

# Comparative Study of Continuous and Batch Heat Treatment in the Manufacturing Process of Cu-30Zn Brass Cup

Muhammad Zainal Furqon<sup>1,\*</sup>, Izzadien Ibrahim Imam<sup>2</sup>, and Bondan Tiara Sofyan<sup>2</sup>

<sup>1</sup>Department of Motion Power Technology, Faculty of Engineering and Defence Technology, Universitas Pertahanan RI, Kawasan IPSC Sentul, Kec. Citeureup, Kabupaten Bogor, Jawa Barat, 16810, Indonesia

<sup>2</sup>Department of Metallurgy and Materials, Faculty of Engineering, Universitas Indonesia, Kampus UI Depok 16424, Indonesia

**Abstract.** Cu-30Zn brass cups are used as raw materials for small-caliber ammunition casings, which must meet strict standards. One crucial process to achieve the desired characteristics is heat treatment. This study compares two heat treatment methods, continuous and batch, at temperatures of 600 °C, 635 °C, and 670 °C for 32 minutes. After the heat treatment process, the samples were cooled to room temperature and washed. Characterization included measuring eccentricity, observing microstructure using an optical microscope, and testing hardness using the Brinell method. Microstructural observations showed that samples treated in a continuous furnace tended to have smaller and more uniform grain sizes compared to batch heat-treated samples. The grain size after continuous heat treatment at 600 °C, 635 °C, and 670 °C was 0.067 mm, 0.085 mm, and 0.097 mm, respectively, while for batch treatment, they were 0.107 mm, 0.123 mm, and 0.143 mm. Hardness increased as grain size decreased, with continuous heat treatment showing 60 BHN, 59 BHN, and 57 BHN. Based on the hardness, microstructure, and eccentricity data, continuous heat treatment at 600 °C to 650 °C for 32 to 45 minutes is recommended, while batch heat treatment does not meet standard specifications.

## 1 Introduction

Small Caliber Munitions is one of the important components in the main weaponry system of the Indonesian National Army (TNI), which plays a crucial role in supporting training activities and the implementation of Military Operations for War. TNI requires a supply of Small Caliber Munitions of around 500 million rounds per year. In addition, small-caliber munitions are also an important requirement for the National Police, Coast Guard, and other agencies with a large number of uses.

The components of a munition consist of projectiles, primers, casings, and propellants. The Casings serves as a container to wrap the projectile and propellant, as well as the primer. Brass casings are a vital component in modern ammunition systems, mainly because they are corrosion-resistant, malleable, and able to withstand the high pressure of propellant explosion [1]. When a weapon is fired, the Casings expands temporarily to form a gas-tight seal in the chamber, preventing pressure leakage, and then contracts again for easy ejection from the chamber. The brass casing is manufactured through a series of processes starting from the brass cup, which undergoes deformation with a specific reduction and heat treatment, thereby enabling its application as a small-caliber ammunition casing. Currently, PT Pindad still imports all of its brass cup needs from overseas. To reduce dependence on imports, research is now focused on developing brass cup materials, especially through

optimizing the heat treatment process. The aim is to eliminate internal stress, improve grain size, increase hardness or tensile strength, and so that meet the ASTM B-129 standard. There are two methods of heat treatment process, the batch and continuous process, which will be compared in this study.

Brass materials that have gone through cold working, 400 °C - 700 °C [2]. In Kumar's research [3], heat treatment of brass cup 70/30 with temperature variations of 500 °C, 550 °C, and 600 °C for 10 minutes and 30% cold rolling reduction result in grain size is increases 12 μm, 18 μm and 32 μm. Gaurav found that annealing at three difference temperatures 420 °C, 520 °C, 620 °C for 30 min after rolled with 75.4 % reduction produce grain size of 22 μm, 39 μm, 42 μm [4]. Widyastuti conducted research on CuZn<sub>35</sub> by varying temperatures of 300-600 °C and 30-60 minutes annealing [5]. The results showed that the increase in temperature eliminated beta phase and simultaneously grain growth will occur which significantly reduces the hardness (from 114.2 VHN to 70 VHN), tensile strength (from 350 MPa to 250 MPa) but increases ductility (elongation from 49.62 % to 60 %.) at a temperature of 400 °C for 60 minutes. Tajally conducted a study on the effect of annealing time on the formability properties of CuZn<sub>35</sub> brass through reducing twinning density and increasing controlled grain recovery [6]. In this research, we compared and studied the heat treatment process of Cu-30Zn brass cup by comparing the continuous and batch heat treatment processes for 32

