921

3D INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS

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The objective of this research is to develop an analytical tool capable of economically evaluating the cyclic time-dependent plasticity which occurs in hot section engine components in areas of strain concentration resulting from the combination of both mechanical and thermal stresses. The techniques developed must be capable of accommodating large excursions in temperatures with the associated variations in material properties including plasticity and creep.

The overall objective of this proposed program is to develop advanced 3-D inelastic structural/stress analysis methods and solution strategies for more accurate and yet more cost-effective analysis of combustors, turbine blades, and vanes. The approach will be to develop four different theories, one linear and three higher order with increasing complexities including embedded singularities.

The objective will be achieved through a four-phase program consistent with the NASA Statement of Work.

In Task I, the linear formulation theory will be developed. These will consist of three linear formulation models in which stress, strain, and temperature are linear functions of the spatial coordinates; and the increments in loading, temperature, and time are linear. Three constitutive relations will be developed for these linear formulation models each capable of predicting elastic, plastic, thermal, and creep strains and cyclic effects. One constitutive relation will be approximate, one will be of the current genre, and one will be a unified theory.

In Task II, the polynomial formulation theory will be developed. These will consist of three polynomial formulation models in which stress, strain, and temperature are polynomial functions of the spatial coordinates, and the increments in loading temperature and time are quadratic. They will also accommodate two-intersecting embedded discontinuities. Three constitutive relations will be associated with these polynomial formulation models.

In Task IV, the special functions theory will be developed. These will consist of three special function formulation models in which stress, strain, and temperature are special functions of the spatial coordinates and the increments in loading, temperature, and time are special functions. These models will accommodate eight intersecting embedded similar discontinuities and have three associated constitutive relations.

In Task V, the general functions theory will be developed. These will consist of three general function formulation models in which stress, strain, and temperature are general functions of the spatial coordinates and the increments in loading, temperature, and time are general functions.

These models will accommodate eight intersecting embedded different discontinuities and have three constitutive relations associated with them. One of the constitutive relations will be more complex than those used for the special functions theory.

Task III and VI are reporting requirements.

Work began on this program in April 1983. A literature survey was conducted in order to identify various solution techniques and constitutive models. In developing an economical computer tool it is essential to consider the interactions of solution technique, constitutive model, integration scheme, load incrementing, temperature incrementing, and time incrementing procedures.

For time dependent plasticity (or creep) problems the solution technique most commonly used in finite element codes is a constant stiffness scheme. Any economical scheme for thermo-mechanical cycling will of necessity require automatic time incrementing. Initially, the constitutive equation subroutines are being developed in the context of a finite element code with a constant stiffness iteration procedure, automatic time incrementing, linear variation of loads and boundary conditions and isothermal conditions. The introduction of time varying temperatures will require a modified solution procedure. The isothermal Bodner formulation has been implemented in a single element computer program and compared with test data and calculations in Reference 1.

In view of the increasing availability of vector processors, work is also underway to develop more efficient numerical procedures for solving sets of linear algebraic equations on such machines. Iterative procedures such as the Jacobi or Gauss-Seidel methods are more feasible with vector machines (Reference 2-3), especially if the stiffness matrix is stored in column form. Improvements in forming stiffness matrices may also be realized (Reference 4) which would greatly enhance the calculation time in tangent stiffness schemes. Eigenvalue calculation procedures may also be more economical using vector processors (Reference 5).

REFERENCES

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