Effect of Aging Time on Phase Transformation Temperature in NiTi Shape Memory Alloys

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Abstract

The development, production or diversification of existing materials constitute the common working area of the engineers to meet the increasing living standards. Shape memory alloys, which are capable of returning to their former form after being subjected to a specific heat treatment, are one of these materials. These materials which have the effect of shape memory are widely used in the industry. Orthodontic braces, stents used in vascular occlusion, orthopedic fasteners, damping elements, spacecraft, robot, and actuator technology, etc. are located in very wide application areas. The shape memory alloys, which can be deformed at low temperatures and return to their pre-deformation shapes when exposed to higher temperatures, are the special form of the phase transformation known as the martensitic phase transformation. NiTi alloys are the most attractive alloy systems in scientific and commercial fields with their general features such as highly recoverable strain and high corrosion resistance. The inclusion of elements in different proportions of this alloy system is important for strengthening the alloy. In addition, it can increase the performance of NiTi shape memory alloy in applied heat treatments. Based on this feature of shape memory alloys, the effect of aging time on NiTi shape memory alloy was investigated.

Keywords: Shape memory alloys, DSC, Aging, Martensitic Transformation

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Introduction

Nowadays, technology is developing rapidly in the face of increasing needs. Rapidly advancing technology comes with new generation materials. In order to meet the endless needs of human beings, scientists are constantly working in this direction. Many different materials are used in industrial and daily applications such as ceramic, glass, polymer, metal and alloy. Different types of materials can do the same material, but in some cases only one type of material may be required due to insufficient properties. In addition to the physical properties of the materials, different types of materials with different functionality have been developed. One of the most functional structures among smart metals is the shape memory alloy (SMA). SMAs are described by the ability of the material to return to its original shape by heating, usually after severe deformations at relatively low temperatures [1].

When it was first discovered, Au-Cd is now divided into three main groups: NiTi, Fe and Cu. In parallel with the development of technology, the development of the production methods of copper and nickel based alloys has improved the physical and mechanical properties of the alloys, making them more usable in the industrial field. These alloys have been classified as advanced technology materials especially in the last 20 years [2, 3].

Shape memory alloys are used in the medical field (orthodontic braces, instruments used in endodontic applications, stents used for non-surgical treatment of vascular occlusions, orthopedic fasteners), micro-electro- has found wide application possibilities in mechanical systems [4].

Martensite transformation is to obtain the martensite phase in metal and alloys by applying the effects such as external temperature and difficult to the material separately or both effects simultaneously. The most important feature of the martensite phase transformation is that it takes place without diffusion. Therefore, the neighborhoods of the atoms in the martensite phase are preserved after the transformation [5].

The shape memory effect (SME) is effected by the solid state phase transformation without diffusion in the material. These phase transformations are generally provided by temperature or magnetic action between the phases known as austenit and martensite. In the alloys, the crystalline structure of the austenite phase in the solid state is transformed to martensite phase by external effects such as temperature [5]. In the shape memory alloys, the transformation of the martensite phase to austenite phase is described as a thermodynamic cycle and generally exhibits a reversible structure. During the transformation between phases, the release of chemical free energy creates the driving force under the shape memory effect. This force occurs the shape memory effect. The location of the atoms during the phase transformation, although the amount of displacement is very small, this movement is made in the same direction as a collective movement on the material causes large scale deformation. Crystal structure change in alloy provides high quality properties such as shape memory effect and superelasticity [6, 7].

The martensite phase transformation occurs by rapidly reducing the temperature of the material or by applying an externally difficult or both to the austenite structure at the same time. If the crystal structure is cooled rapidly from this temperature, after a critical temperature (M_s), the martensite structure forms in the austenite structure. The temperature at which the martensite structure begins to form is called the martensite start temperature and is indicated by M_s. The externally applied mechanical difficulty also increases the volume of the formed product. The martensite transformation starting at the temperature M_s continues and stops within a certain temperature range. The temperature at which the transformation finishes is called the martensite transformation finish temperature and is indicated by (M_f). The temperature at which the austenite phase starts is called the austenite phase start temperature and is indicated by (A_s). The temperature at which the austenite phase is completed is called the austenite phase finish temperature and is indicated by (A_f). Here, the martensite phase transformation temperature (M_s) can take different values depending on the type of alloy [8].

