AML 883 Properties and selection of engineering materials

LECTURE 6. Home assignment and solutions to plastic problems

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Home assignment

- Write an essay (of three to five pages) on any one of the following topics; the essay should (a) describe the manufacturing process; (b) describe the advantages and disadvantages of the processing technique; (c) describe the type of materials for which the process is used; and, (d) what properties of the material is affect by the process and why. Any other interesting (for example, historical) information is welcome!
- The assignments are due on or before 18th, February, 2009.

Home assignment

- The assignments may be submitted in electronic format – as a pdf, or a word file; mail it to guru.courses.
- You can also submit, if you so wish, a hard copy.
- All write-ups will be corrected graded; after grading, I will have office hours fixed so that I discuss the reports with each and every one of you – for comments and clarifications.

Home assignment

- Some suggestions:
  You may use points (a)-(d) as an outline!
  Give definitions if possible!
  If there are more than one way of defining, given them and let me know which one you prefer and why.
  You are welcome to point out any discrepancies that you notice in the literature.
  I will be happy if you also tell how to deal with them or get rid of them.

Home assignment

- Essay should be in your own words.
- Use as many figures, schematic drawings, graphs, tables and pictures as you wish – they are not counted towards the number of pages.
- All figures/drawings/pictures/graphs should be neatly labelled and titled.
- The essays should have a bibliography and/or reference section – these again are not counted towards the number of pages.

Home assignment

- The references should be in a consistent (and, standard) format.
- All the materials in the write-up (including data, tables, information, figures, pictures, graphs and schematic drawings) should be correctly attributed.
- Use plain and direct language; avoid jargons; expand all abbreviations.
- Make sure you list your topic, your name, and registration number on the first page of the report.

Home assignment

- Some online resources of help!
- On plagiarism:
  http://www.indiana.edu/~wts/pamphlets/plagiarism.shtml
  http://owl.english.purdue.edu/owl/resource/589/01/
  http://en.wikipedia.org/wiki/Plagiarism
- Report writing:
  http://www.scn.org/cmp/modules/rep-btr.htm
  http://www.askoxford.com/betterwriting/osa/reports/?view=uk
- Handbook for scholars
  http://www.cs.uu.nl/docs/tandt/html/Scholars/

Home assignment: topics

- [1] Sand casting
- [2] Die casting
- [3] Investment casting
- [4] Forging
- [5] Extrusion
- [6] Sheet forming
- [7] Powder methods

Home assignment titles

- [8] Electro-machining
- [9] Conventional machining
- [10] Injection moulding
- [11] Blow moulding
- [12] Compression moulding
- [13] Rotational moulding
- [14] Thermo-forming

Home assignment: titles

- [15] Polymer casting
- [16] Resin-transfer moulding
- [17] Filament winding
- [18] Fusion welding
- [19] Friction welding
- [20] Grinding
- [21] Lapping
- [22] Polishing

Home assignment

- At the end of the class, pick a lot; let me know your number.
- The assignment topics, instructions and the specific student for each topic will be uploaded on the web.
- Please feel free to write to me in case you have queries and clarifications; you can also fix a time to have a discussion with me if you have any questions; do not hesitate to contact me at any stage (except for requesting extension of last date).

Home assignment

- You **may** go through the reports of your friends; you **may** suggest references to your friends; you **may** correct the technical and literary aspects of your friends' reports; however, **you get credit only for your report** (and **are completely responsible for it** too!).
- I would appreciate if you do not write the reports or collect materials *in toto* for your friends though!

Back to the course!

- A couple of comments about the last lecture
- I guess I got the number of veneers wrong – by an order of magnitude!
- Densification of wood: nearly three times dense
- Surprising from what we discussed – but still is true; the idea is getting rid of pores
- By the way, did you know that wood can be friction welded?

