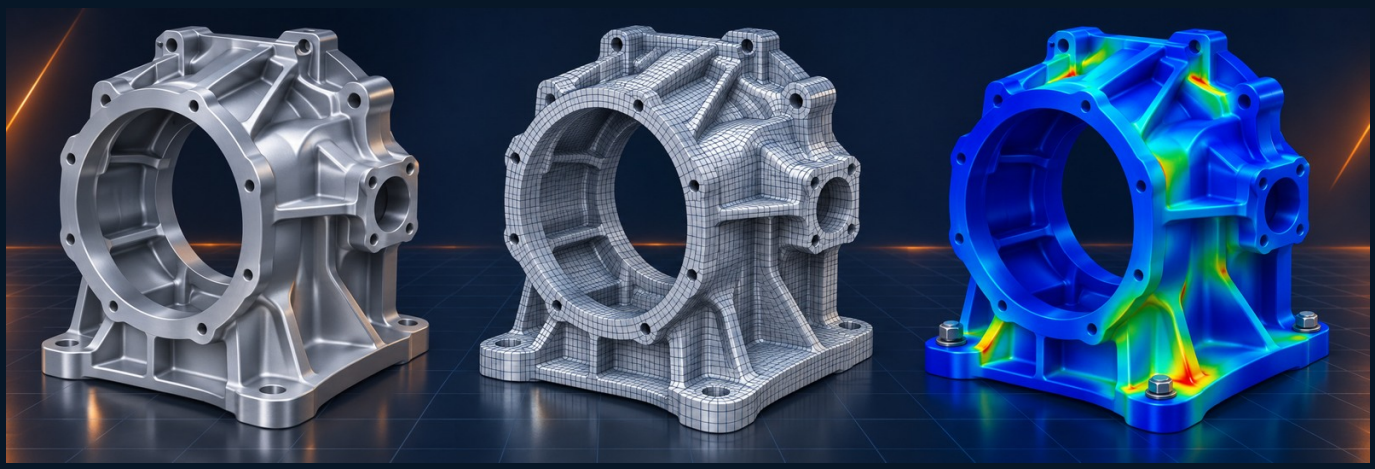
FEACORE®
ENGINEERING SIMULATION & COMPUTATIONAL MECHANICS

FC-H02 / FREE ENGINEERING HANDBOOK

Practical Finite Element Analysis

From model definition to engineering evidence



01 Model planning

02 Elements and mesh

03 Verification and reporting

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

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ENGINEERING NOTE 01

Plan before opening the solver

A model is an approximation

Start from the engineering question and expected load path. Decide whether a beam, shell, axisymmetric, plane or three-dimensional solid model is justified. Retain geometry that influences stiffness, contact or failure; remove detail only with a reason.

Write an input register

Record geometry revision, material source, load cases, support representation, temperature, units and the target quantity. State which inputs are measured, estimated or assumed. The least certain assumption may matter more than a finer mesh.

Separate model credibility tasks

Verification asks whether the equations are solved appropriately. Validation asks whether predictions are adequate for the intended physical use. A successful solve and an attractive plot establish neither by themselves.

Linear statics: $K u = f$. This equation alone says nothing about the correctness of K, f or the modelling assumptions.

REVIEW CHECKS

- Define the intended use and unacceptable outcomes.
- Choose quantities of interest before running variants.
- Agree data gaps and a validation plan at scoping.

ENGINEERING NOTE 02

Elements, mesh and interfaces

Match formulation to behaviour

Interpolation order, integration, locking, distortion and through-thickness representation all influence accuracy. A well-designed hexahedral or quadrilateral mesh can be efficient, but element shape alone does not guarantee correctness.

Resolve the important gradients

Use local refinement around contact, fillets, holes and crack-driving regions while retaining sensible transitions. Check Jacobians, aspect ratios and mesh continuity with formulation-specific criteria. Shell offsets and normals can change interface geometry.

Constrain the physical model

Prevent unwanted rigid-body motion without inventing stiffness. Remote constraints, multipoint relations and symmetry need a mechanical justification. Assembly ties are not interchangeable with frictional or separating contact.

> For a linear elastic solid element, K_e = integral(B^T D B dV). Geometry, interpolation and material law all enter the stiffness.

REVIEW CHECKS

- Check element family, order and integration choice.
- Inspect thickness, normals and connectivity.
- Review constraints and interface load paths visually.

ENGINEERING NOTE 03

Convergence that answers the question

Monitor a defined quantity

Track the same location, averaging convention and output quantity while refining the mesh. A converged displacement does not prove a local stress is converged. Set a tolerance appropriate to the engineering decision, not a universal percentage.

Recognise singularities

A sharp re-entrant corner, point load or idealised restraint can generate a stress peak that grows under refinement. Reconsider geometry and load application, or use a justified structural or fracture quantity rather than chasing the maximum nodal stress.

Use independent numerical checks

For nonlinear models, mesh refinement is only one axis: examine load increments, tolerances, contact settings and material integration as relevant. Energy or reaction checks can expose errors hidden by apparent iterative convergence.

A useful change metric is |q_fine - q_coarse| / |q_fine|. If q is near zero, use an appropriate absolute tolerance instead.

REVIEW CHECKS

- Use multiple systematic mesh levels where practical.
- Hold other modelling choices consistent.
- Report the finest available result and residual uncertainty.

ENGINEERING NOTE 04

Report evidence, not screenshots

Build a reviewable package

Include problem statement, assumptions, geometry revision, input sources, element and mesh choices, boundary conditions, load history, checks and the quantities that support the decision. Make result units and deformation scaling explicit.

Connect a result to a recommendation

Explain whether the model supports the requirement, which uncertainty could reverse that conclusion and which design change or test would reduce risk. Avoid claiming that numerical verification substitutes for physical validation.

Try the FEACORE benchmark

The website includes an open cantilever study with analytical comparison and downloadable source/results. It illustrates why a tip value alone may not reveal the error throughout a field. Read its assumptions before adapting it to another problem.

Open benchmark: https://www.feacore.com/studies/beam

REVIEW CHECKS

- Check force and moment balance.
- State validation status and unresolved uncertainties.
- Archive solver version, model, scripts and output definitions.

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

A.F. Bower - guide to using finite-element software
https://solidmechanics.org/Text/Chapter7_1/Chapter7_1.php

NAFEMS - The Importance of Mesh Convergence
https://www.nafems.org/publications/knowledge-base/the-importance-of-mesh-convergence-part-1/

NAFEMS - Code Verification Exemplars, R0135
https://www.nafems.org/publications/resource_center/r0135/

FEACORE - open beam verification study
https://www.feacore.com/studies/beam

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