EFFECT OF STEEL LINERS ON CONCRETE CONTAINMENT STRUCTURE

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Abstract: Being a critical element of the nuclear power plant, it is imperative that the containment structure must be designed optimally. In this paper, the effect of steel liner on concrete containment structure was studied by Finite Element Method (FEM) in ABAQUS software. For doing so, containment structure was modeled by taking the dimensions from previous research work [Jiachuan Yana,2018] which are used in third generation power plant and was subjected to LOCA (Loss of Coolant Accident) pressure. To study the effect of thickness of steel liners, the magnitude of the principal stress at critical nodes in concrete containment structure without steel liner was compared with steel liners in the concrete containment structure. 15 different models were developed by varying the thickness of the steel liner to study the behavior of principal stresses. Upon doing the analysis, it was found Maximum principal stresses in tension reduce 1.778% & Maximum principal stresses in compression reduce 5.911% by adding 5mm steel liner to structure on the inner most edge of the structure.

***Keywords* – Concrete containment structure, Steel liner, LOCA (Loss of Coolant Accident)**

I. Introduction

Concrete containment structure is very essential part of nuclear power plant. It is the outer most system which prevents leakage of radioactive gas and material. So, it is basically airtight concrete structure. Fuel ceramic, Reactor Vessel, Coolant System are the first three system which prevents the radio activity.

There are two types of the concrete containment structure, one is single wall concrete containment structure and another one is double wall concrete containment structure (double shell concrete containment structure). As their name suggests single wall concrete containment consists of only one cylinder and one dome part while the double shell concrete containment structure consists of two thick concrete walls and two domes. Double shell concrete containment structure is practiced to improve its performance due to the possible threat of external attack (like airplane crash on structure, blast near the structure) on the structure. After the event of the Fukushima Daiichi nuclear disaster in Japan, government and other responsible agencies became more conscious about the safety issue of structure. A number of researches have been carried out on how the structure behaves during the external attack.

The concrete containment structure is made up of two parts, one is concrete and the other one is steel liner. Steel liner is attached to the concrete section at the innermost part of the structure in both types of the concrete containment structure. Steel liner was introduced to the structure to reduce the stresses on the important part of the structure.

The concrete containment structure is designed for self-weight, service loads (machinery), temperature difference and loss of coolant accident load.

II. Structural Model and Methodology

Figure 1 shows the cross-section details of a concrete material part in which dimension of cylinder part, inner and outer dome, height of the structure and other necessary dimensions are mentioned. Figure 2 shows cross-section of steel liner (with varying thicknesses as per model requirements).

Concrete part is having modulus of elasticity 35355 N/mm2 and poission ratio 0.18. Steel liner is having modulus of elasticity 210000 N/mm2 and poisson ratio 0.25. C3D10 Element has been used for the analysis concrete part & S8R Element has been used for the analysis of steel liners. The structure has been analysed for 250KPa LOCA pressure.

