

THE EFFECT OF HEAT TREATMENT AND PRESSING AT 400 °C WITH COCONUT SHELL CHARCOAL MEDIA ON THE HARDNESS, MICROSTRUCTURE, AND DENSITY OF AL-SI ALLOYS

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ABSTRAK

Penelitian ini bertujuan untuk mengetahui pengaruh proses heat treatment dan penekanan terhadap kekerasan, densitas dan perubahan morfologi pada struktur mikro paduan Al-Si. Pada penelitian ini, media yang digunakan adalah arang tempurung kelapa dengan mesh ukuran 80 pada proses heat treatment 400 °C dan waktu tahan 75 menit. Penekanan dilakukan dengan beban 150 N. Hasil dari penelitian ini adalah adanya peningkatan kekerasan paduan Al-Si dengan nilai rata-rata 133 VHN setelah proses heat treatment dan penekanan. Pada struktur mikro terjadi perubahan morfologi pada paduan Al-Si dengan berkurangnya unsur Si dan juga adanya peningkatan nilai densitas setelah proses Heat treatment.

Kata kunci: aluminum, arang, heat treatment, tempurung kelapa, kekerasan.

ABSTRACT

This study aims to determine the effect of the heat treatment process and pressing on hardness, density, and morphological changes in the microstructure of Al-Si alloys. In this study, the medium used was coconut shell charcoal with a mesh size of 80 at a heat treatment process of

400 °C and a holding time of 75 minutes. The pressing was carried out with a load of 150 N. The result of this research is an increase in the hardness of the Al-Si alloy with an average value of 133 VHN after the Heat Treatment and pressing process. In the microstructure, there is a morphological change in the Al-Si alloy with the reduction of Si elements and also an increase in the density value after the heat treatment process.

Keywords: aluminum, charcoal, coconut shell, hardness, heat treatment.

1. INTRODUCTION

Currently, aluminum is a non-ferrous metal that is most widely used in many branches of industry because of its superior and superior properties, especially Aluminum-silicon (Al-Si) alloys. In its development, Aluminum-silicon is widely used as a material for making a product because it has excellent castability, good weldability, good thermal conductivity, high strength at high temperatures, and excellent corrosion resistance [1-6].

The strength of aluminum alloys can be increased through a process, one method that can be taken to increase the strength of a metal is through a heat treatment process. Therefore, it is necessary to conduct research on aluminum as a result of the sand casting method with the addition of the carburizing process and the pressing process before the artificial aging process [7-12]. So that the results of this research can be used by the industry as a consideration in the selection of casting methods and with the aim of increasing the economic value of the product.

Supriyono [13] conducted a study on the effect of pack carburizing using charcoal on the properties of mild steel. These properties are represented by the results of the microstructure, hardness test, and tensile test. The carburizing process is carried out at 930 °C which is the austenitic temperature of mild steel. The carbon source is charcoal. The specimens were held for 2, 3, and 4 hours at carburizing temperature. The carbon content of the raw material is 0.17%. The raw material is hypo eutectoid steel with a microstructure of ferrite and pearlite phases. After the carburizing process, the microstructure can be divided into two zones. Case zone and core zone. The case zone consists of hypereutectoid, eutectoid, and hypoeutectoid sub-zones. The core zone is the same as the raw material. The longer the holding time, the deeper the case zone and the stronger the material.

Gubicza et al. [14] processed the ultrafine-grained (UFG) Al-4.8%Zn-1.2%Mg-0.14%Zr alloy by high-pressure torsion (HPT) technique and then aged at 120 and 170 °C for 2 hours. These microstructural changes due to artificial aging were studied by X-ray diffraction and transmission electron microscopy. It was found that the HPT-processed alloy had a small grain size of about 200 nm and a high dislocation density of about 891014 m^{-2} . The majority of the deposits after HPT are in the Guinier–Preston (GP) zone with a size of 2 nm, and only a few large particles are formed at the grain boundaries. Annealing at temperatures of 120 and 170 C for 2 hours resulted in the formation of stable MgZn₂ deposits from some of the GP zones. It was found that for higher temperatures the MgZn₂ phase fraction was larger and the dislocation density in the Al matrix was lower. Changes in precipitates (precipitation reactions) and density changes in shape due to aging correlate with the evolution of hardness. It was found that most of the reduction in hardness during aging was due to crushing deformation and some grain growth at 170 °C. The effects of aging on the microstructure and hardness of the HPT-processed specimens were compared with those observed for UFG samples processed with the same channel angle pressure. It was revealed that in the HPT samples, fewer secondary phase particles were formed at the grain boundaries, and a higher amount of precipitate in the interior of the grains resulted in higher hardness even after aging.

