morphology of the structure. Influence of Sr content in an alloy different mechanisms are used to modify eutectic Si morphology one is twin plane re-entrant and either is interface step mechanism. Irrespective of mechanisms, Sr atoms are observed at Si-liquid interface which prevents further growth of Si phase thereby changes direction of growth of Si phase leads to change in morphology and size of silicon (Si) phase. When Sr atoms are observed which increases twin energy and therefore effect of modification is reflected in twin density in Si phase. It is observed that only 0.02%Sr is the optimum value for increase of twin densities. Crystal structure were also changed. It is observed that more Sr content is needed for better modification of the Si morphology. Before treatment, it is observed that microstructure consist of flake Si phase oriented at an angle of 45 degree and after treatment the Si phase is converted into round shape. These type of orientation is very dangerous to its application because these sites act as a area for stress concentration or stress risers. It is observed that average length of Si phase has reduced rapidly within Sr content of just 0.02% and become slower upon increase of Sr content.0.02%Sr has large effect on modification of morphology of Si phase. With addition of Sr, almost all Si particles are formed into fine structures with further increase in Sr about 0.08% all Si phase is converted into fine fibre. Further increase in Sr causes air admission into the metal leads to formation of defects like pores etc. Holding time during casting is also an important parameter in modification and observed that 2min is optimum time for transformation of Si from course to fine. Increase in holding time after 60min there is no much changes in morphology of Si phase. Manping Liu *et al.* [8], here differential calorimetry is used to study the behaviour of precipitation hardening. Artificial aging was conducted at 191 degree celsius with aging times of 4h and 10h in age hardening, atomic clusters are the super saturated solid solution. GP zones are generally spherical in nature. Beta particles are generally present in aluminium alloys aged to high hardness and these are rod like precipitates having hexagonal structure generally present in over aged specimen. These beta particle are considered as main things for the strength. Toughness of Al can be increased by static aging here static aged specimens have no GP zones, which indicate that these zones are formed before DCS analysis. Lizhen Yan *et al.* [9], pre-aging on early aged behaviour is analysed by DCS. After precipitation beta' is formed which is a metastable structure “Beta”. Beta are occurred by nucleation and growth. “Beta” phase gives best aging strength. From experimental observation, it is noted that strength of pre-aged alloy is less than natural aged bur they showed better formability as compare to natural aged specimen. Here specimens are solution treated at 550 degree celsius for 15min then quenched in water at room temperature followed by pre-aging for 2 week. Properties are noted for different aging conditions and observed that T4 yield strength is more than T4P yield strength. Pre-aging is largely inhibit the formation of cluster. The precipitates of alloy is analysed using 3-D atom probe. Fraction of GP zones in pre-aged are more than that of non-pre-aged samples. Results showed that pre-aging suppressed the effect of natural aging it is observed that cluster formation increases the strength of the alloy. Super saturation of pre-aged specimen is more than that of natural aged specimen. Yasuhiro Aruga *et al.* [11], atom probe tomography was used to analyse clustered state of pre-aged and natural aged samples. It is observed that large number of cluster atoms are formed after natural aging. Silicon (Si)-rich clusters decrease the hardness of the alloy due to long natural aging. It is observed that pre-aging at 170 degree celsius increased number of precipitates during artificial aging which directly improve the strength of the alloy. This study showed that negative effect with natural aging after pre-aging. Here solution treating is done at in a salt bath at a temperature of 570 degree celsius followed by quenching at 90 degree celsius for these results were found. Natural aging is done at room temperature for 40,000 seconds after pre-aging at 90 degree celsius for 18 ks. Hardness was not so changed when specimen were naturally aged for 1000 seconds and an increase in natural aging time beyond 1500 seconds, hardness gradually increased almost linear with natural aging time. With prolonged natural aging after pre-aging, cluster density increased. Long time storage at room temperature, Si-rich cluster increases and these formed after solution treatment. Si-rich clusters are more prone to form after solution treatment and these are not directly form into clusters. Nguyen Hung *et al.* [11], tailored heat treated blanks indicate possible method to improve the formability. Here first step includes prevention of wrinkling due to compression stresses. Run Bai *et al.* [12], it was found that precipitation and aging treatment, uniform second phase particles are formed. These second phase particles act as a obstacles to deformation and dislocation thereby increase in strength of the metal at higher temperature L. Dimithe Aboumou *et al.* [13], fatigue crack growth is investigated at different conditions of aging in steel. Fatigue crack growth increased at 300 degree celsius regardless of temperature and time. Precipitation hardened steel has natural corrosion resistance and high strength. Because of this it is widely used in heavy duty like aerospace, ship and nuclear reactor etc. Pedro A. Ferreirós *et al.* [14], Fe based alloys are well known for their capacity at high temperature that is they have high resistance to creep. Addition of elements proved their high strength at the expense of ductility. Aging of an alloy resulted coherent precipitation of second phase particles and leads to form stable ferrite matrix which directly increases the strength of an aluminium alloy. Vicker's hardness is carried out at different aging conditions and it is found that maximum hardness was present at longer times and more concentration as temperature decreases. Increase in hardness as temperature increases indicates that solid solubility is decreased with temperature. Fe-Al base alloys have their melting temperature of 1200 to 1400 degree celsius because of this they used in high temperature application. Hardness is controlled by size of precipitates which vary according temperature and time. Because of this reason, control of size of precipitate is vital in precipitation or age hardening in aluminium alloy system. LSW theory predicted that growth of precipitates as cube of radius at constant time rate. Aging treatment: aging behaviour was analysed by differential scanning calorimeter for time of less than 10 hour. It is carried out in two stages one is solution treatment and second one is aging. Temperature was reduced at the rate of 90 degree celsius per minute. Microstructure is examined under transmission electron microscope with 160KV voltage. Average radii of precipitates calculated as individual radius from measured precipitate areas. Spherical shape of precipitates have showed better strength, aging treatment is performed at different temperature and time after hot rolling. Maximum hardness increased as aging temperature decreases and this is primarily because of growth of precipitates but ratio between volumes of matrix to precipitate matrix is remain constant. Maximum hardness is a result of resistance to dislocation. These results attributed to reduction of precipitate dispersion as aging temperature decreases. Average radius of precipitates at aging temperature of 700 degree Celsius and 0.37 hour is around 11.02nm. Hu¨seyin *et al.* [15].

