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EFFECT OF POURING TEMPERATURE ON IMPACT TOUGHNESS ON BRASS (Cu-Zn) THROUGH METAL CASTING

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The purpose of this study is to investigate the impact toughness of brass (CuZn) with five variations of pouring temperature during the production of cast-samples through a metal casting process. Five variations of the pouring temperature are 1 060, 1 110, 1 160, 1 210, and 1 260 °C, respectively. Meanwhile, the mold is produced from medium carbon steel and does not preheat (room temperature). The results show the maximum impact toughness is 20,67 Joule at 1 110 °C of pouring temperature, then the minimum impact toughness is 17,67 Joule at 1 260 °C of pouring temperature. In general, it can be concluded that the impact toughness decreases with increasing pouring temperature.

Keyword: casting, brass, pouring temperature, impact toughness, scanning electron microscope (SEM)

INTRODUCTION

Copper alloy and copper base are materials that are widely applied in various engineering products. Brass alloy is the result of a combination of copper and zinc in various contents [1]. The parameters of the copper casting process such as core making, melting, pouring, shot blasting, and others. The effect of brass casting temperature can reduce shrinkage defects which were analyzed using the Pareto chart [2]. Microstructure modification of brass alloy by heat treatment affected the impact toughness (Charpy) number has been studied. The number of crack toughness (impact energy) on CW510L with 775 °C of a treatment temperature for 60 min. can be increased from 47 to 52 Joules, while the CW511L with 850 °C a temperature for 120 min. decreased from 104 to 84 Joule [3].

The effect of sintering temperature on Cu-28Zn brass alloys has been investigated through a surface response methodology. The result shows that the sintering temperature affects the impact of energy [4]. Besides, the effect of pouring temperature on impact strength has been reported in several aluminum alloys [5-11]. Modification in micro-structure of brass alloys that affect to improve mechanical properties has been evaluated in cast products with gravity casting [12]. Based on this background, this study aims to evaluate the impact of toughness on brass alloys after variations of pouring temperatures.

Iqbal, Doctoral Program-School of Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia
Department of Mechanical Engineering, Universitas Abulyatama, Banda Aceh, Indonesia
N. Ali, Department of Mechanical Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia
H. Husin, Reaction Engineering and Catalysis Laboratory, Department of Chemical Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia
Akhyar (akhyar@unsyiah.ac.id), Department of Mechanical Engineering and Industrial Engineering, Univeritas Syiah Kuala, Banda Aceh, Indonesia
Khairil, Department of Mechanical Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia
A. Farhan, Department of Physic Education, FKIP Syiah Kuala University, Banda
Aceh, Indonesia

EXPERIMENTAL PROCEDURES

The sample casting process begins with cleaning the brass alloy from all the dirt. The raw material is cut from a brass rod with a length of 609,6 mm and a diameter of 25,4 mm into small pieces so that it can be placed in a ladle for melting. The melting furnace used in this study is a furnace with liquefied petroleum gas (LPG) as fuel combined with oxygen for complete combustion. The furnace was developed at the Motor Fuel Laboratory of the Universitas Syiah Kuala.

The pouring temperature during casting samples in this experiment was varied by five temperature variations, such as 1 060, 1 110, 1 160, 1 210, and 1 260 °C (± 5 °C) respectively, while the metal mold was not preheated (room temperature). The temperature is held for about 60 minutes in the furnace before it is poured into a metal mold, assuming the molten temperature is evenly distributed. The metal liquid is poured with five temperature variations into the rectangular plate mold with dimensions is 400 x 400 x 12 mm, and the distance between the cavity and the outer mold wall is 100 mm (Figure 1). The casting technique was carried out by the gravity casting process with steel mold [13,14]. The cast-sample mold is made of medium carbon steel with an open upper side for easy pouring and control. The temperature is measured at three positions, there are at the brass molten or cavity, at the body of the metal die, and at molten before pour into die. The temperature is measured by using a Chromel-Alumel Type-K thermocouple.