Tensile tests on smooth and notched cylindrical samples were used by Westermann et al. [15] to investigate the work-hardening and ductility of an artificially aged AA6060 aluminum alloy. The alloy was tested following three processing steps, each of which was followed by artificial aging. Casting and homogenization, extrusion, cold rolling, and heat treatment were used to achieve a recrystallized grain structure. Following each of these processing steps, the material was tested in underaged, peak aged, and overaged conditions. A laser-based measurement system was used to determine the true stress-strain curve to failure. To estimate the equivalent stress-strain curves, the Bridgman correction was used, and the work-

hardening behavior was examined using an extended Voce approach. Fractography was used to investigate the failure mechanisms of materials exposed to various processing steps and temper treatments. Finite element simulations using the Gurson model were used to evaluate the use of the Bridgman correction and to investigate the notch strengthening effect observed experimentally. The experimental study shows the effects of thermomechanical processing and artificial aging on the alloy's stress-strain behavior and tensile failure strain.

Friction stir welding (FSW) of heat treatable Al alloy causes thermal cycle degradation of strength properties in the as-weld condition. As a result, post-weld heat treatment is used to restore the lost joint properties. The effect of artificial aging on microstructure characteristics was scientifically investigated by Joseph et al. [16] in this study. A microscope was used to examine the microstructural features. The grain size was found to be related to the strength and hardness properties. Due to the formation of equiaxed grains and fine precipitates, the aged joint exhibited higher lap shear strength than the weld joint.

Hardness is one of the important mechanical properties [17-20]. Hardness can be increased by artificial aging and carburizing heat treatment processes. Therefore, this research was conducted with the aim of increasing the hardness of Al-Si alloys.

2. MATERIALS AND METHODS

This research used materials: Al-Si alloy, coconut shell charcoal powder, and sodium carbonate (NaCO_3). Then raw material was cast. After that, Al-Si alloy with coconut shell charcoal powder was heated to a temperature of 400 °C and held for 75 minutes. Furthermore, the furnace is turned off, and pressing with a load of 150 N is given until the temperature drops to 170 °C. After that, artificial aging is carried out at a temperature of 200 °C (Figure 1).

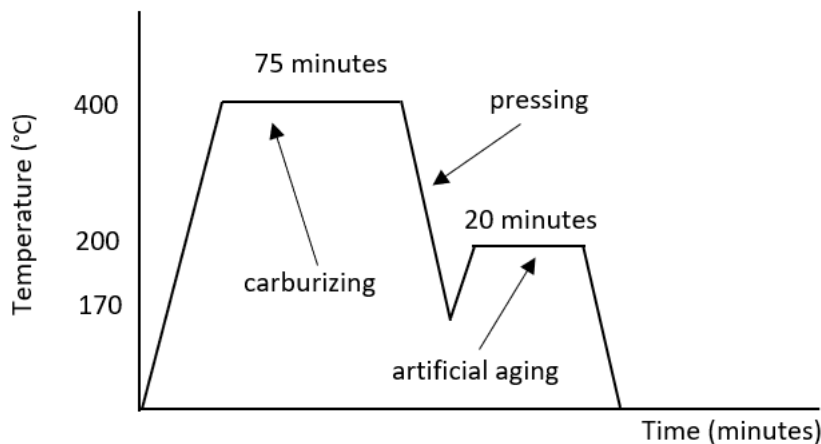


Figure 1. Heat treatment process scheme.

