Effect of T6 Heat Treatment on Mechanical Properties and Microstructures of Cast Al-Si-Sn-Fe-Cu

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Abstract: Al-Si alloy is a famous casting material which has excellent characteristics to apply, such as good casting ability, excellent welding ability, and corrosion resistance. This study discusses the percentage of the chemical composition of Al-Si with the addition of Sn. the solubility of Sn is a study to study these effects that affect the mechanical properties of Al-Si players. The results show that with a higher Sn concentration, the mechanical properties of the mixture of Al-Si and Sn will increase and can increase precipitation. the evaluation aims to identify the distribution of chemical composition in materials using SEM-EDS and XRD. in this study a mixture of Al-Si and Sn after casting and the T6 heat treatment process formed precipitation of Mg2Si and Fe3Si, which could enable increased mechanical properties.

Key words: Al-Si, strengthening precipitation, casting, heat treatment.

1. Introduction

Characteristics Aluminum has excellent casting ability and is corrosion resistant. so aluminum can be said to be very good for use in conventional and renewable applications. Therefore, for the composition of the mixture used and also the heat treatment the thing to note is the ability to optimize grain size, eutectic structure, cell size, good casting, and the size of the intermetallic distribution that determines its properties. An important influence on the mechanical properties of Al-Si alloys has eutectic silicon morphology [1]. Silicon is a change in phase and makes eutectic Al-Si as an erect eutectic. Aluminum-silicon binary alloys have excellent fluidity, castability, and corrosion resistance. The strength, tenacity, and castability of eutectic aluminum alloys can be further optimized by modification of eutectic silicon-aluminum [2].

Sn element is a metal that has a low melting point which is around 231.89°C. The effect of adding a third element or in the ternary phase of the element Sn will be Al-based alloys, such as Al-Cu-Sn, Al-Mg-Sn, and Al-Si-Sn because the effect of Sn can result in an increase in the cooling temperature range due to the solubility limit Sn in Al alloy. During the solidification process, macro separation can be formed due to the low temperature of the liquidus Sn-rich melt in the interdendritic region. Other influences that can occur are changes in mass and the effect of temperature distribution derived from molten metal which is very influential on the melting flow rate, which can affect the process of primary phase growth. It can be predicted that adding Sn to Al-Si to melting temperature and adjusting the flow rate of molten metal during cooling can effectively produce precipitation and separation of the primary Si [3].

The application of pure Tin addition to Al-Si-Sn alloys aims to improve the mechanical properties of aluminum alloys by testing mechanical properties such as Rockwell Hardness testing. On the application of

Al-Si combined with Sn, it produces Sn intermetallic deposits which can increase mechanical properties by means of T6 heat treatment which causes an increase in thermal stability and wearability in Al-Si-Sn alloys. by adding Sn to Al-Si alloys can produce new phases, Al_2Cu, Fe_2Si and Mg_2Si. the degree of cooling, the presence of other alloying phases greatly influences the eutectic morphology of Al-Si-Sn-Fe-Cu. In the eutectic microstructure, α-Al imaging after casting undergoes a change in which the shape of the silicon is thin like a needle, while for Al-Si-Sn after addition Sn has the available field segments, and so morphology is like a round shape [4]. With the treatment of T6 mechanical properties after the heat treatment process, T6 has several experimental variables solid solution temperature, solid solution time, aging temperature and aging time. In the heat treatment process T6 aims to produce changes in the microstructure of Si elements in different silicon morphology and precipitation formation after the addition of Sn composition for Al-Si alloys, so that aluminum with T6 heat treatment can improve high heat resistance and wearability for piston applications and engine block. In this experiment, the aim was to increase the tin content in Al-Si-Sn-Fe-Cu alloys which would then increase the strength of the alloy material [5].

2. Experimental Steps

2.1. Materials

Chemical compositions (wt.%) of Al–Si alloys used in the experimental work before casting process Al-8,4Si-1Sn-0.3Fe-0.2Cu. Al-Si alloy raw materials obtained from PT. Inalum Indonesia. Al-Si hypoeutectic and eutectic casting alloys (containing 6-12% Si) are widely used in the automotive industry. It is expected that the addition of Cu will improve the mechanical properties of Al-Si-Sn-Fe-Cu alloys and can produce new phases such as Al_2Cu, Fe_2Si and Mg_2Siafter the process of adding Sn during the T6 heat treatment process [6].

2.2. T6 Heat Treatment

Al-Si-Sn-Fe-Cu casting stage, then proceed with the T6 heat treatment process, where the variable T6 used is a variable temperature solid solution, solid solution time, quenching, aging temperature and aging time. The application of T6 heat treatment is used to determine the effect of adding Sn alloys after the casting process and T6 heat treatment. In addition, it also aims to obtain microstructure and mechanical properties according to the specified standards [7].

Table 1. T6 Heat Treatment Conditions in This Study

Heat Treatment Process	Holding Time (Hour)	Temperature (°C)
Solid Solutions	30 m, 1 h, 3 h, 5 h	450°C,500°C, 520°C, 550°C
Quenching	10 m	450°C, 500°C, 520°C, 550°C
Artficial Aging	1 h, 3 h, 5 h, 8 h	160°C, 180°C, 200°C

2.3. Structure Charaterization

X-ray refers to electromagnetic radiation which has a wavelength range of 10-3 nm to 10 nm X-Ray Diffraction (XRD) measurement conditions, namely: Cu Kα radiation (nm) with a diffraction angle of 10°-100° and step speeds of 0.020 and 20 / minute with amperes of 30 and 40 kV. X-ray diffraction analysis is used to characterize the chemical composition before and after T6 heat treatment and has been used to identify intermetallic alloy compounds. where both as-cast micro-structures mainly consist of the Al phase and the Si phase [8].

All samples were tested by SEM Hitachi Su-3500 brand, Horiba EDX Detector. Morphological observations conducted at 250X magnification and VACC 20 Kv. SEM-EDS testing point analysis was carried out to obtain the elemental composition (element) of the Al-Si-Sn-Fe-Cu. Sem-Eds are used to characterize the chemical composition before and after T6 heat treatment to evaluate their microstructure [9].