DSC analysis is performed to determine how the heat capacity in materials changes against temperature. In this way, phase changes analysis can be made on the material. A typical DSC curve and a graph showing the phase start and finish of the peaks in this curve is shown in Figure 1 [9].

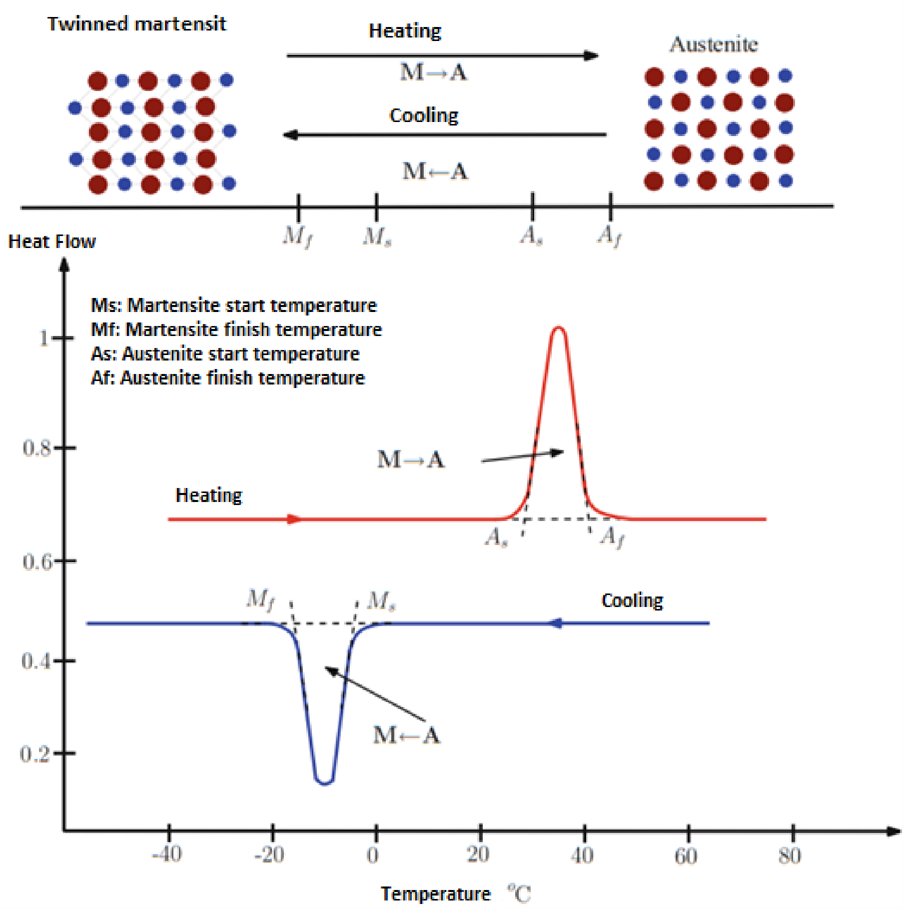

Figure 1. Martensitic transformation DSC curve [9]

In this study, the effect of aging process applied to Nickel-Titanium alloy at the same temperatures and at different times on phase transformation temperatures was investigated based on these properties of shape memory alloys.

Experimental Details

The 1 mm thick NiTi shape memory alloy whose chemical composition is given in Table 1 is divided into four equal samples (NiTi0 -NiTi1 - NiTi2 - NiTi3 - NiTi4) with a length of 6 mm. NiTi0 is an untreated reference sample. The chemical composition of the samples was determined on the EDS. Aging process was applied to the samples at the temperature values and times given in Table 2. Then DSC (differential scanning calorimetry) analysis of the samples were performed. In this technique, the heat flow generated by heating and cooling the mass is monitored. In this way, phase changes analysis can be made on the material. The DSC results of the samples at a running speed of 35 °C / min are shown in Table 3.

