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EFFECT OF POURING TEMPERATURE VARIATION ON COOLING RATE, HARDNESS AND MICROSTRUCTURE OF AL-ZN IN AIRCRAFT STRUCTURES

A. Pambekti[1], A. Prakoso[1], O. Dinaryanto[1], A. Rahmandhika[2], and R.I. Yaqin[3]*

[1] Adisutjipto Institute of Aerospace Technology, Bantul, INDONESIA
[2] University of Muhammadiyah Malang, Malang, INDONESIA
[3] Polytechnic of Marine and Fisheries Dumai, Dumai, INDONESIA

Abstract

Al-Zn alloys are widely used in automotive manufacturing, aircraft component manufacturing, and advanced military equipment applications because of their very high strength. Based on the Al-Zn phase diagram, the melting point of aluminum alloy 7075 with wt% Standard Aluminum Association is at 660°C. This research was carried out with the addition of temperature at the time of casting at 30°C each. The casting temperature has an important role because it affects the mechanical properties. Al-Zn alloy is melted with three variations of pouring temperature 690 ℃, 720 ℃, and 750 ℃ then it is poured into the mold, while the mold temperature is kept constant at 220 ℃. Cooling rate, Hardness, and microstructure were observed. The result is that the pouring temperature of 750 ℃ has the highest hardness value of 60.7 BHN. The cooling rate for a pouring temperature of 690 ℃ is 1.55 ℃/S, 720 ℃ is 1.13 ℃/S, and 750 ℃ is 1.05 ℃/S.

Keywords: *Al-Zn Alloy, Cooling rate, Hardness*

*Corresponding author: Tel. +62 274 451263 Fax +62 274 451265
E-mail address: arif.pambekti@itda.ac.id

1. Introduction

Aluminum alloys have been widely used in automotive manufacturing, aircraft component manufacturing, and advanced military equipment applications [1]–[4]. For example, Al–Zn–Mg–Cu is an aluminum alloy with very high strength. Aluminum alloys are used primarily in high-performance aircraft components, such as stringers, fuselage, and wing skin. Al–Zn–Mg–Cu alloy is a 7xxx series of an aluminum group, which has the properties of corrosion resistance, high impact resistance, and good thermal conductivity. The strength and toughness of these alloys are generally improved by the T6 heat treatment [5]–[7]. Metal casting is a structural component fabrication process, but the weakness of this technique is the lower mechanical properties compared to the base material before it is melted down. Pouring temperature is a casting parameter affecting material properties [8]. Casting variables such as mold material and casting temperature have an effect on improving the quality of aluminum alloy castings. The effect of cooling rate on the mechanical properties of aluminum alloys has been extensively studied [9], [10]. Research has been carried out on the effect of the cooling rate on the microstructure, and the solidification parameters of the Al−7Si−0.3Mg−0.15Fe alloy were investigated. The results showed that Hardness increased with increasing cooling rate [11].

The effect of heat treatment and cooling rate on the hardness properties of the addition of Sr to alloys A319.1, A356.2, and A413.1 has been studied [12]. Two degrees of quenching are used to estimate Hardness (85 and 110-115 BHN) in commercial alloys. The results show a higher hardness index at a high cooling rate when compared to a low cooling rate. The alloy without Sr addition showed slightly higher Hardness than the Sr-added alloy, and the hardness index also decreased with Sr addition for both cooling rates. The interaction between Sr and Cu, and Mg elements which form various intermetallic phases, can be associated with a decrease in hardness values. The increase in these elements was followed by a decrease in the formation volume fraction of the precipitation-hardening phase (Al_2Cu and Mg_2Si phases) in alloys A319.1 and A356.2, further reducing the Hardness.

The Cooling Curve Analysis (CCA) method can predict microstructure and grain refinement and determine latent heat solidification. It can determine the thermo-physical properties of the alloy and the latent heat of solidification [13], [14]. The main objective of this experiment is to determine the behavior of the cooling curve, microstructure, and Hardness of the Al-Zn alloy with variations in pouring

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temperature. The research was divided into two parts, and the first part observed the cooling rate during the solidification of the Al-Zn alloy with variations in pouring temperature. The second part is observing the microstructure and Hardness at the variations of pouring.

2. Experimental and Procedures

Alloy aluminum is obtained by import from Russia. Aluminum is used to produce automotive components, with a chemical composition close to that of the 7xxx series aluminum (Al–Zn–Cu–Mg). The material is cut into several pieces, as shown in Fig. 1, which are then melted in the furnace Fig. 3. The pouring temperature is carried out at 690 ± 2 °C, 720 ± 2 °C, and 750 ± 2 °C then it is poured into the mold, while the mold temperature is kept constant at 220 ± 3 °C. The steel molds used during this study were made of EMS/17330 carbon steel Fig. 2. The chemical composition of aluminum alloy, as shown in Table 1, was analyzed using spectroscopy.

