

RELATIONSHIP BETWEEN MICROSTRUCTURE AND MECHANICAL
PROPERTY OF NICKEL-ALUMINUM BRONZE ALLOY SOLIDIFIED AT
DIFFERENT COOLING RATE AND HEAT TREATED

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*This thesis is dedicated to my beloved Husband
(Abdul Hakim Chow), my late Father (Razali Yahya)
Mother (Azizah Rosly), Family, and Friend*

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ABSTRACT

Nickel–Aluminium Bronze (NAB) is copper-based alloy, which widely used in marine applications because it provides high mechanical strength and low corrosion rates under turbulent flow conditions. Belongs to group of aluminium bronzes it contains 5–12 wt. % aluminium with additions of iron and nickel up to 6 wt. %. Presence of aluminium increases the mechanical properties of the alloy by the establishment of a face-centered cubic (FCC) phase that could improve the casting and hot working properties of the alloy. With the use of computer aided cooling curve thermal analysis (CA-CCTA) the phase transformation during casting can be revealed which can be done by the first derivation from the cooling curve data of the NAB alloy. This method is can be useful for designing the casting parameter of the NAB alloy in order to improve its mechanical property and obtained desired mechanical properties. In this research, the effect of cooling rate during solidification is demonstrated by using different mould during casting of NAB alloy whereby high cooling rate will produces finer grain as compare to slow cooling. Similarly, at higher cooling rate will result in higher hardness in comparison with the slower cooling rate. The mechanical properties of the as cast alloy will be further improved by applying heat treatment at temperature of 900 °C for two hours and water quenched followed by ageing at temperature of 350 °C - 400 °C for 1-3 hours and air cooled. Aged samples from ceramic mould attained highest hardness after aged at 350 °C for 3 hours and samples from permanent mould gave higher hardness after aged at 350 °C for one hours. Prolonged soaking time and increasing ageing temperature resulted in reducing hardness due to over aged.

ABSTRAK

Nikel-Aluminium Gangsa (NAB) adalah aloi yang berasaskan tembaga telah digunakan secara meluas dalam aplikasi marin kerana ia memberikan kekuatan mekanikal yang tinggi dan kadar kakisan yang rendah di bawah keadaan aliran laju. Ianya tergolong dalam kumpulan aluminium gangsa mengandungi antara 5-12 wt. % aluminium dengan penambahan besi dan nikel sehingga 6 wt. %. Kehadiran aluminium meningkatkan sifat-sifat mekanik aloi dengan fasa berpusat muka (FCC) yang boleh meningkatkan kerja panas aloi. Dengan menggunakan bantuan komputer, analisis terma lengkung penyejukan (CA-CCTA) boleh melihatkan pembentukan fasa semasa kaedah tuangan dilakukan. Kaedah ini berguna untuk merekabentuk parameter kaedah tuangan aloi bagi meningkatkan kekuatan mekanik aloi. Dalam kajian ini, kadar penyejukan semasa pemejalan di tunjukkan dengan menggunakan acuan yang berbeza bagi menghasilkan kadar penyejukan cepat yang menghasilkan bijirin yang lebih halus berbanding dengan penyejukan perlahan. Dan juga, pada kadar penyejukan yang lebih cepat akan menyebabkan kekerasan yang tinggi pada aloi berbanding dengan kadar penyejukan perlahan. Nilai mekanikal aloi ini boleh diperbaiki dengan menggunakan rawatan haba dengan sampel dari kadar penyejukan yang berbeza telah dirawat pada suhu 900 °C selama dua jam dan disejuk cepat dengan menggunakan medium air dan kemudian dirawat haba dengan suhu 350 °C -400 °C selama 1-3 jam. Sampel terawat haba dari acuan seramik mencapai kekerasan tertinggi selepas rawatan haba pada suhu 350 °C selama 3 jam dan sampel dari acuan kekal memberikan kekerasan yang lebih tinggi pada 350 °C selama satu jam. Masa rawatan haba yang berpanjangan dengan peningkatan suhu rawatan haba menyebabkan mengurangkan kekerasan pada aloi.

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LIST OF ABBREVIATION

NAB	Nickel Aluminium Bronze
XRD	X-Ray Diffractometer
EDX	Energy Dispersive X-ray Analysis
SEM	Scanning Electron Microscope
GDS	Glow Discharge Spectrometer
OM	Optical Microscopy
CA-CCTA	Computer-Aided Cooling Curve Thermal Analysis
FCC	Face-centered cubic
BCC	Body-centered cubic
Fe	Iron
Cu	Copper
Al	Aluminium
Si	Silicon
Ni	Nickel
Mn	Managanese

LIST OF SYMBOLS

B	-	Beta
A	-	Alpha
κ	-	Kappa
γ	-	Gamma
μm	-	Micrometer (micron)
$^{\circ}\text{C}$	-	Degree Celsius
T	-	Temperature
T	-	Time
Hv	-	Microhardness (Vickers)
>	-	Greater than

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CHAPTER 1

INTRODUCTION

1.1 Background

The phase transformation during solidification of cast Nickel-Aluminium Bronze (NAB) alloy can be revealed by using computer-aided cooling curve thermal analysis (CA-CCTA). The CA-CCTA method of analysis is more preferred since it is easier to use as well as low cost, faster, and simple. Moreover, the most important factor is its suitability for commercial applications in comparison with other thermal analysis techniques. Besides, it is suitable for investigating the non-equilibrium solidification for various industrial alloys [1, 2].

Currently, the usage of computer-aided cooling curve thermal analysis (CA-CCTA) is not being used extensively in determining the phase transformation during solidification of NAB alloys which is important to predict and control the rate of cooling and produce a better product especially in metal casting industries [3]. CA-CCTA technique also has been used for other alloys in order to obtain the desired microstructure and prediction of the phases transformed in solidification which lead to improvement of better mechanical properties of the alloys [4, 5].

By applying heat treatment to the as-cast NAB alloy, it can significantly further improve its mechanical properties [6]. Consequently, a combination of heat treatment and micro-hardness testing with detailed microstructural analysis of samples before and after heat treatment will be conducted.

1.2 Objectives of the Study

This project is intended to study on the relationship of the microstructure of Nickel-Aluminium Bronze (NAB) alloy solidified at different cooling rate with the use of different mould types and subsequent heat treatment by:

- i. Evaluation on the effect of cooling rate on microstructure
- ii. To establish the relationship between microstructure and the hardness.

1.3 Problems Statement of the Research

Microstructures of the NAB alloy can be varied by different cooling rate during casting as well as after heat treatment. Then, those variations in microstructures are expected to affect the mechanical property of the NAB alloy. Therefore, by applying good prediction method on the phase development and transformation during solidification of the alloy can be useful in order to attain the desire microstructure through controlling the cooling rate.

The heat treatment process will improve the mechanical property but also it may provide poor result and later reduce the alloy performance in service. Therefore, selection of the correct heat treatment process is vital in order to have the NAB alloy with better mechanical properties.

1.4 Scope of the Study

- i. To prepare casting of Nickel-Aluminium Bronze by using the electrical induction furnace and let to solidify by ceramic and permanent mould.
- ii. To apply the computer-aided cooling curve thermal analysis (CA-CCTA) during solidification of the NAB alloy.

- iii. To conduct heat treatment processes on the material; solution treatment at 850 °C (2 hours) followed by ageing at 350 °C – 400 °C (1 – 3 hours)
- iv. To conduct hardness test on material before and after heat treatment.
- v. To study and analyse the microstructural of the Nickel-Aluminium Bronze by using optical microscope (OM), SEM and EDX as well as XRD.

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