DABJ

Design and Analysis of Bolted Joints

Includes a close look at NASA-STD-5020

Course Overview

Just about everyone involved in developing hardware for space missions (or any other purpose, for that matter) has been affected by problems with joints using threaded fasteners. Common problems include structural failure, fatigue, galling, inadequate preload, fasteners losing preload or falling out completely, low or nonlinear stiffness, joint slipping or loss of alignment, excess weight, procurement cost and lead time, incompatibility with the space environment, and time-consuming assembly. This course includes many examples and class problems. Participants should bring calculators. This course is three full days or five 5-hour days.

The objectives of this course are to ...

- build an understanding of how bolted joints behave and how they fail
- impart effective processes, methods, and standards for design and analysis, drawing on a mix of theory, empirical data, and practical experience
- share guidelines, rules of thumb, and valuable references
- help you understand NASA-STD-5020

Target Audience

Mechanical design engineers, structural analysts, and others interested in or involved with bolted joints

Course Developer & Teacher

Tom Sarafin is President and Chief Engineer of Instar Engineering and Consulting, Inc. He has worked full time in the space industry since 1979 as a structural engineer, a mechanical systems engineer, a project manager, and a consultant. Since founding Instar in 1993, he's consulted for NASA, DARPA, the DOD Space Test Program, Lockheed Martin, DigitalGlobe, Space Systems/Loral, Spaceflight Industries, and other organizations. He was a key member of the team that developed NASA-STD-5020, "Requirements for Threaded Fastening Systems in Spaceflight Hardware" (March 2012). He is the editor and principal author of *Spacecraft Structures and Mechanisms: From Concept to Launch* and is a contributing author to *Space Mission Analysis and Design*. He's also the principal author of a series of papers titled "Vibration Testing of Small Satellites." Since 1995, he has taught over 250 courses to more than 5000 engineers and managers in the aerospace industry.

Testimonials:

"It was a fantastic course—one of the most useful short courses I have ever taken."
"Interaction between instructor and experienced designers [in the class] was priceless."
"[The] examples [and] stories from industry were invaluable." "Everyone at NASA should take this course!" "Wonderful course."
"Your presentation skills are excellent, with patient attention paid to class questions."
"[This class] should be mandatory for design engineers at [our company]."
What I found most useful: "Strong emphasis on understanding physical principles vs. blindly applying textbook formulas."
"Great course! Lots of lessons learned. The examples made it that much better."
What I would tell others: "Take it!" "You need to take it." "Take it. Tell everyone you know to take it."
"Excellent instructor. Great lessons learned on failure modes shown from testing."
"A must course for structural/mechanical engineers and anyone who has ever questioned the assumptions in bolt analysis"
"Well-researched, well-designed course." "Kudos to you for spreading knowledge!"

Instar also offers the following courses: "Ten Principles for Successful Space Programs" (TenP), "Engineering for Success in the Space Industry" (ESSI), "Space Mission Structures, From Concept to Launch" (SMS), "Structural Test Design and Interpretation" (STDI), "Vibration Testing of Small Satellites" (VTSS), and "Vibration Testing on an Electrodynamic Shaker" (VTES). Go to instarengineering.com/available_courses.html for details.

Course Outline

1. Overview

- Common problems with bolted joints
- A process for designing a bolted joint
- Bolting as a method of attachment
- General design guidelines
- The importance of preload
- Introduction to NASA-STD-5020
- Key definitions
- Top-level requirements from NASA-STD-5020
- Factors of safety, fitting factors, and margin of safety
- Establishing internal standards and criteria

2. Introduction to Threaded Fasteners

- History of screw threads
- Thread forms and compatibility
- Rolled vs. cut threads
- Bolt features and geometry
- Tensile-stress area
- Fine threads vs. coarse threads

3. Developing a Concept for the Joint

- General types of joints and fasteners
- Configuring the joint
- Designing a stiff joint
- Shear clips and tension clips
- Avoiding problems with fixed fasteners

4. Calculating Bolt Loads when Ignoring Preload

- How a preloaded joint carries load
- Temporarily ignoring preload
- What about friction as a load path?
- Common assumptions and their limitations
- Finite element modeling of a bolted joint
- An effective process for calculating bolt loads in a compact joint

5. Failure Modes and Assessment Methods

- Understanding stress analysis
- An effective process for strength analysis
- Bolt tension and shear
- Tension joints
- Shear joints
- Identifying potential failure modes
- Fastened shear joints with composite materials

6. Thread Stripping and Pull-out Strength

- How threads fail
- Computing shear engagement areas
- Including a knock-down factor
- Test results

7. Selecting Hardware and Detailing the Design

- Selecting compatible materials
- Selecting the nut
- Commonly used threaded inserts
- Use of washers
- Selecting fastener length and grip
- Recommended fastener hole sizes
- Guidelines for simplifying assembly
- Establishing bolt preload
- Torque-preload relationship
- Locking features and NASA-STD-5020
- Maintaining preload

8. Mechanics of a Preloaded Joint

- Mechanics of a preloaded joint under applied tension
- Estimating bolt stiffness and clamp stiffness
- Understanding the loading-plane factor
- Worst case for steel-aluminum combination
- Key conclusions regarding load sharing
- Effects of bolt ductility
- How temperature change affects preload

9. Analysis Criteria per NASA-STD-5020

- Objectives and summary
- Calculating maximum and minimum preloads
- Tensile loading: ultimate-strength analysis
- Separation analysis
- Tensile loading: yield-strength analysis
- Shear loading: ultimate-strength analysis
- Interaction of tension, shear, and bending
- Shear loading: joint-slip analysis
- Low-risk classification for fastener fatigue

10. Design Tables: Preliminary Bolt Sizing, Based on NASA-STD-5020 Analysis Criteria

- Objectives for generating design tables
- Setting up a spreadsheet
- Assumptions and equations
- Typical driving parameters
- Design tables for selected situations

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Graphic design by Sarafin Design www.sarafindesign.com