\* Corresponding author: [muhammad.furqon@tp.idu.ac.id](mailto:muhammad.furqon@tp.idu.ac.id)

minutes at various temperatures so as to produce a material that can be applied as a brass cup material

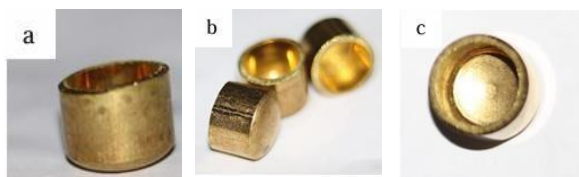
## 2 Methods and materials

This study used Cu-30Zn brass cup samples in an untreated condition. The nominal composition of the samples can be seen in Table 1. The samples were then heat-treated with temperature variations of 600 °C, 635 °C, and 670 °C for 32 minutes. The heating process was conducted at two types of furnace, the batch and the continuous furnace. The later furnace was regulated through an inverter system a frequency of 2.55 Hz to achieve target time of 32 minutes.

**Table 1.** Composition of the alloy (in wt. %)

Chemical Composition (wt%)			
Cu	Zn	Pb	Sn
69.4	30.4	<0.005	0.011
P	Mn	Fe	Ni
<0.003	0.005	0.038	<0.005
Si	Mg	Cr	Al
<0.005	0.0006	<0.001	<0.002
As	Ag	Co	Bi
0.003	0.002	0.029	0.033

Sample characterization included composition testing using Optical Emission Spectroscopy (OES), Brinell hardness measurement using ASTM E19 and ISO 6506-1 standards, grain size calculation using planimetric method in accordance to ASTM E112-10 standard, microstructure observation using *Carl Zeiss* optical microscope with standard sample preparation, namely sanding, polishing using Al<sub>2</sub>O<sub>3</sub> and continued etching using a 10% ferric chloride etching agent by mixing 10 grams of FeCl<sub>3</sub> solid into 95 ml of alcohol with a sample etching time of 10 seconds based on ASTM E-3 standard.

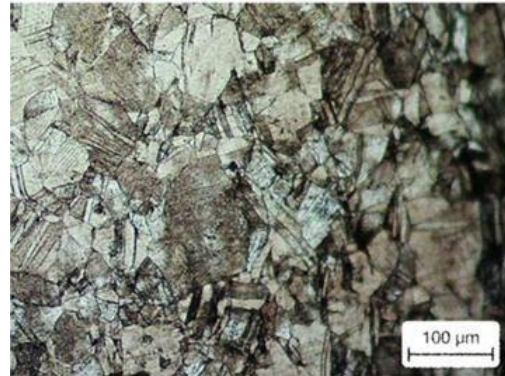


**Fig. 1** Visual Appearance of Cu-30Zn brass cup sample (a) Side View (b) Side and Base View (c) Top View.

The visual representation of the brass cup sample revealed defects in the side, top, and bottom views. The side view (a) exhibited uneven wall height, which did not meet ASTM B-129 standards as injurious defects and potentially compromised the validity of eccentricity testing. The side and bottom views (b) showed transverse lines suspected as joints between wall sides, although the bottom remained within normal limits and the outer diameter did not form an oval. The top view (c) displayed uneven wall thickness, resulting in eccentricity levels exceeding standards for brass cups.

## 3.1 Characterization of Cu-30Zn Brass Cup in the As-Received condition

The microstructure in the Fig. 2 shows the as received sample brass cup before heat treatment, Grain Size from the data obtained with a size of 0.043 mm is classified as coarse with equiaxial grain morphology, referring to grains (grains) in materials that have almost the same length in all directions and do not have a dominant growth orientation and are randomly distributed. The grains clearly show the majority of dislocation twinning, as is common in materials with low stacking fault energy (SFE) such as copper and its alloys [7].



