Applications of Nitinol Propulsion Device

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***Abstract:* - This research paper is a technical work done to analyze and implement the shape memory property of an alloy known as Nitinol (Nickel Titanium Naval Ordinance Laboratory). This alloy has a unique feature of regaining is shape back to its original shape once subjected to a temperature range of about 60- 80^{0}C. This research paper focuses mostly on this property of NiTinol, using it as wired loop around two wheels in the form of a pulley in which one a is a driving wheel, and the other is the driven one. The device is known as Nitinol Heat device. Both the wheels are designed and aligned in such a way that one of its wheels immersed in hot water (generally the bottom wheel) which is the driving wheel, the other wheel is suspended in the air which is the driven wheel. The wire initially annealed in the form of a straight wire provides the necessary torque for generating enough power so that the pulley starts to move on its own just by using the heat created by the hot fluid. The bottom wheel, which has NiTiNOL bent around it, when it comes in contact with the hot water, the alloy starts to regain its original shape. The bent wire at the bottom starts to push the lower wheel generating enough torque that drives the bottom wheel on its own and hence leading to a cyclic Reaction and this, in turn, drives the upper wheel creating a self-driven pulley which no mechanical effort or force provided for its motion. Moreover, this project focuses on the useful applications of the NiTiNOL Thermobile in the current industrial scenario where there are ample sources of waste hot water. Some of the viable applications are Radiator fan an automobile Residual hot water from the boiler (for power generation).**

***Key Words*- Nitinol, Heat Device, Boiler.**

I. INTRODUCTION

NiTinol comprises of nickel and titanium, where these two metals are present in vaguely equal molecular percentages. For example, NiTinol-55, NiTinol-60. NiTinol as an alloy exhibits two relatable and unique properties, shape memory effect, and super elasticity or pseudo elasticity. Shape memory effect is the characteristic of NiTinol to undergo deformation and then recovery to its original shape at different temperatures. Now the restoration to its non-deformed shape occurs upon heating it above its transformation temperature. Super elasticity occurs at the smaller range of temperature just above its transformation temperature. In this case, heating is not necessary to cause the non-deformed shape to regain its shape, and the material shows enormous elasticity, around 20 times that of any ordinary metal.

II. MECHANISM

The various properties of NiTinol, derived from a reversible phase transformation in the solid phase, known as martensitic transformation, between two different crystal phases of martensite requiring 68-137 Mpa of mechanical stress. At high temperatures, NiTinol inhibits an interpenetrating simple cubic structure called as austenite, primarily called as the parent phase [8]. The NiTinol very spontaneously transforms into a complicated body-centered tetragonal crystal structure referred to as martensite or the daughter phase. The temperature at which the austenite transforms to martensite is associated to be the transformation temperature. More prominently, there are four transition temperatures. When the NiTinol is fully austenite, martensite is initiated towards formation as the alloy cools at the called martensite start (Ms. temperature), and the temperature at which the transformation is complete, is referred to as the martensite finish (Mf temperature). When the alloy is fully martensite and exposed to heat, austenite is initiated towards transformation at the temperature and ends at the Af temperature [1]

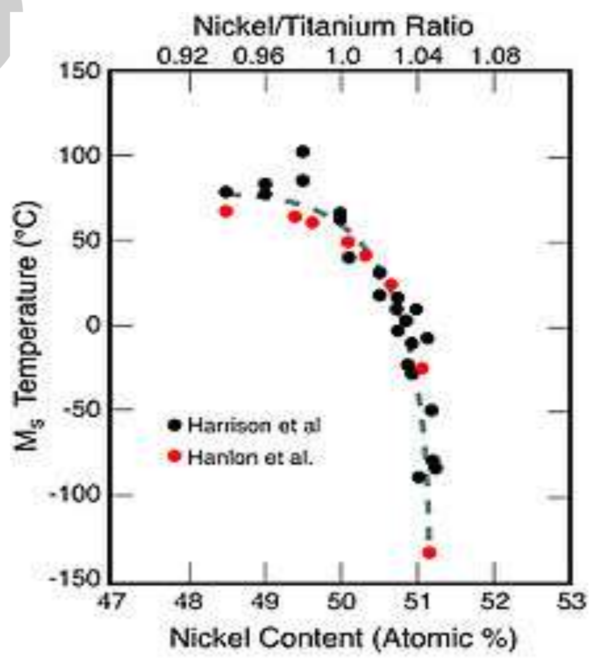

Figure 1.

