

The characteristics of the mechanical and acoustic bronze cu20sn as traditional bell material

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Abstract

This study is aimed to find out the mechanical and acoustic characteristics of casting traditional bell's result using metal mold and sand mold. The mechanical and acoustic characteristics of casting traditional bell's result are compared between metal molded and sand molded casting.

The bronze alloy was smelted in a crucible furnace at the casting temperatures of 1000, 1050, and 1100 °C. The melted alloy is poured into a sand mold and a preheated metal mold at a temperature of 200 °C. Specimens were formed into bell and billet. The bell form was for acoustic testing. The Billet casted was cut into a few parts and were manufactured as a specimen for hardness test.

This study has showed that mechanical characteristic specifically the hardness of metal molded casting is better than sand molded casting. The Acoustic properties of particular damping characteristics depended on the porosity of casting's result. The bell's tone isn't produced by the mono frequency but it's generated by more than one frequency domain. Similarly, the subjective test of acoustic characteristic didn't show a significant obvious difference.

Keywords: Traditional bell; Mechanical characteristics; Acoustic; Metal and sand mold

1. Introduction

The conventional process of manufacturing traditional bell is begun from the preparation of fabricating molds from raw material i.e. bronze. High tin bronze is a bronze alloy since the main composition of this alloy are copper (Cu) and tin (Sn). Tin bronze with the composition of 80%Cu – 20% Sn in general is used as a material for musical instruments such as bell and gamelan due to the great mechanical characteristics of this alloy, stable in the room temperature condition, good acoustic characteristic which can produce lengthy sound (low damping vibration) [1][2][3].

Tin bronze has a louder sound compared to the other metals. It's loudness e.g. bronze bell is affected by the composition of the alloy between copper and tin. In case there's an excess of tin, the bronze will be more easily cracked, the damping capacity will increase e.g. short produced sound if the content of tin has decreased [4]. The knowledge of bronze's mechanical and acoustic as the raw material for musical instruments becomes the primary consideration, because cracks are frequently found in bronze made musical instruments (bell or *gamelan*). Therefore, mastership of metallurgy science and production process turn out into a extremely fundamental consideration.

The utilization of copper tin composition as the musical instrumental material varies such as: the manufacturing of modern cymbals uses the composition of 80% Cu-20%Sn, the manufacturing of cymbals in Switzerland uses the

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composition of 92%Cu-8% Sn. The composition 84%Cu -16% Sn is quite commonly used for cymbals., bronze bell Br 022 with the composition of 78,12%Cu, 21,8% Sn,0.007%Zn, 0.018% Pb, 0,003%Fe, 0.048 P [1].

The bronze material that's smelted as the bell's material normally uses bronze composition (17,5-23% Sn) that being used for gamelan's material. Sufficient time is required to prepare for mold fabrication. Around $\pm$ 20-30 minutes are required for the preparation of mold fabrication. Sand molded casting's result frequently causes porosity defects that impact the strength and acoustic of the material. Permanent metal molds have the superiority of shorter production time since they can be used again and again. Metal molds can also accelerate the solidification process in casting process [5].

This research will review the use of metal molds in the bell manufacturing process as a work for better productivity, strength, and acoustic characteristic of bell. This research is expected to result a new production method, strength characteristic, and acoustic characteristic of bell particularly the loudness of the bell.

2. Material and methods

The casting material of bell is an tin bronze alloy that's an alloy with a proportion of copper to tin 10:3. Figure 1 presents the mechanism of the bell manufacturing casting process. The bronze alloy (Figure 1.a) is smelted into a *crucible furnace* at the temperature of 1000, 1050 and 1100 °C (Figure 1.b). Thereafter, the melted material is poured into preheated metal molds at temperature of 200 °C (Figure 1c). The purpose of preheating molds is to avoid the thermal shock between the melted alloy that is poured into the molds with the mold walls. The melted metal that is poured into the molds will fill in the mold space that is marked by the mold channel fully filled with liquid metal (Figure 1 d). The filler metal is released from the mold after the mold's temperature drops to 150-100 °C. Afterwards, thermocouple type K is used to measure solidification temperature through the casting process. Thereafter, the casting result is manufactured for specimen manufacturing, strength test, and bell sound test (Figure 1 e).



