Research on Pressure Measuring Device with Magnetic Fluid

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Abstract. Magnetic fluid is a novel material which could be applied in many fields including sensors, sealings, biomedicines, and so on. Its super magnetism and fluidity could be used in the sensor as an inducting core. Magnetic fluid and its characteristics were introduced to adapt to the application in the pressure measuring devices. A pressure measuring device with magnetic fluid was proposed and the structure was analyzed and designed according to the characteristics of magnetic fluid. The working principle of pressure measuring device with magnetic fluid was analyzed, and the structure of pressure measuring device was designed and reformed to avoid the overflow and recovery of excessive of magnetic fluid. One arm of the U tube was designed to be a large cylinder to storage large quantities of magnetic fluid. The higher the required precision is, the larger the diameter of one arm should be designed with respect to the other arm of the tube. The measuring range of designed device could also be adjusted as needed. The measuring efficiency of the device could be improved by the designing and reforming work.

1. Introduction
Magnetic fluid is a novel functional magnetic material which is composed of nano-magnetic particles, surfactant and base liquid [1]. It possesses lots of unique characteristics such as supermagnetism, fluidity, lubricity, etc.[2]. Because of the unique characteristics of magnetic fluid, it could be applied in lots of fields including sensors, sealings, biomedicines, damping, and so on [3-11].

The application of magnetic fluid in pressure measuring field is a hot research subject in recent years[12]. The pressure measuring device with U tube could respond rapidly and measure parameters sensitively and stably. However, the device with U tube has some problems in measuring work. For example, if the pressure value for measuring exceeds the measurable limit of the device, magnetic fluid in U tube will overflow from the tube arm. Then environment around the tube will be polluted, and magnetic fluid will be wasted. So as magnetic core, magnetic fluid in the tube should be added to the required volume to induct magnetic field for measuring the pressure parameters, which is inconvenient for measuring work. The recovery work of magnetic fluid is a necessary work to start a new measuring work. Then the preparation before measuring should spend time and the work efficient will be reduced.

To overcome the problems such as inconvenience for recovering magnetic fluid, and long time should be spent to recover the magnetic fluid overflowed. a new pressure measuring device should be designed and reformed to solve the problems caused by the overflow of magnetic fluid.

In the designing and reforming work, the structure of tube should be redesigned and reformed to satisfy that even if the pressure for measuring should exceed the measuring range of the device,
magnetic fluid will not overflow from the tube in the device. It is an important work to improve the characteristics of the pressure measuring device with magnetic fluid.

2. Structure Design

To solve the problems caused by overflow of magnetic fluid in tube arm, a new structure of pressure measuring device was designed and reformed. The structure designed includes non magnetic tube(1), magnetic fluid(2), current coil(3), induction coil(4), measure and display device(5), and power supply(6), which is shown in Fig.1. Because the non magnetic tube is a container for magnetic fluid, the non magnetic tube is designed from the shape of kettle. There are two arms parallel with each other. One arm is designed with small diameter and the other arm is designed with large diameter. The air inlet is set at the end with the arm of the non magnetic tube with small diameter. A small air vent is set at the top of the large arm to prevent the air pressure above the magnetic fluid in the large arm to increase.

![Structure of pressure measuring device with magnetic fluid](image)

1. non magnetic tube 2. magnetic fluid 3. current coil 4. induction coil 5. measure and display device 6. power supply

**Figure 1.** Structure of pressure measuring device with magnetic fluid

Fig.2 shows the specific shape of the non magnetic tube which could be divided into four parts named horizontal installation part(101), measuring part(102), connection part(103), and storage part(104). The horizontal installation part is to input the air and connect the inlet pipe conveniently. The measuring part is to contain the magnetic fluid core in it. There are two coils rounded the outside wall of the measuring part. One coil is the current coil which is rounded outside the tube arm connected with the power. The other coil is the induction coil which is rounded outside the current coil. The induction coil is connected with the measure and display device for measuring the induction current produced by the induction changes in the coil. The storage part is designed as a large cylinder shape to storage the excess magnetic fluid flowed from the measuring part and connection part of the non magnetic tube. The connection part is to connect the measuring part and the storage part successfully. At the top of the storage part of the non magnetic tube, an air vent is designed and set to prevent the air pressure in the storage part to increase.