2. Problem statement
2.1 Statements
To study and evaluate mechanical properties of aluminium (AA-7175) alloy with addition of strontium in different percentage and subjected to age hardening. More number of studies have shown that the mechanical and other properties of aluminium (AA-71745) alloy are better as compared to other. As discussed above, it is prudent that addition of strontium in aluminium improves properties by modifying morphology of silicon from coarse to needle shape. Also Sr addition adds value to the mechanical and other properties usual method of improving strength of this alloy is through heat treatment. In our project, these alloys are subjected to age hardening and it is also called precipitation hardening henceforth this alloy is widely used in aerospace application and in corrosive environment. Its corrosion resistance is observed to be almost equal to titanium alloy. The demerit of Titanium alloy is its high cost compared to AA-71715. Since aluminium is available abundant in earth crust it has attractive cost but its disadvantage is low strength to mechanical properties but these can be overcome by heat treatment called age hardening. Additional strength is improved by adding strontium to that alloy which helps to form fine precipitates during aging. It is easy to strengthen the aluminium alloy and since it is having low density and high strength this is widely used in many industrial especially in aerospace application wherein weight to strength ratio is matter of concern. Different modifiers are used depending upon requirements. One more attractive property of this alloy is resistance corrosion. By considering all the above parameters we have selected aluminium alloy (AA-7175). Main Objective of the research work, to find the optimum percentage of, adding grain refiner's strontium to improve the properties of aluminium alloy AA-7175. To obtain better properties, utilizing Age-Hardening (heat treatment) process. To investigate the mechanical and thermal properties of age hardened aluminium (AA-7175) alloy by addition of varying percentages of strontium. Comparison of properties of heat treated alloy with non-heat treated alloy. Examination of the microstructure.

2.2 Scope of the Research
Aluminium is the third most abundant material in earth, having low density, relatively soft, durable, lightweight, ductile malleable, better strength and cost effective. Titanium alloys have comparably high strength to weight ratio and hence they are prominently used by aerospace industries, furthermore the use of Titanium alloys add much cost to the product compared to aluminium alloys. This study aims mainly on aluminium (AA-7175) alloy as this alloy is having good mechanical and thermal properties and also resistance to corrosion like titanium, since Titanium alloy's high cost and more weight compared to AA-7175 and because of these attractive properties its application can be extended to even further. The aluminium alloy has wide range of application in almost all industrial fields ranges from kitchen utensils to aerospace and even in space. To improve the properties of Aluminium alloy AL-7175 by adding various percentages of strontium and improve its by age hardening to obtain high strength to weight ratio, light weight alloy and commercially/economically feasible Aluminium alloy in feeding both aerospace and automotive technologies.

3. Methodology
3.1 Selection of Grain Refiner
Aluminium AA7175 here we used is a base metal and it is selected based upon survey that we carried out at an initial stage. This alloy, among all the aluminium series is a strongest one in terms of strength; corrosion resistance and even it exhibit high resistance to thermal elongation. It is widely used in various industries ranging from small rivets to aerospace applications like turbine engine blades, body sheets and landing gears. It is also widely used in constructional applications. Titanium alloy is also widely used in aerospace industries but due to high and other demerits its use has been replaced with aluminium material since it gives similar properties as that of titanium alloy at low cost hence now it is becoming common material in aerospace and other industries. On comparing above properties between titanium and aluminium we chose aluminium as the best material for our research.

3.2 Preparation of Aluminium alloy AA7175
This alloy is formed in casting process by adding various alloying elements in exact quantity. The below table shows the composition of an alloy that we prepared.

