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Characteristics and Application of Ti-Ni Leaf-Spring Actuator

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Ti-Ni shape memory actuators are commonly used in wire shape. On the other hand, no applications were made in the form of leaf-spring. The purpose of the present study is to use Ti-Ni leaf-spring actuator to construct robot arms to examine their actuation and clarify the shape memory characteristics. In this experiment, the leaf spring actuators were made of Ti-Ni thin plates with a thickness of 0.5 mm, the sample composition was Ti-49.8at% Ni, and they were heat-treated at 673 K for 3.6 ks. Transformation temperatures were determined using DSC, and the stress-strain curves were obtained by bending test using a tensile test machine. The robot arm was made by using this actuator. The time to shutting of the finger of the robot is five seconds.

Key words: Ti-Ni alloy, Shape memory alloy, Leaf-spring, Robot arm

1. INTRODUCTION

Among the known shape memory alloys, Ti-Ni has the best shape memory properties. This alloy is widely used in the form of wire, but no applications were made in the form of leaf-spring. The motor is used in general for the entertainment robot. The actuator without driving sound is necessary to model more genuine the entertainment robot. The shape memory alloy is an actuator without driving sound, and it is possible such field to apply it. The present author have investigated shape memory characteristics of Ti-Ni thin plates [1]-[3]. The purpose of the present study is to clarify shape memory characteristics of Ti-Ni rolling thin plate and use a Ti-Ni leaf-spring actuator for actuation of robot arms.

2. EXPERIMENTAL

Ti-49.8at%Ni thin plate made by Daido Steel was used in this research. These specimens were heat-treated at 673K for 3.6ks, followed by quenching in water. The plate was spark cut into squares of 3X3mm^2 for DSC and rectangles of 5mm wide and 40mm long for bending tests. The shape memory characteristics of the leaf spring is measured by the bending test. The maximum generation power of one leaf actuator is 17N. The robot arm has three fingers. Joints are arranged in two places of each finger. Two board spring actuators are set in each joint and shape of actuators is memorized in the opposite direction respectively. The time to fingers shutting is five seconds. This operation speed is applied level. The maximum weight this robot arm can grip is 110g. Shape memory behavior was measured by the bending test under constant temperature.

3. RESULTS AND DISCUSSION

Figure 1 shows the DSC curves during cooling and heating. In the specimen, a two-stage transformation from B2(parent)-phase to R(rhombohedral)-phase to M(martensitic)-phase appeared upon cooling, while only a single-stage transformation from M-phase to B2 appeared upon heating.

The transformation temperatures of the Ti-49.8at%Ni thin plates used are shown in Table 1. The martensitic transformation starts at *Ms* and finishes at *Mf* from B2

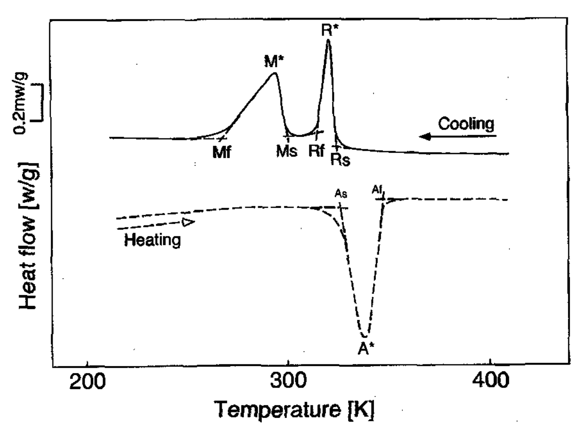


Fig1. Differential scanning calorimetry curves of Ti-49.8at%Ni plate.

Table 1. Transformation temperature of Ti-49.8at%Ni,(K)

Rs	*R**	*Rf*	*Ms*	*M**	*Mf*	*As*	*A**	*Af*
324.5	321.1	315.0	300.3	294.3	267.6	326.3	337.8	347.5

to M-phase upon cooling, while the reverse martensitic transformation starts at *As* and finishes at *Af* from M-phase to B2 upon heating; *M** and *A** stand for the peak temperatures measured by DSC upon cooling and heating, respectively. The R-phase transformation starts at *Rs* and finishes at *Rf* upon cooling only *R** being the peak temperature measured by DSC upon cooling. This sample is martensite phase at room temperature and it transforms into the parent phase at higher temperature.

Figure 2 shows the displacement-strain curves based on the data obtained from bending test at 325K and 366K respectively. The solid line is 366K and the dotted line is 325K. In 366K, the curve shows the

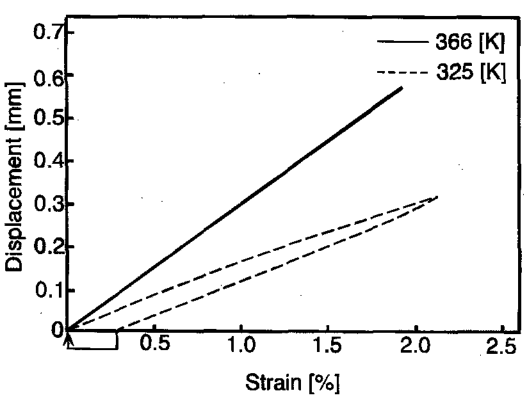


Fig 2. Displacement-strain curves of Ti-49.8at%Ni plates at 325K and 366K.

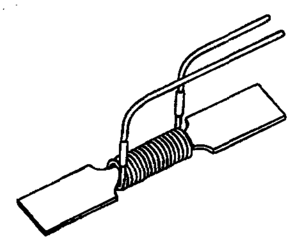
same D-S curves as the elastic deformation during loading and unloading. However, the 325K curve shows the hysteresis.

