

# The Effect of Different Approach Methods on the Mechanical Properties of CuNi12Zn24 Material Production

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This research study aimed to examine the mechanical properties of CuNi12Zn24 material produced using two different processes. The impact of both processes on fundamental mechanical properties such as hardness, tensile strength, yield strength, and electrical conductivity of the material was evaluated. The first process involved subjecting the cast output samples to cold rolling from 9mm to 2mm thickness. Mechanical tests conducted after the rolling process showed that the material had a hardness of 227 HV, tensile strength of 625.10 MPa, and yield strength of 618.69 MPa. Additionally, the material exhibited good conductivity with a value of 7.9% IACS. The second process involved annealing the samples at 750°C for 2 hours followed by quenching and subsequent cold rolling down to 2mm thickness. The samples obtained from this process had a hardness value of 226 HV, tensile strength of 527.50 MPa, and yield strength of 526.18 MPa. The conductivity value was determined to be 8.8% IACS. Comparative analysis revealed that the mechanical test values of the samples subjected to annealing were more favorable. The slight difference in mechanical properties between the two processes indicates that both methods are applicable for the production of CuNi12Zn24 material.

**Keywords:** CuNi12Zn24 alloy, Mechanical Properties, Different Processes

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## 1. Introduction

Historically, humanity took its initial steps into materials science with the discovery of pure metals, especially gold and copper, to meet societal needs. During the Bronze Age, people began alloying materials with the discovery of copper and arsenic, subsequently evolving over time to develop binary (e.g., Fe-C), ternary (e.g., Ni-Co-Al), quaternary (e.g., Ni-Co-Al-Cr), quinary (e.g., Ni-Fe-Cr-Ti-Al), and more complex alloys [1-4]. Alloying involves enhancing the properties, particularly mechanical properties, of base metals through the addition of various elements [2,5]. These alloys have evolved from simple to complex in line with technological advancements and societal needs. Consequently, each newly developed alloy

emphasizes its contribution to the advancement of materials and civilization with its unique properties. Beyond fundamental characteristics, there is an increasing demand for secondary properties, necessitating the exploration of traditional boundaries in material design [6].

Copper alloys are widely preferred in various industries such as aviation, electronics, machinery manufacturing, and communication due to their excellent mechanical properties, high thermal conductivity, and impressive corrosion resistance. These properties have made copper alloys indispensable for societal development and high-tech industries. With rapid advancements in science and technology, traditional materials may now fall short of meeting the increasing requirements of high-tech industries.

Therefore, special materials like copper alloys play a significant role in meeting these needs by providing broader and enhanced performance [7,8,9,10,11]. Cu-Ni-Sn alloys can compensate for the deficiencies of traditional Cu-Be alloys, such as better thermal stability, high-temperature resistance, and resistance to stress relaxation at high temperatures, while also offering advantages in terms of toxic emissions during the production process [12]. However, due to the significant differences in the melting points of Cu, Ni, and Sn (Cu: 1083°C, Ni: 1453°C, Sn: 232°C), serious segregation can occur during the melting and solidification of this alloy. This segregation can lead to various defects by causing the concentration of Sn in the alloy, potentially resulting in cracks and compromising mechanical properties during hot processing [13]. Many scientists have focused on methods such as mechanical alloying, rapid solidification, powder metallurgy, and melting in a vacuum to improve the preparation process of Cu-Ni-Sn alloys and address the adverse effects of segregation. Cu-Ni-Sn alloys belong to the category of alloys supporting typical amplitude modulation decomposition. Developed by adding Ni to Cu-Sn alloy in 1928, this alloy has been notably enhanced in performance, especially through age-hardening methods [14]. In the 1960s, Cu-Ni-Sn alloys became a fundamental material for lead frames due to their superior strengths and electrical conductivities, and have since been extensively researched [15, 16]. The properties of Cu-Ni-Sn alloys have been significantly enhanced through precise control of the relative content of each component and the addition of other elements, enabling their effective use under various operating conditions. Recent research has confirmed the addition of trace elements that can improve the alloy's performance. These trace elements, found in a dissolution process causing cage distortion, include Fe [17], Ti [18], Mg [19], Cr [20], Co [21], Ce [22], Ni [23, 24], and Y [25]. Wang et al. [26] found that the addition of an appropriate amount of Zn had a significant effect on the mechanical properties of the alloy in terms of increased yield strength, ultimate tensile strength, and elongation. In this context, CuNi12Zn24 alloy has garnered attention in recent years. CuNi12Zn24, classified as a copper alloy, is primarily composed of copper, nickel, and zinc elements [27]. This alloy is known for its excellent conductivity properties and durability. The high copper content results in excellent conductivity, while the additions of nickel and zinc enhance its mechanical strength. CuNi12Zn24 is an excellent choice for electrical conduction. Therefore, it is used as an ideal material for energy transmission lines and electrical devices. This material also exhibits good performance in terms of mechanical durability, supporting its use in machinery and structural applications. CuNi12Zn24 is known for its resistance to corrosion, which is important for the maritime

