# RESEARCH AND MANUFACTURING OF HIGH-MECHANICAL COPPER ALLOYS FOR SHAFT LINERS

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**Abstract.** This article presents the results of research and manufacturing of copper alloys with good mechanical synthesis to manufacture shaft liners. The results show that CuAl10Fe4Ni2 alloys are reasonably heat treated; The hardness value achieved is 105HRB and the mass loss is 0.1044g. Further, by SEM; EDS and TEM, we have identified intermetallic phases as fine $Fe_3Al$ and fine NiAl dispersed on the microstructure. These phases have increased the hardness and wear resistance for this alloy.

## 1 INTRODUCTION

The shaft liners usually are lubricated with natural water; This is an easily corroded environment, especially with electrochemical corrosion. In addition, the position where the shaft works with its bearing is subject to a large load. Therefore, to protect the shaft and create a good friction, it is often necessary to cover the steel shaft with a component called shaft liners.

The shaft liners are mounted in a slidable mounting mode with the shaft in the position where the shaft works directly with the bearing, in direct contact with the seawater. When working the shaft liners work under the load and the following harm: The suspension shaft has a resilience to the shaft, so the shaft liners are initially stressed due to the bucket. Torsional tension due to average torque on the shaft; Stress changes due to twisting, bending and deformation; Pulled by compressed shafts; Abrasion due to contact with sea water and abrasion-resistant when working with bearings.

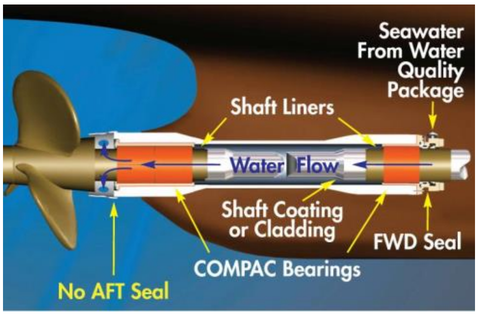



**Figure 1**: Location of shaft liners

As such, the shaft liners are subject to variable loads, abrasion and corrosion resistance, so the ship shaft is often damaged due to fatigue; abrasion resizing. If there is a slippage that leads to abrasion, rust on the contact surface

Due to the special working conditions, the shaft liners must to have a special mechanical property; that is resistance against abrasion.

Under the same working conditions, the copper alloys are commonly used today. Copper alloys have a variety of mechanical mechanisms, such as the spinodal decomposition mechanism, martensite phase transition and dispersing phases, alloying and intermetallic phase. In this study, we are studied about the copper alloys which added of iron and nickel alloys combined with heat treatment producing martensite transformation, disperse γ2 and intermetallic phases. [1,2,4,7]

Copper-aluminum alloy has some more highly mechanical and technological properties compared to other copper alloys. When it is alloyed with iron and nickel, intermetallic phases are created, increasing durability by heat treatment.

Iron dissolves in aluminum very little; when iron content increases, it will form intermetallic phase $Fe_3Al$; if this phase is fine-grained in the form of spheres, and it distributes evenly in the microstructure, the mechanical properties of the alloy will be improved. Iron is a good element in the copper-aluminum alloys because it enhances the crystalline temperature, fine grain, durability, hardness and the wear resistance of the alloy. The intermetallic phase is generated around $\alpha$, across the boundary and also inside phase β, preventing the phase difference of phase β and reducing the velocity of the reaction with eutectoid $\beta \rightarrow (\alpha+\gamma_2)$; Therefore, if the phase $\gamma_2$ is made, it is fine-grained and dispersed evenly throughout the structure, and it overcomes the self-composting phenomenon of aluminum-copper bar to improve durability, hardness and significant wear resistance for alloys as well [3,4].

Phase α of copper-aluminum alloys can dissolve up to 4% iron as the higher iron content produces the intermetallic phase $Fe_3Al$. Iron has a denaturing effect on the microstructure of the copper aluminum alloys, improving durability, hardness, and lubricity along with reducing the tendency of embrittlement of 2-phase bromine due to slowing down the eutectoid decomposition of phase β and separation of phase $\gamma_2$ [6].

In addition, the alloy is added Nickel which dissolves infinitely in copper but very little soluble in aluminum. Ni improves the mechanical properties of the alloy, however, it contributes to increased resistance to abrasion and works at low temperatures. When implementing the quenching process, this alloy was formed martensitic microstructure based on 3R structure (or 18R) or 2H; these two types are commonly called β 'or γ'. Continuing to implement the tempering process, the alloy will form the intermolecular phase based on electronic compound NiAl, $Fe_3Al$ simultaneously the background is the copper-rich solid solution [3,5,6].

