ANALYTICAL PROBLEMS ASSOCIATED WITH CORE SUPPORT STRUCTURES OF PWR

G.J. BÖHM,

Westinghouse Electric Corporation, Power Systems, Pittsburgh, Pennsylvania, U.S.A.

The design of core support structures of a pressurized water reactor requires the solution of structural problems with a degree of sophistication that is not usual to other types of power generating plants. This situation arises not only from the complexity of both the structures and the external loads, but also from safety specifications requiring a precise knowledge of components behavior. Some of the analytical tools needed to study these problems are available in the current technical literature derived from research and development work performed in the last decade by the aircraft industry and others have been developed for direct application to the analysis of reactor internals. The present paper reviews the existing type of analytical problems derived from normal operation (steady state and transients) covers a wide range of static and dynamic problems.

One of the dynamic problems that have mostly concerned the designers is flow induced vibration. This vibration has been studied using experience gained from reactors in operation, model work and analysis. Problems such as flow induced vibration of submerged shells and oscillations of components due to parallel and cross flow need to be analyzed to assure that the response is within allowable limits. These limits are selected taking into consideration the strength and the fatigue properties of the materials.

Another important dynamic problem that is analyzed is the seismic excitation using different maximum ground accelerations. The type of the forcing functions and the modelling techniques are important to determine the response of the structures.

A complex dynamic analytical problem is to determine the behavior of the internals in case of a severe loss of coolant accident. In this case the main concern is to assure a safe shutdown of the reactor which implies that the analysis must not only consider stresses but also deformations and functioning of the components.

In general, the analytical studies of internals behavior under normal operation and expected transients are performed in a more realistic manner than the seismic and accident cases where conservative assumptions tend to provide extreme upper bounds and safe results. The actual trend is to obtain the information needed to substantiate the analysis from measurements taken during preoperational reactor tests. In this manner data regarding frequency, damping and other properties are obtained and included in the analysis with the intent of reaching a better understanding of the system.

Extensive use of modern high speed computing tools is required to solve these problems. Linear and non-linear analysis for static and dynamic problems use computer programs of varied complexity, leading to the use of newly developed techniques in the area of finite elements and numerical stability of integration methods.

The present paper summarizes these analytical techniques for the various cases and provides results of the analysis for typical cases.

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DISCUSSION

Q G. R. WAYMIRE, U. S. A.

You stated that the licensing requirements may be reduced to more realistic levels in the future. Experience has shown that the contrary is true, e. g. less realistic levels as new plants are designed. What is your basis for more realistic conditions in the future ?

A G. J. BÖHM, U. S. A.

I am predicting that some of the unrealistically conservative accidents postulated today will not be considered in the future. I must admit that this is not the actual trend of the licensing agencies, but I feel that the experience acquired by analyzing, testing and operating reactors will give the regulatory bodies sufficient confidence to modify present policies. As an example, I do not believe that the actual requirement of analyzing the blowdown accident for 0.001 sec. pipe break will be maintained, because it is completely unrealistic.

Q S. CURIONI, Italy

The vibrations due to internal flow are very important and difficult to be determined; have you put in operation some numerical or analytical method to foresee those vibrations and control this method with experience ?

A G. J. BÖHM, U. S. A.

As explained in the paper, the response of reactor internals during operation is studied as a combination of experimental and analytical methods. For some cases there are explicit numerical analytical methods (such as excitation of tubes due to cross flow) where a mathematical method gives the response in a closed form. This response should be superimposed to the response from other sources such as pump excitations. For more complex structures such as shells, several shell modes could be superimposed to the pumps plus a fluidelastic interaction.
Results obtained using these methods have been very helpful in predicting reactor internals vibration during operation. Measurements taken during preoperational tests confirmed fairly well the predicted values.

Q E. KOCH, Germany

To what tests did you check your computer models when calculating blowdown and earthquake loads ? Did you already e. g. compare analytical results to experimental ones obtained from the Idaho semiscale tests ? Did you check earthquake response measured after external excitation e. g. after an external explosion, to predicted loads and deflections ?

A G. J. BÖHM, U. S. A.

Some of the dynamic characteristics computed with the analytical models have been verified by tests on reactor models and/or measurements during preoperational tests. In other cases, conservative assumptions are made as input to the analytical model, e. g., some damping coefficients. The code itself is verified by solving particular cases having closed form solutions or results available in the technical literature. I am not aware of an application of these models to the experimental tests performed under the LOFT program. Perhaps in the future, some work will be performed in this area.

Very little experimental work has been done to measure reactor components' response under seismic excitation or external explosions (the University of California at Los Angeles has been involved on some studies in this area). No measurements are available for reactor internals' response under seismic excitations or external explosions.