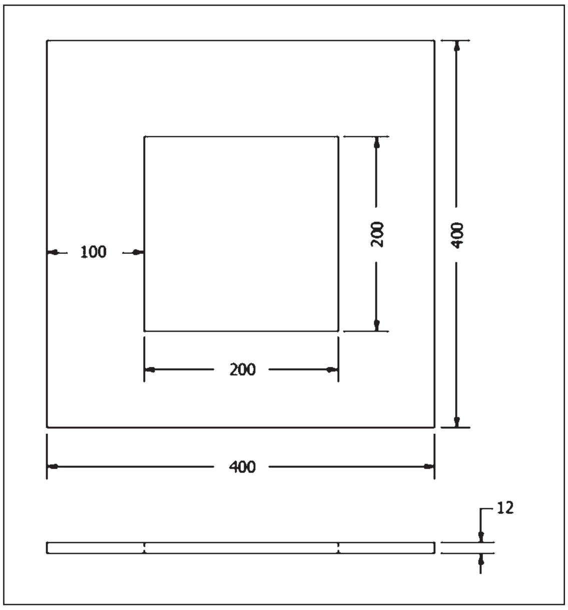

Figure 1 Schematic of a plate-shaped metal mold

Table 1 **Chemical composition / wt.%**

Zn	Pb	Sn	Fe	Cu
28,7	2,09	1,33	1,16	Bal.

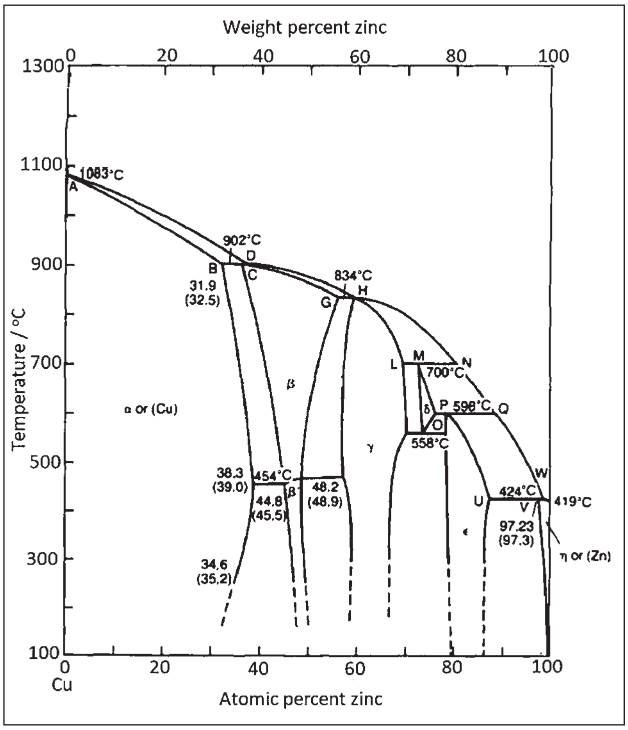

Figure 2 Equilibrium phase diagram for Cu-Zn alloy [15]

The material used in this study is brass (Cu-Zn) with a chemical composition as shown in Table 1. Referring to the phase equilibrium diagram (Figure 2) for Cu-Zn shows the melting point of the brass sample-cast in this experiment is about 910 °C [15]. Based on the phase diagram during melting of brass alloy, it shows the brass temperature increases from room temperature to semi-solid temperature (it is about 900 °C), the metal alloy phase is the α phase. Furthermore, the temperature continues to increase in the furnace, so that the brass alloy becomes a semi-solid area. The five variations of super-heat evaluated in this experiment are 150, 200, 250, 300, and 350 °C, where these super-heats is the reference for determining the pouring temperature. A larger super-heat causes a larger solidification range, which results in a longer solidification rate. The longer freezing interval affects the growth of granules, which starts from nucleation, dendrite growth, dendrite network bridging each other and forming solid metal. Referring to the phase diagram, the larger super-heat interval produces the longer of freezing range, thus allowing the formation of the α phase and its supporting phases to arrange or regulate during solidification. The size of the granules formed can affect the impact toughness of Cu-Zn alloys.

The chemical composition of the alloy was carried out using a Spectrolab Jr CCD Spark Analyzer. The impact toughness of the alloy is evaluated by recording the total energy absorbed by the brass alloy. The impact toughness test specimen is cut from the brass plate product which is produced through a metal casting process. The impact test specimens were machined following ASTM standard: E23 with V-notch and the tests were carried out using the Charpy method (Karl Frank GmbH type 53580) with a pendulum load of 1 Kg. The dimension of the impact sample is 55 x 10 x 10 mm, V-notch with angles is 45°, depth is 2 and 0,25 mm (Figure 3) [9]. The average number of impact test is obtained from three tests.