Wood densification

Fig. 1. (a) THM reactor without pisten and removable cover, (b) Overview of the THM machine

Heger et al, The proceedings of the workshop on environmental optimization of wood protection

Wood densification

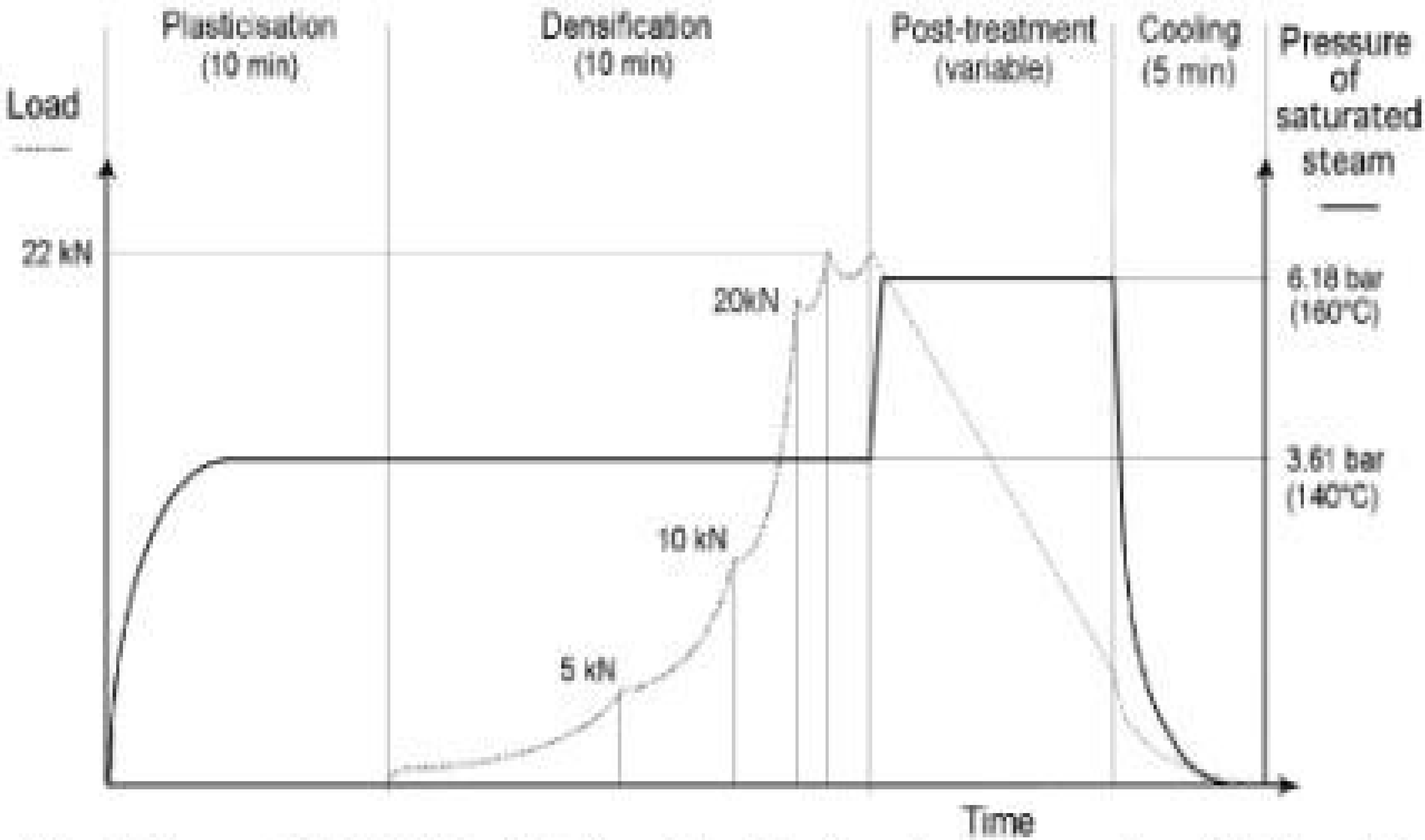


Fig. 3. Diagram of the THM densification and post-treatment procedure, external loading and steam pressure variations

Heger et al, The proceedings of the workshop on environmental optimization of wood protection

