Design of a Dual Axis Thermal Accelerometer using Single Axis Structure

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INTRODUCTION: In this paper, a dual axis thermal accelerometer using a single axis structure has been designed in 3D and simulated in FEM simulator COMSOL Multiphysics®. The sensitivity of the accelerometer is improved by this structure. In this accelerometer, when acceleration is applied along x-axis its sensitivity is 1.07 K/g and along y-axis 0.23 K/g with the heater temperature of 610K.

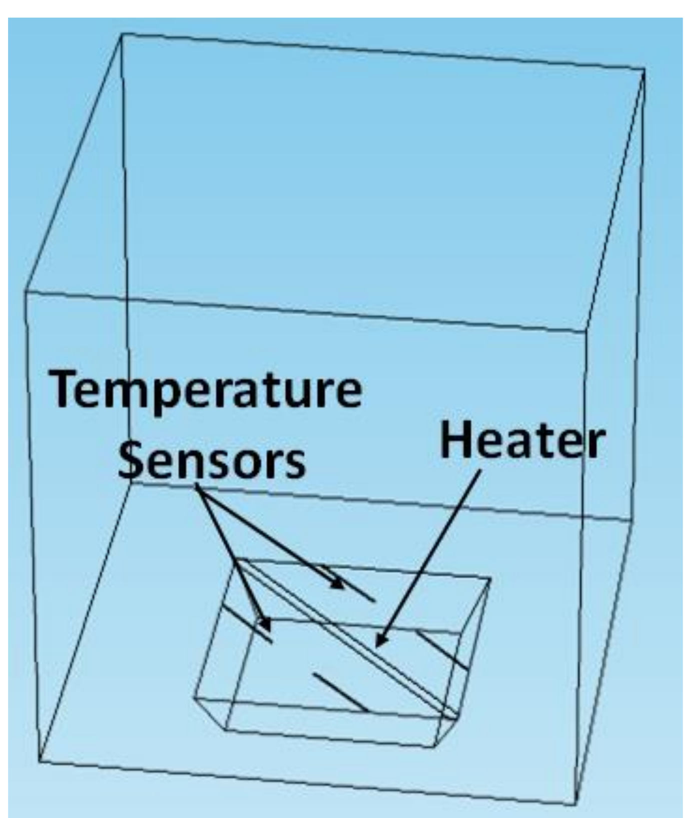


Figure 1. 3D view of the thermal accelerometer

GOVERNING EQUATIONS: Thermal accelerometer working principle is based on heat transfer and natural convection of fluid.

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \mathbf{v}) = 0$$

$$\rho\left(\frac{\partial v}{\partial t} + \mathbf{v}.\nabla \mathbf{v}\right) = -\nabla p + \nabla.\mathrm{I} + \mathbf{f}$$