From the results of the theoretical analysis, the article presents about the results of research and manufacturing the copper and aluminum alloys are alloyed with 4% Fe and 2% Ni to increase the wear resistance of this alloy.

## 2 EXPERIMENTAL PROCEDURE

In the results of the research group, the team made a copper alloy with 10% of Al; 4% of Fe and 2% of Ni.

**Table 1**: Component of this alloy

| Elements | Al | Fe | Mn | Ni | Sn | Zn | Pb | Si | Cu |
|---|---|---|---|---|---|---|---|---|---|
| (%) | 9,41 | 4,98 | 0,15 | 2,44 | 0,04 | 0,49 | 0,07 | 0,07 | Bal. |

This alloy is heat treated to ensure its homogeneity at 850°C for 2 hours, then quenched in water and aging tempered at 350°C in 02 hours. The samples after treatment were analyzed microstructure, hardness, and abrasion resistance. Xray analyzes were conducted at the Faculty of Physics, Hanoi National University. The microstructure of the sample being studied Axiovert optical microscope 25A, scanning microscope JEOL - JSM 7600F. The results of the study on SEM images were made at the Electronic Simulation Laboratories - Advanced Institute of Science and Technology - Hanoi University of Technology. Also in this report, the phase is analyzed by the transmittion electron microscope at the Polytechnic University of Ho Chi Minh City. Mechanical properties of the samples are determined on ATKF1000 equipment.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Microstructure

***After casting***

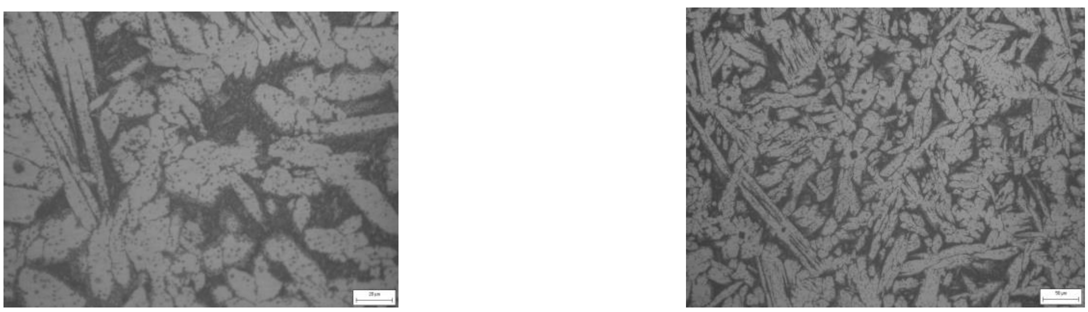


**Figure 2**: Microstructure of casting

After casting the microstructure consists of two phases, mainly phase α branching and dark phase is the phase (α + γ) hard and brittle. In addition, on the microscopic image can also see some suspected phase is the alloy phase of Fe. However, it is difficult to detect these phases by optical microscopy

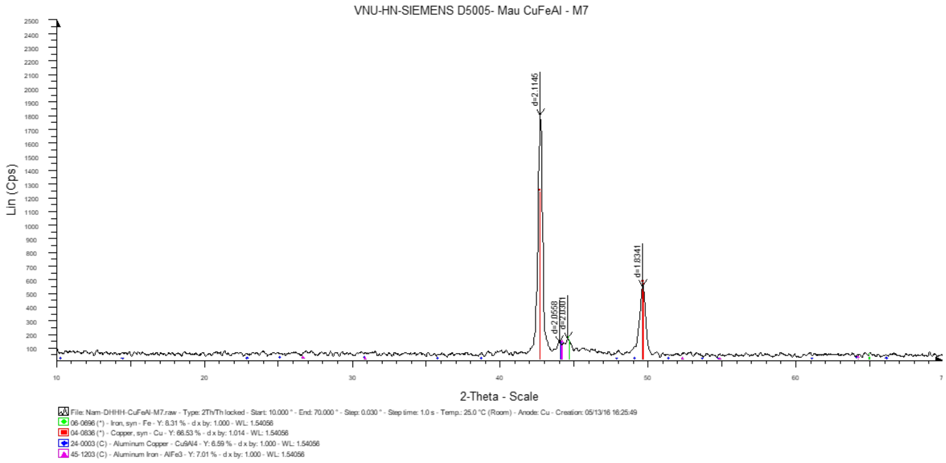



**Figure 3**: Xray of casting

By Xray analysis, it is found that: In the microstructure of the alloys, there are two phases in equilibrium: α and β. There is also the little phase of Fe alloys with Al. In the state of dissolved Ni dissolved in the unconformable copper phase.