Wood densification

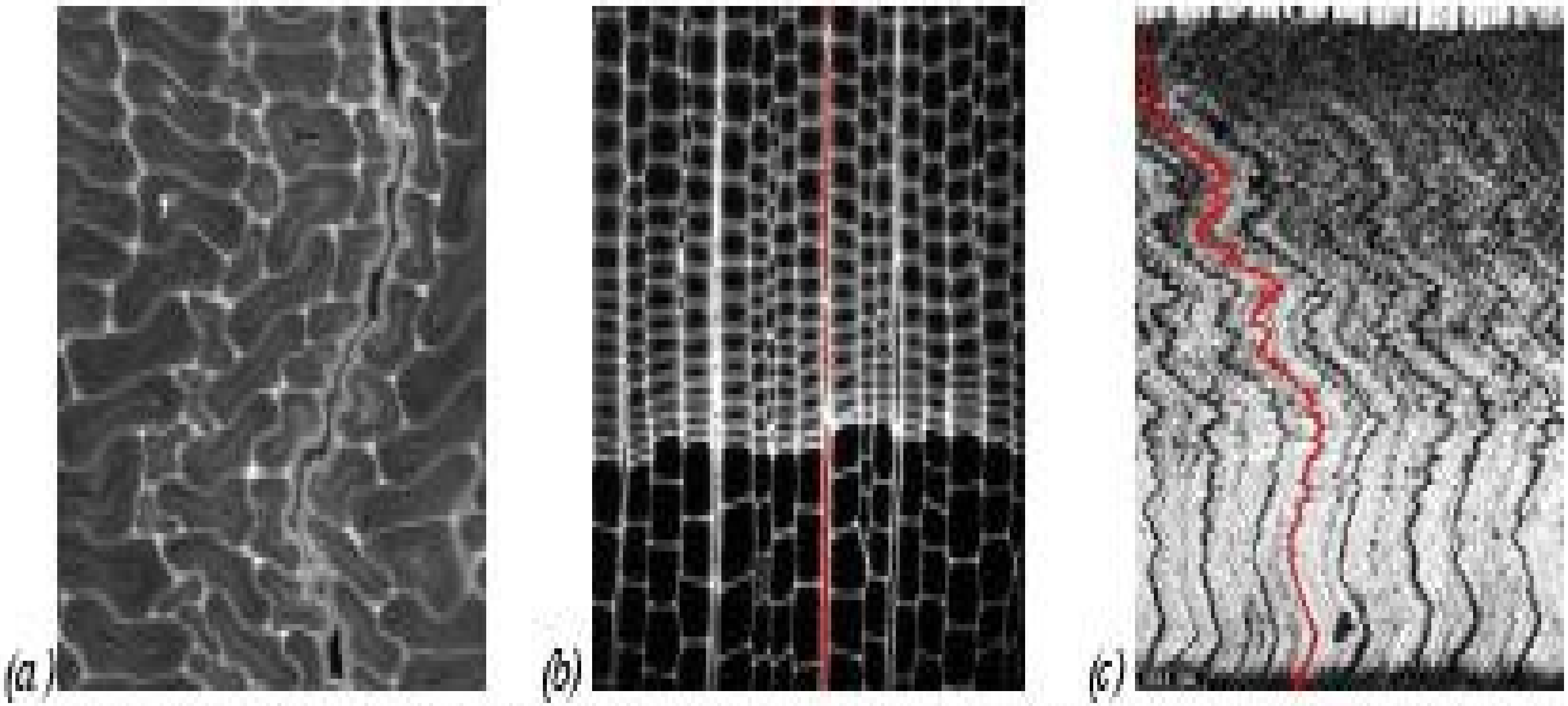


Fig. 9. a) Residual pores of latewood cells and wood rays in densified wood. b) Wood rays in non-densified simple c) Densified spruce. Densification has transformed wood rays to a zigzag form shape

Heger et al, The proceedings of the workshop on environmental optimization of wood protection