3. RESULTS AND DISCUSSIONS

From the photo of the microstructure in Figure 2, it can be explained that the element formed was an Al-Si alloy with a silicon content of 13.14% which was hypereutectic. In the picture, the Al element is light gray while the Si element is dark gray. The hypereutectic Si matrix forms small, thin, short, and dense flakes.

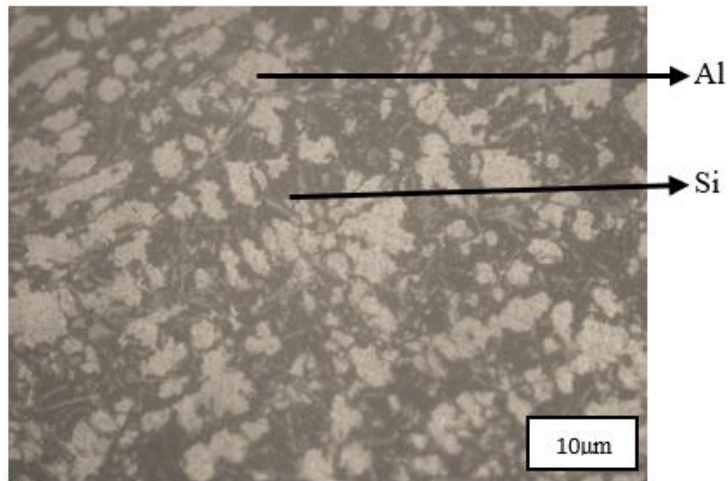


Figure 2. Microstructure of raw material.

In Figure 3, after the casting process, micro-photos are obtained that were different from the raw material. In the photo of the microstructure after casting, the shape of the microstructure is not homogeneous, this is because the density level decreases differently from the raw material. The specimen also contains hyperutectic elements which are slightly elongated, uneven, and slightly thickened.

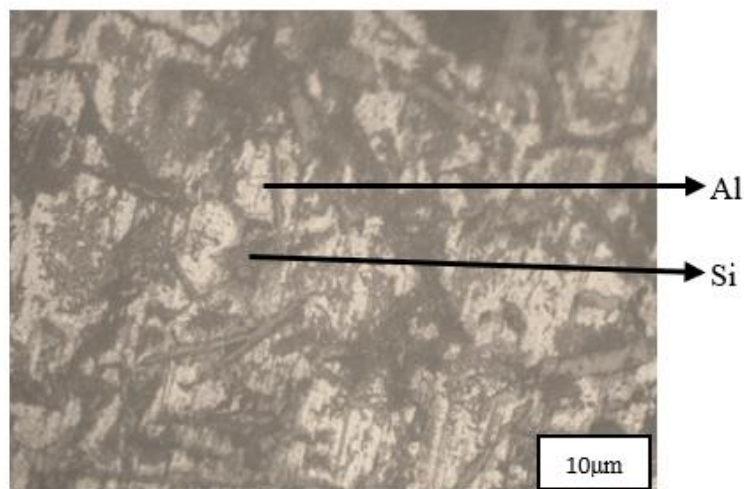


Figure 3. Microstructure of casted material.

In Figure 4, the photo analysis of the microstructure test on the surface of the Al-Si specimen after the heat treatment process obtained photos with the bright part which is the phase, namely the Al element, while the dark part is the phase, namely the Si element. It can also be noted that after the heat treatment and pressing process, there was a grouping of elements and some elements experienced a decrease in value, one of which was Si which after casting had a content value of 13.08% to 12.83%. This can be caused by the heat treatment process and the emphasis changes the density of the specimen and there is grouping of elements and the distance between elements is not tight. For specimens after casting, the solidification process took a long time, causing the formed phase to be not very clear.