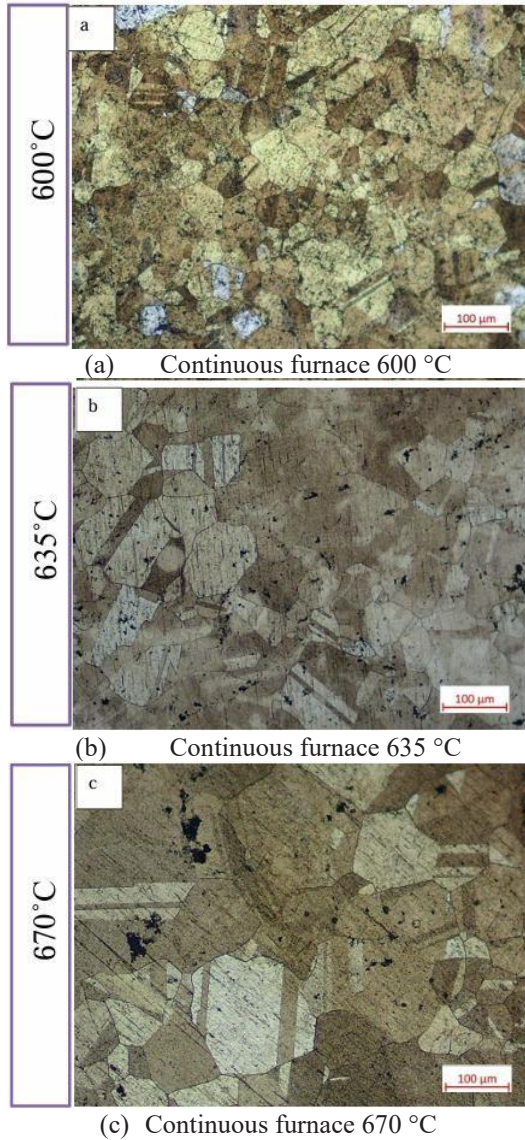
**Fig. 2** Microstructure of Brass alloy Cu-30Zn in the as-received condition

Hardness tests were carried out on Cu-30Zn material in the as-received condition with a value of 106 BHN, referring to the standard brass cartridge used by PT. Pindad requires the required hardness in the range of 60 – 100 BHN [8]. Therefore, it becomes one of the reasons for the need for additional treatment processes so that the mechanical properties produced are by the brass cartridge standard used.

## 3.2 Characterization of Cu-30Zn brass cup with continuous heat treatment for 32 minutes

In a continuous furnace with a 32-minute duration, the microstructure exhibited grain sizes that tended to be more equiaxed at 635 °C, as shown in Fig. 2(b). Nucleation appeared to have just occurred at 600°C, as depicted in Fig. 2(a), due to the dominance of numerous small grains. At 670 °C, illustrated in Fig. 2(c), the grains nearly entered the grain growth phase, displaying larger grains that dominated over smaller ones, commonly known as abnormal growth. This phenomenon occurred because the Cu-30Zn material possessed differences in surface energy and grain energy, which facilitated the growth and absorption of surrounding grains, thereby causing abnormal grain growth [9].

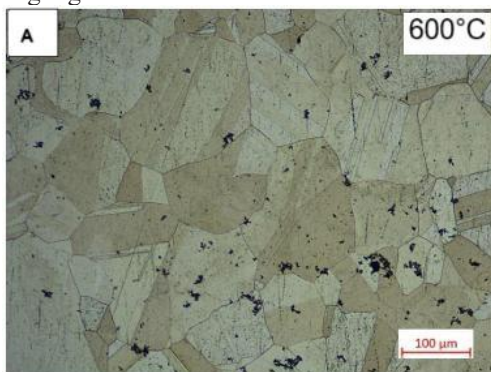
## 3 Results and discussion



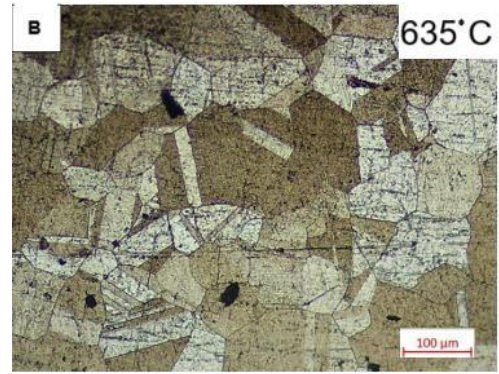
**Fig. 3.** The microstructure of Cu-30Zn samples after heat treatment for 32 minutes through a continuous Furnace

### 3.3 Characterization of Cu-30Zn brass cup with 32-minute batch heat treatment

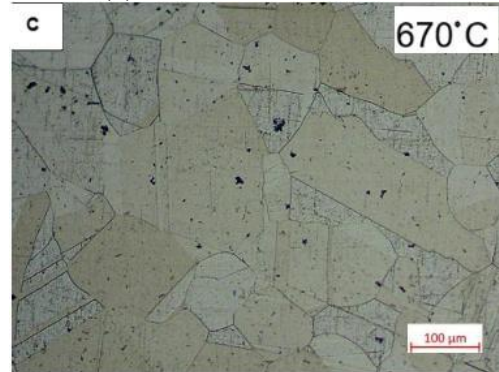
In the batch furnace, the microstructure photograph revealed a more uniform grain size at 635 °C, followed by 600 °C with a predominance of small grains over large ones, and then 670 °C, where small grains diffused into larger grains.