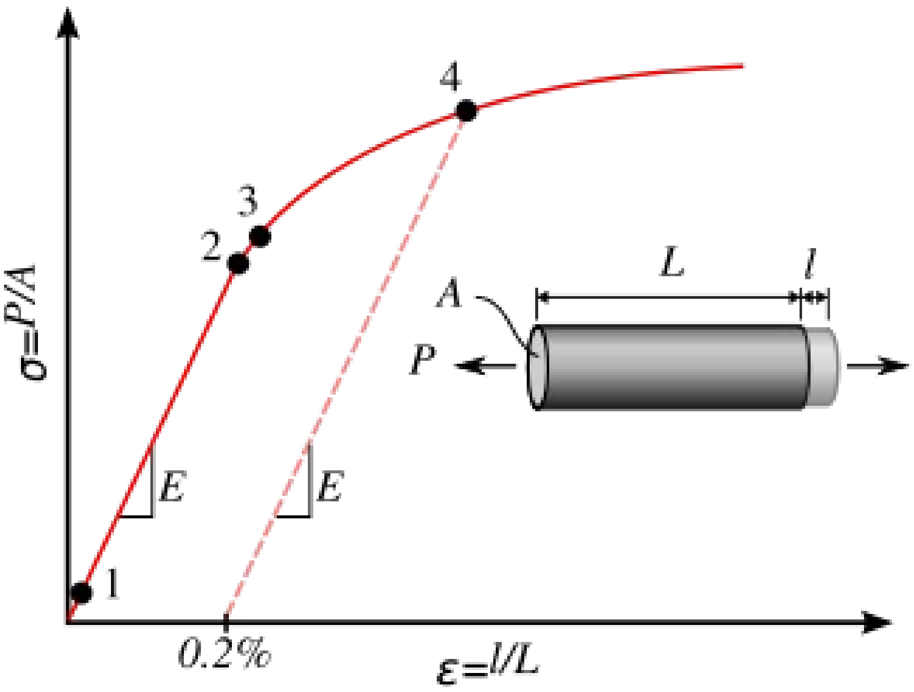
A related note!

- Aluminium foam panel reinforced with steel mesh
- Wood – a natural composite that is also foamy
- Image courtesy: Slovak academy of sciences

Yielding in ties

- Tie – rod loaded in tension
- Stress within a tie – uniform
- If the stress is below the yield strength σ_y, then the component is elastic
- If the stress exceeds yield strength, the tie yields!