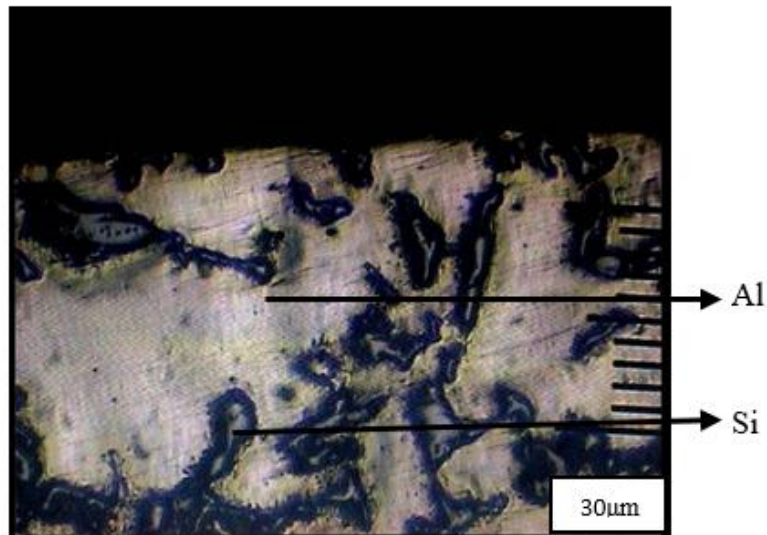


Figure 4. Photo of microstructure after heat treatment and pressing processes.

From the hardness test results (Figure 5), the raw material hardness values are 121.18 VHN, 120.45 VHN, and 121.67 VHN respectively with an average value of 121.1 VHN, the specimens after casting get successive hardness values from edge to center of 76.54 VHN, 75.55 VHN, and 76.87 VHN with an average value of 76.32 VHN, while the specimens after being given a heat treatment process with emphasis were found to have hardness values of 130 VHN, 132 VHN, 137 VHN with an average value of 133 VHN.

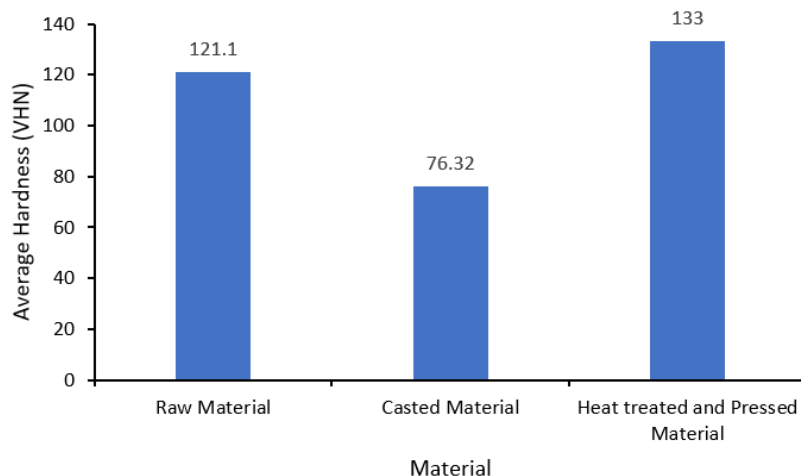


Figure 5. Average hardness test results.

From Figure 6. It can be explained that the raw material specimen has a density value of 2.80 gr/cm³ with a mass of 84 grams and a raw material volume of 30 cm³. After casting, there was a decrease in the density value of 2,598 gr/cm³ with a mass of 42.35 gr and a specimen volume of 16.30 cm³. After the carburizing process and pressing, the density value increased slightly by 2,599 gr/cm³ with a mass of 42.36 gr and a specimen volume of 16.30 cm³.

Then, it can also be explained that the highest value is when the specimen is still a raw material with a value of 2.80 gr/cm³. This is because the piston forming process uses the metal forming method, which

through this method can increase the density value. After the casting process, the density value decreases until it reaches a value of 2,598 gr/cm³. This is caused by the porosity of the specimen which causes a decrease in the density value. After the carburizing and pressing process, the density value increased, although not significantly, with a value of 2,599 gr/cm³. This can occur due to the process of adding carbon and also due to the process of pressing the specimen during heat treatment.

