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Smart regulator for temperature control of oil in a hydraulic system

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ABSTRACT : *The main objective of this work is to regulate the flow of oil in a hydraulic system and maintaining its temperature within a specific range by employing a shape memory alloy. The project involves design and development of the regulator. Currently in hydraulic systems, a thermometer is used for periodic checking of oil temperature in the reservoir. One of the functions of a reservoir is to reduce the temperature of oil, whose effectiveness depends on the size. An automatic temperature regulator can help reduce the large size of reservoir and maintain the temperature of oil circulating in the system. The basic elements of the device are the Shape memory alloy, A helical tension spring with the appropriate stiffness against the SMA, An Aluminum rod which connects the restoring element and the SMA a spool is combined with the connecting rod to open and close the hot fluid inlet, separate hot and cold fluid inlets and an outlet. Apart from this the mechanism can also be used as a Temperature check valve in a system. If the operating temperature exceeds the limit the flow through the valve is restricted. A three dimensional virtual model of the oil temperature regulator was made by using modeling software. Finally the product was developed/ fabricated and experimented.*
Keywords- *NiTiNOL, Regulator, Shape memory alloy, Smart Materials, Temperature control.*

I. INTRODUCTION

Plastics and composites have dominated the material sector in our industries. These came in to existence in the last one, one and half centuries. In the midst of their respective eras came along an unusual material which is called Smart material. Smart Materials change their properties in response to external stimulus. It involves both sensing and actuating. Unlike conventional materials which only sense and change shape but do not act. Their intelligence comes from ability to transform basic forms of energy such as mechanical strain to electricity, or thermal to strain etc. Smart materials can receive, transmit, or process a stimulus and respond by producing a useful effect that may include a signal that the materials are acting upon it. This paves way for a functionality that cannot be expected from ordinary materials. They also pack a higher energy density, making it possible to have lighter and smaller devices with greater controllability. There are many such materials out of that SMA (Shape Memory Alloy) is proposed as a better material for present work. Shape Memory Alloy is a metallic alloy which has the ability to “remember” a preset shape. It can be easily deformed in its cold state but upon heating regains its original shape.

II. METHODOLOGY

The main objective of this work is to regulate the flow of oil in a hydraulic system and maintaining its temperature within a specific range by employing a shape memory alloy. The project involves design and development of the regulator. The basic elements of the device are the Shape memory alloy, a helical tension spring with the appropriate stiffness against the SMA, An Aluminum rod which connects the restoring element and the SMA; a spool is combined with the connecting rod to open and close the hot fluid inlet, separate hot and cold fluid inlets and an outlet. Initially a prototype was built to ensure that the SMA worked as expected. The prototype was subjected to same working conditions as that of the model and thus errors were improvised and necessary modifications were made in the model design. Extreme temperature and pressure conditions were taken care by suitably designing the model and selecting the appropriate materials.

III. MODELING AND COMPONENTS FUNCTION

3.1 Shape Memory Alloy Helical spring:

The SMA Spring is one of the prime components required for the working of the mechanism. It is easily deformable in its cold state and regains its original shape when subjected to heating. In the device it is connected to the connecting rod and the fixture on the outlet pipe. Whenever the SMA spring contracts it pulls the connecting rod which pulls the spool along with it.

3.2 Spool and Connecting rod:

The spool and connecting rod are one whole component. The spool is the free moving component. The spool in the spool casing resembles the piston cylinder arrangement.

3.3 Helical Tension Spring:

This is another important component in the device which is hooked to the spool and placed above it.

3.4 Inlets:

3.4.1Cold inlet:

The cold fluid flows to the device through the cold inlet. It allows constant flow of the fluid to the device. This inlet is connected to the mixing chamber in which mixing of the cold and hot fluid, coming from the hot inlet, takes place and the resultant is sent to the outlet pipe. Hot inlet: The hot inlet is connected to the spool casing. The hot fluid flows to the device through the hot inlet. The flow is either restricted or open depending on the position of the spool.

3.4.2 Outlet:

The outlet is a pipe which gives out the resultant fluid from the mixing chamber.

The detailed structure of the smart regulator is as shown in below Fig (1).

