The Effect of Annealing Temperature on Damping Capacity of the Bronze 20%Sn Alloy

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***Abstract* - The aim of this study is to investigate the effect of annealing temperature on damping capacity of the bronze 20%Sn. A simply supported beam model was used for measuring damping capacity. The damping capacity of the bronze 20%Sn by different annealing temperature was investigated. The investigation showed that the microstructure of the alloy depends on annealing treatment but there is not any phase transformation during annealing process. Different microstructure forms were followed by the variance of damping capacity of the alloys. As the result, the damping capacity increases due to the increased of annealing temperature. On the other hand, the impact strength of the materials increase but hardness of the materials decrease, when the annealing temperature increase**

***Index Term*-- Annealing temperature. Bronze 20%Sn alloy, Damping capacity, Microstructure**

I. INTRODUCTION

Bronze as for music materials should have high strength, hardness, specific elastic properties and low damping capacity. The high tin bronze alloys with composition 20-22%Sn was widely used as a music instrument such as bell, saxophones, cymbals and materials for Javanese and Balinese gamelan (gong). They have good acoustical properties, which were capable of producing long-lasting sound, because slowly damping vibrations. They also have good hardness and stability at room temperature. This alloy has a good formability that easy be casted and easy to change the shape. Also it alloy has good wear resistant, corrosion resistance and good strength [1]-[3]

The high tin bronze has double phase alloy containing brittle particles of $Cu_{31}Sn_8$ intermetallic (δ phase). This alloys become brittle due to appearance of a high amount of δ phase, which can cause cracks or fracture damage on music instruments. The research focused on the effect of annealing temperature on damping capacity of musical instruments that is limited information. Researches were generally done for damping capacity of materials for construction applications [4]-[7]. The effect of heat treatment especially hardening temperature on damping alloy of bell bronze has been studied by Favstop, 2003. Heat treatment changes the structure of bell bronze and causes considerable changes in its damping capacity.

So far, the research on the effect of annealing temperature on damping capacity properties 20%Sn not studied yet. This study is necessary to do further studies to find correlation between microstructure change and damping capacity that are very limited in information.This study was carried out to determine the effect of annealing temperature on the damping capacity and microstructures of bronze 20%Sn alloy.

II. EXPERIMENTAL PROCEDURE

2.1. Materials and process

The alloy that was studied before in this research was Cu-20Sn. Table 1 shows the composition of the alloy. The commercial pure copper (99.99 wt. %) and commercial pure tin were melted in crucible furnace at temperature of 1100^{o}C. The molten metal was poured into the preheated permanent mold at 200^{o}C, 300^{o}C, and 400^{o}C. The hardness, impact, and damping capacity test specimens were cut from as-cast materials 250 x 55 x 10 mm. Test specimens were annealed at temperatures of 450ºC,550 ºC,650 ºC and the holding time are 2, 4 and 6 hours. Hardness test was carried out on Vickers type hardness-test. The notched specimens were used for impact toughness measurement by using a Charpy hammer impact testing machine.

2.2. Damping test

The logarithmic decrement method is used to measure damping capacity of the specimens. The logarithmic decrement δ, derived from the amplitude decay of specimen under free vibration, is given by [8]

$$\delta = \frac{1}{n}\ln\left(\frac{A_i}{A_{i+n}}\right) \qquad (1)$$

Where A_i and A_{i+n} are the amplitudes of the i th cycle and the (i + n) th cycle, by n periods of oscillation. For the case of relatively small damping capacity, the relationship between δ and ζ is simple and it is given by [8].

$$\zeta = \frac{\delta}{2\pi} = \frac{A_i - A_{i+1}}{\pi(A_i + A_{i+1})} \qquad (2)$$

In this research, free beam vibration (simply supported) was used to measure the damping capacity. It was arranged based on ASTM E 1876-01 standard. It was shown in Fig 1.

TABLE I
CHEMICAL COMPOSITION OF ALLOY

Bronze alloy	**Content of elements wt%**						
	Cu	Sn	Pb	Zn	Mn	S	As
Cu-20%Sn	79.18	19.1	1.18	0.505	0.0008	0.014	0.055

