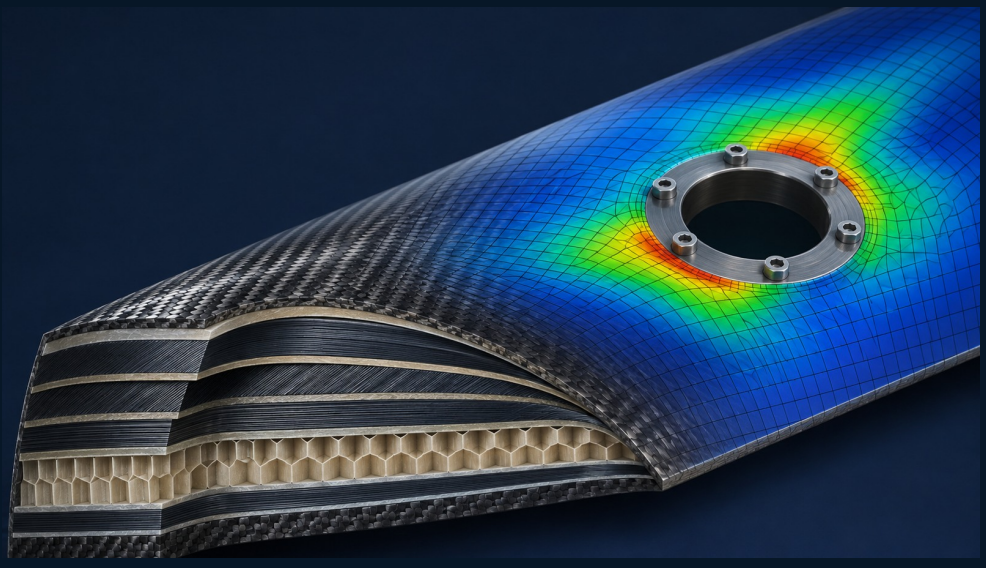
FEACORE®
ENGINEERING SIMULATION & COMPUTATIONAL MECHANICS

FC-H01 / FREE ENGINEERING HANDBOOK

Advanced Solid Mechanics

Stress, deformation and material behaviour



01 Stress and strain

02 Constitutive behaviour

03 Failure and model limits

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

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ENGINEERING NOTE 01

Start with the physical question

Define the decision

Identify the component, service loads, relevant time scale and possible failure modes. Select quantities that answer the question: displacement, strain, interface force, fatigue range or crack-driving force. A stress contour alone is not a decision.

Keep the units coherent

One consistent system is N, mm, s and MPa, where 1 MPa = 1 N/mm². In this system mass is tonne. Do not mix a density entered in kg/m³ with N-mm units without conversion.

Small or finite deformation?

The infinitesimal strain tensor is eps = 0.5[grad(u) + grad(u)^T]. Large rotations can invalidate a small-strain kinematic description even when material strain remains small. Check the solver formulation, not only the displacement magnitude.

Static balance: div(sigma) + b = 0. Boundary traction: t = sigma n.

REVIEW CHECKS

- Sketch the load path and free-body diagram.
- Separate prescribed displacement from applied traction.
- Record the quantity of interest and acceptance basis.

ENGINEERING NOTE 02

Read stress as a tensor

Hydrostatic and deviatoric parts

Mean stress is sigma_m = tr(sigma)/3. The deviator is s = sigma - sigma_m I. Hydrostatic stress influences volumetric response; deviatoric stress is central to classical metal yielding.

Choose the right measure

Von Mises equivalent stress is sqrt(3/2 s:s). It is useful for isotropic ductile-metal yielding, but is not a universal fracture criterion. Brittle solids, polymers, composites and interfaces require a material-appropriate assessment.

Principal stresses and averaging

Principal values are the eigenvalues of the symmetric Cauchy stress tensor. Solver nodal averages can smooth discontinuous extrapolated element stresses. Inspect unaveraged values near interfaces, corners and steep gradients before interpreting a peak.

Example: uniaxial stress diag(100,0,0) MPa gives sigma_m = 33.33 MPa and sigma_vm = 100 MPa.

REVIEW CHECKS

- State coordinate system, stress measure and location.
- Distinguish tension/compression and shear response.
- Do not treat a singular peak as a converged allowable.

ENGINEERING NOTE 03

Select a constitutive model

Linear elasticity

For isotropic small-strain elasticity, sigma = lambda tr(eps) I + 2G eps, with G = E/[2(1+nu)] and lambda = E nu/[(1+nu)(1-2nu)]. Check the nearly incompressible limit before selecting element formulation.

Plane stress is not plane strain

Thin plates loaded in their plane often admit plane stress; long constrained sections may motivate plane strain. Neither assumption is justified by a two-dimensional drawing alone. Out-of-plane constraint changes stiffness and stress state.

Plasticity and time dependence

Yield surface, flow rule and hardening law must match the purpose. Isotropic hardening changes yield-surface size; kinematic hardening represents translation. For polymers, creep and relaxation demand time-dependent calibration at relevant temperature and strain range.

> Elastic constants: E = 210000 MPa, nu = 0.30 gives G = 80769 MPa.

REVIEW CHECKS

- Record test method, temperature and strain rate.
- Keep calibration and independent validation data separate.
- Check whether anisotropy or incompressibility matters.

ENGINEERING NOTE 04

Failure, fracture and a hand check

Fracture is not just maximum stress

In mode-I linear elastic fracture mechanics, $K_I = Y \sigma \sqrt{\pi a}$. Geometry factor Y and crack-size convention must match the specimen. $G = K_I^2/E'$, where $E' = E$ for plane stress and $E/(1-\nu^2)$ for plane strain, under the corresponding assumptions.

Respect applicability

Small-scale yielding, material toughness, thickness and constraint determine whether an LEFM assessment is appropriate. Cohesive and phase-field models add parameters and regularisation choices that also need calibration and sensitivity studies.

Cantilever sanity check

For a rectangular beam with $b = 10$ mm, $h = 20$ mm, $L = 100$ mm, $P = 1000$ N and $E = 210000$ MPa: $I = bh^3/12 = 6666.7$ mm^4; Euler-Bernoulli tip displacement is 0.2381 mm; root extreme-fibre bending stress is 150 MPa. This idealisation excludes shear, local support effects and plasticity.

Beam references: $\delta = PL^3/(3EI)$; $\sigma_b = Mc/I$. These are not universal 3D hotspot predictions.

REVIEW CHECKS

- Compare reactions with applied force and moment.
- Use hand checks to detect order-of-magnitude errors.
- State assumptions before quoting strength margins.

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, Applied Mechanics of Solids - forces in solids
https://solidmechanics.org/Text/Chapter2_3/Chapter2_3.htm

A.F. Bower - linear elasticity
https://solidmechanics.org/text/Chapter3_2/Chapter3_2.htm

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

A.F. Bower - linear elastic fracture mechanics
https://solidmechanics.org/Text/Chapter9_3/Chapter9_3.htm

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