THE INFLUENCE OF AGING TIME TO MECHANICAL PROPERTIES ON ALUMINUM SILICON

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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2009
JUDUL: THE INFLUENCE OF AGING TIME ON MECHANICAL PROPERTIES OF ALUMINUM SILICON

SESJI PENGAJIAN: 2009/2010

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The members of the supervisory committee are as follow:

Dr. Nur Izan Syahria Bt. Hussein
(Main Supervisor)
ABSTRACT

Heat treatment is a process to alter the structure and properties of the materials used. Heating to a higher temperature, go through aging and tempering of the aluminum silicon alloy increases the strength at the expense of ductility. At the mean time, the alloys become though. Addition of the silicon composition in aluminum silicon alloy affects the structure and properties of this alloy. Tensile strength and hardness tests were performed in order to analyze the properties. The results showed that at a higher silicon content, the alloy becomes less ductile and harder because of the presence of harder and more brittle silicon particles.
ABSTRAK

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heartfelt gratitude to my supervisor, Dr. Nur Izan Syahria Bt. Hussein for guiding me through the project from the preparatory stages until the end. Thank you for your guidance and encouragement every step of the way and for attending to my questions each and every time. I appreciate the opportunities of learning that she supported me to complete my project. Hence, I would like to thanks the technicians of manufacturing engineering faculty who had helped me improvident the information and knowledge of my research laboratory work. Lastly, I would to thank each and every individual who have either directly or indirectly helped me throughout the efforts of this report be it in the form of encouragement, advice or kind reminder. A special thanks to my beloved family members, I extend my gratitude for their support, understanding and love.
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LIST OF ABBREVIATIONS, SYMBOLS, AND SPECIALIZED NOMENCLATURE

Al  Aluminum
AlSi  Aluminum silicon
A₀  Original area
Aₐ  Final area
C  Carbon
%RA  Percentage of reduction area
G.L.  Standard gauge length (50mm or 2’)
HRB  Rockwell hardness number
I₀  Original length
Iₐ  Final length
Mₐ  Modulus of feeder
Mₖ  Modulus of casting
N  Newton (measurement unit for force)
rpm  Revolution per minute
SEM  Scanning electron microscope
UTS  Ultimate tensile stress (unit N/mm²)
%wt  Percentage of weight
Vₛ  Volume of sprue
Vₐ  Volume of feeder
Vᵣ  Volume of riser
1.1 Background Of Study

Daily life necessities such as cloth, food, properties, transportation, communication, and recreation are highly influenced most by various materials and the way they are created. Development of materials is more probably more deep-seated and grip to our heart and culture than most of us know. The expansion and advancement of societies have been intimately tied to the members’ ability to produce and manipulate materials to fill our needs. The earliest generation had access to a number of natural resource (stone, wood, clay, skins). With time changes, mankind discovered techniques for improving and producing materials that have demanding properties.

Furthermore, it was found that the properties of a material could be altered by heat treatments and by the addition of other substances. Here, material utilizations were totally a selection process. Knowledge, wisdom and understanding that we have gained, has empowered us to fashion and enlarge the characteristics of materials. The development of advanced technologies make our existence so comfortable and easy accessibility of suitable materials. As for example, automobiles would not have been even possible without the availability of inexpensive steel or some other comparable substitutes.

The properties of metals and alloys during manufacturing and their performance during their service life depend on their composition, structure, and processing history, as well as on the heat treatment to which they have been subjected. The most common ways to work with a material whether to test it sensitivity toward its surrounding, or to improve it, is by heat treatment.
Heat treatment modifies microstructures that found in a material, and thereby, will encourage tested material to produce a variety of mechanical properties that are important in manufacturing such as improving formability and machinability.

By doing this, it will also enhance the service performance of the metals when used in machine or electrical components and also in tools, dies, and molds. For example, pure aluminum is too soft for most structural applications and therefore is usually alloyed with several elements to improve its corrosion resistance, inhibit grain growth and of course to increase the strength. The optimum strengthening of aluminum is achieved by alloying and heat treatments that promote the formation of small and hard precipitates which interfere with the motion of dislocations. Heat treatment is a method used to alter the physical, and sometimes chemical, properties of a material (Elwin, 2004).

