ON THE FORMULATION OF PROBABILISTIC VISCOELASTIC MODELS FOR THE LONG-TERM DEFORMATION OF REACTOR FUEL ELEMENTS

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In formulating computational models for the long-term, irradiation induced, deformation behavior of an LMFBR fuel pin, it appears reasonable to ask the degree to which the fine details of a fuel pin's history may be neglected through a model based on a probabilistic consideration.

In deciding on the constitutive relations best describing the material response of the fuel element, the complexity of the load history has a further significance. Since, however, the distant past has very little effect compared to more recent events, it is desirable to consider models possessing "fading memories".

The paper examines the use of viscoelastic models with "fading memory" in conjunction with random loading in the context of determining qualitative features of the long term response of fuel elements - for example, the prediction of non-swelling induced strain. The emphasis is on an examination of the assumptions necessary to produce such models, the form of the expectation value of certain strain differences, and the sensitivity of results to details of the assumed stress process. For example, in considering the use of fading memory, an examination is made of the expectation value of the difference between the strain using the full time interval and that using only the near past. Thus, given a bound on how accurately one wishes to measure the strain, one has information on how far back in time it is necessary to consider the history.

The paper develops the relevant analysis first in the simple case of a one-dimensional linear viscoelastic medium, extends these results to a general non-linear one-dimensional description, and finally considers the plane-strain response of a thin tube. In all cases, the stress process is assumed to be decomposed into a deterministic part plus a random part. General bounds on the probability of certain strain measures exceeding a given value are developed for various forms of the non-deterministic stress process. These results can then be specialized to a given viscoelastic material model by use of specific material response functions. A discussion of the computational aspects of these bounds is given and their likely value in simplifying fuel element modeling is considered in both linear and non-linear cases. Results are examined in terms of sensitivity of the error bounds to changes in the various material and stress process parameters. This parametric analysis is essential to an evaluation of the feasibility of such models since few of the occurring parameters have a direct physical defintion in terms of "first principles". The net result is thus a model which, while having some parameters directly derived from given input data (e.g. the form of the stress process assigned to a given power history), still has a large empirical content consisting of parameters that must be fit to known results - the length of the material memory being a typical example.

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DISCUSSION

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I understood that, instead of describing the total stress history you aim to describe only the recent history neglecting the antique history. In the case that something happens during the antique history period which needs the boundary conditions to be changed or consideration of mass transfer or partial failure, can your formalism still help ? I doubt it, because it concerns the recent period only.

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I too doubt it. My intention was to produce a method of analysis that could be used in the "far future" when we are sure that the problems of unexpected incidents are only those of the most ordinary type - slight unplanned overpowers, etc.. While LMFBRs are still in the development stage, safety analyses based on probabilistic considerations will not gain in popularity. One wants more than expectation values and variances.