Yield point



- Image courtesy: wiki

Yielding in columns

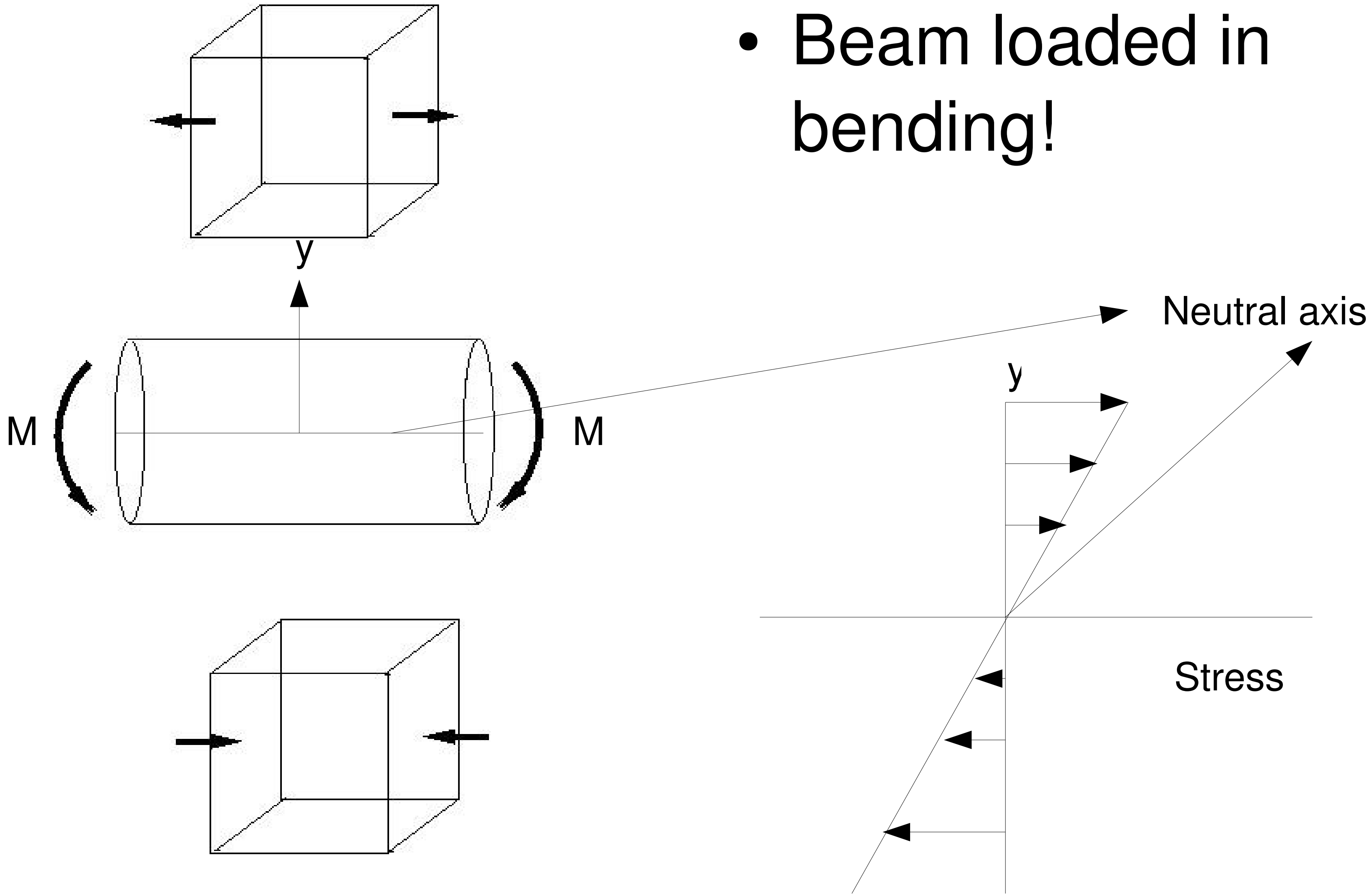
- Columns – rods loaded in compression
- State of stress within the column is uniform
- If the stress is below the yield strength σ_y, then the component is elastic
- If the stress exceeds yield strength, the column yields!
- Issue only for short, squat columns. Why?