In this project, AlSi alloy has been selected to be studied. Its affect to the heat treatment condition in the production of automotive piston due to its special properties used, which is the great influence on the wear properties of the alloy as it reduced the wear rate of the specimens, exceptional high tensile strength and hardness as well as a decrease in ductility.

1.2 Problem Statement

Principle describing heat treatment requires knowledge of the interaction mechanisms. These properties are often unknown at the elevated temperatures resulting from the heating. Therefore, a model describing the heating process has not yet been fully established. Various factors must be considered and evaluated. These factors include the percentage of silicon that desired to test on the AlSi specimen, hardness or yield strength that material can withhold for certain load, and the aging time that designed to be tested on specimens, the work piece thickness and thermal properties.

Effective utilization of the heating furnace depends very much upon the proper selection and optimization of these factors. Limited information on how these factors
affect the heating subject quality have seriously hindered the growth of furnace heating applications in machining. Therefore, a systematic study to establish and recognize the machining standards to produce smooth outcome with good quality is necessary. There are various research objectives that have been performed by researchers in the past. One of them is the repeatability of furnace heating element due to the period of time that has been designed for that particular of material. The fact shows that it is often difficult to produce repeatable process. This makes the process of fabricating heating product with desired geometry to the industrial tolerances difficult to achieve.

1.3 Objectives and Aims of Study

The overall aim of this study is to understand the influence of aging time to the mechanical properties of AlSi alloy.

Specific objectives of this study are:

- To observed the aging time on the AlSi alloy.
- To experiment the heat treatment process to the strength of the aluminium alloy.
- To study the hardness and microstructure of the aluminum alloy after undergone heat treatment activity.

1.4 Scope of Study

As stated above, the main objective of this research project is to observe the effect of heat treatment on the properties of Aluminum piston alloy.

In order to achieve this, the following experiments were carried out in the present study:

- Study the properties of automotive parts that used aluminum alloy.
- Preparation of different percentage of silicon content in Aluminum-silicon alloy through melting and casting processes.
• Application of heat-treatment on these alloys
• Study the microstructure characterization of heat treated aluminum alloy using optical microscope with image analyzer.
• Perform Tensile and hardness tests to compare the properties.
CHAPTER 2
LITERATURE REVIEW

2.1 Fundamental Principle of Heat Treatment

Heat is defined as energy in the process of being transferred from one object to another because of the temperature difference between them, while, treatment in common, is a way of particular element behaving towards or dealing with thing or an element in the universe. The properties of alloying that decided to be used in heat treatment are related to its structural combination. The desired intensity of physical and mechanical properties can be obtained by differentiate and grouping the size, shape and distribution of its diverse constituents.

The activity of differentiating element can only be achieved in practice by the process of heat treatment. Generally, the structural bonding of any steel consist of transformed any particular product starting from austenite into another different stages, depending whether the alloy used is of hypoeutectoid, eutectoid or hypereutectoid type. Formation of alloying element in this type (hypoeutectoid, eutectoid or hypereutectoid) of process are differs from each others at a particular temperature.

Changing an alloy phases is depending on various parameters that desired to be undergone by a researcher. The presence of microconstituents stages mentioned earlier, together with the morphology of particular product contents is a significance way of deciding the resultant and discussion of its properties.

Therefore, in any way before proceeding with a heat treatment process, it is important for an examinee to understand and to know about a nature of austenite and
its subsequent transformation behaviour. Besides, object that undergone heat treatment process can be successfully held depends on its proper choice of heat treating furnace and the type of atmosphere maintained in the furnace used.

One can achieve an effective result and reproducible properties when heat treatment cycles factors, for example, the rate of heating, cooling and uniform temperatures range are ensured according to the requirements given. In general, an object to be heat treated is put into a heat treatment furnace at room temperature.

Then, the furnace will heat up to a predefine temperature. The heating rate depends on the size and shape of the object and the thermal conductivity of an alloy. The larger the size of the object, the lower shall be the rate of the heating. Heat treatment temperature is governed mainly by chemical composition of the alloy. Therefore, a thorough understanding heat treatment of an object is very important for one to start undergo the experimental process because the area of application for any metal or alloy is limited by its own properties.

