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The Effect of Heat Treatment on Hardness and Microstructure of Al-Cu Squeeze Casting Product

Ali Saifullah[a], Ferdian Reynaldi[b], Iis Siti Aisyah[c], A. Fauzan HS[d]
[a,b,c,d]Jurusan Teknik Mesin Fakultas Teknik Universitas Muhammadiyah Malang
Kampus 3, Jl. Tlogomas Raya, Malang, Indonesia.

E-mail: siti@umm.ac.id

Abstract

This research was conducted with the purpose of knowing the change mechanical properties of Al - Cu squeeze casting product which applied heat treatment and quenching. This study uses Al with the addition of 2% and 4% Cu,with the squeeze casting pressures applied are 100, 200, 300 and 400 bar. Heat treatment temperature constant at 520 ° C and 90 minute holding time. The heat treatment results were observed using Optical Microscopy with 800 times magnification and the hardness was measured using the Vickers hardness test method. The highest result of hardness is on the pressure 400 bar with the addition of 4% Cu which is 120.53 VHN and the average percentage of the most Al_2Cu *compounds is 23.125%. Heat treatment followed by quenching process significantly increase the hardness, it is because of the more solid and smaller granular shape due to quenching*

***Keywords**: Al-Cu; hardness test; heat treatment, squeeze casting*

1. Introduction

Metal processing technology in generals are classified such as casting, machining and forming. The development is so much done recently in terms of material technology and metal processing technology, to get the desired product. One material that is often used is aluminum (Al) which is the first metal to be reduction process by H.C. Orsted was also the inventor in 1825 (1).

Aluminum can replace other metals in the same function when combined with other elements. The composition of aluminum alloy can be varied according to the properties required in the application of a product. For example, the need of materials for aircraft construction and engine components that have characteristics of strength and high hardness, corrosion resistance and light even the needs in the automotive industry that cannot be described without aluminum (2).

In pure aluminum conditions it is too soft and low strength, for that aluminum needs to be combined with other metals so that its properties become better. While metals that are usually used as aluminum alloy elements are copper (Cu), silicon (Si), magnesium (Mg), manganese (Mn), zinc (Zn), iron (Fe) etc. According to Tata Surdia and Kenji Chijiiwa (1976: 42) said that "Aluminum as a pure metal is used as an alloy, because it does not lose its light and mechanical properties, to be able to cast it can be improved by adding other elements. The alloying elements are Copper (Cu), Silica (Si), Magnesium (Mg), Manganese (Mn), Nickel (Ni) and so on, which can change the properties of aluminum alloys "(3).

One element that is often combined with aluminum to increase its strength and hardness is copper (Cu). By adding Cu to Al, it will form a chemical compound called Al2Cu. In order to obtain solid mechanical and microstructure repairs, it is not enough to simply add metal elements. It needs to do several ways, such as squeeze casting and heat treatment. Squeeze casting is often called liquid metal forging, which is a process in which molten metal is cooled while under pressure. This process aims to reduce porosity and make the form of granules more dense (4). Whereas heat treatment is a controlled heating and cooling process, with the aim of changing the physical and mechanical properties of a material or metal as desired (5).

According to Duskiardi, Tjitro Soejono (2002) that the squeeze casting process decreases porosity to 85.15% and improves the hardness value of 5.29% (6). So this study conducted the heat treatment to determine the Al-Cu hardness and microstructure of the results of the squeeze casting.

2. Research Methods

This study is a true experimental research with a laboratory scale that aims to examine the effect of heat treatment on Al-Cu hardness and microstructure from the results of the squeeze casting process, assuming the other variables are kept constant and can increase the value of the strength of the material after heat treatment This research follows the flow diagram as shown in the Figure 1 below.

