

Study of He-3 gas behaviour in the CAST model installed on the magnets of the Telescope at European Organisation for Nuclear Research, CERN

Project by:

Om Namassivaya Koneti

4th year UG student, IIT Kharagpur

Guided by:

Mr. Michele Battistin

CFD team, CERN, Geneva.

Introduction:

CFD Team:

The CFD team is a part of the Detector cooling (DC) section of the Cooling and Ventilation (CV) Group in the Technical Support (TS) department at CERN. It's mission is to provide engineers, physicists and scientists working at CERN units, with flow and thermal analysis using CFD tools and methods to solve fluid flow and heat transfer related problems.

Why CFD ?

The term Computational Fluid dynamics (CFD) covers all aspects of computational techniques that can be applied to the solution of the problems involving fluids and related thermal phenomena. CFD applications are not limited to chemical and environmental applications. In engineering, CFD is primarily used as a design support for producing the performances of equipment involving fluid flow and heat transfer. The possibility to simulate heat transfer and fluid flow problems numerically before or instead building a prototype, cuts drastically the development cost and time of project.

Why CFD at CERN ?

At CERN, a parallel commercial CFD code is used to provide assistance to the LHC machine and Detectors during prototype, design and installation phases of their components. Most Investigations involve prediction of velocity and temperature fields in natural convection environments. Since May2005, the CFD team at CERN can rely on the high performances of the openlab cluster to perform compute-intensive computational fluid dynamic simulations.

Availability of the openlab cluster increased up to eight times the performances of the CFD simulations allowing reducing the delivery time and the accuracy of studies.

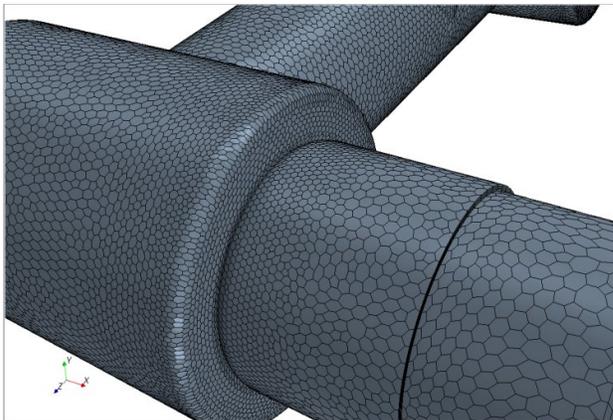
Model Description:

CAST model consists of two parallel pipes of approximately 10 metres length, interconnected at both the ends. This model is mounted on the magnets of the Telescope at European organisation for Nuclear Research (CERN), Geneva. Model is divided into two parts Magnet Rear Box (MRB) end and Magnet Front Box (MFB) end. Centre Pipes are called Cold Bores (CB). A thin sheet of stainless steel of .001m thickness is rapped on both the ends of the model. A He-Sleeve is present at immediate vicinity of the thin sheet rapped at both the ends of each Cold Bore. He-3 gas at low temperature is passed into the model from the inlet at the MRB end. Four windows, one on each open end of the cylinders that are part of MRB and MFB. The model is assumed to be steady and parallel to the ground.

3D-Modelling and Meshing:

A CAD model is prepared in STAR CCM+ with above mentioned dimensions only for the fluid region. solid part will be later extruded using extrusion option available in Star CCM+. Extrusion was preferred because of 2 reasons: 1. When a separate solid surface is created it is more likely that there can be gaps between both the surfaces because of difference in the surface size. 2. As the sheet is very thin, studying the variation of parameters across the sheet can be seen more prominently in the extruded surface rather in separate surface.

Initially face mesh is created with 0.01m base size and keeping all the other parameters to default. Then proceeding to polyhedral volume meshing resulted in very bad cell connectivity and also number of cells formed was approximately 8 million. This problem was overcome by increasing the surface curvature on the edges and reducing it at the corners, increasing the surface size on the cold bore and by using cell density variation factor. A prism layer mesher



is used to create a prism layer near the wall for having more accurate results.

