A Water-cooled Radiator Driven by Memory Alloy

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Keywords: Water-cooled electronic radiator, Ni-Ti memory alloy, Dual diameter pulley turbine, Cobweb model.

Abstract. The traditional electronic equipment cooling system uses electric to drive water pump, it will consume energy. The motor operating power is constant, resulting in a waste of power. After cutting off the power supply, water pumps stop working so that the heat inside the appliance can’t be cleared. In this paper, use the recovery characteristics of shape memory alloy to create dual diameter pulley turbine, the two groups of alloy wires including heat coil and cold coil drive dual diameter pulley turbine rotating to form a pump system to replace the traditional water cooling system driven by an electric pump in order to save energy. Then the article analyses the system stability with Cobweb model. Realize the innovation of structure and principles. Enhance environmental protection of the water-cooled units.

1. Traditional Way of Driving Water-cooled System

Water cooling known as liquid cooling, the efficiency of water-cooled is 20 times than air-cooled. In addition to the specific heat capacity and density of liquid is much larger than gas, water cooling can make the system structure more compact. Cooling system need to use a pump to provide pressure to circulate water in the system, cooling fluid make heat transfer process between the wall of pipe and radiator. Traditional water-cooled electronic radiator’s water pump impeller is rotated by electric motor to drive water flowing in the pipe. Electric driver will consume some energy. The use of electric-driven motor makes output power a constant, resulting in a waste of power. After cutting off the power supply, water pumps stop working, so that the heat inside the appliance can’t be scattered, causing the loss of electrical life. As can be seen, there are many non-environmental considerations in traditional water cooling system.

2. Memory Alloy Driven Approach of Water Cooler

Nickel-Titanium memory alloy will form a reversible thermo-elastic martensitic transformation when cooled below a certain temperature. The recovery of shape can be achieved at high temperatures. When the shape memory effect occurs, it will result in a great force so that we can use the shape memory effect to transfer heat into mechanical energy. In 1977, Johnson proposed dual diameter pulley turbine engine [1]: the pulley guided nitinol spiral coil through cold sink and hot water tank, one coil is suspended on a dual diameter pulley turbine to cause the stretch effect; the other is suspended to cause compression effect. The heating coil’s tension is greater than the cooling coil’s tension, so it will result in power outputting.

As the Fig. 1 shows, with the use of memory alloy dual diameter pulley turbine principle, the heat sink pulley 3 is provided in the collector device 5, the heat generated by the heating element 5-1 go through the first metal radiator 4 so that nitinol wire 13 wounded on the hot groove pulley will produce tension by thermal expansion; cold groove pulley 10 is provided on slot 9 of the cooling liquid reservoir 8, the nitinol wire wound on a cold groove pulley will produce tension by cold contraction; the two sets of coils are set on the same differential double diameter pulley 1. This time, the power done by the hot spiral coil’s tension is greater than the power done by the tension of the cold spiral coil, making dual diameter pulley rotates by the force difference between the hot helical coil and cold spiral coil, so as to drive the impeller 12 and the linkage 11 which connected to the...
pulley to rotate, so the pump device is formed. This pump system instead of the traditional electric water-cooled cooling system pumps, drive cold water through the second conduit 2-1 from the cold water storage tank, and out to the enclosed drive slot 14, and then flows go through the first conduit 2 to collector device, cold water absorb the heat in element area where the heat continue to heat up to form hot water, then flow through the heating zone by third conduit 2-2 into the heat exchanger, radiator cooling fan 7 and metal heat exchanger 6 will make heat dissipation of water. The cooled water flows back to 8 to achieve the purpose of cooling the heating elements.

As can be seen, this work retains the traditional water cooler collector modules, flow ducts, etc. Add the heats storage module and memory alloy modules, to use memory alloy heat engine to replace electric motor cooling pumps. Memory alloy driving the water cooler can be adjusted with the internal temperature of the power changing size. After the heating elements cutting off power, the heat pump system can continue to work driven by disperse heat, which will help prolong the life of electrical appliances, and enhance the cooling system’s environmental protection.

