A Numerical Approach of Designing the Primary Containment Building of a Pressurized Water Reactor

M. Hossain,[a]* A. H. Khan,[b] M. A. R. Sarkar[a]

[a]*Department of Mechanical Engineering, Bangladesh University of Engineering and Technology (BUET)*
[b]*Department of Industrial and Production Engineering, Jessore University of Science and Technology (JUST)*
[*] *mosharrof.buet@gmail.com*

INTRODUCTION

This study includes both the mechanical analysis and the attenuation of thermal neutron released from the reactor core. Comparing both of these phenomena, an optimum design of the containment has been predicted.

Mathematical Modeling

Mechanical Stress

Considering the primary containment as a thin walled cylinder, the tangential stress can be calculated to be:

$$\sigma = \frac{P \times D}{2t}$$

Neutron Attenuation point of view

High density aggregates (such as barite, magnetite and hematite aggregates) are used as ingredients of construction material to absorb the gamma radiation as well as neutron of various energies. Radiation intensity is attenuated following the formula:

$$I = I_o e^{-\sigma N x}$$

RESULTS

Using finite element method, the following results have been obtained.

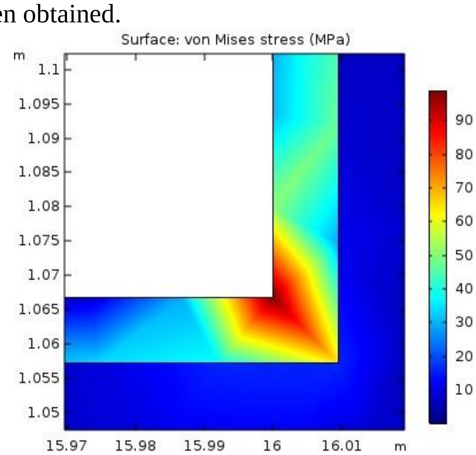

Fig. 1: Stress Distribution in the wall of Reactor Containment Building (RCB).

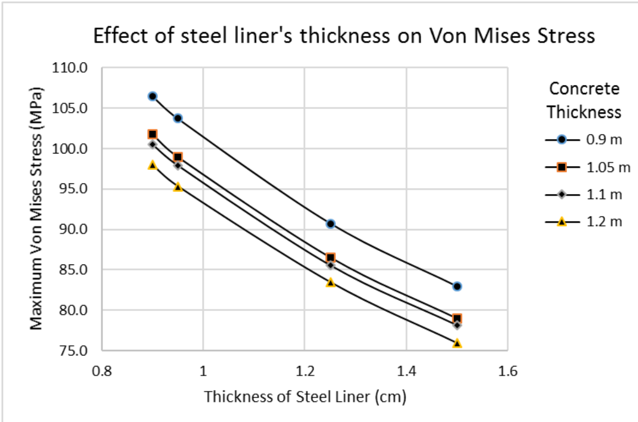

Fig. 2: Effect of steel liner's thickness on maximum Von Mises stress.

Effect of steel liner's thickness on Neutron's intensity has been predicted through mathematical analysis.

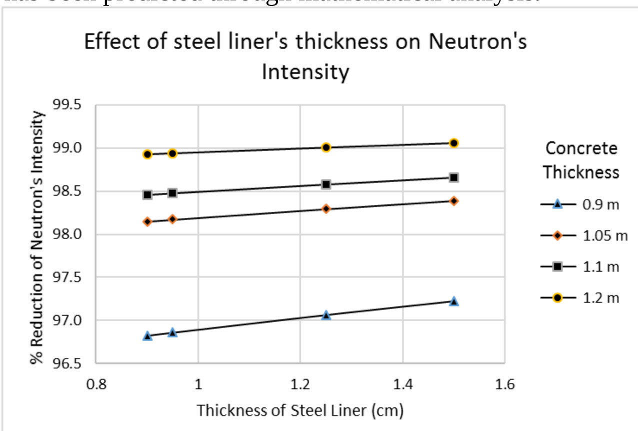

Fig. 3: Effect of steel liner's thickness on neutron's intensity.

APPENDIX A: PRELIMINARY TESTING ALGORITHM

A simplified approach was adopted for this simulation. Predicting the symmetrical condition of the geometry, 2D axis-symmetric model of the primary containment building was implemented on COMSOL Multiphysics. For physics-controlled mesh and normal element size, number of domain elements were varied from

85405 to 47496 depending on the case study. All the elements were taken to be triangular in shape. The base of the concrete section was defined as fixed-end condition. Top of the spherical dome was defined as axial-symmetric condition. The inner pressure was set to be 414kPa which is the design pressure of this specific containment.

NOMENCLATURE

σ = Stress on the element

φ = Radiation flux density after attenuation

I = Radiation intensity after attenuation

σ_a = Absorption cross section of the material

N = Atomic density of the material

ENDNOTES

This work has only considered sixteen possible combinations of thicknesses of steel liner and concrete in order to justify the existing design condition. Even the openings were not considered for the sake of simplicity. Further studies may be done to overcome the limitations of this work.

REFERENCES

[1] Hans Lorenz (1967), "Design of the Concrete Containment Vessel for the R.E. Ginna Nuclear Power Plant". Nuclear Engineering and Design, Volume 6, pp. 360-366.

[2] Hansraj Ashar, "Containment Structures of U.S. Nuclear Power Plants: Background, Regulations, Codes and Standards, and Other Considerations", page 20.

[3] Daria Jóźwiak-Niedźwiedzka et. al. (2015), "Mineral composition of heavy aggregates for nuclear shielding concrete in relation to alkali-silica reaction". Procedia Engineering, Volume 108, pp. 162 – 169.