2.4. Mechanichal Properties Tests

In a test sample by using the tool merk MITUTOYO HR-430MR. The Rockwell hardness test is defined in ASTM E18 and several other standards. Rockwell's hardness testing is different from Brinell's test that Rockwell's hardness rate is based on the difference in indentor depth from two load applications. Tensile test testing methods with the properties measured are tensile stress, yield stress, elongation and breaking stress. Using the ASTM E 8 testing standard using the Srenck Treable machine with a capacity of 60 KN to test the tensile strength of non ferous metals. Strength test of the Impact test using the Charpy method, to determine the impact energy of metals on shock loads and to find out the termperature transition britaldusctile (DBTT). Using standard test ASTM E 23 [10].

3. Results and Discussions

3.1. Result SEM-EDS Test Al-Si-Sn-Fe-Cu After Casting Process

At this stage will discuss the results of the analysis of SEM-EDS testing on Al-Si-Sn-Fe-Cu after going through the casting stages. The discussion explained covers the analysis of the results of mapping and point spectrum analysis, while the locations used in this analysis can be explained as follows:

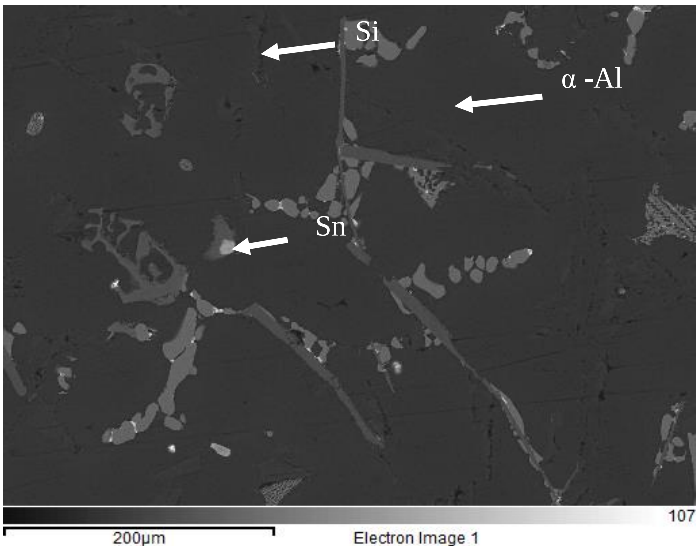

Fig. 1. Image of BSE Al-Si-Sn-Fe-Cu at 250x magnification.

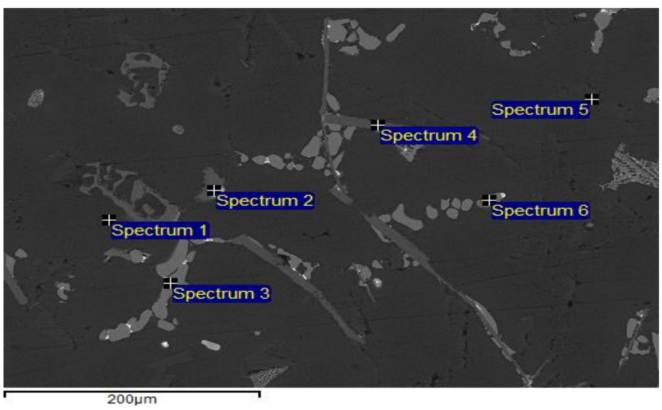

Fig. 2. Enlarged EDX Analysis Location 200µm.

Can be explained in the description of the picture above that Fig. 1 shows the results of BSE image analysis with a magnification of 250. Furthermore, Fig. 2 displays EDX location analysis of 6 points with

200um magnification. and after that Fig. 3 shows an example of the analysis of EDX spectrum mapping which shows the elements contained in a mixture of Al-Si-Sn-Fe-Cu. EDX analysis here uses two variables, namely the EDX point spectrum and EDX mapping spectrum, where for one sample Al-Si-Sn-Fe-Cu after casting was analyzed 6 times (point + mapping). After the SEM-EDX analysis process, it was found that the analysis of EDS Al-Si-Sn-Fe-Cu showed that there were a small number of elements, namely Al, Si, O, Cu, Fe, Sn in α-Al matrix elements and the alloy accumulated very high in the eutectic phase at the grain boundary [11].

