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MODELLING OF MICROFLOW SENSORS BASED ON MEASURING OF TEMPERATURE FIELDS

M. Adámek , L. Macků
Department of Electronic and Measurement
Institute of Information Technologies
Tomas Bata University
Mostní 5139, Zlín
Czech Republic

M. Matýsek
Department of Applied Informatics
Institute of Information Technologies
Tomas Bata University
Mostní 5139, Zlín
Czech Republic

ABSTRACT

In the presented investigation, the problem of accurate determination of micro mass flow was studied. The measurement of mentioned flow range is becoming more and more important for a lot of applications in the life science, analysis, biotechnologies, synthesis (of e.g. pharmaceuticals) and nanotechnology markets. In this paper a flowmeter design applicable for measurement of low gas flow amounts is presented. To this end, the numeric model of designed flowmeter was made and the flowmeter was numerically simulated using compressible Navier – Stokes equations in two dimensions. The computations were carried out for several types of agitated gases. The results were compared with experimental data.

Keywords: modelling, flow, sensor.

1. IMTRODUCTION

The modelling of microsystems requires appropriate compact or macro models for microdevices. In general, it is difficult or almost impossible to obtain closed form analytical models for microdevices. Thus, models are obtained by a simplification of the full physical model. The compact models allow for fast system level simulation of the microsystem. However, the accuracy of such a model can be questionable because of the simplifications made during the model development phase. Model accuracy and simplicity are important for the design of complex systems. Microflow sensor modelling has been examined by several authors [1]. These approaches have used a solution of the partial differential equations (PDEs) for the coupled fluid/thermal problem. The work of [2] employs equivalent circuit descriptions that are solved in SPICE whereas [3] solve the PDEs using the finite-element and the finite-difference methods, respectively. However, none of these methods provide a simple and accurate macromodel for the flow sensor.

In this paper is presented modelling approach for microflow sensor. This paper is organised in the following manner. In Section 2, modelling of flow sensor is described. Section 3 describes experimental set-up; Section 4 concludes the paper.

2. FLOW SENSOR MODELLING

This work is focused on the modelling of a thermal method for mass flow determination of flowing media. A basic principle of a design flowmeter is shown in Figure1. This flowmeter type is called as Time – of – flight sensor. The time – of – flight sensor consists of a heater and one or more temperature sensors downstream. The heater is activated by current pulses. The transport of the generated heat is a combination of diffusion and forced convection. The resulting temperature field can be detected by temperature sensors located downstream. The sensor output is the time difference between the starting point of the generated heat pulse and the point in time at which a maximum temperature at the downstream sensor is reached.

The time – of – flight sensors have the same limitations as the intrusive type of calorimetric sensors: corrosion, erosion and leakage. Since the signal processing needs a short while to measure the time difference, this sensor type is not suitable for dynamic measurement.

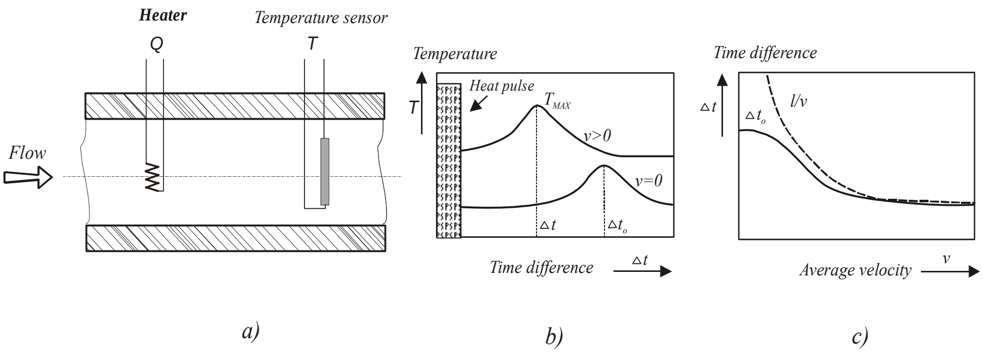


Figure 1. Time – of – flight sensor

The transport of the heat generated in line source through a fluid is governed by the energy equation:

$$\frac{\partial T}{\partial t} + v\nabla T = \left(\frac{\lambda}{\rho c}\right)\nabla^2 T + \frac{q'}{\rho c} \tag{1}$$

where T is the temperature, c is the specific heat at the constant pressure, ρ is the density, v is the kinematic viscosity of the fluid, λ is the thermal conductivity and q' (in $W\,m^{-3}$) is the amount of heat per unit of volume and time. The analytical solution of this differential equation for a pulse signal with input strength $q'o$ ($W\,m^{-1}$) is given in [4] as :

$$T(x,y,t) = \left(\frac{q_o'}{4\pi\lambda t}\right)\exp\left\{-\frac{\left[(x-vt)^2\right]}{4at}\right\} \tag{2}$$

where a denotes the thermal diffusivity.

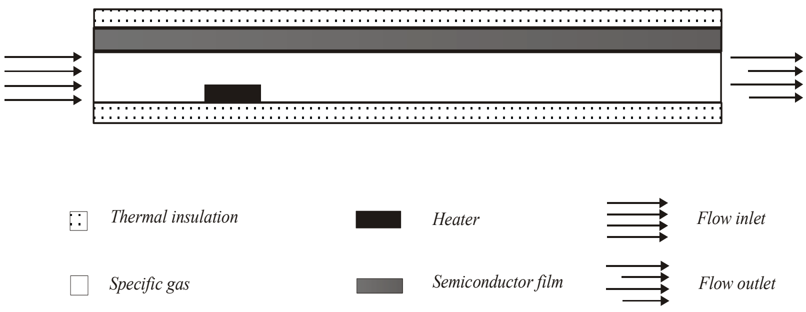


Figure 2. Modified version of Time – of – flight sensor

2.1. Basic configuration

The designed flowmeter was modified. The temperature in a classical design of the Time – of – Flight sensor is measured by temperature sensors located downstream. There are two or one sensors usually; these sensors measure a temperature in two points. In the modified version of designed flowmeter a temperature field is measured by semiconductor film. The temperature profile is dependent on gas velocity. The heater is activated periodically; the period of the heat pulses generation can be different for different velocity size of can be constant.

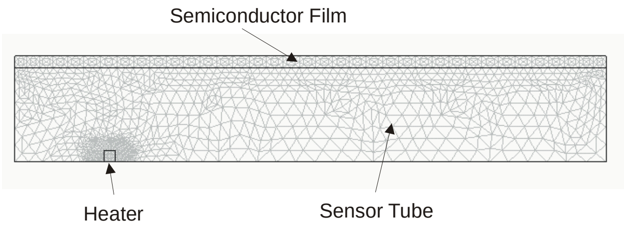


Figure 3. Partial view of the computational grid for the basic configuration

2.2. Modelling results

The properties of the modified time – of – flight sensor were simulated and verified for different flowing gases (CO_2, *air, chlor,* N_2). The dependence of T_{MAX} on flow velocity v can be found in Figure. 5; the temperature T_{MAX} was measured in semiconductor film.