Table 1: Chemical composition of AA7175 alloy

Alloy	Mg	Si	Fe	Cu	Mn	Cr	Zn	Al
7175	2.54	0.05	0.18	1.57	0.05	0.22	6.4	balance

Fig 1: Aluminium alloy AA7175 ingots

3.3 Selection of alloying metal for AA7175
Strontium is selected as an alloying element in our study based on literature survey. It is found that the strontium plays a significant role in changing the morphology of Al-Si alloy which considerably increases the mechanical and other properties of an alloy. There are also other alloying elements like Nb, Ca, Na etc but we found that strontium gives good results as compare to rest. It effectively modifies the morphology as silicon from coarse to round shape this is the main reason that the strength of alloy is increased.

3.4 Preparation aluminium strontium super alloy
Preparation of super alloy is essential because pure form of strontium metal is not available in the market hence strontium is prepared in the form of alloys. In order to get required strontium alloy we have to form it with aluminium

alloy and then it is added to base metal according to the requirement that is aluminium AA7175 alloy this combination forms aluminium strontium super alloy. These super alloys available in different form as shown in table.

Table 2: Aluminum-10% Sr super alloy

Alloy	Designation	Sr	Si	Fe	Ca	P	Mg	Ba	Other	Total
10% Sr	AA-H2007	9.0-11.0	0.20	0.30	0.03	0.01	0.05	0.10	0.05	0.15

Fig 2: Aluminium-strontium super alloy ingot of 10% Sr

3.5 Casting of Aluminium AA-7175 alloy

After the preparation of ingots casting should be done in order to prepare the specimens for different tests to assess required mechanical properties as this is main objective of our project. As it is stated in problem statement that addition of different percentage of strontium into the aluminium (AA7175) alloy. For this purpose different percentage of strontium should be selected. The strontium percentage selected for test specimens are as follows. 0.01%, 0.05%, 0.1%, 0.2% 0.3%. These percentages are selected based upon survey where Sr is added around 0.02% with aging time of 6hours because they get peak aging time at this. The selected material Al-Sr super alloy, therefore particular percentage of Al-Sr is added to a sample. To obtain these percentages a particular weight of Al-Sr is added to a base metal as shown in table 3.

Table 3: AA-7175 and Al-Si for samples

Sample	Strontium content	AA7175 (g)	Al-Sr alloy
1	(As cast)	As cast	-
2	0.01%	893	1.8
3	0.05%	880	4.4
4	0.1%	877	8.8
5	0.2%	831	16.6
6	0.3%	819	24.5

3.6 Casting process

Casting process is the basic method of manufacturing of different materials therefore it is also called “MOTHER OF ALL THE PROCESS”. There is no manufacturing method that involves no casting hence it is the first step for all manufacturing process. We performed stir casting. It consists of stirring step where it rotates in melting furnace during addition of alloying elements in order to disperse this alloying uniformly in base molten metal because this degree of uniformness decides the strength and other properties of an alloy.

Fig 3: Aluminium-strontium super alloy

Fig 4: Crucible

Fig 5: Melting furnace

Fig 6: Pre-heating of mold box

Fig 7: Castings with different percentage of alloying element

Fig 8: Cutting of castings

Fig 9: Aluminium alloy AA 7175 ingots

Electric furnace used in for our research is induction furnace. It is heated to about till it gets melted to red hot and then poured into metal die where it is allowed to solidify or cooled to room temperature. Alloying elements are added to molten metal during melting. Metal mold have high dimensional stability therefore it is used in many industries. Sand mold box is also used but problem is reclamation of sand and its availability also its dimensional stability is less as Compared to the metal mold. The sand mold box is prone to have defects due to presence of sand Particles. Casting has its disadvantages like formation of large fumes in the field area.

Fig 10: Pouring of molten metal into

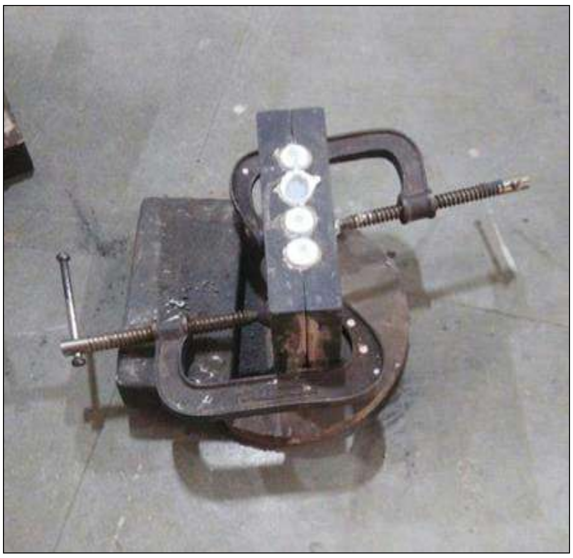

Fig 11: Mould box filled with molten metal

3.7 Machining process

Machining compared to all manufacturing, is the process which gives final shape of the products with expected tolerance. Dimensions are selected based upon testings to be performed. Initially castings are cut into pieces to get uniform cylindrical structures. Specimens are prepared

according to the standard like ASTM E8 (American Society of the International Association for Testing and Materials).
Steps followed during machining are

1. **Facing:** This is one of the common process in every machining. This operation is usually done in lathe machine. Work piece is fixed in the rotating four jaw chuck firmly and single point facing tool is used. Here tool moves in the direction perpendicular to the axis of work piece rotation.