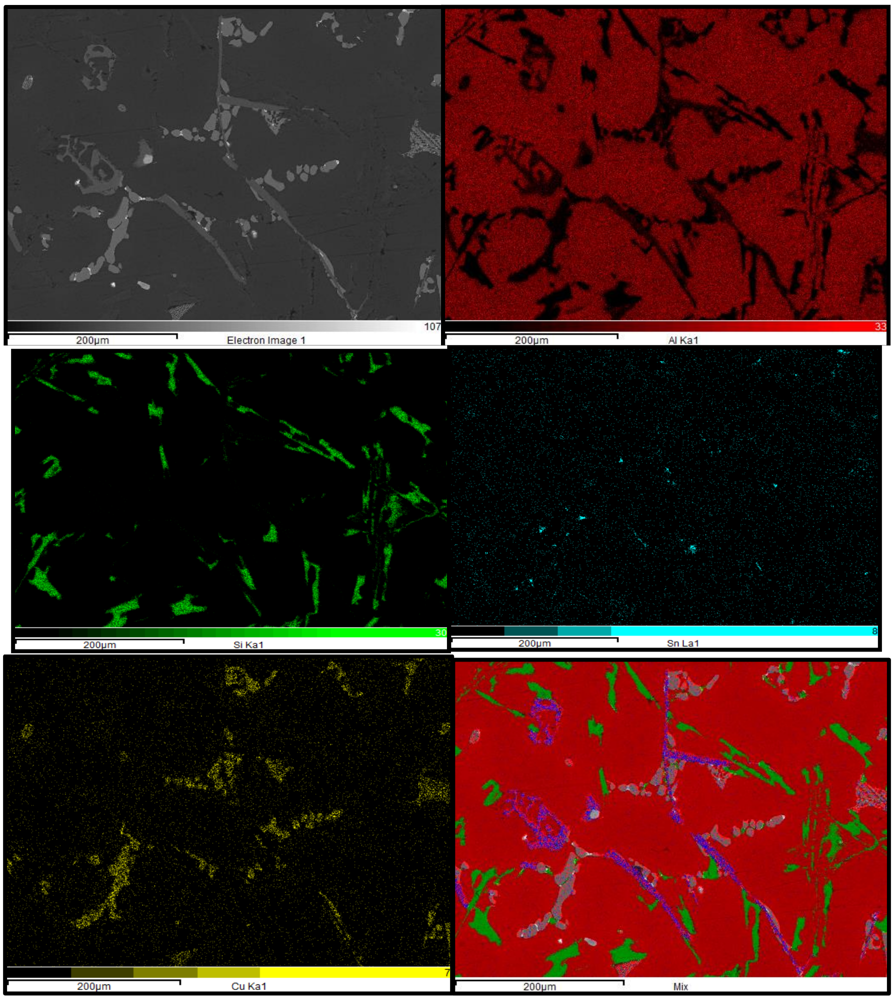

Fig. 3. Result of mapping Al-Si-Sn-Fe-Cu after casting.

For the EDX spectrum analysis results as in Table 2, where for each spectrum has been summarized in the table, the results of phase mapping obtained from SEM-EDS analysis are α-Al, Aluminum, Silicon, Copper, Tin and oxygen phases. It can be explained the results of the mapping analysis above which shows that image mapping with 250x magnification gets a picture of each element found in Al-Si-Sn-Fe-Cu alloys after casting. in Fig. 3 the matrix element Al is indicated by the red mapping image that dominates each element because this matrix is the parent metal. and for Fig. 3 also shows the results of mapping the silicon element image (Si) it can be explained that mapping green images is a silicon element. Next to Fig. 3 is a picture of Sn element mapping, which can be seen that the Sn element is displayed in light blue, Sn element distribution is still very little. in Fig. 3 is the result of mapping images of Cu elements. The Cu element is represented in yellow with Cu elements [12].

After knowing the Al-Si element the image mapping is then shown Fig. 3 it is a mapping of iron or iron elements, which can be seen that this element of Fe is displayed in bronze, where the distribution of Fe elements is very evenly distributed so that it can improve its mechanical properties. In the analysis of the mapping phase contained in the sample Al-Si-Sn-Fe-Cu after casting showed an alloy between Mg and Si converging or forming precipitation, which in this case Mg_2Si has a tendency that contrast tends to be a black morphological image. In the formation of new elements after casting this not only forms one but Al_2Cu is formed which is where the elements Al and Cu combine. the formation of this new element aluminum alloy has high mechanical properties [13].

3.2. Analysis of Al-Si-Sn-Fe-Cu After Casting and T6 Heat Treatment Process

It can be explained that the hardness testing carried out using the Rockwell method. Which is knowing the hardness of Al-Si alloys with the addition of the percentage of Sn which has undergone the casting process and the T6 heat treatment stage can be explained in the diagram below.

Based on Fig. 4, the casting results are processed by T6 heat treatment. In the graph, there are several results from the Al-Si-Sn-Fe-Cu casting process that has been carried out by the T6 heat treatment process. The first experiment was carried out using a variable temperature solid solution where the solid temperature was from 450°C, 500°C, 520°C, and 550°C. Then for 1-hour solid holding time, an aging temperature of 180°C with a holding time of 5 hours. It can be seen that the comparison that has the highest hardness value is found at a temperature of a solid solution of 520°C which is around 48.6 HRB. The best solid temperature falls at 520°C, so it can be seen in the Fig. below the OM results at temperatures of 520°C and 550°C [14].

Tabel 2. EDX Spectrum 1 - Spectrum 6 Analysis Results

	Weight %					
Element	1	2	3	4	5	6
O K	35.48	63.58	1.08	-	0.76	1.10
Al K	32.63	5.60	46.28	56.40	2.84	46.47
Fe K	3.93	-	-	23.98	-	-
Cu K	7.45	3.12	50.96	0.42	-	50.69
Sn L	20.51	-	-	0.08	1.36	-
Mg K	-	26.64	-	-	-	-
Si K	-	1.05	0.94	17.34	95.04	0.94
Ni K	-	-	0.74	-	-	0.79
Mn K	-	-	-	1.79	-	-
Totals	100.00	100.00	100.00	100.00	100.00	100.00

In experiments conducted according to Emmanuel Georgatis (2012), experiments on T6 Heat Treatment were carried out using Al-Si-Sn-Fe-Cu alloy samples. in experiments using variable solid solution temperature around 540°C with the holding time of the solid solution process using time variations ranging from 1 hour to 4 hours. In a study conducted at a solid temperature of 520°C with a holding time of about 3 hours can be seen in Fig. 5 that the temperature of 520°C silicon has a dense shape and conversely silicon at a temperature of 550°C has a large shape in Fig. 6. When the alloy is held at this temperature allows sufficient time for the diffusion process, which will then become the fully solid solution. Then in material distribution can be proven based on the XRD results, from the results of the casting process Al-Si-Sn-Fe-Cu that has been carried out by the T6 heat treatment process it can be proved that these alloys form new elements Mg_2Si and Fe_2Si [15]. And then for the level of homogenization of Al-Si-Fe-Sn from the alloy, it can be explained that when the atomic state is not fused from particles that occur during the freezing stage, it spreads through the matrix to reduce concentration, which then forms a homogeneous solid solution. So the purpose of a solid solution is to produce a solid solution that is almost homogeneous. Stages of heat treatment of solid solutions the first aluminum alloy metal is processed in the heating kitchen until it reaches T1 temperature. And then when the temperature of the T1 phase of the aluminum alloy will form a mixture of α crystals in the solid solution. In addition, the T1 temperature treatment aims to heat the alloy metal so that the solid solution is homogeneous [16].