Meshing models:

1. Surface Remesher
2. Polyhedral mesher
3. Prism layer mesher
4. Extruder

Base size: 0.01m
Prism layers: 8
Prism layer stretching: 2
Prism layer thickness: 15 %
Tet/Poly density: 0.8
Tet/Poly Growth: 0.8

Surface Curvature: 36 pts
Surface growth rate: 1.05
Surface size:
Relative target size: 15%
Relative minimum size: 10%
Tet/Poly Volume density: 1.0

The following are the details of the meshing :

Remeshed Surface : 1. Faces: 495624

2. Edges: 1876

Volume Meshing : 1. Cells : 2866578

2. Interior Faces: 12968676

3. Vertices: 8310303

Simulation:

Cast model is divided into four regions: 1. MRB Region 2. MFB Region 3. Stainless steel region 4. Windows region.

Physics Models:

Physics 1: MRB Region and MFB region

3-Dimensional

Steady state

Real gas: Helium-3 Gas

Reynolds Averages Navier-Stokes equations

Vander-walls approximation

K-E Turbulence modelling

Realizable K-E two layer model

Two layer all y+ wall treatment

Physics 2: Stainless steel Sheet

3-Dimensional

Steady state

Solid: Stainless steel

Coupled solid Energy

Constant Density

Physics 3: MRB and MFB windows

3-Dimensional

Steady state

Solid: Poly Propylene

Coupled solid Energy

Constant Density

Material Properties :

Helium -3: Critical Pressure: 0.186 bars

Critical temperature: 4.25 K

Dynamic viscosity: 1.9891E-5

Molecular Weight: 3.01603 kg/kg. Mol

Specific Heat: 6890 J/Kg-K

Turbulent Prandtl number: 0.9

Thermal conductivity: 0.001 W/m-K

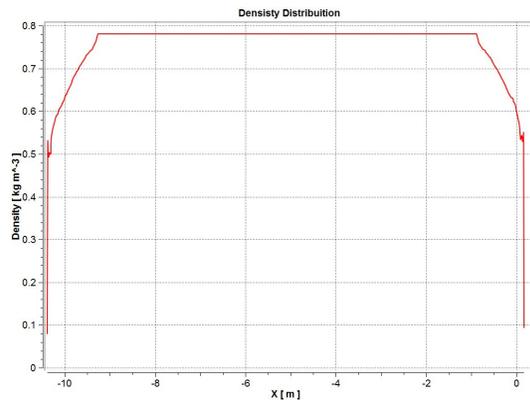
Stainless Steel: Density: 8055.0 Kg/m³

Specific heat: 480.0 J/Kg-K
Thermal Conductivity: 15.1 W/m-K

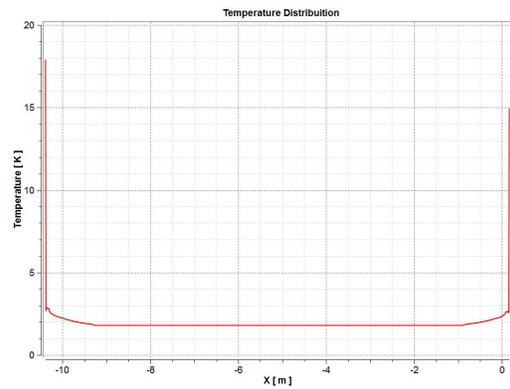
Poly Propelene: Density: 0.946 Kg/m³ (crystalline)
Specific heat: 26.15E-4 J/Kg-K at T=1 K
Thermal Conductivity: 0.03 W/m-K

Results:

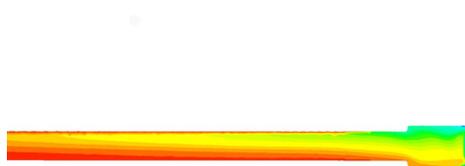
Graphs were drawn for Density, Temperature at different points on the Cast model, considering the centre of the cold bore as origin. Temperatures at different are visualized by creating two layers, each through the axis of both the Cold Bores.



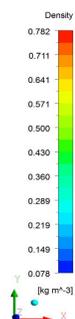
Density variation:



Temperature variation :



0 0.050 0.100 0.200 (m)



0 0.050 0.100 0.200 (m)