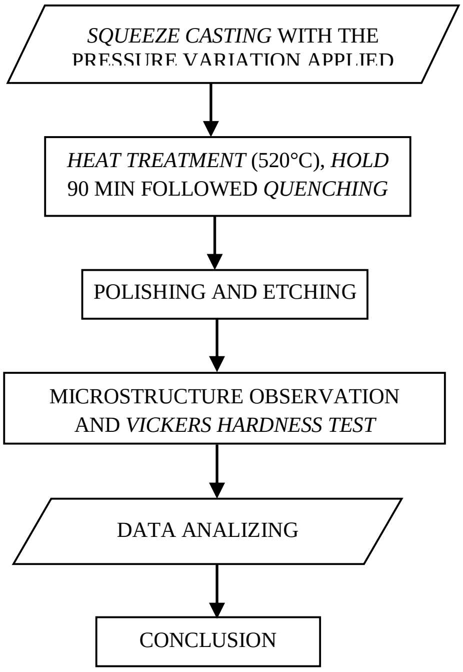


Figure 1. Flow diagram of the research

In this study, the material used is an Al - Cu alloy of squeeze casting made of solid cylinder pressed for 30 seconds. And the sample classification can be seen in table 1 below.

Table 1. Sample identification

The pressure of Solidification (Bar)	Cu composition (%)	
	2	4
100	S_{121}, S_{122}, S_{123}	S_{141}, S_{142}, S_{143}
200	S_{221}, S_{222}, S_{223}	S_{241}, S_{242}, S_{243}
300	S_{321}, S_{322}, S_{323}	S_{341}, S_{342}, S_{343}
400	S_{421}, S_{422}, S_{423}	S_{441}, S_{442}, S_{443}

Sample Identification:
S_{XY}
Where the x is = Tekanan (Bar)
y is = % composition of Cu

The equipment that used in this study were metal heating ovens, Vickers Hardness Test, Optics microscopy, cutting grinders, polishing paper, etching fluids and others.

3. RESULTS AND DISCUSSION

Vickers hardness test results of 2% Cu addition at different squeeze casting pressures show an increased hardness value, as shown in Figure 2 below. The increasing compared with the data of Vickers hardness before applied the heat treatment.

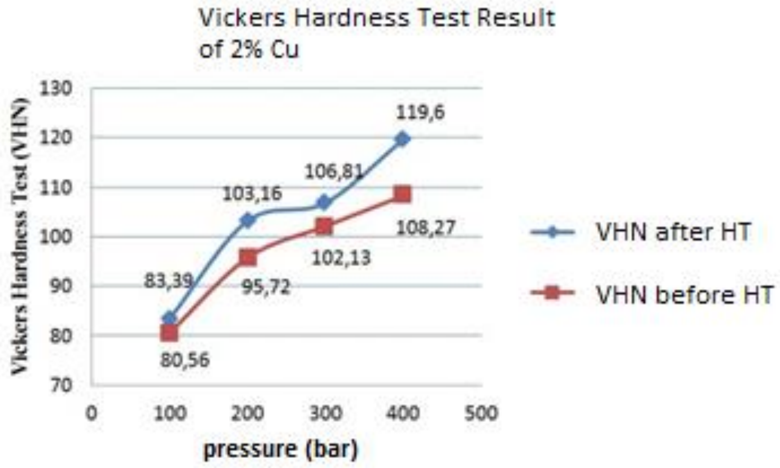


Figure 2. The graph of relationship between pressure squeeze casting with the Vickers test results of 2% Cu composition

Vickers hardness test results of 4% Cu addition at different squeeze casting pressures, show an increased hardness value, as shown in figure 3 below. The increasing compared with the data of Vickers hardness before applied the heat treatment

