Influence of Compositions of Sintered Ti-Ni Alloys on their Thermo-mechanical Properties

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Abstract

This paper presents the influence of the compositions of sintered Ti-Ni alloys on their thermo-mechanical properties. The Ti-Ni alloys having various compositions from 50at%Ni to 51at%Ni were sintered using elemental Ti and Ni powders by a pulse-current pressure sintering equipment. The deformation resistance in stress-strain curves increased with an increase in Ni content. In the case of Ti-50at%Ni, tensile strength and elongation were more than 500 MPa and 7%, respectively. The increase in Ni content also makes the transformation temperatures lower. The deformation resistance at a test temperature change from 293K and 353K in isothermal tensile test increased with elevating test temperature.

Keywords : Shape memory alloy, Ti-Ni alloy, pulse-current pressure sintering, tensile strength, recovery stress

1. Introduction

Ti-Ni alloys having superior shape memory characeritics are widely applied to various functional materials. It is, however, difficult to change the ompositions of the alloy in casting process. On the ther hand, powder metallurgy process has some dvantages such as ease in controlling composition of the alloy. The authors [1-2] have investigated the abrication of Ti-Ni shape memory alloy by a pulse-current pressure sintering method using elemental owders. The Ti-50.2at%Ni sintered alloy that having uperior shape memory characteristics could be fabricated, but the influence of the compositions of sintered alloy on their shape memory characteristics has been scarcely investigated in detail.

In this research, we investigated the influence of the compositions of sintered Ti-Ni alloys on their thermo-mechanical properties.

2. Experimental and Results

Gas-atomized Ti powder and carbonyl Ni powder were used in this research. Table 1 shows the mean particle diameters and chemical compositions of these powders. These powders were mixed and blended well by a ball-mill at 200 rpm for 0.6 ks in the compositions of Ti-x at%Ni (x=50.0, 50.4, 50.8 and 51.0). The mixture was filled into a graphite die set and sintered by a pulse-current pressure sintering equipment. The sintering was performed in a vacuum at a sintering temperature of 1113 K and 1143 K for 1.8 ks under loading of 33.5 MPa. And then, the solution treatment was performed in vacuum at 1273 K for 43.2 ks. The shape memory treatment was carried out after this treatment at 773 K for 3.5 ks.

Measurement of density by the Archimedes method, observation of microstructure by an optical microscope and a SEM, XRD measurement, DSC measurement and EDX analysis were performed. The tensile test and the isothermal tensile test were carried out by a tensile testing machine.

Table 1. Mean particle diameters and chemical compositions of Ti and Ni powders

Powder		Mean particle diameter(μm)	Chemical composition (mass%)				
			Fe	O	N	H	C
Ti	Gas-atomized	24	0.039	0.110	0.006	0.003	0.008
Ni	Carbonyl	6	0.003	0.069	-	-	0.078

3. Results and Discussions

At first, we examined the fabrication conditions of the powders of various compositions and then investigated the fabrication conditions of the sintered compacts. As a result, the relative density of the as sintered compacts and shape memory compacts of various compositions were more than 97% and 95%, respectively. The microstructures of the shape memory treated compacts were fairly homogeneous.

Figure 1 shows the changes in transformation temperatures of the shape memory treated compact measured by a DSC with Ni content. The peak reverse transformation temperature of A^* is much higher than that of the wrought alloy of the same composition, but the peak martensite transformation temperature of M^* are higher than that of the wrought alloy in a higher Ni content range. The

A^* lowers with increasing Ni content, while the M^* scarcely change with Ni content.

