Design and Simulation of MEMS Anemometer

D. Tandon[1], N. Kothari[1], R. Mishra[1]

[1]Birla Institute of Technology & Science, Pilani, Rajasthan, India

Abstract

Introduction: Wind speed measurement is a very important factor in various fields such as aeronautics, meteorology and farming. The conventional wind sensor comprises small mechanical apparatus such as propeller and cup anemometers, or consists of thermal element such as hot wire anemometers, or has acoustic part such as acoustic radar. This paper concentrates on the design and simulation of a MEMS wind speed sensor (Anemometer) which is sensitive to low wind speed. The sensor that is based on the thermal anemometer principle was designed using COMSOL Multiphysics software and subsequently simulating its working, performing a thorough study of the parameters involved and proposes inroads into possible improvements in design and applications.
Use of COMSOL Multiphysics: The simulation was performed in COMSOL Multiphysics and the physics used were Conjugate Heat Transfer and Laminar flow. Inlet and Outlet conditions were specified for various flow vectors. Materials were assigned to insulation as silicon nitride and the thermal sensors and heaters were assigned with polycrystalline MEMS materials. We assume a lumped heat capacity model for the heater. Since our analysis is based only on convective model we will neglect conduction and radiation effects. Parametric sweep was conducted to plot the various temperatures at the heater and sensors to obtain a simulated data set. The first model was developed to prove the possibility of the transfer of heat from the heater to the thermal sensors through the moving fluid. A simple array of silicon square chips insulated from each other through a highly non-conductive material was used. This was done to make sure that heat transferred to the micro thermal sensor was transmitted through the fluid and not through conduction.
Results: Heat convection can happen in two ways - forced and natural. Natural convection is independent of the free stream velocity. To see the influence of natural convection in our problem we calculate Gr (Grashoff's number). If Gr/Re2 << 1, then the effect of natural convection is negligible. The calculations were of the same order as the value obtained in our simulation, which is 0.0005 W. Since the rate of heat transfer is proportional to the temperature difference between heater and the surroundings, the temperature vs. heat input plot would be linear.
Conclusions: Firstly, the simulation was performed in a one dimensional array Anemometer followed by a detailed analysis of a two dimensional model. The relation between the temperature of the heating element and the power input with different inlet velocities was plotted and graph obtained was a straight line which was in accordance with what was predicted using the theoretical relations.
The direction of airflow can be inferred from measuring the temperature difference across

sensors on opposite sides of the heater in both X and Y directions, using salient mathematical relations.

Reference

1. Buder, U., and A. Berns. "AeroMEMS Wall Hot-Wire Anemometer on Polymide Foil Measurement of High Frequency Fluctuations." IEEE (2005): 545. Print.
2. Adamec, Richard, and David Thiel. "Self Heated Thermo-resistive Element Hot-Wire Anemometer." IEEE Sensors Journal 10.4 (2010): 847. Print.
3. Liu, Hao-Bing, Nay Lin, and Shan-Shan Pan. "High Sensitivity Miniature Full 2-D Anemometer Based on MEMS Hot Film Sensors." IEEE Sensors Journal 13.5 (2013): 1914. Online.
4. Neda, T., and K. Nakamura. "A Polysilicon Flow Sensor for Gas Flow Meters."Sense.Actuators A.54 (1996): 626. Online.
5. Ebefors, T., E. Kalvesten, and G. Stemme. "Three Dimensional Silicon Triple Hot-Wire Anemometer Based on Polymide Joints."IEEE (1998): 142. Print.

Figures used in the abstract

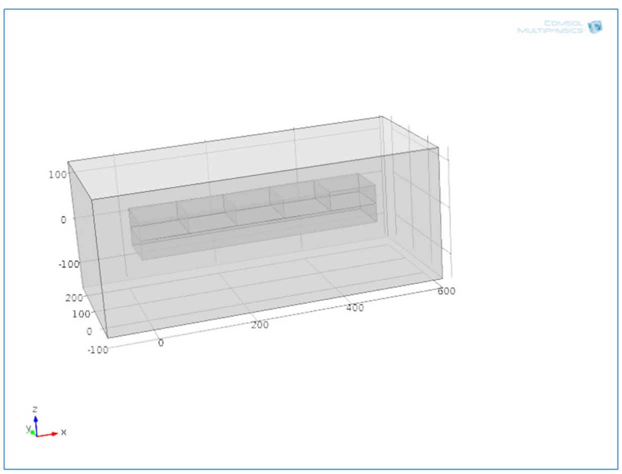

Figure 1: Geometry and Model.

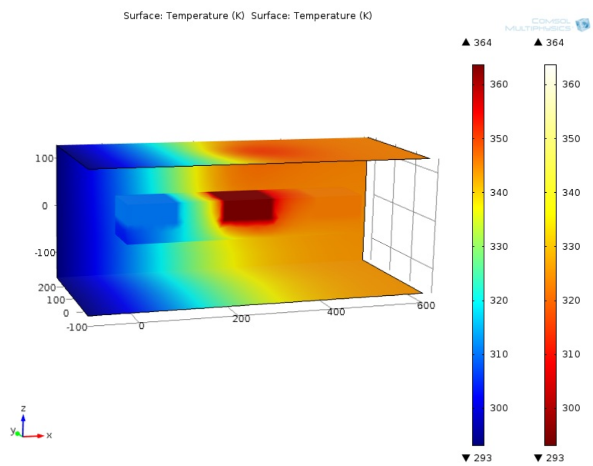

Figure 2: Difference in Temperature of Surface 1 and Surface 2.

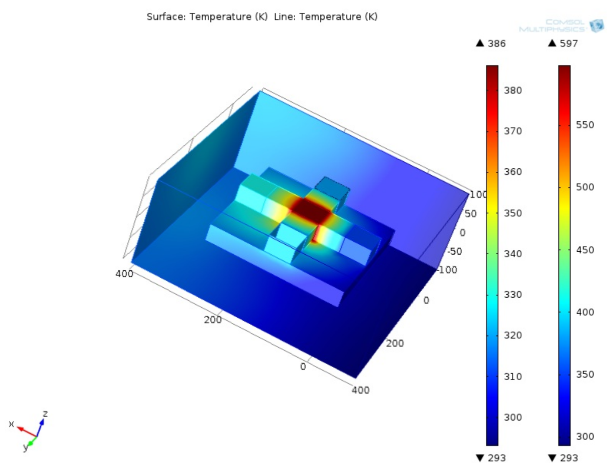

Figure 3: Difference in Temperature of Surface 1 and Surface 2.

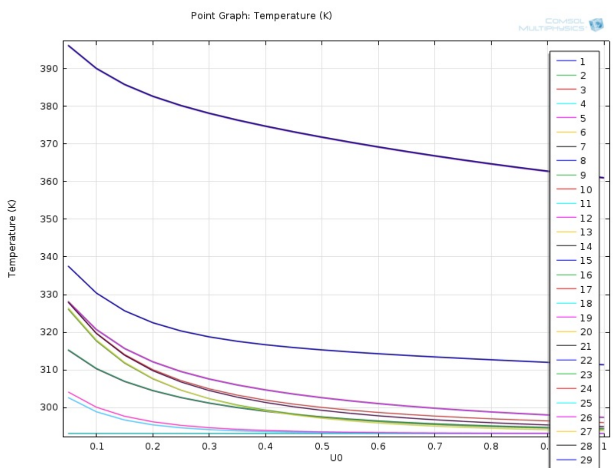

Figure 4: Variation of Temperature at Surfaces with Inlet Velocity.