2. **Turning:** Facing is followed by turning wherein orthogonal cutting mechanism is takes place which means that cutting tool moves along axis of the work piece. Different feed and speed will be given for the work piece. Finally grooving toolis used to make specimens round and be chamfered.

3. **Grooving:** This is done after turning to make specimens round at the gage length or between the holder maintaining proper standard dimensions.

Different tests are conducted on respective specimens. We have conducted three tests namely tensile hardness and thermal elongation test. For these tests, specimens are prepared according to ASTM E8 STANDARD. Specimens are prepared in lathe machine with different tools. Aluminium alloys are usually strengthened by precipitation or age hardening heat treatment. After machining specimens are subjected to treatment process and it is discussed below.

Tensile test: test specimens are prepared according to ASTM E8 standard.

Fig 12: Tensometer

Fig 13: Tested specimen (broke at right side)

3.8 Rockwell Hardness test

Rockwell hardness: Different types of hardness tests are there but Rockwell hardness the basic and very easy to understand because it does not need any calculations. Rockwell hardness involves indentation on specimen with an indenter and this s diamond cone and ball indenter. The indenter is forced to apply load usually 100 KGF on the specimen to check its hardness. In ferrous metals, hardness is measured by amount of carbon present in the parent metal but in case of aluminium alloy it is determined by number of precipitates present in the alloy matrix. Different devices are used to measure the hardness. Precipitation or age hardening is the common method used to strengthen aluminium alloy system. Hardness is increases after specimens are subjected to aging wherein fine precipitations are formed and these will be responsible for increase of hardness. Usually hardness is measured as the depth of indentation when load is applied. From experiment it is found that increase in hardness in heat treated alloys as compared to that of non-heat treated alloy system. In ferrous alloy there are various methods to improve this hardness like surface treatment and full heat treatment. Hardness of aluminium alloying system also depends upon its ingredients and largely on number density of precipitated particles.

Fig 14: Rockwell hardness testing machine

3.9 Thermal elongation test

Thermal elongation is defined as amount of increase in length due to temperature rise in the material. In aerospace application dimensional stability is very important but due to extreme temperature environment the alloy may substantially distorted and this leads to improper functioning of components. Usually turbine blades are made of this aluminium they experience adverse temperature effects. We have conducted experiment in special instrument called Dilatometer in our college. We observed that as strontium content increases the elongation decreases this effect may be attributed to both additions of strontium as well as heat treatment. In heat treatment, the precipitates act as resistance to dislocation moment thereby increasing resistance to thermal stresses induced due to applied temperature.

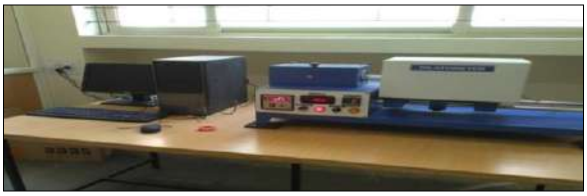

Fig 15: Dilatometer

Fig 16: Dilatometer tube with specimen

Fig 17: Specimens for thermal elongation test

Linear thermal expansion is the property of the material to expand linearly as a function of temperature. The coefficient of thermal expansion is defined as

CTE (α) = 1/L* dL/dT

Where L is length of specimen, dL/dt is the change of linear dimension per unit change in temperature. Thermal expansion (and contraction) must be taken into account when designing products with close tolerances fits, as tolerance will change when temperature changes. This aspect is more critical if material used have different values of coefficient of thermal expansion. It should also understand that thermal expansion also cause significant stress in components if design does not allow expansion or contraction. The standard test method for measurement of linear thermal expansion of solid material is with a push-rod dilatometer (ASTM E8). This method is used to determine the coefficient of thermal expansion of rigid solids such as a metals ceramics, refractories, glasses, rocks and mineral, graphite, cements and variety of components.

4. Polishing

Fig 18: Polishing machine

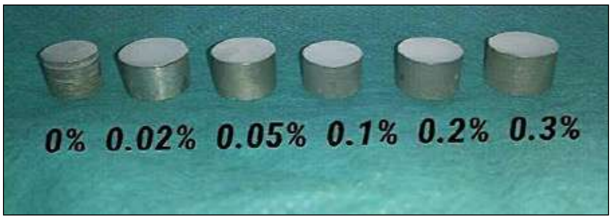

Fig 19: Specimen for polishing

Polishing is done to observe microstructure of the specimens under microscope may be optical microscope or scanning electron microscope depending upon what we wish to study on. In our research work, we used scanning electron microscope. Both as-cast as well as strontium added alloys are polished using silicon carbide paper with different numbers ranging from number 60-1200. The specimens are placed on rotating disc. In dry polishing low grade polishing paper is used to make surface rough. Water is used during wet polishing and paper number is increased from 60, 100, 200,560,800, & 1200 and it is the final. When we used higher number we get good surface finish and this process is followed by dry polishing. In wet polishing we have not used any liquid and here also specimen is placed on rotating disc. Here instead of E-paper we used velvet cloth and diamond paste is used to get the mirror finish. The particle size in diamond paste is approximately 10 micron. This paste is gently applied on the top surface of the specimen and then placed on rotating disc. Surface is polished till it get mirror finish then cover specimens with cotton in order to set it free from dust and rust when exposed to the environment. Degree of surface smoothness is depends on the no. that polishing paper has. If we increase the number of the paper, for example, 1200 we get good surface finish and so on.