Table 1. NiTi chemical composition

	At.%	**Wt.%**
Nickel	46.84	51.93
Titanium	53.16	48.07

Table 2. Heat treatments applied to samples

	Temperature	**Time**
NiTi0	-	-
NiTi1	300°C	1h
NiTi2	300°C	2h
NiTi3	300°C	3h
NiTi4	300°C	4h

Table 3. DSC results at 35 °C / min operating speed

	A_s (°C)	**A_f (°C)**	**M_s (°C)**	**M_f (°C)**
NiTi0	57.52	75.01	36.42	30.26
NiTi1	58.89	86.57	37.36	30.21
NiTi2	64.82	88.55	38.27	32.24
NiTi3	63.05	86.21	36.70	30.43
NiTi4	63.28	89.32	36.43	29.71

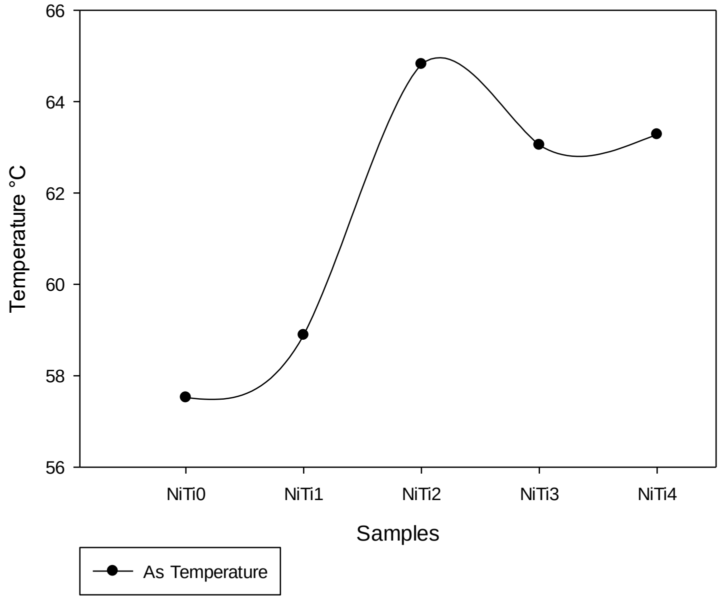

Figure 2. A_s change of transformation temperatures

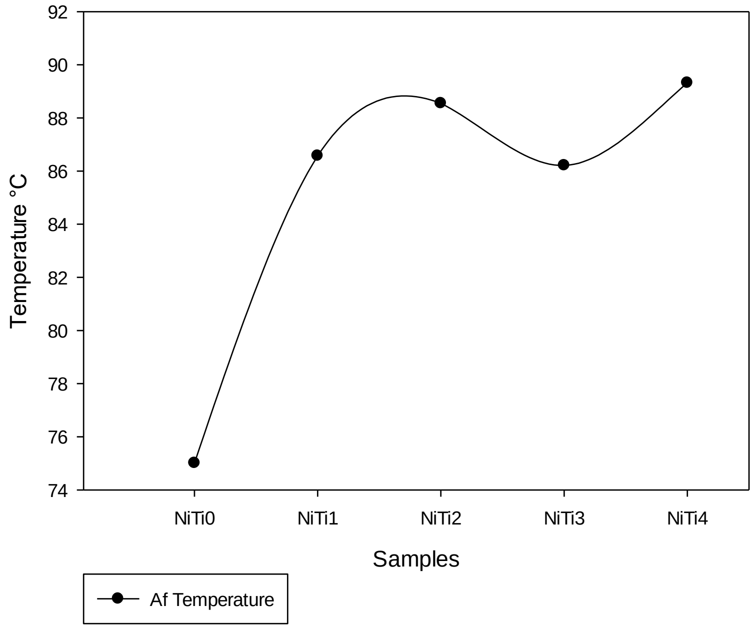

Figure 3. A_f change of transformation temperatures

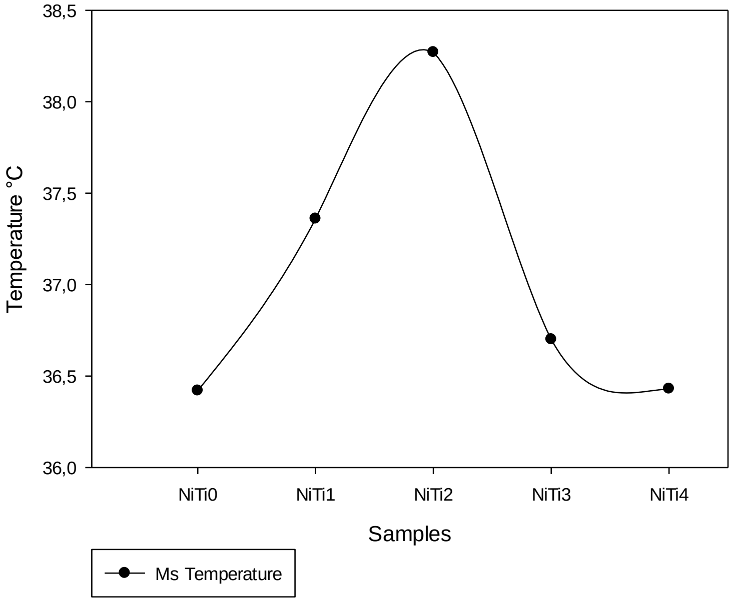

Figure 4. M_s change of transformation temperatures

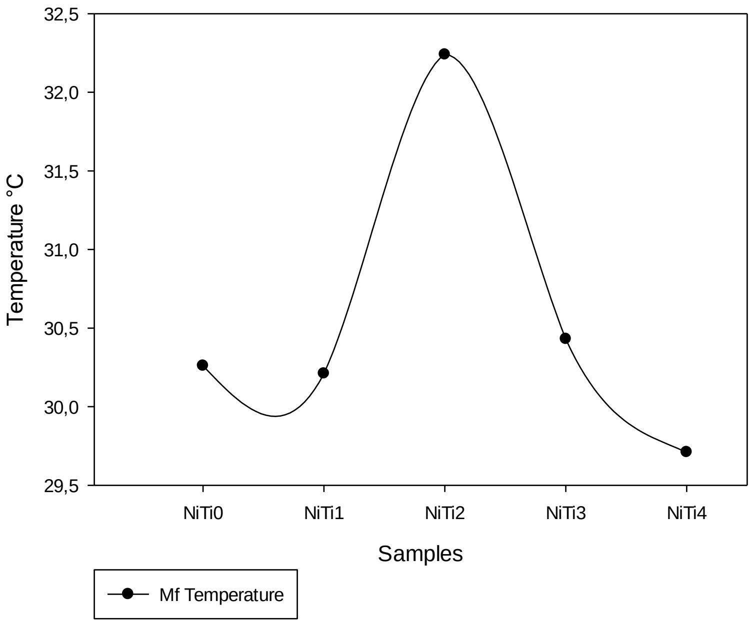

Figure 5. M_f change of transformation temperatures

Conclusions

Shape memory alloys widely used in many industries with any various circumstance. The different medium conditions can be applied for in applications and that can be structural shifts. That aging affects material properties and purpose of the device can show deviation. So the all possibilities should be considering and design should be lack of any failure. So in this study NiTi polycrystalline wire alloy were investigated under with different aging operations. Experimental conducted at 300°C for four dwell times. The results were shown that the alloy was performed max Δ 14.31°C - min Δ 1.85°C in Ms, Mf, As and Af transformation temperatures. That an important result for that experimental because of effective differences between aged and reference sample.

Acknowledgements

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