*Available online at*www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Applied Science Research, 2015, 7 (4):64-67
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0975-508X
CODEN (USA) AASRC9

Development of design of motor using one way nitinol

Mohit R Jiwnani, Shubham Shekhar, Pulak Agrawal, Shubham Bansal, Priyank Srivastava and R. K. Tyagi

Amity School of Engineering and Technology, Amity University, Noida, India

---

ABSTRACT

The aim of this research is to make a Nitinol motor using One-Way Nitinol, based on the previous design of Nitinol Heat Engine invented in 1973's. The main principal behind our motor was based on the Nitinol property known as "Shape Memory". The motor basically comprises of "U-shape" Nitinol wire mounted a centre spoke wheel using hook and a container containing separate section of hot and cold water. Unlike two-way Nitinol, one way Nitinol can only memorize one shape so it was necessary to provide outside force to retract to its "U-shape". For this, springs were mounted on one of hook to retract the Nitinol back to its U-shape. The intension of this research is to develop a feasible design of the motor which runs on one way nitinol.

INTRODUCTION

With the invention of Nitinol, i.e. Ni-Ti alloy, there have been a few works on the development of Nitinol motor for developing green energy. In 1973, Ridgway M. Banks invented Nitinol Heat Engine, using two-way Nitinol, to produce green energy. Since then, there have been a few developments in the use of Nitinol to develop Nitinol motor, but due to complications in manufacturing of two-way Nitinol, its use has been restricted.[1]

The research aimed to develop the Nitinol motor using one way Nitinol to develop green energy. The one way Nitinol has got the property to memorize one shape at its austenite temperature. The principle of operation of nitinol is dependent on the Transformation and the change of crystalline structure between the two phases i.e. Austenite (high temperature phase) and martensite (low temperature phase). During the austensite phase the crystalline structure of the material is symmetrical. In the martensite phase the grains of the crystal are in a twinned structure. On application of force on the material, a deformation is produced which is due to the movement of the twinned boundaries. This results in a pseudo-plastic deformation of the material. [2][3]

The design of motor involves use of U-shaped Nitinol wires, with its austensite shape as straight wire. The wire is connected to the spoke of a wheel and when dipped in hot water, i.e. austensite temperature, the wire would expand to its austensite shape creating a force. This force could be used to rotate the centre spoke wheel continuously. Further, if the number of wire are connected it such a way that it could develop a series of force which would add up to give a massive force. As one way nitinol is being used, an outside force is required, which is provided by use of tension springs to retract back the wire to its U-shape.

MATERIALS AND METHODS

1. The setup basically consisted of three entities – centre spoke wheel (Fig 1), container (Fig 4), and mechanism for fixing the wheel with the container. The centre spoke wheel was designed using the bicycle wheel rim on 20 inches. The wheel rim was sized accordingly and was arranged so that it consisted of 18 centre spokes attached to a cycle hub at the centre. The Nitinol was attached to the spokes of the wheel by using hooks in a U-shape. The cylindrical container open on the top is divided into three portions by using two separating metal sheets for holding hot and cold

water and to provide space for fixing the wheel. A suitable wooden box and nut arrangement was used to fix the wheel to container. Arrangement was also provide for the Nitinol to transit from the hot side to cold side of the container and vice versa. The arrangement was made of metal sheets such that the Nitinol would slide on them to move to the other side. The dimensions are given below-

Dimension of the components involved in the Container:		
S. No.	Parameters	Dimensions
1.	Container Diameter	57 cm
2.	Container Height	18.5 cm
3.	Height of the partition	17 cm
4.	Distance between Partition	3.5 cm
4.	Sheet Thickness	0.52 mm
5.	Sheet Material	Galvanised Iron
6.	Dimension of Wooden Holder	25.7x2.5x15.8 cm
7.	Diameter of the nut hole on wooden holder	1.6 cm
8.	Depth of the nut hole	2.5 cm

