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Performance Analysis of Cooling Device Made by Nickel-Titanium Memory Wire

Prof. Narayan D More¹, Ms. Gauri H Jadhav², Ms. Kasturi K Mukherjee³, Mr. Sachin S Kesgire⁴, Mr. Ayush A Rai⁵

¹Faculty, ^{2,3,4,5}UG Students, Mechanical Engineering Department, D Y Patil Institute of Engineering and Technology, Ambi,

Pune, Maharashtra, India

Abstract: The name Nitinol is derived from the elements, which comprises the alloy (nitinol) Ni-Nickel Ti-titanium NOL-Naval Ordnance Laboratory. This alloy had unique properties, it was non corrosive and had the ability to change crystalline form with changes in form with changes in temperature. A heating/cooling system that first stresses then releases Nitinol wires to make heated and cooled air at twice the efficiency of a heat pump. The device is predicated on the very fact that Nitinol wires absorb significant amounts of warmth when bent out of shape, then they release that heat when allowed to come back to normal shape. The temperature difference between the loaded wire and therefore the released wire are often the maximum amount as 20°C (36°F). Researchers says that "the heating or cooling power of the system can be thirty times extra than the mechanical power required to load and unload the alloy wire bundles," depending on the specific alloy. They say that this makes the new system quite twice nearly as good as a standard apparatus, and 3 times as good as a conventional refrigerator. The device also uses no refrigerant gases, meaning it is far more environmentally friendly thanks to heat or cool an area.

I. INTRODUCTION

SMA's are newer types of metal alloys that consist of two or more different materials of a particular composition. The name Nitinol is an acronym which has derived from the elements, which comprises the alloy (nitinol) Ni-Nickel and Ti-Titanium NOL-Naval Ordnance Laboratory. This alloy have unique properties, they are noncorrosive and has the ability to change its crystalline form which changes with respect to change in temperature. The main characteristics of this alloy is shape memory effect, that they have the ability to regain its memory and return to their initial shape in case heat treatment is applied to them. The plastic deformation of these alloys starts at low temperature and as soon as the alloy is exposed to high temperature, it returns to its original form. For various applications NiTi is preferred because of its numerous advantages such as high strength, high electrical resistivity, large recovery strains, easy workability and excellent corrosive resistance. Using these properties an environment friendly cooling device, which does not emit any harmful chemical and also which provides higher efficiency and low-cost refrigeration can be built by using nitinol wires.

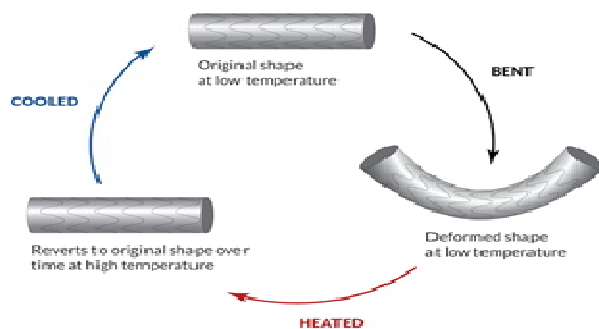


Fig. 1. The Phase Transformation Process For SMA's

SMA's are newer types of metal alloys that has two or more different materials of a particular chemical composition. The main characteristic of these alloys is the Shape Memory Effect (SME), means that they have the ability to return to their initial shape just in case that heat treatment is applied to them. The plastic deformation of such alloys starts at low temperatures, and after the alloy is brought in contact with high temperatures, it returns to its initial form. Internally responsive SMA, the reversible solid-solid, diffusionless thermoselastic phase transformations between an austenitic phase and martensitic phase are causing amazing phenomenon like SME and Superelasticity (SE).