Table 1. Al-Zn chemical composition

Element	(wt%)
Si	0.2411
Fe	0.5275
Cu	0.13.10
Mn	0.0705
Mg	0.0081
Ti	0.0104
Cr	0.0043
Pb	0.0754
Sr	0.0109
Ni	0.0072
Zn	1.6542
Al	Balance

Fig. 1. Al-Zn aluminum alloy

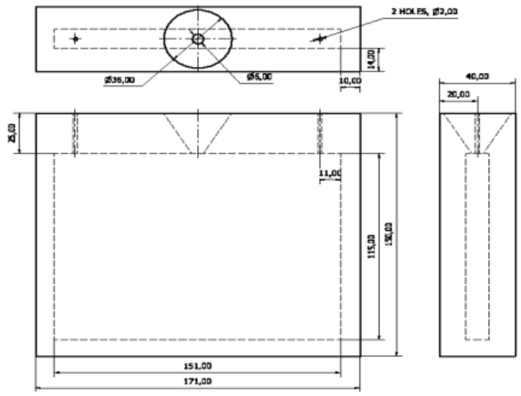

Fig. 2. Trapezoidal mold for testing specimens

The molten metal was poured into a 10mm diameter (permanent) metal mold and allowed to cool to room temperature. The steel molds used during this study were made of EMS/17330 carbon steel with the consideration that this material is sufficiently capable of holding liquid aluminum (because carbon steel has a melting point above that of aluminum alloy). The cooling temperature was recorded using a chromel-alumel (type K) thermocouple during solidification. The Hardness of the Al-Zn alloy in the specimen was tested using the Brinell test with a steel ball indenter diameter of 2.5 mm with a load of 612.9 N for 10 seconds. The average hardness value is taken from six tests with samples. Metallographic specimens were made by grinding using SiC paper and polishing and then etching using a solution of 2 ml HF and 100 ml H_2O.

Fig. 3. Furnace

3. Results and Discussion

3.1 Cooling Rate

Fig. 4, Fig. 5, and Fig. 6 show the cooling and first derivative curves for Al-Zn alloy with variations

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in pouring temperature. The cooling curve shows the difference in cooling time at each pouring temperature. The temperature drops significantly to 550 °C within 90-200 seconds. The temperature drops due to differences in pouring temperature (690 °C, 720 °C and 750 °C) and mold temperature (220 °C). The illustration shows that the temperature simultaneously decreases from 690 ºC to 550 °C in 90 seconds, 720 °C to 550 °C in 150 seconds, and 750 °C to 550 °C in 200 seconds. The cooling rate for a pouring temperature of 690 °C is 1.55 °C/S, 720 °C is 1.13 °C/S, and 750 °C is 1.05 °C/S. Cooling rate as a thermodynamic parameter is strongly influenced by pouring temperature and will decrease with increasing pouring temperature [11].

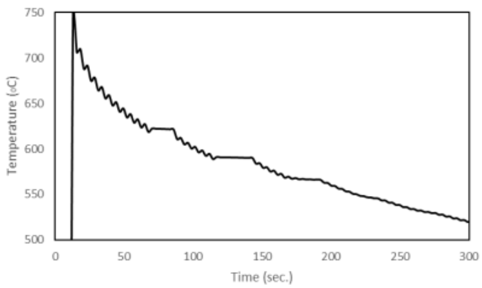

Fig. 4. Pour temperature cooling curve 750 °C

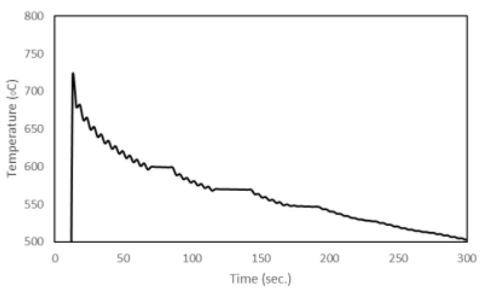

Fig. 5. Pour temperature cooling curve 720 °C

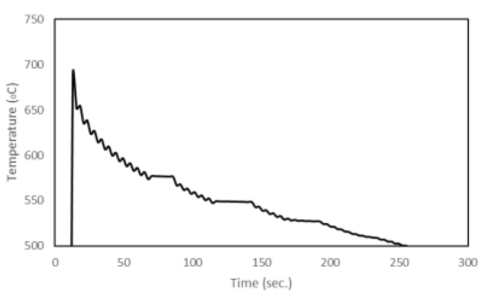

Fig. 6. Pour temperature cooling curve 690 °C

3.2 Hardness and Microstructure

Fig. 7 the average hardness value of the Al–Zn alloy specimens was obtained through six hardness test points. The hardness value was obtained through the Brinell test. The hardness value of pouring temperature 690 °C is 59.65 BHN, 720 °C is 60.63 BHN, and 750 °C is 60.7 BHN higher than the hardness value obtained from the research of Akhyar et al. [15], which is around 38.43 BHN. This is made possible by the difference in pouring temperature, which causes the grain size to increase as the pouring temperature increases. Grain-size images can be seen in Fig. 8.

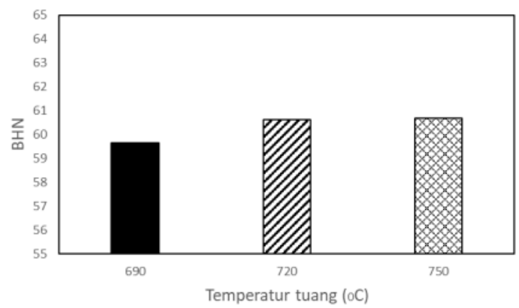

Fig. 7. Brinell test with three variations of pouring temperature

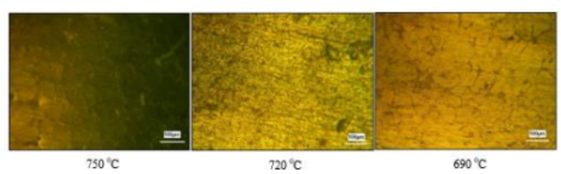

Fig. 8. Microstructure with three variations of pouring temperature

4. Conclusions

The Al-Zn alloy specimens have a chemical composition very close to that of the 7xxx series aluminum alloys (Al–Zn–Cu–Mg), which have applications in automotive, aircraft, and military equipment manufacturing. The greatest cooling rate at a temperature of 690 °C is 1.55 °C/S. The hardness value of the Al-Zn alloy is highest at a temperature of 750 °C, namely 60.7 BHN.

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