***After quenching:***

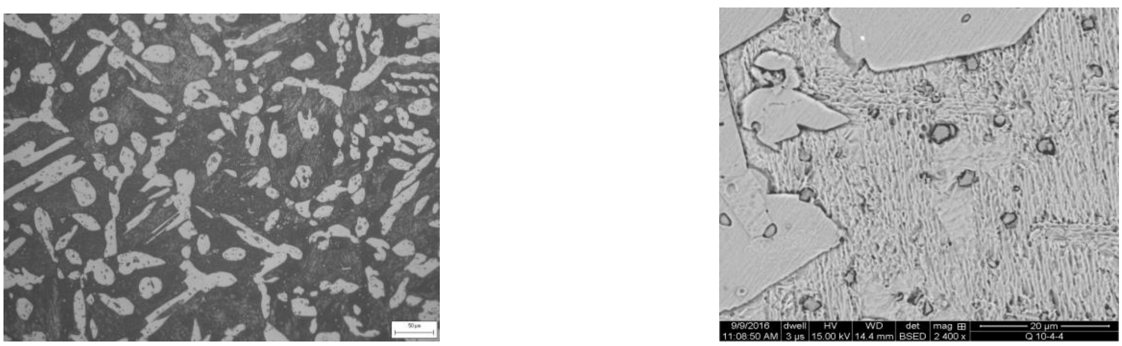



**Figure 4**: Microstructure of quenching

After quenching the analysis of the results found: The samples were heated and held to $850^0$C (heating to the α and β phase area) over a period of two hours and then cooled rapidly in water. The β-phase turns into β-martensite (sheet form). In addition, by optical analysis, the α phase is finer than the α phase after casting. By BSED analysis, a suspicious black phase is suspected. In addition, under the influence of Fe after heat treatment of the alloy phase will make the $\gamma_2$ secreted smooth and dispersed.

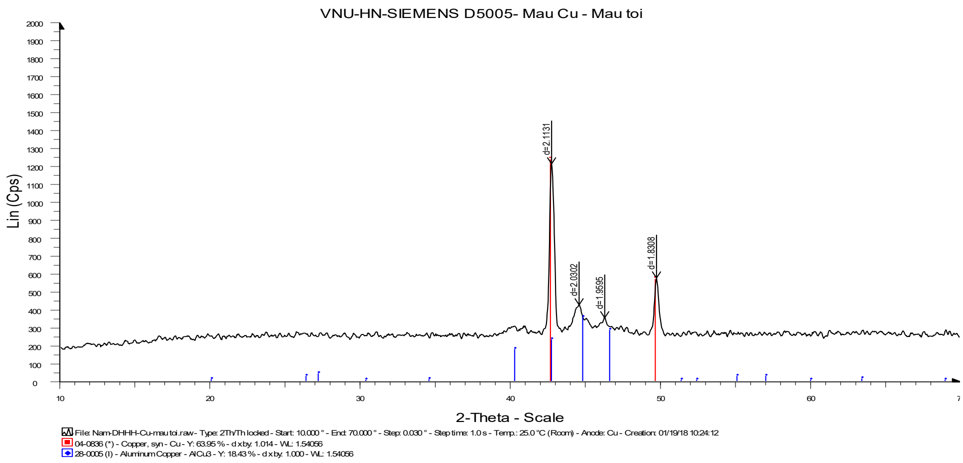
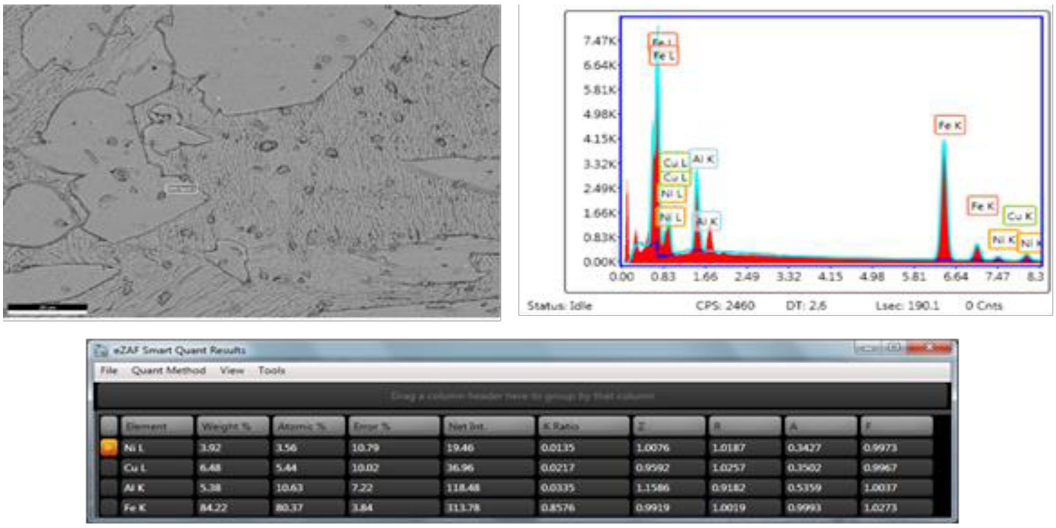