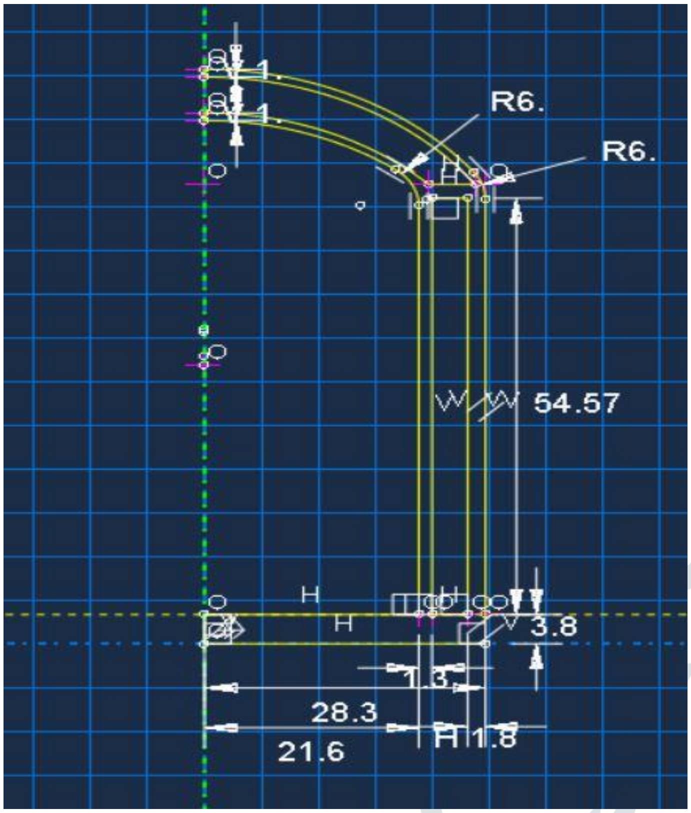

Fig 1 (Cross section of only concrete part of structure)

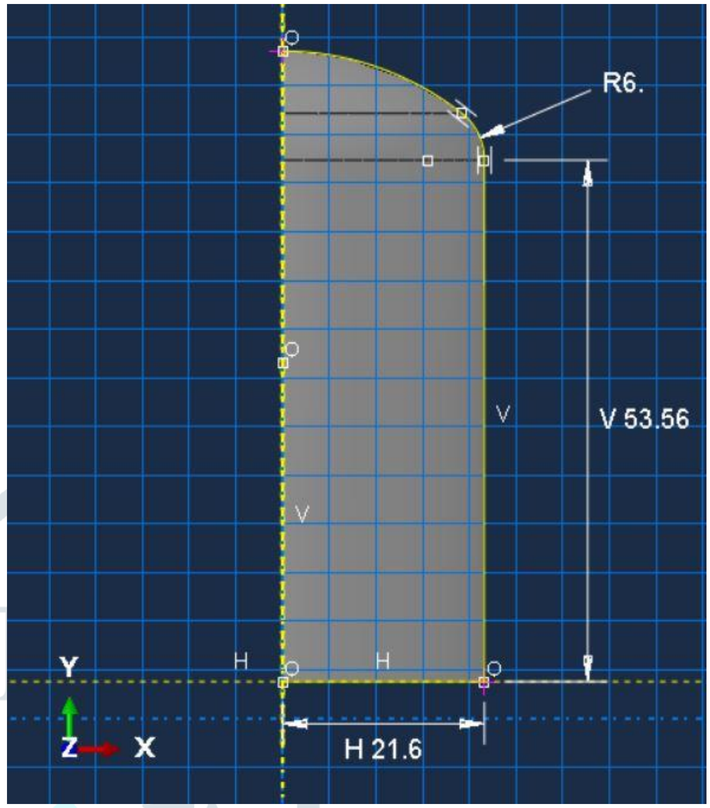

Fig 2 (Cross section of steel liner of structure)

