CFD SIMULATION ON COOLING DOWN OF BERYLLIUM FILTERS FOR NEUTRON CONDITIONING FOR SMALL-ANGLE NEUTRON SCATTERING

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- Malaysian Nuclear Agency.

Presentation content

- Intro.
- Objectives
- Methodology
- Result and discussion
- Conclusion

Intro.

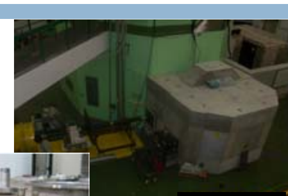
- Small Angle Neutron Scattering (SANS) instruments installed at beamtube #4 of TRIGA MARK II PUSPATI reactor required large thermal neutron wavelength, around 3.9 Angstrom and above in order to capture a morphological structure, the interfaces, the porosities in the materials.
- The cooled beryllium (Be) placed in cryogenics tank is used to filter thermal neutron wavelength smaller than 3.9 Angstrom. However, cooling rate is slow but thermal lost is high, causes the temperature in the tank to increase beyond 77 K during experiment. Eventually, increases in temperature would change the thermal neutron wavelength.
- This presentation focus on the temperature profile along the Be filters.

Cryostat – Cooling of Beryllium (Be) filters

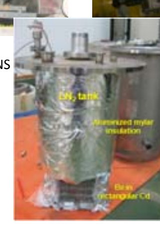
- Small Angle Neutron Scattering (SANS) - required large thermal neutron wavelength, around 3.9 Angstrom(Å) above.
- Requires a cryogenics cooling system – cryostat.
- To increase the transmission of neutron wavelength of 3.9 Å above, 16 bars of Be 3 x 3 x 15 cm assembled in a pigeon hole mesh of Cadmium (Cd) and is cooled by a thermal link to a liquid nitrogen tank.

Existing cryostat

Location of cryostat at SANS beam port (beam port #4)



Small Angle Neutron Scattering Instrument



Cryogenic tank and Be matrix

Existing Cryostat …

The existing cryostat is at Small Angle Neutron Scattering instrument which is at beamtube # 4

Cryostat – CAD model

Objectives

- To increase the flux of cold neutron and maintains the cold neutron wavelength.
- To come up with a new cryogenic system (cryostat) for neutron beam conditioning.
- To reduce cost and time.

Methodology

- Preliminary study
  - To study the current cooling system and work on the area of improvement.
- Computer Simulation
  - A number of computerized simulation will be undertaken to obtain the optimum design of the cooling system. The simulation is done using engineering and scientific simulation package.
- Experimental Work
  - Based on the simulation results an experimental setup was done to validate the simulation results using the test rig.
- Fabrication and Testing
  - The chosen cooling system design is fabricated and will be tested at site.

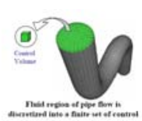
Preliminary study

- Cooling of Be is less efficient.
- Low heat transfer rate.
- Single plane heat transfer.
- Operational cost increase.
- This is why we need to increase the efficiency of the cryostat

Computer Simulation - CFD Simulation

- Computational Fluid Dynamic (CFD) package – FLUENT
- FLUENT solvers are based on the finite volume method.
- General conservation (transport) equations for mass, momentum, energy, species, etc. are solved on this set of control volumes.
- Partial differential equations are discretized into a system of algebraic equations. All algebraic equations are then solved numerically to render the solution field.

$$\underbrace{\frac{\partial}{\partial t}\int_V \rho\phi\, dV}_{\text{Unsteady}} + \underbrace{\oint_A \rho\phi \mathbf{V}\cdot d\mathbf{A}}_{\text{Convection}} = \underbrace{\oint_A \Gamma\nabla\phi\cdot d\mathbf{A}}_{\text{Diffusion}} + \underbrace{\int_V S_\phi\, dV}_{\text{Generation}}$$

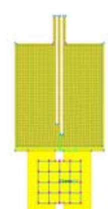


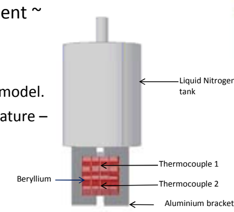
Source: www.fluentusers.com

Cryostat Simulation..

- Gambit – Preparation of 2D model with mesh.
- Solver – Fluent, Transient ~ 240 minutes.
- Assumptions;
  - k – epsilon turbulence model.
  - Liquid nitrogen temperature – 77K
  - Conjugate heat tranfer

Cryostat - 2D mesh model

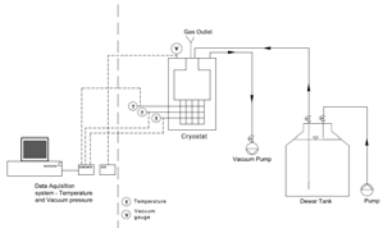




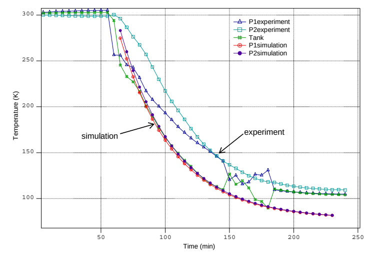
Model of simulation and location of thermocouple at Beryllium filters

Experimental work

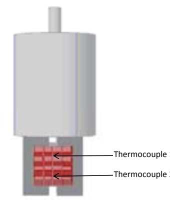
- Schematic of experimental work
  - Type-T thermocouple sensor integrate with data acquisition system.
  - Wide range vacuum gauge – atmospheric to 10^{-9} torr.



Result & Discussion

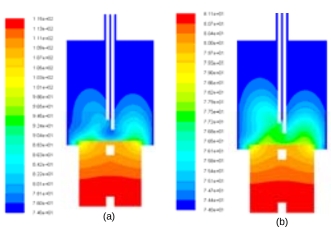


Comparison of temperature data between Experimental and simulation.



Location of thermocouple at Beryllium filters

Result & Discussion



Temperature profile : 2D Temperature profile at: (a) 30 min; (b) 60 min

Result & Discussion

- The simulation data shows that the temperature decrease exponentially after 240 min and achieved ~ 80K.
- The experimental data shows that the temperature achieved 110K after 240 min.
- The different is 21 % between simulation and experimental data.

Conclusions

- From the simulation, there is a decrease in temperature to cool the Be and need to be improve.
- The experimental data shows that the cooling is in plateau region after 240 minute. Therefore, a new design with multiple cooling plane to increase the efficiency of the cryostat.
- A reduce in time and prolonged cooling is preferable in the new design.

Thank you