THE EFFECT OF AGING TREATMENT ON THE MICROSTRUCTURE AND THERMODYNAMIC PARAMETERS OF CuAlNi -Mn SHAPE MEMORY ALLOYS (SMAs)

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ABSTRACT

This thesis presents the effect of heat treatment on the microstructure and thermodynamic parameters of CuAlNi -Mn SMA. The effects of different aging temperatures of 300°C, 400°C and 500°C at various aging times were evaluated using the optical microscopy, FESEM and the XRD, to investigate their microstructure and phase transformation. The martensite and austenite transformation temperatures of CuAlNi -Mn SMA have been determined by the differential scanning calorimetry (DSC), while the hardness property using Vickers hardness. The variation of the structure and properties of alloy were influenced by the morphology and the type of the phases obtained. The observation revealed that the grain size and the grain boundary of CuAlNi -Mn SMA increase with increasing the aging temperatures and aging times. Due to this, the values of Vickers hardness were observed to decrease at elevated temperatures and prolonged aging times. On the other hand, the changes of thermodynamic parameters were observed with regard to the variation of aging temperatures and aging time. The enthalpy and entropy were observed increase with increasing the aging temperatures and aging times.

ABSTRAK

Tesis ini membentangkan kesan rawatan haba ke atas mikrostruktur dan parameter termodinamik untuk aloi memori bentuk CuAlNi -Mn. Kesan–kesan suhu penuaan yang berbeza iaitu 300˚C, 400˚ dan 500˚C pada pelbagai masa penuaan dinilai dengan mikroskop optik, FESEM dan XRD, untuk menyiasat mikrostruktur dan perjelmaan fasa. Suhu penjelmaan fasa austenite dan martensit aloi memori bentuk CuAlNi -Mn ditentukan menggunakan alat DSC, manakala sifat kekerasan menggunakan alat kekerasan Vickers. Kepelbagaian struktur dan sifat aloi ini dipengaruhi oleh morfologi dan jenis fasa yang di hasilkan. Pemerhatian menunjukkan saiz bijian dan sempadan bijian CuAlNi -Mn meningkat dengan peningkatan suhu dan masa penuaan. Ini menyebabkan kekerasan diperhatikan menurun dengan peningkatan suhu dan masa penuaan. Disamping itu, parameter termodinamik turut berubah dengan perubahan suhu dan masa penuaan. Entalpi dan entropi diperhatikan meningkat dengan peningkatan suhu dan masa penuaan.

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CHAPTER 1

INTRODUCTION

1.1 Background

Shape memory alloys (SMAs) are one of the unique classes of smart materials, which have the ability to recover their shape when the temperature is applied. Shape memory alloys (SMAs) can absorb and dissipated the mechanical energy by undergoing a reversible hysteresis shape change when subjected to applied mechanical cyclic load. These unique characteristics of shape memory alloys (SMAs) have made them more suitable to be used of sensing and actuation, impact absorption and vibration, damping applications. Moreover, the functional characteristic of shape memory alloys (SMAs) is largely related to the thermoelastic martensitic transformation, which generally occurs in the 173-473 K temperature range, depending on the alloy composition and heat treatment. These properties are significantly affected by the mobile nature of the interfaces (twin boundaries, martensitic variants, parent/martensite phase boundaries). Among the several alloy systems that exhibit shape memory characteristics, Cu-based SMAs have received a considerable attention because of their high thermal stability. One of the most important Cu-based shape memory alloys are the Cu–Al–Ni, whereas it has a high transformation temperature comparing with other shape memory alloys, that made it more suitable for works for high temperature applications. There are several literatures and experimental works related to these alloys, whereas they showed that there are two main parameters are mostly affected on the phase transformation behavior, they are the addition of alloying elements and aging treatment. Aging treatment is mainly time- temperature dependent, which can control the redistribution of the materials atoms into the phase structure. The variation of aging times or aging temperatures can cause into the variation microstructure and phases. For the CuAlNi -Mn system, three stages of aging process have been described. In the first stage, the transformation characteristics remain generally stable; sometimes a slight decrease of the transformation temperatures is shown. In the second stage, the transformation temperatures increase whereas progressive deterioration of the shape memory occurs in the third stage hysteresis.

Therefore, the aim of the project is to study the effect of aging treatment on the microstructure and thermodynamic parameter variations of CuAlNi -Mn shape memory alloys (SMAs) at different aging temperatures and aging times.

1.2 Problem Statement

CuAlNi shape memory alloys are loss prone to the stability of the obtaining phase due to the high brittleness that may related to the type and structure of the this phase, that may obtain a limit by the applications of these alloys. To overcome these problems alloying elements have been added to adjust the phase diagram and improve the mechanical properties. This project will concern on finding the changes of the microstructure and thermodynamic parameter of the CuAlNi -Mn SMAs that can cause by varying the aging treatment parameters, such as aging times and aging temperatures.

1.3 Objectives

The project work aimed to fulfill the following objectives:

- To examine the microstructure and phase variations of CuAlNiMn (SMAs) after various aging treatment processes.
- To investigate the effect of different aging treatment temperature and time on the thermodynamic parameters of the obtained phase.

1.4 Scope

- Apply different aging treatment process with varying the aging time and aging temperature (300, 400, and 500) ^{o}C for (1, 2, 3, 4, and 5) hrs.
- Use the optical microscope (OM) and scanning electron microscope (SEM) to investigate the effect of aging treatment on microstructure of CuAlNi -Mn Shape memory alloys.
- Use the X-Ray Diffraction (XRD) for obtaining the phase transformation variation after the aging treatments are applied.
- Use the Differential Scanning Calorimetry (DSC) to determine the variation of transformation temperature during the aging treatment (M_s, M_f, A_s, and A_f).
- Use the theoretical calculation to measure the thermodynamic parameters of CuAlNi -Mn SMA under different aging treatment.

1.5 Thesis Organization

This thesis comprises of six chapters. The first chapter is the Introduction. It describes the background of the problem included problem statement, project objectives and project scope. Chapter 2 focuses on Literature Reviews. This chapter highlights the background knowledge on the Shape Memory Alloys (SMAs), Common properties, Classification and application of Shape Memory Alloys (SMAs), and the effect of aging treatment on microstructure ana thermodynamic parameter of CuAlNi and CuAlNi -Mn SMAs. Chapter 3 describes the Methodology used to carry out this project and method to analyze experimental results. Chapter 4 discusses the results that will obtain by X-ray Diffraction, Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Differential Scanning Calorimetry (DSC) and Vickers Hardness Test. Chapter 5 presents the conclusion.

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