FEA ACADEMY

ON-DEMAND ONLINE COURSE

# Practical Nonlinear Finite Element Analysis

Take your FEA to the next level: geometric, material and contact nonlinearity, taught by two industry specialists.

15 lectures | 17 FEA workflows | 12 hours | On-demand

In partnership with EVOTECH Computer-Aided Engineering Ltd

www.fea-academy.com

COURSE OBJECTIVES

# What this course gives you

## The best practical methods

To offer the best practical methods and guidelines for the development and validation of finite element models in solid mechanics and structural analysis, for nonlinear behaviors.

## Accurate, reliable models

To give mechanical and structural engineers the keys to developing accurate and reliable finite element models, by avoiding the most frequent errors.

**Software-agnostic:** the modeling techniques apply whatever FEA software you use.

WHY THIS COURSE

# Learning FEA is a lot more than learning software

It is also about learning the good modeling practices and methods.

**This course will deliver the real and practical knowledge that you need for your day-to-day work with FEA.**

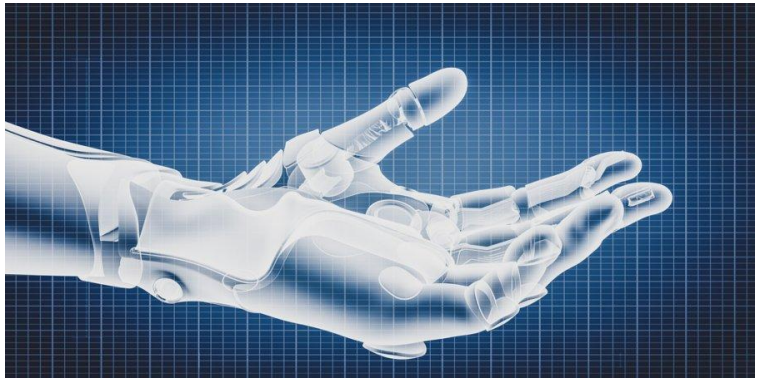
EXPAND YOUR CAREER HORIZONS

# Unlock the power of FEA to excel in engineering

## Gain an edge with comprehensive FEA training

**Learning FEA in detail** opens doors to expanded career opportunities and sets you apart.

**Master good modeling practices** and take your engineering skills to new heights.



## Boost your versatility to conquer diverse projects

**FEA is incredibly flexible:** apply it in many industries and projects.

**Become an engineering virtuoso,** ready to navigate any challenge with confidence.

## Join an inspiring community of FEA enthusiasts

**Enroll in FEA Academy's courses** and access a network of like-minded engineers.

**Collaborate,** share ideas and connect with instructors and fellow engineers.

STRUCTURE OF THE COURSE

