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STRUCTURAL DYNAMICS: PROBABILISTIC STRUCTURAL ANALYSIS METHODS

PROGRAM OVERVIEW

Christos C. Chamis and Dale A. Hopkins
NASA Lewis Research Center
Cleveland, Ohio 44135

Deterministic structural analysis methods, as we are seeing, will not be sufficient to properly design critical components in hot structures and particularly, in propulsion structures. Because these structural components are subjected to a variety of complex and severe cyclic loading conditions, including high temperatures and high temperature gradients, most of them are quantifiable only as best engineering estimates. These complex loading conditions subject the material to coupled nonlinear behavior, which depends on stress, temperature, and time. Coupled nonlinear material behavior is non-uniform, very difficult to determine experimentally, and perhaps impossible to describe deterministically. In addition, hot rotating structural components are relatively small. Uncertainties in fabrication tolerances on these components, which are slight variations in thickness, can significantly affect the component structural response. Furthermore, the attachment of components in the structural system generally differs by an indeterminate degree from that assumed for designing the component. These uncertain factors can be grouped into: (1) loading conditions, (2) geometric configuration including supports on which structural analyses are based, and (3) material behavior. In order to formally account for all of these aspects of random nature, we develop probabilistic structural analysis methods where all participating variables are described by appropriate probability functions.

The development of the probabilistic structural analysis methodology is a joint program of NASA Lewis in-house and research sponsored by industry, universities, and support service contractors (ref. 1). Theoretical considerations, computer codes, and their respective applications are described in papers presented in conferences (refs. 2 to 32). Activities and progress up to June 1989 are summarized in reference 33.

The objectives of this session are: (1) to provide a brief description of the fundamental aspects of the quantification process as depicted schematically in figure 1 and (2) to summarize progress since the last structural durability conference in 1989. The methodology to date and that to be developed during the life of the program is presented in the block diagram in figure 2. In this figure the uncertain factors are presented in the top three blocks. This figure outlines the approach required to achieve component/system certification in the shortest possible time for affordable reliability/risk (ref. 34). Two new elements appear in the block diagram (enclosed in dashed lines): (1) uncertainties in human factor and (2) uncertainties in the computer code. We have initiated research to quantify the uncertainties in the human factor as will be discussed in one of the presentations. The progress of the program, which includes relevant sample cases, is summarized and discussed in the presentations listed in figure 3.

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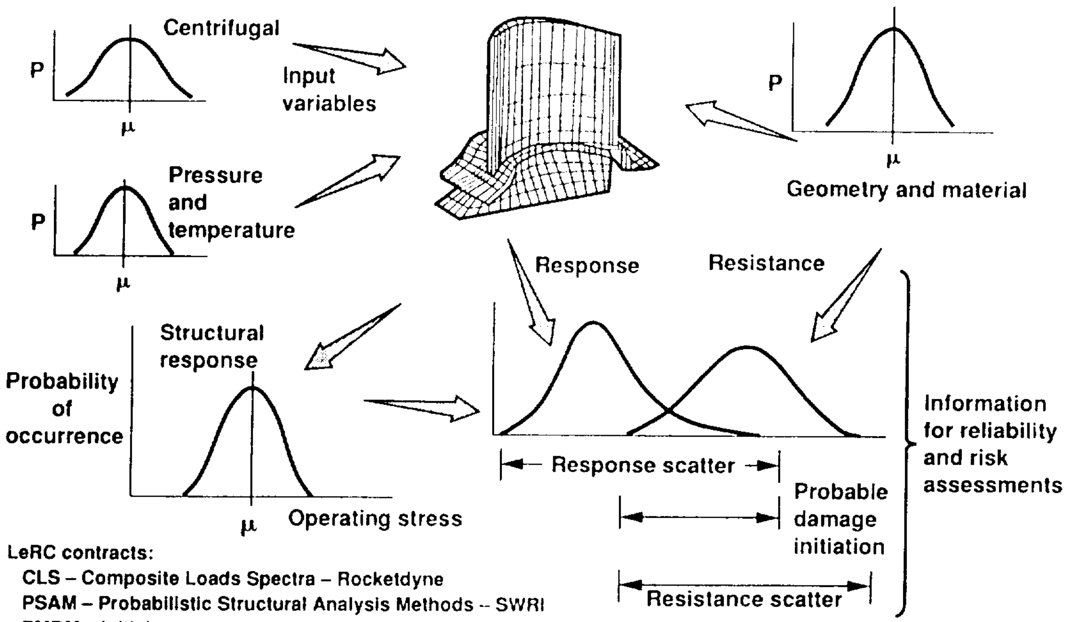
Probabilistic Simulation of Component Reliability Using CLS Coupled With PSAM and PMBM