(a) Batch furnace 600 °C



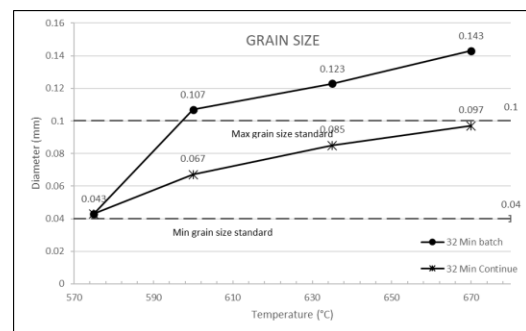
(b) Batch furnace 635 °C



(c) Batch furnace 670 °C

**Fig. 4.** Microstructure of Cu-30Zn samples after 32 minutes of heat treatment through batch Furnaces

When compared, the temperature of 600 °C exhibited a higher ratio of small grains to large grains, which indicated that nucleation had just occurred and the recrystallization stage had begun at that temperature. At 635 °C, both samples underwent an increasingly uniform grain phase; therefore, that temperature marked nearly full recrystallization. For 670 °C, both displayed dominantly larger grains than at the previous temperatures, thereby showing a tendency toward grain growth.



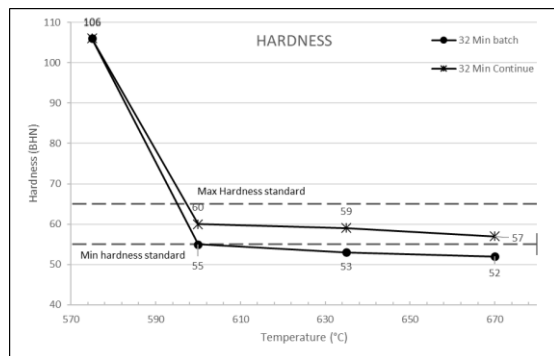
**Fig. 5.** Grain Size Comparison of Cu-30Zn Samples

Before the heat treatment process, the as-received sample exhibited a grain size of 0.043 mm. After annealing in a continuous furnace at temperatures of 600 °C, 635 °C, and 670 °C for 32 minutes, the grain sizes increased to 0.067 mm, 0.085 mm, and 0.097 mm, respectively. In the batch furnace, the sample showed the smallest grain size of 0.107 mm at 600 °C and the largest of 0.143 mm at 670 °C, with 0.123 mm at 635 °C. It was observed that the heat treatment process in the form of annealing resulted in increasingly enlarged and

uniform (equiaxed) grain sizes, with higher temperatures leading to even greater grains [9]. Microstructural observations indicated that heat treatment affected changes in grain size in Cu-30Zn samples, with a 32-minute duration yielding grain sizes that conformed to applicable standards. However, when comparing furnace variations, the continuous furnace produced smaller and more uniform grain sizes than the batch furnace. This occurred because the continuous furnace maintained more stable temperatures, and the conveyor belt served as a driving medium to move the sample from the entry zone to the cooling zone, ensuring a more precise heat treatment duration [10].

### 3.4 Analysis of annealing temperature on alloy hardness

Fig. 6 compares the hardness of Cu-30Zn samples before annealing with those after annealing heat treatment at temperatures of 600 °C, 635 °C, and 670 °C for 32 minutes in continuous and batch furnaces.



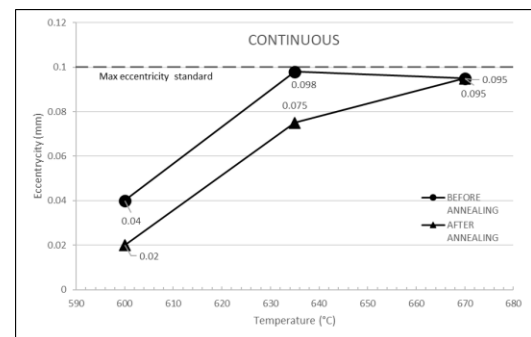
**Fig. 6.** Relationship between the effect of temperature and time on the hardness of Cu-30Zn brass cup samples

