Study on Measurement and Alarm Device with Magnetic Fluid for Air Flow Safety

Ruican Hao*, Huagang Liu, Shang Wang, Jinru Ma
School of Automotive Engineering, Beijing Polytechnic, Beijing, China
haoruican@bpi.edu.cn

Abstract. For many engineering fields, the air flow should be controlled into a safety range to ensure the production safely. A novel flow measurement device was designed for large safety range. A separable structure of the device was proposed to meet the convenience to carry. Magnet and magnetic fluid was selected as an inducting core. The characteristics of the inducting core were researched. The working principle of the measurement and alarm device for air flow safety was introduced and analyzed. The separable structure was designed to achieve two modes of the measuring and alarm device that one mode is for measuring and alarming work and the other mode is for storing and transporting conveniently. A pipe was designed for the air to pass through. Two coils were designed and chosen to be set up at two ends of the pipe to detect the changes of the internal magnetic flux and then alarm for the changes. An adjustment element was designed and set into the pipe to adjust the position of the inducting core to satisfy the requirements of the working conditions. The designed device is feasible to keep the air flow safely and to alarm when the air flow exceeds safety range.

1. Introduction

The flow sensor with magnetic fluid has lots of advantages such as the simple structure, the low cost and the strong induction signal, which has wide application fields including mechanics, aerospace, pipeline leak detection, and so on.

However, there are some disadvantages of the existing air flow sensor with magnetic fluid. Firstly, for the large measuring range, in addition to increasing the spring elastic coefficient, the length of the non magnetic tube has to be increased to expand the sensor’s measuring range. In this way, the length of the sensor increases, the volume increases, and it is not convenient to carry. Secondly, for another example, for some workshops, it is not necessary to measure the specific value for workers, only a flow range is required. It spends too much to measure the specific flow value. So, a measuring device for a certain flow range is necessary. Thirdly, the alarm device of the existing measuring sensor should be improved. It could alarm only when the air flow is too high. Actually, either the flow value is too high or too low, the alarm device should be activated. For example, in textile workshop, the proper ventilation is necessary for workers’ health. But the flow sensor with magnetic fluid could only alarm while the air flow is too high.

So the functions and characteristics of the sensor with magnetic fluid should be improved, especially for the conditions only alarm but not specific flow value is need. And the configuration of the device should be designed again for large flow range.
2. Magnet and Magnetic Fluid
Magnet and magnetic fluid are designed as parts of the inducting core for the measuring and alarm device. Magnet is mainly used to measure the flow change and the position of the magnet could be detected by the coil wound outside of the pipe. Magnet could be flown by the gas passed through the pipe and be controlled by a spring. Magnetic fluid is selected to bond with magnet to lubricate between the pipe and the magnet.

Magnetic fluid is a novel nano functional material [1-3] which could be controlled by magnetic field and has lots of applications [4-8]. Magnetic fluid could be attracted to the surface of the magnet. So the bonded magnetic core including magnet and magnetic fluid was designed and selected as the inducting magnetic core for the coils rounded outside the pipe. Fig.1 shows the bonded magnet and magnetic fluid core [9].

![Fig.1 Bonded Magnet and Magnetic Fluid Core](image1)

3. Principle of the Device
The function of the measurement and alarm device is that if the air flow value is in the safety range, then output normal on the display screen, else alarm and adjust the ventilation. Fig.2 shows the working flow chart of the measurement and alarm device.

![Fig. 2 Working Flow Chart of the Device Designed](image2)
In the initial state, input the air flow through the measuring pipe. The inducting core including magnet and magnetic fluid is designed in the middle of the pipe as a sensing medium to generate magnetic flux. The next step is to judge whether the inducting core is in the inducting coils. If the inducting core moves into the upper limit detecting coils, there is a change of magnetic flux in the upper limit detecting coils. Then there is an induced current in the inducting coils and the alarm device set in the circuit works to alarm, so that workers could reduce the ventilation. If the inducting core moves into the lower limit detecting coils, there is a change of magnetic flux in the lower limit detecting coils. Then there is an induced current in the inducting coils and the alarm device set in the circuit works to alarm, so that workers could increase the ventilation through the pipe. If the inducting core is between the upper limit detecting coils and the lower limit detecting coils, it shows that the ventilation through the pipe is normal. Then characters like ‘Normal’ could be displayed on the screen connected in the circuit.

4. Designing Work

The designing work was developed according to the working principle of the device. The device was designed including one end of pipe(2), the other end of pipe(8), the 1st spring(3), the 2nd spring(6-1), magnet(4), magnetic fluid(5), the lower part of the middle pipe(7), the upper part of the middle pipe(10), the adjusting element(6-2), the 1st detecting coil(12), the 2nd detecting coil(11), the 1st alarming device(13), and the 2nd alarming device(14). The specific structure of the measurement and alarm device is shown in Fig.3.

