Journal of The Gujarat Research Society
ISSN: 0374-8588
Volume 21 Issue 10, October 2019

A REVIEW ON TYPES OF MEMS THERMAL FLOW SENSORS

Sunil M P
Faculty of Engineering and Technology
Jain (Deemed-to-be University), Ramnagar District, Karnataka - 562112
Email Id- mp.sunil@jainuniversity.ac.in

Abstract

In different medical, industrial and environmental implementations, there is an important need for fluid flow rate and path sensors. In addition to the crucial criteria for the sensing spectrum of flow parameters (such as intensity, velocity, direction and temperature), the characteristics of the various target gases or liquids to be detected pose challenges to the production of sensors that are accurate, affordable and low-powered. This paper provides a summary of the work that has been performed in recent years on the design and creation of Micro Electromechanical System (MEMS) based flow sensors. MEMS flow sensors can be roughly classified into 3 major groups, namely thermal sensors, piezoresistive sensors and piezoelectric sensors, considering the use of several similar concepts, varied manufacturing processes, analysis techniques and various sensing materials. MEMS flow sensors have a variety of uses, ranging from control of industrial gas flow, environmental flow sensing, marine hydrodynamic sensing, and systems for biomedical flow sensing. MEMS flow sensors are very desirable for commercial and industrial applications due to their small scale, low-cost, high sensitivity, and batch manufacturing compatibility. The multiple MEMS sensors are addressed briefly in the present review article.

Keywords: *MEMS, Piezoresistive, Piezoelectric, Sensors, Thermal Flow.*

I. INTRODUCTION

In various applications, flow sensors are needed to measure the velocity and path of liquid and gas flows, involving flow pattern determination, wall shear stress calculation, and viscosity and density calculation. Several types of sensing instruments have been developed and became widely usable for flow analysis over the past decades. It is recognised that the flow as calculated can be impacted by the systems' velocity, strain, temperature or chemical material. Therefore, by calculating a number of physical variables, flow sensing instruments are usually focused on the direct identification of length, mass, velocity, or combination thereof. Micro-electro-mechanical system (MEMS) technology has created new opportunities in the production of flow sensors for diverse applications over the past few decades. In the 1960s, after the investigation of the piezo resistive potential of silicon and germanium, MEMS devices were first introduced. Since the 1980s, research and development in this area has steadily expanded. MEMS technologies provide features such as compact scale, low-cost and flexible devices that could not be accomplished using conventional techniques in engineering. Micro-manufacturing technologies have lately been commonly used in the manufacture of MEMS sensors for use in a wide variety of applications, like healthcare, physical processes, protection and environmental sensing. MEMS flow sensors are miniaturised instruments capable of achieving high precision (up to a few micro to nano litres per minute) and, relative to conventional sensing devices, provide low-cost alternatives. Because of these fundamental advantages, MEMS flow sensors are commonly used in numerous applications, like Autonomous Underwater Vehicle (AUV) navigation and object tracking, biomedical surgery flow analysis, diagnostic instruments, chemistry and medicinal areas, liquid dispensing systems, and gas control systems[1].

In the past, MEMS flow sensors have been built using both silicon and polymer materials and by the implementation of different sensing components and structural designs. Thermal, torque and drag force based flow sensing are the most prevalent types of sensing. For air and water flow sensing applications, MEMS hot wire anemometer sensors have also been commonly used. In comparison, with the developments in micro-machining technologies utilizing polymers and non-silicon components, in ways to construct miniaturised yet sensitive fluid flow sensors, it has become feasible to emulate the stimulus transmitting mechanisms of biological sensing systems, such as hair cells and the lateral line of blind cave fish, leaf veins, seal whiskers and human hairy skin structure.

In this article, we include a thorough overview of the numerous micro/nano-scale flow sensors produced to date, which, based on the sensing theory employed, fall mainly into three broad categories. The groups are: piezo resistive flow sensors, thermal flow sensors, and piezoelectric flow sensors. Centered on the sensing factor material for the unit, we have addressed each of these sensing concepts. By the use of various sensing concepts and modern sensor architectures that increase the contact between the sensor and the ambient fluid, the sensitivity of the sensors has been increasingly increased over time[2].

II. DISCUSSION

A. **MEMS thermal flow sensors: -**

In order to assess flow rate, thermal flow sensors use the speed of heat transfer. With small output signal drift, this concept offers high sensitivity and precision in calculation. Furthermore, such sensors have the added benefit of being able to detect any mechanically moving micro-components without the need for them. Thermal flow sensors are typically made up of two basic components, including heaters and sensing components. The difference in heat transfer between the heater and the work flow is sensed by a sensing element, so the sensitivity of the system increases as more heat is added to the working fluid. It seems that one of the most significant drawbacks to the precision of traditional temperature-based flow sensors is the precise conservation of the temperature of the sensor module. Their failure to calculate low flow velocities is another problem associated with thermal flow sensors. In conventional hot-wire and hot-film sensors, sensing elements have a high specific heat power, making it difficult to adopt the weak transfer of heat convection, leading to a poor carrier frequency[3].

3 kinds of thermal flow sensors are being categorized in the history, in spite of the different heater control system and statistical measurement modes. The first type is hot-wire and hot-film(H-type) sensors that calculate the flow by either constant change in temperature in heating power or constant heating power change in temperature. The distinction between them is due to the structural design: the metallic wire resistor is free of the substrate in hot-wire sensors and positioned inside the flow, while the resistor is deposited on a membrane placed adjacent to the flow in hot film sensors. Calorimetric (C-type) sensors are the second type, which measure flow by measuring adjustments in the heat profile around the heater. The third type is a time-of-flight sensor that uses the detection of heat pulses to measure the flow at a given distance from the heater[4].