The cooling-heating cycle here shows thermal hysteresis. The hysteresis width depends on the composition, processing and manufacturing of NiTiNOL. The value of temperature typically spans about 20-50 K (20 – 50℃) [7].

The two critical aspects of this phase transformation are, firstly, the change is "reversible", which means that once the alloy, is heated above the transformation temperature, it will revert the structure back to the pure austenite phase. Secondly, the conversion is bidirectional and instantaneous.

Also known as the monoclinic structure or B-19 structure, martensite's crystal structure has a unique ability to go through limited deformations and without breaking atomic bonds. This phenomenon is known as twinning; that consists of the rearrangement of atomic planes without slipping or permanent deformation because of this it can undergo 6-8% strain. When martensite, reverted to austenite by heating the original austenite gets restored, despite the fact whether the martensite phase gets changed. A significant amount of pressure attained by restricting the reversion of the deformed martensite to austenite of about 689 Mpa [6]. One of the reasons which force NiTinol to return to its original shape is not just that it's an ordinary metal alloy but rather an intermetallic compound in which the atoms are at very specific locations inside the lattice.

The NiTinol, an intermetallic is mainly responsible for the difficulty in fabricating devices made from the alloy.

The preferred mechanism (cooling austenite to form martensite and deforming the martensite, heating to get back to austenite, thus returning the original, initial unreformed shape) is known as the thermal shape memory effect. To fix the original "parent form," the alloy must be held in order and evaluated to about 500 °C (932 °F). The second effect called super elasticity or pseudo elasticity, is also measured in NiTinol. The effect is the direct result of the fact that martensite attained by applying the stress as well as by cooling. Hence in a particular temperature range, one can implement a pressure to austenite, causing martensite to form while at the same time deform shape. The NiTinol spontaneously returns to its original shape. In this mode, NiTinol behaves like a super spring, possessing an elastic range 10–30 times greater than that of a regular spring material [3].

NiTinol is typically composed of approximately 50 to 51% nickel by atomic percent (55 to 56% weight percent) [2]. Making small changes in the composition can modify the transition temperature of the alloy significantly. One can control the Af temperature in NiTinol to some extent, but convenient super elastic temperature ranges are from about −20 °C to +60 °C.

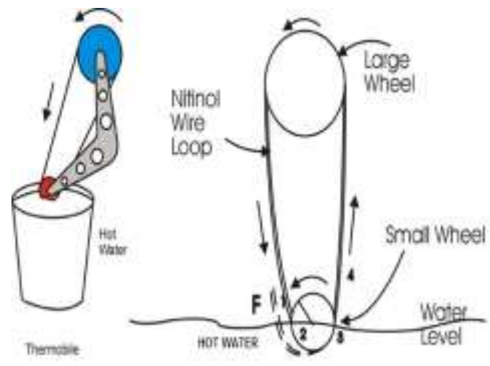

Figure.2

III. APPLICATIONS OF NITINOL

1. NiTinol Heat Device

The Heat device uses a loop of NiTinol wire to generate power. The NiTinol loop placed on two free moving wheels. The device applies only hot water (hot side) and cold ambient air (cool side). The wheel of the heating device is immersed in a hot liquid [5] .

In the Heat device, the NiTinol loop wire has the property of remembering a straight shape. When the loop moves into the hot water, it is brought above its transition temperature and attempts to straighten out. At position one, the NiTinol wire is relatively straight and cold. As the wire moves from position 1 to 2, it is bent around the small plastic wheel and enters the hot water.

Figure 3.

Uses of NiTinol Thermobile in the Industry

The NiTinol Thermobile being a device which utilizes heat energy to generate power can be considerably employed in the industry where there are numerous sources of heat energy as a by-product. To make the project environment-friendly we focused on those chemical and mechanical processes in the sector which release heat or hot water as waste during the process.

During our research we found that there are two viable applications of the Thermobile:

1. Radiator fan of an automobile

The radiator of a car works on the principle of heat rejection from the engine with the help of radiator fluid (coolant). This coolant stored in a reservoir which collects hot incoming coolant from the motor body. Also, the radiator fan which is used to cool the engine by the inflow of cold air works with the power provided from the crankshaft of the engine. Now the objective of our project is to utilize the heat of the radiator fluid to rotate the radiator fan hence increasing the power of the crank shaft and eliminating the use of a thermostat providing an alternate arrangement.

