Fundamentals of Threaded Fasteners & Joint Design Course Content

A training course delivered by NNi Training and Consulting Inc. and Matrix Engineering Consultants.

May 10–13, 2027

Fundamentals of Threaded Fasteners and Joint Design

Course Overview

This four-day course provides engineers, designers, and technical professionals with the knowledge and practical tools to specify, design, assemble, validate, and troubleshoot threaded fasteners and bolted joints. The course covers fundamental fastener technology, bolted joint engineering principles, and common failure mechanisms, with particular emphasis on dynamically loaded joints. Classroom exercises, practical demonstrations, and a capstone project reinforce applying these methods to real-world engineering problems.

Note: The course focuses on mechanically fastened joints in equipment and machinery, particularly those subjected to dynamic or cyclic loading. Structural steel connections governed by AISC 360 are not a primary focus. VDI 2230 principles will be referenced throughout the course, but detailed instruction on the standard is outside the course scope.

Learning Outcomes

After completing this course, participants should be able to:

1. Interpret fastener standards, thread designations, thread fits, strength grades, and material requirements used to specify threaded fasteners.
2. Select bolts, screws, nuts, washers, materials, and coatings appropriate for the joint design, assembly conditions, and intended service.
3. Estimate applied tensile and shear loads, joint stiffness, bolt loads, and required preload using simplified engineering methods.
4. Evaluate joint strength and common failure risks, including bearing stress, thread stripping, fatigue, joint slip, and joint separation.
5. Evaluate tightening and inspection methods, accounting for torque-tension behavior, preload scatter, elastic interaction, and the limitations of torque auditing.
6. Identify causes of preload loss and self-loosening, evaluate ways to reduce these risks, and recognize when detailed analysis or physical testing is needed.

Target Audience

This course is designed for engineers or technical staff involved in the design, specification, procurement, quality assurance, or assembly of bolted joints.

Prerequisites

The course is intended for technical professionals with a basic understanding of mechanical engineering principles. Some topics include engineering equations and algebraic calculations. Prior experience with threaded fasteners or bolted joint design is helpful but not required.

In-Person or Online Learning

Students may choose to attend in person or via a live online stream concurrent with the in-person training. The in-person session will be held at Matrix Engineering Consultants, located at 12986 Valley View Road, Eden Prairie, Minnesota 55344 (Note: Matrix Engineering Consultants is co-located with RFA Engineering)

Professional Development Hours (PDHs)

- The four-day course provides 24 PDHs.

Fundamentals of Threaded Fasteners and Joint Design

Day 1: 1–6 p.m.

- **Course Introduction**

- **Introduction to Fastener Standards** (NNi)
  - Overview of North American Fastener Consensus Standards
    - ASTM
    - ASME
    - SAE
    - NASC Family of Standards
    - ISO
  - Explanation of fastener standards format
  - How to use fastener standards
  - How to find appropriate fastener standards

- **Screws & Bolts** (NNi)
  - Design considerations when choosing a screw or bolt
  - Common screw and bolt head styles and why a designer might choose one style over another
  - Drive recesses and why a designer might choose one style over another

- **Nuts and Washers** (NNi**)**
  - Fundamentals of nuts
    - Nut "Pairing" Rule
  - Fundamentals of washers

- **Basics of Threads and Thread Fit** (NNi)
  - Thread terminology and definitions
  - Explaining thread pitch
  - Thread handedness
  - How to understand and interpret Thread Designations (Inch and Metric)
  - The importance of the thread Pitch Diameter
  - Explaining Thread Fit (Inch and Metric Versions)

- **Fastener Materials & Metallurgy / Heat Treatment** (NNi)
  - Common Materials used to manufacture fasteners
  - Important Fastener Material Properties
    - Strength
    - Ductility
    - Hardness
    - Toughness
  - Making sense of Fastener Strength Classes/Grades and the standards that define them
  - Fundamentals of Fastener Metallurgy
  - Understanding the three main contributing factors that explain why materials exhibit different material properties
    - Crystal structure
    - Solid-phase constituents and distribution
    - Alloying

- Explaining the significance of the following metallurgical and heat-treating concepts:
  - The Equilibrium Iron- Carbon Phase Diagram
  - The Time-Temperature-Transformation (TTT) Diagram
  - Hardenability
  - Tempering Curves
- Heat Treating Fasteners
  - Quenching and tempering
  - Solution Hardening and Aging
  - Surface Hardening
  - Annealing

Day 2: 8 a.m.–4 p.m.

