SEISMIC ANALYSIS OF NUCLEAR COMPONENTS CONSIDERING MODELING UNCERTAINTIES

by

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SYNOPSIS

The question concerning the effects of input parameter uncertainty in the dynamic analysis is investigated. It is pointed out that the current practice of attempting to define a "worst case" dynamic analysis is ambiguous. The alternative approach taken here is to treat the problem as probabilistic in nature and to perform many deterministic dynamic analyses with probabilistic variations assigned to the dynamic model input variables. The Monte Carlo method is used with a standard computer program to probabilistically synthesize the several dynamic analyses performed.

INTRODUCTION

The elements of the dynamic seismic analysis are usually ascribed definitive properties. There is inevitably uncertainty concerning the application of all such properties. Current practice attempts to vary selected parameters over some range to determine the so called "worst case" analysis. It is difficult to establish over what range the variables should be varied and it is generally found that each variable will affect different components of the dynamic analysis in a different way. This means that no "worst case" parameter can be identified which will produce a conservative result for all components. In addition, there are usually several sensitive parameters which cause change in the dynamic load on any particular component.

THEORY

This study used a typical 81 degree of freedom BWR reactor and building model as a reference and reduced the degree of freedom to 9 preserving accuracy in the modal frequencies which have been found important to reactor component loadings. A response spectrum method

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was used and the 9 degree of freedom dynamic analysis was set up on the probabilistic computer code PA 300. Twenty-seven different types of input probability distributions were fed into the program so that observations could be made concerning the simultaneous effects of all major uncertainties in the dynamic analysis including the normalizing factor on the ground acceleration. The usual deterministic values of the OBE (operating basis earthquake) and DBE (design basis earthquake) were assigned probability values as shown in Figure 1(a) for use in this study. The OBE was assigned 0.5 for the design life encounter probability while the DBE was assigned a range varying from 0.01 to .0001. These assigned values are usually not identified in U. S. practice and it would be helpful to reactor risk analysis if they were.

The results of the probabilistic analysis are shown qualitatively in Figure 1(b) as a probability density function for load on the component. If the linear dynamic analysis were ideally "perfect" in the sense that no uncertainty exists in the input properties, the output load uncertainty would have a density function Figure 1(b) exactly like the probability density function for the ground acceleration Figure 1(a) except to a different scale. The effects of parameter uncertainty is to broaden the resulting density function as shown in Figure 1(b), and this broadening is illustrated quantitatively by the results shown in Table A for a typical component.

The important point to note from Table A is that no unique answer exists for the low probability case unless we identify the probability level for the component load. Also notice that the 0.5 probability load is the same as the OBE deterministic load showing that the central trend load is not significantly affected by balanced input uncertainties. These same conclusions will occur for the problem related to determining equipment floor spectrum corresponding to OBE and DBE earthquake levels as indicated in Figure 2. Thus we see, that the best we can do concerning parameter uncertainty effects is to compute the load probability, and that the low probability load commonly associated with the DBE has no unique value other than in a probabilistic sense.

The important question concerning what probability load combination is acceptable in the reactor seismic dynamic analysis can be answered through the use of curves as illustrated in Figure 3. Here are displayed the classic load-strength probability interactions for the case of normal distributions. Use of this set of curves requires assigning probability values to the strength of the particular component and finding the overall failure probability. The acceptable value for this failure probability for each component should be dependent on appropriate risk-benefit considerations and regulatory requirements.

Figure 1

Design Life Encounter Probability Density Functions

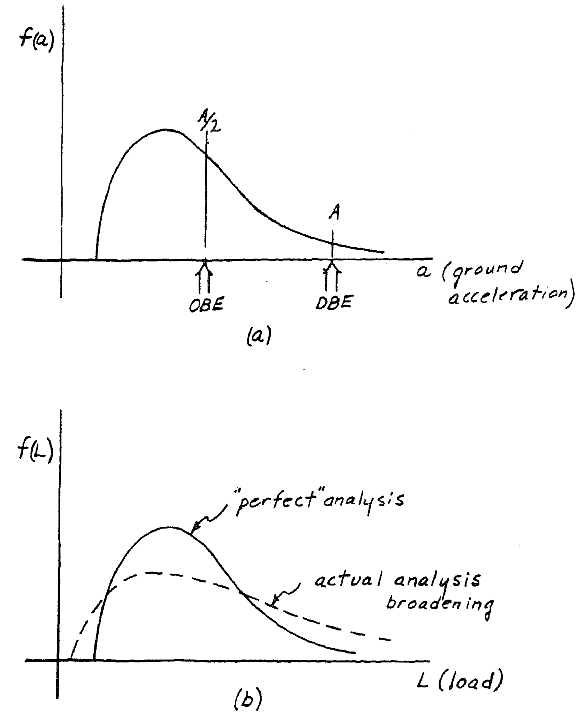

Table A

Typical Load Results for Reactor Component

Probabilistic Results

DBE ground acceleration, A, probability ⇒	0.01		0.001		0.0001
OBE ground acceleration, $\frac{A}{2}$, probability ⇒	0.5		0.5		0.5
load probability ⇓	⇓		load ⇓		⇓
0.5	0.5		0.5		0.5
0.01	1.30		1.26		1.24
0.001	1.59		1.50		1.48
0.0001	1.84		1.72		1.70

Deterministic Results

DBE ground acceleration, A. ⇒	DBE load = 1.0
OBE ground acceleration $\frac{A}{2}$ ⇒	OBE load = 0.5

Figure 2

Floor Spectrum Broadening

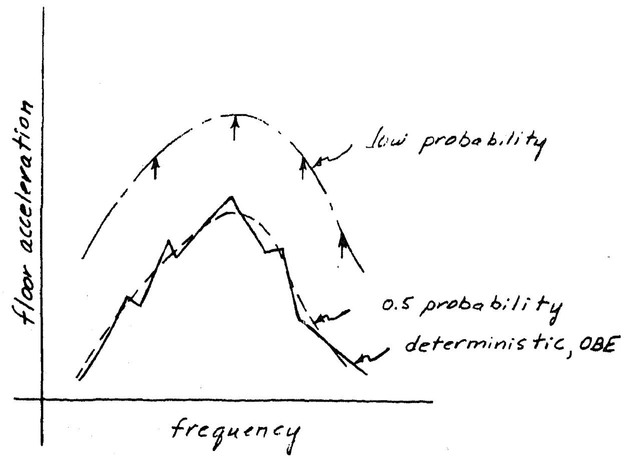

Figure 3

Normal Load-Strength Interaction