industry and underwater applications. However, CuNi12Zn24 may be costly due to its inclusion of valuable metals such as copper and nickel. Additionally, it is a dense material, which may pose weight issues in some applications. CuNi12Zn24 finds application in various fields. It is widely used for energy transmission lines, electrical devices, and electric vehicles. It is an ideal material for submarine cables, ship engines, and marine research equipment. It can also be used for structural components, coatings, and durable construction materials. In conclusion, CuNi12Zn24 has become a preferred material in many application areas due to its electrical conductivity, durability, and corrosion resistance. However, some disadvantages such as cost and weight should be considered. This material will continue to contribute to further industrial and technological advancements in the future. The CuNi12Zn24 material has drawn attention due to its excellent conductivity properties and mechanical strength potential. However, the impact of the process processes used in its mass production on the mechanical properties of the final product has been a significant question for researchers and industrial manufacturers. This study aims to investigate the effect of two different process processes on the mechanical properties of CuNi12Zn24 material mass production. The first process involves subjecting the cast output samples to cold rolling, reducing the material's thickness from 9mm to 2mm. The second process involves annealing the samples first, followed by cold rolling. The mechanical properties of the samples obtained from both processes were subjected to comprehensive analysis in terms of hardness, tensile strength, yield strength, and electrical conductivity. The results of this study will help identify the most suitable process process for the mass production of CuNi12Zn24 material and contribute to its wider use in industrial applications. Therefore, a detailed examination of mechanical properties and production processes will be an important step in advancing industrial production and material engineering.

## 2. Material and Methods

### 2.1. Sample Preparation and Chemical Analysis

To achieve the desired chemical composition of the CuNi12Zn24 material, 1.28 kg of Copper (Cu), 0.24 kg of Nickel (Ni), and 0.48 kg of Zinc (Zn) consumables were used. Chemical analysis was conducted using an Amatek Spectrolab modal device. The chemical composition of the CuNi12Zn24 alloy was determined to be 64% Cu, 24% Zn, and 12% Ni. A total of 2 kg of consumables were used to obtain this composition. The materials consist of components with the specified proportions of Cu, Ni, and Zn content. After testing the chemical analysis of the produced CuNi12Zn24 rolled material (Fig.2), a machining process

was applied to remove the scale and burrs from the surface of the material using a circular milling operation.

Process 1: The cast output samples initially were in the form of plates with a thickness of 9mm. These samples underwent necessary pre-treatment processes for surface cleaning and leveling before subjecting them to cold rolling. The samples were placed into a cold rolling machine and underwent mechanical pressing. As a result of this process, the samples were transformed into plates with a thickness of 2mm (Fig.1).

Process 2: The samples used for this process were based on the same cast output samples. However, this time the samples underwent a special heat treatment process called annealing before commencing mechanical processes. The samples were annealed at 750°C for 2 hours. Subsequently, the annealed samples were subjected to cold rolling down to plates with a thickness of 2mm after being quenched in a solution (Fig.1).



Fig.1. Representation of the rolled samples after casting.

The final rolling process was conducted based on reduction and pass calculations. After the rolling process, samples were taken (Fig.2), and the conformity was tested by measuring the spectral analysis values and microstructure values of the product.

