Automatic Fire Sprinkler By Using Nitinol Wire

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***Abstract:** Fire Sprinkler is a device which discharges water when fire is detected or when predetermined temperature has been exceeded. The existing type of fire sprinkler system is of destructive type of operation that is once it is actuated the fire sprinkler system needs the maintenance work in it. The water from the pipe line is completely drained even after the fire has been put off. Due to this wastage of water is more. And its operating phenomenon is of non stoppable type. This put forth the need of the automatic SMA activated fire sprinkler system. A fire sprinkler with shape memory alloy (SMA) wire is to be modeled and fabricated. It will actuate automatically and puts off the fire. Apart from that it will automatically cuts off the water supply after putting off the fire and does not require periodic maintenance of the sprinkler every time it is operated. The model of automatic fire sprinkler is designed and simulated in Pro-E software*

***Keywords:** Fire Sprinkler, SMA, Pro-E*

I. INTRODUCTION

The basics of memory materials have been extensively documented by numerous papers and it is not the intention of this research to expand on this area, but rather than to give the reader a primer into the subject to better understand latter topics. The term shape memory alloy indicates a material that has the ability to deform to a preset shape when heated and in the process perform a useful engineering function.

A. SHAPE MEMORY ALLOY

A relatively new group of materials that exhibit an interesting phenomenon are the shape memory alloys or (SMAs) A shape memory alloy is polymorphic i.e., Figure 1 It may two crystal structures or phases and shape memory effect involves phase transformation between them. One phase (termed an austenite phase) has a Face centered cubic crystal structure and other phase (termed as martensite) has Body centered Tetragonal structure.

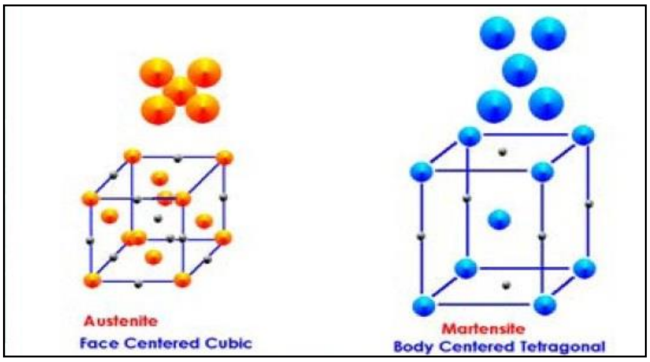


Figure 1: Crystal structure of Austenite and Martensite

Shape memory alloys are a type of material that uses to meet a growing demand for light weight, powerful actuators that can be scaled down. Figure 2 Memory materials exhibit the ability to induce large mechanical strains upon heating and cooling many shape memory materials are metal alloys; therefore, they can also produce large mechanical stress when thermally activated. These properties make them well suited for applications in controllable shape change, vibration control, and it can be used as a damper. SMAs display the shape memory effect (SME) when annealed appropriately. This effect describes a material's ability to return to a predetermined shape through heating after being plastically deformed from that shape. Heating can be achieved through Joule heating via electrical current.

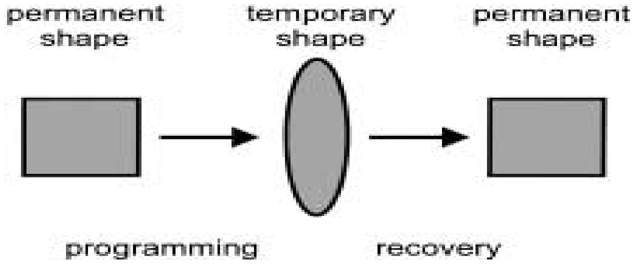
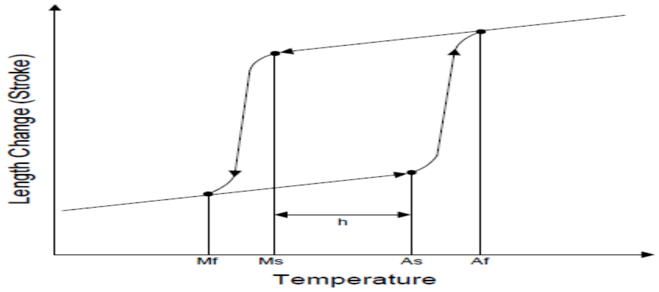


Figure 2: Simple Diagram represents SMA property

B. PROPERTIES OF THERMAL ACTIVATED SHAPE MEMORY MATERIALS

a. SHAPE MEMORY EFFECT

The shape memory effect (SME) is a material's ability to return to a predetermined shape through heating after being plastically deformed from that shape as shown in Figure 3. An SMA in its cold-worked condition does not display the SME, but a shape-set anneal will activate the SME in an SMA. A shape-set anneal is a process that requires constraining the SMA in a desired shape and then performing a heat treatment. This heat treatment must occur at a specific temperature and pressure for certain duration of time. The method chosen depends on the size of the SMA and equipment availability. Typically, the annealing temperature is in the range of 450° C to 550° C Higher temperatures result in lower tensile strengths. Since cooling should be rapid to avoid aging effects, a water quench is recommended. The time required for the heat treatment should be calculated before the experiment. The above mentioned temperature is used to set memory for the alloy to desired shape, but for our experimental purpose 60° C to 100 ° C is enough to control the vibration.



