Design and Analysis of Kinematic Strut Mounts For NIRCam, a JWST ISIM Instrument

Daniel Young, Swales Aerospace
Andrew Bartoszyk, Swales Aerospace
Emmanuel Coffie, Mega Engineering
John Johnston, NASA Goddard Space Flight Center
Cengiz Kunt, Swales Aerospace

Background
- NIRCam bench and optical assembly is being designed and built by Lockheed Martin.
- NIRCam Kinematic Mount Struts are being designed and built by GSFC to be delivered to NIRCam in Fall of 2005.
- Struts are in post PDR detailed design phase.

Synopsis
Finite element analysis was vital to the design and optimization of the kinematic mounts for the NIRCam instrument. The design had to meet dualing structural requirements driven by 1D3 launch loads, a survivability of bulk cool down from room temperature to 22 K, minimum first mode of 50 Hz and mass allocation constraints. Additionally, the design had to meet stability requirements for the NIRCam bench along with limits to interface loads to both the instrument and ISIM interfaces when cooled to 22K.

Derived Requirements for the NIRCam Kinematic Struts
- Fundamental Mode Frequency of at least 50 Hz for the NIRCam bench as mounted on the struts.
- Bend hard mounted (without struts) frequency requirement is 60 Hz.
- Maintain a margin of 15% at PDR and 5% at CDR.
- Survive Bulk Cool Down (BCD) load from 293K → 22K.
- Standard Analysis Safety Factors including 1.50 on composites and bonded Joints ultimate failure under both mechanical and thermal environments.
- Cool-Down induced interface Reactions must be less than 330 N shear force and 65N.m moment per pad at ISIM interface.
- Cool-Down Reactions shall be less than 66 N shear and 12.2 N-m moment (maybe higher if Lockheed OK’s) at NIRCam bench interface.
- ISIM cool-down induced motions are enveloped by the so-called “Pad Motions,” 0.6 mm or 6 arc min for each pad at ISIM interface in any direction.
- Mass allocation of 5 kg, very unlikely to get relief.

MSC/NASTRAN FEM

Summary of Loading used to predict Cool-Down Interface Reactions
- The following 2 load cases are run to determine Interface Reactions:
  1) ISIM Pad Motions, 36 separate pad motion sub-cases are considered to envelope all possible pad motions.
  2) A Bulk-Cool-Down, 293K → 22K, (BCD) case for the NIRCam bench and struts only.
- Results of these 2 cases are combined as follows:
  - The absolute max value for each reaction component of each strut end is found under the Pad Motions. This value is added to the corresponding absolute value obtained from the bulk cool down case.
  - Row labeled “AMAX” lists the final combined results
  - Row labeled “BCD” lists the reactions only due to Bulk Cool Down of the NIRCam bench and the struts. It is included for reference only.

Buckling of Composite Tubes, Pin - Pin

Invar, t = 3 mm

Composite Tube 3 Stacks Thick
\[ \frac{P_{cr}}{F_t} = \frac{1.46E1 \text{ MPa}}{L = 0.71 \text{ m (longest length)}} \]

Composite Tube 4 Stacks Thick
\[ \frac{P_{cr}}{F_t} = \frac{1.46E1 \text{ MPa}}{L = 0.80 \text{ m (longest length)}} \]

Note: 30% of 413MPa = 123.9 MPa for low risk fracture analysis with Invar
Factor > 1.65 (=1.5 * 1.1 where 1.1 accounts for any mechanical loading present)

Bulk Cool Down (293K → 22K) Stress

Summary of NATURAL FREQUENCY ANALYSIS OF BENCH ON STRUTS

Max. Combined Bar Element Stress
From 12 G Single Axis Launch Stress

Bulk of Bonded Joint Safety Factors from Interaction of FEM Element Stresses under BCD Loading

Plug-Tube Bonded Joint Safety Factors from Interaction of FEM Element Stresses under BCD Loading

Natural Frequency Analysis of Bench on Struts
Strut Design Sensitivity Studies

Design (No.9) meets Cool-Down Survivability Requirement of Calculated Safety Factor = 1.65 (>1.5 * 1.1 where 1.1 accounts for any mechanical loading present)

MMU:  F_t = 20 MPa, S = 488MPa
T300:  F_t = 30 MPa, S = 665MPa

Note: 30% of 413MPa = 123.9 MPa, 123.9 MPa for low risk fracture analysis with Invar
Factor > 1.65 (=1.5 * 1.1 where 1.1 accounts for any mechanical loading present)