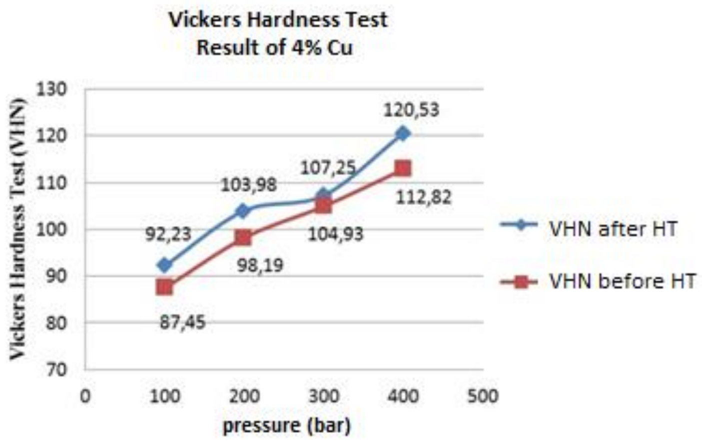


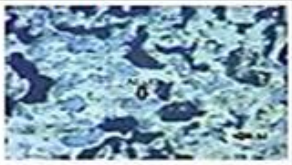
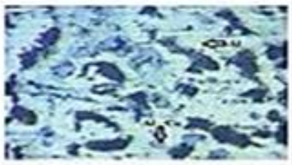
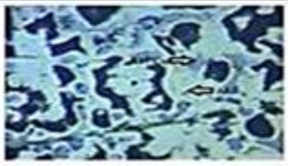
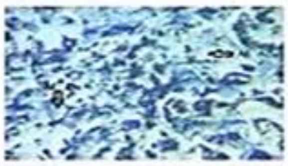
Figure 3. The graph of relationship between pressure squeeze casting with the Vickers test results of 4% cu composition

From the two graphs above there are significant differences in the values of different hardness. More Cu content tends to be harder and improve the ability to cast, this is due to the nature of copper (Cu) as an aluminum alloy element (Al) which gives an impact to increase the value of hardness. In addition, because of the heat treatment, the hardness value varies between after and before. From the results of Tholaba Ilmi (2015) data, that the hardness value of Al-Cu alloy metal can still be increased by means of heat treatment (7). This can be evidenced from the explanation of the data as follows, where the average hardness value of 2% Cu is: 100 bar pressure gets hardness before heat treatment of 80.56 VHN while hardness after heat treatment is 83.39 VHN. At a pressure of 200 bar, the hardness before heat treatment was 95.72 VHN and the hardness after heat treatment was 103.16 VHN. Pressure of 300 bar hardness before the heat treatment was 102.13 VHN and hardness after heat treatment was 106.81 VHN. The 400 bar pressure has a hardness before heat treatment of 108.27 VHN, while the hardness after heat treatment is 119.60 VHN.

At 4% Cu, the average hardness value from the graph is greater than 2% Cu. The following is an explanation of the data: 100 bar pressure has a hardness before heat treatment of 87.45 VHN and hardness after heat treatment is 92.23 VHN. The 200 bar pressure received hardness before the heat treatment of 98.19 VHN and the hardness after heat treatment was 103.98 VHN. At a pressure of 300 bar, the hardness before heat treatment was 104.93 VHN and the hardness after heat treatment was 107.25 VHN. The 400 bar pressure received hardness before heat treatment of 112.82, while the hardness after heat treatment was 120.53 VHN. Utama, Hari (2009) examined the effect of the addition of Cu (1%, 3% and 5%) on aluminum with a solution of heat treatment and natural aging on physical and mechanical properties where the highest hardness was on the addition of 5% Cu to 147, 1 VHN (8).

From the results of the heat treatment of Al-Cu alloy metals there is a change in the shape of the microstructure. Microstructure observations between before and after heat treatment can be seen in table 2 below the following:

Table 2. Microstructure observation of before heat treatment of 2% and 4% cu composition

Spesification	Before Heat Treatment 200x	After Heat Treatment 500x
200 Bar 2% Cu		
200 Bar 4% Cu		
400 Bar 2% Cu		
400 Bar 4% Cu		

From the table above, it can be explained that the micro structure before heat treatment has large and visible elements of grain, besides that precipitates (Al2Cu compound elements) are more visible because the cooling process from the squeeze casting results is done using normalizing. While the microstructure after heat treatment is denser and its precipitate with smaller granular forms due to rapid quenching.

