Study on developing application fields of micro differential pressure sensor with magnetic fluid

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Abstract. Magnetic fluid is a new novel nano magnetic material which could be applied in many engineering fields. Micro differential pressure sensor is a potential application field for measuring technology. Magnetic fluid is introduced. The potential engineering application fields are explored and researched, which includes industrial boiler, converter in steelmaking furnace, measuring the weight of solid, the distribution of pressure field, air volume, respirator, mine passage, warehouses, bioengineering, textile workshop, predicting leakage of container, fluid throttle, medical devices, and so on. Sensors with magnetic fluid could certainly create a new way for engineering application.

1. Introduction
Differential pressure sensor is widely used in weapon equipment matching and industrial process control. Since the 1950s, many kinds and models of differential pressure sensors have been developed. It has the characteristics of high sensitivity, small volume and relatively simple structure. However, the design and development of micro differential pressure sensor has been relatively slow.

With the development of science technology, sensor is increasingly important for measuring and auto-control. In some measuring fields, kinds of novel materials are popular. For micro differential pressure measuring, magnetic fluid is a new inductance core for sensors. Magnetic fluid is a new novel nanometer magnetic material which could be applied in many engineering fields[1-3]. It is composed of magnetic particles, surfactant and base carrier fluid[4-5]. The composition of magnetic fluid is shown in Figure 1.

Figure 1. Composition of magnetic fluid

New potential application fields for magnetic fluid in micro differential pressure measuring were explored and discussed in the following.
2. Application fields

With the development of computer technology, we can make a breakthrough in dynamic measurement, medicine and monitoring if the micro differential pressure could be measured and processed. In the process of braking control, small flow gas can be measured by matching with throttling element, and small leakage of oil container in gas station can be detected by matching with liquid level system. In a word, people no longer ignore the micro differential pressure, but use the micro differential pressure signal measured to achieve breakthroughs in their fields[7-12].

2.1. Industrial boiler

An industrial boiler example is shown in Figure 2. Because of lots of pipes delivering the gas and liquid, the pressure change should be controlled accurately for safety. The micro pressure to be measured for industrial boiler includes: air pressure at each point on the air supply channel, negative pressure at each point on the induced air channel, furnace negative pressure and pressure difference of air supply volume, etc. In the past, membrane box micro manometer or hall, differential micro pressure transmitter and other instruments were widely used. Most of the output signals of these instruments are not standard signals, and there are some problems such as unstable zero point, large error and high failure rate.

For example, in the boiler of the power plant, the static pressure measurement can’t correctly reflect the flow speed and condition in the primary and secondary air pipes. Because there is no accurate monitoring means and meters, the operators can’t effectively adjust the combustion of the boiler. The boiler operates under the condition of uneven air distribution, which will cause fire delay and combustion instability in serious cases, leading to flameout and shooting. Using micro differential pressure sensor to detect the change of flow velocity can avoid the occurrence of pipe plugging accident and improve the thermal effect of boiler.

2.2. Converter in steelmaking furnace

In the early stage of converting, because the temperature of molten steel is low silicon, manganese and other elements easy to oxidize in molten iron are first oxidized while converting in steel making furnace. The oxidation rate of carbon is low, flue gas and CO in flue gas and is little. With the increase of temperature in the middle and later stage of blowing, the reaction of carbon and oxygen is violent, the furnace gas volume increases greatly, and the content of CO in the furnace gas increases gradually. The addition of bulk materials in the blowing process makes the furnace gas volume increase a lot in a moment. According to the signal of micro pressure difference between furnace mouth and atmosphere, which is collected by a device, the automatic regulating device control the flow of flue gas by adjusting the opening of secondary venturi throat. Thus the differential pressure between converter mouth and atmosphere is relatively stable at the set value, and the balance between converter flue gas volume and fan extraction volume is maintained. The dedusting efficiency is improved and the CO content of converter gas is ensured. So, micro differential pressure sensor plays a very important role in the steel industry.
2.3. Measuring the weight of solid
The micro differential pressure sensor can also be used for a solid weight meter. For example, micro differential pressure sensor could be applied in measurement system of raw coal loading of ball mill in power plant. The raw coal enters the ball mill for grinding under the driving of the hot air door through the coal hopper and the coal feeder. Each ball mill has a certain amount of coal loading. Under this rated amount of coal loading, the grinding efficiency is the highest. Generally, the air pressure difference between the inlet and outlet of the ball mill is used as the indirect measurement of the amount of coal loading. If the loading amount of the coal increases, the resistance of hot air passing through the ball mill increases, thus pressure difference increases. Otherwise, if the loading amount decreases, the pressure difference also decreases. So the amount of coal loading can be indirectly known by measuring pressure difference.

2.4. Measuring the distribution of pressure field
In the measurement of pressure distribution by aerodynamics, the probe is usually used to measure the pressure with inclined water column. And then the size and direction of the pressure value are calculated. In this way, the measurement error is large and the test data is slow. By using the micro differential pressure sensor, the differential pressure can be directly converted into a measurable electrical signal, and the distribution of the pressure field can be displayed directly after being processed by programmable logic controller.

