Fundamentals of Threaded Fasteners & Joint Design Course Content

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

MATRIX
ENGINEERING CONSULTANTS

NNi
Training and Consulting Inc.

Fundamentals of Threaded Fasteners and Joint Design

Course Overview
The course will provide participants with an in-depth explanation of fastener terminology, technology, and threaded fastener joint design calculations and strategies which will enable the student to design the joint and select the proper threaded fasteners so the system will not fail in service. The course will include case studies, problems which will be solved during class and a demonstration of preload scatter achieved through torque tightening. All critical calculations are summarized in the Simplified Bolted Joint Design Guideline which defines a systematic method for evaluating most bolted joints for the common failure modes.

The focus of the course will be on dynamically loaded fastened joints rather than structural joints according to AISC 360. Although the VDI-2230 standard will often be referenced, the course is not intended to provide a detailed presentation of this standard.

Target Audience
This course was developed for engineers or technical staff tasked with design, specification, procurement, quality, or assembly of threaded fastened joints.

Prerequisites
This is an intermediate technical level course which includes equations which need to be solved with algebra. Individuals with some prior experience with fasteners and bolted joint design may find this course easier but there is something for everyone to learn in this course.

In-Person or On-line Learning
Students may choose to attend in-person or via a live on-line stream concurrent with the in-person training. The in-person session will be held in the training facilities at Matrix Engineering Consultants, 12986 Valley View Road, Eden Prairie, Minnesota 55344.

Professional Development Hours (PDHs)
- The three day in-person and on-line learning event is worth **21 PDHs.**
- Students who solve the supplemental learning exercises and participate in the follow up webinar to review the results will receive an additional **3 PDHs.**

Day 1

- **Course Introduction**
- **Basics of Threads and Thread Fit**
  - 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)
- **How Fasteners are Manufactured**
  - The fundamentals of cold heading
  - What are Warm and Hot Heading
  - Screw Machining
  - Understanding the different machines in cold heading
  - Fundamentals of Roll Threading

Fundamentals of Threaded Fasteners and Joint Design

- **Introduction to Fastener Standards**
  - 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**
  - 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**
  - Fundamentals of nuts
    - Nut "Pairing" Rule
  - Fundamentals of washers
- **Fastener Materials & Metallurgy / Heat Treatment**
  - 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 which 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
    - Quench and Tempering
    - Solution Hardening and Aging
    - Surface Hardening
    - Annealing

Fundamentals of Threaded Fasteners and Joint Design

Day 2

- **Plating & Coatings**
  - 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 aluminium 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
- **Introduction to Bolted Joint Design**
  - Terminology
  - The bolted joint as structural system.
  - System parameters which affect joint performance.
- **Methods of Tightening Threaded Fasteners**[1]
  - 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.
  - Overview of other tightening methods.
  - Tension indicating methods using load indicating bolts and washers.
  - Application of ultrasonic technology and other instrumentation in bolt tightening.
  - Combined stress during torque tightening.
  - Student problem using the nut factor equation.
- **Demonstration of Preload Scatter Using Skidmore Device**[1]
- **Tightening Procedures and Elastic Interaction**[1]
  - Problems associated with the tightening of a multi-bolt joint.
  - Elastic interaction.
  - Tightening sequences.
- **Quality Assurance/Control of Fastener Assembly**[1]
  - Torque Auditing – Why is it done?
  - Torque auditing methods.
  - Issues with torque auditing.

Fundamentals of Threaded Fasteners and Joint Design

- **Calculations and Demonstration Justifying of Washers & Flange Hardware**
  - The bolted joint 'stress cone'.
  - Simplified equation to estimate compressive stress.
  - Example calculation & demonstration**.**
- **Calculations to Address Thread Stripping**[1]
  - Shear cylinder concepts.
  - Example calculation of stripping in large plate.
  - Stripping calculations in nuts and thin wall tubes.
  - Long thread engagements.
  - Thread Inserts & Weld nuts.
- **Fatigue Failures in Threaded Fasteners**[1]
  - Common causes for fatigue failure.
  - Common fatigue fracture locations.
  - Overview of endurance strengths of a threaded fastener.
  - Common methods of reducing risks of fatigue fractures.
- **Introduction to Joint Diagrams**[1]
  - 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.
- **Fatigue Failure Case Study**

Day 3

- **Shear Capacity of the Bolted Joint and Failure Mechanisms**[1]
  - Estimating bolted joint shear reactions in eccentrically loaded joints using rigid body methods.
  - Shortcuts focusing on most highly loaded joint.
  - Failure mechanisms caused by joint slip.
- **Tension Capacity of the Bolted Joint and Failure Mechanisms**[1]
  - 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.
- **Loosening Due to Relaxation**[1]
  - Explanation of relaxation.
  - Embedment and other causes of relaxation
  - Calculations to estimate relaxation.
  - Methods of reducing relaxation.
- **Self-Loosening of Threaded Fasteners**[1]
  - The self-loosening torque inherit in all tightened threaded fasteners.
  - Junker's theory on self-loosening of fasteners and why fasteners self-loosen.
  - The Junkers 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]
  - Why do loose threaded fasteners fallout.
- **Preload Requirements Charts**[1]
  - Explanation and justification for the methodology.
  - Statistical considerations in bolted joint design.
  - Example problems.
  - Methods to address bolted joint issues.
- **Simplified Bolted Joint Design Guideline**[1]
- **In-Class Student Problems**
  - Lifting bracket bolted joint.
  - Cantilevered bracket bolted joint.
- **Overview of Bolted Joint Analysis Software and FEA Methods**

Optional Learning Exercises *(3 Professional Development Hours)*

- Electrical connection joint.
- Driveline bolted joint.
- Lawn mower front caster wheel bolted joint.

Course Instructors

Mr. Claus has over 35 years in the fastener 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 32 years of engineering and design experience. He is a Licensed Professional Engineer and the Principal Engineer of Matrix Engineering Consultants of Eden Prairie Minnesota where he utilizes his expertise in engineering and design of on and off-road vehicles and the design and validation of bolted joints. Mr. Ness has led many root cause investigations of bolted joint failures. Mr. Ness will share his expertise in topics such as fundamentals of bolt preload, understanding joint diagrams, load factors and other joint design principles, simplified bolted joint design guidelines, an introduction to VDI-2230, methods of bolt tightening, and fatigue and other failures in fasteners.