International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design & Development Of Nitinol Loop Engine Operated By Waste Heat

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A B S T R A C T :

We present in this paper the fabrication of a primitive burner-driven Nitinol-based loop engine for operation on waste heat. It also harnesses the shape memory characteristic of a Nitinol wire for converting low quality thermal energy to mechanical rotational motion. The functioning prototype was constructed and tested with a hot water bath, and ambient air. Results show that the engine is capable of the reliable and continuous operation when the heat sources are lower than 100 °C, indicating the possibility of this engine for energy recovery in low-power generation process applications

Keywords: Nitinol loop engine, Nickel-titanium alloy, Mechanical energy, Shape memory, Waste heat, Low-grade thermal energy.

1. Introduction

Nitinol is a shape memory alloy material which returns to a specified shaped when it is heated to a specified temperature. This exotic behavior arises from the reversible phase transformation between its low-temperature (martensite) and high-temperature (austenite) phases. Because it contracts when heated, Nitinol can use a high force, which means it can do mechanical work from thermal energy. The appropriate working temperature (equals to 50°C-100°C) makes it fit for low-grade waste heat.

Manufacturing, power generation, and chemical reactions generate large volumes of waste heat in industrial processes. But since this heat is relatively low in temperature, it is unsuitable for use with the standard energy systems and a great deal of it is discharged into the atmosphere. Through combining the high energy capacity, and dynamic actuation unique to shape memory materials, and the fact that shape memory materials can be reversibly cycled through discrete "hot" and "cold" operational zones (referred to herein as the temperature hysteresis characteristic), our work here expands the utilization of Nitinol and its loop-engine configuration to a new application for the practical harvesting and conversion of waste heat to mechanical energy using a low enthalpy equivalent engine cycle.

2. Literature Review

One shape storage compound frequently studied, Nitinol might be an extraordinary fabric which changes shape consistent with temperature, and can, therefore, be used to transform warm into movement. A number of the paces have provided valuable insight into the behavior of Nitinol under alternate heating and cooling for extended periods, opening to view weariness restrain and vitality performance of the material over time.

More recently, you've also been hearing increased interest in Nitinol loop engines' capability to access low-temperature heat sources, such as solar thermal systems or waste mechanical heat. Despite the fact that the innovation sounds important, a great deal of those framework despite everything face moderate cooling and moo mechanical yield. Overall, Nitinol remains a feasible material for small power generation. This effort aims to continue those efforts, developing a simple, robust engine which can use waste heat more effectively in practical applications.

3. Nitinol Material

Nitinol is a nickel-titanium alloy that is characteristic for its specific memorization of a shape and return to the shape in advance after position and receiving a predetermined temperature. The transformation is typically achieved at a temperature in the range 50°C-100°C, indicating that Nitinol is a viable candidate for low-grade or waste heat systems.

This warm reaction gives the nitinol wire a chance to warm and draw back and relax as it chills and grants a forward moving movement when utilized in an endless loop. A commercially available Nitinol wire (approximately 55% nickel and 45% titanium) was selected for this application due to its strength, flexibility, and thermal response. The wire was configured in a roundabout shape with overlapping heating and cooling cycles. As it is quality in warm cycling, it is suitably utilized for snatching little measures of squander warm and for its transformation to gainful mechanical vitality.

4. Working Concept of Nitinol Loop Engine

The engine runs on waste heat and the impulse of shape memory Nitinol wire to generate mechanical motion. This design is fundamentally simple: a closed loop of Nitinol is passed over two pulleys, with one part of the loop exposed to a heat source (e.g. industrial waste or heat, warm water) and the other to the relatively cooler environment (e.g. ambient water, air).

The heated part of the wire at the transition temperature continues to 'transform' from martensite to austenite and in so doing decreases in size and length. This muscle contracts, leaving tension to pull the loop and hence to loop forward to turn the pulleys. Then, as the wire returns to the cooler realm, it returns to martensite, with higher ductility but slightly more elongation-ready to begin the process again.

