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A new drive system using a shape memory alloy (SMA) heat engine and its applications

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A new drive system using a shape memory alloy(SMA) wire is introduced. A SMA heat engine of the system is drived by the shape recovery force of SMA wire. Two mechanism, a reversal rotation system and SMA wire winding of the engine is developed newly. Finally it is applied to mobile displays and a car.

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1. Introduction

A new drive system using a shape memory alloy(SMA) wire is introduced in this paper. The system is designed for a heat engine with the shape recovery force of SMA wire. A loop of SMA wire processed to memorize the straight line is set around both a large pulley and a small one. When the wire around the small pulley is heated partially with hot vapor, it generates a recovery force at the heated part of the wire and turn to the torque to run the pulley. A bundle of wires can produce larger torque and it is possible to make a SMA heat engine which is mainly composed of two pulleys and SMA wire loops.

The drive system have been introduced in the previous works [1,2]. In the paper, the factors of the performance of the engine, the torque and rotational speed which depend on the diameter of small pulley, wire loop number, room temperature and wire thickness, were discussed.

2. Mechanism and performance

2.1 Mechanism of a SMA heat engine

The schematic figure of the SMA heat engine is shown in Fig. 1. Basically it is composed of three parts, a large pulley, a small one and a loop of SMA wire. The typical specifications are as follows:

・ Large pulley: bicycle wheel with no tire, diameter 520 mm.

・ Small pulley: Aluminum disc, diameter 70.0 mm and thickness 8.0mm.

・ SMA wire: NiTi (Nilaco Co.Ltd.), diameter 1mm, shape recovery temperature 333 K, memorized to be straight.

・ Loop length: 3 m

When the vapor temperature is high enough to recover the shape, the two pulleys begins to run. Essentially The starting rotational direction is unknown. But if the heating point as shown by thick arrow is shifted from just side to upper side, the first rotational direction is decided as upper thin arrow shown in the figure, and vice versa.

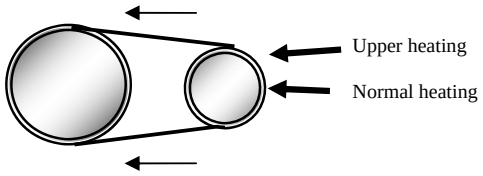

Fig. 1. Drive system of SMA heat engine, starting rotational direction is unknown at normal heating position.

This tendency is understood as follows. The shape recovery effect is a phenomena that a deformed SMA recovers the memorized straight line by high temperature. A part of the wire is forced to deform at the small pully side in every cycle and when the heat is applied to the part, the wire recovers the original straight line if a room for the motion is left. So the sequence, from a deformation to a recovery, is indispensable for the recovery. If not, it is from recovery to deformation and impossible. This is the reason why the upper side heating does not produce a clock-wise rotation in Fig. 1.

2.2 Reversal rotation

I contrived a reversal rotation device based on the rotation mechanism. The device is shown in Fig. 2 and Photo 1. This enables the pulleys to reverse a rotational direction automatically. In case of a normal heating position in Fig. 1, the rotational direction can be changed reversely by hand during rotation. But the device, a set of a spring and a string can substitute for this motion. A small spring is fixed to wheel edge and bound with a long stirng at the other side. The string is fixed to the wheel stand at the opposite edge as shown.

When the axle is wound fully with the string by rotational motion the spring stretches to the limit and after

short stop the wheel begins to rotate reversely. The string length between spring and wheel is adjustable, therefore it can control the number of one directional rotaion.

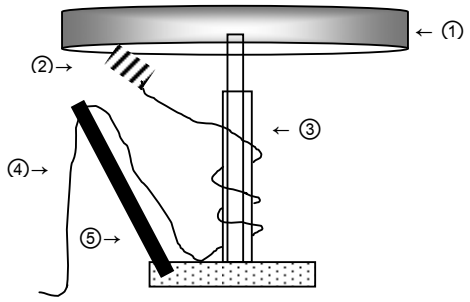

Fig. 2. Composition of reversal rotation system, ①large pulley ②spring ③plastic cover ④string ⑤bar fixed to stand.

Photo 1. Reversible rotation wheel device.

