Observations of mechanical and manual forging on bronze as a gamelan material

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Abstract. Gamelan is a traditional musical instrument used by Hindu Balinese in religious and cultural activities. The process of making gamelan begins with the manufacture of copper alloy composition (Cu) and lead (Sn), melting, casting, forging and tone forming by grinding on the surface of the blades. The process of forging on the manufacture of bronze gamelan (CuSn) with an open casting method absolutely must be done because the casting results tend to cause the occurrence of porosity. Porosity that occurs in the bronze as a gamelan material will affect the sound produced. The research conducted is to compare the results of manual forging and mechanical means, where the observations are made on the percentage of deformation that occurs, the density, the hardness and the microstructure of the bronze material. The observations show that mechanical forging provides better mechanical properties, deformation rates, and product microstructure.

1. Introduction

Gamelan is a traditional musical instrument whose existence is used to accompany religious and cultural activities for Hindus in Bali. There are several stages in the making of this gamelan, starting with the manufacture of bronze alloys consisting of copper (Cu) and tin (Sn). The process of melting from the alloy at melting temperature in accordance with its composition, the melting temperature of the bronze is determined based on the composition of the alloy and can be seen in the CuSn phase diagram [1].

The forging process used is forging that still relies on human power. The main disadvantage of this process is that the forging of the gamelan material is uneven. The importance of the compaction process in the series of gamelan production processes is a sufficiently deep consideration to applying mechanical forging machines. Forging machines that are planned to be electrically powered with an ergonomic form of construction. This research is expected to produce the uniform quality of compaction of gamelan material so that the mechanical properties and microstructure of the material are better compared to manually compacted material.

Properties testing for the results of forging both manual and mechanical means include hardness test, density test, microstructure and percentage of deformation level. Hardness testing was carried out by the Vickers method where the test refers to the ASTM E 92-82 standard [2]. The load used in hardness testing is 10 kg, with a 100 x magnification lens. Material hardness is known by the following equation:

\[
VHN = \frac{2 \times P \times \sin (\theta / 2)}{d^2}
\]

where:

\(d = \frac{d_1 + d_2}{2}\)

so that

\(VHN = \frac{2 \times P \times \sin (\theta / 2)}{d^2}\)
Density testing is carried out based on Archimedes's theory. Measurement is done by weighing the weight of the specimen in the air and in pure water on a digital weighing device. The specimen density is determined by the following equation:

\[
\rho_b = \frac{w_d}{w_d - w_b} \cdot \rho_w \quad (g/cm^3)
\]

where:
- \(\rho_b\) = Specimen density
- \(\rho_w\) = liquid density
- \(w_d\) = the dry weight of the specimen
- \(w_b\) = Specimen weight in water

This research specifically has a purpose where mechanical forging produces material characteristics (blades) of gamelan namely mechanical properties and microstructure that are better than traditionally produced blades.

Contributions that are expected to be achieved directly or indirectly are perceived in terms of elements of science, society, and the company can be described as follows:

- Gamelan craftsmen industry; Crafters can apply appropriate technology to increase the quantity and quality of production and produce quality products that are capable of competitiveness.
- Institutions; the results of this study can contribute to the improvement of the gamelan production process, as an effort to assist the craftsmen industry.
- Art and cultural contribution; It is expected that with the improvement of the process, it is expected that the production time can be reduced so that the craftsmen are more productive so that it can lift the crafter's economy which will indirectly continue to develop traditional culture and art.

2. Methodology

Research conducted on the forging process, both manually and mechanically based on the experimental method, where the process of making specimens was carried out in gamelan craftsmen. The specimen is then tested for properties that are owned by the following steps:

1. Conducting forging testing on a designed mechanical forging device. Forging is carried out in hot conditions which are burned in a furnace with a temperature of 300 – 400°C
2. Tests were carried out on bronze material with the same dimensions as the production of gamelan craftsmen in Tihingan village, Banjarangkan district, Klungkung
3. Test specimens in the form of gangse blades made from bronze are then cut according to dimensions adjusted to the test equipment
4. Vickers hardness testing both manual and mechanical forging
5. Conducting density tests to obtain material porosity both manual and mechanical forging results
6. Conduct microstructure testing to get the shape of the structure for both manual forging and mechanical forging
7. Perform an analysis by comparing the results of hardness, porosity and microstructure testing of manual forging material and mechanical forging.
Tests for forging bronze material are made with test specimens in the following form:
3. Result and Discussion

3.1. Hardness test results

The number of specimens for manual forging as much as 3 and forging with mechanical devices as many as 3 specimens where in each position taken as many as 5 points. The position of taking data as
shown in Figure 3. The mean of the hardness test showed that the manual forging was 175.58 VHN while the mechanical forging was 176.52 VHN. The test results show that forging using mechanical devices with a load of 78.5 N gives better hardness results. This statement was supported by other researchers who stated that the forging with the heat process and carried out mechanically gave violence, shape and dimensions and better both [3]. Other studies also state that the forging process mechanically gives a quality product mechanically such as its hardness to be better [4].

3.2. Density Test Results
Test specimens are as shown in Figure 4 of the test results as shown in Graph 2 as follows:

Graph 2. Results of density testing

The results of density testing to determine porosity in the sample where manual forging has a mean percentage of 1.342% while the forging is mechanically averaging 1.320%. This shows that with this level of porosity, it can be said that forged bronze materials using mechanical devices give better results. Such conditions occur because mechanical forging provides consistent loading in all areas forging. The forging process carried out on the material can reduce the porosity that occurs [5]. Mechanical forging that has been carried out also causes the distribution of porosity shrinkage [6].

3.3. Microstructure Testing Results
Testing of microstructure for manual and mechanical forging as shown in Figure 5:

Figure 5. Microstructure size of 10 μm enlargement of 200 x from forging results
Microstructure can be seen in Figure 5, where in part a the result of manual forging shows the long and pointed dendrite structure this happens because the pressure is not constant. Such structures tend to be more ductile. Part b is mechanical forging, it looks like the dendrite shape is shorter and rounder structure like that tends to have hard mechanical properties. The shape of the structure is caused by the pressure applied to the forging to occur more constant and almost evenly distributed in the area of the forged area. The forging process is carried out at a temperature of 300 °C to 400 °C according to the phase diagram of Cu-Sn in Figure 4.8 this condition shows that there is no phase change. The research that has been carried out states that the determination of temperature when conducting hot forging is very influential on the mechanical quality of materials [7].

3.4. Deformation Rate
The deformation level is a change in the dimensions of the material form after the forging process. The forging process is carried out at a temperature of 300 °C to 400 °C with a load of 78.5N where at this temperature phase changes have occurred, making it easy to forging. The deformation rate for forging is shown in the following graph:

![Graph 3. Deformation rates](image)

Graph 3 shows the level of deformation that occurs in the forging process, where the initial dimensions of 9 mm and the end of the forging are expected to be 7 mm. The manual forging process to achieve these dimensions requires 5 times forging with a duration of 10 seconds with an average deformation level of 4.88%. Forging using mechanical equipment with the same conditions requires 4 forging processes with an average deformation rate of 6.07%. Temperature determination according to the phase diagram gives an influence on the degree of deformation as well as the load given. The lower process temperature decreases the material ductility and deformation level [8].

4. Conclusion
The conclusion of the application of ergonomically based mechanical forging equipment that is intended to help gamelan craftsmen in the forging process. Based on the mechanical work of the forging tool it is able to provide results such as hardness, reduction in porosity, microstructure, a better deformation rate than forging done manually.

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