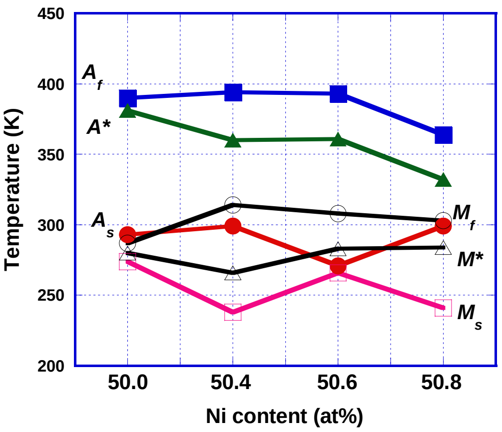

Fig. 1. Changes in transformation temperatures of the shape memory treated compacts with Ni content.

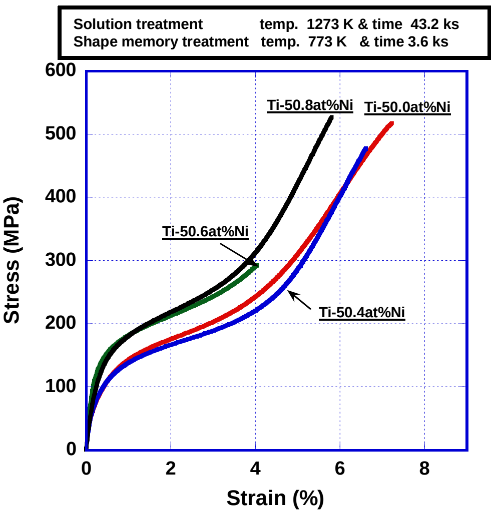

Fig. 2. Stress-strain curves of tensile tests of the compacts.

Figure 2 shows the stress-strain curves of the shape memory treated compacts of various Ni contents. The yielding behavior due to the stress-induced martensitic transformation is clearly observed at any Ni contents. The tensile strength and elongation of the shape memory treated compacts of the 50.0at%Ni and 50.4 at%Ni are approximately 500 MPa and 7%, respectively. The tensile strength and elongation of the shape memory treated compact of the 50.8at%Ni is approximately 500 MPa and 6%, respectively. But the deformation resistance of the compact of higher Ni content is greater than that of the compact of lower Ni content because the transformation temperature of the former is lower than that of the latter.

In order to design the shape memory elements, it is important to investigate the thermo-mechanical properties of the shape memory alloy. The isothermal tensile test was carried out by loading up to about 2% strain at various temperatures and then by unloading completely. Figure 3 shows the results of isothermal tensile tests of the shape memory treated compacts of 50.0at%Ni and 50.6at%Ni. The deformation resistance increases with elevating test temperature. In the case of 50.6at%Ni, the maximum stress is over 500 MPa at a test temperature of 353 K.

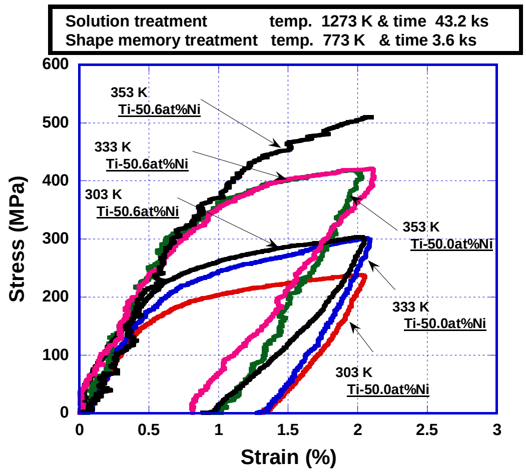

Fig. 3. Results of isothermal tensile tests of the compacts.

4. Summary

In this research, we investigated the influence of thecompositions of sintered Ti-Ni alloys on their thermo-mechanical proerties. The results obtained are as follows:

(1) The change in Ni content scarcely affects the relative density and microstructure of the compacts.

(2) The increase in Ni content makes the reverse transformation temperature lower.

(3) The increase in Ni content makes the deformation resistance of the shape memory treated compact greater.

(4) The shape memory effect could be observed in the shape memory treated compact of any Ni contents.

5. References

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