Fig.1.The developed smart regulator

IV. WORKING METHODOLOGY

There are basically three important components in the device, namely SMA, connecting rod-spool and the helical tension spring. Initially the SMA is in its expanded form and the spool is above the hot inlet thereby letting the flow of hot fluid into the regulator. Both the inlets are open and hence mixing takes place. As long as the resultant temperature remains under the transition temperature of the SMA the position of the spool remains unchanged and therefore both inlets remain opened. But as and when the temperature goes beyond the transition temperature the SMA spring begins contracting and the spool is pulled downwards thereby closing the hot inlet and allowing the cold fluid to neutralize the present hot fluid in the mixing chamber. This ensures that the temperature at the outlet is always either equal to or below transition temperature. After a few seconds the resultant fluid temperature quickly returns to a lower temperature as the cold fluid is uninterrupted. Due to the low temperature the SMA also cools down and now the transition from the high temperature phase to low temperature phase occurs making it easily deformable again. Due to the tension in the helical tension spring the spool is pulled upwards and the SMA is not strong in its present martensitic phase. This cycle keeps repeating whenever the temperature goes beyond the limit thereby maintaining the outlet temperature within the specific range. The following Fig (2) shows the 3D model and working mechanism of the regulator.

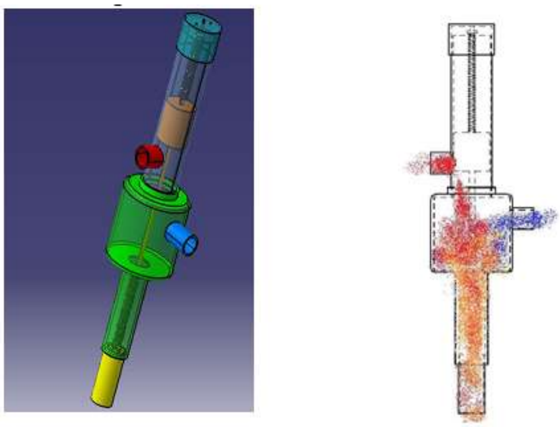

Fig.2. 3D model and working mechanism of the regulator.

V. EXPERIMENTATION AND RESULTS

According to our hypothesis, however hot the inflowing oil may be, the outlet oil that we obtain must always be ranging from the room temperature to 45oC(transition temperature of the SMA). We repeated our experiment to verify that our results are consistent and not just an accident. Basically the experiment is divided into 3 sets so that clearly understand the devices behavior' under different circumstances.

Experiment no. 1:

- At first, we needed to confirm whether the spool moved properly as we predicted.

- Only hot oil was poured into the device and within fraction of a second, the spool moved down covering the entire hot inlet.
- Then only cold oil was poured into the device and within few seconds the spool moved up opening the hot inlet.

Result:

The spool moved smoothly covering and opening the hot oil inlet as expected and the SMA reacted very quickly.

Experiment no. 2:

- The setup was mounted on the stand and a trough was placed beneath to collect the sample oil. A thermometer was placed in the trough to check the resultant temperature.
- Both hot oil and cold oil were supplied to the device at equal flow rate.
- After the oil supply was cut off, the thermometer reading was noted down.

Result:

When the flow rate of both hot oil and cold oil is constant, then the outlet oil temperature that we obtain will always be in the range of room temperature till 45^{o}C.

Experiment no. 3:

- Another question that raised now was "what if the hot oil flow rate is greater than the cold oil flow rate?" So it has been conducted another experiment to answer this question, without a specific expectation about what the experiment will reveal, or to confirm prior results.
- The setup was mounted on the stand and a trough was placed beneath to collect the sample oil. A thermometer was placed in the trough to check the resultant temperature.
- Hot oil was supplied to the device at a faster rate than the cold oil.
- After the oil supply was cut off, the thermometer reading was noted down.

Result:

When the flow rate of hot oil is higher than that of the cold oil, then the outlet oil temperature that we obtain will not be within the expected range. This case does not satisfy our hypothesis.

VI. CONCLUSIONS

The chosen task was to design and fabricated a regulator to control the temperature of oil in a hydraulic system such that the obtained oil from the device will always be within room temperature and 45oC. For this purpose, a smart material was taken and then developed a mechanism to suit the purpose. It has been found that SMA is suitable to serve the purpose and the device can be used to regulate the temperature of any other fluid.

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