Ansys Fluent Thermal Analysis of the Beamline Test Stand Assembled with Aerogel

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June 13, 2023

This note presents the results of Ansys Fluent's computational fluid dynamics thermal analysis of the test stand beampipe section, assembled with aerogel insulation, to study the thermal interaction between the beampipe and the silicon detector's layer one (SL1) [1] of the Electron Ion Collider (EIC). The results provide SL1's temperature as a function of the airflow velocity through the annulus—the space between the beam pipe and SL1.

The goal of the analysis is to compare the simulation temperatures to the temperatures measured on the test stand's SL1—represented by an aluminum tube—for different airflow rates through the annulus.

In the current version of the test stand, the aluminum tube representing the beampipe is wrapped in a 1-mm thick layer of aerogel to retain the heat of the immersion heater inside the beampipe and keep its temperature at 100°C.

The test stand was modeled in Ansys SpaceClaim software, Fig. 1. Table I shows the dimensions and the material of the components used in the simulation.

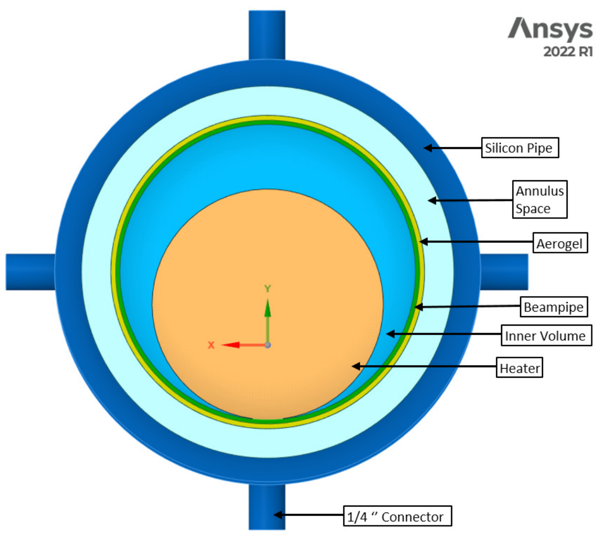

FIG. 1. End view of central section of test stand model.

Component	ID [in]	OD [in]	Length [in]	Material
Heater pipe	1.61	1.90	18	steel
Beampipe	2.43	2.50	18	aluminum
Aerogel	2.50	2.58	18	aerogel
O-ring	2.58	3.06	0.25	rubber
Silicon pipe	3.06	3.50	18	aluminum
Inlet connectors (x4)	0.25	0.30	0.50	aluminum

TABLE I. Components of test stand model.

The model was meshed and implemented in Ansys Fluent, where all required boundary and cell conditions were set, e.g. fixed 102°C for the immersion heater pipe, 23°C for inlet air, and 5 W/m^{2}K for the convection value of the silicon pipe for air at 23°C. Simulations were performed for different air flow rates 0–250 SLM through the annulus, .

The velocity contour plot, Fig. 2, shows that the highest velocity was at the four annulus inlet inputs (red color) and were equal to each other. The region where there is no fluid volume, only solid volume, is shown as a grey tube.

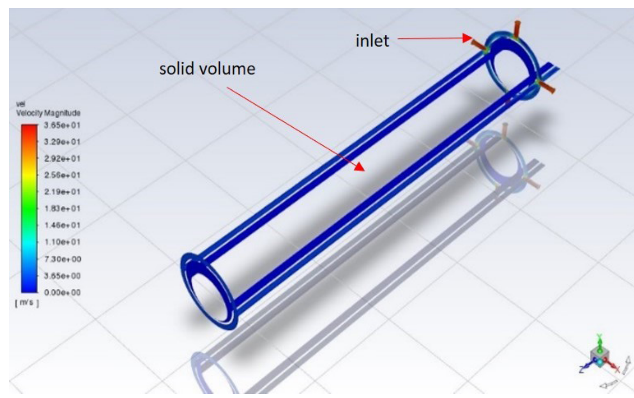

FIG. 2. Velocity contour plot.