Advantage to recover initial shape when warmed is related to SME, and property to recuperate larger strains than other materials (up to 8%) during mechanical loading-unloading is related to SE. Superelasticity is the ability to elastically deform to higher than normal levels when mechanically deformed, nearly to 11%, between the A_f and M_d temperatures. Most metals only have the ability to elastically deform less than 1% strain. While in this temperature range, SMA material results in a phase transformation from austenite to detwinned martensite. Upon unloading, the upon removing load the martensite phase becomes transforms and unstable back to its original austenite phase. With simple words SMA shows its superelastic property when load is removed and shape memory effect is being activated with heating or cooling. It is generally accepted that SMA's are controlled superelastic materials.

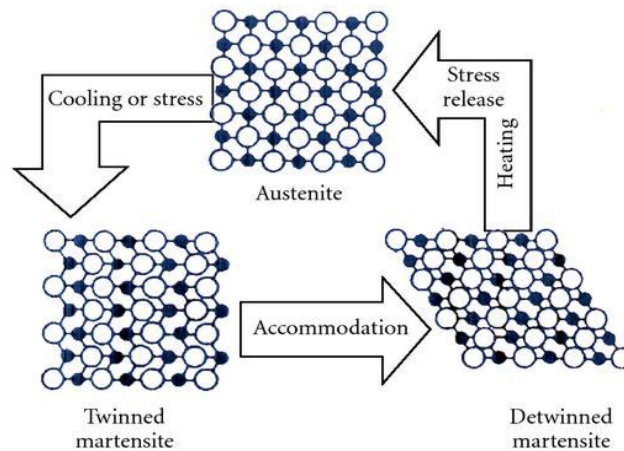


Fig. 2. Changes in crystal form of SMA which leads to Superlasticity (induced by stress) and SME (induced by heating).

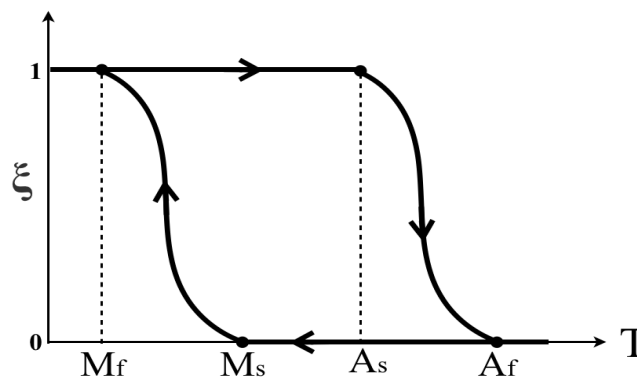


Fig. 3. Phase transformation of shape memory alloy (SMA) as a function of temperature.

II. CONVENTIONAL REFRIGERATION SYSTEM V/S NITINOL BASED COOLING SYSTEM

As we know, Refrigeration can be defined as cooling a space, substance or system to lower temperature and maintain it's temperature below the atmospheric temperature. Refrigeration can also be said as Humanmade cooling system which is achieved by mechanical means. Substitute materials for refrigeration are elastocaloric and magnetocaloric. In these types of refrigeration system, cooling is obtained by change in electric and magnetic field consequently. Higher efficiency and lower cost refrigeration are the necessities of large and small scale cooling .However, when compared with conventional refrigeration system, a solid changes its entropy when deformation takes place ,this possibly provides us with higher efficiency, lower cost, weight and volume that results into more convenient miniaturization. Earlier in 1805, an ordinary rubber band was taken as an example ,to heat when stretched and to cool when stretch is released. But nor elastocaloric neither magnetocaloric are able to able match the performance needs for real life applications. Thermoelectric are the only coolers that can be used as an economic exploitation, but these coolers are expensive also they have low energy conversion efficiency. In Conventional Rerigeration System, we need to use refrigerants in order to achieve cooling at low temperature. Due to which even if this refrigeration system provides us with higher efficiencies and lower cost , it causes harm to the environment . Since the chemicals used for cooling are released into the atmosphere.

