EIC Beampipe Section Thermal Analysis with Aerogel Insulator

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I continued with the thermal analysis of the Electron Ion Collider (EIC) beampipe central section, which is made of beryllium and will be heated to 100°C to ensure that the molecules of water are broken on its inner surface. The analyzed simplified models consists of beryllium pipe, aerogel of 0.5 mm thickness, silicon sensor layer 1, and an enclosure. I considered air flow and no flow through the annulus space (fluid domain formed between the outer face of the aerogel and the inner face of the silicon sensor layer 1) and the enclosure.

For the analysis, two models were considered, models with 2 mm and 5 mm of separation between the outer face of the beryllium pipe and the inner face of the silicon sensor layer 1, as shown in Fig. 1. The modifications for both models were done in Ansys—Design Modeler software, the major modification occurred for the annulus space region and the addition of an aerogel part, which was added as a solid domain volume with the corresponding dimensions shown in Table 1.

Model Separation	Part Name	ID [mm]	OD [mm]	Thickness [mm]	Length [mm]
2mm	Beryllium Pipe	62	63.52	0.76	320.5
	Silicon Sensor L1	67.52	67.6	0.04	
	Aerogel	63.52	64.52	0.5	
5mm	Beryllium Pipe	62	63.52	0.76	320.5
	Silicon Sensor L1	73.52	73.6	0.04	
	Aerogel	63.52	64.52	0.5	

Table 1. Model dimensions

- **Modified existing model to add aerogel to insulate the beryllium pipe**
- **Imported model, configured material properties, thermal boundary conditions**
- **Ran multiple simulations for different aerogel properties**
- **Compared Fluent results of models with aerogel and without aerogel under specified thermal conditions**

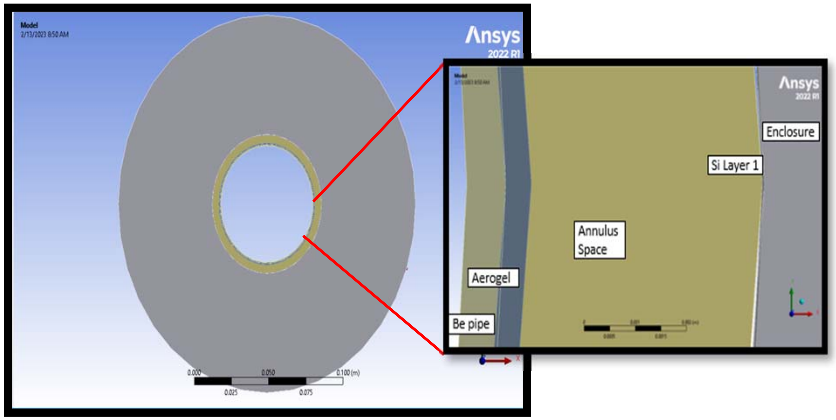

Fig. 1. Model with 2mm separation with aerogel implemented for simulation

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With the geometry of the model completed, I set up four contact regions: beryllium pipe to aerogel, aerogel to annulus space, anulus space to silicon sensor layer 1, and silicon sensor 1 to enclosure. I generated a mesh with 609871 elements.

I implemented the model to *Ansys—Fluent* software and set the material properties such as density, thermal conductivity and specific heat for beryllium, silicon, aerogel, and air. The boundary conditions for both models were configured with an inlet velocity and outlet constant pressure at the anulus and enclosure fluid domain solids. Conditions are detailed in Table 2.

Solver	Fluid Flow Fluent
Model	k-omega, Shear Stress Transport (SST)
Precision	Double
Simulation Iterations	100
Beryllium pipe inner face temperature	100 °C
Air temperature	20 °C
Air flow velocity	0 to 5 m/s

Table 2. Boundary conditions

Simulation results shown in Fig.2 indicate a reduction of the temperature in silicon sensor layer 1, but not enough to get the temperature below 30 °C as desired, especially, when there is no flow. I also ran simulations with different aerogel properties to see effect on silicon sensor layer 1 temperature. I changed the density from 50 to 250 Kg/m3 and used two values for thermal conductivity (cp = 0.0156 and 0.0140 W/m*K). From the results, I noticed that the only change in thermal conductivity affects silicon sensor layer 1, by less than 0.01°C.

I plan to increase the thickness of the aerogel to 1 mm and run more simulations to calculate the total heat transfer generated by the beryllium pipe and the mass flow rate in the annulus and enclosure volumes.

I completed the thermal analysis for the model with the added aerogel and made comparisons with model without aerogel.

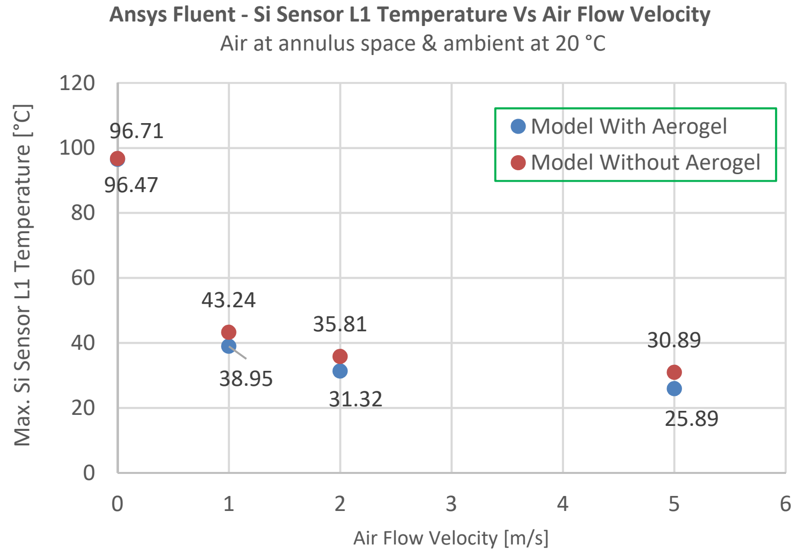

Fig.2. Comparison of maximum temperatures for the silicon sensor layer 1 with and without aerogel for the model with 5 mm of separation

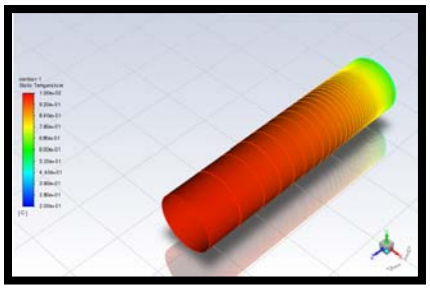

Fig. 3. Isometric view of Si Layer 1 for 5mm separation model with aerogel and air flow velocity at 0.001 m/s

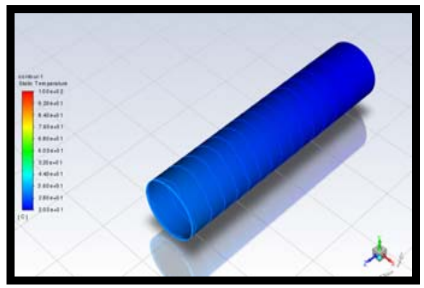

Fig.4. Isometric view of Si Layer 1 for 5mm separation model with aerogel and air flow velocity at 2 m/s