Dimension of the components involved in the Wheel:		
S. No.	Parameters	Dimension
1.	Wheel Diameter	20 inch or 50.8cm
2.	Wheel Material	Aluminium
3.	Number of Spokes	18
4.	Spoke length	22 cm.
5.	Type of Spoke	Centre Spoke wheel
6.	Width of the rim	2.7 cm
7.	Spoke material	Stainless Steel

2. The new setup consisted of a frame (Fig 2) which was attached to a cycle wheel hub at the centre. The frame consisted of four spokes attached to the hub at right angles. The free ends of these spokes were joined to each other by four different spokes. Thus giving it a shape of a square where the hub is at the centre and spokes forming the edges and diagonals of the square. The frame used the same of wooden box for fixing the wheel hub to the container. The Nitinol was to be attached to the edges of the square frame with one side fixed and other side free to move. A tension spring was attached between the two ends of Nitinol. Two separate halves of container was used for this apparatus which was placed at separation based on the size on wooden box. The arrangement of the metal sheets for the transition of nitinol was developed accordingly. The dimensions are given below-

Dimension of the components involved in the Wheel:		
S. No.	Parameters	Dimension
1.	Container Diameter	29 cm
2.	Container Height	7.7 cm
3.	Sheet Thickness	0.52mm
4.	Sheet Material	Galvanised Iron
5.	Diagonal of square frame	20.8 cm
6.	Edge of square frame	14.8 cm
7.	Diameter of hub	4.8 cm
8.	Dimension of Wooden Holder	25.7x2.5x5 cm
9.	Diameter of the nut hole on wooden holder	1.6 cm
10.	Depth of the nut hole on wooden holder	2.5 cm

3. The new apparatus consisted of a frame (Fig 3) in the shape of a pentagon connected to a bearing at the centre. The vertex of the pentagon was connected to the bearing using spokes. A similar fixing attachment was developed using a wooden box using the previous dimensions. The Nitinol was attached to the edges with the same tension spring. The same container and sliding mechanism for Nitinol was used. The dimensions are given below-

S. No.	Parameters	Dimensions
1.	Diameter of Bearing	3.1 cm
2.	Length of edge of pentagon	14.8 cm
3.	Length of the spokes joining the vertex and the bearing	12.5 cm

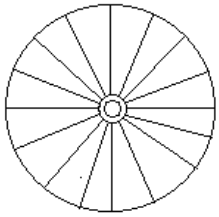

Figure 1 - Centre Spoke Wheel with hub.

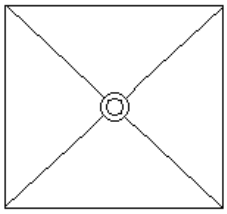

Figure 2 - Square frame with Bearing.

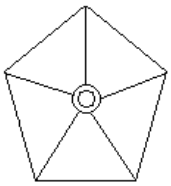

Figure 3 - Pentagonal Frame with Bearing.

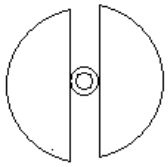

Figure 4 - Container with Hot and Cold side.

4. The nitinol used in our research was SM495. SM495 is a standard shape memory wire that is malleable at room temperature and returns to shape in boiling water or autoclave. Typical applications for the material are actuators and surgical tools. Properties of the nitinol is given below-

Properties	SM495
Type	One way
Melting Point	1310°C
Density	6.5 g/cm3
Electrical Resistivity	76 µohm-cm
Modulus of Elasticity	28 – 41 GPa
Coefficient of Thermal Expansion:	6.6 x 10-6 / °C
Ultimate Tensile Strength	≥ 1070 MPa
Transition temperature	60-65^{O}C
Length of wire used	14 cm

Observation and results:

- The first experimental setup was used in this case with a centre spoke wheel. 18 spokes were taken. Nitinol wire was attached to each spoke using hooks and the container was filled with hot and cold water. No movement of the wheel was observed when the wheel was fixed to the wooden attachment. An initial startup torque was externally provided expecting the wheel to rotate indefinitely. Though no movement was observed. It was observed that when Nitinol wire came in contact with cold water it remained in its austenite shape (straight shape) and does not return to its martensite shape (U-shape).