Samples at temperatures of 600 °C, 635 °C, and 670 °C in the continuous furnace exhibited hardness values of 60 BHN, 59 BHN, and 57 BHN, respectively. Under the same conditions, the batch furnace yielded 55 BHN, 53 BHN, and 52 BHN, respectively. Samples at higher temperatures produced lower hardness and deviated from the ASTM B-129 brass cup hardness standard [8]. During the annealing stage, prolonged heating or elevated temperatures caused radical microstructural changes. Crystals emerged with low dislocation density (similar to pre-cold working conditions) and tended to be softer. These crystals nucleated at sites of higher dislocation density, particularly near twinning deformations and grain boundaries. Nucleation then grew until adjacent crystals met, gradually eliminating elongated grains and residual stresses from cold working, alongside stress relaxation, which contributed to reduced hardness [11]. This phase was commonly known as recrystallization, during which hardness decreased dramatically compared to pre-heat treatment levels. This finding reinforced the initial hypothesis and literature conjectures that, at the same temperature over time, samples nearly entered the grain growth stage, leading to a tendency for decreased hardness [12]. Differences also emerged between furnace types, with

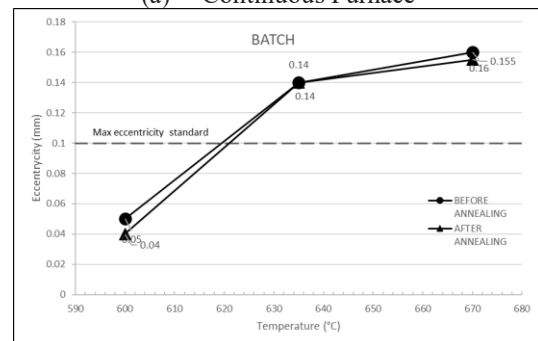
the batch furnace producing lower hardness than the continuous furnace.

### 3.5 Annealing temperature analysis of Cu-30Zn brass cup eccentricity

Changes in eccentricity values occurred before and after the heat treatment process using continuous and batch furnaces. Based on Fig. 7(b), samples annealed at temperatures of 600 °C, 635 °C, and 670 °C in the continuous furnace exhibited eccentricity values of 0.04 mm, 0.098 mm, and 0.095 mm before heating, which decreased to 0.02 mm, 0.075 mm, and 0.095 mm afterward. For the batch furnace (Fig. 7(a)), eccentricity values before annealing at 600 °C, 635 °C, and 670 °C were 0.06 mm, 0.13 mm, and 0.16 mm, and after heat treatment, they became 0.05 mm, 0.14 mm, and 0.155 mm.



(a) Continuous Furnace



(b) Batch Furnace

**Fig. 7.** Eccentricity Results of Cu-30Zn Samples Before and After Heat Treatment Through

It was observed that the differences in eccentricity values before heat treatment varied between the continuous and batch furnaces, and the changes in eccentricity between before and after the heat treatment process were minimal, indicating that these changes were not influenced by annealing temperature. However, samples from both continuous and batch furnace heat treatments remained within the ASTM B-129 standards (source), with a maximum limit of 0.1 mm.

## 4 Conclusion

From the testing and analysis of continuous and batch heat treatment on Brass cup Cu-30Zn as raw material for

small caliber munitions (MKK) 5.56 mm, it can be concluded that:

- The increase in heat treatment temperature is directly proportional to the increase in grain size. In the continuous furnace method with a duration of 32 minutes, the grain size reached 0.067 mm (600 °C), 0.085 mm (635 °C), and 0.097 mm (670 °C), respectively. Meanwhile, the batch hot furnace method at the same temperature and duration produced larger grain sizes of 0.107 mm (600 °C), 0.123 mm (635 °C), and 0.143 mm (670 °C), indicating that the combination of high temperature and longer duration contributed to grain growth.
- Effect of Temperature and Heat Treatment Method on Material Hardness: An increase in heat treatment temperature causes a decrease in the hardness value of the material. In the continuous furnace method with a duration of 32 minutes, the hardness values were recorded as 60 BHN (600 °C), 59 BHN (635 °C), and 57 BHN (670 °C). Meanwhile, the batch furnace method at the same duration produced lower hardness values of 55 BHN (600 °C), 53 BHN (635 °C), and 52 BHN (670 °C). This shows that the combination of high temperature and longer holding time accelerates the decrease in hardness, although under certain conditions (e.g., 650 °C), hardness may stabilize or decrease more slowly. Complete recrystallization is expected to be achieved at 635 °C in continuous heat treatment, resulting in more uniform grains with a smaller size and within the ASTM B-129 and DIN 17670 standard of 0.100 mm.
- Heat treatment with temperature variations (continuous and batch methods) only caused a very narrow range of eccentricity values, 0.01 – 0.02 mm. This insignificant decrease confirms that the eccentricity of the material tends to be stable and does not show a significant influence from the heat treatment process.
- Based on the hardness, microstructure, and eccentricity values, the recommended heat treatment process for the manufacture of Cu-30Zn brass cups by ASTM B-129 and DIN 17670 standards is the continuous furnace heat treatment process with temperatures of 600 °C to 650 °C, with a time of 32 minutes to 45 minutes. While the batch heat treatment does not meet the standard specifications.

