Numerical Investigation for the Effect of Guide Panel on Heat Transfer from Steel Containment

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Introduction: A typical steel containment of nuclear reactor along with thick RCC concrete structure and guide panel has been modelled using COMSOL Multi Physics. Steady state analysis has been carried out to study the significance of guide panel on heat transfer from containment. The effect of location of guide panel on heat transfer was also carried out for two different distances from steel containment.

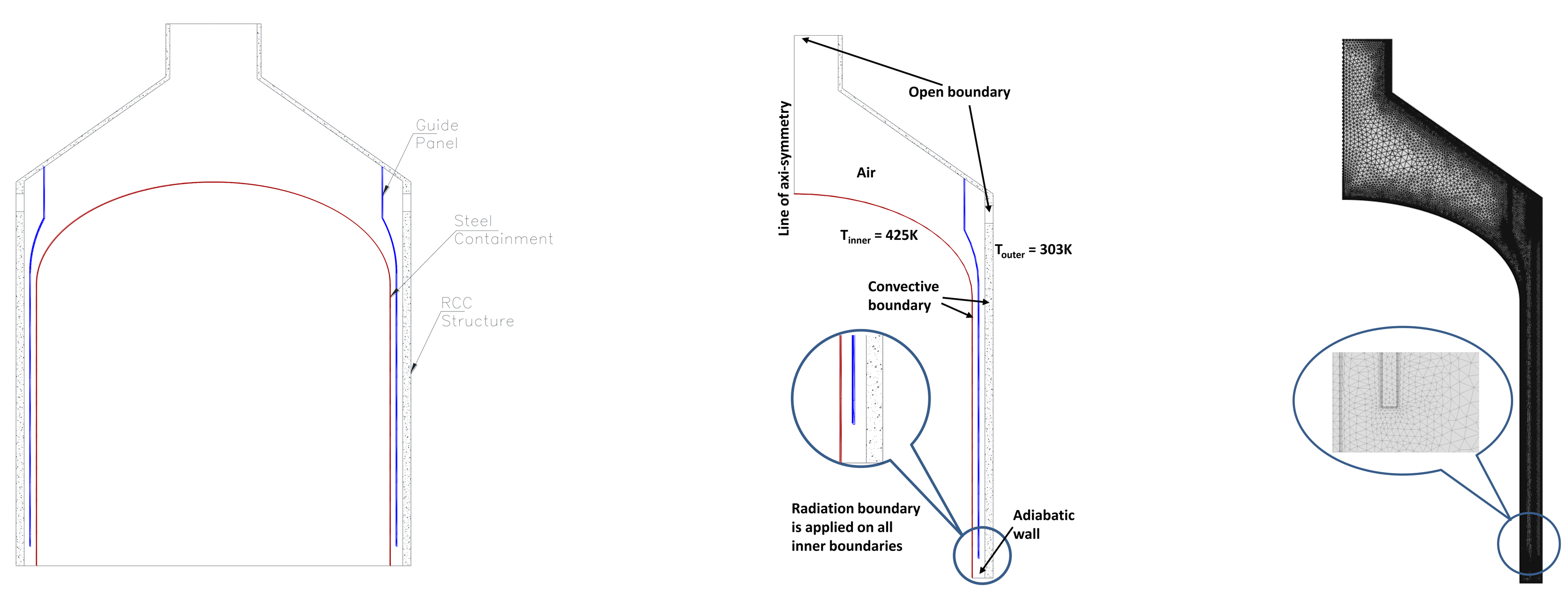


Fig.1. Steel Containment and RCC structure – Schematic diagram, Computational domain and Grid arrangement.

Numerical Approach:
Based on the Navier-stokes time averaged equations and using Bousssinesq approximation for Reynolds stresses, differential equations for governing viscous turbulent flow is solved. The fluid is assumed incompressible.. The current case is solved as 2-D axisymmetric problem with the typical computational domain along with boundary conditions. Because of the complex geometry, unstructured grids with appropriate boundary layers have been employed to adequately capture momentum and thermal gradients. Conjugate heat transfer module with K-epsilon turbulence model and radiative heat transfer has been used. Although complete accident analysis is transient in nature, in this work, steady state analysis was carried out to study the effects of guide panel. Peak temperature and condensation heat transfer coefficient was given as boundary condition at the inside surface of steel containment and at outside surface of concrete structure, heat transfer takes place by convection.

