The effect of pouring temperatures to tensile strength and porosity of aluminium processed with vacuum casting

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Abstract. Pouring temperature also affects the mechanical properties of aluminium. High pouring temperature will make aluminium grains become large and a lot of gas will be trapped into the liquid metal when the metal is poured into the mould. The right temperature will prevent metal porosity and the metal does not freeze before filling the entire mould cavity. The casting process used permanent mould. Temperature of the moulds was 150 °C and the pressure 0.35 atm (absolute pressure). Pouring temperature were 750, 800 and 850 °C. The increasing pouring temperature reduce the tensile strength and specific density of aluminium. Pouring temperature aluminium in vacuum casting system at 750 °C produce the highest tensile strength (130.26 MPa). The specific density of the aluminium is 2.65 g/cm³

Keywords: aluminium, tensile strength, porosity, vacuum casting

1. Introduction
Aluminium is one of the metal widely used in the manufacturing industry. The aluminium has some advantages than other metals; i.e. a low melting point, corrosion-resistant properties, and good mechanical properties [1,2]. Aluminium with high strength can make the component more light compared with less strength metals [2,3].

Vacuum casting can reduce the grain size and porosity on the casting product [3]. Reducing grain size and reducing the amount of porosity in aluminium can increase the strength of the aluminium. Grain size in metals greatly affects the tensile strength of the metal (Hall-Petch Law) [4-6], in addition the decreasing grain size also increase ductility of the metal. Permanent moulding is a casting process uses moulds that can be used repeatedly. This type of mould has the advantage of a faster production process, because the preparation time for printing is much faster compared to sand moulds. The Mould for the casting vacuum system is a non-porous mould to prevent outside air into the mould cavity.

Metal moulds have a high cooling speed, to reduce the cooling speed of the mould being heated to a certain temperature. In this study moulds were heated to a temperature of 150 °C [7]. Pouring temperature also affects the mechanical properties of aluminium. High pouring temperature will make aluminium grains become large and a lot of gas will be trapped into the liquid metal when the metal is poured into the mould [8]. The right temperature will prevent metal porosity and the metal does not freeze before filling the entire mould cavity. In this
research, testing on the influence of pouring temperature on the porosity and tensile strength of aluminium in the vacuum system casting process.

2. Material and methods
The aluminium used in this research is recycled aluminium alloy. The aluminium is obtained from waste treatment from the aluminium casting industry, the aluminium composition can be seen in Table 1.

Table 1. Aluminium composition (equal to A 356)

| Element | Composition (%) |
|---------|----------------|
| Al      | 94.70          |
| P       | 0.70           |
| Ca      | 0.79           |
| Ti      | 0.04           |
| V       | 0.04           |
| Eu      | 0.04           |
| Cr      | 0.04           |
| Fe      | 1.30           |
| Ni      | 0.05           |
| Zn      | 1.39           |
| Cu      | 0.69           |

The casting process was done by using an electric furnace. The maximum capacity of the furnace is 2 kg and maximum working temperature of 1000 °C. The casting process uses metal mould (permanent moulding) made from low carbon steel (Figure 1).

Figure 1. Permanent Moulding for Sample Casting
Casting was carried out at temperatures of 750, 800 and 850 °C. The mould temperature is made equal to 150 °C and the mould pressure was 0.35 atm (absolute pressure). Temperature is controlled electronically to obtain a stable temperature. The air in the mould cavity is vacuumed using a vacuum pump (Figure 2). The vacuum pump used requires 125 Watts electricity.

Cast aluminium is formed into a tensile and porosity test object using a milling machine. Tensile test specimens are formed in accordance with ASTM B557 standards. Tensile testing is carried out using a universal testing machine (UTM) tensile testing machine which has a maximum capacity of 30 tons. The porosity test was carried out using the ASTM B311-17 standard.

3. Results and discussion
Aluminium casting results by vacuum process are weighed to determine the specific gravity. After that the aluminium porosity is calculated. The results of measurements of aluminium density can be seen in Figure 3.

The highest specific gravity of aluminium is cast aluminium which is poured at a temperature of 750 °C which is 2.66 kg m$^{-3}$, while the lowest specific gravity is aluminium poured at of 850 °C which is 2.59 kg m$^{-3}$.

Tensile strength test result of the aluminium can be seen in Figure 4. The Highest tensile strength is aluminium poured at 750° C (130.26 MPa) and the lowest strength is aluminium are poured at 850 °C (81.73 MPa). Fractography on tensile test specimen can be seen in Figure 5.
Figure 3. Effect pouring temperature to aluminium density

Figure 4. Tensile strength of aluminium at different pouring temperature
The aluminium density measured results showed that aluminium porosity shows the most porous is aluminium poured at 850 °C. Low specific gravity at the aluminium indicates the presence of porous in the aluminium. The presence of porosity in aluminium can be proven by the tensile strength of aluminium. Aluminium with density will have lower tensile strength compared to aluminium which has a higher density (Figure 4). In addition to the density that is more influential on the trait strength of aluminium is the size of the aluminium grain. According to Hall-Petch law smaller grain size in metal will increase tensile strength of the metals [5,9,10]. The increasing tensile strength on the metal will increasing ductility metals.

The grain size of the aluminium can be seen on the fractography of the tensile test fracture. The fracture surface of aluminium poured at 850 °C is rougher than aluminium poured at 750 °C (Figure 5). Enlargement of grain size of aluminium will reduce ductility of the aluminium, from
strain measurements that occur in aluminium poured at 750 °C has the highest strain which is 0.41% much higher than that aluminium poured at 850 °C (0.27%).

4. Conclusion
The increasing pouring temperature reduce the tensile strength and specific density of aluminium. Pouring temperature aluminium in vacuum casting system at 750 °C produce the highest tensile strength (130.26 MPa). The specific density of the aluminium is 2.65 kg m⁻³.

5. References
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