Evaluation of Structural Integrity for the Magazine Housing of Fuelling Machine

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1. Introduction

Wolsong NPP 1 which is the reactor type of the PHWR uses the natural uranium and has 380 fuel channels. For 100% power operation, the refueling is accomplished in-service. The fuel changing operation is based on the combined use of two remotely controlled fuelling machines (F/M), one operating on each end of a fuel channel. New fuel bundles, from one F/M, are inserted into a fuel channel in the same direction as the coolant flow and the displaced irradiated fuel bundles are received into the second F/M at the other end of the fuel channel. Fig.1 shows Fuelling Machine in operation.

The F/M Magazine acts as a temporary storage area for fuel bundles and the various plugs in the F/M during refueling. It generates thermal and mechanical loads in the F/M Magazine. Together with seismic loads during seismic activity, these loads are considered in the Magazine design.

In this paper, the evaluation of the structural integrity of the F/M Magazine housing is performed for Design, Test and Service condition loads given in the analysis requirement [1] for the extended life time from 30 years to 50 years. The Magazine is classified as Safety Class 1. A stress analysis of the Magazine is carried out based on the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 1998 Edition with 1999 Addenda [2]. As shown in Fig.2, the Magazine housing is made up of a thick cylindrical shell and is connected to the End cover at one end through 30” Grayloc clamp. The other end of the Magazine is clamped to the ram housing with a 10” Grayloc clamp. The material of construction of the magazine housing is ASME SA-182, F6a, class 2. The stress analysis is done by using the finite element method.

2. Analysis

The analysis of the Magazine housing is carried out using commercial code ANSYS [5] for the loads specified in the analysis requirement [1]. The finite element model used in the analysis is shown in Fig.3. Throughout the analysis a global coordinate system as follows is used. Z-axis, Y-axis and X-axis mean axial, vertical and transverse direction respectively. Due to symmetry (X-axis) only half of the Magazine is modeled. The analysis is divided into separate thermal analysis to determine the temperature distribution due to the thermal loads, stress analysis to calculate the stress in the Magazine due to the mechanical loads and due to the calculated temperature distribution and seismic load analysis and the fatigue analysis to calculate the cumulative usage factor.

The loads are given in References [1, 3, 4]. Non-seismic loads are summarized in Table 1. Seismic loads are summarized in Table 2. Mechanical loads acting on the Magazine are bolt preload, pressure inside the magazine, ram force required to transfer the fuel bundles, misalignment load generated during the clamping of the F/M with the endfitting or ports. The temperature distribution is an important load for fatigue evaluation. The reasonably combined loads are applied to the FE model under each service condition.

There are two mounting brackets on the magazine connected to the support cradle. The bigger bracket near to front end is constrained in the vertical direction (Y). The smaller bracket near to rear end is constrained in the axial (Z) and vertical direction (Y). Fig.3 shows the applied loads and boundary condition to magazine housing.

Table 1. Summary of Non-seismic Loads

Load Type	Design Cond.	Test Cond.	Level A	Level B		Level C	
				Case1	Case2	On Reactor	Off Reactor
Pressure (psi)	1900	2375	Fig. 2-1 (Ref. 1)			1650	450-2090-450
Temp. (ºF)	300	70				100-595-100	125-640-135
Ram Load	8200	-	Fig. 2-3 (Ref. 1)	8200	-	8200	-
Misalignment Load	Radial Load V=670 lbf Bending Moment M=76194 lbf·in			V=920 lbf M=100346 lbf·in		V=670 lbf M=76194 lbf·in	
Preload 30” Grayloc Clamp Stud	30” Grayloc clamp studs are tighten in such a way that each stud extends by 0.016 to 0.017 in., No. of cycles=50						
Fatigue Cycle	-	50	32000	167	50	17	4