Because of the use of one way Nitinol, the Nitinol was not able to return to its original shape when in cold water. Hence a tension spring was used to retract the nitinol wire back to its martensite shape.

- The arrangement of the apparatus along with a tension spring was tested. But No movement was observed.

The reason understood was that the nitinol was attaining its martensite shape in hot water but because the force developed by the ends of the Nitinol wire was in opposite direction. Hence, the forces cancelled each other. It was decided to fix the Nitinol on one end so as to obtain force only in one direction.

- The new arrangement of the wheel was tested with Nitinol fixed on one end. Though no rotation was observed. An initial torque was also provided but to no avail.

The force generated by Nitinol provides radial force in this case but a tangential force was required for the wheel to rotate. A new design with a square frame was designed for this purpose.

- The second experimental setup was used where a square frame and the nitinol arrangement along with the tension spring was fixed to the edges of the frame. The wheel showed no movement when the test was conducted.

The reason that was made out that the force provided by Nitinol was not sufficient for the frame to rotate.

- The third experimental setup with pentagon arrangement was developed so as to have more number of Nitinol and so that the timing of nitinol to come in contact with hot side is perfect. No rotation was observed in this arrangement.

The amount of force developed was understood to be insufficient.

- The same arrangement was used with two Nitinol per edge. Still the arrangement was a failure.

It was noticed that the force from Nitinol was never less to move the wheel. Instead the force was so much that the Nitinol used to cut through the water without providing any reaction tangential force. Though when the water was at a lesser temperature (nearly 60-70 ^{O}C) a tangential force was attained .Though in this arrangement it was difficult to set the timing of the next Nitinol to come in contact with the hot water.

- Further a different method was implemented by hitting the free end of the nitinol onto the separation wall on the hot side of the container. A positive result was obtained.

The problem with this method was that the rotation that was achieved was dependent on various factors. Such factors included the random angle of hit and the random position of the hit on the separation wall. It was a very difficult task to control the random angle of hit and hence to setup proper timing of the wheel.

- A new inclusion was made into the previous arrangement by using small flaps attached to the free end of the Nitinol wire which were used to provide a reaction force to rotate the frame. This provided a jerk force for the frame to rotate.

With this method a small motion was observed as the nitinol displaced some water using flap and when the flap hit the other side resulting in a jerk motion. But the motion was not smooth and continues, and eventually stops. As soon as nitinol comes in contact with hot water and hits the separation a jerk motion is achieved but it eventually ceases. So the motion obtained would be uneven or jerk motion which was again difficult to control and set timing.

Conclusions and Recommendations:

There are many constraints affecting the working of motor by using one way nitinol. These constraints may be like

- Nitinol don't retract to its shape in cold water. An arrangement has to be provided for it.
- The arrangement used such as spring actually decreases the force of the nitinol that can be achieved and thus we attain lesser force.
- The arrangement also affects the free motion of the motor. Etc.

A free and continuous motion was not achieved in the one way nitinol motor. A jerk motion was achieved which eventually stops because of unbalanced created by it. The random angle of hit and the random position of the hit on the separation wall could not be set properly. This made the timing arrangement very difficult. Around the temp 65-70 ^{O}C when nitinol opens to its austenite shape (straight position) the wire did not cut through the water but actually provided the tangential force for the wheel to rotate in water. But this force was not sufficient for the proper motion.

Further work can be done with the flap arrangement by using nitinol with flap to displace water and thus provide force for the motion of wheel. A positive result may be obtained by using a offset wheel could be used to vary the eccentricity of the wheel and would hence provide a continues motion of the wheel

REFERENCES

[1] Jillcha Fekadu Wakjira: 'The VT1 Shape Memory Alloy Heat Engine Design'.
[2] Mohit R. Jiwnani, Shubham Shekhar, Shubham Bansal, Pulak Agrawal and Dr. R. K Tyagi, *International Journal of Applied Engineering Research*, **2015**, 10, 589-618.
[3] Richard Lin: 'Shape Memory Alloy and Their Application'.
[4] J. Klaput, *Archives of Foundry Engineering*, **2010,** 10, 155 – 158.