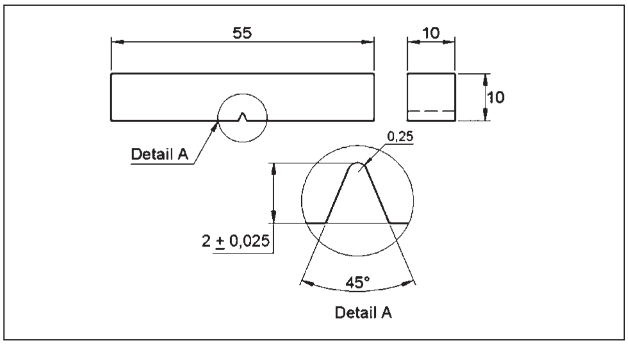

Figure 3 Schematic of impact testing

RESULTS AND DISCUSSION

The impact test is used to evaluate the brittleness of material toward shock loads. The impact toughness value of the brass alloy was investigated for the effect of five variations in casting temperature, as shown in Figure 4. The results of the impact test show that there is an effect of pouring temperature during casting, the maximum impact value is 20,7 Joule and found at the cast-sample with 1 110 °C of the pouring temperature. The highest pouring temperature was 1 260 °C resulting in the lowest impact toughness value is 17,7 Joule. In general, the impact toughness number from this test shows an effect on the brass cast-sample by varying the pouring temperature. The impact toughness decreases with increasing the pouring temperature in the cast-sample.

The impact toughness result of the Cu-Zn alloy obtained from five variations of pouring temperatures is

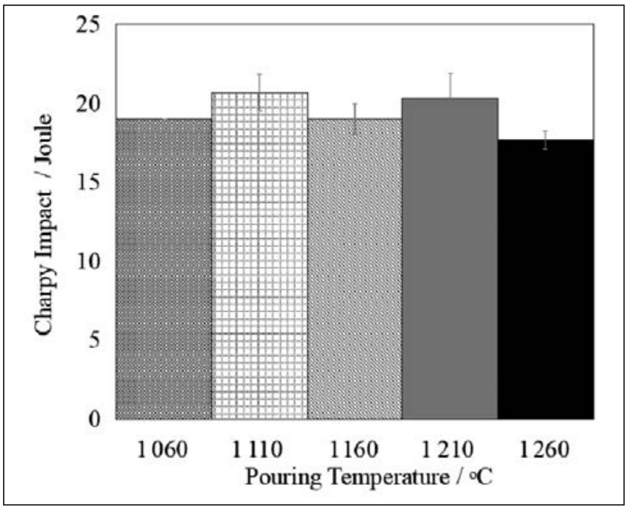

Figure 4 Charpy impact of CuZn alloys with variations in pouring temperature

17,7 - 20,7 Joule. Referring to the material properties data from MatWeb [16], the Charpy impact value of the brass alloy is 15 - 69 Joule. However, the Charpy impact value depends on the chemical composition and treatment of the metal alloy. The results in this experiment can be divided into two parts when compared to several references. First, the Charpy impact value of this study is high compared to investigations on Brass Type 1 alloy, namely 14,69 J/cm^2 [17] and Cu38Zn3Pb alloys, which are around 5-8 J/mm^2 [18]. Second, the Charpy impact value of this study is low when compared to the results of the investigation on the brass C26000 alloy, which is around 25 - 35 Joule [19], and the CW510L alloy is from 47 to 52 Joule [20]. The difference in the value of Charpy impact energy is caused by differences in research objectives such as alloy chemical composition, treatment, temperatures during testing, and pouring temperature. So, the Charpy impact energy result in this experiment is in the range of brass alloy values.

The fracture surface of the cast-sample for CuZn alloy can be seen in Figure 5 with magnifications of 100 x and 500 x. This test uses the Charpy method with a load of 1 kg. The SEM Photograph of the fracture surface of the cast-samples took from five variations of pouring temperature, there are visible in a wavy and slightly smooth structure (with light and dark gray colors). This indicates that the impact test was slightly brittle (near to ductile fracture). Surface fracture photograph at pour temperature 1 110 °C looks smoother than other pouring temperatures. The impact toughness value at 1 110 °C of pouring temperature (Figure 4) reaches the maximum, if compare with other pouring temperatures, it is 20,7 Joule. Figure 5, the pouring temperature of 1 110 °C shows the presence of brittle fracture, which is shown in the bright part of the SEM image with 500 x magnification.

