3-D INELASTIC ANALYSIS METHODS FOR HOT SECTION COMPONENTS

BRIEF DESCRIPTION

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BACKGROUND

The most severe structural requirements imposed upon aircraft gas turbine engine components result from the extreme environmental conditions in the engine hot section. These conditions include very high temperatures with steep thermal gradients, high and fluctuating pressures, rapid transients, vibration, oxidation, corrosive and erosive atmospheres, and an assortment of structural loadings both from within the engine and as a result of engine/aircraft system interactons. Accurate prediction of structural response and life assessment of the components under these conditions require sound 3-D inelastic analytical methods. Present 3-D inelastic analysis methods usually rely on large volumes of input data to define the problem, frequent user intervention during the analysis process, and considerable care in assessing the accuracy and interpreting the results. Most of these methods are parts of general purpose structural analysis programs which were not intended for the complex 3-D inelastic analysis problems associated with gas turbine engine components. Thus highly-skilled technical manpower is required to set up the problems and frequently, to interpret the results.

OBJECTIVE AND APPROACH

The objective of this program is to develop advanced 3-D inelastic structural/stress analysis methods and solution strategies for more accurate yet more cost-effective analysis of components subjected to severe thermal gradients and loads in the presence of mechanical loads, with steep stress and strain gradients, and which include anisotropy and time and temperature dependent plasticity and creep effects. The approach is to develop four different theories, one linear and three higher order theories (polynomial function, special function, general function). The theories are progressively more complex from linear to general function in order to provide streamlined analysis capability with increasing accuracy for each hot section component and for different parts of the same component according to the severity of the local stress, strain and temperature gradients associated with hot spots, cooling holes and surface coating cracks. To further enhance the computational effectiveness, the higher order theories will have embedded singularities (cooling passages, for example) in the generic modeling region.

Each of the four theories consists of three formulation models derivable from independent theoretical formulations. These formulation models are based on (1) mechanics of materials, (2) special finite elements, and (3) an advanced formulation to be recommended by the contractor.

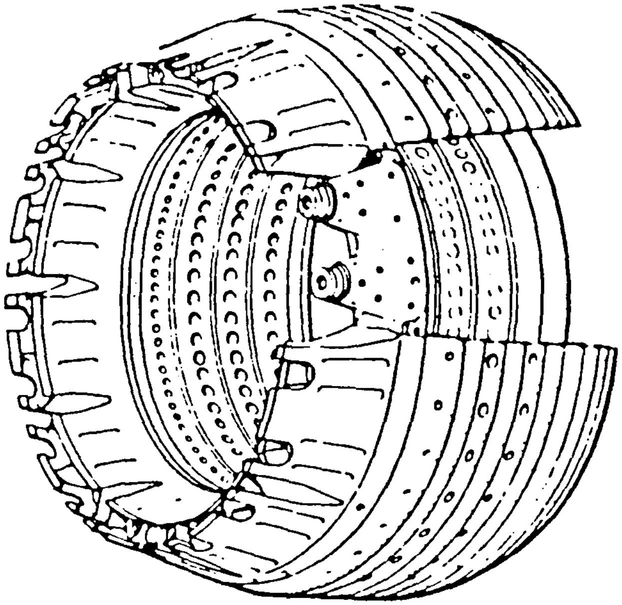
The mechanics of materials models shall be formulated for easily amenable solution (approximate calculations). The special finite elements will be formulated to be used as "stand-alone" modules and as modules integrated (using interfacing links) into general purpose structural analysis computer programs. The advanced formulation model shall be formulated to provide an alternate and complementary analysis capability to the special finite elements so that each theory can be used to check the other, and thereby minimize costly experiments that otherwise may be needed. In addition, each model shall be formulated to accommodate three different levels of constitutive theory with progressive levels of complexity. The three different levels of constitutive theory are needed in order to: (1) provide formulation flexibility, (2) provide for modeling different material behavior in different parts of the component, and (3) increased accuracy to assess the validity of the approximations made. Appropriate solution strategies with self-adaptive features shall be developed along with numerical solution algorithms with self starting and dynamic incrementation to further enhance the computational effectiveness of these theories.

