Victor Bailey

Test Verification of Static Equivalent Random Vibration Load Factors

Pathways Start Date: May 2018 **School: Georgia Southern University**

Graduation Date: May 2020 **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?

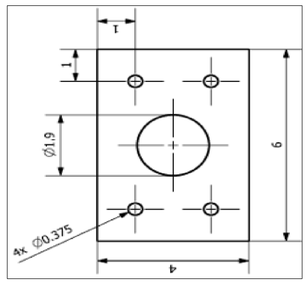
- Conduct structural analysis for flight vehicle components
- Determine if hardware capabilities meet/exceed NASA standards
- Participate in structural tests
- Support hardware acceptance reviews

Concept of Project

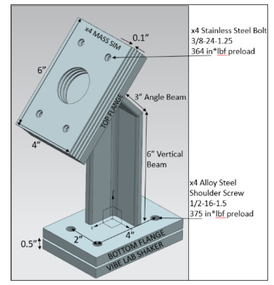
- **DESIGN** a structure capable of adding/removing mass simulators
- Complete **ANALYSIS** of structure using knowledge of statics and finite element modeling software
- **TESTING** to determine natural frequency and maximum strain
- Compare analytical and experimental **RESULTS** to determine the differences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

Design

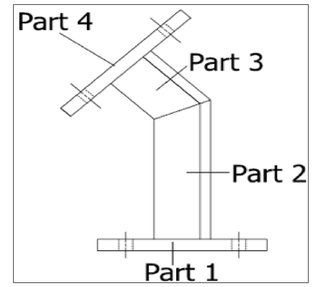
- Design requirements
- Design constraints based on testing methods
- Material selection
  - Availability
  - Mechanical Properties
  - Welding effects in various metals
- Optimization
  - Cost vs. Performance
  - Geometry of design
  - Milling vs. Welding vs. 3D Printing



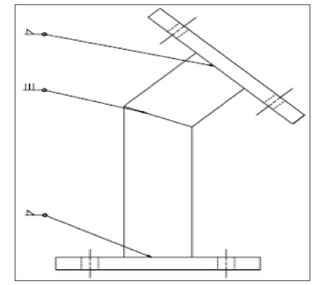
Engineering drawing of mass simulator



Assembled view of model

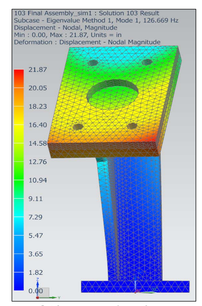


Design labeled by individual part number



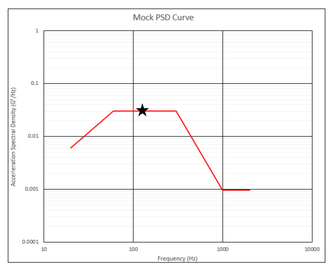
Welding callouts for location and method

Eigenvalue Solution Mode 1: 127 Hz



Front view of the mode shape caused by fundamental frequency

Power Spectral Density Curve (PSD)



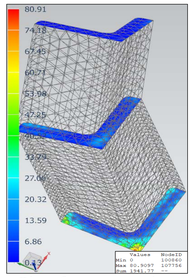
Miles Equation & Peak Load

$$G_{RMS} = \sqrt{\frac{\pi}{2} f_n Q [ASD_{input}]}$$

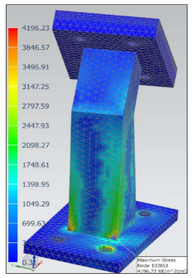
Analysis

- Using fundamental frequency to generate load case
  - Hz -> PSD -> [G^2/Hz] -> Miles' Equation -> Peak Load (*n) -> F = ma -> σ = F/A -> ε = σ/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

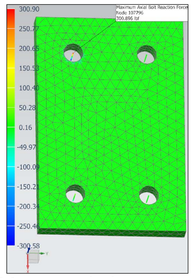
Welded and Bolted Joint Analyses



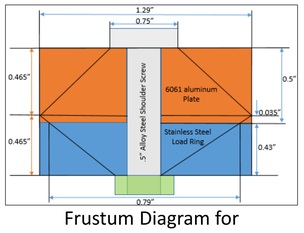
Glue forces used to calculate shear stress in weld line



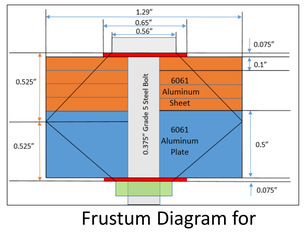
Maximum stress the welded joint will experience



Maximum bolt reaction force, used in joint analysis calculations



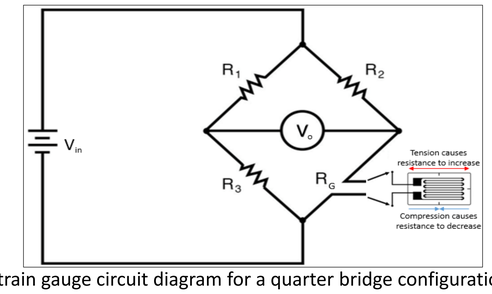
Frustum Diagram for Bottom Joint: Bolt in Tapped Hole



Frustum Diagram for Top Joint: Bolt and Nut

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



Strain gauge circuit diagram for a quarter bridge configuration

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

ε – Strain
ΔR – Change in Resistance
R – Resistance
GF – Gauge Factor

Equation for calculating strain using a strain gauge

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