THERMAL ANALYSIS OF MAIN VESSEL- ROOF SLAB JUNCTION WITH SPILLWAY WEIR IN FAST REACTOR

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ABSTRACT

Main Vessel is an important structure used in Reactor assembly that need to be cooled to avoid non uniform Temperature distribution. Main vessel cooling system consists two concentric cylindrical shells attached to inner side of main vessel. This can be achieved by providing a Spillway weir over the outer baffle in the Main vessel cooling system. This paper describes the thermal analysis of Main vessel -roof slab junction in fast reactor .The analysis is done by varying the height of this junction using computational Fluid Dynamics technique. Fluent is the Post processor used for this thermal analysis. The temperature distribution around the surface of spillway profile is analysed for better results.

Keywords: Computational Fluid Dynamics, Spillway weir, Thermal analysis.

I. INTRODUCTION

Main vessel cooling system consists of two concentric cylinder baffles attached to the inner side of the main vessel. In which the temperature difference between the bulk of hot and cold pools is 150k. The gap between inner vessel and main vessel is only 300mm for a height of 4m. Due to the temperature difference between the hot and cold pools there is a continuous heat transfer from the hot pool to cold pool to the extent of 11MW. Due to this, the temperature of main vessel increases and approaches a value close to that of hot pool (820k). The main vessel is made up of ss-316, which undergoes significant creep, once the temperature exceeds 753k (480°C). Hence, it is decided to cool the main vessel using the sodium leaking from feet of the subassemblies. Cooling the main vessel also minimize the effects of thermal fatigue and embrittlement. It also reduces the axial temperature gradient in the vessel at sodium-argon interface.

II. DESIGN OF SPILLWAY WEIR SYSTEM

The one fourth scale model of main vessel cooling system with spillway profile is designed using

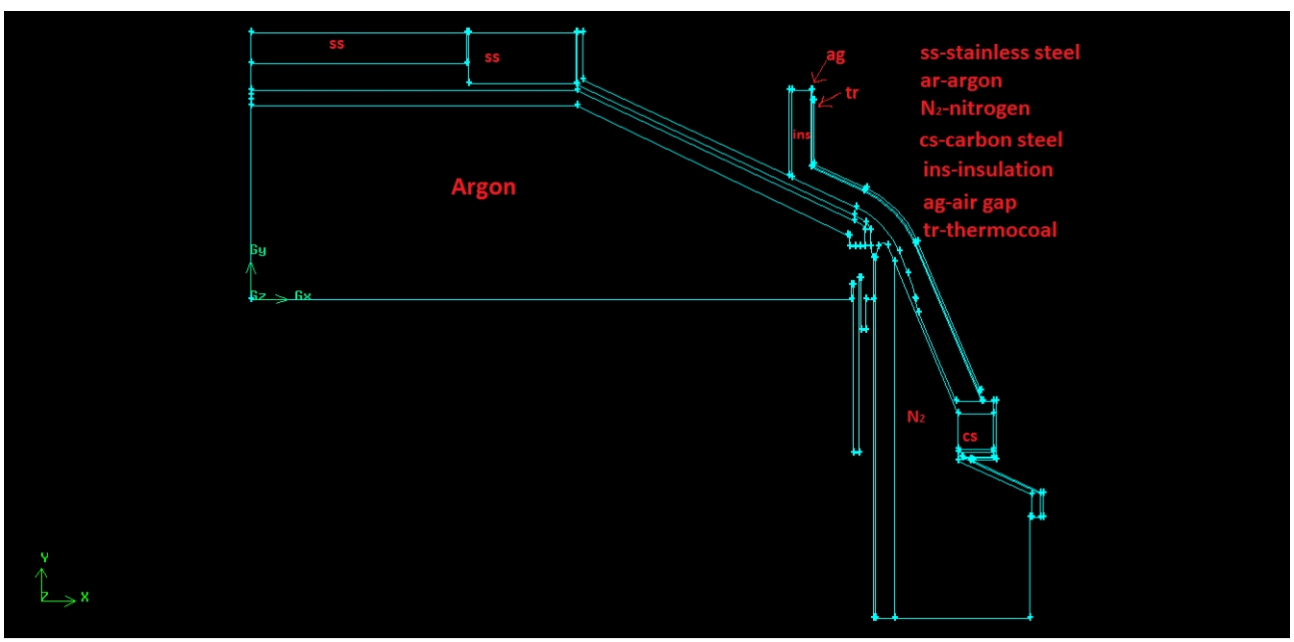

Fig. 1. 2D Sketch without change in height of Main Vessel-Roof Slab Junction (Design 1)

