Analysis of alloying elements and Mechanical properties of T6 treated Aluminium Silicon Alloys

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Abstract

In last decade there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in automobile industries due to high specific strength, high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application prompted to study wear and tensile behaviour of these alloys utmost importance. Aluminium based alloys containing 7%, 12% and 14% weight of silicon were synthesized using casting methods. Compositional analysis and Microstructural studies of different samples of same composition have shown near uniform distribution of Si in the present alloys. Study of microstructure has showed the presence of the primary silicon. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength has increased with increase in silicon percentage. Wear behaviour were studied by using computerized pin on disc wear testing machine. Resistance to wear has increased with increase in silicon amount. The worn surfaces were analyzed using scanning electron microscope.

Key words:
Microstructure, Tensile strength, SEM, Wear

1. Introduction

In last decade there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in automobile industries due to high strength to weight ratio(specific strength), high wear resistance, low density and low coefficient of thermal expansion. The advancements in the field of application *prompted to study wear and tensile behaviour of these alloys.* Aluminium based alloys containing 7%, 12% and 14% weight of silicon were synthesized using casting methods. Compositional analysis and Microstructural studies of different samples of same composition have shown near uniform distribution of Si in the present alloys. Tensile tests were carried out with universal testing machine. Yield strength and ultimate tensile strength has increased with increase in silicon percentage.

This paper carries out review of the of Al cast alloys, followed by a discussion of the various enabling tools available to the industry, which were not available to the metal casting industry ten years ago or so.

2. INDUSTRY NEEDS

First and foremost, as an industry we must meet the needs of the design community. This requires understanding of the needs of designers, and to appreciate the boundary Conditions and constraints of their work. Secondly, the casting industry should have the means and tools to tailor and optimize alloys for specific performance. Alloy requirements for low cycle fatigue are different than say for thermal management systems, etc. As pointed out above, developing alloys for specific processes is not the norm, and it should not be. We need to optimize the performance attained from specific processes by ensuring that the alloy process is to be optimized to take advantage of the merits of the particular process. Today, we have predictive tools that enable us to work in a much more intelligent and effective way than in years past. The trial and error approach of alloy development is not only ineffective but also economically unsustainable. Cast components undergo post-processing operations, such as heat-treating, etc. In complex alloys, the range of elemental composition may make all the difference during heat-treating. Predictive tools mitigate if not prevent the occurrence of incidences such as incipient melting. So it is not only during the alloy and processing stages that the enabling tools are useful, but also during post-processing operations. In brief, what the major transformation for the metal casting industry is the paradigm shift from State-of-the-Art to State-of-Science.

As per industries need as in railway industry have a problem in slack adjuster. A double acting compression actuator can be adopted as slack adjuster to adjust the slack in the brake rigging of a railway vehicle.

3. Aluminium Alloy – Fundamentals

3.1. Influence of the alloying elements on the properties of aluminium cast alloys.

There are many ways of changing properties of aluminium cast alloys. One of them is of course change in composition of the alloy. Although the influence of elements that are noticeable in the alloy is mainly considered, elements which are known as impurities cannot be omitted, and its effect are not always negative.

Silicon

Addition of Si to the aluminium alloys has a great number of benefits. It is one of the elements which do not increase the weight of the alloys and at the same time improves it properties. The casting ability of Al-Si alloys are extremely good, which reduces costs of producing Al-Si castings. Mechanical properties of aluminium alloys depends more on the distribution of added silicon than on the amounts of it. In these alloys if the Si particles are uniformly distributed increases its ductility. while alloys in which these particles are acicular, show small increase in strength. While adding silicon to the Al alloy corrosion resistance is only slightly affected. Generally it stays on the same level or is slightly better than in case of pure aluminium. With increase content of Si the decrease of the fluidity and the freezing range is observed. Moreover silicon expands during solidification, which compensates the shrinkage of the aluminium. When the content of Si in the Al-Si alloys is as high as 25% volume shrinkage of these alloys reaches zero level.