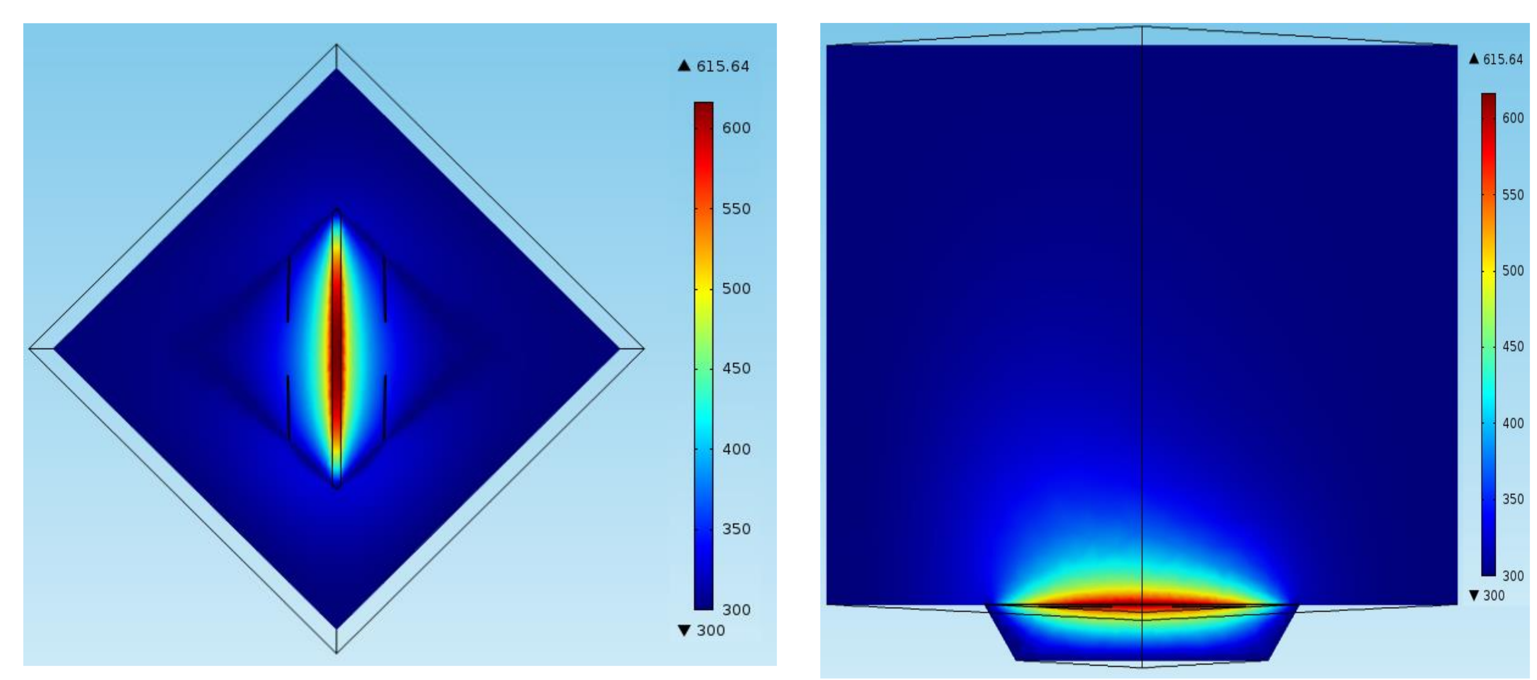
$$\rho \frac{D\mathbf{v}}{Dt} = -\nabla p + \nabla.\mathrm{I} + \mathbf{f}$$

The thermal effect has been simulated using *Joule heating* interface and the acceleration effect on the device has been simulated using *Laminar flow* interface. The properties of the materials (e.g. thermal conductivity, density, heat capacity) are considered as temperature dependent and varies with temperature. A constant current is supplied to the heater to generate heat. The temperature of the cavity walls and outer walls of air cover has been set as 300 K. The acceleration has been applied along x and y axes using volume force of laminar flow physics. The mesh elements are generated in tetrahedral mode. Higher numbers of mesh elements are generated in the critical regions (heater and sensors regions) to get more accurate results. The results has been studied on stationary mode i.e. steady state condition.

RESULTS and DISCUSSION: In Fig. 2(a), it can be observed from the top view of the device that the highest temperature occurs at the middle of the heater and decreases towards cavity as a parabolic function.

In Fig. 2(b), the deformation of thermal bubble due to acceleration along x-axis can be seen. The temperature difference with acceleration is plotted in Fig. 3(a). The temperature difference is directly proportional to the applied acceleration. From the figure, it can be observed that the temperature difference in x-axis is much higher than y-axis.

Heater temperature is another influencing factor for sensitivity. When the heater temperature is increased, the sensitivity also increases proportionally as shown in Fig. 3(b). When the heater temperature is around 615K the x-axis sensitivity is 1.07 K/g and y-axis sensitivity is 0.23 K/g.



