LogDynamics
International Graduate School

Flow Sensors and their Applications to the Convective Transport in the Intelligent Container

"Logistics is the management of the flow of goods, information and other resources between the point of origin and the point of consumption in order to meet the requirements of customers. Logistics involves the integration of information, transportation, inventory, warehousing, and other parameters". This definition shows the importance of the transportation of goods for logistics operations. Accordingly, the Intelligent Container is a project developed as an autonomous transport monitoring system for perishable and sensitive goods. The systems links technologies from the fields of RFID and sensor networks to provide a supervision of each transport package along the supply chain.

Measurements of temperature and humidity inside the Intelligent Container showed a non negligible difference between different points in both horizontal and vertical directions. Understanding the convective transport and later improving it to obtain more a homogenous distribution of temperature and humidity inside the Intelligent Container involves an accurate measurement of the air flow inside this container. This highlights the necessity of introducing sensitive flow sensor to the sensor networks.

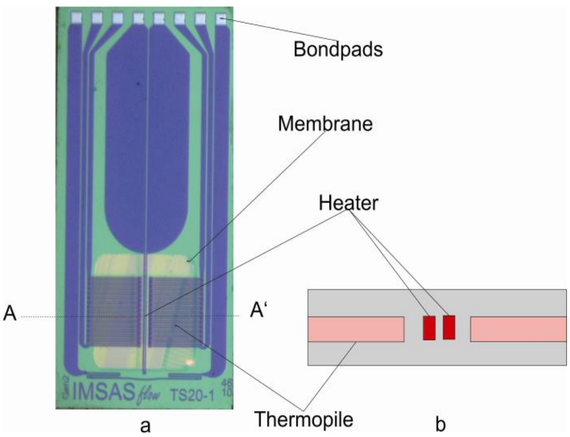

Figure 1: a) An example of IMSAS thermal flow sensors. b) A cross section (AA') of the sensor membrane.

Due to the complexity of studying and measuring fluid in motion applying flow sensors in a measurement system and performing measurements are difficult matters. This research will deal with these difficulties and aims at solving them.

Research Questions

Challenges were identified and then transferred to the following research questions:

- To what extend will the suggested flow sensors fulfill the air flow measurement requirements in the Intelligent Container?

The measurement of the air flow requires sensitive flow sensors. IMSAS develops thermal flow sensors based on silicon as substrate material (Fig. 1). The use of these sensors measuring the air flow which moves in very low rates in the Intelligent Container involves in-depth understanding of sensors characteristics for such rates.

- How does the convection react within the container? Understanding the convection transport is a very important and complex subject. It will enable us to explain what happens inside the container.
- How can we improve the transport process and the cooling system in the Intelligent Container? This will be the feedback from answering the previous questions.

Characterization of Flow Sensors

Characterization of flow sensors is a basic issue to clearly understand their behavior. Firstly, modeling is one of the effective methods to grasp the theory behind the principals of these sensors, which is for these sensors the heat transfer. A simple modeling program for the response time and other characteristics of thermal flow sensors has been already developed at an earlier stage of this research. It uses the finite-difference method to solve the heat transfer equations, taking into consideration the transient conduction and convection between the sensor membrane and the surrounding fluid. Program results of sensor response time agree with experimental measurements (Fig. 2) and explain its dependence on the mode of operation, the velocity and the distance between heater and thermopiles. This program provides 2D or 3D graphs for the temperature distribution in the membrane and the air channel. Moreover, it produces curves for sensor signals, i.e. up- and downstream thermopiles and their differences.

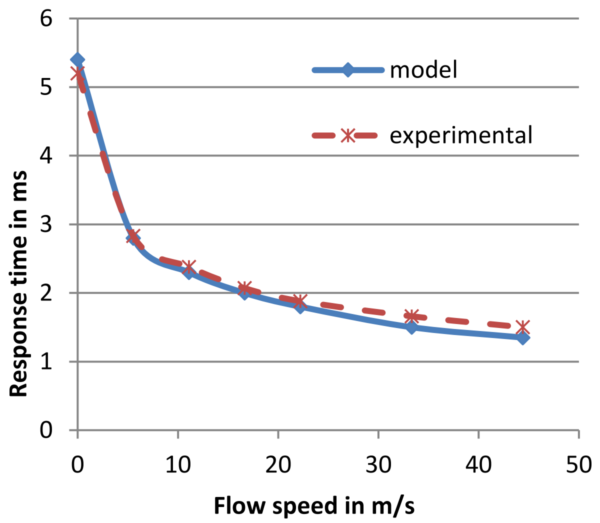

Figure 2: Comparison between experimental and model results for sensor response time.

Secondly, this research investigates standing flow sensor's behavior in very low flow rates. These flow sensors are used for many applications and they cover a wide range of flow rates for fluids and gases. Concerning the case of the Intelligent Container, where the air flow is very low, involves the focus on the flow characteristics for this range. The suggested methodology is to characterize the flow sensors for an ultra small flow ranges. This requires using calibrated mass flow controllers with high precision. They will be controlled by a labview program via a NI data acquisition device. This program accurately control the air flow through an air channel mounted to the sensor membrane. Investigations will be done for a new set of thermal flow sensors. These sensors differ in the distance between heater and thermopiles which value is between 5 and 50 µm.

Flow sensors can be characterized by many parameters as responsivity, sensitivity, noise equivalent power, noise equivalent temperature difference and minimum detectable flow rate or velocity. All of these parameters will be explored during this research. The results produce well defined curves for sensor output.

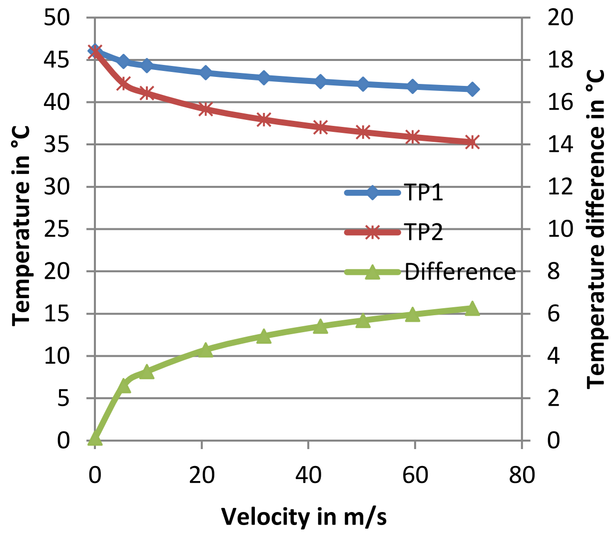

Figure 3: Sensor output signals: up and downstream thermopiles and their difference as a function of air velocity.

Experimental Measurements and Evaluation

The main purpose of this research is to achieve the precise measurement of the air flow in the Intelligent Container. Additionally to the previous characterization, this requires the development of the necessary electronic circuits which should be homogenously agree with the sensors network. Furthermore, applying the flow sensors in a system of measurement will be the next research step. Afterwards follows designing many measurements set up according to the type of container. Deciding the number of needed sensors and distributing them in different positions in the container are expected tasks. Choosing directions for measurement, fixing the sensors and communicating with them are transient problems to be solved. After measurements, analyzing data and comparing results with models will give clear ideas about the convection transport within the container.

The output of the previous study and measurements will be suggestions to improve the measurement system, and also making proposals for the improvement of the transport process and the cooling system to achieve more homogenous temperature distribution within the container.

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