At working state, the measurement and alarm device is shown in Fig.3. In the processing of the designing, an adjusting element (6-2) was designed with the 2nd spring (6-1) to adjust the initiate position of the inducting core. After the measurement and alarm device is set up, the inducting core was adjusted into the middle of the pipe by stirring the adjusting element. Then air could be input into the air inlet (1). After entering the pipe, the air blows the inducting core to right and was output through the outlet (9).

At the beginning, the inducting core keeps balanced under the actions of the two spring forces and the normal air flow. If the air flow exceeds the upper limit of the safety range, the blowing force from the air is larger than the spring forces acted on the inducting core. Then the inducting core will move
into the inner cavity of the 2nd detecting coil (11) under the blowing force of the air. Then the magnetic flux in the 2nd detecting coil increases to excite the induced current in the coil which will start up the 2nd alarming device(14) for workers. Fig.4 shows the forces acted on the inducting core.

![Fig.4 Forces Acted on the Inducting Core in the 2nd Detecting Coil](image)

If the air flow is lower than the lower limit of the safety range, the blowing force from the air is smaller than the two spring forces acted on the inducting core. Then the inducting core will move into the inner cavity of the 1st detecting coil (12) under the forces toward left. Then the magnetic flux in the 1st detecting coil increases to excite the induced current in the coil which will start up the 1st alarming device (13) for workers. Fig.5 shows the forces acted on the inducting core.

![Fig.5 Forces Acted on the Inducting Core in the 1st Detecting Coil](image)

If the air flow value is in the safety range set up by the device, the inducting core is in the middle of the pipe shown in Fig.3.

A separated pipe was designed and the specific configuration was shown in Fig.6. The pipe could be divided into 4 parts including the 1st end of the pipe, the 2nd end of the pipe, and the middle part of the pipe. The middle part of the pipe could be separated into two parts including the upper part of the middle pipe and the lower part of the middle pipe which is shown in Fig.6.

![Fig.6 The Storage State of the Device](image)
The configuration of the measuring and alarm device was designed for storage conveniently. The convenience is one of the most important innovations of the designing work for storages and transportations.

5. Conclusions
The measurement and alarm device was designed to solve the problems including the inconvenience for storage and transportation, and the insufficient capacity for alarm. The device improved could alarm either the air flow is too high or too low. And the new production is a feasible device with low cost because there is no coil around the middle part of the pipe. The pipe material and the coils around the two ends of the pipe are easy to get, and the magnet and magnetic fluid are convenient to produce. So it is a new production for measuring and alarm in engineering fields.

Acknowledgments
Thanks for the Research Funds from Beijing Municipal Commission of Education Technology Plan Project (KM201910858005), Beijing Polytechnic Science and Technology Project (2018Z002-029-KXZ) and (2020Z172-KXZ).

References
[1] LI Decai, “Theory and application of magnetic fluids”. Beijing: Science Press, 2003:1-6.
[2] LI Decai, “Magic magnetic liquid”, Beijing: Science Press, 2017:28-90.
[3] Li X H. “Preparation, Performance and Application” (in Chinese). In “Nano-magnetic Fluid”, Beijing: Science Press, 2009:1–5.
[4] HAO Ruican, LIU Huagang, GONG Wen, et al, “Research Experiments on Pressure-Difference Sensors with Ferrofluid”. Journal of Magnetism and Magnetic Materials, 2016,416:231-235.
[5] LIU Qingzu, YANG Huikai, LIU Jianheng, LIU Chongyang, MAO Keya, “Research advances in magnetic nanomaterials for chemotherapy drug-delivery”, Acad J Chin PLA Med Sch, December,2021, 42(11): 1-5.
[6] Zhang Zheng, Feng Baomin. Properties, preparation methods and application of nano magnetic fluids in biomedicine[J]. Biotechnology world. 2014 (5) :1-2
[7] LI Qiang, YUAN Zuobin, Yang Yongming, et al. Numerical Simulation Research on the Coupling between Magnetic Field and Fluid Field of Ferrofluid Targeted Drug[J]. Journal of Hubei University for Nationalities(Natural Science Edition), 2014,32(3):305-310
[8] Chao Yang, Liang-Yin Chu, Rui Xie, et al. Advances in Magnetic targeted drugs delivery system. China Academic Journal Electronic Publishing House.
[9] Ruican Hao, Shang Wang, Huagang Liu, etc. Research on Magnetic Fluid and its Application in Gas Flow Sensor. Not published.