**Figure 5**: Xray of quenching

Xray analysis is mainly a solid solution of α and β'-phase. After quenching, if it was only by Xray analysis, it would be difficult to identify the intermetallic phases. Because these are very fine and scattered phases. Xray analysis only determines β 'martensite (non-diffusive transition)




| Element | Weight % | Atomic % | Error % | Net Int. | K Ratio | Z | R | A | F |
|---|---|---|---|---|---|---|---|---|---|
| Ni L | 3.92 | 3.56 | 10.79 | 19.46 | 0.0135 | 1.0076 | 1.0187 | 0.3427 | 0.9973 |
| Cu L | 6.48 | 5.44 | 10.02 | 36.96 | 0.0217 | 0.9592 | 1.0257 | 0.3502 | 0.9967 |
| Al K | 5.38 | 10.63 | 7.22 | 118.48 | 0.0335 | 1.1586 | 0.9182 | 0.5359 | 1.0037 |
| Fe K | 84.22 | 80.37 | 3.84 | 313.78 | 0.8576 | 0.9919 | 1.0019 | 0.9993 | 1.0273 |

**Figure 6**: EDS of quenching

EDS analysis found that when analyzing the dark color phase, suspicions on the SEM image showed the peaks of the intermolecular phase between Ni and Fe and Al. These phases are very small in size and disperse evenly in the base of the alloy. It's high strength alloys that improve the hardness and wear resistance of alloys. In addition, when the phase of $\gamma_2$ phase metal is released in a small smooth and dispersed in the metal base.

***After tempering***

Analysis of the research results showed that:


**Figure 7**: Microstructure of tempering

The microstructure image analysis revealed that the post-tempering sample showed that in the microstructure, phase α was observed with a fine-grained size dispersed on the background. These phases would contribute to increasing hardness and resistance against abrasion of the alloy.

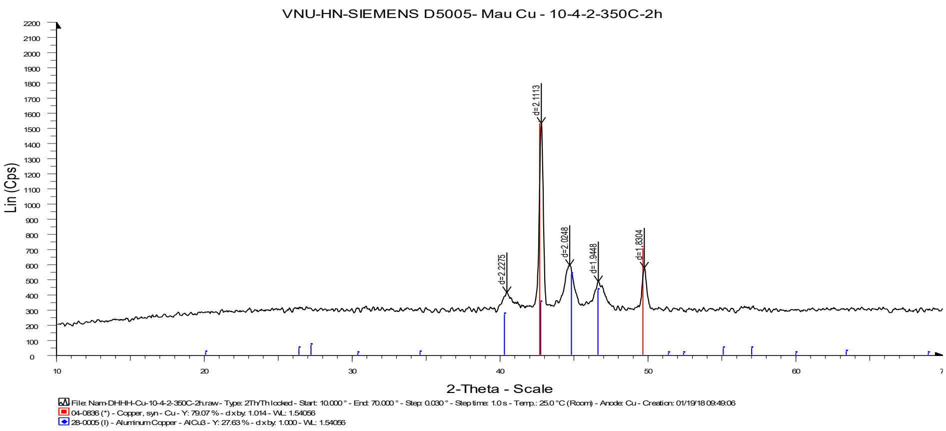
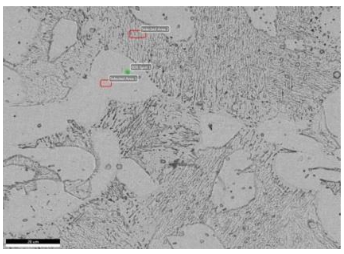