3. Theoretical Analysis of Stability with Cobweb Model

The calculation formula for the efficiency of memory alloy engine is shown below [1]:

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\eta = \frac{\Delta T(0)}{T_0(0)} \left( \frac{\ln(1 + \xi)}{\xi} \right) \frac{T_0(\sigma)}{T_0(0)} + \frac{C_p \Delta T_0}{\Delta Q(0)}
\]  

(1)

According to the data of nickel—titanium alloy [1]: \( \xi = 0.10, \ C_p = 4 \text{card/mole}, T_0 = 100K, \Delta Q = 100\text{card/mole}, \Delta T_0 = 100K, A_f = 110K, M_f = 70K \), obtained the efficiency of heat engines is 20%.
By using the knowledge of thermodynamics, we can know the memory alloy heat engine power calculation formula is:

$$P = \Delta q \eta = 0.2 \Delta q \eta$$  \(2\)

For example, use a typical computer water cooler to analyze the stability of this new type water cooler. According to the data [3], when the traditional computer water cooler’s pump engine at 70 degrees (close to the electronic components of a stable operating temperature limit) and 21 degrees (water temperature) when operating, the speed is 2000 rpm, power is 0.217 watts. Heat transfer flow \(\Delta q\) is about 1.8w.

The acting loss coefficient \(\eta_{loss}\) (including hydraulic pipeline flow loss and the rotation of the impeller friction losses, etc.) is about 0.7 according to data [2]. We can calculate the power of memory alloy pump using Eq. 2.

$$P = \Delta q \eta \eta_{loss} = 0.2 \times 0.7 \times 1.8 = 0.252w$$  \(3\)

It can be seen that the maximum power is more than 0.217w, so memory alloy pump performance can meet the needs of water cooling max limit.

Now, use Cobweb model to analyze the working stability. First, analyze the influence between the memory alloy pump and heat source.

![Fig. 3 Influence between the memory alloy pump and heat source](image)

![Fig. 4 Cobweb analysis](image)

It can be seen that the power of the memory alloy and the element temperature (or heat) there is a negative feedback phenomenon, power and temperature in the upper and lower shock. Set \(X_k\) to the power of the memory alloy pump at the K time period and \(Y_k\) to the temperature of the heating element for the period K, then the following formula can be obtained:

$$\begin{cases} x_{k+1} = h(y_k) \Leftrightarrow y_k = g(x_{k+1}) \\ y_k = f(x_k) \end{cases}$$  \(4\)

Among them, the h function as an increase function represents the positive feedback on the increase in power of temperature increasing, its anti function g is also an increase function; the f function as a reducing function represents the negative feedback on the temperature reducing of the power increasing.
By \( y_k = f(x_k) \quad x_{k+1} = h(y_k) \Leftrightarrow y_k = g(x_{k+1}) \), it can be pushed \( x_1 \rightarrow y_1 \rightarrow x_2 \rightarrow y_2 \rightarrow \ldots \). When \(| K_f | < K_g \), we can know \( x_k \rightarrow x_0, y_k \rightarrow y_0 \), that it is stable:

For the works of the cobweb model, with the function \( f \& g \) approximation for linear, mathematics to describe as:

\[
\begin{align*}
g(\lim x_{n+1}) > \lim y_n, g(0) = 0 \Rightarrow K_g > \lim \frac{y_n}{x_{n+1}} = M \\
f(0) = \lim y_n, f(\lim x_n) = 0 \Rightarrow |K_f| = \lim \frac{y_n}{x_n}
\end{align*}
\]

The meaning of \( g(\lim x_{n+1}) > \lim y_n \) is that the actual power of the memory alloy when the heat source reaches the limit temperature is less than that of the memory alloy. So we can push \(| K_f | < K_g \) which means the system can work in a stable condition.

4. Summary

Cooling of electronic equipment is mainly divided into air-cooled and water-cooled, water cooling with its high thermal efficiency, low noise characteristics is more favored. The traditional water cooling equipment pumps has many non-environmental factors because of electric-driven way. To solve the problem above, according to the recovery characteristics of memory alloys, use shape memory alloys solid heat engine driving pump instead of the traditional water-cooled electric motor driven pump for the energy-saving purposes, which will help prolong the life of appliances, in line with the sustainable development concept, enhance the cooling system’s environmental protection, and achieve innovation.

Reference

