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## The effect of pure temperature and pressure on alloy hardness of Al-6.7% Cu using squeeze casting method

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**Abstract.** Squeeze casting is done by combining the casting and forging processes. The metal solidification process is carried out in a metal mold by pressing it with hydraulic pressure. This study aims to determine the effect of pouring temperature and pressure on the hardness value of the squeeze casting of Al-6.7% Cu alloy material. The process is that the material is melted using a crucible furnace until it melts then poured with a temperature variation of 710 ° C, 730 ° C and 750 ° C. Then it is poured into a metal mold that is heated to a temperature of 250 ° C and then pressed for 60 seconds with variations of 0 MPa, 2.5 MPa, 5 MPa and 7.5 MPa. The test results show that; (1) the higher the pouring temperature, the lower the hardness value, (2) the higher the pressure, the higher the hardness value. (3) The highest hardness value was at pouring temperature of 710 ° C with a pressure of 7.5 Mpa (59 HB) while the lowest hardness value was at pouring temperature of 750 ° C with a pressure of 0 Mpa (34 HB)

**Keywords:** squeeze casting, pressure, pouring temperature, and hardness value

### 1. Introduction

Casting is the process of forming metal by heating the metal until it melts then pouring it into a mold and cooling it until it freezes. The advantage of the casting process is that it is able to produce both simple and complex products. The casting product resembles the shape of the printed pattern that is made. Various types of casting methods are used by the casting industry from micro, small, medium and large scale businesses. Among others, casting sand molds, evaporative, investment, metal molds (graphity), pressure metal molds, squeeze and so on. Casting methods commonly used by the casting industry include sand mold casting, evaporative, investment, metal molding (graphity), pressure metal molds, squeeze and so on.

Squeeze casting is also called liquid metal forging. This process is done by combining the forging and casting processes. The metal solidification process is carried out in a metal mold by pressing it with hydraulic pressure. Thus the molten metal is frozen in a mold under relatively high external pressure. Pressing the molten metal in the mold results in rapid heat transfer and results in decreased porosity.

The squeeze casting process can improve physical and mechanical properties, especially in materials with aluminum and magnesium base alloys [1]. Squeeze casting on aluminum base alloys is able to produce castings that have characteristics such as the results of the forging process [2].



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The result of the squeeze casting process is a product that is close to the final size with good quality. The microstructure of the squeeze casting results is denser than that of the cast casting [3]. This occurs because the contact of the liquid metal with the die surface allows a fairly fast heat transfer to produce a homogeneous microstructure with good mechanical properties.

Aluminum (Al) is a metal that is often used in everyday life, including household furniture, construction, automotive components, electrical components, aircraft components (aerospace), ships and so on. It is estimated that the use of aluminum in the future will still be wide open, either as the main material or as a supporting material in the presence of an abundance of aluminum ore. Apart from having a small density, corrosion resistance and fairly good electrical conductivity, when combined with the elements and processed by certain methods, it will produce good physical and mechanical properties. Aluminum properties; relative mass density (2.7 gr / cm<sup>3</sup>) and melting point 660°C. Pure aluminum is not good for use as a machine element, therefore it must be combined with other elements, for example; Cu, Mg, Si, Ni and so on.

Copper (Cu) is a metal after steel that has been widely used since time immemorial because it has good machinability, corrosion resistance, high conductor of electricity and heat. Copper is easy to mold, shape and is resistant to corrosion. Therefore, copper was very important to humans in ancient times and continues to be the material of choice for a variety of household, industrial, and high-tech applications today. The properties of copper are a density of 8.96 g/cm<sup>3</sup> and a melting point of 1.085°C. The use of copper as an alloying element will increase the hardness of the castings, have better tensile strength and make machining easier.

## 2. Methods and materials

### 2.1 Methods

The experimental material from Al-6.7% Cu alloy was heated in a crucible furnace at a temperature of 800 ° C. The liquid metal in the kowi was stirred for 60 seconds at 600 RPM rotation. Furthermore, the molten metal is poured into a metal mold with various pouring temperatures (710 °C, 730 °C and 750 °C). Metal mold is heated to a temperature of 250 ° C. Furthermore, the press is carried out using hydraulic press with pressure variations (0, 2.5, 5 and 5) MPa for 60 seconds. Furthermore, the castings are removed from the metal mold and cooled in air until they reach room temperature. The results of casting are made of specimens for hardness testing (Brinell).

### 2.2. Research tools and materials

- Metal mold
- Crucible furnace (1 set)
- Cup / Kowi
- Thermocouple
- Ladel
- Hammer
- Hydraulic press
- Mixer Machine
- Stopwatch
- Tools for safety and health
- Clamp Pliers
- Camera
- Sandpaper
- Brinell Hardness Tester

The material used in this study was the alloy Al-6.7%Cu.