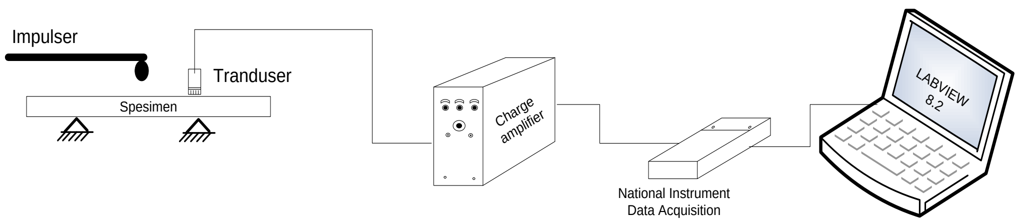

Fig. 1. Set–up of damping measurement

2.3. Microstructure observation

The microstructure characteristics of the alloys are evaluated using optical microscope. To observe the microstructure, the specimens of Ø20 mm × 10 mm in size were prepared by cutting, mounting, grinding and polishing.
Having cut them off, they were polished using silicon carbide abrasive paper of: 240, 400, 600, 800, 1000, 2000, grits, respectively, and then were polished perfectly using diamond pasta and etched using 10% HNO3+90% alcohol. These procedures were applied according to the standard of metallographic techniques

III. RESULTS

3.1. Damping capacity

The damping capacity was measured to investigate the variation of damping capacity of bronze 20%Sn alloys at different annealing temperature from 450^{0}C to 650^{0}C. (Fig 2). It can be observed that the logarithmic decrement δ increased along with increasing of annealing temperature treatments. The damping capacity of the alloys correlates with the microstructures of the alloy.

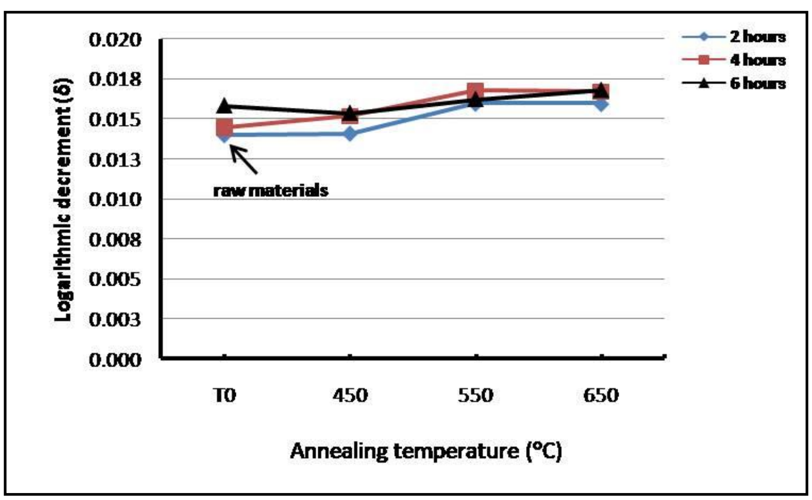

Fig. 2.The effect of annealing temperature on damping capacity of bronze 20%Sn alloys

3.2. Mechanical properties

Figs 3 and 4 illustrate the effect of annealing temperature on the mechanical properties such as the hardness and the impact strength shows respectively. Figures 3 and 4 show changes in mechanical properties caused by the annealing temperature. When the annealing temperature increases from 450ºC to 650 ºC the hardness strength of the material decrease, but the impact strength increases. There was not any phase transformation during the annealing temperature treatments. The main transformations are recovering and recrystallization.

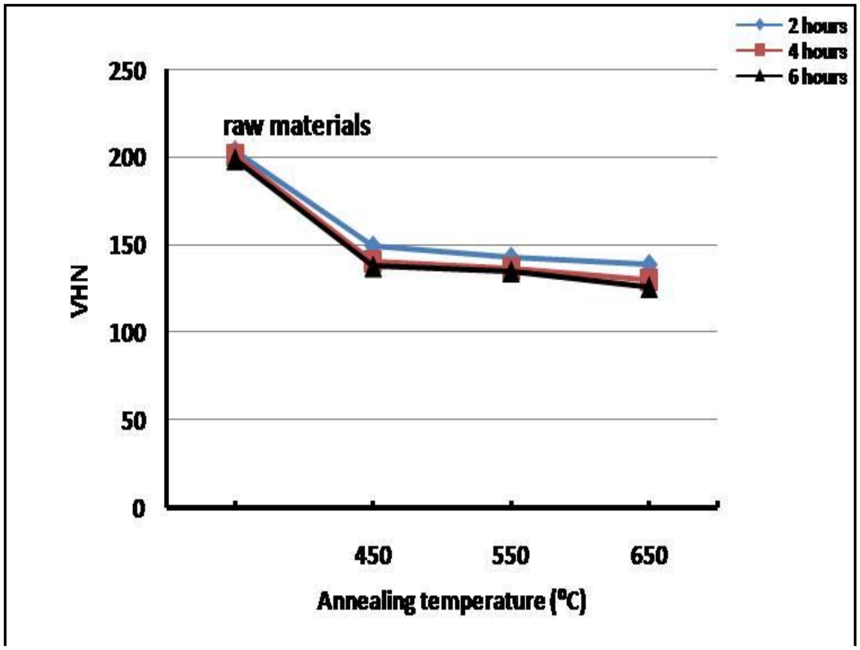

Fig. 3. The effect of annealing temperature on Vickers hardness of bronze 20%Sn alloys