All theories, including models and constitutive relationships, will be validated with respect to accuracy and computational effectiveness using available analysis results from simulated and actual hot section components. In addition, the theories shall be verified using available experimental data and data generated under this program. The end product of these theories will be computer programs (modules) for stand alone use and for integration into other structural analysis programs. It is expected that the 3-D inelastic analysis capability being developed under this program will provide considerable flexibility for the solution of 3-D nonlinear structural problems; eventually it should lead to longer lifetimes and improved overall durability of the hot section components made from present and future materials. Also, this capability will provide enhanced capability to experimentally evaluate constitutive relationships.

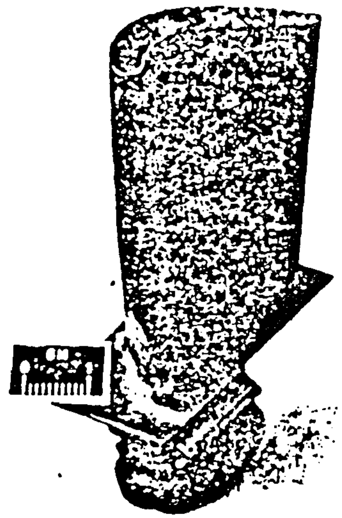
GENERAL SCOPE OF WORK

This program is a four year, 45,000 man-hour effort.

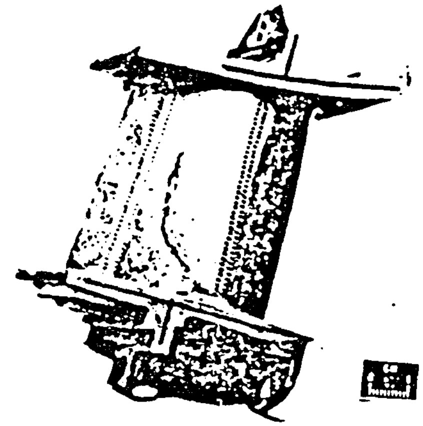
HOT SECTION COMPONENTS REQUIRING 3-D INELASTIC ANALYSIS