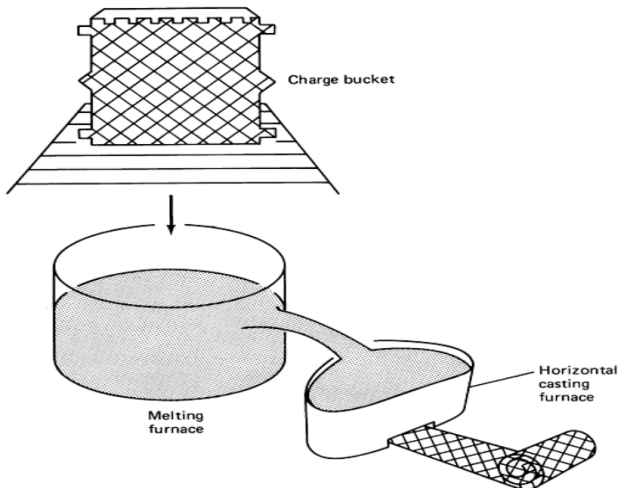


Fig.2. Schematic representation of the horizontal continuous casting and rolling process.

## 2.2. Adjustment of Casting Parameters

The melting point of the CuNi12Zn24 alloy is known to be 1060°C. For the casting process, a casting temperature of 1300°C has been preferred (Figure 3a). Additionally, it has been determined that the mold temperature should be at least 350°C during pneumatic mechanism mold casting experiments (Figure 3b). It has been observed that low mold temperatures hinder the sufficient flow of the alloy into the mold cavity.

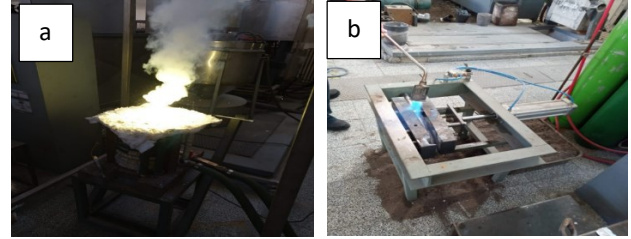


Fig.3. a) Representation of the sample melting process, b) Mold and Preheating process with Pneumatic Mechanism.

## 2.3. Adjustment of Heat Treatment Parameters

According to the phase diagram of the CuNi12Zn24 alloy, the solution treatment (homogenization annealing) process was carried out at 750°C for 2 hours. Following the solution treatment, a rapid quenching process was applied to the material for rapid cooling. Cold rolling was then applied after the cooling process.

## 2.4. Adjustment of Cold Rolling Parameters

The cast CuNi12Zn24 alloy was obtained in the form of a slab with dimensions of 9 mm thickness, 50 mm width, and 300 mm length. This slab was quenched in water after the solution treatment. Subsequently, cold rolling was applied. This process was conducted using a mechanical adjustable rolling mill with dimensions of 65 cm in width and 40 cm in diameter. The rolling mill operated at a speed of 40 revolutions per minute (rpm). The slab, initially 9 mm thick, was gradually cold-rolled to thicknesses of 5 mm and then 2 mm. The final product produced is shown in Fig 4.



Fig.4. Representation of the final product produced.

**2.5. Determination of Mechanical Properties**

Hardness Measurement Test (Zwickzhv10): Hardness values were measured using the Vickers hardness scale and expressed in HV units.

Tensile Strength Test (Zwick-Z030): Tensile strength was determined using a tensile testing machine, and the results were reported in megapascals (MPa).

Yield Strength Test (Zwick-Z030): Yield strength was determined using the data obtained during the tensile test, and the results were expressed in megapascals (MPa).

Conductivity Test (FISHER-SMP350): The electrical conductivity property of the material was measured in IACS (International Annealed Copper Standard) units. The conductivity test was conducted using appropriate test equipment to evaluate the electrical properties of the samples. Microstructure Analysis (Microscope-AXIOLAB-5): Microstructure analysis was conducted to examine the microstructure of the samples and evaluate the effect of both processing methods on the material structure. These analyses were performed using suitable microanalysis methods such as optical microscopy and/or scanning electron microscopy.

