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Test Verification of Static Equivalent Random Vibration Load Factors
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Degree Program: Mechanical Engineering
Organization: Launch Services Program > Flight Analysis Division > Flight Structures Branch > Strength and Fatigue/ Fracture Mechanics Group

What Does a Strength Analyst Do?
- Conduct structural analysis for flight vehicle components
- Determine if hardware capabilities meet/exceed NASA standards
- Participate in structural tests
- Support hardware acceptance reviews

Concept of Project
- DESIGN a structure capable of adding/removing mass simulators
- Complete ANALYSIS of structure using knowledge of statics and finite element modeling software
- TESTING to determine natural frequency and maximum strain
- Compare analytical and experimental RESULTS to determine the differences between “static equivalent” strain against random vibration strain

What Is a Strength Analyst
- Design requirements
- Design constraints based on testing methods
- Material selection
  - Availability
  - Mechanical Properties
  - Welding effects in various metals
- Optimization
  - Cost vs. Performance
  - Geometry of design
  - Milling vs. Welding vs. 3D Printing

Analysis
- Using fundamental frequency to generate load case
  - Hz -> PSD -> $[G^2/Hz] ->$ Miles’ Equation -> Peak Load (*n) -> $F = ma$ -> $\sigma = F/A$ -> $\varepsilon = \sigma/E$
- Comprehensive knowledge of statics
  - Use of applicable formulas
- Assess critical locations and failure modes
  - Structure composition
  - Joint Analysis
- Directional loading (tension vs. shear)
- Finite Element Modeling/Analysis (FEM/FEA)
  - Input methods controls output accuracy

Testing Objectives
- Random vibration to determine fundamental frequency
- Use PSD Curve as input for 25,000 lbf shaker table
- Collect strain data using strain gages

Results
- Do the analytical results make sense?
  - Compare/contrast hand calculations against FEA
- Compare analytical to experimental results to assess conservatism

Lessons Learned
- Failure to plan is planning to fail
- Fully understand the fundamentals first
- Save resources and references
- Advice goes a long way

Design
- Frustum Diagram for Bottom Joint: Bolt in Tapped Hole
- Frustum Diagram for Top Joint: Bolt and Nut

Power Spectral Density Curve (PSD)

Miles Equation & Peak Load

Strain gauge circuit diagram for a quarter bridge configuration

$\varepsilon = \frac{\Delta R}{R \cdot GF}$

GF = Gauge Factor
R = Resistance
$\Delta R$ = Change in Resistance
$\varepsilon$ = Strain

Gauge factor equation for calculating strain using a strain gauge

![Engineering drawing of mass simulator](image1)
![Assembled view of model](image2)
![Design labeled by individual part number](image3)
![Welding callouts for location and method](image4)

![Front view of the mode shape caused by fundamental frequency](image5)

![Strain gauge circuit diagram](image6)

![Glue forces used to calculate shear stress in weld line](image7)
![Maximum stress the welded joint will experience](image8)
![Maximum bolt reaction force, used in joint analysis calculations](image9)