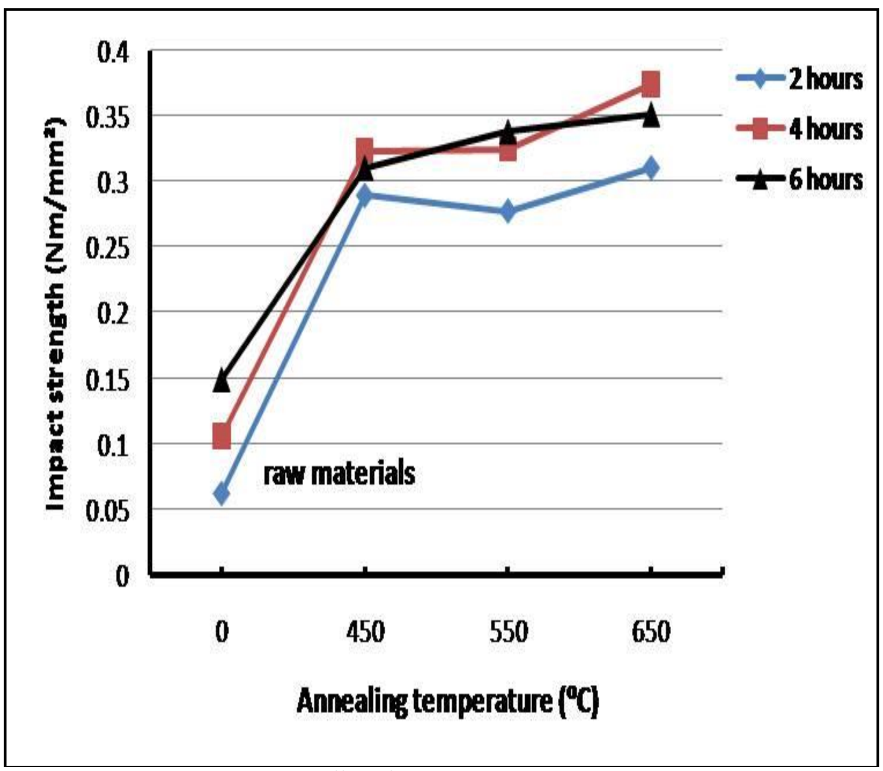

Fig. 4. The effect of annealing temperature on impact strength of bronze 20%Sn alloys

