Intelligent Heat Dissipation Device Based on Shape Memory Alloy

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Abstract. With the miniaturization of electronic products, heat dissipation has gradually become a focus issue. Most current heat sinks use sensors to detect temperature. After reaching a certain threshold, the sensor generates a signal to drive the motor to drive the heat sink blades to rotate to achieve heat dissipation. This kind of heat dissipation method is more commonly used, but the sensor's anti-interference ability is poor, and the heat dissipation device works at a higher temperature for a long time, the service life will gradually decrease, and the sensing and feedback structure is more complicated and prone to damage. In view of the shortcomings of the above existing products, this article uses the material characteristics of shape memory alloy springs to creatively design a green intelligent heat sink that combines memory alloy springs with sprocket drives. The device uses a memory alloy spring to sense the heat source, and makes full use of its mechanical characteristics to drive the blades of the radiator to rotate, ultimately achieving the purpose of heat dissipation. Experiments and simulation analysis on the operation of the device were conducted to further demonstrate its feasibility, and the benefit analysis and application prospects of the device were clarified through the benefit analysis.

1. Introduction

In industrial production or daily life, temperature-controlled heat sinks are widely used. In terms of industrial cooling, industrial deep wells, hydraulic oil, electric vehicle batteries and other industrial equipment often cause equipment life to be reduced or malfunction due to insufficient heat dissipation; in life, computers, TVs, refrigerators and other large appliances need to be installed with cooling inside. Device, insufficient heat dissipation will affect the service life and working efficiency of the appliance.

Most existing temperature-controlled heat-dissipating devices use sensors (such as G53 sensors) for detection and are driven by motors. Because the service life of the sensor is greatly affected by temperature and sensitive to dust interference, this type of radiator is easily damaged and scrapped, and the use of a large number of sensors and motors will also consume a certain amount of power.

Based on the above background, this project creatively designed a heat dissipation device that combines memory alloy spring and sprocket drive. The device has a simple structure and does not need to rely on external power during operation; and the wear resistance of the memory alloy makes the life of the device longer than ordinary heat sinks; in addition, the heat dissipation effect of the
device can be automatically adjusted according to the temperature of the object to be cooled, and has good Energy-saving benefits and broad application prospects.

**Table 1.** Industrial heat dissipation equipment and its critical operating temperature.

| Device name          | Deep well | Motor winding | Cable Connector | Hydraulic oil | Isolation switch | Sulfuric acid cooler | Cable conductor | Dry-type transformer | Brake knife |
|----------------------|-----------|---------------|-----------------|---------------|------------------|----------------------|------------------|----------------------|-------------|
| Critical temperature | 50°C      | 60-125°C      | 45°C            | 30-80°C       | 45-105°C         | 40-70°C              | 65-90°C         | 105°C                | 75°C        |

2. **Systematic research content and research objectives**

2.1. **Drive module**

The device is mainly composed of a sprocket, a cylindrical wheel and a chain composed of memory alloy springs connected with large and small chain links, supplemented by a one-way clutch to ensure the normal cycle operation of the device. This device is half immersed in a heat source (hereafter, taking hot water as an example), and the other half is placed in the form of exposure to air. The hot water surface is distinguished as upper and lower. There is a sprocket and two cylindrical wheels arranged in the order of sprocket-cylindrical-cylindrical wheel. The chain is interspersed to form an intermediate cylindrical wheel on the outside of the chain, and the remaining two wheels are surrounded by an S-shaped structure on the inside. The lower sprocket is the same as the upper sprocket and engages it on the inside of the chain.