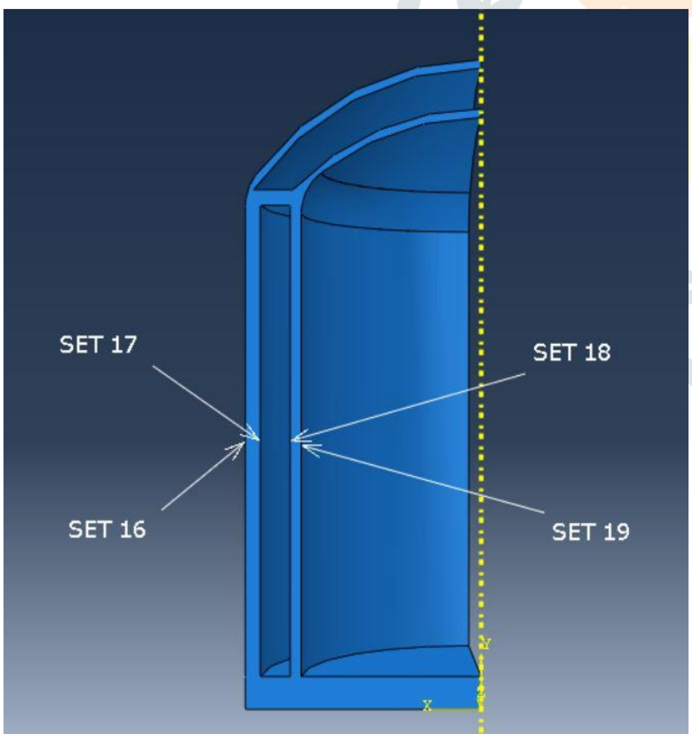

Fig 3 (Important edges of structure)

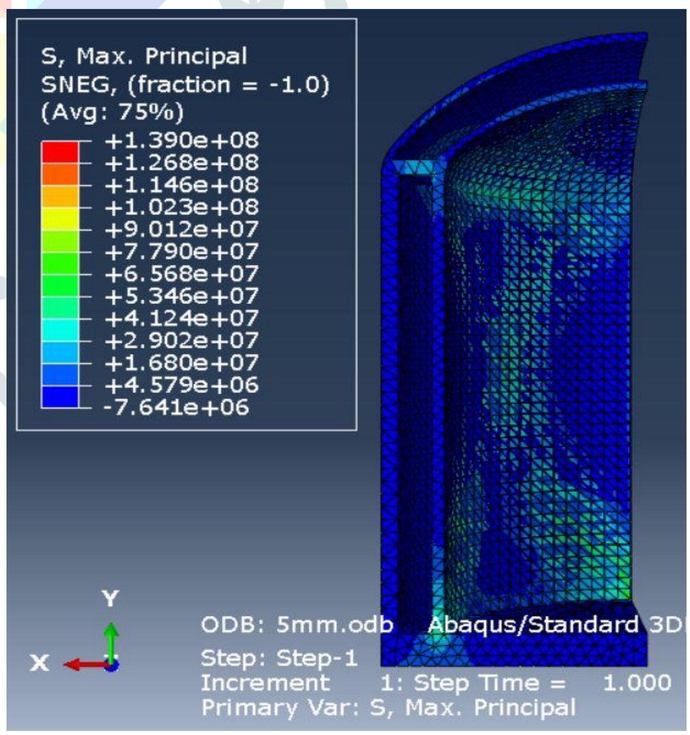

Fig 4 (result of max. principal stress with 5mm steel liner)

First, the axisymmetric model having only concrete part is being analysed. Then steel liner of different thickness is being provided in different 15 models (thickness 5,5.3,5.6….9.2) at the innermost edge of the structure. Model is being analysed as an axisymmetric model in two directions. Maximum principal stress at important edges (as shown in following figure 3) are being observed.

Figure 3 shows the important edges (SET 16, SET 17, SET 18, SET 19) in structure. Maximum principal stress on these edges is observed. Following table shows maximum principal stress in tension and compression & percentage variation of maximum principal stress on a particular edge (SET). Figure 4 shows the maximum principal stress with a 5mm steel liner.

III. RESULTS

Table 3.1 Comparison of maximum principal stress on set 16

Thickness of steel liner (mm)	Maximum principal stress in tension (N/mm^2)	Percentage variation
Without steel liner (concrete containment structure)	3.376	NA
5	3.316	-1.762
5.3	3.313	-0.089
5.6	3.310	-0.088
5.9	3.307	-0.087
6.2	3.305	-0.087
6.5	3.302	-0.087
6.8	3.299	-0.086
7.1	3.296	-0.086
7.4	3.293	-0.085
7.7	3.290	-0.084
8	3.288	-0.083
8.3	3.285	-0.079
8.6	3.283	-0.077
8.9	3.280	-0.075
9.2	3.278	-0.075