Figure 1 Mechanism of bell's production a. Bronze raw material. b. Process of smelting and preheating the molds c. Mold's temperature measurement. d. Pouring process. e. Bell product

3. Results and discussion

3.1. Mechanical characteristic

The mechanical characteristic is studied is the value of material hardness, because material hardness has a huge impact of the material acoustic. Figure 2 shows the influence of casting temperature on the casting result's hardness. At the same mold's temperature, it's shown that variations of casting temperatures affect the casting material's hardness which is the higher casting temperature that's used will result to a lower casting material's hardness. This thing happened because of the difference solidification rate as the result from the gradient of the difference between the

casting temperature and the mold temperature. The solidification rate is referred by how fast the liquid metal in the mold begins to solidify. The higher the mold temperature will affect to the slower solidification rate.

The weakened hardness is caused by a quite longtime solidification which happened because of the relatively small temperature difference between mold and casting. Likewise, slow solidification enhances the microstructure which affects to the material's hardness [6].

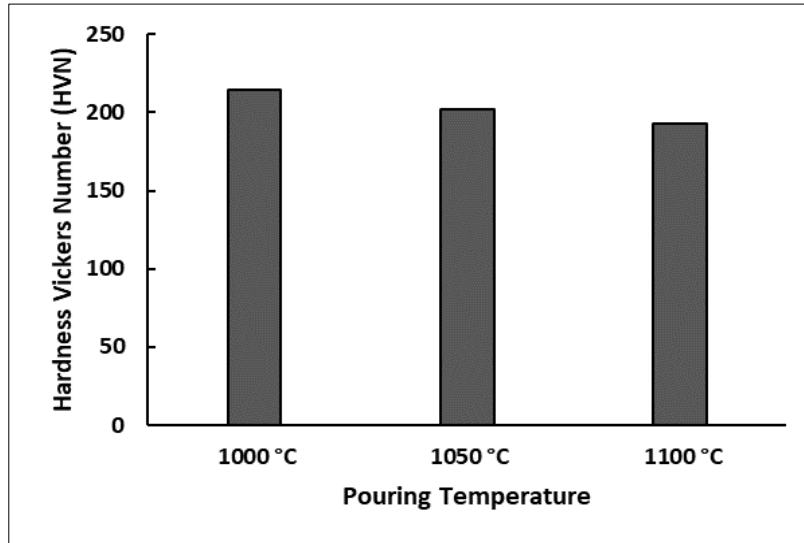


Figure 2 The effect of Pouring's temperature to the hardness

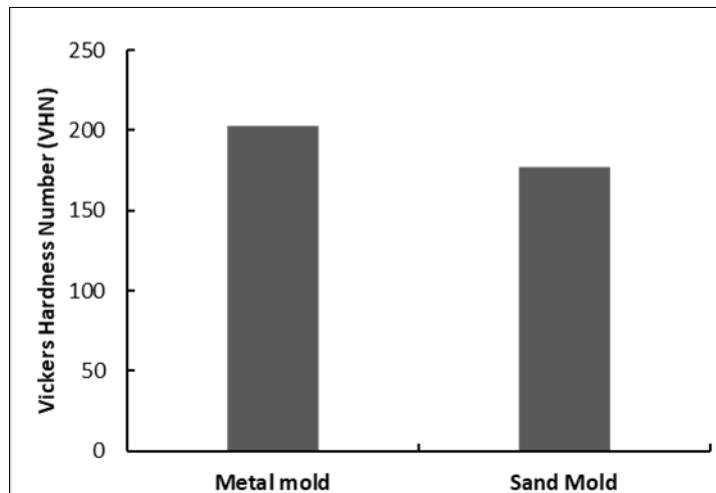


Figure 3 The comparison of average hardness

Figure 3 shows the comparison between hardness of traditional bell's material casted using metal and sand mold. Material's hardness casted with metal mold is greater than sand molded casting [7]. Metal mold has great heat conductivity characteristic so the heat of the liquid that is poured into the mold is absorbed more rapidly than sand mold, liquid's temperature will rapidly come down that affect to a rapid solidification rate [8]. The formed microstructure is finer than the microstructure of the slow solidification casting material [9][10]. Thus, the fine microstructure causes the material becomes more harden [11] [12] [13].