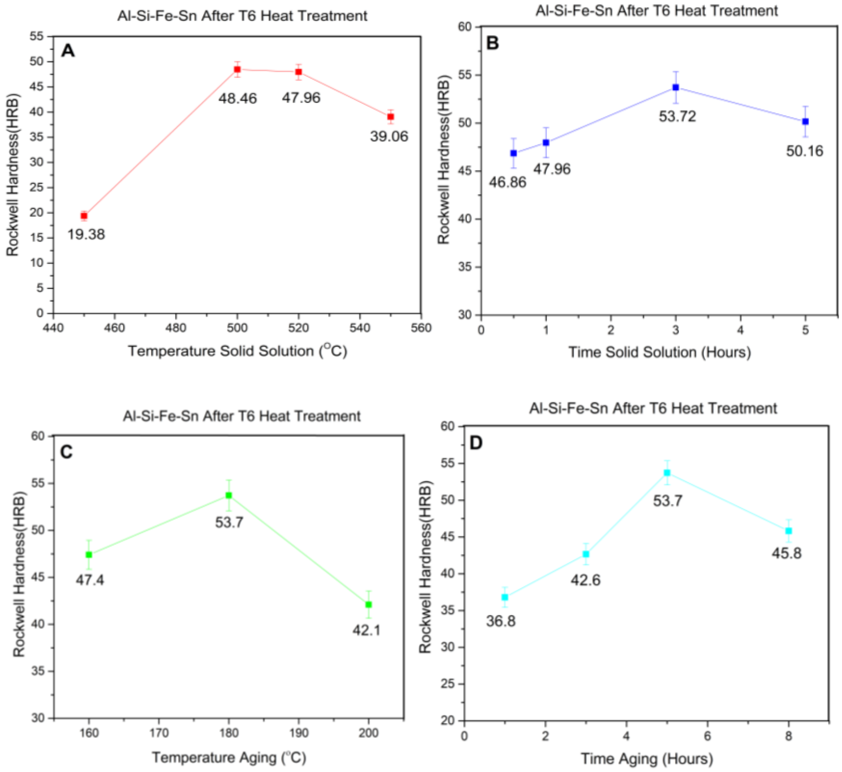

Fig. 4. Result of rock well Al-Si-Sn-Fe-Cu hardness after T6 heat treatment process (a) variable temperature solid solution, (b) variable time solid solution, (c) variable temperature aging, (d) variable time aging.

Table 3. The Results of the Analysis of the Sample Elements of Al-Si-Sn-Fe-Cu after Casting and T6 Heat Treatmeant

Nu	Element	% Weight*
		Al-Si-Sn 1 wt%
1	Al	53,38 ± 11,36
2	Si	2,59 ± 4,49***
3	Fe	2,34 ± 2,22**
4	Cu	1,81 ± 1,17
5	Sn	4,75 ± 8,23***
6	Pb	0,58 ± 1,01***
7	C	26,47 ± 4,96
8	O	3,07 ± 5,31***

*semiquantitative, the mean of the 3 measurements, was found in 3 of 3 measurements
**semiquantitative, the mean of the 3 measurements, was found in 2 of the 3 measurements
***semiquantitative, the mean of the 3 measurements, was found in 1 of 3 measurements
ND = not detected

Fig. 4a and Fig. 4b can show casting results that have been processed by T6 heat treatment variable temperature solid solution and variable time solid solution. In the graph, there are several results from the casting process of Al-Si-Sn-Fe-Cu that has been carried out by the T6 heat treatment process. After determining the solid temperature, the next experiment is to use a variable time solution which is a solid time of 30 minutes, 1 hour, 3 hours and 5 hours. then for solid temperature, around 520°C and aging temperature 180°C with a holding time of 5 hours. It can be seen that the comparison that has the highest hardness value is found in a solid solution of 3 hours, which is around 53.72 HRB. Based on the experiment, the best solid time fell within 3 hours [17].

In a test conducted by Zedi Li, it was explained that the time needed to hold the temperature of a solid solution was only 6 hours to dissolve all the elements contained in the study carried out with a temperature resistance of about 3 hours needed to obtain concentration. elements of each alloy are homogeneous. this process aims to improve the strength of mechanical properties. It was explained that if the temperature is too high the mechanical properties will decrease. Then the cooling processor can also be called the cooling process of metal that has been heated in the heating kitchen which is then put into the cooling media, the media cooling used in this study is water. Cooling is done quickly, from the heating temperature (520°C) to a temperature close to room temperature. Quenching aims to make a solution of homogeneous solids formed in the heat treatment of solid solutions and the state of atoms in constant thermal equilibrium at high temperatures. In the cooling phase, it tends to produce a supersaturated solid solution called an unstable phase. During cooling, the phase not only makes the atoms dissolve but also produces a large amount of atomic displacement. After cooling, soft aluminum alloys are compared with the initial conditions [18].

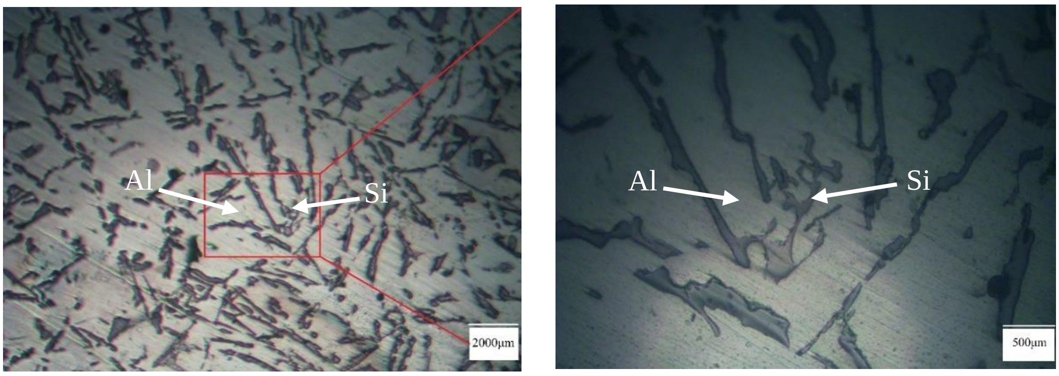

Fig. 5. Micro structure with a temperature solid solution 520°C.