5. Results and discussion

Table 4: Chemical composition of Aluminium AA7175 and AA7075

Alloy	Mg	Si	Fe	Cu	Mn	Cr	Zn	Ti	Zr	Al
7075	2.24	0.28	0.19	1.76	0.07	-	6.15	0.06	0.14	balance
7175	2.54	0.05	0.18	1.57	0.05	0.22	6.4	-	-	balance

The above samples shows chemical composition of an aluminium (AA 7075) & (AA7175) alloy.

The casting procedure is followed as mentioned in methodology. As the percentage of strontium is selected as 0%, 0.02%, 0.05%, 0.1%, 0.2% and 0.3% added to the aluminium AA7175 alloy in the form of Al-Sr super alloy. Ingots are prepared for melting and placed in furnace as melting is over, this molten melt is poured into mold box then it is allowed for cooling that is for solidification then these castings are removed from cavity. Castings are machined for the preparation of test specimen. Different specimens are prepared according to the standard ASTM E8. One sample from each percentage total fifteen samples are prepared and three tests are conducted namely hardness, tensile and coefficient of thermal elongation. Before conduction of tests, Specimens are subjected to heat treatment (artificial aging) with different time and temperature conditions. In our research work according to literature survey, we have adopted two different conditions one is T6 and another one is T77 concentration. Specimens are subjected to natural aging for 24 hours with temperature of 120 & 180 degree Celsius respectively for T6 and T77 condition. Solution treatment is done at 470 degree Celsius and for quenching water at room temperature is used as a quenching agent. As the result of addition of strontium (Sr) into the aluminium alloy, we found that desired mechanical properties are increased considerably and amount of coefficient of thermal elongation is also decreased upto certain limits thereafter not much significant increase in mechanical properties. We have made indentation on the same specimen at five different locations. Here we found that significant increase in hardness. We have observed that there is no significant increase in mechanical properties due addition of strontium but improvement is found due to heat treatment. According to Hall-Pinch rule yield strength is proportional inversely with grain size or square root of diameter of grains.

5.1 Results of Rockwell hardness test

Rockwell hardness is a simple test to conduct as it is not involves any calculations. This test is usually conducted to examine the behaviour hardness. Indentation is made on different location of the specimen and average value has been taken. It is observed that hardness values are not increased as percentage of Sr instead increased upto certain limit and then decreased due to non-uniform distribution of Sr particles during casting. Hardness is significantly increased due to formation of precipitated particles during aging**.**

Table 5: Hardness test results

Alloy		Hardness number				
	1st indentation	**2nd indentation**	**3rd indentation**	**4th indentation**	**5th indentation**	**Average**
As-cast	76.5	59	69	71.1	66.3	68.38
0.02%	77	67.2	89	86.9	89	81.82
0.05%	73	84.2	85	86	86.9	83.02
0.1%	90	85	85.5	87.5	81.9	85.98
0.2%	54	81.1	84.9	83	81	76.8
0.3%	76	83	81.1	82.5	79.9	80.5

From the above table it is observed that hardness is not constantly increased this is because of non-uniform distribution of strontium particles and moreover non uniform formation of precipitate particles. There are various reasons that can be attributed to this like location of indentation that is where you made the indentation for example, if you made indentation on where large particles are precipitated at a particular location which shows more hardness and if at the location where there is a lean distribution of particular shows less hardness. Improper heat treatment conditions like time and temperature also greatly affect to the hardness.

