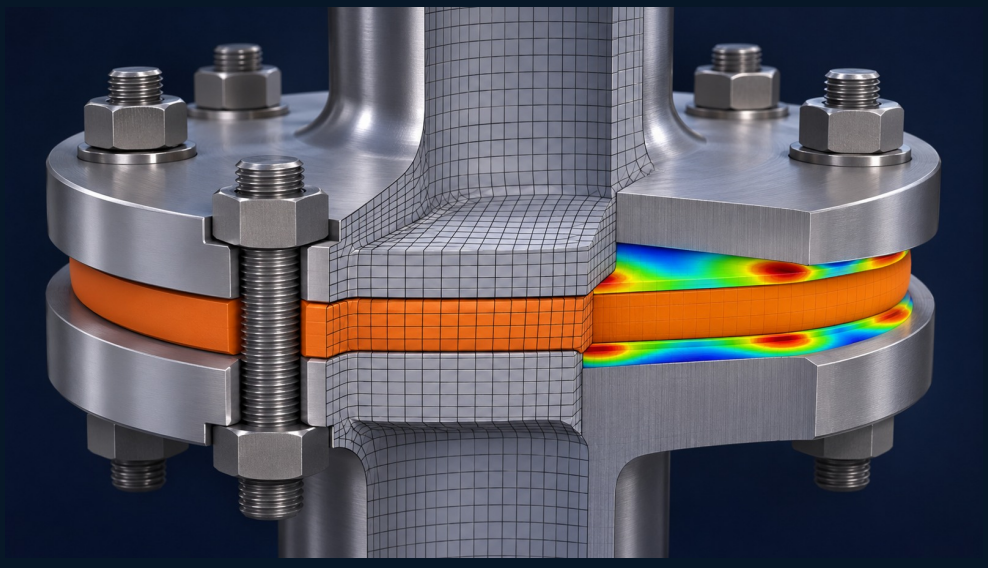
FEACORE®
ENGINEERING SIMULATION & COMPUTATIONAL MECHANICS

FC-H03 / FREE ENGINEERING HANDBOOK

# Nonlinear Contact & Verification

A practical setup and diagnostic checklist




01 Contact and load paths

02 Material calibration

03 Convergence diagnostics


Concise reference - not a complete textbook or project-specific design standard.


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ENGINEERING NOTE 01

# Identify the nonlinear mechanism

## Three common sources

Geometric nonlinearity changes equilibrium with deformation. Material nonlinearity changes constitutive response. Contact nonlinearity changes the active interface constraints. Several mechanisms can operate together in a single assembly.

## Preserve the real loading sequence

Bolt preload, press fit, assembly displacement, temperature and service loads may not commute. Establish initial contact state and intended sequence before applying the final load. A one-step shortcut can produce the wrong retained force or interface pressure.

## Residuals and tangents

An iterative equilibrium procedure reduces r = f_ext - f_int. A tangent system provides displacement corrections; convergence criteria assess residuals and/or corrections. Passing the numerical criteria is necessary but does not make the physical idealisation correct.

A typical Newton correction has K_t Delta u = r. The exact tangent and controls depend on the solver and formulation.

REVIEW CHECKS

- Separate load steps by physical event.
- Start from a simple, stable reference model.
- State which mechanisms are deliberately excluded.

ENGINEERING NOTE 02

# Define contact deliberately

## Normal and tangential behaviour

Specify potential interacting surfaces and whether they can separate, slide or remain bonded. Review initial gaps, interference, surface normals and search settings. Frictional behaviour should be supported by data or an explicit sensitivity range.

## Constraint enforcement

Penalty methods allow controlled constraint violation in exchange for contact stiffness. Lagrange multiplier approaches introduce constraint forces as additional unknowns. Augmented methods combine ideas; availability and details are solver-specific.

## A simple friction bound

For a dry Coulomb idealisation, tangential force capacity is bounded by mu times compressive normal force while sticking. With mu = 0.20 and normal force 10000 N, the nominal bound is 2000 N. A real bolted joint requires the distributed pressure field, preload loss and load path to be considered.

> Do not identify a high coloured band as contact pressure unless that is the actual selected output field.

REVIEW CHECKS

- Inspect gap, slip, pressure and contact status.
- Compare contact resultant with the assembly free body.
- Test friction and contact-stiffness sensitivity.

ENGINEERING NOTE 03

# Material data and convergence

## Use the required stress/strain convention

Many metal plasticity inputs use true stress against plastic strain. Before diffuse necking, true stress = engineering stress times (1 + engineering strain); logarithmic strain = ln(1 + engineering strain). Subtract the elastic strain using the compatible modulus for a uniaxial conversion.

## Worked conversion

For engineering stress 400 MPa, engineering strain 0.10 and E = 210000 MPa: true stress is 440 MPa, logarithmic strain is 0.09531 and the uniaxial plastic strain estimate is 0.09321. This conversion is not valid as a uniform deformation reconstruction after necking.

## Diagnose before adjusting controls

Check rigid-body motion, wrong units, poor elements, abrupt contact changes, unstable response and unsuitable material data. Smaller increments may help resolve events; they do not repair an incorrect constitutive law or impossible restraint.

> Large deformation, unloading and cyclic behaviour can require additional constitutive choices beyond a monotonic stress-strain curve.

REVIEW CHECKS

- Review the first failed increment and physical event.
- Change one control at a time and retain an audit trail.
- Inspect artificial energies and stabilization dependence.

ENGINEERING NOTE 04

# Decide when the model is credible

## Numerical checks

Review reaction balance, contact penetration, load-step sensitivity and changes in the quantity of interest. For applicable formulations, assess energy terms. Solver tolerances and acceptable penetration must be related to geometry, material and the intended decision.

## Physical comparison

Use tests, analytical references or suitable published evidence with matching geometry, material, loading and outputs. Compare curves and mechanisms, not only one peak. State differences between model and reference rather than masking them with parameter fitting.

## Close with a bounded conclusion

A defensible report states what the model represents, what it predicts reliably, what remains uncertain and what action follows. Medical devices and safety-critical components need their own qualification and regulatory route; a concept analysis is not approval.

> Final review: assumptions -> inputs -> numerical checks -> physical evidence -> decision.

REVIEW CHECKS

- Record formulation, solver and controls.
- Show sensitivity and validation evidence separately.
- Document limitations and the recommended next check.

# Use, limits and references

About this handbook
Original FEACORE quick-reference material. It is not the full Finite Element Thinking book and is not a reproduction of another publisher's handbook.

Engineering responsibility
Use alongside solver documentation, applicable standards, material data and a qualified review. Equations are conditional on their stated idealisations. Do not apply a numerical example directly to an unassessed product.

Image status
Cover artwork is a representative engineering concept illustration, not measured or validated project data. Equations and numerical examples in the text are separate from that artwork.

Further reading - primary references

Dassault Systemes Abaqus - About Contact Interactions
https://docs.software.vt.edu/abaqusv2025/English/SIMACAEITNRefMap/simaitn-c-contactoverview.htm

SimScale - Physical Contacts
https://www.simscale.com/docs/simulation-setup/contacts/physical-contacts/

A.F. Bower - small-strain plasticity
https://solidmechanics.org/Text/Chapter3_7/Chapter3_7.htm

NAFEMS - Guidelines for Validation of Engineering Simulations
https://www.nafems.org/publications/resource_center/nwc25-0007290-pres/

Book and further resources
Finite Element Thinking: existing Amazon book listing
www.feacore.com/resources