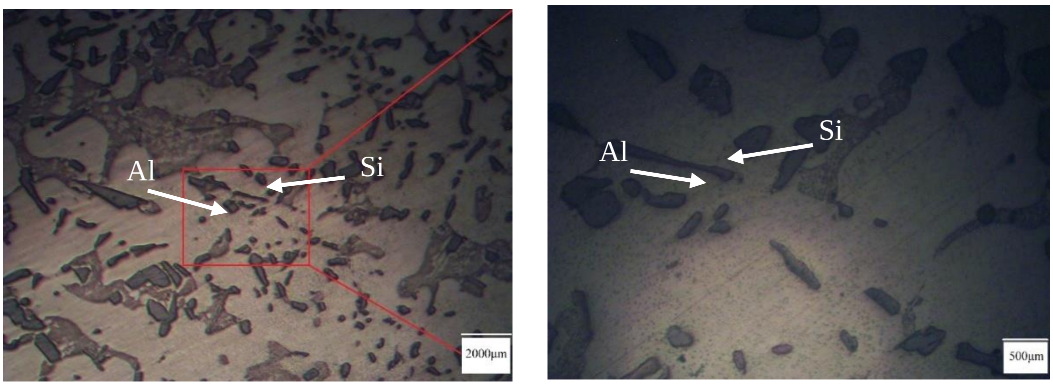

Fig. 6. Micro structure with a temperature solid solution 550°C.

Fig. 4c and Fig. 4d can show the results of casting that has been processed by T6 heat treatment variable temperature aging and variable time aging. In the graph, there are several results from the casting process of Al-Si-Sn-Fe-Cu that has been carried out by the T6 heat treatment process. In the graphic image, the determination of the aging temperature variable used is 160°C, 180°C and 200°C. Then for solid temperatures, around 520°C and 5 hours of aging time. It can be seen that the comparison which has the highest hardness value is found at 180°C aging temperature, which is around 53.7 HRB. Based on experiments the best aging temperature falls at 180°C. The aging process occurs at room temperature or in natural aging range of about 20°C to 60°C and can also occur at high temperatures in the range of 115°C-190°C or which can be called artificial aging. With artificial aging, the aim is to obtain a homogeneous distribution of deposits so as to produce high material strength [ASTM]. It can be concluded that at this temperature, the atomic structure can move further and thus deposits formed during artificial aging have a much smaller form compared to the results before the T6 heat treatment process. This aging process can be confirmed in the results of the SEM-EDS (Point + Mapping) test, it can be seen that mapping the size of silicon after the T6 heat treatment process is much smaller and slimmer than the size of silicon before the T6 heat treatment process is carried out [19].

In the process, according to Emmanuel Georgatis, declaring Zone [GP 1] can be formed in the first stage of the artificial aging process in aluminum alloys with low aging temperatures. In the zone process [GP 1] will occur at temperatures below 100°C but the Zone [GP 1] will not be formed at the temperature of the artificial aging process above 100°C. With the process of changing each phase of the zone [GP1] can allow an increase in value hardening of the solid solution in saturated α solution. Then for the formation of the second phase of the Zone [GP2]. begins to form when the temperature reaches 120°C and in the β phase 'will improve the hardening of the aluminum alloy when the temperature and aging are fully met. In aluminum alloy when artificial aging up to 120°C is the final stage of the aging process, at this stage, the formation of the intermediate phase and phase balance will be formed in the aging process of the aluminum alloy so that the alloy will return to the initial phase, namely β. From these steps can be identified by the following notation [20].

$$\longrightarrow \text{GPzones[GP 1]} \longrightarrow \beta''\text{[GP 2]} \longrightarrow \beta' \longrightarrow \beta\ (Mg_2Si)$$

If the Al-Si-Sn-Fe-Cu alloy artificially increases the temperature or the aging time is extended but the temperature is fixed, it will form deposits with ordinary crystal structures so that the aging stage will produce a new phase, namely β (Mg_2Si). Therefore, because resistance to artificial aging is an important stage that can affect the results of the entire age hardening process and temperature, the holding time at the artificial stage, and therefore determine the aging temperature with aging time is very important in terms of increasing metal mechanical properties. Based on the picture above shows the results of casting processed by T6 treatment. In the graph, there are some results from the casting process of Al-Si-Sn-Fe-Cu which has been carried out by the T6 heat treatment process which aims to produce a new phase of the T6 heat treatment process which is useful for improving the mechanical properties of Al-Si alloys which when added Sn, because Sn has been used to improve wear resistance. So that the characteristics of the Al-Si alloy add wear resistance. In the data retrieval stage, it involves several T6 heat treatment variables, including the variables used here, are the variable temperature of the solid solution, variable time of solid solution and variable temperature of aging and time variableaging. For the cooling time of each variable, 10 minutes is used with cooling media using water, then the aging process uses room air media for 5 hours [21].

This study has obtained a variable that has the optimum value found in the variable solid temperature solution after T6 heat treatment, the highest value is at a temperature of 520°C, so for the variable solid solution holding time is 3 hours, which is the variable temperature tested 30 minutes, 1 hour, 5 hours, while the highest aging temperature is 180°C for 5 hours, so that the variable Al-Si-Sn-Fe-Cu obtained which is suitable for improving the mechanical properties of the heat treatment process T6 is a temperature of 520°C for 3 hours cooling 10 minutes using water media which is then followed by an aging process with a temperature of 180°C for 5 hours with space air cooling media.In various cases, it has been found that the hardness value of aluminum alloys can be affected in the phase changes formed which occur during the precipitation hardening process starting from saturated solid solutions after the cooling stage. Although in the later stages of the aging process, the process that occurs is using artificial aging, the aging process is influenced by the aging factor of temperature with aging time which aims to make the hardness value increase well in Al-Si-Sn-Fe-Cu. The artificial aging process begins with a saturated solid solution, at the age stage here it is explained that in relation to the addition of aging time during the underage process, it can be said that during the underage process the deposition zone begins with the term [GP 1] at this stage resulting in hardening. then it will enter the peak age stage, at the peak age, the sediment area will begin to form a zone [GP2] and produce the β phase. After going through several stages, the phase will begin to form so that the hardness increases from aluminum alloy metal. When the age of artificial aging is added again, this results in artificial aging which will be at an older stage (180°C). Therefore older areas will form a new phase β and in the β phase formed during the artificial aging process which affects aluminum alloys will result in a decrease in the hardness value [22].