Figure 3 shows the outline of the actuator. The actuator is rectangular in shape, with a thickness of 0.5mm. To coil the Nichrome wire around, the small parts in the center of long sides are cut out. This actuator moves by applying current to the Nichrome wire. This actuator is memorized in bended shape. In the martensite phase, it is flat in shape. The maximum strain of this actuator is 3.3% and it generates a power of 17N.

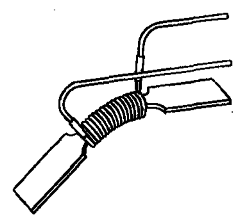
Figure 4 shows the illustration in the finger part of the robot arm. The robot arm has two joints. Each joint has two actuators. The actuator moves by applying the current to the Nichrome wire. The finger of the robot opens and shuts with this mechanism.

Figure 5 shows the illustration of the robot arm. The finger is made from on acrylic fiber. The actuator is arranged in the joint of the finger. The finger is shut by applying the current to the Nichrome wire. The robot arm has three fingers, and the object is gripped by this robot.

Figure 6 shows the operation of the robot arm. The open



(a) Martensite-phase



(b) Parent-phase

Fig 3. Ti-Ni leaf-spring actuator

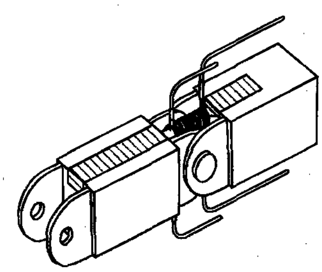


Fig 4(a). Finger in straight shape

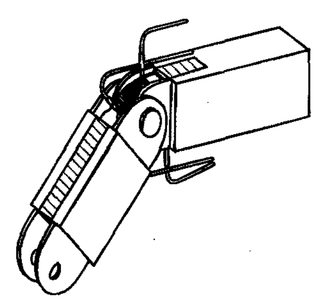


Fig 4(b). Finger in bent shape

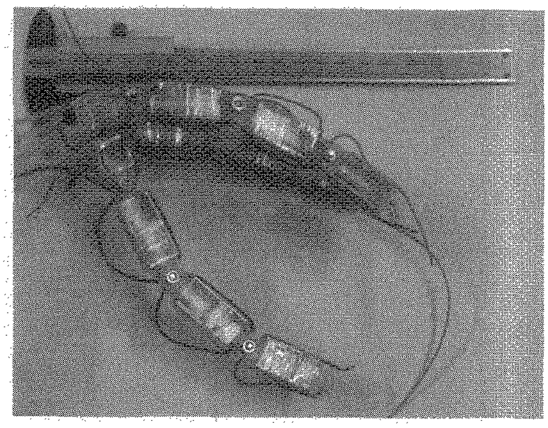


Fig.5 Illustration of the robot arm

shape is shown in figure 6(a) and the grip shape is shown in figure6 (b). When all inside actuators bend, this robot can grip the object. The finger opens when all outside actuators bend. This robot can grip the object in five seconds. Driving voltage of robot is 4V and driving current is 2.1A. The power generated by one finger is 2.2N. The maximum weight that this robot can grip 110g.

4. CONCLUSIONS

The leaf spring actuators were made by using Ti-Ni rolled thin plate. The robot arm was made by using this actuator. The time to shutting of the finger of the robot arm was five sec. The power generated by one finger is 2.2N, and the maximum weight that this robot can grip is 110g.

5. REFERENCES

[1] K.Kitamura, S. Miyazaki and M. Kohl, Proc. of Inter. Conf. on New Actuators, Bremen, Germany, 401-4 (1996).

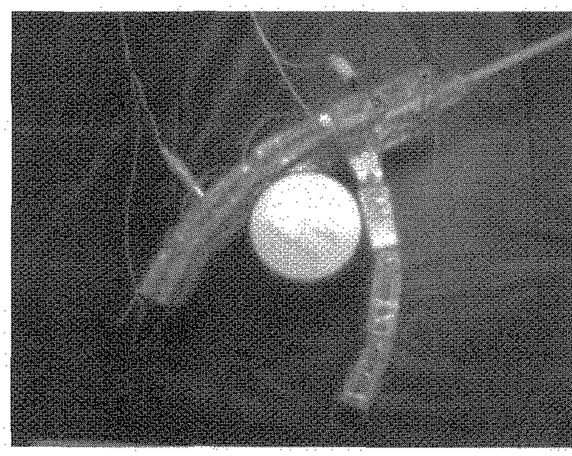


Fig 6(a). Robot in shape to open

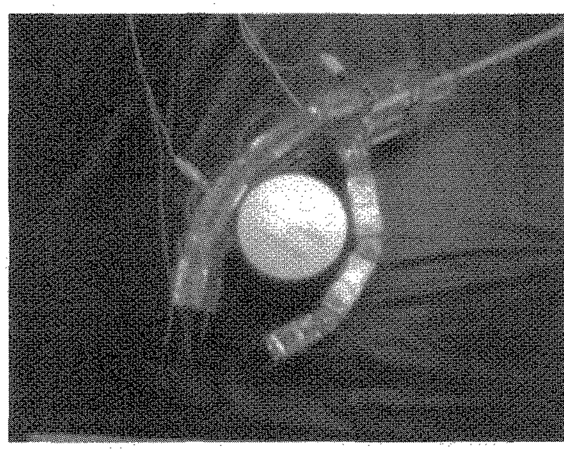


Fig 6(b). Robot in shape to grip

[2] K.Kitamura, S. Miyazaki H. Iwai and M. Kohl Proc. of Inter. Conf. on Shape Memory and Superelastic Technologies, Asilomar, U.S.A.,
[3] K.Kitamura, S. Miyazaki, H. Iwai, M. Kohl Materils Science and Engineering, A273-275, 758-62, (1999).

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