COMBUSTOR LINER

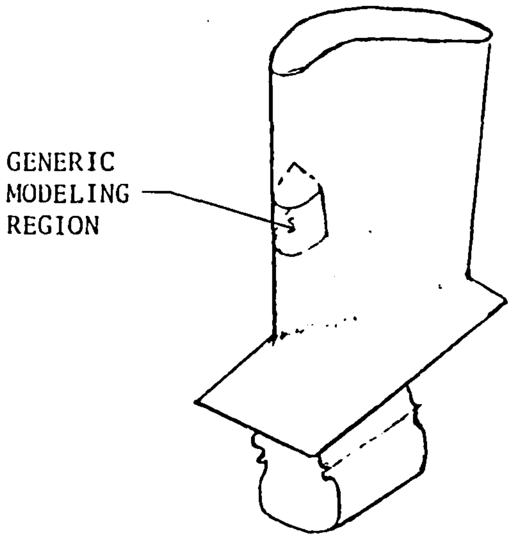


TURBINE BLADE

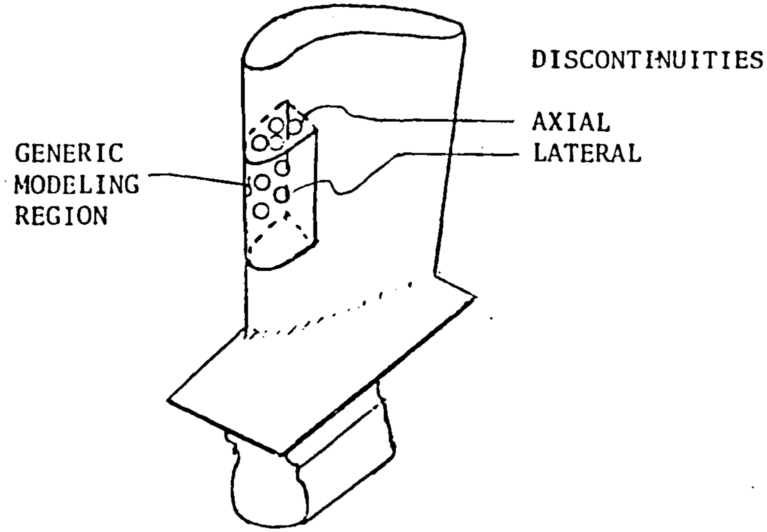


TURBINE VANE

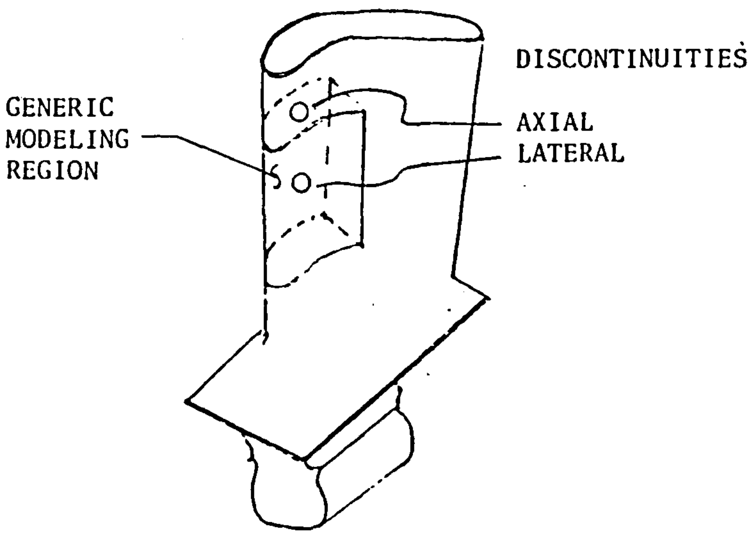
SCHEMATIC ILLUSTRATING REGIONS FOR THE FOUR DIFFERENT ORDER THEORIES



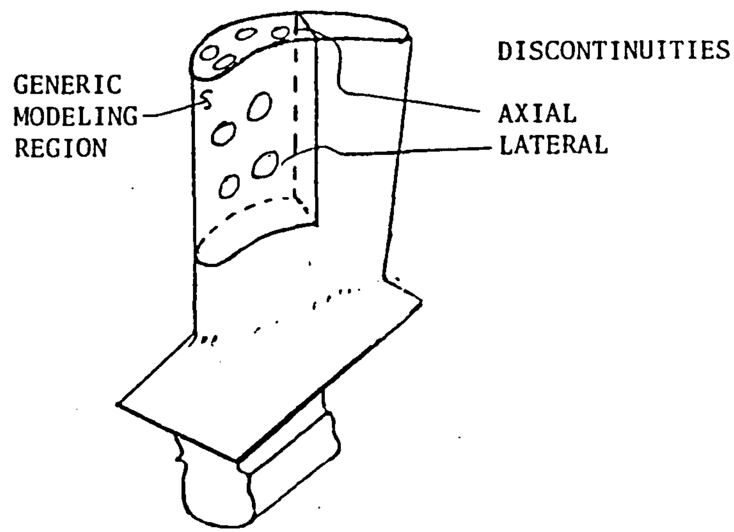
LINEAR



POLYNOMIAL



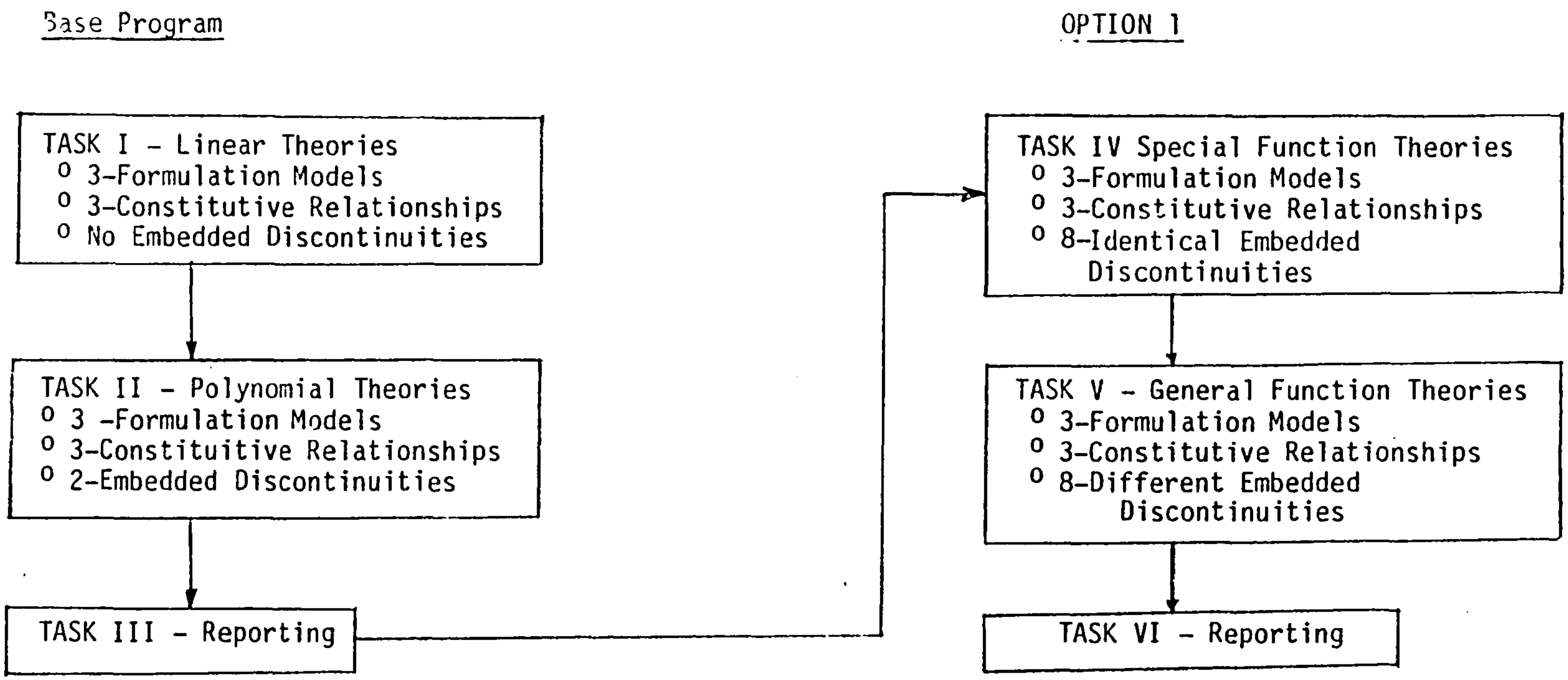
SPECIAL FUNCTIONS



GENERAL FUNCTIONS

3-D INELASTIC ANALYSIS OF HOT SECTION COMPONENTS

FLOW CHART



NOTE: Each technical Task (I, II, IV and V) consists of three (3) subtasks describing the formulation models and constitutive relationships.

3-D INELASTIC ANALYSIS: TASK TIME SCHEDULE

TASK NO.	DESCRIPTION	PERCENT EFFORT
	BASE PROGRAM	
I	Linear Theories	15
II	Polynomial Theories	22
A	Common Requirements for Tasks I and II	
III	Reporting (Base Program)	1
	Option 1	
IV	Special Functions Theories	26
V	General Functions Theories	34
B	Common Requirements for Tasks IV and V	
VI	Reporting (Option 1)	2