3.3. Result SEM-EDS Test Al-Si-Sn-Fe-Cu After Casting and T6 Heat Treatment

At this stage, we will discuss the results of the analysis of SEM-EDS in Al-Si-Sn-Fe-Cu after going through the casting stage and T6 heat treatment process. The discussion described covers the analysis of the results of point spectrum mapping and analysis, while the locations used in this analysis can be explained as follows:

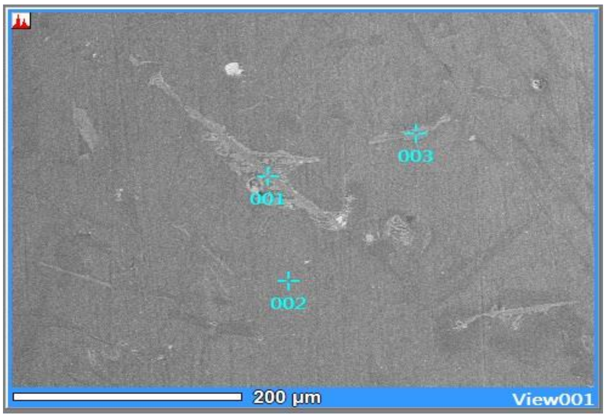

Fig. 7. image of BSE Al-Si-Sn-Fe-Cu at 200µm magnification.

Table 4. The Results of the Point Analysis of the Sample Elements of Al-Si-Sn-Fe-Cu after Casting and T6 Heat Treatmeant

	%Weight		
Element	1	2	3
C K	6.60	17.23	12.17
Al K	29.30	80.71	71.12
Si K	5.17	-	-
Fe	5.85	-	-
Cu K	4.61	2.06	6.12
Sn	40.10	-	4.40
Pb	8.58	-	-
O K	-	-	6.20
Total	100	100	100

Based on Fig. 7, BSE image analysis with magnification used is 250x and Fig. 8 shows the results of the EDX spectrum analysis pattern with 2000x magnification, while Fig. 9 shows an example of EDX analysis and spectrum analysis 1 EDX, where -Si-samples Sn after SEM analysis EDS. For EDX here uses two variables, namely the EDX point spectrum and EDX mapping spectrum, where for one Al-Si-Sn-Fe-Cu after casting it is analyzed 3 times (point + mapping). After the SEM-EDX analysis process, it is known that EDS analysis of Al-Si-Sn-Fe-Cu shows a small number of elements, namely Al, O, Cu, and Sn in the α-Al matrix and alloy elements. accumulates very high in the eutectic phase at the grain boundary [23].

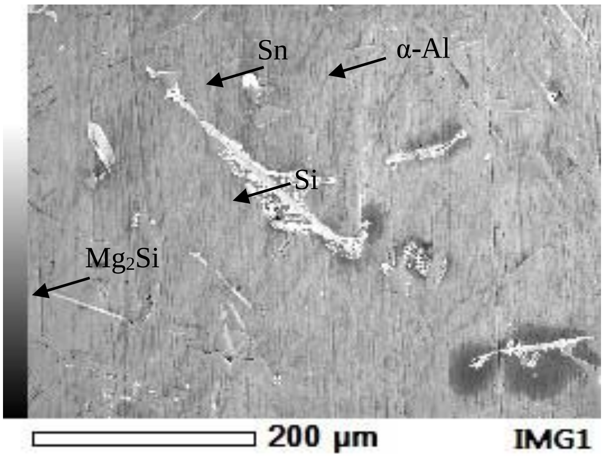

Fig. 8. 200µm EDX magnification analysis location.

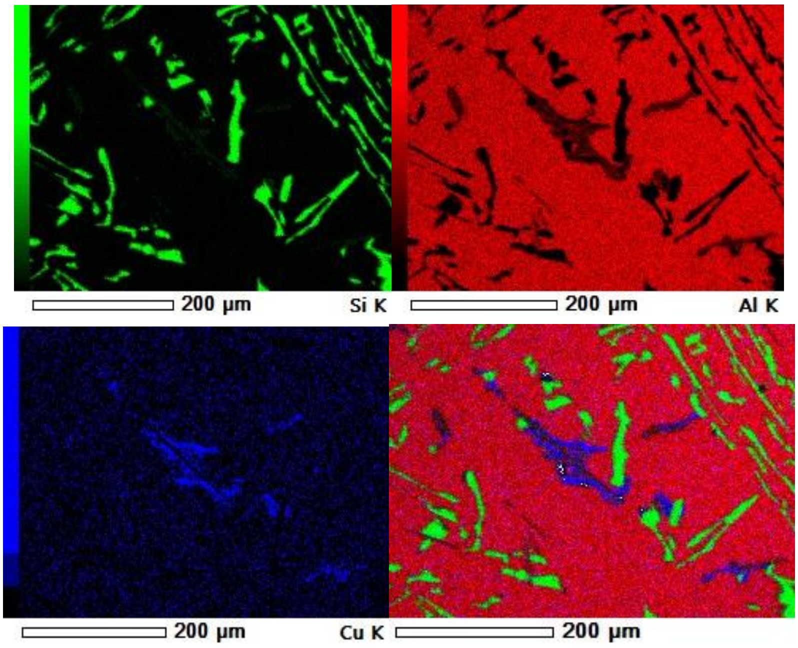

Fig.9. Result of mapping Al-Si-Sn-Fe-Cu after casting and T6 heat treatment.

For the EDX spectrum analysis results as in Table 4, where for each spectrum has been summarized in the table, the results of phase mapping obtained from SEM-EDS analysis are the phases of the α-Al, Aluminum, Silicon, Copper, Tin, and Oxygen matrices. Could explained the results of the mapping analysis showing above that mapping images with 250x magnification have captured images of each element found in Al-Si-Sn-Fe-Cu alloys after casting and T6 heat treatment. In Fig. 14, there is a red Al matrix element that dominates each element because this matrix is the parent metal of various other mixtures. in Fig. 6 above is the result of mapping images of silicon elements (Si), it can be explained that mapping green images is a silicon element [24].

