N87-22783

# PROBABILISTIC STRUCTURAL ANALYSIS TO EVALUATE THE STRUCTURAL DURABILITY OF SSME CRITICAL COMPONENTS

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It is becoming increasingly evident that deterministic structural analysis methods will not be sufficient to design critical structural components for upgraded space shuttle main engines (SSME). Structural components in the SSME are subjected to a variety of complex (cyclic and transient) loading conditions including high temperatures and severe thermal gradients. Most of these are quantifiable only as best engineering estimates. These complex loading conditions subject the component material to coupled nonlinear behavior which depends on stress, temperature, and time. The nonuniform nature of this coupled nonlinear material behavior makes it very difficult to characterize experimentally and perhaps impossible to describe deterministically.

In addition, critical SSME structural components are relatively small. Fabrication tolerances on these components, which in essence are small thickness variations, can have significant effects on the component structural response. Fabrication tolerances by their very nature are statistical. Furthermore, the attachment of the components to the structural system generally differs by some indeterminant degree from what is assumed for design purposes. In summary, all four fundamental aspects - (1) loading conditions, (2) material behavior, (3) geometric configuration, and (4) attachment - on which structural analyses are based, are of statistical nature. One direct way to formally account for all these statistical aspects is to develop probabilistic structural analysis methods where all participating variables are described by appropriate probabilistic functions.

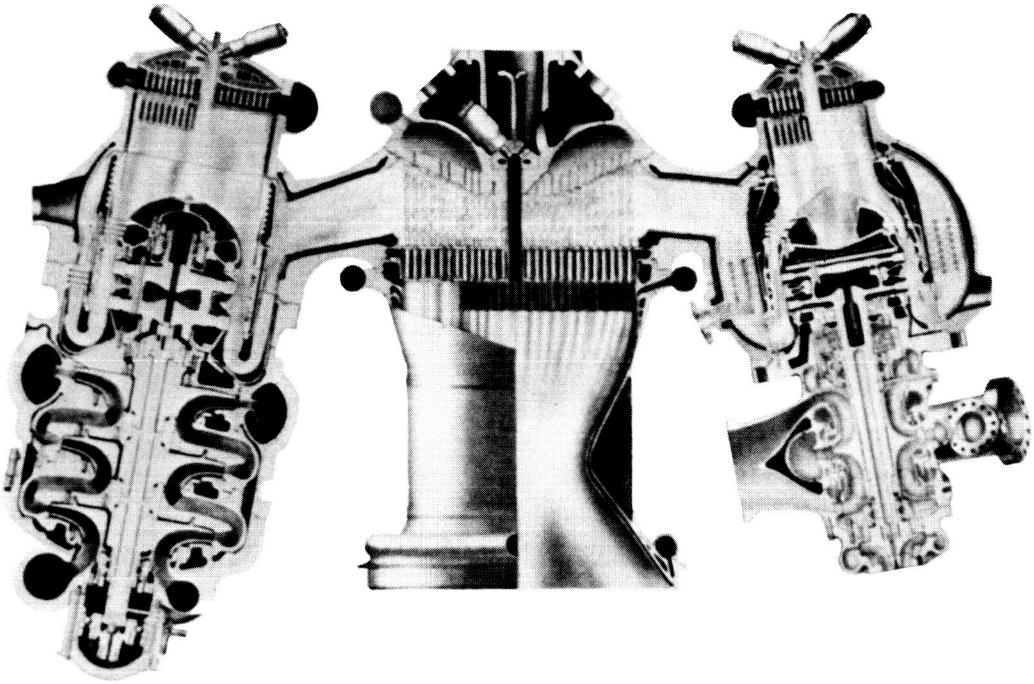
NASA Lewis Research Center is currently developing probabilistic structural analysis methods for select SSME structural components. Briefly, the deterministic, three-dimensional, inelastic analysis methodology developed under the Hot Section Technology ((HOST) and R&T Base Programs) is being augmented to accommodate the complex probabilistic loading spectra, the thermoviscoplastic material behavior, and the material degradation associated with the environment of space propulsion system structural components representative of the SSME such as turbine blades, transfer ducts, and liquid-oxygen posts (fig. 1).