2.5. Measuring air volume
In the large air conditioning system, the air volume is always fed before the heater is started for heating. The accident will occur if the heater is started with no air volume. At present, most of them are interlocked by temperature measuring elements or by fan start button signals. However, indirect measurement often leads to accidents. For example, when the fan motor is started, but the belt pulley is loose and there is no air volume, while the heater heating will generate a fire. The air volume pressure measurement is a direct parameter measurement, which can be adjusted according to the air volume. The differential pressure sensor is so important for measuring air volume measurement.

2.6. Application in respirator
In the artificial respirator shown in figure 3, the pressure difference generated by the throttle is used to measure the expiratory flow of the patient. According to the flow size and frequency, the computer automatically carries out artificial respiration. When the expiratory flow of patients is very small, the pressure difference is very small. The purpose of rescuing patients can be achieved by measuring the micro pressure difference of the patients’ expiratory flow. By applying the measurement of micro pressure difference, the application value of respirator increased.

![Figure 3. The respirator](image)

2.7. Application in mine passage
Micro differential pressure sensor is also very important and widely used in mine ventilation measurement. In mine passage, the air flow is usually constant. However, the air flow in the mine
passage changes to be abnormal while accident such as fire occurs. Even in mine fire and forest fire, the size and direction of air volume can be measured by probe and micro differential pressure sensor. According to its maximum value, the oxygen supply condition can be prevented, so that the fire accident could be controlled. In addition to being used in the coal system, the micro differential pressure sensor can also be widely used in the laboratory of industries and pipeline flow test on-site in chemical and power systems.

2.8. Measurement of micro pressure difference between warehouses
Micro pressure difference sensor could be used for measuring the pressure difference between warehouses. The pressure difference value between two warehouses should be controlled at a constant to ensure the safe conditions.

2.9. Application in bioengineering
In biological research or cultivation, the air in the space should be discharged to the outside, and the polluted air should not be allowed to enter the biological space. Usually, the sterilized gas is introduced into the biological space, and then discharged to the atmosphere through the biological space. At the same time, the pressure of biological space is not allowed to be too much higher than atmospheric pressure. The micro differential pressure sensor is used to measure the pressure difference between the space and the atmosphere, and the measurement value is used to control the intake air flow. In this way, it can realize that organisms will not be under great pressure, and small pressure difference can save energy.

2.10. Application in textile workshop
The constant humidity condition is considered in the textile workshop. The air in workshop and the outdoor air are not allowed to flow into each other. Generally, micro positive pressure must be maintained indoors. If the pressure in the workshop is 2kPa higher than the atmosphere pressure, it is harmful for the health of the workers in the workshop. So the pressure difference between the indoor air and the outdoor air is suggested in the range of 25-50Pa according to the international labor law. For this kind of workshop, the intake air volume must be adjusted according to the differential pressure measured by the micro differential pressure sensor to meet the micro positive pressure requirements of the workshop.

2.11. Measuring leakage of container
Any leakage of oil container in gas station is not allowed due to the safety. Oil container leaks due to age, and if the liquid level drops by 0.25 mm in 24 hours due to leakage, the leakage into groundwater will cause environment pollution. To prevent the environment pollution, the leakage could be monitored by micro pressure difference sensor and computer. So the micro pressure difference sensor would be more and more popular applied in measuring the leakage of the oil container in gas stations.

2.12. Measuring the micro differential pressure of the fluid throttle
Usually, when calculating orifice, venturi, pitot tube and other throttling parts, the pressure difference generated by throttling parts is too small to measure. So the resistance is increased artificially. However, the artificial increasing wastes energy, and even small flow can't be measured according to the accuracy of the device. The small flow in large diameter pipe could be measured by micro pressure difference sensor, which is very significant.

In the measurement system of throttling device, the micro differential pressure sensor receives the differential pressure of the fluid from throttling device, and converts it into digital signal and analog signal output through the differential pressure sensor. So the flow of the liquid is obtained and the measurement is achieved.
2.13. Measuring blood flow in medical devices
In medical devices, the blood flow could predict some diseases. The pressure difference in blood flow may be 2.5Pa. The micro pressure difference sensor and computer could be applied broadly in the medical devices.

In summary, the micro pressure difference with magnetic fluid is a novel sensor for measuring pressure difference. It could be certainly create a new way in many fields.

3. Summary
Magnetic fluid is introduced. As an inductance core of micro differential pressure sensor, there are lots of potential application fields such as industrial boiler, converter in steelmaking furnace, measuring the weight of solid, the distribution of pressure field, air volume, respirator, mine passage, warehouses, bioengineering, textile workshop, predicting leakage of container, fluid throttle, medical devices, and so on. In summary, sensors with magnetic fluid could certainly create a new way for engineering application.

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