According to Takasaki (2013) that the fabrication results of Al - Cu - Mg increase in hardness after undergoing a heat treatment process because the elements of Cu and Mg are separated at the grain boundary and are widespread so that the grain shape can occur in minutes called the none-equilibrium stage (9).

To find out the percentage of elemental content in this research, the grid calculation was carried out at three different points on each microstructural image using planimetric methods. The following data on microstructure test results after heat treatment are shown in table 3 below.

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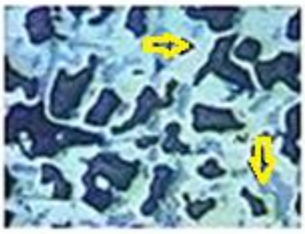
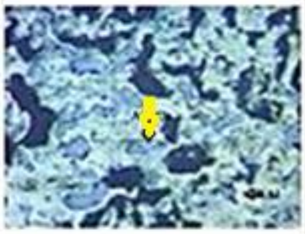
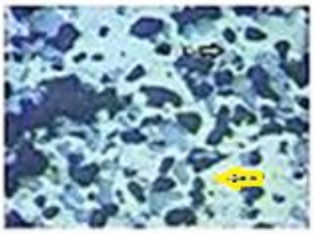
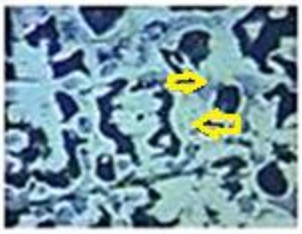
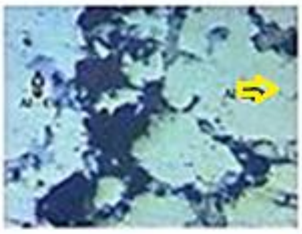
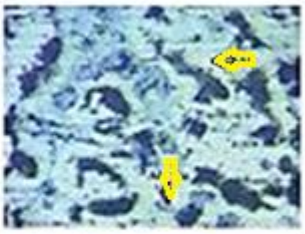
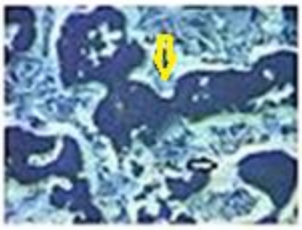
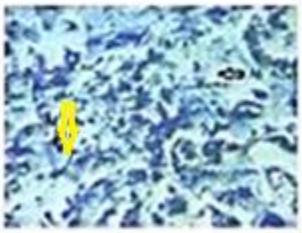
Table 3. Microstructure observation results of 2% and 4% cu composition after heat treatment

Pressure (Bar)	2% Cu	4% Cu
100		
200		
300		
400		

From the results of microstructure observation in Table 3 it can be explained that the average percentage of the elemental content of 2% Cu and 4% Cu is different. At the addition of 2% Cu, the results of the average percentage of Al alloy values are 19.87%, the average percentage value of Al is 64.50% and the average value of Al2Cu is 9.83%. Whereas in the addition of 4% Cu, the results of the average percentage of Al alloy values are 20.22%, the average percentage value of Al is 69.91% and the average value of Al2Cu is 23.125%. According to Suherman and Syahputra (2014), the A356 alloy value increased by up to 40% after adding 3% Cu elements and providing a heat treatment solution at a temperature of 540 ° C and quenching in warm water at a temperature of 70 ° C (10). In the solution process heat treatment T6 in Al - Si - Mg alloys, the best heating temperature is at a temperature of 540 to 550 ° C (11).

The content of more Cu elements will make the number of elements more compound as well. Of the many elements of the alloy against Al, Cu is one of the non-ferrous metals that is widely used to increase strength and fatigue resistance (fatigue). According to B.H. Amstead (1997: 71) says that "Copper as an element of aluminum alloy in a certain amount will increase its strength and hardness" (12). Wahyudi (1997: 31) further said that "Good castings start from Al-Cu alloys up to 8% Cu".