### 2.3 Research variable

- Independent Variables
  - Pour temperature 710 ° C, 730 ° C and 750 ° C
  - Pressure 0 MPa, 2.5 MPa, 5 MPa and 7.5 MPa
- Control Variables
  - Melting temperature 800 ° C
  - Mold temperature 250 ° C
  - Stirrer rotation of 600 rpm
  - Stirring time for 60 seconds
  - Press time for 60 seconds
- Dependent Variable
  - Hardness testing

Figure 1 is a metal mold, which consists of a die, punch and bottom cover.

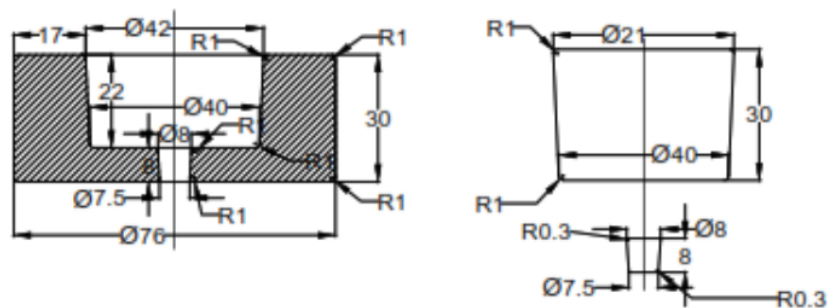


Figure 1. Die and punch

## 3. Results and discussion

### 3.1 Composition testing

The test results for the complete alloy material composition with the raw material composition are as shown in table 1.

Table 1. Test results of raw material composition

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
%	%	%	%	%	%	%	%
0.0940	0.305	6.7	0.3708	0.0090	0.0045	0.0131	0.0080

Na	Ca	Ni	Pb	P	Sn	Sb	Sr
%	%	%	%	%	%	%	%
0.00009	0.00014	0.0068	0.00090	<0.00050	0.0038	0.0041	0.00018

Be	Zr	Bi	Cd	Al
%	%	%	%	%
0.00006	0.0015	<0.00030	0.0012	92.4

### 3.2 Hardness testing

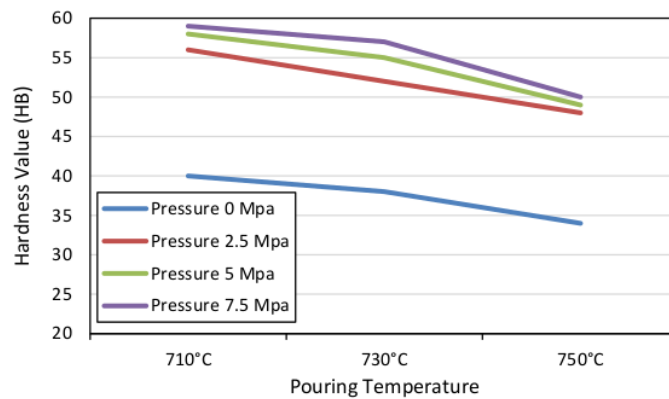
Data on the results of the Brinell scale (HB) hardness test can be seen in table 2.

**Table 2.** Hardness Testing Results

Specimen Code	Pouring Temperature (°C)	Pressure (MPa)	Brinell Hardness (HB)
X.Al-0	710	0	40
X.Al-1		2.5	56
X.Al-2		5	58
X.Al-3		7.5	59
Y.Al-0	730	0	38
Y.Al-1		2.5	52
Y.Al-2		5	55
Y.Al-3		7.5	57
Z.Al-0	750	0	34
Z.Al-1		2.5	48
Z.Al-2		5	49
Z.Al-3		7.5	50

### 3.3 Relationship of pour temperature and hardness value

Figure 2 is a graph showing the relationship between the pouring temperature and the hardness value at pressure (0, 2.5, 5, and 7.5) MPa. Based on the graph, it shows that the hardness value of the squeeze casting result of the Al-6.7% Cu alloy changes with changing pouring temperature. The resulting hardness value at a pressure of 0 MPa with a pouring temperature of 710 °C of 40 HB, a pouring temperature of 730 °C and a hardness value decreasing to 38 HB (-5.25%), a pouring temperature of 750 °C the hardness value decreasing to 34 HB (-11.76%).



**Figure 2.** Graph of the relationship between pouring temperature and hardness value at pressure (0, 2.5, 5, and 7.5) Mpa.