3. How to increase the rotation of the heat engine

Invetigation are carried in order to realize an effective recovery strength in relation to the rotation, as the cooler wire temperature becomes before next heating, the more effective the recovery realizes and so the rotation number inceases. Therefore the longer wire loop brings the more rotation number because that a cooling is more effective in comparison with a short one after one rotation.

In case of a short wire loop with a middle sized large pulley, another device is possible as follows, the large pulley may be covered on its edge by a copper thin tape and be cooled by icy water. As this works similarly to a long wire loop, it produce the same effect.

Another method is that the wire is wound doubly or more around small pulley. This is shown in Fig. 2 schematically. In this case, different from Fig. 1, transformed to semicircle, since the wire is transformed roundly, heating point is everywhere on the circular edge of small pulley. Moreover as the wire contacted roundly, the long contacted area produces stronger frictional force to rotate than the case of Fig. 1.

A measurement shows that both the torque and rotation number increase as winding number increase as shown in Fig. 3. and Fig. 4. The loop length is 3.6 m. The torque and the rotation are not proportional and a torque is more essential to produce a driving force of the engine.

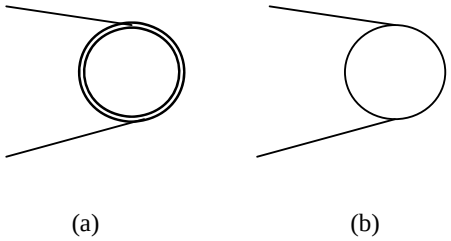

Fig. 2. (a)Double winding and (b)Single winding.

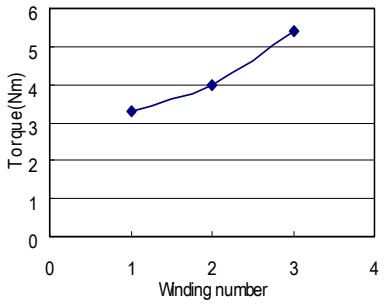

Fig. 3. Torque vs. winding number of small pulley.

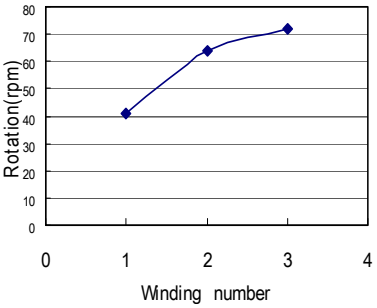

Fig. 4. Rotation vs. winding number of small pulley.

4. Applications

4.1 A mobile display: type A

As far as it goes, a large pulley of the engine can be added more than one, up to four wheels. One set has four wheels. Photo 2 shows the case. This is performed in public at night festival held in some local town where bamboo and candle light are main theme. For attractive effect, a few devices are applied. A conical shape on the wheel is composed of bamboo rods and a few candles are placed on the edge of each wheel. A single long wire loop is set crossed between wheels side by side, so every wheel rotates in reverse from next one.

Extensively using three similar sets, the arrangement as a whole can be figured with geometrical pattern,”Y”,

triangle , three radial line or circle for instance.

Photo 3 and photo 4 show one of the patttern, “Y” and radial line “∈ ” respectively.

Photo 2. SMA heat engine and lined pulleys.

Photo 3. First night setting, pattern ”Y”.

Photo 4. Second night setting, pattern “∈ ”.

4.2 A mobile display:type B

Type B suggests Ferris wheel as shown in Fig. 5.

Two wheels are connected and set vertically, and each wheel has four candles which move like a swing.This can reverse the rotation too. The small pulley is sandwiched between compact discs in order not to get wire loop derailed. The discs work for heat concentration too.

Actually mixed arrangement of type A with B is effective on the ground.

Photo 5. Type B suggests Ferris wheel.

4.3 A SMA Car

A car driven by SMA heat engine is shown in Photo 6. A bundle of wire loop up to 44 enables to drive the SMA car. This car can run slowly like a toddler step.

Photo 6. The SMA car with heat engine runs slowly outside.

4. Conclusions

Many people who visited the local event admired the displays. In the manufacturing process, we found two changes for the better. One is cooling large pulley with copper thin tape and icy water. Another is winding a wire around small pulley. Though it needs longer loop, it shows that the engine can increase its torque. In addition, though hot vapor should be applied at only one point, normal position in the case of Fig. 1, this pulley can rotate by hot vapor at every circular point heating.

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