In the analysis of the mapping phase contained in the sample Al-Si-Sn-Fe-Cu after casting and heat treatment T6 showed that precipitation ie β (Mg_2Si) were more visible because the phase was agglomerated homogeneously. the SEM-EDS image shows precipitation can improve the mechanical properties of Al-Si alloys. The EDX analysis results in spectrum 1 show that the presence of small amounts of Al-Si-Sn-Fe-Cu elements in the α-Al matrix and phases accumulates very well in the eutectic phase at the grain boundary between each element or its constituent elements [25].

3.4. Result X-Ray Diffraction (XRD) Test of Al-Si-Sn-Fe-Cu After Casting and T6 Heat Treatment

Fig. 10 is the result of the XRD graph of the Al-Si-Sn-Fe-Cu after casting alloy wherein the elements formed such as Al and Si are more dominant, then followed by other constituent elements Sn, Cu. It can be seen that Al has a high diffraction intensity because Al is here as the parent metal which dissolves the other metal mixture. Due to more than 2 constituents, new elements can occur such as Fe_2Si, Al_2Cu and Mg_2Si.In the graph, it appears that the highest point of the Al-Si particle is seen at point 2θ (diffraction angle) which is between the dimensions of the diffraction pattern with measurement angles of 28° and 46° with variable testing step velocity of 0.02° and 2° / minute. Whereas for the lowest point of the element Al-Si is seen at point 2θ (diffraction angle) which is between the dimensions from the angle of measurement of the angular patterndiffraction 48° and 97°. The XRD process pattern is shown in Fig. 1, each point has a very narrow and strong peak diffraction angle, indicating that the particles obtained are crystallized properly [26].

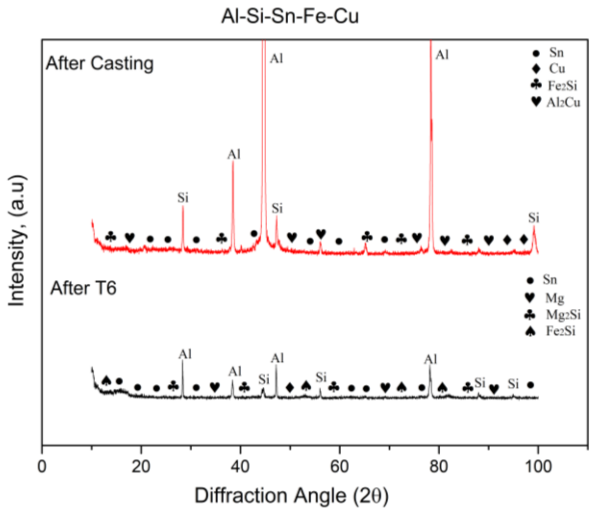

Fig.10. Result X-Ray Diffraction (XRD) Al-Si-Sn-Fe-Cu after casting, and after T6 heat treatment.

Fig. 10 it is clear that it can be seen from the results of testing the diffraction angle range 48°- 70° seen the formation of new elements but at the measurement angle of diffraction angle 80°- 100° with variable step velocity 0.02° and 2° / min element aglomeration Sn clearly visible and does not occur forming a new mixed element Sn. On the results of the measurement of diffraction angle 48°- 70° Alloy Sn appears agglomeration with other elements. The new elements appear after the casting process with the addition of Sn and form new elements Fe_2Si, Al_2Cu and Mg_2Si. In XRD analysis, the formation of new elements is not only β '(Mg_2Si) but there are other elements from the results of the agglomeration process between Fe alloys namely Fe_3Sn. Formation of Al_2Cu, Fe_2Si, and Mg_2Si is precipitation which is generally found in Al-Si alloys and is easily formed at room temperature in amounts based on the amount of Si content added to Al alloys after the casting process. so the Al-Si alloy is strengthened along with the addition of Sn as evidenced by the XRD test results which form a new element.The pattern of Al-Si XRD testing after the T6 heat treatment process is shown in Fig. 10 the diffraction angle has a peak angle variation that dominates the direction of the higher value, and overall the peak width of the diffraction angle is greater, which results in an increase in the solubility of Si and Sn in Al. In the graph, it shows that the highest point of the Al-Si particle is seen at point 2θ (diffraction angle) measuring angle 20° and 80° by testing variable step speed 0.02° and 2°/minute. Whereas for the lowest point of the Al-Si element is seen at point 2θ (diffraction angle) that is between the dimensions from the point of view of the pattern of diffraction angles 80° and 90°. The pattern of XRD testing after the Al-Si-Sn-Fe-Cu casting process is shown in Fig. 10a, each point has a very narrow and strong peak diffraction angle, which indicates that the particles obtained are crystallized properly. With the cooling rate, the diffraction angle changes slightly to a higher value diffraction angle, due to the freezing effect of the solute [27].

The results of the XRD graph displayed have differences between the results of the X-Ray T6 heat treatment Fig. 10 has a significant difference to the silicon phase change, which is the silicon phase after T6 heat treatment shows a relatively high peak point at 45°-50° diffraction angle and for Sn phase after T6 heat treatment. The diffraction angle has a high intensity due to the T6 heat treatment process. With the T6 heat treatment process in Al-Si-Sn alloy elements increases the grain boundary size of the phase formed in the alloy and due to the presence of Si and Sn elements this alloy can improve mechanical properties and good wear resistance. In the XRD Al-Si-Sn-Fe-Cu pattern after casting, it is obtained that the pattern results in a stand-alone Sn phase, this stand-alone phase is formed due to the casting stage especially during the mixing process when all alloy elements are at their melting point. Because the Sn element is mixed in solid form and also Sn has a low melting point of around 232°C so it reacts faster in the stage of unification of each element and has good homogeneity. With the good homogeneity of each alloy so that it can form a new intermetallic phase, namely β (Mg_2Si), this arises because the effect of the T6 heat treatment process is a shift in bonds between atoms. At the stage of the formation of β (Mg_2Si) in the Al-Si-Sn alloy is the artificial aging process, when the artificial aging process is improved and the aging process is extended but the temperature is constant, it can produce deposits of general crystal structures but continue in the aging phase it will produce a new phase, namely β (Mg_2Si) which causes an increase in the hardness value of the Al-Si-Sn alloy when compared to the phase Zone[GP 2]. in the phase β (Mg_2Si) increase in hardness it happens a little slow, this is because it might be influenced by the factor shifting Sn elemental atomic structure towards the homogenization of Al-Si alloys [28].