Buckling

- Slender columns and plates – buckle under compressive loads
- Buckling – an elastic phenomena
- But, disastrous nonetheless!

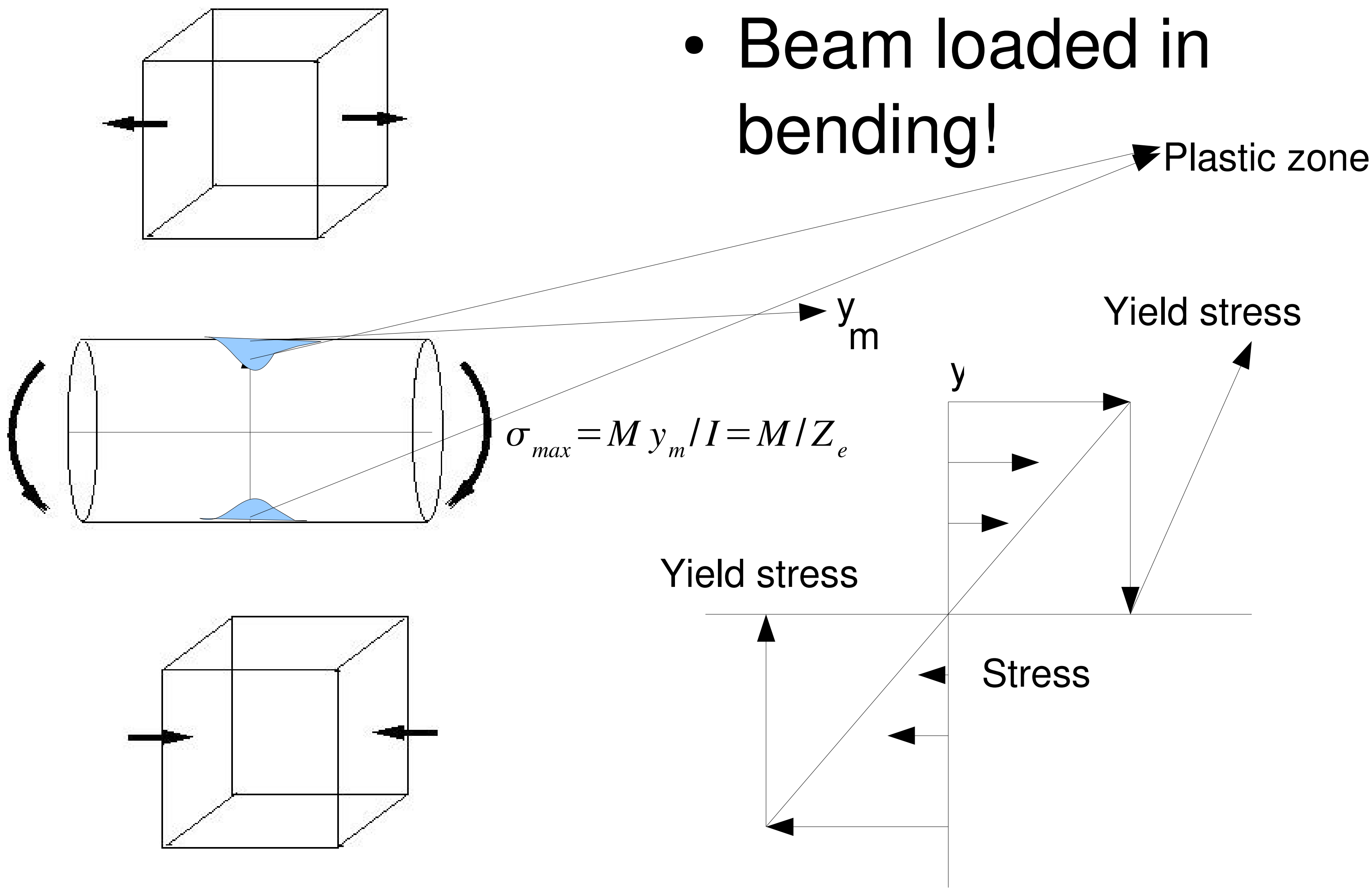
Yielding of beams

- Beam loaded in bending!



Onset of plasticity

- Beam loaded in bending!