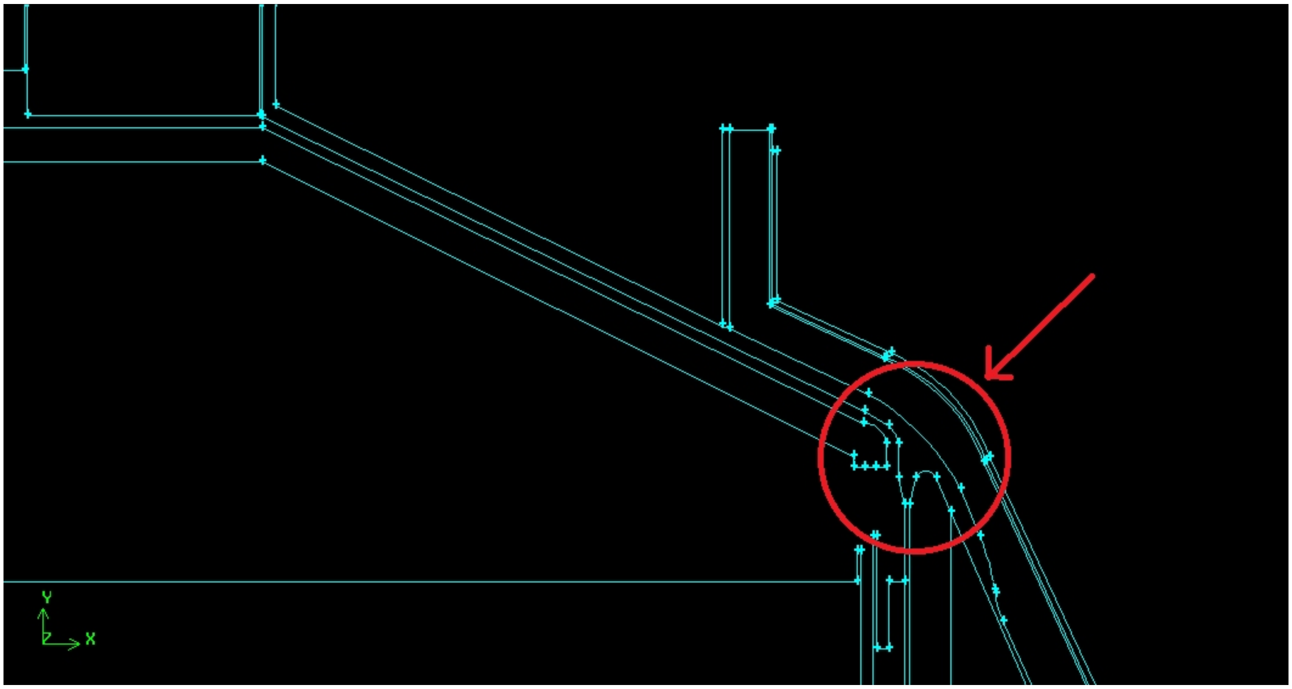

Fig. 1. 2D Sketch with change in height of 50 mm in Main Vessel-Roof Slab Junction (Design 2)

GAMBIT. Th designs process is done by the software called gambit 2.4.6 version which also be the meshing software so that we can export the files to fluent (computational fluid dynamic software) software for analysis. In this software the design are done by the steps

In which geometry involves vertex, edge, face, volume. In our design the mesh volume generated for each zone is also listed in this paper.