3.3. Microstructure Examination

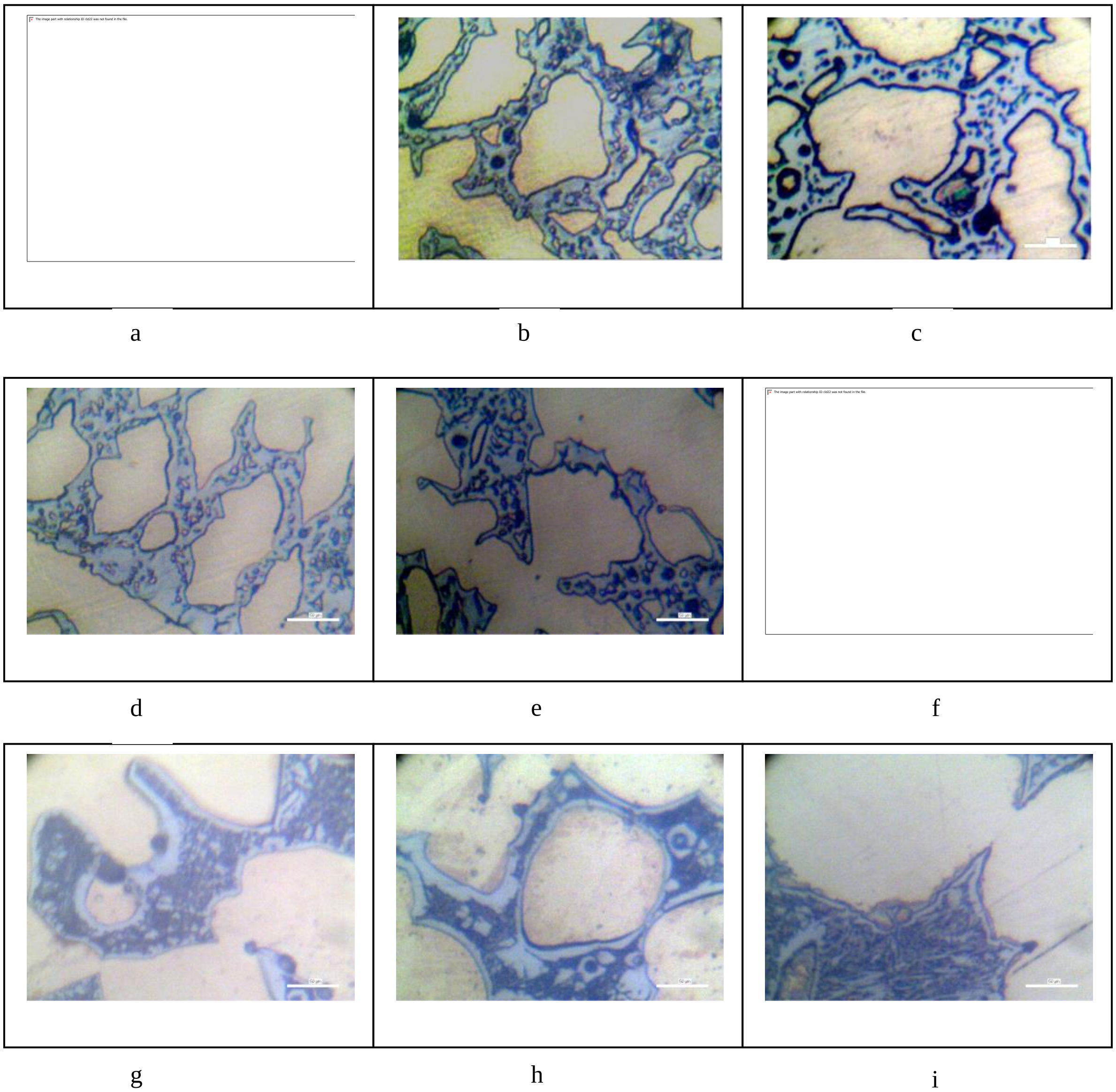

Fig. 5. Microstructure of Bronze 20%Sn alloys at different temperatures (a). 450^{0}Cx2h, (b) 450^{0}Cx4h, (c) 450^{0}Cx6h, (d).550^{0}Cx2h, (e) 550^{0}Cx4h, (f) 550^{0}Cx6h, (e).650^{0}Cx2h, (f) 650^{0}Cx4h, (g) 650^{0}Cx6h,

Fig. 5 shows the microstructural evolution of bronze 20%Sn alloy during annealed at different temperatures. Metallographic examination revealed a significant effect of annealing temperature on the microstructure forms. There is not any phase transformation during the annealing treatment. The main transformations are recovering and recrystallization. The microstructures of the as-annealed bronze 20%Sn alloy only consists of coarse α and δ phase in the microstructure. From Fig. 5, it indicates that as the annealing temperature and holding time treatment increases, the enlargement of grain size is the main microstructure change in the process. The higher the annealing temperature the larger α phase grains that influence on decreasing hardness of materials.

IV. DISCUSSION

According to the experimental results, the mechanical properties and damping capacity are influenced by the variation of annealing temperatures. These treatment decrease the brittleness of bronze which correlated by impact strength increased. The grain size of microstructure became larger which caused by increasing annealing temperatures which correspondingly decrease the amount of grain boundary area per unit volume. The strength and hardness decreased due to increase of the grain size of structure. So the difference in grain size is the main reason for the variation response of mechanical properties and damping capacity of the annealed alloy. The residual stress in the materials will also decrease by annealing treatments. [10]

As is shown in Fig. 2, as the annealing temperature increases, the logarithmic decrements of alloys decrease. Internal damping of materials is characterized by the energy dissipation associated with microstructure defect, such as grain boundaries, thermo elastic effect, dislocation motion in metals, and non uniform stresses. When the metal is under cyclic loading, the phase interface slipping or the grain boundary viscous sliding may occur, which results in the dissipation of the vibrating energy. Since the vibrating energy is dissipated, the damping capacity of the alloy increased. In the metals and alloys, the damping may be raised from the thermo elastic damping, magnetic damping, viscous damping and defect damping. On the other hand, it is found that as the annealing temperatures increase; the grain size becomes large, which makes the grain boundary area smaller in the alloy Meanwhile, referring to the conclusion of some researchers, the damping capacity may also be related to grain size [3].[4].[7]. As is discussed before, recovering and recrystallization are the main transformations of microstructure of bronze 20%Sn alloy annealed at different temperatures. (a) 450ºC; (b) 550ºC and 650ºC. (Fig. 4).

V. CONCLUSION

Based on the results and analysis of data The damping capacity and mechanical properties of 20% Sn bronze were influence by annealing temperature, Damping capacity of the alloy is affected by grain size of microstructure. Annealing temperature treatments can improve the toughness but lowering acoustic quality of the music alloys, that characterized by increasing the damping capacity.

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