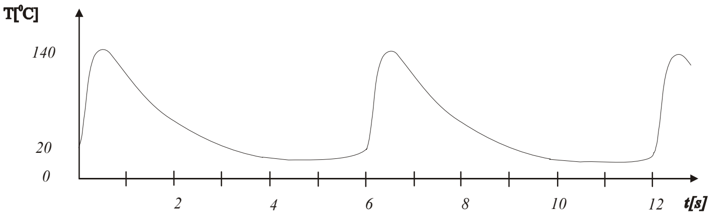


Figure 4. The time path of the temperature of the heater

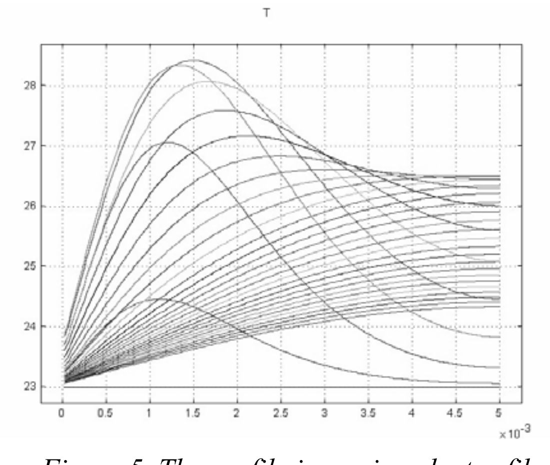


Figure 5. The profile in semiconductor film

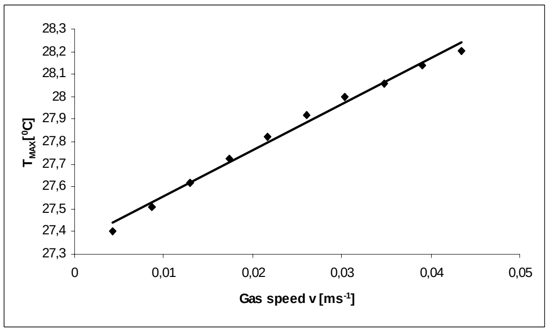
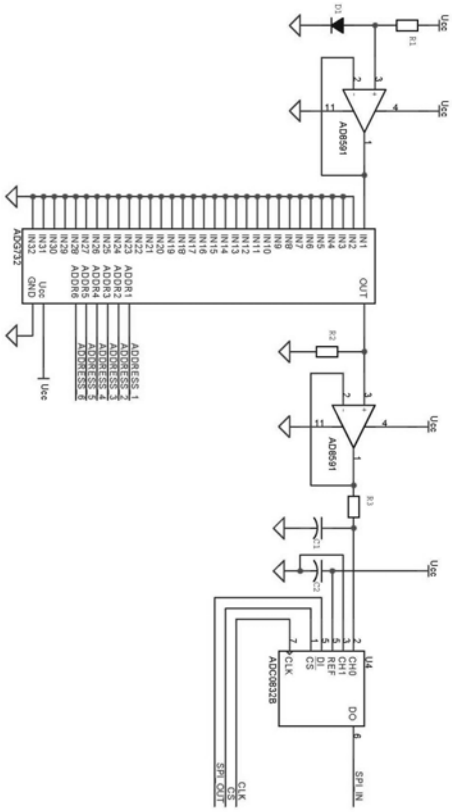


Figure 6. The time response of flow sensor: flow variation from 30ml/hr to 100ml/hr, the height o the fluid channel d=0,8 mm.

3. EXPERIMENTAL SET-UP

The modified time-of-flight sensor consists of a heater placed on the pipe's floor and series of downstream sensors (semiconductor diodes) placed in the pipe's upper wall. The heater is activated for 1 second by a current pulse. The heat generated by the heater spreads with the flowing gas and leads into resistance changes on the diodes. The resistance change upon each diode is measured as a voltage change by an A/D converter. From the particular points along the pipe is set the wave's heat profile which is scanned for the temperature maximum position. The flow volume is proportional to the position shift in time. The scheme drawing is shown in Figure 7.



Fiure .7. Block diagram of the modified sensor

4. CONCLUSION

This article describes properties of the modified time – of – flight sensor. The designed flowmeter has been used in a biochemical laboratory for study of reaction kinetic of a decomposition of sediments in waste water.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Swart, N. R. and Nathan, A.: Flow-rate microsensor modeling and optimization using SPICE. Sensors and Actuators, A., 34, 109-122, 1999.,

[2] Swar, N. R. and Nathan, A.: Mixed-mode device circuit simulation of thermal-based microsensors. Sensors and Materials, 6, 179-192, 1994.,

[3] Mayer, F., Salis, G., Funk, J., Paul, O. and Baltes, H.: Scaling of thermal CMOS gas flow microsensors: experiment and simulation. Proc. IEEE International Workshop on MEMS, 126-121, 1996.,

[4] Webster, J.: Measurement, instrumentation and sensors. IEEE Press, 1999.,

[5] Hardy, J. and Hylton, O.: Flow measurement methods and applicatons. Viley –Interscience, USA, 1999.,

[6] Rasmussen, A. and Zaghloul, M.: The design and fabrication of microfluidic flow sensors. Proc. ISCAS-99, 136- 139, 1999.