Also the process of cooling is forced cooling. Whereas, in nitinol based cooling system no refrigerants are utilized for cooling. The only medium used for cooling is air or water, due to which the process of cooling is natural cooling. Nitinol wire has the property of selfheating and cooling when twisted and untwisted respectively. This property of nitinol wire is used in this system. Thus, we can say that the device is environment friendly since no chemicals are used. Although conventional refrigeration system provides us higher efficiency, its fabrication is complicated as it comprises of compressor, condenser, evaporator and expansion device due to which it occupies greater space area. Whereas, in nitinol based cooling system, its design is very simple as the use of all these devices are eliminated, also it occupies less space. Since, the conventional refrigeration system consist of many devices it produces noise while working. In the new cooling device our motto is to increase its efficiency level and optimize noise , if possible try to make a noise free cooling device . Conventional refrigeration system are heavier in weight whereas the nitinol based cooling system is lighter in weight. In conventional refrigeration cooling is achieved by mechanical drives which can also be driven by magnetism, electricity and laser. Whereas in this device only nitinol wires and electricity is needed. Nitinol based cooling system can be used in small scale industries, standard refrigerators at home, small scale medical applications, coolers and etc. So here we can conclude, that this Future refrigerator proves to be best by all means from the conventional refrigeration system. The only problem that needs to be solved is how to make this device more efficient and less in cost just like the conventional refrigerator

III.HOW THE CONCEPT WORKS

A heating or cooling system that first stresses and then releases Nitinol wires in order to create hot and cold air at twice the efficiency of a heat pump. This device is based on the fact that Nitinol wires absorbs a specific amount of heat when bent out of shape ,and then they let out that heat when allowed to revert to it's normal shape. The temperature difference between the loaded and unloaded wire can be as much as 20 Degree C (36 Degree F). According to the researches held before, researchers claim that ,”the heating or cooling power of the system is upto thirty times greater than the mechanical power required to load and release the alloy wire bundles”, depending on certain alloys. According to them, this makes the new system two times as good as conventional heat pump and three times as good as conventional refrigerator. This device also uses no refrigerant gases , which means the device is completely environment friendly in order to heat or cool a space. In order to make a cooling device, using nitinol wires, there are certain things to be kept in mind while making this device. The desired goal is to construct a cooling device that generates a cold air at thrice the efficiency on air conditioner, without the emission of chlorofluorocarbons in the environment. About 20% of electricity used in buildings today is consumed in air conditioning and the global demand for space cooling is projected to triple by 2050 due to rising population and standards of living in countries with high cooling degree days such as India, Indonesia and China. Instead of vapour compression cycle Elastocaloric refrigerators can be used. Since, they do not require refrigerants with high Global Warming potential. However, these coolers are yet to achieve low enough temperature for cooling. At the same time, problems such as metal fatigue and how long will these alloy wires sustain at variable environmental temperatures before they get brittle and break off. Although it's commonly used in medical devices ,particularly implantable ones such as stents ,where it's remarkable flexibility allows a stent to bend, crush, stretch and twist with the artery as body moves. The objective of constructing this device is to make a cooling appliance that manufactures cold air thrice the efficiency of an air conditioner without the emission of hazardous chemicals in the atmosphere. In order to fabricate such a cooling device we have proposed the use of Shape memory wires i.e nitinol wires as they have the properties of super elasticity and shape memory. It will absorb significant amount of heat from Refrigerant space and then release the hot air to the surrounding by using this Shape memory alloys. It will indirectly help us to solve the issues related to Global Warming. It improves and optimizes the present procedure of refrigeration at the same time it also helps us boost up the efficiency. Also our aim is to build a machine which causes less noise at the same time more efficient than today's refrigeration system. The fundamental principle is simple and essentially involves subjecting a certain shape memory alloy, in this case nickeltitanium wires are used to control loading and releasing cycles.one of the research says ,”Depending on which part of the cycle the material is in, The resulting phase transitions occurs in the alloy's crystal lattice release or absorb latent heat ”. This research has found that , when prestressed nitinol wires are unloaded at room temperature, then cools down by 20 deg C. When the wires are mechanically loaded they heat up by a similar amount , so that the process can also be used as a heat pump. The cooling device is quite simple in concept to construct. It consists of a rotating cylinder which is covered with Nitinol wire bundles. The wires are bent as they pass through one side ,sucking heat out air and stores it. Then as they rotate past the other side, they snap back into shape, dumping the heat on the second side. In this condition, air is blown through chambers on each side, enabling one feed of heated air and another feed of cool air.