Table 2. Summary of Seismic Loads

	Load Direction		Due to Dead weight	Due to Dead Weight + Seismic
Snout Assembly End	Force in Transverse	Fx(lbf)	187	17765
	Force in Vertical	Fy(lbf)	2740	20697
	Force in Axial	Fz(lbf)	2109	57287
	Moment in Transverse	Mx(lbf·in)	41100	1134884
	Moment in Vertical	My(lbf·in)	8736	1124155
	Moment in Axial	Mz(lbf·in)	6681	12730
Ram Housing End	Force in Transverse	Fx(lbf)	25	2735
	Force in Vertical	Fy(lbf)	5778	15838
	Force in Axial	Fz(lbf)	0	18717
	Moment in Transverse	Mx(lbf·in)	446280	1766641
	Moment in Vertical	My(lbf·in)	1711	559968
	Moment in Axial	Mz(lbf·in)	103	57655

3. Results

For each condition, stresses through a section are linearized and classified into membrane (P_m, P_L), bending (P_b) and peak (F) stresses for various ASME Code evaluations. The linearization is performed through all thicknesses of the Magazine housing, especially where high nodal stress intensities exit.

For P_L case, the P_m allowable is conservatively used in this paper. Under level C, the stress intensities due to the non-seismic loads and the seismic loads are combined absolutely for conservatism.

Maximum membrane stress is found in Cut 14 of Fig.2 through every service condition. Maximum bending stress is found in Cut 9 and Cut 16.

The bearing stress in the flange hub between the 30" Grayloc clamp and Magazine housing is calculated by dividing the gap reaction forces with the bearing area.

Maximum pure shear in the flange hub due to 30" Grayloc clamp is calculated by dividing these forces with the shear area. Maximum triaxial stress is calculated by absolute sum of highest three possible principal stresses. The fatigue analysis was carried out at every section used in the primary stress evaluation. The fatigue curve used is Fig. I-9.1 from ASME Code [2]. The maximum cumulative usage factor calculated is calculated to 0.773 at Cut 9.

The results of the analysis evaluation are summarized in Table 3. They are under their respective allowable.

Fig.4 shows the stress intensity distribution of service level A.

Table 3. Results Summary

	Loading Condition	Stress Classification	Maximum Stress Intensity (ksi)	Allowable Stress Intensity (ksi)	
Primary Stress	Design	$P_m(P_L)$	17.1	S_m	28.3
		$P_m(P_L)+P_b$	21.8	$1.5S_m$	42.4
	Test	$P_m(P_L)$	21.4	$0.9S_y$	49.5
		$P_m(P_L)+P_b$	23.2	$1.35S_y$	74.2
	Level B	$P_m(P_L)$	18.8	$1.1S_m$	31.1
		$P_m(P_L)+P_b$	21.7	$1.65S_m$	46.7
	Level C	$P_m(P_L)$	18.8	S_y	46.0
		$P_m(P_L)+P_b$	22.7	$1.5S_y$	69.0
Bearing Stress	Design		10.3	S_y	46.0
	Test		10.9	S_y	46.0
	Level A		11.4	S_y	46.0
	Level B		11.6	S_y	46.0
	Level C		21.7	S_y	46.0
Pure Shear	Design		4.7	$0.6S_m$	15.0
	Test		5.0	$0.6S_m$	15.0
	Level A		5.2	$0.6S_m$	15.0
	Level B		5.4	$0.6S_m$	15.0
	Level C		10.0	$0.6S_m$	15.0
Triaxial Stress	Design	S1+S2+S3	53.5	$4S_m$	113.2
	Test	S1+S2+S3	51.1	$4S_m$	113.2
	Level A	S1+S2+S3	54.9	$4S_m$	113.2
	Level B	S1+S2+S3	52.8	$4S_m$	113.2
	Level C	S1+S2+S3	53.6	$4.8S_m$	120.0
Stress Range	Level A/B	$P_m(P_L)+P_b+Q$	50.8	$3S_m$	84.9
Fatigue	Stress Concentration Factor		Max. CUF	Allowable	
	2		0.77281	1	

4. Conclusions

In order to evaluate of the structural integrity of the F/M Magazine housing, the stress and fatigue analysis is performed. Using finite element method calculation, stress intensities developed in the Magazine housing are calculated for Design, Test and Service conditions and compared with the allowable given in ASME Code Section III Subsection NB[2]. All calculated values satisfy their respective allowables.