2.2 Reviewed on Machine and Material

2.2.1 Heat Treatment Furnace

Uniformity of temperature and precise control of temperature time cycles are important in heat treatment activity. Good furnace equipment used for heat treatment process is a must. This is because experimental wise, heat treating activity consume great amounts of energy, their insulation and efficiency are important in design considerations. Heat treatment furnace is classified into three types of furnace, which is as batch, semi-continuous, and continuous.

Among all, batch furnaces are the most common and versatile in the industry. The heat treating work typically held stationary in the furnace chamber vestibule. The furnace will be loaded or unloaded in a single batch mode operation. In continuous furnaces, the load applied moves through different zones and different temperature in the chamber.
However, the process of heating happened to be continuously. For semi-continuous furnaces, it happened to be similar with continuous furnaces but in a stepwise manner.

For the purposes of discussion, batch furnace is to be considered for experimental usage. The N 31/H - N 1491 batch heat treatment furnace model as shown in Figure 2.1 and Table 2.1 used, whereby manufacture by Nabertherm, is a furnace integrate the best of traditional and modern materials to produce an outstanding product quality combination in terms of performance and reliability.

![Figure 2.1: Heat treatment furnace](Source: Engineering Mechanical Laboratory UTeM)

The unique concept of this furnace is the heating module that it’s provide to its user, with both side are situated of the chamber. Each side of heating module consists of high quality alumina based hard wearing element carrier, housing a free radiating coiled wire element. The graded winding elements compensate for heat loss and optimise the uniformity of temperature inside the chamber. Furnaces can really working temperature rapidly and efficiently. The N 31/H - N 1491 Nabertherm furnace provide excellent resistance to everyday wear and tear by designing hard wear refractories around the chamber entrance, while secondary low thermal mass insulation ensures maximum thermal efficiency.
Some instrument panel of the furnace is removable for the ease of servicing. This is also for an easy access to the element modules and thermocouple through the rear of the ease.

**Table 2.1:** Technical specification of Nabertherm N 31/H - N 1491 range of furnace  
(Source: Nabertherm manual)

<table>
<thead>
<tr>
<th>Model</th>
<th>Tmax °C</th>
<th>Inner dimensions in mm</th>
<th>Volume in l</th>
<th>Outer dimensions in mm</th>
<th>Supply power/kW</th>
<th>Electrical connections</th>
<th>Weight in kg</th>
</tr>
</thead>
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<tr>
<td>N 31/H</td>
<td>1280</td>
<td>350 550 250</td>
<td>30</td>
<td>840 950 1320</td>
<td>13</td>
<td>3-phase</td>
<td>210</td>
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<tr>
<td>N 41/H</td>
<td>1290</td>
<td>350 550 250</td>
<td>40</td>
<td>840 1100 1320</td>
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<td>3-phase</td>
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<tr>
<td>N 61/H</td>
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<td>350 750 250</td>
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<td>840 1350 1320</td>
<td>20</td>
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<tr>
<td>N 81</td>
<td>1200</td>
<td>500 750 250</td>
<td>80</td>
<td>1140 1900 1790</td>
<td>20</td>
<td>3-phase</td>
<td>820</td>
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<tr>
<td>N 161</td>
<td>1200</td>
<td>550 750 400</td>
<td>160</td>
<td>1180 1930 1980</td>
<td>30</td>
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<tr>
<td>N 321</td>
<td>1200</td>
<td>750 1100 400</td>
<td>320</td>
<td>1400 2270 2040</td>
<td>47</td>
<td>3-phase</td>
<td>1300</td>
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<tr>
<td>N 641</td>
<td>1200</td>
<td>1000 1300 500</td>
<td>640</td>
<td>1690 2670 2240</td>
<td>70</td>
<td>3-phase</td>
<td>2100</td>
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<tr>
<td>N 781</td>
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<td>800 1900 500</td>
<td>760</td>
<td>1550 2540 2650</td>
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<tr>
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<td>1490</td>
<td>2430 1840 3150</td>
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<tr>
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<td>500 750 250</td>
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<td>1220 1960 1840</td>
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<tr>
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<td>550 750 400</td>
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<td>1260 1990 2030</td>
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<tr>
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<td>320</td>
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<tr>
<td>N 641/13</td>
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<td>1000 1300 500</td>
<td>640</td>
<td>1770 2730 2290</td>
<td>80</td>
<td>3-phase</td>
<td>2500</td>
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2.2.2 Mitutoyo Digital Hardness Machine

Hardness is a measure of resistance of a material to deformation when an external force or load is applied to the material. Different hardness test use different methods of applying force and quantifying the resistance to deformation. Hardness is closely correlated to other mechanical characteristics. It is, like many other mechanical characteristics, a relative value that has no fundamental quantity or absolute standard and is different from physical quantities such as length, time, and force. Because of this, hardness values are determined using a standard testing machine under standard conditions.