Governing equations

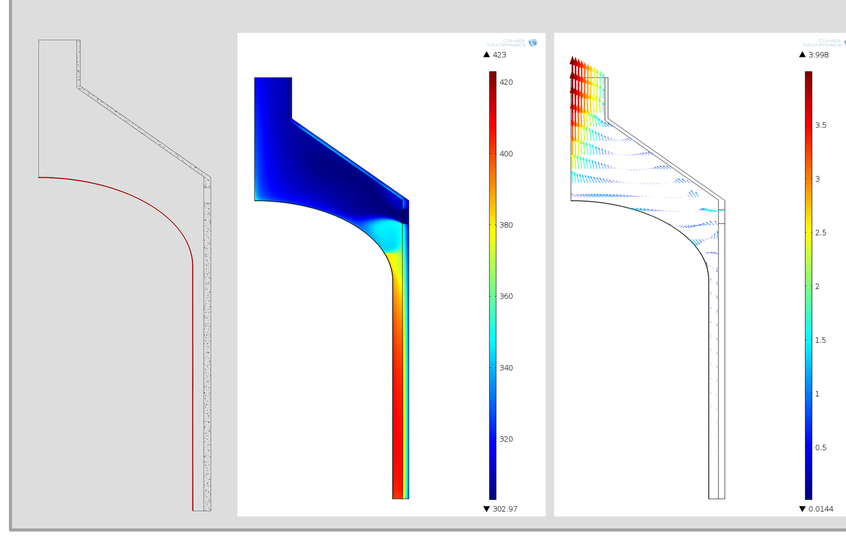
$$div(\rho u) = 0$$

$$div(\rho uu) = div(\mu_{eff}\, grad u) - \frac{\partial p}{\partial x} + f_x$$

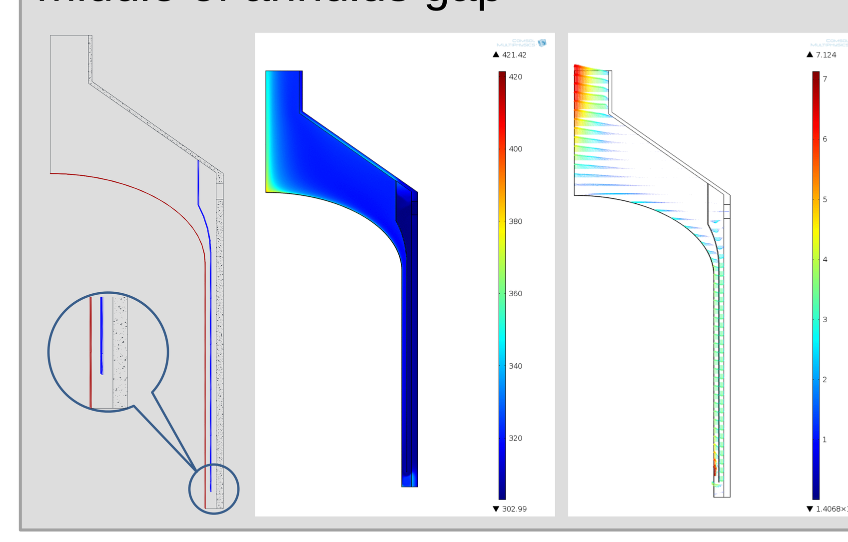
$$div(\rho uv) = div(\mu_{eff}\, grad v) - \frac{\partial p}{\partial y} + f_y$$

Results: To study the importance of guide panel and effect of location of guide panel analysis has been carried out for three cases, which are (case-i) without guide panel, (case-ii) With Guide panel located in the middle of annulus gap and (case-iii) With Guide panel in the annulus gap located near the steel containment.

Case-1 : Without Guide panel



Case-2 : With Guide panel in the middle of annulus gap



Case-3 : With Guide panel in the annulus gap near the steel containment

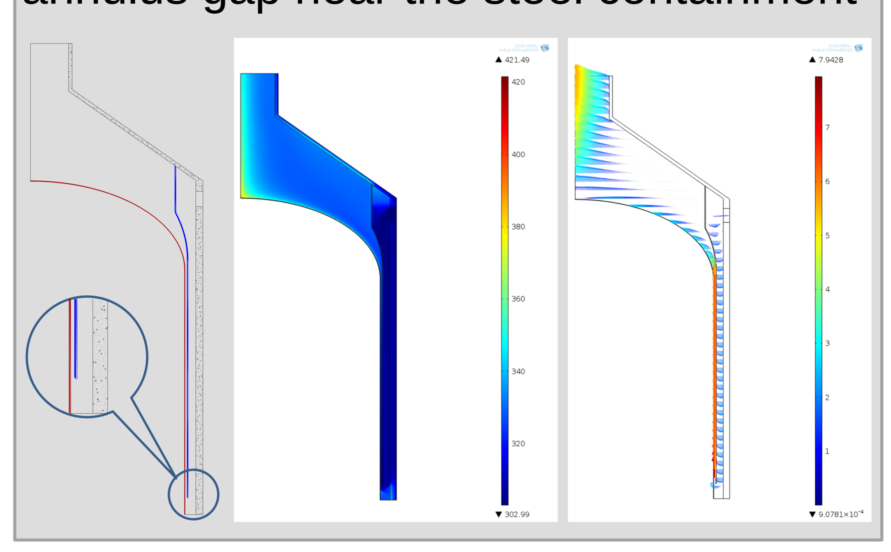


Table-1 : Heat removal rate for all cases

	Air Inlet Temp (K)	Avg. Air Outlet Temp (K)	Peak Velocity (m/s)	Avg. Velocity at stack (m/s)	Total air mass flow rate (kg/s)	Heat removal rate (MW)
CASE-1	303.0	313.14	4.00	2.87	257.5	2.60
CASE-2	303.0	329.40	7.10	4.34	389.4	10.30
CASE-3	303.0	335.90	7.94	3.65	327.3	10.78

Conclusions: The guide panel in steel containment allows the air to pass over the full length of the steel containment and also transfers heat to air by receiving the heat from the steel containment through radiation. The guide panel provides enhanced heat removal passively by 4 times than when guide panel is not provided. It also avoids the formation of local air pockets which leads to increase in concrete temperature. The effect of location of guide panel (i.e. gap between steel containment and guide panel) on the heat transfer has been studied for two cases, however the heat removal rate for both the cases are almost same.

References:
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