2. Power generation using residual hot water from Boiler.

Nowadays industries dispose of their waste hot water directly into the rivers or the environment, even when the government has imposed stringent laws. The water rejected by the industries is hot, and hence we can use the hotly refused water and convert it into mechanical energy using the NiTinol their mobile and hence we can convert this mechanical energy into electrical hence creating a renewable form of energy.

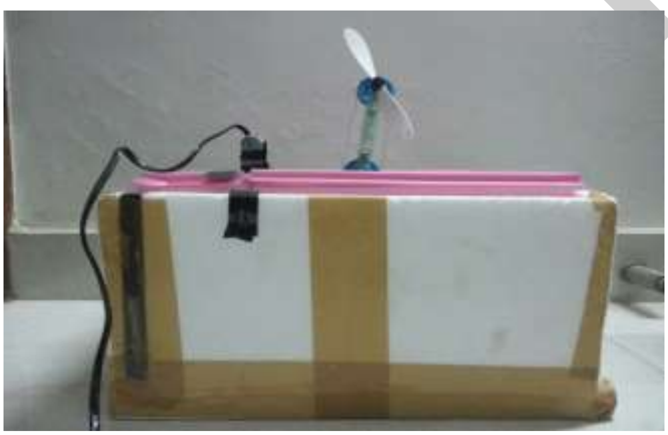

Figure 4.

IV. CALCULATIONS

The amount of mechanical work generated by the wire in the heating device can best be depicted through the stress-strain curves of NiTinol for both curvature O and U as shown in the figure. The points corresponding to the positions, (a) through (d) are identified in the stress-strain curves remembering that work equal to the force times distance this relation requires the work to be,

$-W_U = \sigma_U (S) \times S$

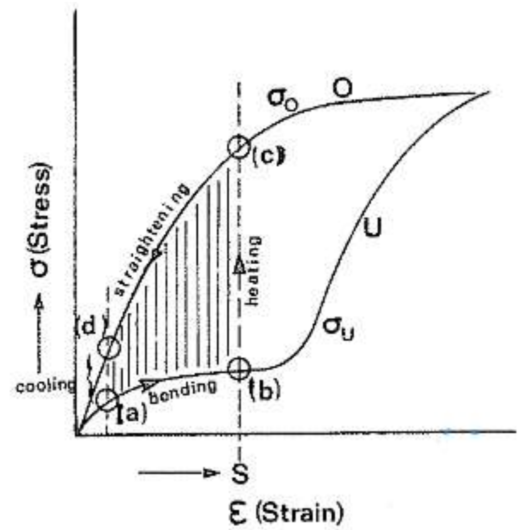

Figure 5.

Through calculations, we obtain,

$\Delta W = W_o - W_u = (\sigma_o - \sigma_u) \times (r/R)$

The increase in torque is attained by either decreasing the radius of the wheel 'R' or by increasing the radius of the wire 'r'[4].

$P = T \times (RPM)$

Now these considerations have been kept in mind while designing our project.

V. CONCLUSION

NiTinol heat device is helpful for various purposes. It is applicable for power generation by reusing water rejected by the industries is hot, and hence we can use the hotly refused water and convert it into mechanical energy using the NiTinol heat device and hence we can convert this mechanical energy into electrical hence creating a renewable form of energy.

The SMAs is helpful in safety devices which will save lives in the future. Anti-scalding devices and fire sprinklers utilizing SMAs are already on the market. The anti-scalding valves are necessary for water faucets and shower heads. After a certain temperature, the device automatically shuts off the water flow. The primary usage of Nitinol-based fire sprinklers is the decrease in response time. The radiator of a car works on the principle of heat rejection from the engine with the help of radiator fluid (coolant). The coolant attained in a reservoir which collects hot incoming coolant from the motor body. Also, the radiator fan which is used to cool the engine by the inflow of cold air works with the power provided from the crankshaft of the engine. The objective of our research is to utilize the heat of the radiator fluid to rotate the radiator fan hence increasing the power of the crank shaft and eliminating the use of a thermostat providing an alternate arrangement. The ideally suited applications of SMAs are fasteners, seals, connectors, and clamps in a variety of applications. Tighter connections and easier and more efficient installations result from the use of shape memory alloys.

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