The sample with 1 110 °C of the pouring temperature shows the classic ductile fracture failure mechanism and according to the fracture surface image, there are many dimples colonies of various sizes (Figure 5). However, several topographical intergranular fractures

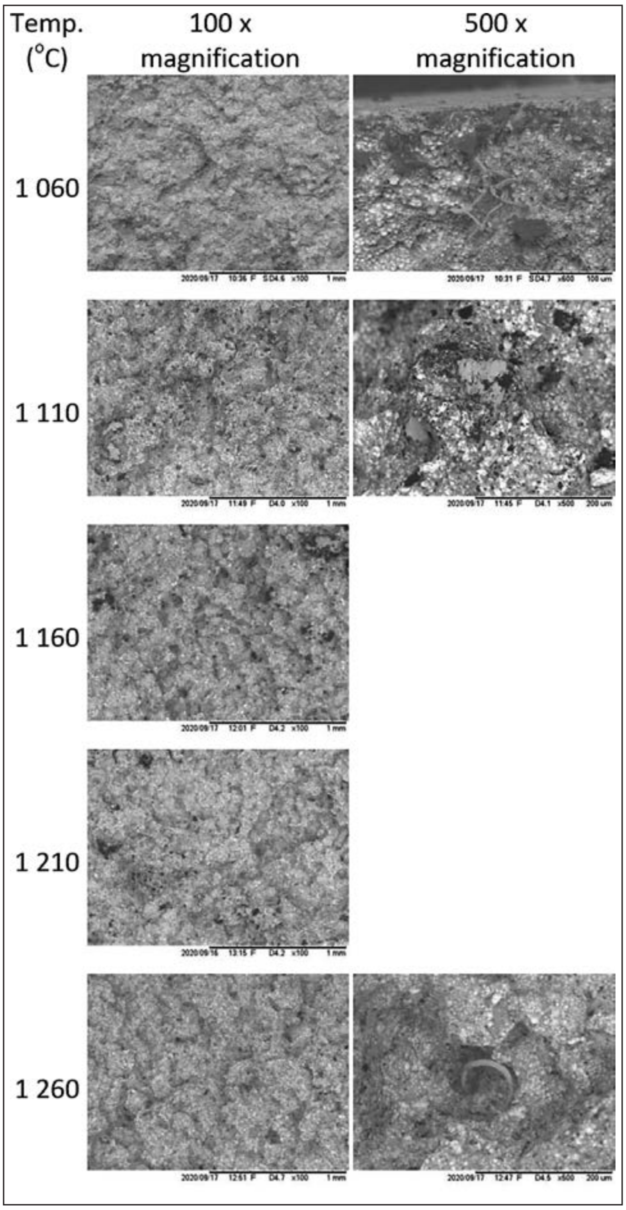

Figure 5 SEM surface fracture of cast samples with differences in pouring temperature.

preceded by a microvoid-coalescence with grain facets were shown in the dimple region. The brass alloy under high-temperature conditions shifts from dimpled transgranular to IG (intergranular) failure mode which is almost entirely macroscopic for impact samples [3]. In the temperature range of trough embrittlement, the cast-sample structure is predominantly intergranular along the grain boundaries of α-α and α-β presenting microcavities, similar to brittle brittle cracking, as the major failure mechanism for 60 - 40 dual-phase brass [20, 21].

The solidification range can affect the growth of the grain in the metal alloy. A higher pouring temperature results in a larger freezing interval and causes a longer freezing time. High-temperature pouring can produce the enlarge of grain size and the distribution of the β phase grows more evenly in the α phase matrix. This condition is almost the same as the Cu-Zn brass alloy sintering, where the sintering time causes grain growth, the number of liquid phases, and the adjustment of atomic diffusion conditions [22]. As we know that larger grain sizes can reduce the impact toughness of metal alloys. Thus, higher temperatures can reduce the impact toughness of metal alloys.

CONCLUSIONS

Investigation of the impact toughness of brass alloys with five differences of pouring temperatures has been carried out through the brass casting process. From the results and discussion, it can be concluded that the variation of pouring temperature can affect the impact toughness of Cu-Zn alloys. Impact Charpy seems to decrease its line trend as the pouring temperature increases. The highest Charpy impact is 20,7 Joule and it is founded at 1 110 °C of pouring temperature during produced the brass cast sample, while the lowest impact number is 17,7 Joules at 1 260 °C of the pouring temperature. The higher pouring temperature causes the solidification rate (time) of the brass alloy to be widened, thus causing larger grain growth compared to the faster freezing time.

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