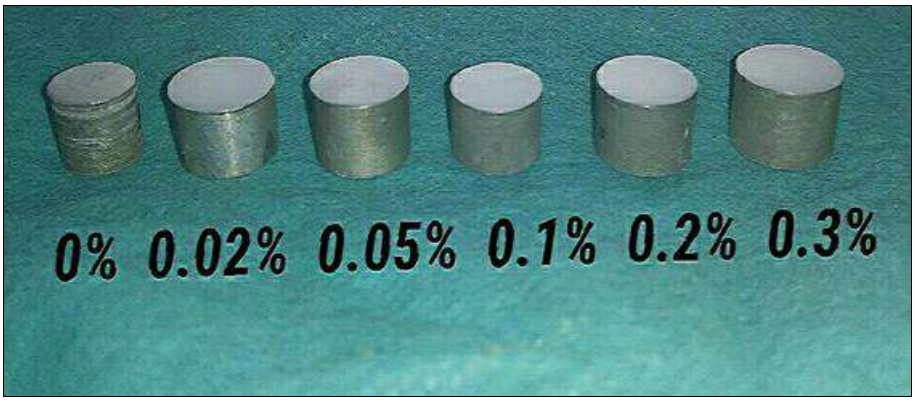

Fig 20: Specimens prepared for hardness test

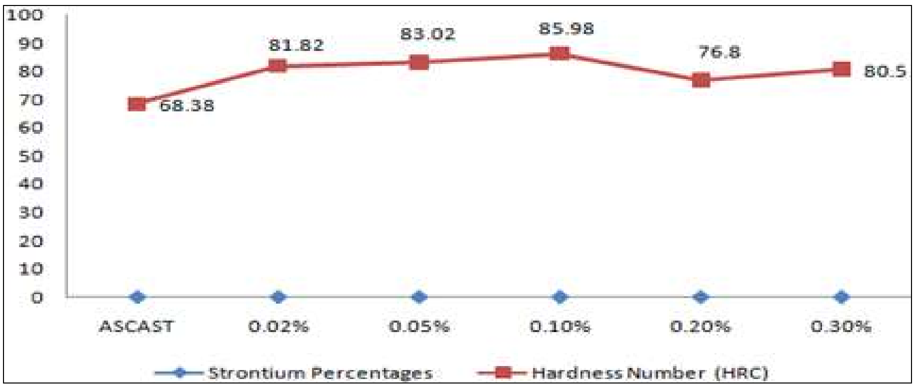

Fig 21: Variation of hardness with Sr content

In above graph we can see that maximum value of hardness we obtain is at 0.1% which is around 85.98 then hardness value is decreased slightly as we increase strontium content.

5.2 Results of tensile test

Tensile test is conducted on each specimen and recorded different strength properties like ultimate tensile strength, Percentage of elongation, displacement etc. strength properties are not uniform but they increase upto certain limit of Sr content then decreases.

These variations of strength properties can be attributed to many things like improper modification of Si morphology by the addition of strontium and improper distribution of precipitated particles. Though we have tried our best to control the heat treatment parameters, there are large number of parameters which influence AGING since it is very difficult to control all the parameters accurately we have got inconsistent results. Defects during castings also affect mechanical properties of an alloy system.

Fig 22: Tensile test broken specimen

Fig 23: Tensile test specimen held in holder

Specimen broke at different section depending upon strength of section this in turn depends on concentration of alloying element at a particular point and precipitated particles. Control of uniform distribution of precipitated particles is very difficult because of its complexity in nature. Sometime specimens may be over aged this leads to decrease in strength of an alloy system because number of precipitates formation is less. Surplus addition of alloying element also causes decrease in strength properties of an alloy system. Dimensions of specimens also decide the strength of the material as its strength is depends upon amount of material. At 0.01% of strontium content, the ultimate tensile strength as well as true tensile strength significantly increased and then decreased irrespective of strontium content.

Table 6: Tensile test results

	As cast	0.02	0.05	0.1	0.2	0.3
Engg UTS	165.3	323.5	300	310	327.5	298.7
True UTS	177.8	348.7	315	325	355.7	330.7
Proof Stress	5	9	4.6	8.1	11.1	6.2

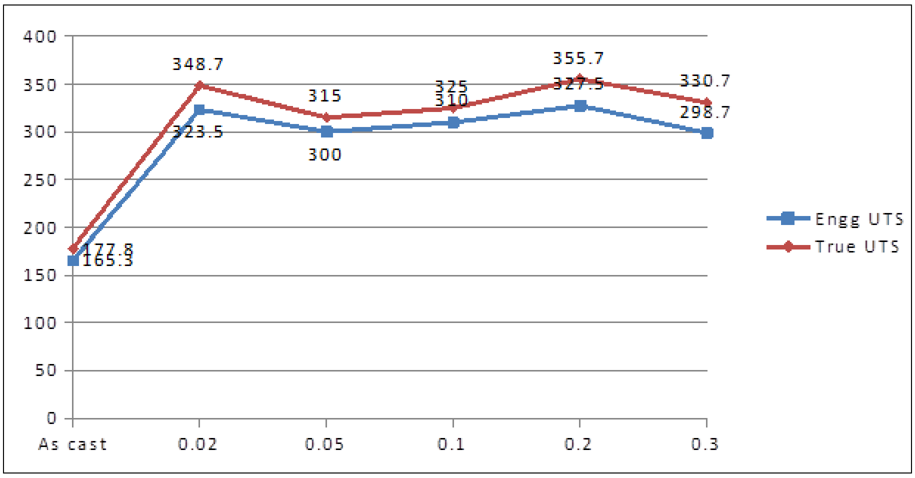

Fig 24: Variations of Eng. UTS and True UTS with Sr content

The above figure 6.5 shows that variation of different strength properties with strontium content added into an aluminum AA7175 alloy. Ultimate tensile strength is increased up to 0.2% of strontium content then decreased this is because of excess addition of strontium into an alloy forms inclusions in the castings which has direct effect on strength properties and hardness and other properties like high coefficient of thermal elongation and corrosion resistance. Errors during heat treatment also effect mechanical properties in between compositions. Uneven distribution of alloying elements leads to uneven strength in an alloy.