LeRC contracts:
CLS – Composite Loads Spectra – Rocketdyne
PSAM – Probabilistic Structural Analysis Methods – SWRI
PMBM – Initial assessment – In-house

Figure 1

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Probabilistic Simulation for Assured Structural Certification

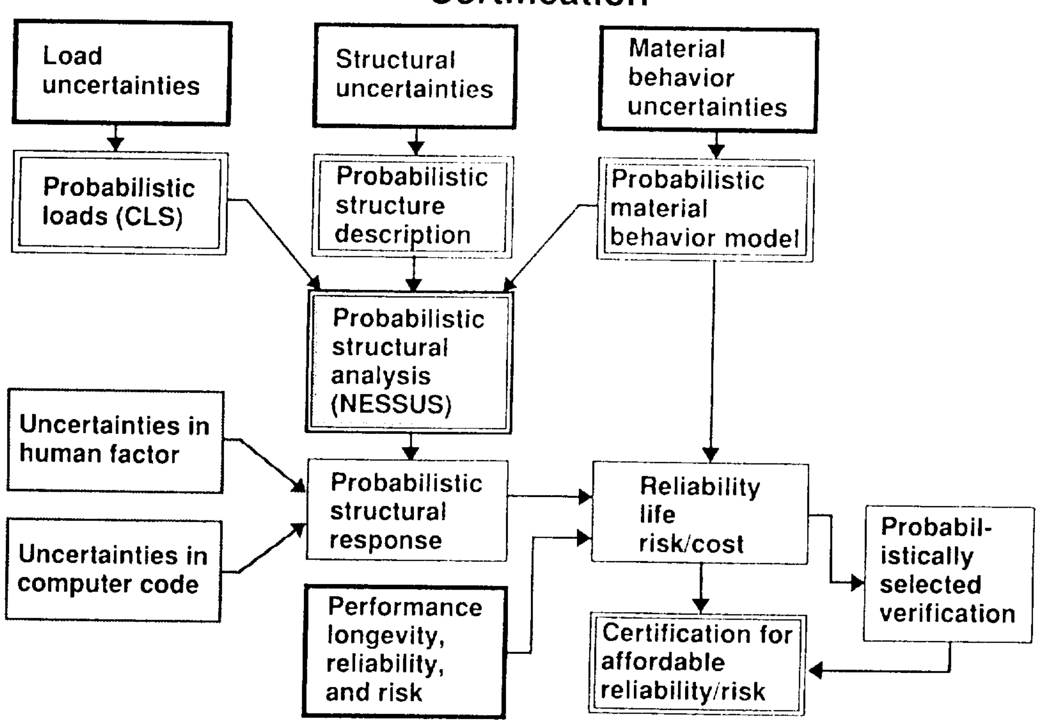

Figure 2

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Session II – Structural Dynamics: Probabilistic Structural Analysis Methods

- Structural Reliability Methods – Code Development Status
  H. Millwater, B. H. Thacker, Y. T. Wu, Southwest Research Institute, San Antonio, Texas; T. A. Cruse, Vanderbilt University, Nashville, Tennessee

- Probabilistic Load Simulation – Code Development Status
  J. F. Newell, Rockwell International, Rocketdyne Division, Los Angeles, California

- Probabilistic Evaluation of SSME Structural Components
  K. R. Rajagopal, Rockwell International, Rocketdyne Division, Los Angeles, California

- Rocketdyne PSAM – In-House Enhancements/Applications
  K. O'Hara, Rockwell International, Rocketdyne Division, Los Angeles, California

- Commercialization of NESSUS – Status
  B. H. Thacker, Southwest Research Institute, San Antonio, Texas

Figure 3 CD-91-52298

Session II – Structural Dynamics: Probabilistic Structural Analysis Methods (continued)

- Added Capability for Reliability and Risk – Status
  T. A. Cruse, Vanderbilt University, Nashville, Tennessee

- Algorithm Development for Computational Efficiency
  Y. T. Wu, Southwest Research Institute, San Antonio, Texas

- Expert System Development for Probabilistic Load Simulation
  H. W. Ho, Rockwell International, Rocketdyne Division, Los Angeles, California

- Probabilistic Fracture Finite Elements
  W. K. Liu, Northwestern University, Evanston, Illinois

- Coarse Analysis Models Scaling for Improved Accuracy
  M. C. Shiao, Sverdrup Technology Inc., Brook Park, Ohio

- Human-Factor in Probabilistic Structural Analysis
  A. Shah, Sverdrup Technology Inc., Brook Park, Ohio

Figure 3–Continued CD-91-52299