**Figure 8**: Xray of tempering



eZAF Smart Quant Results

| Element | Weight % | Atomic % | Error % | Net Int. | K Ratio | Z | R | A | F |
|---|---|---|---|---|---|---|---|---|---|
| Ni L | 5.29 | 5.14 | 5.64 | 30.71 | 0.0639 | 1.0308 | 1.0050 | 1.1745 | 0.9973 |
| Cu L | 83.23 | 74.77 | 3.22 | 401.61 | 0.7066 | 0.9613 | 1.0120 | 0.8679 | 0.9967 |
| Al K | 7.64 | 16.15 | 8.69 | 50.13 | 0.0425 | 1.1858 | 0.9066 | 0.4688 | 1.0018 |
| Fe K | 3.84 | 3.93 | 22.69 | 5.29 | 0.0434 | 1.0201 | 0.9958 | 0.9954 | 1.1111 |

**Figure 9**: EDS of quenching

EDS analysis showed the occurrence of intermetallic phases. These phases would contribute to increasing the hardness and resistance against abrasion of the alloy.

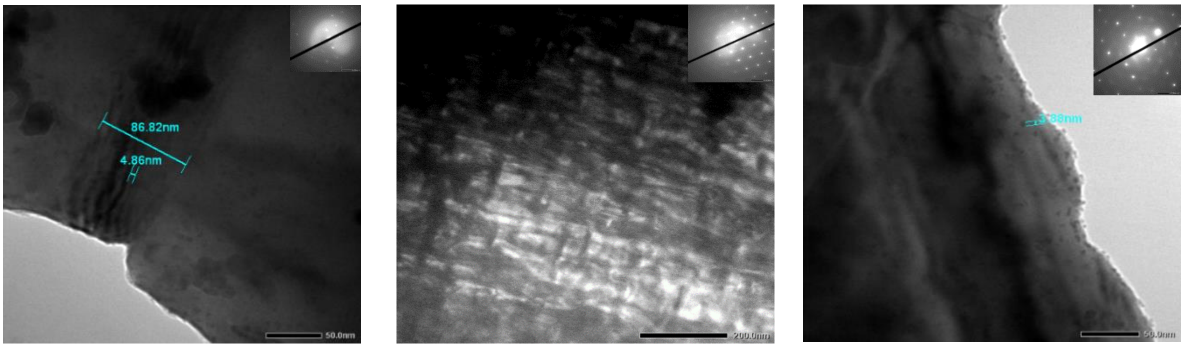


**Figure 10.** TEM and diffraction

TEM image analysis revealed the presence of fine-grained phases dispersed in the background. These phases increase the durability and wear resistance of the alloy.

The TEM image analysis after heat treatment showed that: When the heat treatment at the two-phase zone temperature occurs, Martensite is formed with two different forms of β 'and γ' (Fig. and b). In addition, after the framework ram obtained the synthesis of copper-rich solid solutions of the fcc network type and electronic compounds NiAl and $Fe_3Al$. NiAl is released on the boundary of martensite. In addition, after the ram, the $\gamma_2$ phase is smooth and dispersed

## 3.2 Mechanical properties

The results of hardness

**Table 2**: Hardness of this alloy

| | Hardness (HRB) |
|---|---|
| After casting | 95 |
| After quenching | 93 |
| After quenching and tempering | 105 |

Analyzing of the hardness value shows that after quenching and tempering process, the hardness of the alloy has the best value. After using the above processing, in the microstructure of this alloy, it has the phase of the metal which it dispersed; however, the microstructure has the fine phase $\gamma_2$. The α phase with small dispersion is increasing the hardness of the alloy. This also causes the mass loss is reduced than the molding state and quenching state

The results of mass loss

**Table 3**: Mass loss of this alloy

| | Mass loss (gram) |
|---|---|
| After casting | 0.1422 |
| After quenching | 0.1386 |
| After quenching and tempering | 0.1044 |

## 4 CONCLUSIONS

This paper presents the results of research and manufacture of fine copper alloys for use in fabrication of the ship shafts. The results show that aluminum alloys alloyed with 4% Fe and 2% Ni alloys and heat treated accordingly will increase the hardness (105HRB) and reduce the mass loss to 0.1044 in the same. a test condition.

The mechanical result is due to the fact that after the heat treatment of the sample with a small phase α; the martensite phase (with low hardness) combined with fine phase $\gamma_2$ and fine phase alloys NiAl and $Fe_3Al$ with high hardness, dispersive increase hardness and resistance to abrasion of the alloy.

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