# An on-demand course you follow at your own pace

**32** on-demand videos

**12** hours of learning

**24/7** access to the virtual classroom: watch the videos at your own pace

TWO COMPLEMENTARY PARTS

# The methods, then the workflows in the software

THEORY & CONCEPTS

## Modeling Techniques

Methods, guidelines and examples

*by Dominique Madier*

**15 lectures** **7 hours**

EXAMPLES

## FEA Workflow Examples

Examples showing FEA workflows

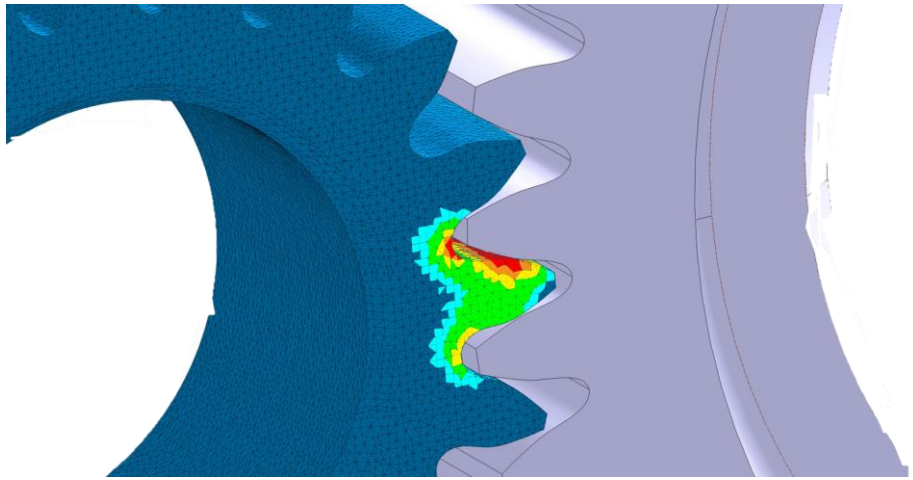
*by Dr. Steffan Evans, Evotech CAE*

**17 workflows** **5 hours**

PREREQUISITES

# What you need before you start

- A robust general physics background.
- A basic knowledge of FEA.
- A review of university-level solid mechanics, statics and strength of materials is recommended.



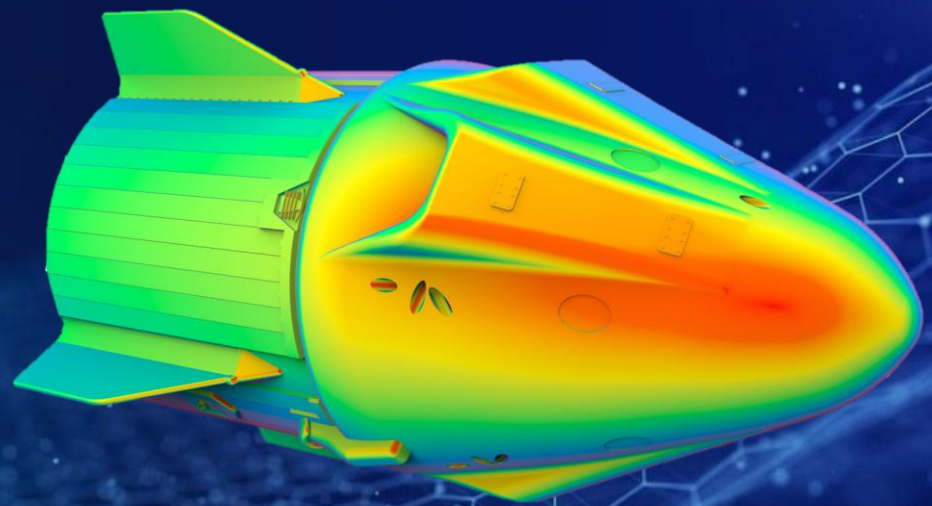
**New to FEA?** Start with the Practical Basic FEA course, or take both courses together in the Basic + Nonlinear FEA bundle.

THE OUTCOME

# Perform your day-to-day FEA with confidence

This course will permit you to perform your analysis for your **day-to-day work in FEA.**

You will understand FEA in detail, and you will **have confidence in your results.**



THE BENEFITS

# Expand your career and your versatility

## Expand your career opportunities

Learning FEA in detail expands your career opportunities and gives you an edge over engineers who don't know the good modeling practices.

## Improve your versatility

FEA is so flexible that it can be used in many applications. An engineer with a very good knowledge of FEA is much more versatile than one who does not know it well.

Since the modeling techniques are universal, mastering FEA lets you work in many industries and on diverse projects.

