TEMPERATURE AND STRESSES IN REACTOR FUEL ELEMENTS DUE TO TIME- AND SPACE-DEPENDENT HEAT TRANSFER COEFFICIENTS

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In this paper various methods are discussed and compared for the prediction of temperature and thermoelastic stress fields in reactor fuel elements due to both steady and transient non-uniform surface heat transfer. It is shown that the customary design assumption of an average heat transfer coefficient applicable over the whole heat transfer area is unsatisfactory, as in practice the heat transfer can vary quite considerably not only spatially but in time as well, and this variation can alter the temperature and increase the thermoelastic stresses. Heat transfer can be determined experimentally, but stress determination under the prevailing conditions is extremely difficult, and the only way to handle the problem is either analytically or numerically.

Actual conditions encountered in a reactor will present a complex, time dependent, thermal-mechanical-nuclear problem with many variables. Before a solution can be formulated, a basic knowledge of the effect of some of the variables is required. A simple model to explain the consequences of non-uniform heat transfer would be based on the assumption of elastic behaviour of the material, in one-region bodies of constant material properties, with spatially and time variable surface heat transfer coefficient. Even this simple model is of great complexity.

A systematic survey is presented here of analytical methods for the solution of temperatures and stresses within the framework of these conditions, the results of which can provide a basis for the formulation of more complex problems. Two basic geometries, the sphere and the infinite half-space, are considered. By the thermal version of St. Venant's principle, any method developed for the half-space would be applicable, as an approximation, to any sufficiently localised heat transfer coefficient variation on any other type of body, such as a cylinder. These methods were developed over the last five years at the School of Nuclear Engineering, University of New South Wales. Those which have already been published are summarised for the sake of continuity, while the more recent unpublished work is discussed in detail. A number of results in the form of graphs are included in the paper, from which conclusions can be drawn as to the effects of non-uniform, time dependent surface heat transfer on temperature and stresses in fuel elements.

The following methods are discussed: - Sphere with steady, non-uniform surface heat transfer coefficient -

Continued fractions method; Legendre polynomials expansion; Iterative perturbation method; Weighted residual methods (Collocation, Discrete least squares, Continuous least squares); Integral equation formulation; Synthesis method (Galerkin); Transformation method.

Infinite half-space with steady, non-uniform surface heat transfer coefficient -

Iterative perturbation solution of integral equation; Laguerre polynomial approximation; Synthesis method; Transformation method.

Sphere with time dependent, axisymmetric heat transfer coefficient -

Coupled integral equations approach.

Infinite half-space with time dependent, axisymmetric heat transfer coefficient -

Laguerre functions expansion method.

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DISCUSSION

A. N. KINKEAD, U. K.

Q

Please excuse my question which is really irrelevant to the subject of your paper and I don't therefore propose to submit it to you.

However, I should be interested in having any reference you might know or could let me have on transient stress solutions in which variations in modulus of elasticity with temperature must be considered.

Z. J. HOLY, Australia

A

The main objective of the paper, as stated, has been to investigate the effects of nonuniformity of heat transfer both on temperature and stresses. The next stage will include the effects of temperature variations of material properties and work is already being carried out.

Q

A. K. RAO, India

1. Given a problem, are there any guidelines that may assist in choosing a suitable method of solution ?
2. Our experience is that solutions for regular shapes do not always provide a satisfactory basis for comparing the effectiveness of different approximate methods in respect of arbitrary domain geometry. Could you please comment ?

A

Z. J. HOLY, Australia

1. We found that for solution of boundary value problems, one should always try the most simple approach first, e. g. , collocation or any other weighted residual method (least squares method, etc.). When confidence is gained with solution, if solution can be obtained, more efficient methods can be then used for the solution.
2. I agree that a simple shape does not always provide a reliable basis for testing of more complex ones. As the solution develops more complex shapes should be used for testing the next solution stage.