The upper sprocket (hereinafter referred to as the large sprocket) and the lower sprocket (hereinafter referred to as the small sprocket) are engaged with the chain with a special structure (see the specific structure below), and the chain is in tension. In this state, this part is used as the drive of the device, and its power comes from the temperature difference between the surface of the chain and the surface. The chain is made of memory alloy springs with special inner and outer chain plates of different lengths, which has a retractable structure. At the same time, the selected memory alloy spring has a two-way memory effect. This characteristic makes the stiffness coefficient of the memory alloy spring different at different temperatures: when the chain in the elongation state is immersed in a high temperature environment, the spring shrinks when heated, and the inner and outer chain plates tighten so that the chain begins to tighten here, that is, using the shrinkage of the memory alloy spring to generate tension at this time, via the chain transmission, the sprocket is torqued at the meshing point of the lower sprocket, and the chain is driven by the assistance of the one-way clutch. The wheel rotates in one direction; when the chain enters the air somewhere, the spring cooling temperature decreases. It is experimentally verified that the stiffness coefficient of the memory alloy spring at room temperature approaches 0, and the chain no longer has a driving effect. The spring cooled in the air is stretched by the tension when passing through the tensioner, preparing for the next stage to enter the hot water again.
In summary, the device uses the expansion and contraction characteristics of memory alloy springs at different temperatures to drive the device. The sprocket is connected to the fan leaf, thereby driving the fan leaf to rotate, and aligning the fan blade with the part to be cooled to achieve the heat dissipation function. Research content:

![Device drive module overall diagram](image1)

**Figure 2. Device drive module overall diagram.**

### 2.2. Link module

The design of the chain link module includes an inner link plate, an outer link plate, and a memory alloy spring. The inner link plate and the outer link plate are staggered, and the shaft holes are connected. Both the inner and outer chain plates are slotted, and the rollers pass through the grooves of the inner and outer chain plates. Two adjacent rollers are connected by a memory alloy spring. When the memory alloy is shortened by the heat of the spring, the tensile force acts on the inner and outer chain plates through the rollers, so that the chain links are reduced.

![Link connection diagram](image2)

**Figure 3. Link connection diagram.**

### 2.3. Auxiliary module

The auxiliary module includes a cylindrical support wheel and a tensioner. The cylindrical support wheel plays a role in supporting the movement of the chain, which also makes the memory alloy spring cool further in the air. The tightening effect of the tensioning wheel promotes the original length of the water after it exits the water and prepares for the next time it enters the heat source, so that the device can run cyclically.

### 3. Research basis and feasibility analysis of the project

#### 3.1. Technical analysis

The following is the principle of the two-way shape memory alloy. The nickel-titanium alloy used in this project is processed into a certain shape during the high-temperature phase (austenite phase) and rapidly cooled, and then plastically deforms in the low-temperature phase (martensite phase) to form another shape. After the above steps are processed and then reheated, the reversible part of the martensite phase is inverted to the austenite phase and restored to the shape of the high temperature phase. When cooled, the structure changes and dislocation martensite is formed, and The shape when
it returns to the low temperature phase is the "two-way memory effect" principle of the nickel-titanium alloy used in the experiment, and the nickel-titanium alloy after repeated "training" is the two-way shape memory alloy.

Figure 4. Shape memory alloy formation principle.

3.2. Feasibility analysis

The performance test was performed on a Ni-Ti memory alloy spring with a wire diameter of 2mm, a diameter of 8mm, and an original length of 25mm at a water temperature of 60°C. Pull the spring to 65mm at room temperature. At this time, the dynamometer indicator floats around 0Kg. Then move the experimental equipment to 60°C water temperature environment and observe the dynamometer indicator is 6.405Kg. From this, it is calculated that the stiffness coefficient of the memory alloy spring under the environment of 60°C. is 1803N/m.

Figure 5. Number of dynamometers before and after the experiment.

In industrial production and actual life, the temperature of most of the objects to be radiated is above 50°C and generally has the characteristics of constant temperature and continuous output, which helps the device to continuously output energy.