6.3 Results of thermal elongation test

Fig 25: Specimen placed in glass tube

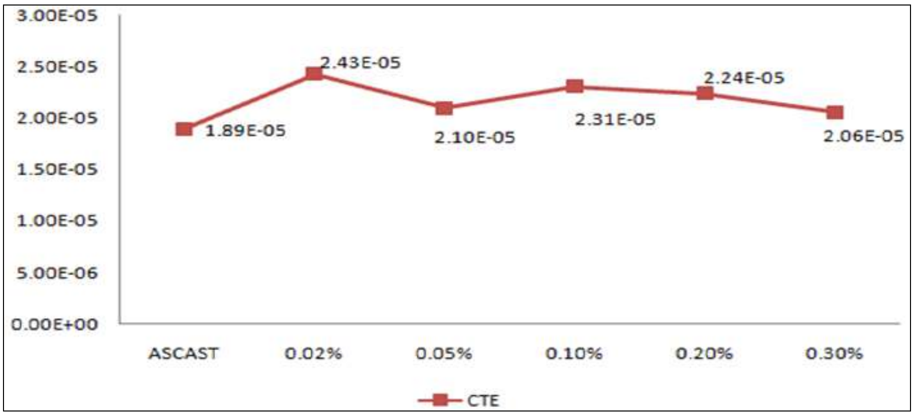

Fig 26: Graph shows variation of CTE with Sr %

6.4 Micro structural examination

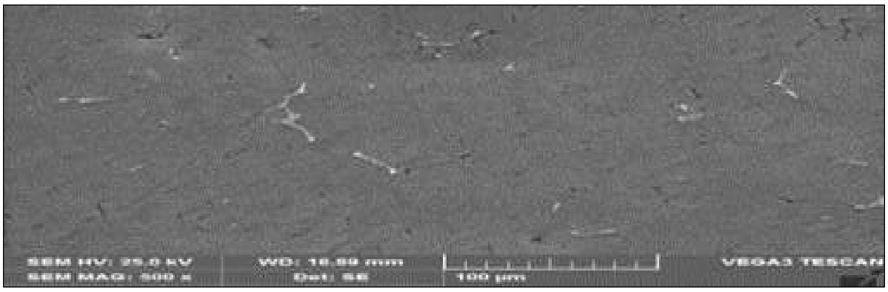

Fig 27: (As cast)

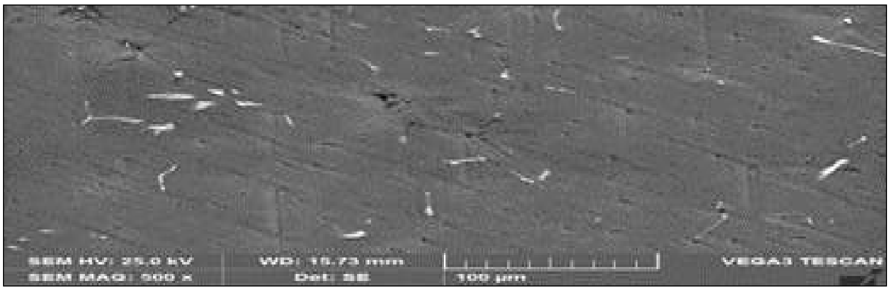

Fig 28: 0.05%

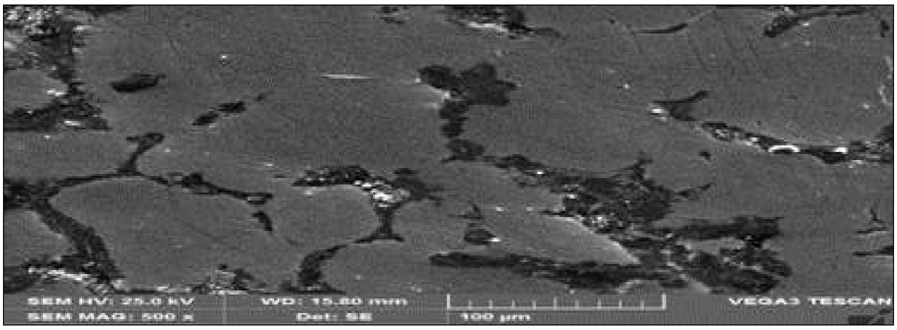

Fig 29: (0.2%Sr)

