APPLICATIONS OF SIMILITUDE TO STRUCTURAL MECHANICS OF REACTORS

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The structural mechanics of a reactor involves the prediction of the behavior of the components of the reactor and the entire reactor system under a combination of gravitational and other force fields, electrical and magnetic fields, thermal fields and radiation fields. The nature of the materials and components is such that under the operational conditions imposed, the behavior is often nonlinear, with the result that the application of the usual techniques of mathematical analysis to predict behavior often results in lengthy computations based on assumptions that are somewhat subjective. Although computer techniques have proven very helpful in many instances, they are often limited in scope through size of available computer storage.

The direct approach, that of cut-and-try design, is often not appropriate because of the possibility of release of radioactive materials in the event of a faulty design or a failure of the containment or other materials. In addition, economics, as well as safety, usually precludes construction of a complete operating unit without preliminary analysis.

Under the conditions of complex mathematical analysis and expensive construction the use of small scale models is suggested as a method of obtaining data from which realistic predictions may be made. In the design of small scale models the theory of similitude is used in the same way that it has been used in many fields of engineering. It is also pertinent to consider current power reactors in the 400-Mw range as models of projected reactors in the 2000-Mw range.

Direct application of the principles of similitude leads to a series of design conditions that cannot be satisfied simultaneously. In such a situation the application of distorted model theory is mandatory. The application of distorted model theory requires the determination of the prediction factors associated with the pertinent distortion factors derived from the significant parameters that are distorted.

Evaluation of the prediction factors as functions of the distortion factors may be accomplished experimentally or analytically, and the remainder of the presentation is devoted to consideration of the applicable methods and procedures for determining the prediction factors. The analytical procedures may be classed as those based on well established laws and those based on fundamental principles.

Specific illustrations of the application of the principles includes fuel element containment, distortion of primary containment, performance of containment shells as a result of sudden release of energy within or from external disturbances, and thermal strains resulting from loss of coolant and subsequent sudden cooling. As the numerical examples will illustrate, distorted model theory often enables one to make practical judgments concerning which distortions are significant and which will have a trivial influence upon the results.

V. HOPPE, Denmark

Q Would you please tell us if your paper contains any method of estimating the error in applying these methods ?

G. MURPHY, U. S. A.

A The paper does not contain such analyses because they are dependent upon the details of instrumentation used in the model. However, it may be noted that if distortion is not present and a displacement is being measured, the absolute error in the model will be multiplied by the length scale in predicting the corresponding displacement in the prototype.

R. W. CLOUGH, U. S. A.

Q I agree with your evaluation of the situations in which mathematical (computer) modeling tends to become difficult; i. e. , where problems of material characterization are encountered.

However, it seems to me that these problems lead to difficulties in physical modeling as well - if the material behaviour is not simple, due to the strain amplitudes or environmental conditions involved, it may be difficult to ensure similarity of material behaviour between model and prototype. Would you care to comment on this aspect of the physical modeling problem ?

G. MURPHY, U. S. A.

A The similitude requirements for materials are that the stress-strain diagrams, temperature-strain, or whatever characterization may be significant be similar in model and prototype if there is to be no distortion. In other words, to avoid distortion the characteristic curve for the prototype must be obtainable from that of the model by multiplying every ordinate at corresponding abscissas by a constant. If the curves are not similar in shape distortion exists and distorted model theory must be used. The problem occurs frequently in the modeling of reinforced-concrete structures, but here if the length scale is not excessive (perhaps less than 40) satisfactory models have been constructed.

R. J. DOHRMANN, U. S. A.

Q Are you aware of any further or current work related to the use of the diffusion phenomenon for simulating thermal stresses in photoelastic materials, i. e. the diffusion equation being analogous to the heat conduction equations ?

G. MURPHY, U. S. A.

A

I am not aware of further work along these lines. You are referring to the class of models known as analogs in which similarity of behaviour between model and prototype relies on the same form of characteristic equation rather than upon physical similarity of model and prototype. Distorted model theory can be applied to such systems when necessary.