Design of New Drive System using Shape Memory Alloy

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Abstract:
This paper is to evaluate the new drive system by using the shape memory alloy (SMA) by using Nickel titanium alloy (NiTi) wire. This work presents a novel approach to arranging the series of shape memory alloy (SMA) wires into a functional heat engine. SMA heat engines convert Thermal energy into Mechanical energy using shape memory alloy material. Significant contributions include the design itself, a preliminary analytical model and the realization of a research prototype; thereby, laying a foundation from which to base refinements and seek practical applications.

Key words: shape memory alloy, shape memory effect, SMA heat engine, design.

I. INTRODUCTION

The discovery of shape memory alloy (SMA) [1] has inspired high enthusiasm in developing solid engines to convert low grade thermal energy to mechanical energy and further to electrical energy. As a result, various types of solid engine have been constructed or proposed by some of the previous works [2] [3] include William J. Buehler(Buehler, 1968), Paul F. Horton (Horton, 1977), Sandoval J. Dante (Dante, (1977), Alfred Davis Johnson (Johnson, 1977), Peter A. Hochstein (Hochstein, 1977 ), Warren K. Smith(Warren, 1978), Yao Tzu Li (Li, 1978), and John J. Pachter (Pachter, 1979). T.9P; Ohe underlying mechanism is a solid-state phase transformation that converts heat into motion through self-rearrangement of atoms in a piece of metal, known as shape memory effect. 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 [4][5] which is mainly composed of three pulleys and SMA wire loops. The drive system have been introduced in the previous works. In the paper, the new design of the engine, the torque and rotational speed which depend on the diameter of small pulley, bigger pulley, wire loop number, room temperature and wire thickness, were discussed.

II. DESIGN OF SMA ENGINE

The schematic figure of the SMA heat engine 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: ply wood pulley with iron coupler, diameter 470 mm.
- Small pulley: Aluminium disc, diameter 100.0 mm and thickness = 10 mm
- SMA wire: NiTi, diameter 1mm, shape recovery temperature 343 K, memorized to be straight.

When the vapour 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. 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 pulley 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.

Figure 1. Schematic figure of designed SMA heat engine¹,²,³

III. DESIGN CONSIDERATIONS

1) Stand:
   - Length: 822mm
   - Breadth: 657mm
   - Height: 913mm

2) Pulleys:
   - Upper pulley diameter: 470mm
   - Lower wheel diameter: 100mm

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3) **Shaft to shaft distance:** 660mm

4) **Bearing Diameter:**
   - For upper shaft: 92mm

5) **For lower shaft:** 50mm **Bore diameter:**
   - For bigger pulley: 36mm
   - For lower pulley: 25mm

6) **Distance between pulleys:** 207.5mm

7) **Tank:**
   - Length: 362mm
   - Breadth: 194mm
   - Height: 125mm

**IV. OPERATION:**

Heating a stretched SMA wire makes it contract. Consider a wire stretched between two pulleys. When heated, the most natural way for the wire to contract would be to pull the pulleys together during operation; half of the lower pulleys are submerged in the hot region while the remaining wire tends to natural convection as rotating towards the upper pulleys. Wires on the hot side all try to contract, driving the engine in the direction that relieves tension. Wires on the upper side soften as they cool. While wires moving towards the upper side due to increase of upper pulley diameter eventually the wire stretches. In this design series of pulleys are used with equal diameter and with equal spacing between the each pulley by rotating towards each another. The unsynchronized pulleys rotate in different speeds; therefore, the only way for the wire to contract is for the entire machine to rotate in the direction. The designed prototype can able to produce the shaft work with an rpm about 150+_ 20.

**V. RESULT**

The considerations made in this design tend to successful SMA heat engine with shaft work. The produced shaft work is represented in terms of RPM (Rotations Per Minute). From the above design considerations range of 145-160 rpm is produced based on the heat input.

**VI. FUTURE MODIFICATIONS**

1. By decreasing the weight of the pulleys and shaft the shaft output may be increased.
2. By increasing the diameter and strength of the wire the force generated will be increased such that power increases.
3. By increasing the shaft to shaft distance the torque may be increased with respect to the wire diameter

**VII. APPLICATIONS**

From the above design prototype used in following applications
1. Weight lifting machine:
   By using a rope drives, weights are lifted.
2. By connecting a dynamo to the shaft high grade mechanical energy is converted into electrical energy, which can be stored or can be directly used.
3. It can be used drive a vehicle which is known as SMA vehicle.

**VIII. CONCLUSION**

The present research evaluates the new design of a SMA heat engine. The purpose of this research work was to present the design and light analysis of an improved heat engine made using shape memory alloy. In of the past work that has been attempted in this area, it seems unlikely that the earlier inventions could be scaled up to the point where they have practical utility. This thesis presents a new design that has the potential to be the basis for large SMA engines

**IX. REFERENCES**


**X. ABOUT AUTHORS:**

Ashok Kumar Raju is currently working as an Assistant Professor in JNTUACE Kalikiri. He has received Master of Technology degree in CAD/CAM specialization in the Department of Mechanical Engineering from Annamacharya Institute of Technology & Sciences, Rajampet in the year 2015. He has published eight papers in International Journals in the areas of CAE in the field of Mechanical Engineering.

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