Hardness covers several properties such as resistance to deformation, resistance to friction and abrasion. The well known correlation links hardness with tensile strength, while resistance to deformation is dependent on modulus of elasticity.
The frictional resistance divided in two equally important parts: the chemical affinity of materials in contact, and the hardness itself. The hardness of metal is measured by forcing an indenter into its surface. The indenter, which is usually a sphere (ball), pyramid or cone is made of a material much harder than the material being tested. For example: hardened steel, tungsten carbide and diamond.

Hardness tests are performed more frequently than any other mechanical test for several reasons. They are simply and inexpensive ordinarily no special sample need be prepared and also testing machine is relatively inexpensive. The test is non-destructive which mean the sample is only deformed with a small indentation and can be used to another test. For this experimental study, the Rockwell and Rockwell superficial hardness (HRB) test machine as shown in Figure 2.3 will be performed on the heat treating specimens. The specification of the machine is shown as in Table 2.3.

Most hardness tests determine hardness from the area of the indentation made in a specimen by the indenter under a known load. In the Rockwell hardness and the Rockwell superficial hardness tests, a conical diamond indenter with a 120° angle and a radius of curvature of 0.2mm, or a steel or carbide ball indenter is pressed into the specimen. First, a preliminary test force is applied, then a total test force is applied, and then the test load is reduced to the preliminary test force.

The hardness number is determined from the difference, h, of the indentation depth of the indenter between the first and second applications of the preliminary test force. The Rockwell hardness test uses a preliminary load of 10kgf, and the Rockwell superficial hardness test uses a preliminary test force of 3kgf. The Rockwell and Rockwell superficial hardness have multiple scales to indicate specific combinations of the indenter type, test force, and formula to obtain the hardness.
The Rockwell tests constitute the most common method used in industry because they are so simple to perform and require no special skill. Indenters include sphere and hardened as in Figure 2.2 is used for the soft materials.

Figure 2.2: Indenters of Rockwell testing (Smith W. F., 2004)

The rockwell hardness number (RHB) is determined by the difference in depth of initial and final penetration load. Initial penetration is obtained from minor load, $e$. The value is 10 kg. Final penetration is obtained from major load, $E$. The value is depending on the scale / type of rockwell indenters. Formula is

$$RHB = E - e$$

(2.1)

Figure 2.3: Mitutoyo Digital Hardness Machine
2.2.3 Shimadzu Universal Testing Machine (The Autograph AG-I)

Tensile tests measure the force required to break a specimen and the extent to which the specimen stretches or elongates to that point. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. The data is often used to specify a material, to design parts to application force and as a quality control check materials. In this test, a sample is held rigidly between a fixed beam and a moving beam (the crosshead) as shown in Figure 2.4.

A load cell (sensor) is used to measure the stress that builds up in the material as its length is increased by moving the crosshead. The change in the length of the sample as pulling proceeds is measured from either the change in crosshead position (extension), or a sensor attached to the sample called extensometer.
This machine is totally designed to carry out continuous testing on the yield strength production of a material. It was enhanced with efficiency by combining the testing machine part with a personal computer. The Autograph AG-I as shown in Figure 2.5 is capable of satisfying its user needs by offering an effective controller with a high level of operability and safety as well. This machine also was linked to the software with the test machine on many dimensions desired.

It can test high quality data during experimental. It also includes a diverse lineup system in its programme. This particular machine will stop automatically when the change in the test force exceeds a specified value during manual operations. For example, sample setting. It provides wide space of inner column covers that are planned off for the operator. This machine has a limited mechanical movement. So, in order to provide a greater safety, a highly reliable photoelectric sensor is attached used for detection.