$$\sigma_{max} = M\, y_m / I = M / Z_e$$

Elastic section modulus

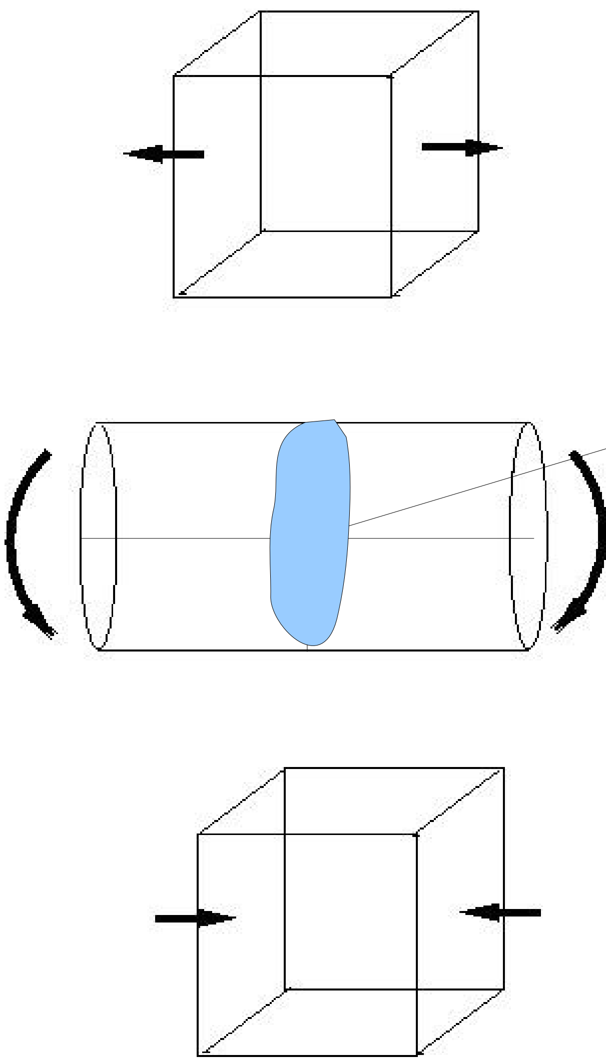
$$\sigma_{max} = M\,y_m / I = M / Z_e$$

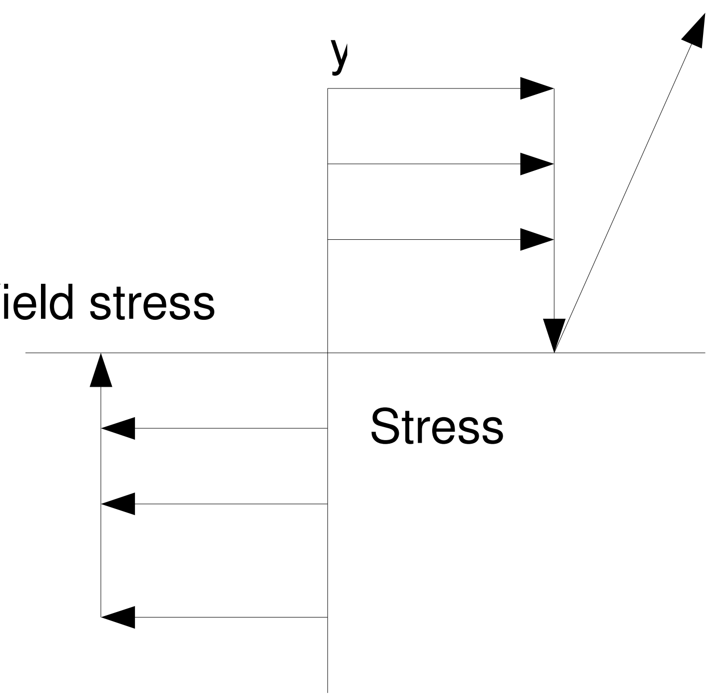
$$Z_e = I / y_m$$ Elastic section modulus

$$\sigma_{max} > \sigma_y$$ Criterion for yield

Full plasticity

- Beam loaded in bending!





Collapse: by rotation about the plastic hinge!