COURSE CONTENT · THEORY & CONCEPTS

# Modeling Techniques

Methods, guidelines and examples by Dominique Madier

15 lectures

7 hours

Dominique Madier
FEA ANALYST

FEA ACADEMY

www.fea-academy.com

LECTURE

1

15 minutes

Modeling Techniques · Concepts & Guidelines

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LECTURE 1 OF 15

# Introduction to Nonlinear Static Analysis

- What is a Nonlinear System?
- The Types of Nonlinearity
- Characteristics of a Nonlinear System

LECTURE

2

25 minutes

Modeling Techniques · Concepts & Guidelines



# Geometric Nonlinearity

- Sources of Geometric Nonlinearity
- How Does Nonlinear Geometry Work?
- The Follower Load Concept
- Small or Large Strain?
- Do You Really Need a Nonlinear Geometric Analysis?
- Example of Geometric Nonlinearity

LECTURE

3

50 minutes

Modeling Techniques · Concepts & Guidelines



# Material Nonlinearity

- Refresher on the Behaviors of Metallic Materials
- Material Models
- Engineering and True Stress-Strain Curves
- Yield Criteria
- Hardening Rules
- How Does Nonlinear Material Work?
- Defining the Nonlinear Material Model in Your FEA Software
- Do You Really Need a Nonlinear Material Analysis?

LECTURE

4

5 minutes

Modeling Techniques · Concepts & Guidelines



# Boundary Nonlinearity

- Variation of Loads and/or Constraints
- Introduction to Contact Conditions

LECTURE

5

5 minutes

Modeling Techniques · Concepts & Guidelines

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# Should You Run a Linear or a Nonlinear Solution?

- 6 Questions to Answer Before Running a Nonlinear Solution

LECTURE

6

1 hour

Modeling Techniques · Concepts & Guidelines

LECTURE 6 OF 15

# How Do FEA Solvers Compute Nonlinear Problems?

- Formulation of a Nonlinear Problem
- Newton-Raphson Methods
- Computational Methods
- Equilibrium Path and Critical Points
- Stiffness Matrix Update Strategies
- Convergence Criteria
- Choosing the Incremental Load Step
- Arc-Length Methods
- How to Select the Right Iterative Solution Scheme?

LECTURE

7

5 minutes

Modeling Techniques · Concepts & Guidelines

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# Summary of the Nonlinear Solution Strategy

- Basic Operations
- Iterative Process
- Stiffness Matrix Updates
- Adaptive Load Increment

LECTURE

8

10 minutes

Modeling Techniques · Concepts & Guidelines

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LECTURE 8 OF 15

# Strategies to Avoid and Solve Convergence Issues

- Non-Convergence Issues
- Tools to Solve Non-Convergence

LECTURE

9

25 minutes

Modeling Techniques · Concepts & Guidelines



# Modeling Contacts #1

- What is a Contact?
  - Contact Definition
  - Contact Strategy
  - Contact Force
  - Friction Force
  - Linear vs Nonlinear
- Types of Contact
  - Contact Definition
  - Types of Interaction
  - Types of Contact Body

LECTURE

10

45 minutes

Modeling Techniques · Concepts & Guidelines

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# Modeling Contacts #2

- Contact Analysis Procedure
  - The Master-Slave Concept
  - Contact Detection
  - Contact Tolerance
  - Detection Algorithms
  - Influence of the Load Increment on Contact Detection
- Guidelines for Defining Contact
- Do You Really Need to Represent Contact in Your Simulations?

LECTURE

11

25 minutes

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# Modeling Contacts #3

- Examples
  - Glued Contact
  - Touching Contact
  - Contact between Deformable Bodies
  - Deformable-Rigid Contact

LECTURE

12

50 minutes

Modeling Techniques · Concepts & Guidelines

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# Examples of Nonlinear Static Analysis

- Geometric Nonlinearity and History Path
- Cumulative Effect of a Nonlinear Analysis
- Influence of the Incremental Load Step on Results
- Material Nonlinearity: The Elastoplastic Plate
- Highly Nonlinear Problem: Metal Forming (Geometric, Material and Contact)

LECTURE

13

20 minutes

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LECTURE 13 OF 15

# General Recommendations for Nonlinear Analysis

- 9 Key Points to Succeed with Nonlinear Analysis

LECTURE

14

10 minutes

Modeling Techniques · Concepts & Guidelines

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# Common Mistakes in Nonlinear Analysis