The above figure shows the one fourth of the dome shape of an nuclear reactor. In which for thermal analysis we need only the 2d design to analyse the temperature distribution in the spillway part which is fabricated with stainless steel. This figure is a normal design in which further modification has to be change with respect to the height of the spillway. The modified design is shown in fig:2 in which height of the spillway is decreased by 50mm so that the temperature may change on the surface of an spillway

III. MESH GENERATION

In meshing process the first step is to select the face to be mesh. Then by selecting the meshing element and meshing type which is suitable for our design and also spacing then meshing processing which be started and takes sometime to finish after smooth mesh processing. In which it will be interconnecting the yellow lines into the selected face with respect to the mesh space value finally it will be calculated the mesh volume of an face selects.

Table 1. Mesh element and type for Design 1

Materials	Faces	Element	Type
Argon	1	quad	pave
Stainless steel	2, 3, 4, 5, 6	quad	2,3,6-pave 4,5-map
Carbon steel	9, 10, 11, 12	quad	9-map 10-submap 11,12-pave
Nitrogen	7, 8	quad	pave
Insulation	13	quad	sub map
Air gap	14	quad	sub map
Thermo coal	15	quad	sub map

Table 2. Mesh element and type for Design 2

Materials	Faces	Element	Type
Argon	1	quad	Sub map
Stainless steel	2,3,4,5	quad	2,4,5-pave 3-map
Carbon steel	6,15, 16,17	quad	6-map 15-sub map 16,17-pave
Nitrogen	10,11	quad	pave
Insulation	12	quad	Submap
Air gap	13	quad	submap
Thermo coal	14	quad	submap

Table 3. Mesh volume of design

Materials	design:1 mesh volume	Design:2 mesh volume
Argon	161371	333532
Stainless steel	45233	136798
Carbon steel	4001	4354
Nitrogen	51928	51808
Insulation	12621	12582
Air gap	409	410
Thermo coal	1092	1088

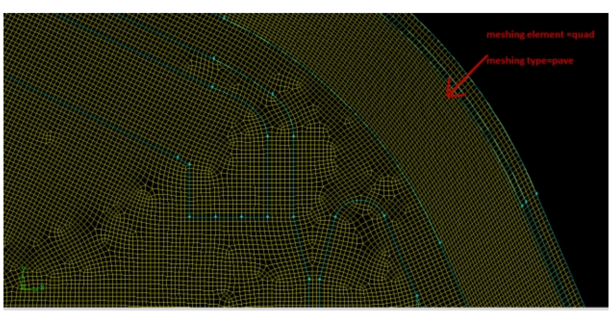

Fig. 3 Mesh Generation for the Designs

The above figure shows meshing of an face area to the given condition. In this meshing process different elements are available in which the element of meshing is respect to there designed area. If it is rectangular design it will be choosing quad and meshing type will be map or submap in 2d design.

After mesh process the mesh volume will be displayed in transcript report sheet. The mesh volume will differ when design alters or areas of the material area design increases. When compare to fig:1 design and fig:2 design the mesh volume of an material area are differ because of the area increase due to increase or decrease in spillway height.

For example:

Design 1: Mesh Volume of insulation area = 12621

Design 2: Mesh Volume of insulation area = 12582

IV. THERMAL ANALYSIS

For thermal analysis fluent software is used to analyse the temperature distribution of the Junction. The fluent software needs only the mesh files to be imported for the operation. So that gambit design software is exported a mesh file to import into the fluent software to analyse the design. When importing the case file the grid check will be evaluating the condition given is correct or wrong. Then by defining the equations and applying the boundary condition the process leads to the iterations for solution is to be converged. Then through contour temperature distribution diagram will be getting the results of our design.