B. **MEMS piezoresistive flow sensors: -**

Piezoresistive materials are those which, when exposed to external stress or pressure, show a shift in resistivity. The imposed strain adjusts the material's internal atomic as well as lattice positions and, thus, changes its resistivity. Piezoresistive substances have been commonly used in the research in the production of MEMS/NEMS flow sensors. In reaction to maximum pressure, the capacity of piezoresistive materials to adjust tolerance allows them desirable to use for flow sensing. The resistance shift can be transformed to a voltage in a flow sensor configuration that differs with the flow rate. Piezoresistive flow sensors have previously been studied for use in various applications, including air fluid flow control[8] and monitoring of stream flow. It is possible to classify most of the recorded piezoresistive sensors into a cantilever or diaphragm configuration[5][6].

C. **MEMS piezoelectric flow sensor: -**

Piezoelectricity is the phenomenon demonstrated by certain organic and inorganic dielectric materials that, once exposed to mechanical stress (direct piezoelectric impact), produce substrate concentrations of electrical charge as well as, contrarily, undergo geometric or dimensional adjustments when exposed to lateral electrical fields (converse piezoelectric effect). In polycrystalline ferroelectric ceramics such as lead zirconate titanate (PZT) or barium titanate ($BaTiO_3$) and polymers like poly vinylidene difluoride (PVDF), that are the most commonly used in practical uses, a major piezoelectric effect can be observed. Piezoelectric flow sensors are self-powered, and therefore no power source is adjusted to achieve the output of the sensor. In the past, MEMS piezoelectric flow sensors that are lead zirconate titanate(PZT) and poly vinyledene difluoride (PVDF)were primarily used in the production of two main materials. This chapter is intended to discuss these two types of MEMS flow sensors[7][8][9].

III. CONCLUSION

Compared to traditional flow sensors, MEMS flow sensors provide various advantages, which include high spatial and temporal resolution, small size, high sensitivity, and precision. Studies have recognized biology and evolved bio-mimetic flow sensors in order to build sensors including higher sensitivity, precision and threshold detection limits. They studied the concepts of sensing, morphological geometry, and architecture of nature's biological flow sensors and applied them to the development of MEMS technologies for artificial sensors. In this paper, we reviewed the creation of three key types of MEMS flow sensors, comprising thermal, piezoresistive and piezoelectric instruments, and evaluated their output critically, taking into account the preference, sensitivity, usage and configuration of components. A quick insight into different ideas and operating concepts is offered in depth. Hot-wire/hot-film flow sensors show good sensitivity over a wide flow spectrum, but at low flow speeds, they suffer from poor sensitivity. Piezoresistive flow sensors display great sensitivity at low flow velocity, but also need a power supply to bias the sensor in a configuration of a wheat stone bridge, allowing the voltage output produced to be determined due to the flow stimulus. Owing to its scale and weight, the power supply creates challenges for automated underwater vehicles (AUVs) and other aquatic technologies. A piezoelectric platform for underwater flow sensing that offers a potential for self-powered sensing is however very desirable. In comparison, an analysis focuses on a hot-wire anemometer built in the history conducts heat transfer-based flow sensing and it would be difficult to use it for aquatic signaling. Owing to the complication of the narrow distance between the plates filled with water and the collapse of the plates caused by capillary action, hair cells on torsion capacitive plates with thin gaps between moving plates are likely to be troublesome for water applications. Finally, we discussed current problems, viewpoints and numerous hot-wire, piezoresistive and piezoelectric MEMS flow sensor applications.

IV. REFERENCES

[1] M. Asadnia, A. G. P. Kottapalli, J. Miao, M. E. Warkiani, and M. S. Triantafyllou, "Artificial fish skin of self-powered micro-electromechanical systems hair cells for sensing hydrodynamic flow phenomena," *J. R. Soc. Interface*, 2015, doi: 10.1098/rsif.2015.0322.

[2] S. Nihtianov and A. Luque, *Smart Sensors and MEMS: Intelligent Devices and Microsystems for Industrial Applications*. 2013.

[3] A. A. C. M. Cabrita, R. Mendes, and D. A. Quintela, "Thermistor based, low velocity isothermal, air flow sensor," *Meas. Sci. Technol.*, 2016, doi: 10.1088/0957-0233/27/3/035307.

[4] S. Wu, Q. Lin, Y. Yuen, and Y. C. Tai, "MEMS flow sensors for nano-fluidic applications," *Sensors Actuators, A Phys.*, 2001, doi: 10.1016/S0924-4247(00)00541-0.

[5] P. Sharma, J. F. Motte, F. Fournel, B. Cross, E. Charlaix, and C. Picard, "A Direct Sensor to Measure Minute Liquid Flow Rates," *Nano Lett.*, 2018, doi: 10.1021/acs.nanolett.8b02332.

[6] J. E. Dusek, M. S. Triantafyllou, and J. H. Lang, "Piezoresistive foam sensor arrays for marine applications," *Sensors Actuators, A Phys.*, 2016, doi: 10.1016/j.sna.2016.07.025.

[7] C. Martin *et al.*, "Stress and aging minimization in photoplastic AFM probes," *Microelectron. Eng.*, 2009, doi: 10.1016/j.mee.2008.12.033.

[8] S. R. Anton and H. A. Sodano, "A review of power harvesting using piezoelectric materials (2003-2006)," *Smart Mater. Struct.*, 2007, doi: 10.1088/0964-1726/16/3/R01.

[9] K.-I. Park, C. K. Jeong, N. K. Kim, and K. J. Lee, "Stretchable piezoelectric nanocomposite generator," *Nano Converg.*, 2016, doi: 10.1186/s40580-016-0072-z.