- The 8 Most Common Mistakes Made in Nonlinear Analyses

LECTURE

15

25 minutes

Modeling Techniques · Concepts & Guidelines

FEA ACADEMY

LECTURE 15 OF 15

# Introduction to Nonlinear Buckling Analysis

- Why Perform a Nonlinear Buckling Analysis?
- The History Path and the Converged Analysis
- Essential Steps in Nonlinear Buckling Analysis
- Examples of Nonlinear Buckling Analysis
  - Buckling of a Curved Panel
  - Snap-Through: Newton-Raphson vs Arc-Length

COURSE CONTENT · EXAMPLES

# FEA Workflow Examples

by Dr. Steffan Evans

Evotech CAE Ltd.

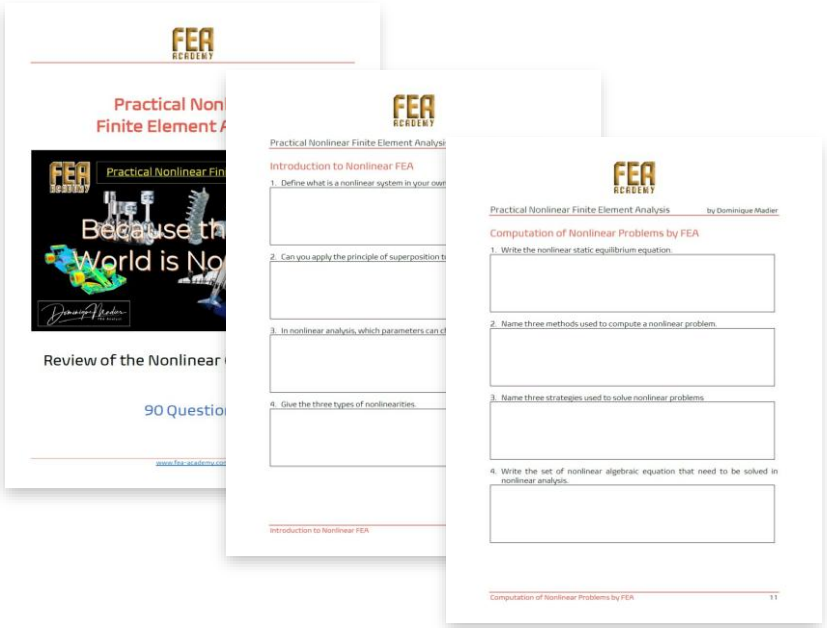
17 videos

5 hours

| Workflow | Duration |
|---|---|
| Stiffened Panel Nonlinear Analysis (4 videos) | 50 min |
| Generalities: Model Build and Analysis Set-Up | 23 min |
| Multiple Load Case and Step Analysis | 20 min |
| Linear vs Nonlinear | 10 min |
| Structural Collapse, Shell Column Structure | 15 min |
| Panel Instability and Load Redistribution | 15 min |
| Fuselage Skin Instability (Load Incrementation Scheme and Load Redistribution) | 25 min |
| Nonlinear Material Behavior | 30 min |
| Plasticity and Permanent Deformation | 15 min |
| Hydroforming / Springback: Punch Forming | 20 min |
| Shock Absorber | 20 min |
| Involute Gear | 25 min |
| 3D Bolt Joint with Preload | 10 min |
| 3D Interference Fit | 15 min |

KEEP TRACK OF YOUR KNOWLEDGE

# Review, test and validate what you learn




## 90 review questions

Download our PDF document with 90 questions to review your knowledge.

## All the answers

Download the PDF document with all the answers to the 90 questions, to check yourself.

## A quiz after each lecture

Test yourself by answering the quiz after each lecture in the FEA Academy learning platform.