At a pressure of 2.5 MPa with a pouring temperature of 710 °C the hardness value was 56 HB, the pouring temperature was 730 °C and the hardness value decreased to 52 HB (-7.69%), and the pouring temperature 750 °C the hardness value decreased to 48 HB (-8.33%).

At a pressure of 5 MPa with a pouring temperature of 710 °C the hardness value was 58 HB, the pouring temperature was 730 °C, the hardness value decreased to 55 HB (-5.45%), and the pouring temperature was 750 °C and the hardness value decreased to 49 HB (-12.24%).

At a pressure of 7.5 MPa with a pouring temperature of 710 °C the hardness value was 59 HB, the pouring temperature was 730 °C, the hardness value decreased to 57 HB (-3.51%), and the pouring temperature 750 °C the hardness value decreased to 50 HB (-14%).

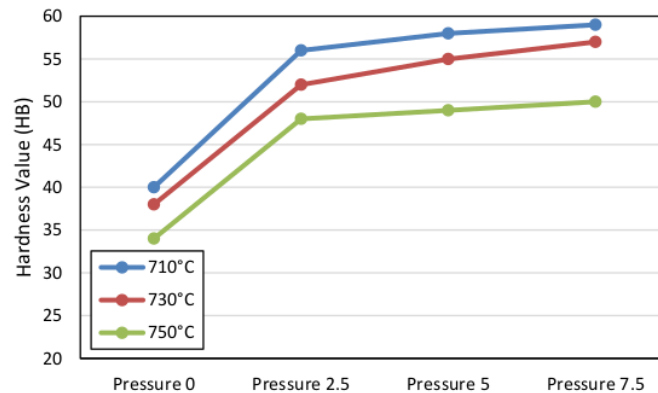
From the results of the graphic explanation, it is concluded that the higher the pouring temperature, the harder the hardness value tends to be. This decrease in hardness value is caused because the rate of cooling and freezing at higher temperatures tends to be slower. With slow cooling and freezing rates, small and even grain structures are formed. This was also stated [4], that at temperatures above 650°C the hardness value decreased along with the increase in the pouring temperature. High pouring temperature and mold temperature will give birth to a slow freezing process [5].

### 3.4 Relationship of pressure and hardness value

Figure 3 is a graph showing the relationship between pressure and hardness value at pouring temperature (710°C, 730°C and 750°C). Based on the graph, it shows that the hardness value of the squeeze casting of the Al-6.7% Cu alloy changes along with changes in external pressure.

From Figure 3 it can be seen that the hardness value of Al-6.7% Cu castings changes with changes in external pressure. The resulting hardness value at a pouring temperature of 710 °C with a pressure of 0 MPa of 40 HB, a pressure of 2.5 MPa, the hardness value increased to 56 HB (28.57%), the pressure of 5 MPa the hardness value increased to 58 HB (3.45%), the pressure 7.5 MPa value the hardness increased to 59 HB (1.69%).

At the pouring temperature of 730 °C, pressing 0 MPa was carried out, the hardness value was 38 HB, the pressure was 2.5 MPa, the hardness value increased to 52 HB (26.92%), the pressure was 5 MPa the hardness value increased to 55 HB (5.45%), and the pressure was 7.5 MPa. the hardness increased to 57 HB (3.51%).



**Figure 3.** Graph of relationship between pressure and hardness value at pouring temperature (710,730 and 750) °C.

At pouring temperature of 750 °C, pressing 0 MPa was carried out, the hardness value was 34 HB, the pressure was 2.5 MPa, the hardness value increased to 48 HB (29.17%), the pressure was 5 MPa the hardness value increased to 48 HB (2.04%), and the pressure was 7.5 MPa. the hardness increased to 50 HB (2%).

From the results of the discussion of the graph above, it can be concluded that the higher the pressure exerted, the resulting hardness value also increases. This is because the pressure also affects the grain structure and porosity of the castings. The higher the pressure applied, the smaller the grain structure and porosity. The increase in pressure will increase the liquidus temperature, cooling speed, inhibit grain growth, and the grain size will become smaller. Smaller grain size causes higher hardness [6]. The external pressure received by the liquid metal during freezing will increase the grain adhesion force and increase the grain density [7].

#### 4. Conclusion

Based on the research that has been done regarding the effect of variations in pouring temperature and pressure variations on the hardness value with the Squeeze Casting method, it can be concluded as follows:

- The higher the pouring temperature, the lower the hardness value.
- The higher the pressure, the higher the hardness value.
- The highest hardness value was at pouring temperature of 710 °C with a pressure of 7.5 Mpa (59 HB) while the lowest hardness value was at pouring temperature of 750 °C with a pressure of 0 Mpa (34 HB).

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