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Seismic Analysis of an Air Intake Filter

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1. Introduction

The purpose of this study is to demonstrate dynamic qualification of a safety-related Air Intake Filter(AIF) for Nuclear Power Plant. The AIF should meet the seismic qualification requirement specified in IEEE 344-1987[1]. The analysis has been performed using a combination of condition A, B and D, which includes several loads such as dead weight, pressure, operating loads and seismic spectra acceleration loads. The AIF is shown in Figure1.

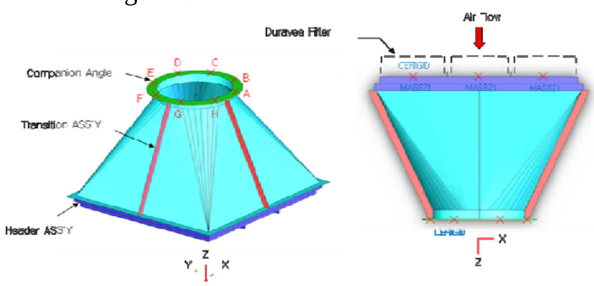

Figure1. Extent of the Air Intake Filter model

The AIF is mounted on the floor and shall be installed at elevation of 135ft of Emergency Diesel Generator Building to filter the combustion air. Most of the Air Intake Filter Structures are made of Stainless Steel 304, designated as AISI 304. The overall size of AIF is approximately 2156.4mm (width) x 2157.9mm (length) x 1467mm (height). The allowable stresses are given below.

Service Limit A $F_a = 0.6Fy$ = 0.6(205) = 123 MPa
Service Limit B $F_a =$ 1.33 x Level A = 163.59 MPa
Service Limit D $F_a = 0.95Fy$ = 0.95(205) = 194.75 MPa

2. Qualification Requirements

2.1. Seismic loading

To perform analysis for AIF of structure, modeling is applying loads. The method of load combination is given below.

Normal (Service Limit A):
Dead weight + Pressure + Operating Loads

Upset (Service Limit B):
Dead weight + Pressure + Operating Loads + OBE seismic

Emergency and Faulted (Service Limit D):
Dead weight + Pressure + Operating Loads + SSE seismic

The method of the combining results for Service Limits B and D include seismic loading. The required seismic loads are included SSE with 3% damping and OBE with 2% damping. The applicable values are determined by interpolation between the OBE (Operating Basis Earthquake) and SSE (Safe Shutdown Earthquake) spectra curves.

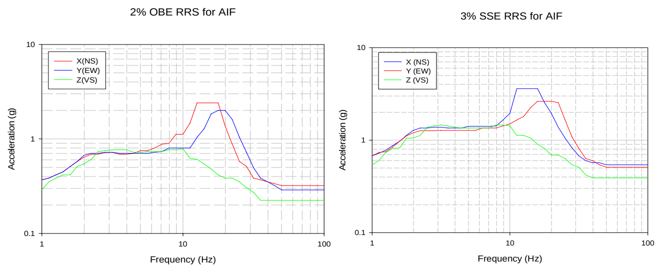

Figure2. Seismic Spectra Curves

2.2. The analytical models

The AIF Assemblies are modeled and analyzed using the ANSYS[3] FE analysis program. A description of the element types is given in Table A.

Table A. the FE model input property data

Element Type No.	Type	Description
1	SHELL63	Transition assembly & Stiffeners, t=5 mm
2	SHELL63	Companion angle, t=12 mm
3	SHELL63	Stiffeners, t=5 mm
4	SHELL63	52x35xt5 angle, at header assembly
5	SHELL63	65x65xt6 angle, at header assembly
6	MASS21	Lumped mass of Duravee filters, m = 7.0

The lumped mass elements (MASS21) are used to simulate the duravee filters and input at their estimated centroid locations. These lumped mass elements are attached to the header assembly elements at 4 points each with rigid elements. The 8 holes of companion angle are fixed in all degrees of freedom.

3. Analysis methodology

3.1 Analysis methodology for model

There are static analysis method and dynamic method for seismic qualification analysis. The static analysis method is performed with the accelerations with a factor of 1.5 applied in each direction. The dynamic method consists of determining the natural frequencies of the system and applying the spectra levels so that the levels are applied according to the mode shapes and modal participation.