The development of probabilistic structural analysis methodology consists of the following program elements: (1) composite load spectra, (2) probabilistic structural analysis methods, (3) probabilistic finite element theory - new variational principles, and (4) probabilistic structural analysis application. In addition, the program includes deterministic analysis elements: (1) development of structural tailoring computer codes (SSME/STAEBL), (2) development of dynamic creep buckling/ratcheting theory, (3) evaluation of the dynamic characteristics of single-crystal SSME blades, (4) development of SSME blade damper technology, and (5) development of integrated boundary elements for hot-fluid structure interaction.

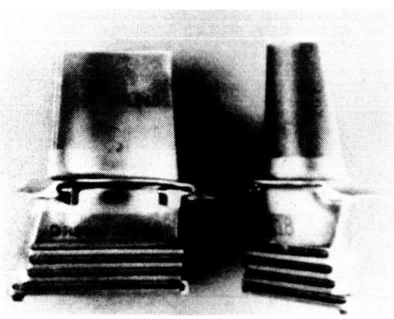
The SSME Structural Durability Program is multidisciplinary integrated and is a joint effort of NASA Lewis in-house research, contracts, grants, and support service personnel (table I). The research activities in the various program elements have collectively led to significant technical progress. The objective of the presentations included in this session is to summarize the highlights of this technical progress.

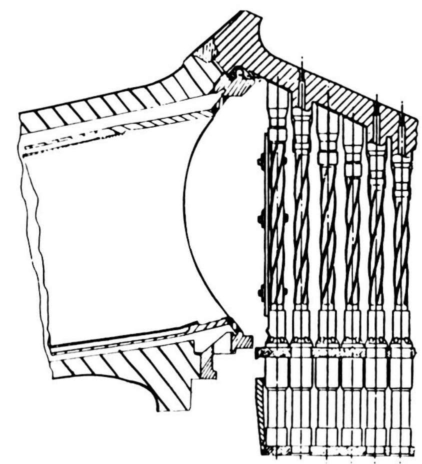
TABLE I. - COMPUTER CODES DEVELOPMENT SUMMARY

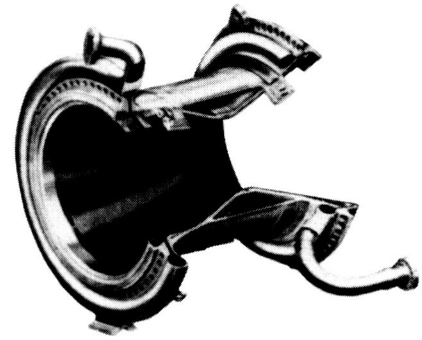
| Code | Description | Status |
|---|---|---|
| NESSUS | Nonlinear evaluations of stochastic structures under stress | Initial version operational |
| CLS | Composite load spectra probabilistic load simulation | Initial version operational |
| SSME/STAEBL | Structural tailoring of SSME turbopump blade | Code available for release |
| VATFEL | Variational theory for probabilistic finite elements | Near completion |
| DYCREBURT | Dynamic creep buckling/ratcheting theory | Near completion |
| BEFSIN | Boundary elements for fluid structure interaction | Planning phase |
| NL-COBSTRAN | Nonlinear structural analysis for high-temperature metal matrix composite turbine blades | Operational |



SSME POWERHEAD COMPONENT ARRANGEMENT







HIGH PRESSURE TURBOPUMP BLADE

LOX POSTS

MAIN COMBUSTION CHAMBER

FIGURE 1. - PSAM WILL BE INITIALLY DEVELOPED FOR SELECT SSME STRUCTURAL COMPONENTS.