- **How Fasteners are Manufactured** (NNi)
  - The fundamentals of cold heading
  - What are Warm and Hot Heading
  - Screw Machining
  - Understanding the different machines in cold heading
  - Fundamentals of Roll Threading

- **Plating & Coatings** (NNi)
  - The Corrosion Process
  - Mechanisms Utilized on Fasteners to Prevent Corrosion
    - Barrier
    - Galvanic Action
    - Passivation/Oxide
    - Self-Healing
  - Explaining key plating and coating concepts
    - Electric current density
    - "Throw"
    - Adhesion
    - Accelerated corrosion testing
  - Reviewing common platings and coatings
    - Electroplating
    - Zinc and aluminum flake coatings
    - Phosphate Coating
    - Oxide Coatings
    - Hot Dip Galvanizing
    - Mechanical Coatings
    - Paint Coatings
    - Other Coatings
  - Examining the environmental and health impact of certain platings and/or coatings and their constituent parts

- **Compressive Stress Under the Head of Bolt or Nut**[1] (Matrix)
  - Explanation of compressive stress.
  - The bolted joint 'stress cone'.

  - Simplified equation to estimate compressive stress under the bolt head or nut.
  - Individual Class Exercise.
  - Demonstration: Show the effect of washer thickness on the compressive stress (aligned with class exercise).

- **Thread Stripping**[1] (Matrix)
  - Shear cylinder concept.
  - Example calculation of stripping in large plate.
  - Stripping calculations in nuts and thin-walled tubes.
  - Long thread engagements.
  - Stripping of thin-walled members.
  - Thread inserts & weld nuts.
  - Demonstration: Demonstrate stripping of internal and external thread.

- **Fatigue Failures in Threaded Fasteners**[1] (Matrix)
  - Common causes for fatigue failure.
  - Common fatigue fracture locations.
  - Overview of the fatigue strength of a threaded fastener.
    - Existing experimental data for the first engaged thread
    - Transition between the threaded and unthreaded shank
    - Transition between unthreaded shank and head.
  - Common methods of reducing risks of fatigue fractures.

- **Introduction to Joint Diagrams**[1] (Matrix)
  - Bolt and joint stiffness calculations.
  - Explanation of basic joint diagram.
  - Effect of bolt preload and applied axial loads.
  - Load factor explanation and calculation.
  - Effect of load introduction location.

Day 3: 8 a.m.–4 p.m.

- **Methods of Tightening Threaded Fasteners**[1] (Matrix)
  - Overview of other tightening methods.
  - Torque control tightening.
    - The factors which affect the torque-tension relationship.
    - Tests to determine the coefficient of friction of threaded fasteners.
    - Torque control and angle monitoring tightening.
  - Tension indicating methods using load indicating bolts and washers.
  - Application of ultrasonic technology and other instrumentation in bolt tightening.
  - Combined stress during torque tightening.
  - Demonstration: Preload scatter using sample of bolts tightened using torque control tightening on a Skidmore device[1]
  - Small Group Exercise: Calculation to estimate preload scatter for fastener tightened using torque control tightening.

- **Elastic Interaction and Tightening Procedures**[1] (Matrix)

- Problems associated with the tightening of a multi-bolt joint.
- Elastic interaction.
- Tightening sequences.

- **Torque Auditing**[1] (Matrix)
  - Torque Auditing – Why is it done?
  - Torque auditing methods.
    - Static torque audit.
    - Residual torque audit.
  - Issues with torque auditing.
  - Demonstration: Show the difference between peak torque and residual torque audits.

- **Loosening Due to Relaxation**[1] (Matrix)
  - Explanation of relaxation.
  - Embedment and other causes of relaxation
  - Methods of reducing relaxation.
  - Demonstration: Relaxation due to embedment and thick paint.
  - Small Group Exercise: Calculation to estimate relaxation due to embedment.