(a) (b)

Figure 2. Temperature contour with 30g acceleration along y-axis (a) top view (b) side view

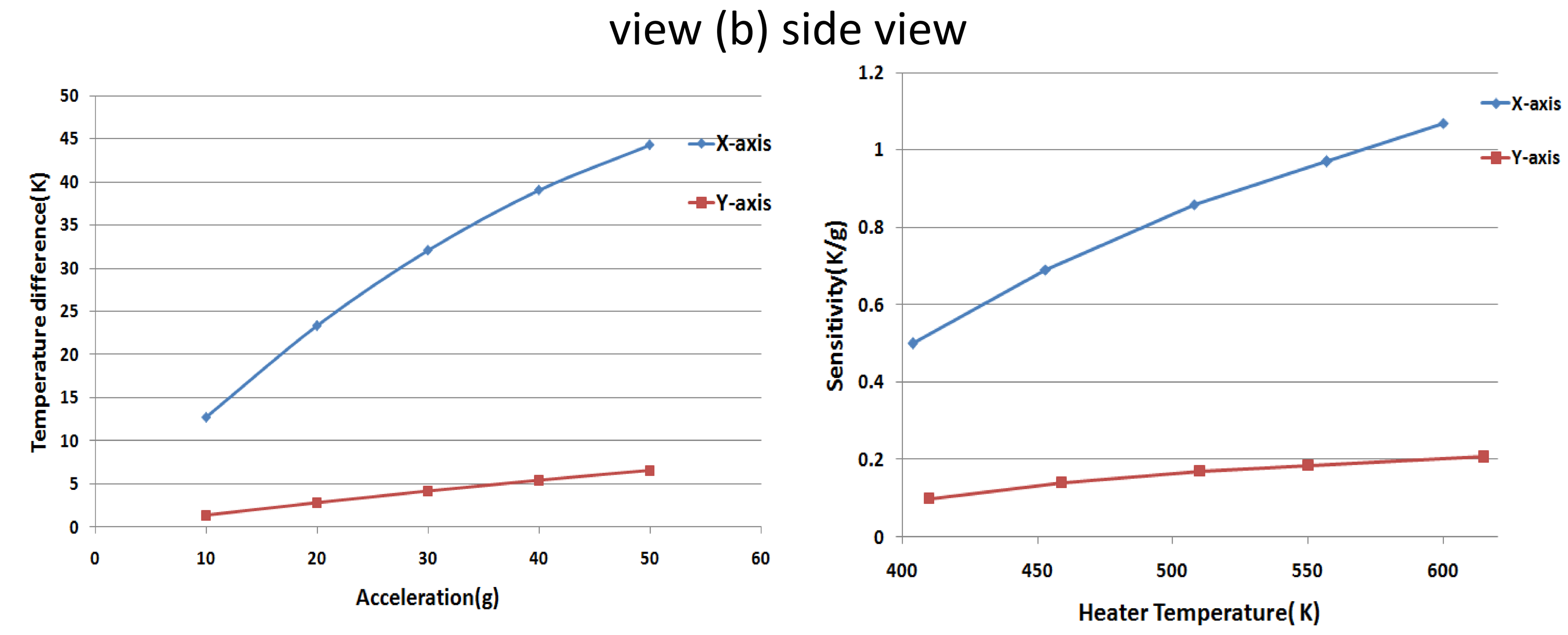


Figure 3. (a)Temperature difference Vs. Accelerarion and (b) Sensitivity Vs. heater temperature

CONCLUSIONS: The higher sensitivity of the single axis accelerometer has been exploited to design this accelerometer, although two additional temperature sensors has been included so that dual axis acceleration can be detected. The accelerometer is designed in 3D and simulated in COMSOL Multiphysics® FEM simulator. The x and y axes sensitivity are found to be 1.07 K/g and 0.23 K/g, respectively when the heater temperature is 610K.

REFERENCES:

1. Mukherjee, Rahul, Joydeep Basu, Pradip Mandal, and Prasanta Kumar Guha. "A review of micromachined thermal accelerometers." Journal of Micromechanics and Microengineering 27, no. 12 (2017): 123002
2. Han, Maeum, Jae Kim, Jin-Hyoung Park, Woojin Kim, Shin-Won Kang, Seong Kong, and Daewoong Jung. "Sensitivity and Frequency-Response Improvement of a Thermal Convection–Based Accelerometer." Sensors 17, no. 8 (2017): 1765.
3. Mukherjee, R., Guha, P. K., & Mandal, P. (2016). Sensitivity improvement using optimized heater design for dual axis thermal accelerometers. Microsystem Technologies, 22(10), 2475-2485.