Table 3.2 Comparison of maximum principal stress on set 17

Thickness of steel liner (mm)	Maximum principal stress in tension (N/mm^2)	Percentage variation	Maximum principal stress in compression (N/mm^2)	Percentage variation
Without steel liner (concrete containment structure)	6.589	NA	-0.328	NA
5	6.473	-1.764	-0.323	-1.566
5.3	6.467	-0.090	-0.323	-0.077
5.6	6.461	-0.089	-0.323	-0.077
5.9	6.456	-0.089	-0.322	-0.076
6.2	6.450	-0.088	-0.322	-0.075
6.5	6.444	-0.088	-0.322	-0.075
6.8	6.439	-0.088	-0.322	-0.074
7.1	6.433	-0.087	-0.321	-0.073
7.4	6.428	-0.086	-0.321	-0.072
7.7	6.422	-0.085	-0.321	-0.071
8	6.417	-0.084	-0.321	-0.070
8.3	6.412	-0.080	-0.320	-0.067
8.6	6.407	-0.078	-0.320	-0.065
8.9	6.402	-0.076	-0.320	-0.064
9.2	6.397	-0.075	-0.320	-0.063

Table 3.3 Comparison of maximum principal stress on set 18

Thickness of steel liner (mm)	Maximum principal stress in tension (N/mm^2)	Percentage variation
Without steel liner (concrete containment structure)	44.978	NA
5	44.363	-1.367
5.3	44.335	-0.064
5.6	44.307	-0.063
5.9	44.280	-0.061
6.2	44.253	-0.061
6.5	44.225	-0.062
6.8	44.199	-0.059
7.1	44.174	-0.058
7.4	44.150	-0.054
7.7	44.128	-0.050
8	44.107	-0.047
8.3	44.084	-0.054
8.6	44.059	-0.057
8.9	44.034	-0.056
9.2	44.010	-0.056

Table 3.4 Comparison of maximum principal stress on set 19

Thickness of steel liner (mm)	Maximum principal stress in tension (N/mm^2)	Percentage variation	Maximum principal stress in compression (N/mm^2)	Percentage variation
Without steel liner(concrete containment structure)	49.564	NA	-2.121	NA
5	48.683	-1.778	-1.995	-5.911
5.3	48.641	-0.087	-1.991	-0.205
5.6	48.599	-0.086	-1.987	-0.199
5.9	48.562	-0.075	-1.983	-0.194
6.2	48.526	-0.075	-1.980	-0.189
6.5	48.486	-0.082	-1.976	-0.161
6.8	48.447	-0.080	-1.974	-0.124
7.1	48.410	-0.076	-1.972	-0.118
7.4	48.378	-0.065	-1.969	-0.129
7.7	48.347	-0.064	-1.967	-0.120
8	48.321	-0.055	-1.966	-0.025
8.3	48.284	-0.076	-1.967	0.050
8.6	48.244	-0.083	-1.967	-0.009
8.9	48.205	-0.080	-1.967	0.000
9.2	48.166	-0.082	-1.967	-0.017

Percentage variation is calculated with reference to above model in the above table.

IV. Conclusion

1. On the outer most edge of structure (outer cylinder part, set 16), Maximum principal stresses in tension reduce 1.762% by adding 5mm steel liner to the structure. Maximum principal stresses Stresses in tension reduce 0.085% for additional 0.3mm steel to 5mm till 8mm.
2. On next to the outer most edge of structure (outer cylinder part, set 17), Maximum principal stresses in tension reduce 1.764% by adding 5mm steel liner to structure. Maximum principal stresses in tension reduce 0.09% for additional 0.3mm steel to 5mm till 8mm.
3. On next to the innermost edge of structure (inner cylinder part, set 18), Maximum principal stresses in tension reduce 1.367% by adding 5mm steel liner to structure.
4. On the innermost edge of structure (cylinder part, set 19), Maximum principal stresses in tension reduce 1.778% & Maximum principal stresses in compression reduce 5.911% by adding 5mm steel liner to structure.

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