1. Martensite Finish (Mf).2. Martensite Start (Ms) 3. Austenite Start (As). 4. Austenite Finish (Af)

Figure 3: Shape memory effect

b. PHASE TRANSFORMATION

The parent phase of the shape memory alloy is austenite due to the room temperature it is cooled and changes to martensite phase. The twinned martensite phase is changed to deformed martensite and the material is heated through current where austenite starts and material will recover its original shape when austenite completes. Temperature and stress should not be increased more over if it increases means it will lose its property. Shape memory alloy has shape memory effect due to this phase transformation.

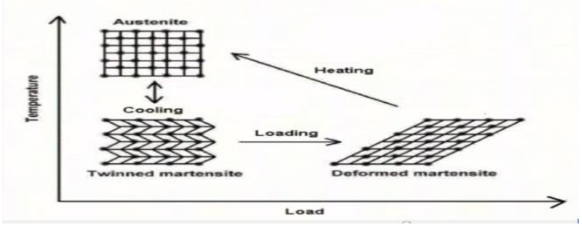


Figure 4: Phase Transformation from parent phase

II. DESIGN CONCEPT

Design of spring

Let,

D=Mean diameter of the spring coil

D=diameter of spring wire

C=spring index

Axial load (w) δ =50N

We know deflection, $= \frac{8\,w.c3.n}{G.d}$

$20=8x50xc^3x\frac{15}{84*1000*d}$

$\frac{c3}{d} = 280$,

Let us assume that d=1.032mm.Therefore

C^3 =280x1.032

C=6.61

$\frac{D}{d} = 6.61$

Mean Diameter of spring coil (D) = 7mm

Outer Diameter of the spring coil (D_O) = D + d

(D_O) = 7+1.032

(D_O) = 8.032

Spring Rate (or) Stiffness (K) $= \frac{W}{\delta}$

= 50/20

= 2.5N/mm

The outer Diameter is less than 15 mm drill. So assumed dimension of wire is correct Maximum shear stress induced.

We know Wahl's stress factor

$$K = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

$$= \frac{4*6.61-1}{4*6.61-4} + \frac{0.615}{c}$$

=1.22

Maximum shear stress induced

$$\tau = K * \frac{8wc}{\pi * d_2}$$

$$=1.22 * \frac{8*50*6.61}{\pi*1.032*1.032}$$

= 964 N/mm^2

Free length of spring L_f = $n^1.d + \delta_{max} + 0.15\ \delta_{max}$

L_f = (10*1.032) +20+ (0.15*20) + 9

L_f = 40mm.

Pressure of water in pipe lines = Density x Acceleration due to gravity x height of water level

= 1000*9.81*15

$= 147150\ N/mm^2$

Force acting on the pressure in the pipe line (F) = pressure x cross-sectional area

$$= 0.147150 \times \frac{\pi}{4} \times 3^2$$
$$= 1.04\ N$$

Weight of the piston W = mg

We know mass = density x volume

= density x cross-sectional x length

$$= 2700\text{x}(\frac{\pi}{4} \times (.005)^2 \times .03 + \frac{\pi}{4} \times (.008)^2 \times .02)$$
$$= 0.04293\ kg$$
$$= 0.42N$$

Load carrying capacity of NiTinol wire of .059mm diameter wire: 71.1 N

III. MODELING OF PROPOSED METHODOLOGY

In this project, the smart material (SMA) is used for automation purpose. SMA (NiTinol) possesses two phases Austenite and Martensite. At normal temperature SMA is in Martensite state, when there is increase in temperature it goes to austenite. At Martensite phase, here is any strain given to SMA, will be retained back with increase in temperature. Using this phenomenon piston 2 is actuated automatically and enable the water flows in the bypass (A ⟶ C).With the working principle of Pascal's law (principle of transmission of fluid pressure with respect to area changes), piston1 is to be actuated and enable the water flows in outlet port (A ⟶B). This actuation is done with the help of hydraulic pressure exerted by the water supply from (A ⟶C). After the room temperature is reduced, the SMA goes to Martensite state (tension in the SMA wire is reduced), With the help of spring action exerted by spring 2, the NiTinol wire is extended along with moves down of piston 2 to its initial position .Thus the pressure in the actuation chamber decrease to atmospheric pressure, which shut off the water in the outlet port automatically with the help of spring 1.