3.2. Porosity

Porosity is a void in the cast product which can degrade its quality of the cast product. The primary cause of the porosity exists in casting's result is the trapping of hydrogen gas through the casting process. One of the causes the existence of porosity in casting bronze alloy is hydrogen gas. The liquid metal that's casted can oxidize with carbon monoxide and carbon dioxide gases. The trapped gas inflicts hole defect in the casting's result. Figure 4 show a comparison of the

porosity that happened in metal and sand molded casting's result. Sand molded casting has more porosity than the metal molded casting. Sand molds that are not dried will result water vapor when the liquid metal streams on the main channel. The water vapor will immediately be trapped when the liquid metal solidify. On the other hand, the porosity of metal molded casting is less than sand molded casting because metal mold tend to be a very great heat conductor and there's no water content in its mold.

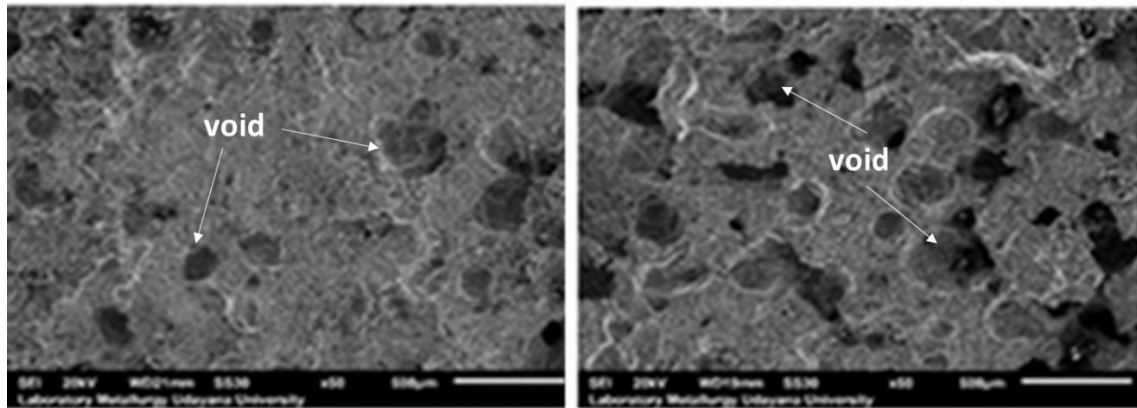


Figure 4 Porosity of casting material

- a. Porosity of casting's result using metal mold
- b. Porosity of casting's result using sand mold

3.3. Acoustic Characteristic

The bell's acoustic testing is done by Experiment Method Analysis and subjectively. Figure 5 shows the frequency response of the bell casted with metal and sand molds. The frequencies that are produced by the result of casted bells from both molds show that there's a non singular frequency. The tone is not produced by one frequency but it's a combination of several frequencies [14]. The phenomenon of bell's damping is shown in the response time of the bell in Figure 6. The bell's damping is shown by the capability of the bell to vibrate or the duration of bell's sound. Bell's damping that is produced by bell that casted with sand mold _Figure 5 c,d, is relatively more stable than the sand molded casting's bell.