**3. Results and Discussion**

**3.1. Chemical compositions of the alloys**

The chemical composition and values of CuNi12Zn24 alloy after the cold rolling process and solution treatment + cold rolling process are presented in Table 1.

Tab.1. The chemical composition values of the CuNi12Zn24 alloy after the cold rolling process and solution treatment + cold rolling process.

Samp	Cu %	Sn %	Zn %	Pb %	Fe %	P %	Mn %	Ni %	Be%
les	63.6	0.0055	21.79	0.0260	0.0136	0.0008	0.0001	14.46	0.049
						2	7		0
	Si %	Cr %	As %	Bi %	Ag &	Co %	Al %	S %	-
	<0.000	<0.000	<0.000	<0.001	<0.000	<0.000	<0.000	<0.002	-
	30	64	40	5	40	30	50	1	
	Cu %	Sn %	Zn %	Pb %	Fe %	P %	Mn %	Ni %	Be%
	63.2	0.0054	22.75	0.0185	0.0274	0.0007	0.0003	13.76	0.028
						9	1		4
	Si %	Cr %	As %	Bi %	Ag &	Co %	Al %	S %	-
	0.228	0.0006	0.0004	<0.001	<0.000	<0.000	0.0034	0.0032	-
						2	8		30

When examining Table 1, it appears that there have been changes in the quantities of some components during the second process (cold rolling + solution treatment). Particularly notable changes are observed in the quantities of zinc, iron, and nickel. Additionally, the alloy seems to be quite pure in terms of other elements (Si, Cr, As, Bi, Ag, Co, Al, S) during both processes, as these elements are present at very low levels or undetectable levels. These chemical composition data demonstrate how the material can change through different processing stages. These alterations can

impact the mechanical and conductivity properties of the material. Therefore, it is important to evaluate which composition of the alloy is more suitable for a specific application or use.

**3.2. Microstructure Imaging Test**

Grain size measurement is an important parameter used to examine and evaluate the microstructure of the material. Grain size determines the size and distribution of particles within the material. Such measurements can significantly affect properties such as mechanical properties, durability, and workability of the material. Therefore, it is an important characterization method for material engineers and scientists. The microstructure images of CuNi12Zn24 alloys after the Cold Rolling process (Fig.5a) + Cold Rolling and Solution Treatment process (Fig.5b) are presented in Fig 6.

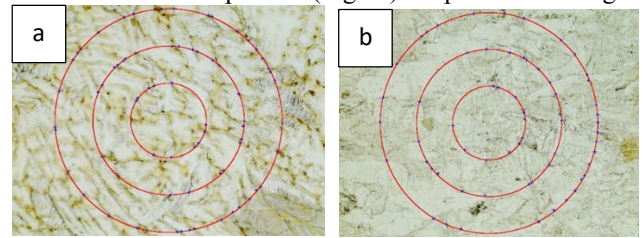


Fig. 5. a) Microstructure image after the Cold Rolling process, b) Microstructure image after the Solution Treatment + Cold Rolling process.

After cold rolling following casting, the grain size measurement value of the samples is 0.041mm, whereas the grain sizes of the materials after solution treatment and cold rolling following casting are 0.19mm. It is observed that the grain boundaries and grain sizes are more pronounced in the samples after solution treatment following casting.

**3.3. Mechanical Properties**

**3.3.1. Hardness Test**

The hardness value after casting is quite high (227 HV). This high hardness indicates that the sample is naturally hard after the casting process. High hardness can increase the mechanical strength of the material, but it can also make it difficult to process. After solution treatment following casting, the hardness value decreases to 226 HV. This indicates that the processing of the material reduces its hardness. This decrease can be associated with the effect of stress relief annealing. Stress relief annealing can relieve internal stresses and lead to grain growth. The hardness test results indicate that the alloying elements contribute to solid solution strengthening. Solid solution strengthening occurs when alloying elements occupy the crystal structure and harden the crystal lattice. This can increase the material's strength. The grain size after casting is 0.041mm, while the grain size after solution treatment is reported as 0.19mm. A larger grain size may lead to a decrease in hardness because larger grains tend to be less hard. Decreasing grain size creates more grain boundaries, which can contribute to an increase in hardness. In conclusion, the hardness test results demonstrate the effects of processing steps, solid solution

strengthening, and grain size on hardness. This information can serve as a valuable guide for material selection and optimization of processing steps for materials engineers.