3.5. Result Impact and Tensile Test Al-Si-Sn-Fe-Cu after Casting and T6 Heat Treatment Process

It can be explained that mechanical testing to find out how tough the material can be done using the Al-Si alloy Charpy impact method and tensile with the addition of Sn which has undergone the casting process and T6 heat treatment stage can be explained in the diagram below.

It can be explained in Fig. 11a shows the difference in the results of the price value of the impact of the Al-Si-Sn-Fe-Cu alloy after the casting process and T6 heat treatment. in the use of casting variables that have been obtained from various variations in the percentage of the mixture of elements of Sn combined with Al-Si, which obtained the optimal percentage in the range of Sn. while for the T6 heat treatment variable process that was studied, it began with a variable solid temperature solution, solid resistance time solution, then continued with the determination of aging temperature and aging retention time. So that the optimal T6 heat treatment obtained is the solid solution temperature at a temperature of 520°C for 3 hours of holding time, then the aging stage at a temperature of 180°C for 5 hours. With increasing aging, sample hardness increases [29].

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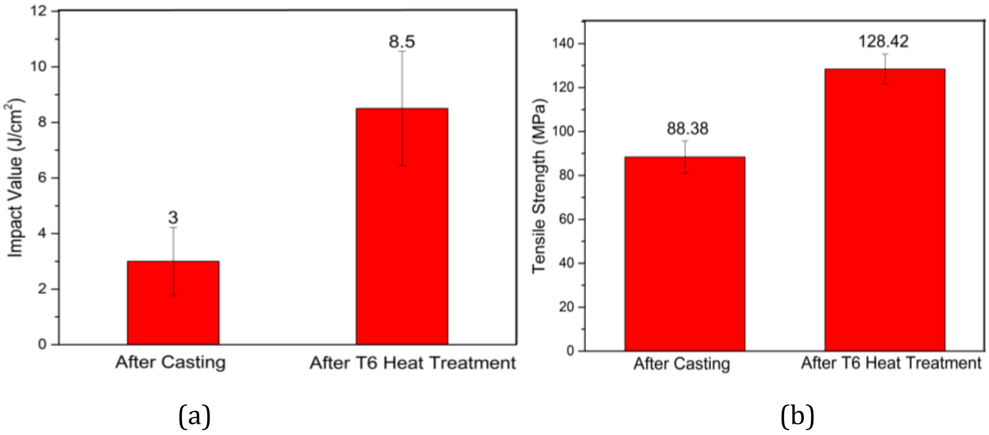

Fig. 11. The result of (a) impact charpy Al-Si-Sn-Fe-Cu, (b) tensileAl-Si-Sn-Fe-Cu.

In the description of the graph 1, the results of testing to determine the toughness and tenacity of a material using the impact Charpymethod applied to the Al-Si-Sn-Fe-Cu alloy material, in the Fig. can be seen that the difference in alloy values after casting and also the T6 heat treatment process. Because the sample that has been processed by T6 heat treatment Al-Si-Sn-Fe-Cu alloy material has a relatively high increase in toughness value. This T6 heat treatment can be proven by the results of electron microscopy testing or can be known as SEM-EDS point testing and mapping. From the results of the imaging that the Si element undergoes changes which are slightly slimmer and also extends it due to the results of the effects of the aging process, and the effect of precipitation makes it important in influencing the increase in hardness and also the toughness of material results. Thus the Al-Si-Sn-Fe-Cu alloy material after the T6 heat treatment process has an increase from the results after casting, which is where the impact Charpy test results are at 8.5 J/cm^2. With values in these ranges material can be said to have brittle properties, the fracture object after the test can be seen to break or break in the middle of the test object and because of the precipitation of the precipitation can be seen the surface shape of silicon particles that have very fragile groups [30].

Fig. 11b shows a comparison of the tensile strenght comparison curve of the Al-Si-Sn-Fe-Cu after the casting process is done and also after passing a series of T6 heat treatment processes. Which is where the heat treatment variable is obtained from a series of experiments using several variations of the variable solid temperature solution, solid time, temperature aging and aging temperature resistance. So that the optimal T6 heat treatment obtained is the solid solution temperature at a temperature of 520°C for 3 hours of holding time, then the aging stage at a temperature of 180°C for 5 hours. Which is where the value of tensile strenght from the results of T6 is 88 MPa. And then the result of the tensile aluminum alloy after casting has a stress value of 128.42 MPa. This the results of the comparison from after casting and T6 heat treatment, that after experiencing heat treatment the material tends to have tensile strength and a decrease [30].

4. Conclusion

1. Add 1% weight of Sn in the form of bars to the Al-Si-Sn base alloy in the sand casting process can improve the mechanical properties of the alloy, and for the results of SEM-EDS (Point + Mapping) testing with the addition of Sn precipitation elements formed Al_2Cu and Mg_2Si but there are some points of the dispersed Sn element which cannot form other precipitation and Sn is not agglomerated well against Al.

2. The results of the heat treatment of T6 with Sn in the form of bars to the Al-Si-Sn base alloy showed an increase in the value of Rockwell Hardness, where the hardness value was 53.72 HRB at a temperature of 520°C with a 3 hour holding time and an aging temperature of 180°C with a holding time of 5 hours. And then continued on the T6 heat treatment process carried out from the results of X-Ray Diffraction after

casting, the highest peak was seen at the Al peak, whereas after the T6 heat treatment process the highest peak was in Sn-Si causing T6 heat treatment to improve the mechanical properties of Al alloys Al-Si-Sn-Fe-Cu. And then for the results of the SEM-EDS (Point + Mapping) test after casting more Sn morphology was seen in the form of a nice little white sphere.

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