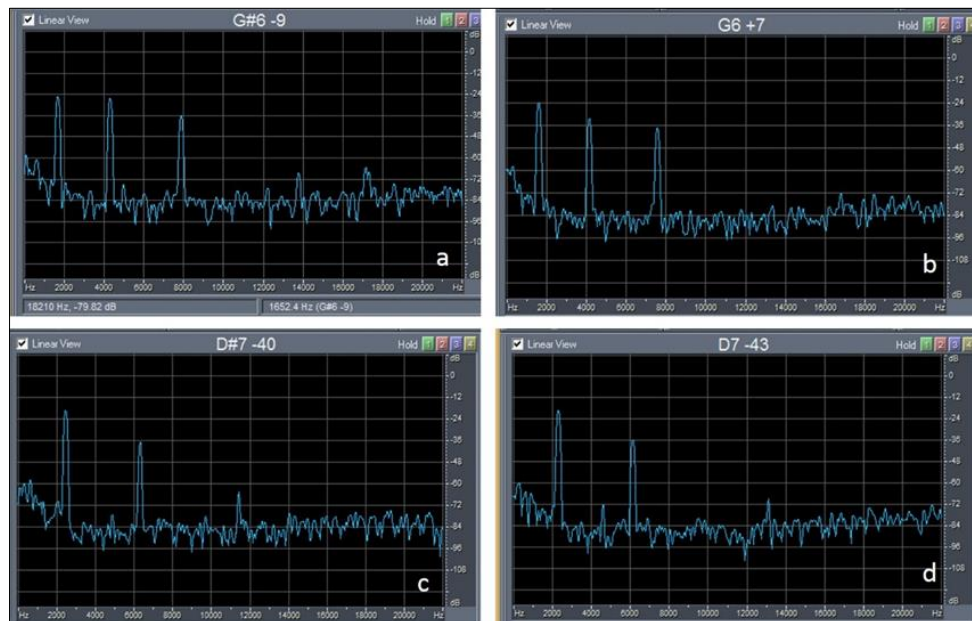


Figure 5 Frequency response
a, b sand molded casting's bell;
c, d metal molded casting's bell

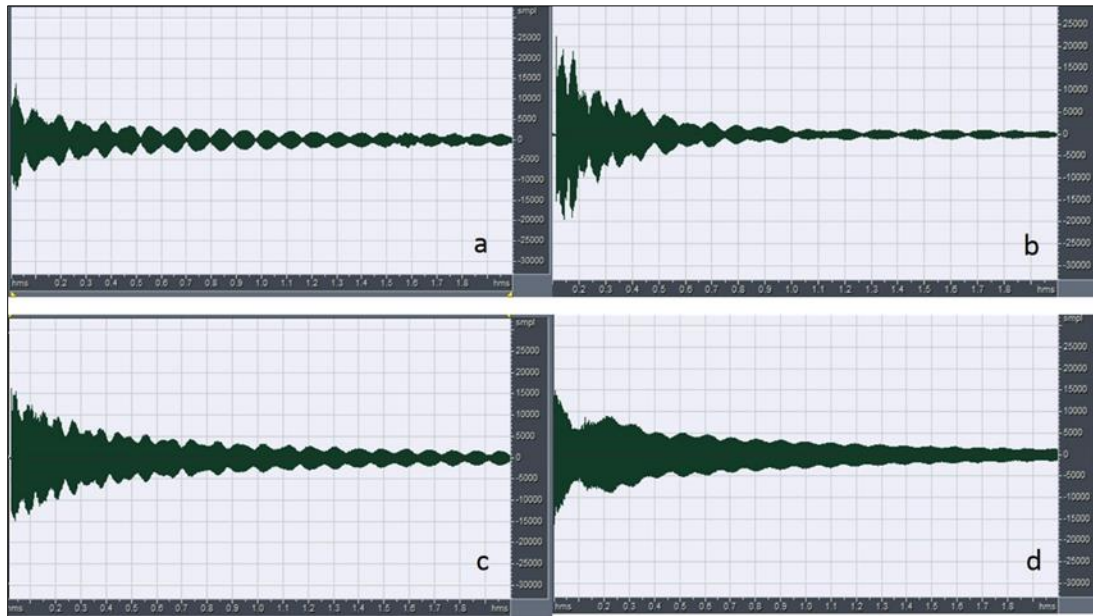


Figure 6 Time Response of bells sound
a, b, sand molded casting's bell
c, d, metal molded casting's bell

Subjectively acoustic testing is a test of person's/user's perception of the acoustic bell that being played/listened to. The acoustic response that being measured are Tonality (Unity) which shows the stability of the resulted tone, Loudness (Sharp) that the material easily produces the sound when it being hit, Damping indicates the material's capability to vibrate (duration during it vibrates), and Clear indicates the resulted tone is unbiased. Statistically, subjectivity testing shows doesn't show obvious significant result. Respondent's responses are more dominant based on their tastes and feelings when listening to the bell.

4. Conclusion

Based on the result and data analysis, Mechanical characteristic, particularly the hardness of bell's casted using metal mold is greater than sand molded casting. The bell's tone is not produced by a mono frequency but it's generated by more than one frequency domain. The porosity of bell's material has impact to the produced damping. Subjectively acoustic, bell doesn't show any significant difference.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have not declared any conflict of interest.

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