BASIC PROBABILISTIC CONSIDERATIONS ON SAFETY OF PRESTRESSED CONCRETE PRESSURE VESSELS

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SUMMARY

The procedure of probabilistic safety analysis pertinent to prestressed concrete reactor pressure vessels is described with an emphasis on the consistency in which various aspects of structural significance are analyzed and then combined into a probabilistic-statistical formulation amenable to practical risk assessment and assurance. In particular, the present paper considers the following aspects:

1) Probabilistic combinations of loads of various temporal nature are formulated (dead load as permanent load, pressure, temperature and prestressing load as sustained load, and earthquake load as short-term load).

2) Probabilistic interpretation of current design format is given. Also, probabilistic significance of load and failure categories as usually defined in the conventional design is discussed and validity of adjusting allowable stresses depending on load categories is investigated. Then, probabilistically more consistent design format is proposed in which the load combination formulated in (1) above is employed.

3) Method of estimation of reliability levels or method of reliability assessment based on the proposed format is described.

4) The probabilistic-statistical algebra used in this study is basically that of the second moment-first order approximation. Accordingly, the degree of uncertainties in any parameter involved is expressed either in terms of standard deviation or coefficient of variation, with the source of the uncertainty consisting of modeling error, intrinsic randomness and sampling error. Usefulness and limitations of such approximation is pointed out. In particular, a discussion is presented as to how the approximation can be improved when additional information becomes available.

5) The method thus established is applied to safety analysis of a prestressed concrete reactor vessel. Two failure categories are considered: limit of elastic deformation and ultimate structural failure. The stress and structural analysis required for the reliability assessment for the failure defined by the limit of elastic deformation, is basically the elastic analysis which identifies critical structural locations in terms of the state of stress and/or deformation. The reliability associated with this failure category is then estimated by comparing the stress (or strain) intensities at these critical locations with corresponding resisting capacities. Both the stress intensities and the resisting capacities are, in general, dependent random quantities. The ultimate structural failure consists of a number of possible modes of failure such as simple tension failure vertically through a cross-section of the vessel cylinder, simple tension circumferentially with crack opening along generator of the vessel cylinder, circumferential failure combined with vertical bending failures at three horizontal sections in the wall, punching shear type failure of the heads, etc.

This research is supported by the U.S. Atomic Energy Commission under Contract No. AT(49-1)-3537.