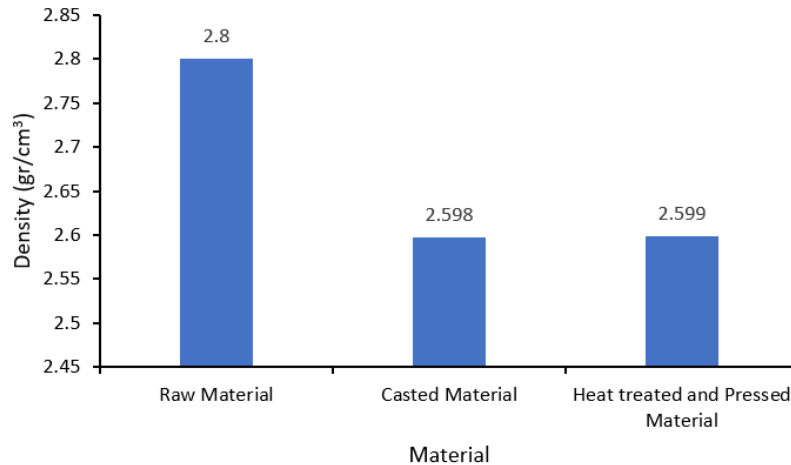


Figure 6. Density test results.

Based on metallographic testing with Scanning Electron Microscope (SEM) and Energy X-Ray Spectroscopy (EDS), photos were obtained which showed that there was an element of carbon attached to the surface of the specimen (Figure 7.). At spectrum 1 of the EDS scan, it was found that there was element C with a concentration of 24.7 wt% and Al with a concentration of 67.1 wt%. Then, at spectrum 2 of the EDS scan, it was found element C with a concentration of 51.3 wt%, Al with a concentration of 12.4 wt%, and Si with a concentration of 1.7 wt%. The presence of carbon elements on the surface of the Al-Si specimen after the heat treatment and pressing process indicates that the heat treatment and suppression processes affect the addition of elements contained in the specimen.

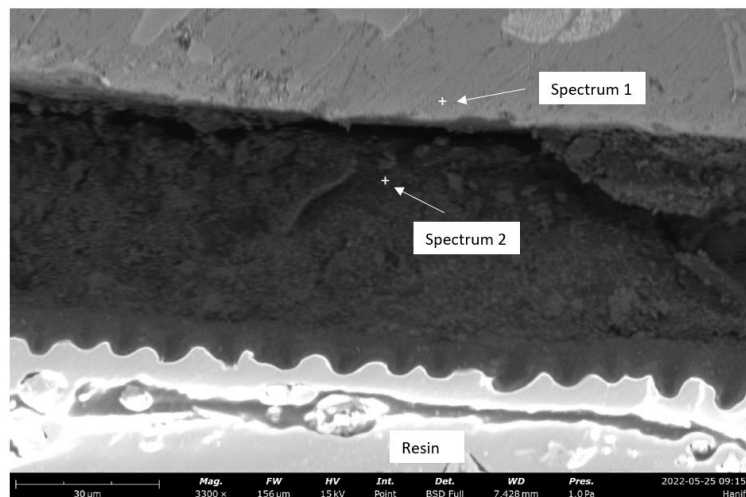


Figure 7. Scanning electron microscope results.

4. CONCLUSION

From the analysis of research that has been carried out and the test results have been obtained from each material, it can be concluded that the results of testing the hardness of the specimen from the raw material, after casting, and after the Heat Treatment process the values obtained are as follows, the raw material of Al-Si castings has a hardness value. an average of 121.1 VHN, after casting the average hardness value is 76.32 VHN, and after the Heat Treatment and pressing process has an average hardness value of 133 VHN, which was the highest hardness value compared to raw material specimens and specimens after casting. In density testing, Heat Treatment has an influence on the density value. The density value of the raw material is 2.80 gr/cm³, which is the highest value. After casting, the density value decreased to 2,598 gr/cm³ and after going through the Heat Treatment process it increased although not significantly, which was 2,599 gr/cm³.

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