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DESIGN OF ROTARY DRIVING ACTUATOR BY USING TORSIONAL DEFORMATION OF SMA TAPES

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1. Introduction

One of the main materials which have activated the research on the smart materials is shape memory alloy (SMA). The main characteristics of SMA are the shape memory effect (SME) and superelasticity (SE). In a recent study using the torsional deformation of a TiNi SMA tube, twist in the blades of rotary aircraft was investigated in order to improve the flight performance. In practical applications making use of SMA tapes, torsional deformation can be obtained simply by gripping both ends without any mechanical process. In the present study, in order to develop the rotary driving actuators of SMA tapes, the torsional deformation properties of TiNi SMA tapes are investigated. The graphical method to design the two-way rotary driving actuator by using torsional deformation of SMA tapes is proposed.

2. Torsional deformation properties of SMA tapes

The torsional testing device for SMA tapes was developed and mounted in the tension test machine. Toque was obtained by measuring the twisting force. Torsional angle was obtained by measuring the circumferential displacement. The relationship between torque and angle of twist per unit length of a TiNi SMA tape at various temperatures T are shown in Fig. 1. In the case of 293 K, the residual angle appears after unloading, which disappears by heating under no load, showing the SME. In the case of 343 K, the partial SE is observed. In the case of 373 K, the torsional angle disappears during unloading, showing the SE. The relationship between torque and angle of twist per unit length of a TiNi superelastic alloy (SEA) tape at 293 K is shown in Fig. 2. In the case of SEA tape, the torsional angle disappears during unloading, showing the SE at room temperature.

3. Design of bias-type two-way rotary element by using SMA tapes

The most widely used two-way SMA element driven by heating and cooling is the bias-type. In the case of bias-type element using the torsional deformation of tapes, the SMA tape and SEA tape are arranged in series. The flat plane was shape-memorized in both tapes. In the case of low temperature for SMA tape, torque of SEA tape is higher. The recovery torque of SMA tape increases at high temperature. The element is therefore automatically twisted in two directions by heating and cooling. The design chart of bias-type two-way twisting element is shown in Fig. 3. The SMA tape is mounted in the unloaded state after twisting at an angle of 180^o. The SEA tape is mounted in the flat plane. The recovery torque appears due to the reverse transformation in the SMA tape by heating. The torque due to the reverse transformation during unloading corresponds to the recovery torque. The loading curve and unloading one of SMA tape at each temperature are therefore shown by the dashed line and solid one in Fig. 3, respectively. The loading curve of SEA tape is drawn from the origin at the unloaded point U after twisting to the point M for SMA tape at 293 K in Fig. 3. The recovery angles of twist per unit length $\theta_r - \theta_1$ and $\theta_r - \theta_2$ are obtained corresponding to the points H_1 and H_2 at each heating temperature of 343 K and 373 K, respectively. The relationship between rotational angle per unit length and temperature obtained by the test is shown in Fig. 4. The recovery angle can be estimated by this method.

4. Automatically opening and closing blind driven by sun light

The bias-type two-way rotary element by using SMA tape and SEA tape is applied to the automatically opening and closing blind model driven by sun light. The photograph of opened and closed states of solar-powered blind is shown in Fig. 5. If the twisted SMA tape is sun-lighted, the tape recovers the original flat plane, resulting in closing the blind. If the SMA tape is shaded, the twisted SEA tape recovers the original flat plane, resulting in opening the blind.