Copper

Changes in mechanical properties of alloy with the addition of copper were observed such as its strength and ductility. Copper has the biggest influence on high temperature strength. These changes, like in Al-Si alloys, do not depend on the amount of added copper but rather on the way how it is distributed in solid solution. Alloys in which Copper can be found in the form of evenly distributed spheroid particles show biggest increase in strength without causing negative effects on ductility.While alloys with Copper present as continuous network at grain boundaries appear to be less ductile without noticeable increase in strength. Addition of copper will also reduce corrosion resistance of the alloy. It happens because Copper disperses the oxide film which appears on the metal surface and thereby it prevents alloy to be electrically neutral. It leads to the fact that Al-Cu alloys can corrode not only with the contact of other materials but also with another Al-Cu alloy.

Magnesium

Magnesium is lighter than aluminium and shows the same strength properties. It is one of the main alloying element in few of the Al alloys. In majority of these alloys the magnesium is rather considered as impurity. The role of magnesium in aluminium-silicon alloys is to precipitate _” phase (Mg2Si). [7] Al-Mg alloys are characterized with high strength with good ductility. Moreover magnesium can be one of the few elements which increases modulus of elasticity of Al alloys. Proper amount of magnesium in alloy will also help in high response to heat treatment. Another property which is very good in Al-Mg alloys is corrosion resistance. It is better in salt water and in mild alkalis than in pure aluminium. The worst part of Al-Mg alloys is it poor cast ability with the content of magnesium is as small as2-4%. But it appears to be better with higher amounts of magnesium (up to 12%)

Iron

Iron added to aluminium alloys, influence negatively its corrosion resistance. As far as mechanical properties are concerned, Fe improves strength of the alloy and at the same time reduces its ductility. Iron improves also resistance to hot tearing during solidification. Formations of beta iron needles have detrimental effect on mechanical properties of aluminium alloy. It happens because needle-shape like iron phases act as stress risers and crack propagation can start at these points.

Manganese

In wrought alloys manganese is added to obtain better results during work hardening. In Al-Si alloys, Mn improves high temperature properties and which is similar to silicon reduces shrinkage during solidification. Nevertheless the most important feature of adding manganese to the alloy is the fact that such addition result in change of iron phases in the alloy. Iron is changed from the needle like shape to more spherical one which results in reduction of worse crack propagation in the alloy.

Nickel

Nickel slightly improves both strength and ductility of the alloys at both room and elevated temperatures. What is more, when adding nickel together with iron, corrosion resistance against hot water is improved.

Chromium

Additions of chromium to the Al-Si alloys will effect in little increase in strength of these alloys. It will also cause slightly increase in tensile properties.

Zinc

Zinc in Al-Si alloys improves its machinability but decrease high temperature strength. It also increase tendency to hot tearing.

Tin and lead

Similarly to Zn, addition of Sn and Pb improves machinability and decrease high temperature strength of the alloys.

3.2 SELECTION OF MATERIAL: Aluminium – Silicon alloys chosen for study is: Alloy 356 – Alsi7Mg whose composition is as follows.

Table 1 Chemical composition of A356 modified with Ti, Sr and RE (mass fraction, %)

Si	Fe	Sn	Cu	Mn	Mg
6.728	0.378	0.250	0.185	0.064	0.223
Zn	Cr	Ni	Ti	Al	
0.165	0.009	0.161	0.036	91.26	

3.3 CASTING METHOD: Low pressure and gravity die casting was adopted for study. The principle of the process is shown in Fig. A metal die is mounted above a sealed furnace containing molten metal. A refractory-lined tube, called a riser tube or stalk, extends from the bottom of the die into the molten metal. When air is introduced into the furnace under low pressure (15–100 kPa, 2–15 psi), the molten metal rises up the tube to enter the die cavity with low turbulence, the air in the die escaping through vents and the parting lines of the die. When the metal has solidified, the air pressure is released allowing the still-molten metal in the riser tube to fall back into the furnace. After a further cooling time the die is opened and the casting was extracted.