Figure 3 shows that the heater is at the maximum temperature, 102°C, red color. Sensor simulation probes were placed in the same region as the RTD sensors on the test stand, Fig. 3.

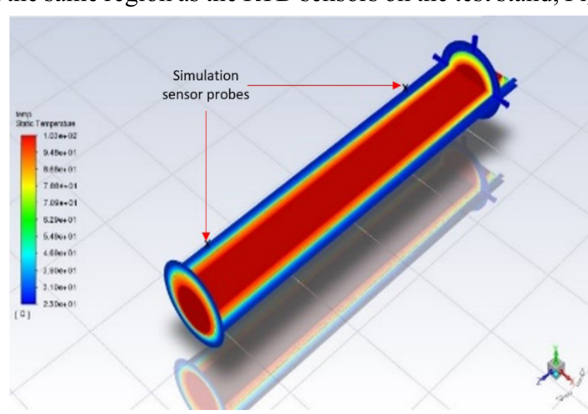

FIG. 3. Temperature contour plot when airflow rate supplied is 250 l/min.

Figure 4 shows that the simulated silicon pipe temperatures are close to the measured values on the test stand when the airflow rate in the annulus is greater than 100 SLM and that the SL1's temperature decreases as the air flow increases.

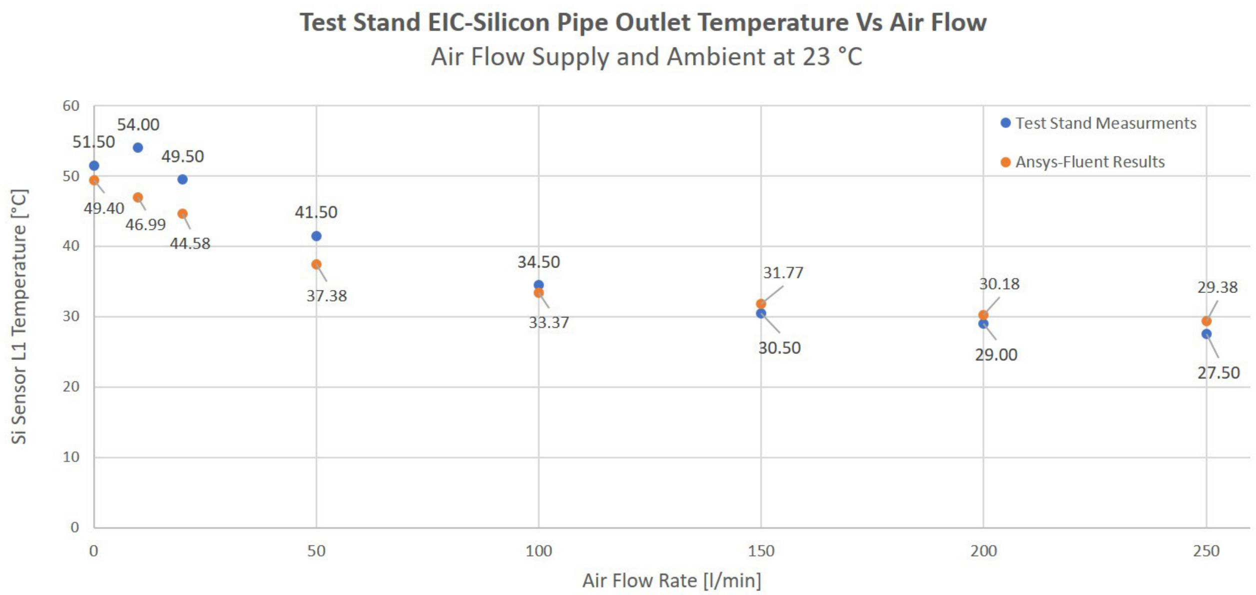

FIG. 4. Silicon temperature vs airflow rate comparison between Ansys analysis and measurements on the test stand.

In conclusion, the thermal analysis of the EIC test stand with an aerogel layer of 1 mm around the beampipe shows that the simulated temperatures are close to the measured temperatures.

[1] B.Eng, G. Jacobs, and M. McMullen, et al. *DSG Beampipe Test Stand Functionality Test,* DSG Talk 2023-01, 2023.