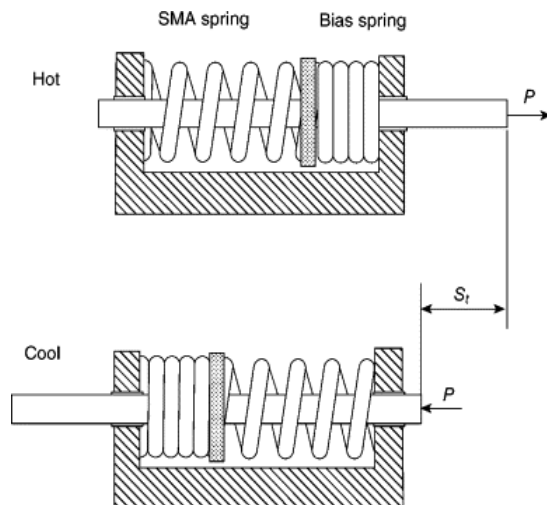


Fig 4. An example of a two-way SMA actuator combined with a bias spring and its actuation by temperature change.

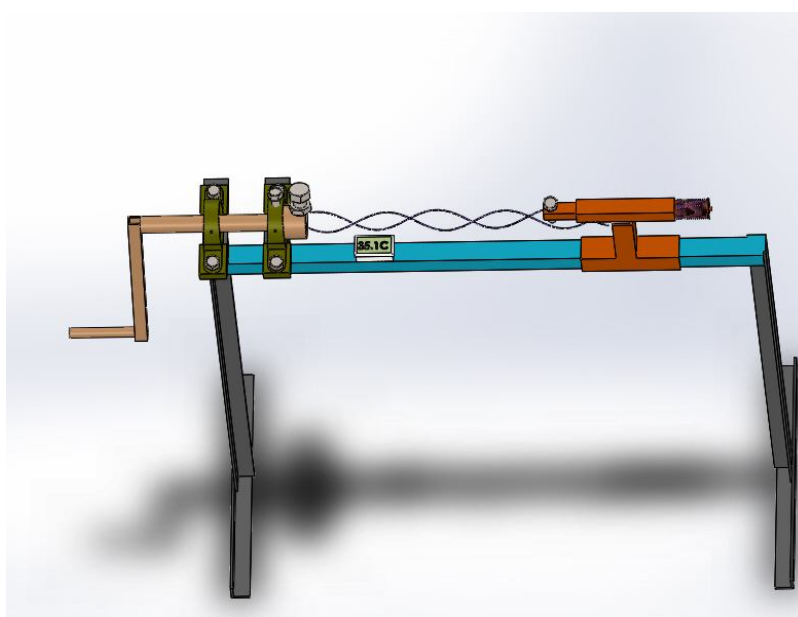


Fig. 5. Mechanism of Nitinol wire in a cooling device

IV. THE FUTURE REFRIGERATOR

Cooling is one of the most important process in today's world. Increased cooling means increased consumption of electrical power, due to which there is higher emission of greenhouse gases into the atmosphere, due to which there is a rise in global warming. Researchers have recently developed a more environment friendly cooling method which does not require any chemically harmful refrigerants and would also consume less energy than the conventional cooling technologies used so far. The system uses shape memory alloys (SMA) i.e made from Nickel-Titanium alloy as explained earlier. If they go through deformation, they will regain their earlier shape. Due to which they are able to tense and flex like muscles. If a Nitinol wire is deformed in tension, the temperature of SMA becomes hotter due to which the crystal lattice structure causes to create change in strain within the material and hence phase transition takes place. If the loaded wire is allowed to relax after temperature equalization with the environment, it undergoes substantial cooling to a temperature about 20 deg C below ambient temperature. Multiple wires are used in order to enhance the cooling power of prototype of rotating air-cooling system developed by the researchers.