Through this statement, the author would like to express his gratitude to the supervisor and all those who have helped the author in completing the article. Especially the Metallurgical Engineering Department of the University of Indonesia and the Department of Motion Power Technology of the Indonesian Defense University.

## References

1. R. Sharma, E. Vijayalakshmi, R. Reddy, P. Tekade, S. Singh, and A. K. Singh, Failure investigation of cartridge case, *Procedia Struct. Integr.*, **vol. 14**, pp. 738–745, (2019) doi: <https://doi.org/10.1016/j.prostr.2019.05.092>.
2. Mutlu, A. Karakaş, H. Kuşdemir, U. K. Koltan, and T. Yalçinkaya, Flow forming and recrystallization behaviour of CuZn30 alloy, *Mater. Res. Proc.*, **vol. 28**, pp. 1021–1028, (2023) doi: <https://doi.org/10.21741/9781644902479-112>.
3. Y. Yu, W. Chen, L. Xie, and Y. Song, Effect of heat treatment on microstructure evolution, phase transformation and mechanical properties of dual phase Cu-Zn alloy, *J. Alloys Compd.*, **vol. 904**, p. 163960, (2022). doi: <https://doi.org/10.1016/j.jallcom.2022.163960>.
4. Gaurav, P. Chakraborty, and S. B. P. Vejenjala, Deformation and annealing of brass, *Mater. Today Proc.*, **vol. 64**, pp. 1380–1383, (2022). doi: <https://doi.org/10.1016/j.matpr.2022.04.502>.
5. Widyastuti, R. Rochiem, D. M. Fellicia, C. F. N. Adrinanda, and A. P. Wibowo, Mechanical Properties, Microstructural, and Deep Drawing Formability Analysis on the Annealed CuZn35 Brass Alloy for Cartridge Application, *Key Eng. Mater.*, **vol. 939**, no. January, pp. 31–37, (2023). doi: <https://doi.org/10.4028/p-21x8y5>.
6. J. Birch *et al.*, A micromechanical study of heat treatment induced hardening in alpha-brass, **vol. 278**, no. August, (2024). doi: <https://doi.org/10.1016/j.actamat.2024.120277>.
7. H. Wang, P. Zhang, C. Wang, Q. Zhu, and G. Chen, Investigation of the size effect on flow stress and deformation mechanism in Cu-Zn thin sheets, *Mater. Sci. Eng. A*, **vol. 922** (2025). doi: <https://doi.org/10.1016/j.msea.2024.147622>.
8. M. Polásek and D. Kezić, Comparison and Assessment of the CuZn30 Brass Structure in the Production of the 9X19 Luger Cartridge Case, *Univ. Rev.*, **vol. 15**, no. 1, pp. 39–44, (2021).
9. I. E. Volokitina, Effect Of Preliminary Heat Treatment On Deformation Of Brass By The Method Of ECAP, **vol. 63**, pp. 163–167 (2021). doi: <https://doi.org/10.1007/s11041-021-00664-y>.
10. T. V Rajan, C. P. Sharma, and A. Sharma, Heat Treatment Principle Technique, Third. Delhi: PHI Learning Pvt. Ltd., 2023.
11. I. Angela, I. Basori, and B. T. Sofyan, Effect of cold rolling and annealing temperature to the characteristics of  $\alpha + \beta$  phases in Cu-29.5Zn-2.5Al alloy produced by gravity casting, *J. Min. Metall. Sect. B Metall.*, **vol. 56**, no. 1, pp. 89–97, (2020). doi: <https://doi.org/10.2298/JMMB180820037A>.
12. J. Luštinec, M. Roško, and V. Očenášek, Structural and Mechanical Properties of CuZn30 Cartridge Brass in Real Production Conditions, *Manuf. Technol.*, **vol. 23**, no. 6, pp. 846–852, (2023) doi: <https://doi.org/10.21062/MFT.2023.090>.