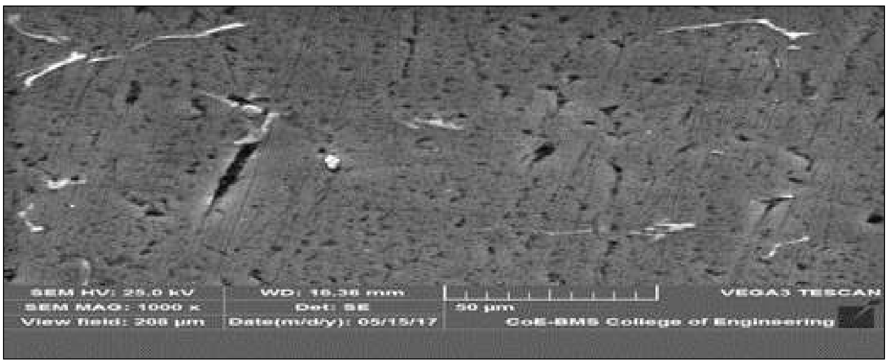

Fig 30: (0.3%Sr)

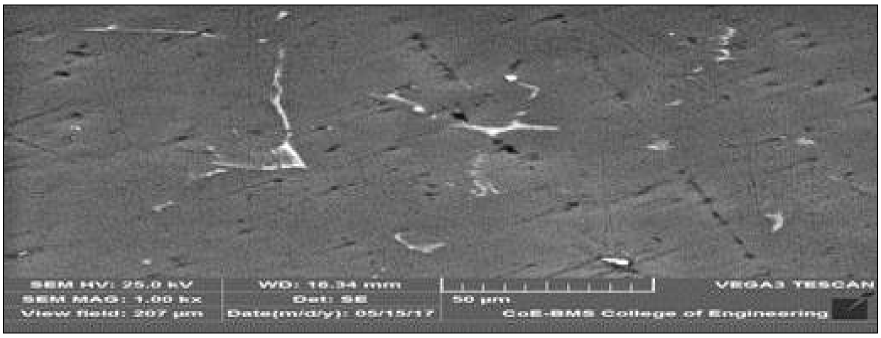

Fig 31: (0.1%Sr)

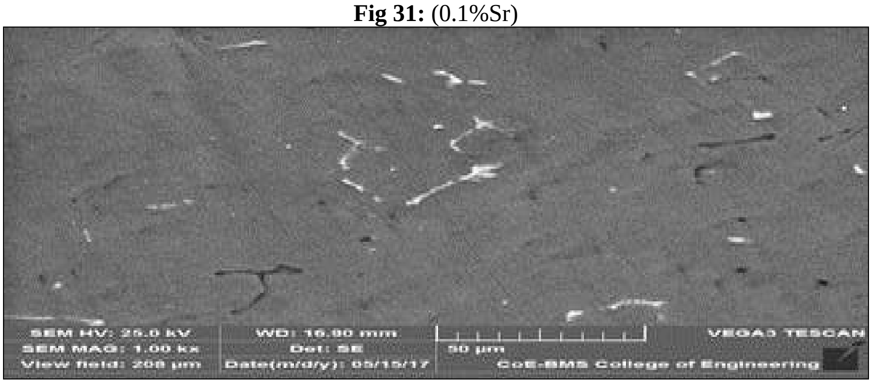

Fig 32: (0.02%Sr)

- This sample contained incipient dendrites of aluminium-rich solid solution and intermetallic compounds around the primary grains.
- Gray areas indicate the primary solid solution and the bright areas indicate the non-equilibrium eutectic solid solution between grains.
- The SEM micrograph reveals the existence of dispersoid particles (bright spots).
- The microstructure of the alloy contained Al5Mg11Zn4, Al2CuMg, Mg2Zn11, and MgZn2 phases.
- Aging heat treatment of Al-Zn-Mg-Cu alloys led to formation of MgZn2 intermetallic phase in the structure.

6. Conclusion

Tensile test: tensile strength of the material is resistance to applied load or capacity of the material to bear applied tensile load. Tensile strength of an aluminium alloy is less than 60Mpa this kept it away from use but this can be improved by refining grains. Various grain refiners like Sr, Nb Sc are used for this purpose. Heat treatment is a best method to improve strength properties and hardness. Different percentage of grain refiners is used but in our project we have used 0%, 0.01%, 0.05%, .1%. 0.2%, 0.3 respectively. Of all these 0.2%Sr gives better results. True UTS is about 355Mpa and eng. UTS is around 328Mpa.

Hardness Test: Hardness is a property of the material which shows resistance indentation or scratch. Diamond is made to indent on the heat treated specimen. Of all strontium content of 0.1% has shown good result around an average numer of 86. Which is far beyond pure aluminium where it has just 30 to 40. Hence by knowing this we can say that hardness is increased upon aging.

Thermal elongation: Thermal elongation is a property of the material which increases under influence of temperature. This property is usually taken into account in precision designs like design of turbine blades, compressor blades etc. Results have shown that coefficient of thermal elongation is decreased with addition of strontium. The 0.3% Sr has shown large decrease in elongation due to formation of precipitates during aging these act as obstacle to dislocation. Hence heat treatment and grain refiners have positive effects on this property. It can be concluded that by heat treating of aluminum alloy with high degree of accuracy, we can get over all mechanical and other properties better as compared to non-treated aluminum alloys. Hence instead of using high cost material with large weight, we can use aluminum alloy for the same application where other costly alloys are used. Since aluminium alloys possess low density and good strength, this alloy can be used in many industries.

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