NESTEM-QRAS: A Tool for Estimating Probability of Failure

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Abstract

An interface between two NASA GRC specialty codes, NESTEM and QRAS has been developed. This interface enables users to estimate, in advance, the risk of failure of a component, a subsystem, and/or a system under given operating conditions. This capability would be able to provide a needed input for estimating the success rate for any mission.

NESTEM code, under development for the last 15 years at NASA Glenn Research Center, has the capability of estimating probability of failure of components under varying loading and environmental conditions. This code performs sensitivity analysis of all the input variables and provides their influence on the response variables in the form of cumulative distribution functions.

QRAS, also developed by NASA, assesses risk of failure of a system or a mission based on the quantitative information provided by NESTEM or other similar codes, and user provided fault tree and modes of failure.

This paper will describe briefly, the capabilities of the NESTEM, QRAS and the interface. Also, in this presentation we will describe stepwise process the interface uses using an example.
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5th Annual FAA/Air Force/NASA/Navy Workshop
Cleveland, OH
June 11-13, 2001
N&R ENGINEERING
Outline of Presentation

• Tool Overview
• Tool Components
  - NESTEM
  - QRAS
• Risk Assessment Process
• Example problem
• Benefits of the tool
Tool Overview

- NESTEM interfaces with APNASA/ANSYS or NASTRAN.
- Visual results in ANSYS environment
- QRAS for engine system Probabilistic Risk Assessment (PRA).

Failure Modes and Uncertainties

APNASA/ANSYS

APNASA/NASTRAN

NESTEM

QRAS

PRA

Visual Post-Processing
Probability of Component Failure using NESTEM

Multidisciplinary Probabilistic Heat Transfer/Structural Analysis Code

Probabilistic Loads

Mechanical

Thermal

Probabilistic Material Behavior

Geometry and Material

Probability of Occurrence

Response (stress)

Resistance (strength)

μ Structural Response

Information for Reliability & Risk Assessment

Failure

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NESTEM Capabilities

• Generates or allows users to import a finite element model from commercial codes such as ANSYS or NASTRAN

• Generates laminate properties from constituent properties in case of composites

• Performs probabilistic heat analysis by perturbing heat transfer variables

• Quantifies influences of uncertainties in material properties and geometry, mechanical and thermal loads on structural responses
NESTEM Capabilities

• Generates probability distributions of the response variables based on quantified influences of uncertainties. This feature provides complete ranges of variation in response variables.

• This information is very useful for assessing risk of failure, cost or allowable risk and developing maintenance schedule.

• Ranks all variables in the order of their influences on response variables. This information is critical for being cost effective.
NESTEM Capabilities

- Estimates fatigue life for random loading
- Post processes results in user’s selected environment
- Works on PC and workstation platforms
Plot of Sensitivity Analysis

Sensitivity Factors for Stress at A Point

- Coef
- Radth
- Matprop3
- Gemish
- Conth
- Emis
- Contc
- Ozz
- Concc
- Matprop8

Random Variables

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Manifold Weld Failure

- Is crack detectable? (MWF-DC-001)
  - Yes
  - Is crack small enough to survive 1 mission? (MWF-LC-001)
    - Yes
      - Loss of flow to LPFTP
    - No
      - HPFTP cavitates LOX rich op.

- Is repair 100% effective? (MWF-LE-001)
  - Yes
  - Successful op.?
    - Yes
    - LOV
    - No
**Risks by**

1. Space Shuttle
2. Element
3. Subsystem

**Risks Ranked**

1. Over entire Shuttle
2. Within Element
3. Within Subsystem, etc.

Probabilistic Risk Assessment

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Risk of Failure
(Using NESTEM, experience, test data, field data, etc.)

Probabilities are assigned to the failure modes and to the mitigating events. Failure modes are quantified as to when in the mission they can occur.
Risk Assessment Process

Create QRAS Database
- Fault tree
- Mission timeline
- Event sequence diagrams
- Failure modes
- Quantify risk of failure

Risk of Failure from other Sources

Risk of Failure from NESTEM analysis

QRAS analysis
- Risk of failure
- Loss of mission
- Mission success
- Sensitivity Analysis

Update the QRAS database using NESTEM output
Example Problem

Example problem Input (Starting Phase):

<table>
<thead>
<tr>
<th>Component</th>
<th>Risk of failure (C)</th>
<th>Mitigation event (E)</th>
<th>Timeline</th>
<th>Mode of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>0.0</td>
<td>0.0925</td>
<td>0-360</td>
<td>Strength</td>
</tr>
<tr>
<td>Rotor</td>
<td>0.03905</td>
<td>0.0705</td>
<td>0-360</td>
<td>Strength</td>
</tr>
<tr>
<td>Blade</td>
<td>0.001438</td>
<td>0.007050</td>
<td>0-360</td>
<td>Strength</td>
</tr>
</tbody>
</table>

(Uniform distribution is assumed)

Example problem output:

Probability of Loss of Mission from QRAS analysis = 0.02763
Benefits of NESTEM-QRAS Tool

This tool provides:

• Risk of failure of individual component
• Risk of failure of a system
• Quantitative ranking of components by degree of risk
• Means to reduce risk of failure
• Cost effective ways to use resources

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Future Work

- Improve the capability of the tool
- Develop an interface between NESTEM and SAPHIRE
Contact for this tool

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