A. Material properties:

Air – density $= 1.277$ kg/m^3

C_p $= 1007$ j/kg–k

Thermal conductivity $= 0.02701$ w/m – k

Viscosity $= 2.837e^{-05}$

Argon – density $= 0.9$ kg/m^3

C_p $= 520$ j/kg–k

Thermal conductivity $= 0.02807$ w/m – k

Viscosity $= 3.572e^{-05}$

Temperature $= 820$ k

Carbon steel –density $= 7850$ kg/m^3

C_p $= 519$ j/kg–k

Thermal conductivity	= 47 w/m–k
Stainless steel -density	= 7781 kg/m^3
C_p	= 560 j/kg–k
Thermal conductivity	= 20.1 w/m–k
Temperature	= 393 k
Nitrogen – density	= 1.138 kg/m^3
C_p	= 1064.3 *j/kg – k*
Thermal conductivity	= 0.04104 w/m – k
Thermo coal – density	= 2.5 kg/m^3
C_p	= 1000 j/kg – k
Thermal conductivity	= 0.035 w/m – k
Insulation – density	= 196 kg/m^3
C_p	= 552 j/kg – k
Thermal conductivity	= 0.05 w/m – k

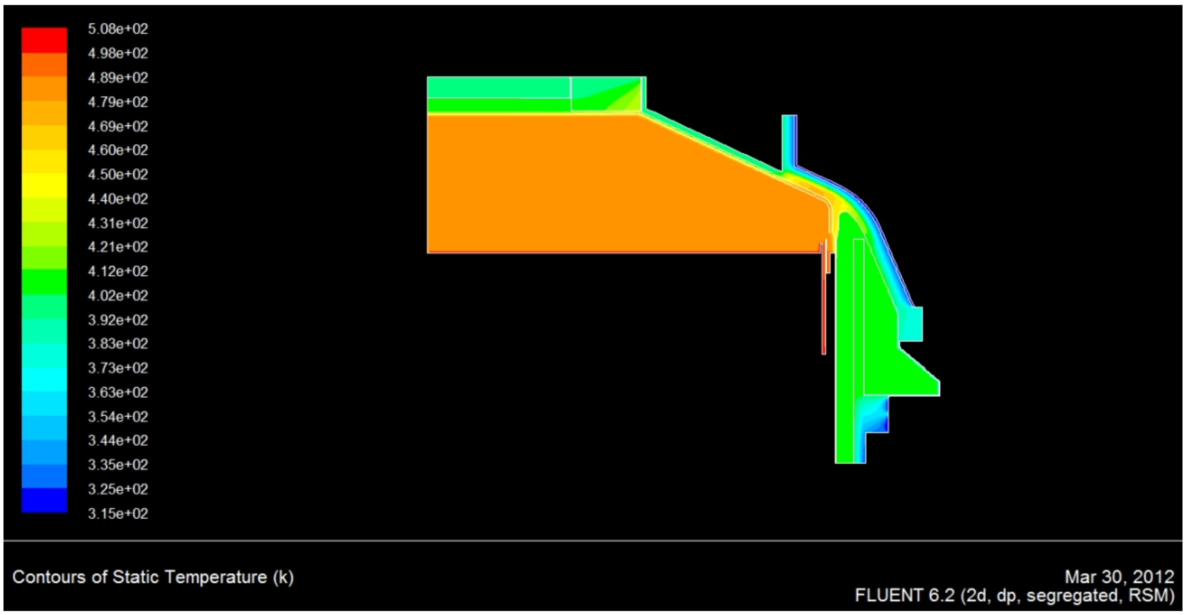

Fig. 4. Without changing the height of the spillway

Fig. 5. Changing the height of the spillway

V. RESULTS AND DISCUSSION

By changing the height of the spillway the temperature also change in various place in the joining surfaces. When height decreases the area decreases in some material space and shows the different heat transfer from one surface to another along the line joining surface. The temperature changes can be noticed at the line joining surface of argon and spillway stainless steel material. Fig.4 shows the result diagram of unchanged height of an spillway which shows the temperature is about 723k, in other case we have that the change in height of the spillway of $-50\,\text{mm}$ in which the temperature decreases at the same region of selection is 708k. The difference in temperature is about 15k due to decreases in height of spillway of 50 mm. By selecting various region along the line joining surface we will be getting the different temperature when compared to two cases in fig.4 and fig.5.

VI. CONCLUSION

Test conducted in spillway indicated that the design 2 is to be chosen for better results in experimentation. It means that the temperature is less when compare to the design 1 along the line joining surface of argon and stainless steel spillway.

VII. REFERENCES

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