REFERENCES

[1] WOL1-FML-DR-G001, Rev.1, Analysis Requirement of Wolsong 1 Fuelling Machine Head Assembly, 10, 2008. GNEC

[2] ASME Boiler and Pressure Vessel Code, Section Ⅲ Sub-section NB, 1998 Edition with 1999 Addenda

[3] 86-35210-SR-002, Rev. 0, Final Stress Analysis of Fuelling Machine Head Assembly Pressure Boundary Components, Wolsong NPP Units 2, 3, 4, AECL

[4] 86-35000-SR-001, Rev. 0, Design Report Fuelling Machine and Support Structure Seismic Analysis, Wolsong 2/3/4, AECL

[5] ANSYS 11.0 Reference Users Manual

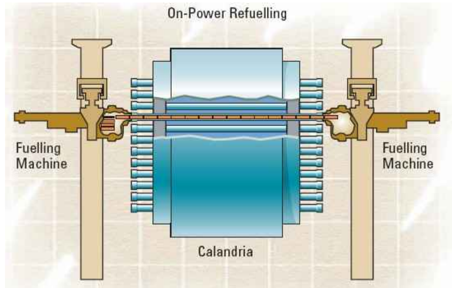

Fig.1 Fuelling Machine in operation

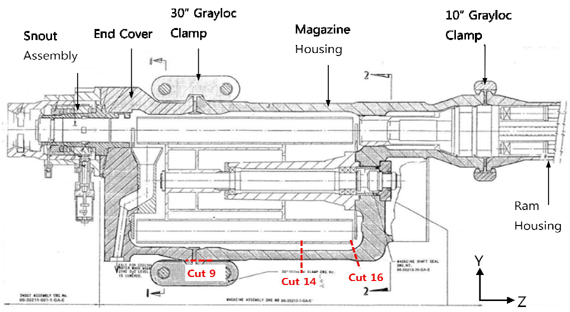

Fig.2 Fuelling Machine Magazine Front View

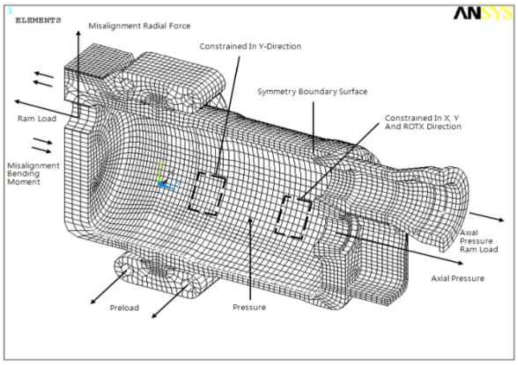

Fig.3 Applied loads and boundary condition

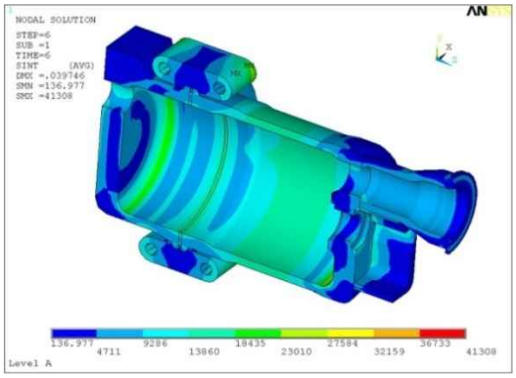

Fig.4 Stress intensity distribution of Level A