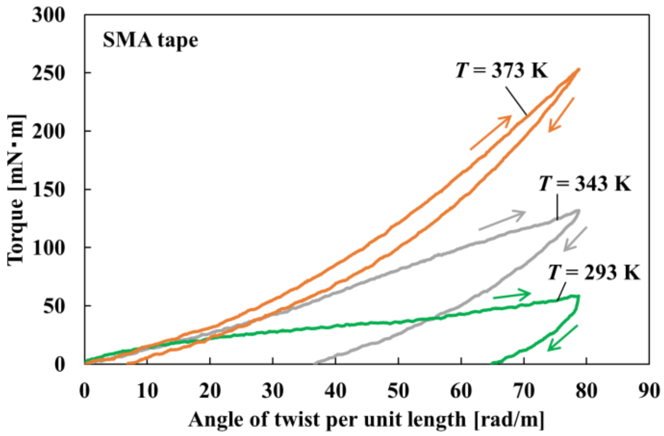

Fig. 1 Torsional deformation of SMA tape at various temperatures T

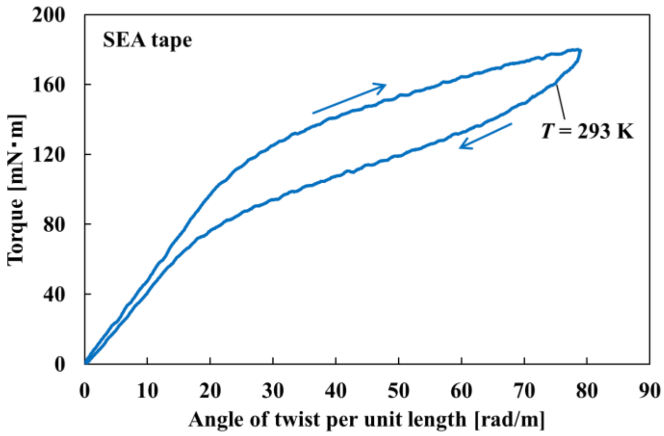

Fig. 2 Torsional deformation of SEA tape at T = 293 K

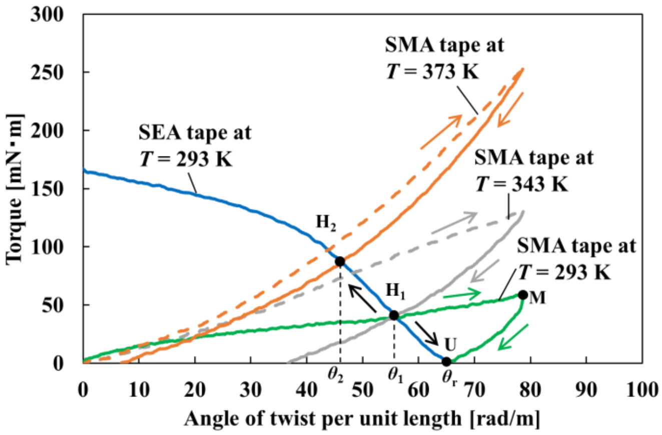

Fig. 3 Design chart of bias-type two-way twisting device

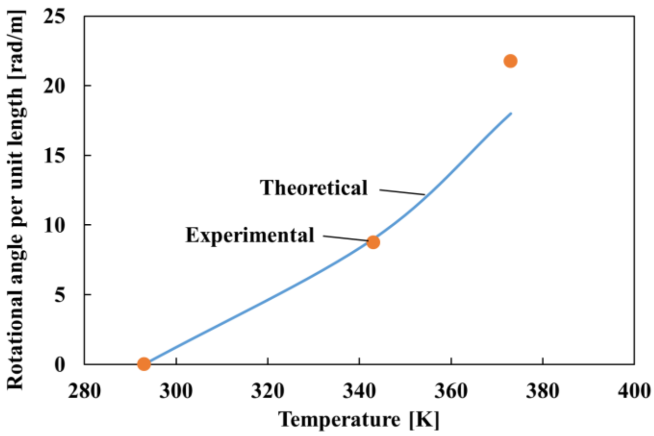

Fig. 4 Relationship between rotational angle per unit length and temperature

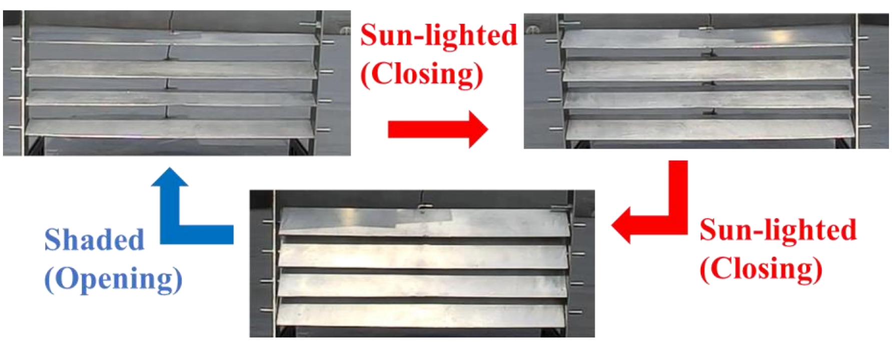

Fig. 5 Photograph of opened and closed states of solar-powered blind