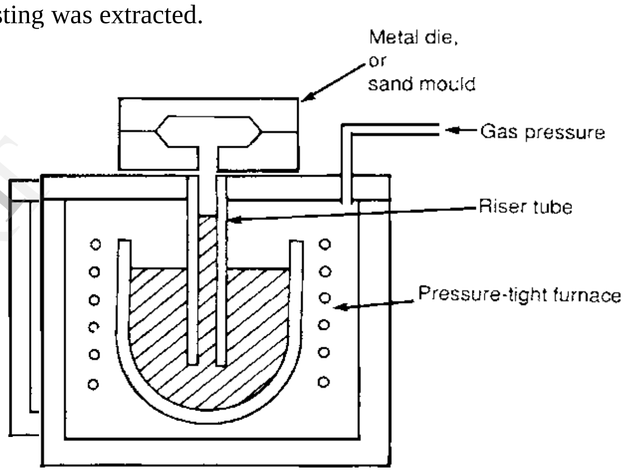

Figure. The principle of a low pressure die casting machine.

The process is capable of making high quality castings. With correct die design, directional freezing of the casting is achieved so eliminating the need for risers, the casting being filled and fed from the bottom. Because there is usually only one ingrate and no feeders, casting yield is exceptionally high, generally over 90%. Good dimensional accuracy and surface finish are possible and complex castings can be made using sand cores.

3.4 Heat treatment

Heat treatment of A356 alloys in combined addition of rare earth and strontium was conducted.

T6 treatment is a long time treatment (solution at 525 °C for 8h + aging at 165 °C for 8 h).The effects of heat treatment on tensile properties of the Al-7Si-0.3 Mg alloys were investigated. Those samples treated with T6 achieve the maximum tensile strength and fracture elongation.

	Solution		Aging	
Treatment	Temperature °C	Holding time/ hr	Temperature °C	Holding time /hr
T6	525 ± 5	8	165	8

The age harden-able cast aluminium alloys, such as A356, are being increasingly used in the railway and aerospace industries due to their relatively high specific strength and low cost, providing affordable improvements in fuel efficiency. The austinetic structure of A 356 can be refined and its properties can be improved by optimized heat treatment for A356. T6 heat treatment is usually used to improve fracture toughness and yield strength. It is reported that those factors influencing the efficiency of heat treatment of Al-Si hypoeutectic alloys include not only the temperature and holding time,[12,13] but also the as-cast microstructure.[1,3,8] The T6 heat treatment of Al-7Si-0.3 Mg alloy includes two steps: solutionizing and artificial aging; the solutionizing step is to achieve α (Al) saturated with Si. And Mg and spheroized Si in eutectic zone, [11, 14] was achieved with the artificial aging by strengthening Mg2S phase. Recently, it is shown that the spheroidization time of Si is dependent on solutionizing temperature and the original Si particle size. [2, 4, 7, 5] with a solution treatment time of 8 h. From thermal diffusion calculation and test, it is suggested that the optimum solution soaking time at 525 °C is 8 h. The maximum peak aging time was modelled in terms of aging temperature and activation energy. According to this model, the peak yield strength of A356 alloy could be reached within 3 – 8 h when aging at 165 °C. [6, 9, 10] However, few studies are on the effect of combined treatment with solutionizing and ageing. In this study, using this alloy modified together with Si and Al, the effect of different heat treatments on the microstructure and its mechanical properties were investigated.

Table 3 Tensile properties of A356 alloys with T6 heat treatment

Heat treatment	σb / Mpa	σt / Mpa	δ %
T6	228	324	2.0

It is well known that shrinkage pores have a great effect on the tensile strength and ductility of A356 alloys. Although the full modifications of eutectic Si particles were reached in this study, those samples treated with T6 treatment do not perform as expected. The main reason is probably due to the higher entrapped gas content (0.25 cm3per 100 g Al). Our further research is aimed to develop a new method to purify the Al-SI alloys to further improve their mechanical properties.

4. Conclusions

1) The solutionization at 535 °C for 8 h and ageing for 6 h can reach full spheroidization of Si particle

2) After T6 treatments, the aspect ratio of eutectic Si particles was reduced.

3) With the T6 treatment the maximum strength and fracture elongation for A356 alloy was achieved. Along with the maximum yield strength, maximum ultimate strength, and maximum elongation can be achieved.

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