- **Self-Loosening of Threaded Fasteners**[1] (Matrix)
  - The self-loosening torque in all tightened threaded fasteners.
  - Junker's theory on self-loosening of fasteners and why fasteners self-loosen.
  - The Junker transverse vibration test.
  - The phases of self-loosening.
  - Preload decay curves of various thread locking devices.
  - Critical slip distance.
  - Micro-slip in large joints.
  - Methods of reducing the risk of self-loosening.

- **Vibrational Detachment of Thread Fasteners**[1] (Matrix)
  - Why do loose threaded fasteners fall out?
  - Demonstration of a magic bolt!

Day 4: 8 a.m.–4 p.m.

- **Preload Requirements Charts**[1] (Matrix)
  - Explanation and justification for the methodology.
  - Statistical considerations in bolted joint design.
  - Example problems.
  - Methods to address bolted joint issues.

- **Shear Capacity of the Bolted Joint and Failure Mechanisms**[1] (Matrix)
  - Estimating bolted joint shear reactions in eccentrically loaded joints using rigid body methods.
  - Shortcuts focusing on the most highly loaded joint.
  - Failure mechanisms caused by joint slip.
  - Small Group Exercise – Estimate the shear load applied to a specific joint.

Fundamentals of Threaded Fasteners and Joint Design

- **Tension Capacity of the Bolted Joint and Failure Mechanisms**[1] (Matrix)
  - Estimating bolted joint tension/compression reactions in joints with bending moments using rigid body methods.
  - Shortcuts focusing on the most highly loaded joint.
  - Failure mechanism caused by joint opening.
  - Small Group Exercise – Estimate the separating load applied to a specific joint.

- **Overview of FEA and Bolted Joint Software**[1] (Matrix)
  - Commercially available software
  - Typical Calculations in BJA software
  - Where FEA shines
  - Load applied to bolted joint vs. the bolt
  - FEA best practices
  - Common modelling techniques
  - Advantages/disadvantages of each method.
  - Validation of FEA and reporting
  - Factors often overlooked in FEA
- **Review the Simplified Design Guide**[1]
- **In-Class Student Capstone Project**

[1]*© Copyright Bolt Science Limited 2026 and: Information contained in this document has been obtained and developed by Bolt Science Limited from sources considered to be reliable.*

Course Instructors

Mr. Claus has over 35 years of experience in the fastening industry. He spent the first 26 years with a fastener manufacturer, becoming an expert in threaded fasteners, especially those in the automotive and aerospace market segments. For the last 10 years he has served the industry as both trainer and consultant as the President of his company NNi Training and Consulting Inc. and as the Industrial Fastener Institute's Director of Training and Education. Additionally, Mr. Claus is the current Chairman of the SAE Fastener Committee, Vice Chairman of the ASTM Fastener Committee F16, Subcommittee Chairman of ASME B18.6 of the ASME Fastener Committee B18, and Subcommittee Chairman of ASTM F16.91 of ASTM Fastener Committee F16. For this course Mr. Claus will share his expertise in topics such as the fundamentals of threads, fundamentals of bolts, screws, and nuts, fastener materials, metallurgy, and heat treatment, making sense of the various bolt strength classes, and fastener platings and coatings.

Mr. Ness has over 36 years of engineering and design experience. He is a Licensed Professional Engineer and a Principal Engineer at Matrix Engineering Consultants of Eden Prairie Minnesota. His career has centered on the development of machines and powertrains, with specialized expertise in the design and validation of dynamically loaded bolted joints. Mr. Ness has led numerous failure investigations and subsequent bolted joint redesigns to mitigate risk and improve system reliability. He is an active contributor to a U.S. Department of Energy SETO-funded research initiative focused on critical bolted joints in solar photovoltaic (PV) mounting systems. He has also delivered extensive training on topics such as Failure Modes and Effects Analysis (FMEA) and Bolted Joint Design and Validation. He serves on the UL 2703 Standards Technical Panel and has contributed to the ASCE Manual of Practice for Solar PV Structures.

Breanna Veltkamp is an Instructor and Consulting Engineer specializing in bolted joints at Matrix Engineering, with over 9 years of engineering and design experience. Her background includes the design of buildings and shipboard structures, including bolted and welded steel connections and aluminum balcony connections. She also has

experience investigating bolted joint failures. Breanna received a Bachelor of Science in Engineering from Dordt University.