Ni-Ti temperature memory alloy springs will gradually produce length changes and deformation forces at 50-80°C. Because industrial wastewater temperatures are more than 50°C, memory alloys can deform and output forces to a large extent, and can generate tensile force $F = 9.14N$ Since there are four memory alloy springs that generate tension and act on the sprocket at the same time, the resultant force on the sprocket is

$$F_h = 4 \times 9.14(N) = 36.56\ (N)$$

When the radius of the sprocket is $r = 51\text{mm}$, its torque is
Because there are 2 memory alloy springs on each link, and 4 springs doing work at the same time, that is, the unit runs two pitch distances within a unit time \( t = 1.5 \text{s} \), and its speed is \( n \)

\[
M = F_0 \times r = 1.865 (N \cdot m)
\]

\[
n = \frac{2 \times \Pi \times 60}{2 \times p \times t \times r} = \frac{60 \times \Pi \times r}{p \times t} = 504 \text{ (r/min)}
\]

Taking the power of the current radiator of the computer case is about 1.5-2.1W, taking 1.5W as an example, and the speed is rated at 2000r/min, the reduction ratio \( m \) required to convert the speed of this device to the radiator fan is

\[
m = 504: 2000 = 1: 4
\]

According to the information, the relationship between the torque \( T \) and the speed \( n \) and the power \( P \) is

\[
T = 9550 \times \frac{P}{n} = 9550 \times \frac{1.5}{2000} = 7.1625 (N \cdot m)
\]

And the torque \( M_s \) that this device can provide is

\[
M_s = \frac{M}{m} = \frac{1.865}{1} (N \cdot m) = 7.46 (N \cdot m)
\]

This output work can effectively drive the generator to rotate to achieve power generation, so it is feasible for theoretical operation.

### 3.3. Benefit Analysis

Because there are many types of heat sinks in life, it is not appropriate to conduct a unified analysis. Here, one of the application points of this project-industrial low temperature waste heat recovery, is used for benefit analysis. China’s primary energy consumption reached 4.62 billion tons of standard coal in 2018 (Converted to standard coal quality), of which the total waste heat resources accounted for about 17% to 67%, the total amount of waste heat resources that can be calculated in 2018 (converted into standard coal quality) are:

\[
46.20 \times 10^9 \times 17\% = 7.854 \times 10^9 t
\]

\[
46.20 \times 10^9 \times 67\% = 30.954 \times 10^9 t
\]

That is, the total amount of waste heat resources in 2018 can reach a minimum of 785 million tons of standard coal and a maximum of 3.095 billion tons.

According to the data, the average recovery and utilization rate of waste heat resources in China is about 30%, including waste heat from cooling media and waste steam waste heat:

\[
5.548 \times 10^9 \times (20\% + 11\%) = 1.720 \times 10^9 t
\]

Because the waste heat of the cooling medium and waste steam waste heat is medium and low temperature waste heat, and most of the medium is water, air and oil, it is currently difficult to recover the remaining heat resources.

Assuming that the project is put into operation on a large scale throughout the country, the medium and low temperature waste heat such as the waste heat of the cooling medium and the waste steam waste heat will be recovered for power generation. The recovery rate is 30%, which can save 5.16 × 10^8 tons of standard coal.

Take the market price of 5500 kcal coal at 500 yuan per ton as an example, one year can save:

\[
0.516 \times 10^9 \times 500 = 25.8 \text{ billion yuan}
\]

### 4. Conclusion

Based on the characteristics of the two-way memory effect of memory alloy, this project designed a heat dissipation device that can be continuously operated in a high temperature environment and uses thermal energy to drive. The device has the following application prospects.
1) Can be used in scenarios where energy consumption generates waste heat and waste heat, such as factories.
2) Can be used in appliances that require heat dissipation in industry and daily life.
3) Can be used as a temperature control mechanism in life.

The device does not need to rely on external power when it works, and no pollution is generated. It has good energy saving benefits. At the same time, due to the wear resistance of the memory alloy, the life of the device is higher than that of the ordinary heat sink, which has higher economic benefits in the long run. However, memory alloys are still in the research stage, and more research needs to be done to truly apply them to life. However, with the continuous development of smart materials, research on memory alloys will also be valued. Therefore, this project has broad application prospects.

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