In this study, the pressure does not affect the percentage of its constituents but rather makes the granules denser. In addition, the heat treatment process in this study is to return specimens in the alpha phase in order to engineer the grain shape using quenching so that the granules do not grow from the grain boundary but are distributed or scattered in the alpha area in a small form or the Ideal Micro Structures.

4. Conclusion

When the heat treatment applied to the sample, the hardness increased, it was because the shape of the grain becomes finer due to quenching. The pressure does not change the percentage of the grain, but only makes the granules denser and small. At the addition of 2% and 4% Cu both contribute to the addition of the hardness. Pressure of 400 bar with the addition of 4% Cu has the highest hardness in this study. The formation of Al_2Cu compounds increases with increasing percent Cu in the Al matrix.

References

1. Hananto Dwi, 2009. "*Pengaruh Solution Treatment 450°C Quenching Dengan Air 27°C dan Aging 210°C Terhadap Sifat Fisis dan Mekanis Aluminium Paduan (Al-Si-Cu)*". Final Works S-1. Teknik Mesin Universitas Muhammadiyah Surakarta. Surakarta.
2. Budisma.net. "*Pengertian, Ciri Dan Sifat Aluminium*". 17 Mei 2016. http://budisma.net/2015/02/pengertian-ciri-dan-sifat-aliminium.html
3. Tata Surdia, Kenji Chijiwa. 1976. "*Teknik Pengecoran Logam*". Pradnya Paramita. Jakarta: Hal 42.
4. Hu, B.H., Niu, X.P., et. Al., Journal of Processing and Fabrication of Advanced Materials VI : *Squeeze Casting of Al-Si-CuFe-Mn-Mg Alloy*, Vol. 1, 1998.
5. Kamenichny, I. 1969. "*Short Handbook of Heat Treatment*". Moscow Peace Publishers: 74.
6. Duskiardi, Soejono Tjitro. 2002. "The influence of Pressure and Die Temperature in Squeeze Casting to The Hardness and Microstructure an Commercial Piston Materials". Mechanical Engineering Journal. Universitas Kristen Petra.
7. Ilmi. Tholaba. Ahmad, 2015. "Pengaruh Tekanan Dan Penambahan CuTerhadap Kekerasan Hasil Coran Aluminium Paduan Pada Proses Squeeze Casting". Tugas Akhir S-1. Teknik Mesin Universitas Muhammadiyah Malang. Malang
8. Utama, Hari. 2009. "*Pengaruh Penambahan Cu (1%, 3% dan 5%) Pada Aluminium Dengan Solution Heat Treatment dan Natural Aging Terhadap Sifat Fisis dan Mekanis*". Tugas Akhir S-1. Teknik Mesin. Universitas Muhammadiyah Surakarta. Surakarta.
9. Fukui, Takaaki., Nonaka, Yoshihiro., Suzuki, Shinsuke. "*Fabrication of Al-Cu-Mg Alloy Foams Using Mg as Thickener Through Melt Route and Reinforcement of Cell Walls by Heat Treatment*". Procedia Materials Science 4 (2014): 33 – 37. Waseda University. Japan.
10. Suherman, Syahputra. 2014. "*Pengaruh Penambahan Cu Dan Solution Treatment Terhadap Sifat Mekanis Dan Struktur Mikro Pada Aluminium Paduan A356*". Jurnal Dinamis Vol II. Sumatra Utara.
11. Shivkumar, S., Ricci Jr., S., Keller, C., Apelian, D., 1990. "*Effect Of Solution Treatment Parameters On Tensile Properties Of Cast Aluminum Alloys*". J. Heat Treating 8: 63–70.
12. Amstead, B.H., Myron L. Begemen dan Phillip F. Ostwald. 1997. "*Teknologi Mekanik jilid I*". Jakarta: Erlangga.