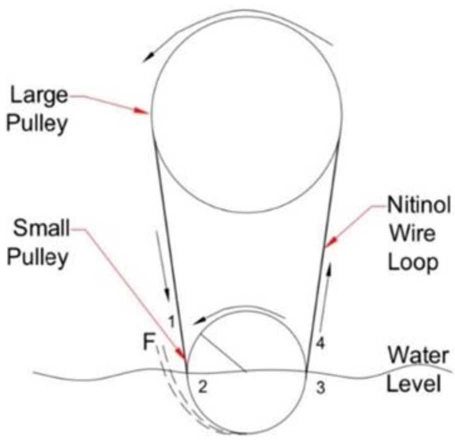
This also yields a continuous temperature cycling which can generate a repeatable rotation for work. This low-cost and clean energy generator can produces kilowatts of power without any gas or electricity supply; it's solely uses waste heat.

5. Experimentation

5.1 Experimental setup

It is composed of two acrylic pulleys. The bigger Pulley is of the size 80mm and the smaller Pulley is 50mm. 2mm deep and 3mm wide V-groove is cut on the periphery of both pulleys. Both pulley are provided with the center bearings (bearing no.- 607 RS). A 0.5mm nitinol wire is attached to the two pulleys. Centre distance of both pulley is 210mm and it can be varied by fixing adjustable bolt at various position. A 320mm tall stand is used for pulleys installation. The mount is attached to the 150x150mm flat base of the stand.

Figure-1: System diagram



It works with hot water on the hot side and ambient air on the cold side. Immersing the lesser one in hot liquid. The motor includes preformed-straight NiTinol loop wire. A segment of this loop touches the hot liquid, heats up to a temperature over the transition temperature, and tries to stretch. The Nitinol wire is not hot and is therefore straight. Between points 1 and 2, the wire wraps around a small pulley and contacts hot fluid.

When it makes contact with hot water, it moves up to contact 3 and so warms above transition temperature and tries to stretch out. When it attempts to straighten, we model the wire in the above manner, in the shape of the dotted curve. The wire 3 at position shifts, therefore, to position 4 and comes into contact with air, its temperature falls with the result that austenite phase generated will turn to a martensite phase. When the wire shifts from state 1 to state 4 it makes this transition and falls off of the bigger pulley. Thus, the time is provided for the wire to cool below its transition temperature and to reinitiate another cycle.

5.2 Experiments performed

Water is utilized in the form of hot fluid since it is readily available and is less viscous, hence it doesn't have much impact on rotational speed of small pulley. Water is heated to 50°C with heating rod and then it is filled in a beaker. The beaker is positioned in a way that the small pulley is half immersed in hot water. Room temperature is employed as the cold side that was 25°C. As the working principle discussed above, the engines begin to rotate. The engine speed is recorded. Next the hot fluid temperature is raised to 60°C and the engine speed is recorded. The process is repeated again and again by raising the temperature by 10°C at a time. This process is done until the hot fluid temperature is 100°C.

Note:

- Laser tachometer was used to measure the speed of the engine.

- Temperature was recorded with thermocouples.
- Immersion heater rod was used to warm the water.

6. Result

Table-1: Speed variation with respect to temperature.

S.No	Temperature (°C)	RPM
1	50	99
2	60	130
3	70	162
4	80	190
5	90	190
6	100	190

7. Conclusion

The present study demonstrates, that Nitinol-based loop engines are promising candidates to serve as a simplistic, yet efficient device to recover heat from low-temperature waste heat sources. Utilizing the shape memory effect of Nitinol, the engine transforms wasted thermal energy into continuous mechanical energy with minimal external energy required. The design conceived in this work shows that very small temperature differences and these are optimal in an industrial or environmental context and can be harnessed in the generation of useful motion.

Although the output is on the low side the system has clear benefits because of its simplicity, the low maintenance and the possibility of using the system in remote or off the grid areas. Additional improvements in terms of heat transfer and set of material could render Nitinol loop engine an effective contributor in decentralized energy recovery systems, especially to small scale ones. This substantial work lays the groundwork for subsequent enhancements and real-world implementations in sustainable energy technologies.

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