IV. CONSTRUCTION

NiTinol operated fire sprinkler consists of adjustable screws (1, 2, 3), pistons (1, 2), ports (inlet, outlet, pilot operated), springs (1, 2) and shape memory alloy

A. WORKING

a. *AT ROOM TEMPERATURE*

Normally, at room temperature 30^{0}c SMA (NiTinol) exists in Martensite phase, which is more flexible for SMA wire to get elongated easily by the spring force 2. Thus the spring 1 helps to retain back the original position of piston1, so that outlet port gets closed. The spring 2 provided between the casing and piston 2 helps to retain back the original position of piston 2, so that there is no water flow through outlet port at normal room temperature.

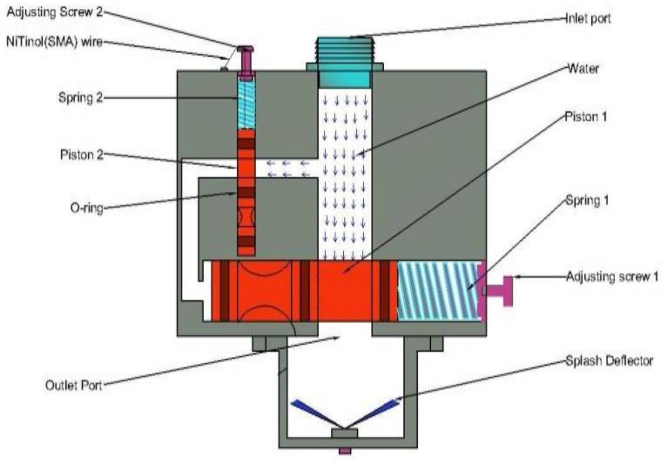


Figure 4.2.1: (a) Closed Position of Fire Sprinkler at Normal Temperature

b. *AT HIGH TEMPERATURE*

When the room temperature exceed above 70^{o}c due to any fire accidents, Martensite phase of NiTinol will shift to Austenite (parent) phase. Hence in Austenite state phase NiTinol wire is more tougher and stiffer., elongated NiTinol wire get back to original shape by compressing the spring 2(Shape Memory Effect). Due to contraction of SMA wire, the piston2 get lifted up thereby opening the bypass port. Thus the pressurized water from the bypass port will enter the actuation chamber (A ⟶ C) and push the piston1 against the spring1 thereby it allows the fluid to flow from Inlet port to Outlet port (A⟶ B), with the help of splash deflector the water is sprayed over fire and put it off.

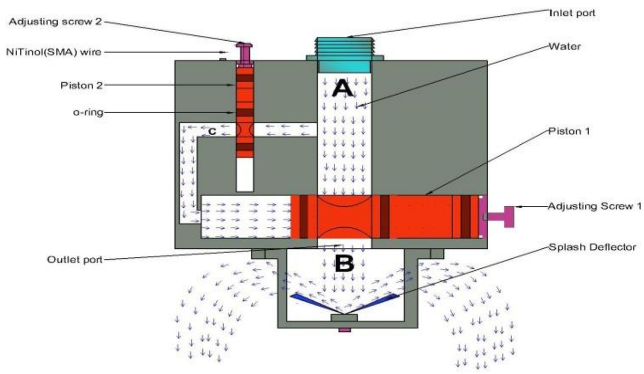


Figure 4.2.2: (b) Open Position of Fire Sprinkler at High Temperature

c. *WHEN TEMPERATURE IS REDUCED*

When the temperature reduced Austenite phase automatically shifted to Martensite phase, thereby with the help of spring 2, piston 2 get back to its normal position by elongating SMA wire easily.

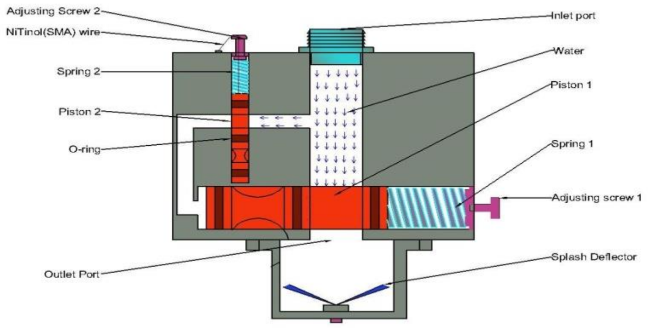


Figure 4.2.3: (c) Closed Position of Fire Sprinkler at Normal Temperature

V. CONCLUSION

The major fire accidents are due to carelessness, gas leakage, short circuit, over heating of electrical appliances, etc… Hence I concluded that fire sprinkler which have designed, will overcome the above problem. In order to use low coefficient thermal expansion fluid as an actuator which is replaced it with thermal actuated shape memory alloy string. Due to this cost is reduced and also implement the automation in the fire sprinkler. The model of automatic fire sprinkler is designed and simulated in Pro-E software.

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