### 3.3.2. Tensile Test

Tensile test results provide important data for evaluating the mechanical properties of samples after processing steps such as cold rolling and heat treatment (annealing and solution treatment) of the cast output samples. These results offer significant insights into materials engineering and manufacturing processes. Firstly, subjecting the cast output samples to cold rolling reduces the grain size of the material and creates a more homogeneous structure. The tensile strength and yield strength of the samples obtained after this process were measured as 625.10 MPa and 618.69 MPa, respectively. These values indicate high mechanical strength of the material. Cold rolling can lead to longitudinal thinning of grains and a tighter structure of the material. The second process involves annealing the samples at 750°C for 2 hours. This process reduces internal stresses in the material and creates a more homogeneous microstructure. Subsequently, the samples are subjected to solution treatment followed by cold rolling again. The tensile strength and yield strength of the samples obtained after this process were measured as 527.50 MPa and 526.18 MPa, respectively. Solution treatment allows the grains of the material to dissolve in the solution and then be reshaped with cold rolling. An important observation is that the tensile strengths of the samples rolled before solution treatment were higher. This suggests that the formation of a second phase between the grains after solution treatment affects the tensile strength. The distribution of the second phase among the grain boundaries can adversely affect the mechanical properties of the material. Therefore, it is important to optimize processing parameters and determine suitable process parameters for the material to have the desired properties based on tensile test results. In conclusion, these tensile test results demonstrate the effects of processing steps on the mechanical properties of cast output samples.

### 3.4. Conductivity

The obtained conductivity test results provide important data for evaluating the effects of the solution treatment process on material properties. Conductivity is a critical parameter that measures the electrical conductivity of a material, and these results can be used as indicators of the structure and purity of the material. According to the conductivity test results, the conductivity measurement value of the sample before solution treatment was measured as 7.9% IACS (International Annealed Copper Standard), while after solution treatment, the conductivity value of the sample was measured as 8.8% IACS. These results indicate an increase in the electrical conductivity of the material after the solution treatment process. This increase can be attributed to the changes in the structure of the material that occur after the solution treatment process. Solution treatment helps dissolve second phases within the material and creates a homogeneous solution. Therefore, the increase

in conductivity values indicates a reduction in heterogeneities within the material and the attainment of a purer structure. Additionally, solution treatment reduces internal stresses in the material, which can further enhance electrical conductivity. These findings demonstrate that the solution treatment process improves the material's structure and enhances its electrical conductivity properties. This is particularly important in applications requiring electrical conductivity. The compliance of conductivity values with standards indicates an improvement in material quality and the successful implementation of processing processes. In conclusion, these conductivity test results document the positive effects of the solution treatment process on material properties.

## 4. Conclusion

This study aimed to examine the mechanical properties of CuNi12Zn24 material produced using two different processing methods. Samples produced in the first process underwent cold rolling from 9mm to 2mm thickness after casting, followed by mechanical testing. The hardness of these samples was measured as 227 HV, with tensile strength of 625.10 MPa and yield strength of 618.69 MPa. Additionally, the electrical conductivity of the material was determined to be 7.9% IACS. Samples produced in the second process were annealed at 750°C for 2 hours, then solution-treated, and subsequently subjected to cold rolling from 9mm to 2mm thickness. The hardness of these samples was measured as 226 HV, with tensile strength of 527.50 MPa and yield strength of 526.18 MPa. The conductivity value was determined to be 8.8% IACS. Consequently, the mechanical test results of the samples subjected to solution treatment were observed to be more favorable compared to those produced in the first process. However, the mechanical differences between the two processes are relatively small. Therefore, it can be concluded that both processes are applicable for the production of CuNi12Zn24 material. These findings provide useful information for material producers and industrial users to optimize material processing processes and select them according to their requirements.

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