SUPPORTING FILES

# Download everything from the virtual classroom

**15**

**PDF files of the lectures**

**~600**

**lecture slides**

**100**

**modeling files**

**MSC Nastran model files for all the examples** (convertible to any FEA package format).

**Geometric files to replicate all the examples** of the lectures and the FEA workflows, in three formats:

**Parasolid (.xmt)** **STEP (.stp)** **IGES (.igs)**

YOUR INSTRUCTOR FOR “MODELING TECHNIQUES”

# Dominique Madier

**FEA Analyst · Trainer · Book Author · Speaker**

**Founder and Director of FEA Academy and Simulation Experts**

dominique.madier@fea-academy.com

- Senior FEA consultant, trainer and coach with 25+ years of experience in FEA.
- Advanced expertise in static and dynamic FEA of linear and nonlinear structural behaviors, on aerospace metallic and composite structures: fuselage, wing, empennage, nacelle, engine pylon and systems.
- Detailed finite element analyses for aerospace companies in Europe and North America: Airbus, Dassault Aviation, Safran, Latécoère, Bell Helicopter, Bombardier Aerospace, Pratt & Whitney Canada, Beta Technologies and their engineering partners.
- Author of “Practical Finite Element Analysis for Mechanical Engineers” and “Harness the Power of FEA”.

YOUR INSTRUCTOR FOR “FEA WORKFLOWS”

# Dr. Steffan Evans

**FEA Analyst and Trainer · “The Apex Guy”**
**Director of Evotech CAE Ltd.**

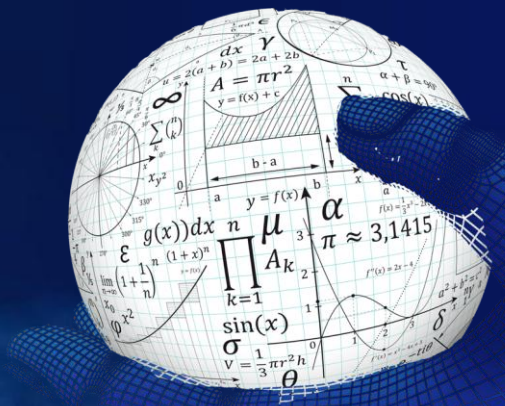
evotechcae.com

- Doctor of Engineering in Multi-Parameter Structural Optimization.
- Chartered Mechanical Engineer (UK) and NAFEMS Certified Professional Simulation Engineer at Advanced Level.
- 20 years in the Airbus / BAE Systems supply chain, in strategic FEA development, analysis and verification.
- Runs Evotech CAE Ltd., an engineered product consultancy in CAE, FEA and design optimization, partnered with MSC Software for training and technical resales.

QUESTIONS AND ANSWERS

# Ask your questions, get answers from the instructors

Ask your questions in the **Discussion** section available with each lecture in the FEA Academy virtual classroom.

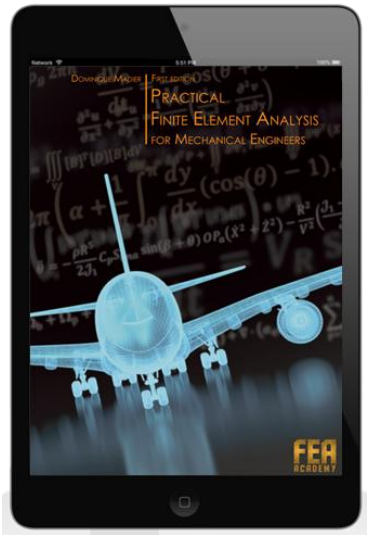


Dominique Madier
FEA ANALYST

FEA Consultant · Book Author · FEA Trainer · Speaker
Helping engineers and students to learn FEA

THE BOOK BEHIND THE COURSE

# Practical Finite Element Analysis for Mechanical Engineers




**650+ pages**
of FEA best practical methods and guidelines

**100+ examples**
illustrating every modeling concept

**Hardcover and eBook**
available in the FEA Academy Book Store

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