The cooling device is quite simple in concept. It uses a rotating cylinder which is covered up by the Nitinol wire bundles. The cooling device is created by passing hot air over one side of a rotating bundle of Shape Memory Wires. The bundle is mechanically stressed on the side as it rotates, thus making the SMA wires hot, and as it rotates further the SMA relaxes and starts cooling.

The air is to be cooled is guided over the cold wire bundle, thus cooling an adjacent space. This remarkable system can create heated and cooled air at two times the efficiency of a heat pump or thrice the efficiency of an air conditioner. The temperature difference between the loaded and unloaded wire is expected to be as much as 20 Deg C. The heat transfer mechanism does not make any utilization of vapours or liquids and also does not harm the environment. Hence, the air in the cooling device can be cooled directly without the need of an intermediate heat exchanger and also there is no need to use expensive high pressure, leak free piping system.

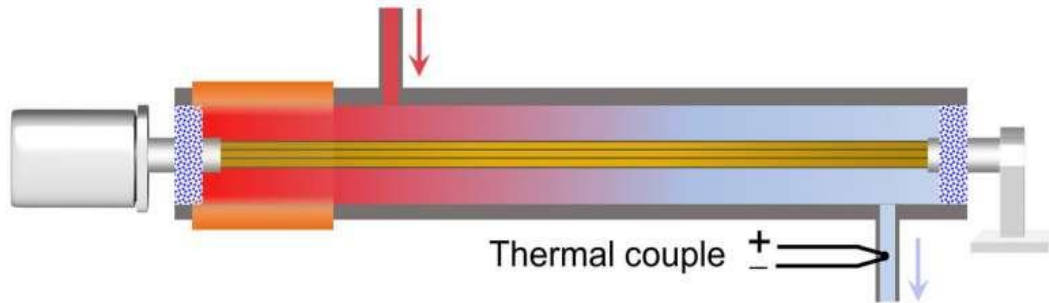


Fig. 6. Device for cooling flowing air by twist & release of Nitinol wires

V. ADVANTAGES OF THE NEW COOLING DEVICE

The new cooling device is twice as good as a standard heat pump and thrice as good as a standard refrigerator. It does not require any chemically hazardous refrigerant, due to which it is also friendly to the environment. Since the cooling device is based on the properties of superelasticity and shape memory of Nitinol memory wires, it absorbs only a specific amount of heat from the Refrigerant space and lets out the heat to the surrounding by using SMA. Thus, it also indirectly helps us to overcome the issue of the increasing Global Warming. The design of this device is easy to fabricate. It also occupies less space. Also, it is not as heavy in weight as that of the conventional refrigerator, due to which it is easy to transport this device from one place to another. Also, since the device does not consist of compressor, condenser, evaporator and expansion device, the device does not make noise while working. The cooling process in this device is carried out naturally by making use of water or air as medium. Hence, in order to drive the Nitinol-based cooling device only electricity is required. Hence, due to all this parameters we can say that this new cooling device proves to be a boon in future.

VI. CONCLUSION

As we have already discussed the properties of Nitinol wires, using which this new cooling device is constructed. We have also discussed the advantages of the Nitinol – based cooling device, on the basis of which we can conclude that it is one of the best alternative to bring the rising issue of Global Warming under control. This device is one of the most advance way to increase the efficiency and at the same time curbs the emission of CFCs. The working time and cost is also reduced.

VII. ACKNOWLEDGMENT

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