Magnetic fluid in the non magnetic tube should be prepared with high magnetization and low viscosity. At the beginning, the volume of magnetic fluid could be set according to volume of the storage part and the pressure range for measuring. For example, the magnetic fluid volume could be half of the storage part volume of the non magnetic tube.
3. Working Principle

The pressure measuring device with magnetic fluid was designed according to the working principle set in Fig.3. It is not necessary to set a judgment module in the working process designing.

At the beginning, magnetic fluid was injected into the non magnetic tube in Fig.1. The position of magnetic fluid surface could be set at the middle height level of the tube. The volume of magnetic fluid could be set as half of the tube volume. The current coil is connected with power supply. The magnetic field produced by the current coil was designed according to calculations. The air pressure above the magnetic fluid surface column in the measuring part is equal to the air pressure above the magnetic fluid surface in the storage part of the non magnetic tube.

The air pressure is input through the air inlet at the end of the horizontal installation part of the non magnetic tube. Under the action of the air pressure, magnetic core (magnetic fluid) in measuring part of the non magnetic tube moves. The magnetic flux in the induction coil changes with the moving of the magnetic fluid column in the measuring part. There is an induction current produced by the magnetic flux changes in the induction coil. The induction current could be measured and converted into the air pressure value to display on the screen of the device.

If the air pressure to be measured increases, the magnetic fluid column in the measuring part keeps moving with the increasing of air pressure. With the moving of magnetic fluid column in the measuring part, the magnetic flux in the coil keeps changing until the magnetic fluid column leaves out of the measuring part of the non magnetic tube which is shown in Fig.4. Then magnetic flux in the induction coil will not change. So the air pressure to be measured exceeds the measuring range of the pressure measuring device with magnetic fluid. Thus the overflow or long backflow time of magnetic fluid is avoided. At this time, an alarm device could be connected in the circuit to inform users to cut off the air input. Even if there is no one to cut off the input air immediately, the magnetic fluid column stops until it keeps moving to the storage part of non magnetic tubes. Because the cross section of the tube increases immediately, the air to be measured could be shaped as bubbles to come out of magnetic fluid and leave out through the air vent on the storage part.
Figure 4. Over range state of pressure measuring device

Once the air pressure is cut off, magnetic fluid column in the non magnetic tube could be backflow to the initial state immediately. It is not necessary to readjusts or other operations. Then it could enter the next measuring work immediately without affecting efficiency.

The diameter of the measuring part is quite less than the diameter of the storage part of the non magnetic tube. So the position of magnetic fluid surface in the storage part could be treated as no changing. So the precision of the device could be designed and adjusted by changing the proportion of the measuring part diameter to the storage part diameter. The measuring range could be adjusted by adjusting the volume of magnetic fluid in the non magnetic tube.

4. Innovations and Conclusions
A non magnetic tube with magnetic fluid storage was proposed and designed to avoid the overflow of magnetic fluid caused by over range of measuring parameters. The diameter of the storage part could be designed as large as required to satisfy the conditions that the whole magnetic fluid in the measuring part could be removed into the storage part without overflow and pollution for environments around.

The non magnetic tube with storage part will not cause any damage to the measuring device when the measured air pressure exceeds the measuring range of the device. Only the air input is cut off, the magnetic fluid column returns to the initial position immediately to prepare to the next measuring work. The long recovery time of magnetic fluid is avoided and the work efficiency is improved.

The measuring range of the device could be adjusted by adjusting the magnetic fluid volume in the non magnetic tube as needed. The measuring range could be adjusted and widen by changing the volume of magnetic fluid in the non magnetic tube. The measuring efficiency of the device could be improved by the designing and reforming work.

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