In ANSYS, the dynamic seismic analysis procedure was done using the spectrum analysis solution option. The modal analysis was done first to determine the natural frequencies, mode shapes, and modal participation. Then the spectra acceleration levels were input and factors were calculated that multiply the displacement results from the modal analysis. The combined seismic solution is SRSS of all the factored results.

3.2 Analysis methodology for AIF

The modal analysis was performed to determine the final mass properties of the model, the 39 natural frequencies in the range of 0 to 50 Hz, and the modal participation factors and effective masses. Expanded mode shapes of all 39 modes are solved for and saved for use in the full spectrum analysis. The total seismic solution includes the dynamic SRSS solution results for spectrum acceleration loads, the vertical dead weight static analysis loads. The spectrum solution calculates the dynamic response at all significant expanded modes and combines the results for those modes with the grouping SRSS method.

4. Analysis results

Since the seismic spectrum is applicable to both OBE and SSE events, and the combined results including the dead weight, the allowable stresses for the Normal, Upset and Emergency/Faulted condition were used in evaluating an acceptance of the Air Intake Filter structure. Displacements in the structure are given below.

Normal Condition : Max. Dis. = 0.001099 m
Upset Condition : Max. Dis. = 0.005426 m
Emergency and Faulted Condition : Max. Dis. = 0.00907 m

The stress contours can be plotted for the maximum principal stress (S1) or the von Mises equivalent stress (SEQV), whichever is greatest for the region. Figure2 shows a close-up view of the maximum stress location, which is at the bottom of the Air Intake Filter.

The SEQV stress is a numerical combination of normal shear stress. The results at node 99787 of the upset and emergency/Faulted condition are the greatest. SINT is equal to the maximum difference in principal stresses, which is twice the maximum shear stress. The maximum stresses contours are given in Table1.

Table1. Maximum stresses contours

Condition (MPa)	S1	S2	S3	SINT	SEQV	Node
Normal	19.28	7.56	0.43	19.28	17.20	100278
Upset	101.24	48.54	1.76	101.24	90.17	99787
Emergency / Faulted	179.57	86.18	3.12	179.57	159.93	99787

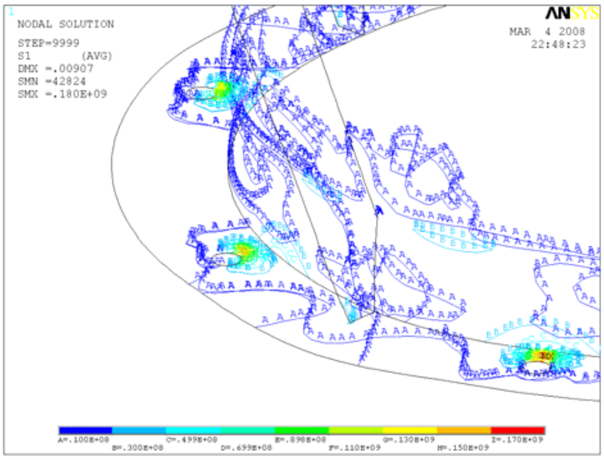

Figure2. Maximum stress contours is located at the bottom of the Air Intake.

Factors of safety, based on the allowable stresses given are:

Normal	F.S = 123/19.28 = 6.38
Upset	F.S = 163.59/101.24 = 1.62
Emergency and Faulted	F.S = 194.75/ 179.57 = 1.08

Node 99787 is at a point near the anchor bolt holes of companion angle structure. In case of allowable stresses at the normal, upset and emergency/faulted conditions are acceptable.

5. Conclusion

In this paper, AIF was modeled and undergone mode analysis in ANSYS. In the mode analysis, such as modal participation factor and effective mass were used to determine frequency response function and modal function. It is known that frequency of the spectra curves is lower than 33 Hz. As a result, it is regarded that AIF could maintain the structural integrity.

REFERENCES

[1] IEEE 344-1987, "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."
[2] AISC Steel Construction Manual, Allowable Stress Design, Ninth Edith
[3] ANSYS, Version 11.0, Finite Element Analysis Computer Program, ANSYS, Ins., USA.