Plastic section modulus

$$M_f = Z_p \sigma_y$$

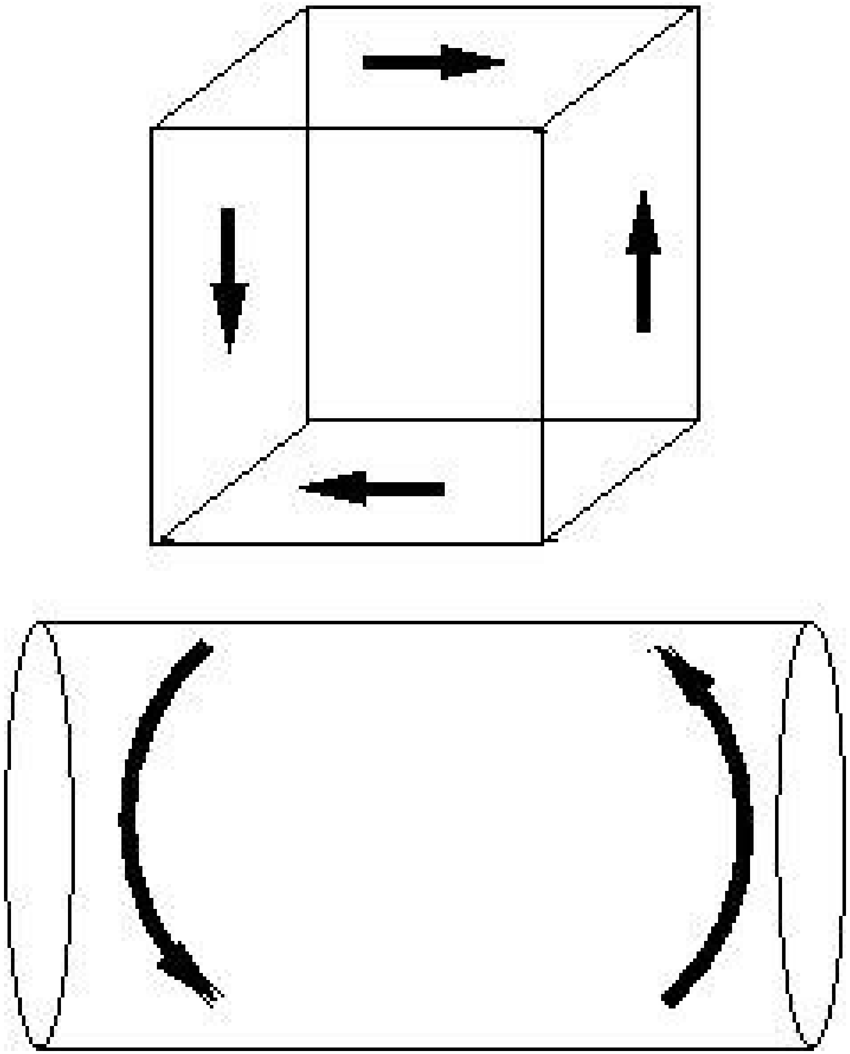
Z_p Plastic section modulus

M_f Failure moment

Failure of beams

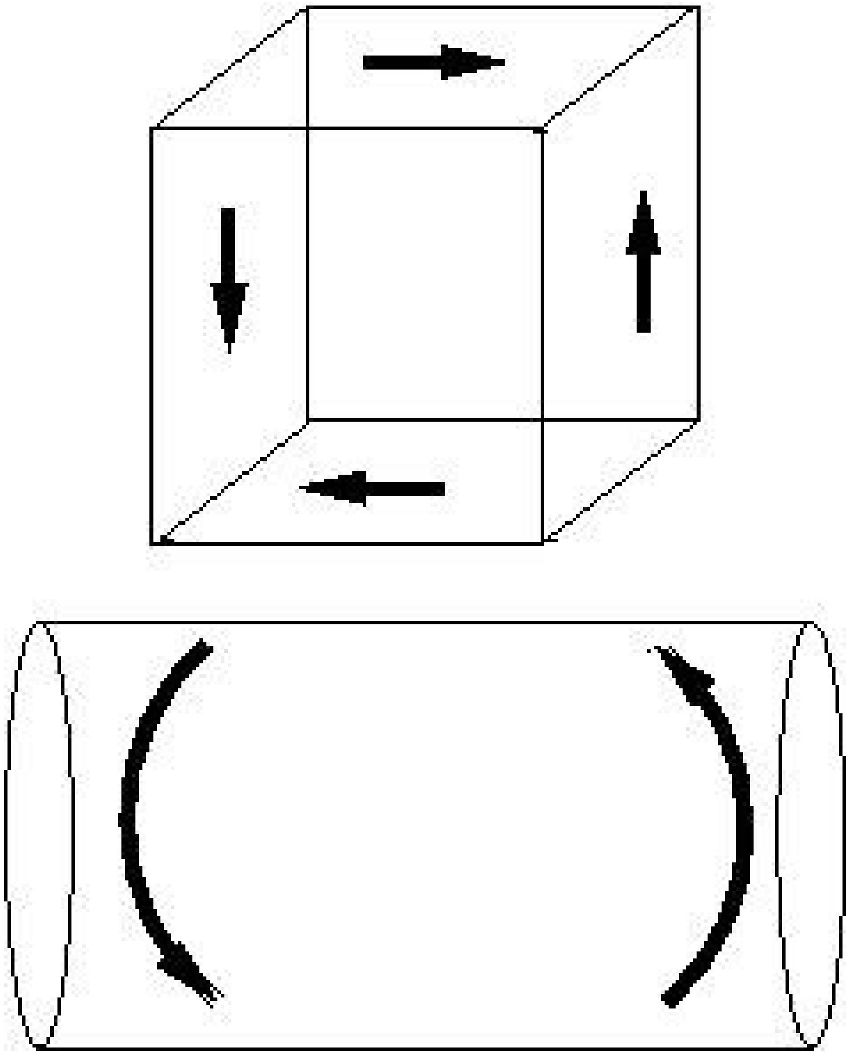
- Two new functions of shape
- Elastic section modulus – first yielding
- Plastic section modulus – full plasticity
- The measure of safety margin between initial yeild and collapse: ratio of plastic to elastic section moduli Z_p / Z_e
- It is always greater then unity!

Yielding of shafts



- Shaft with an applied torque
- Elastic deformation: angle of twist per unit length
- Failure when the maximum surface stress exceeds yeild strength

Yielding of shafts



- Note: yield strength in shear is half the tensile yield stress
- Helical springs – a special case of torsional loading
- Formulae: in the book!

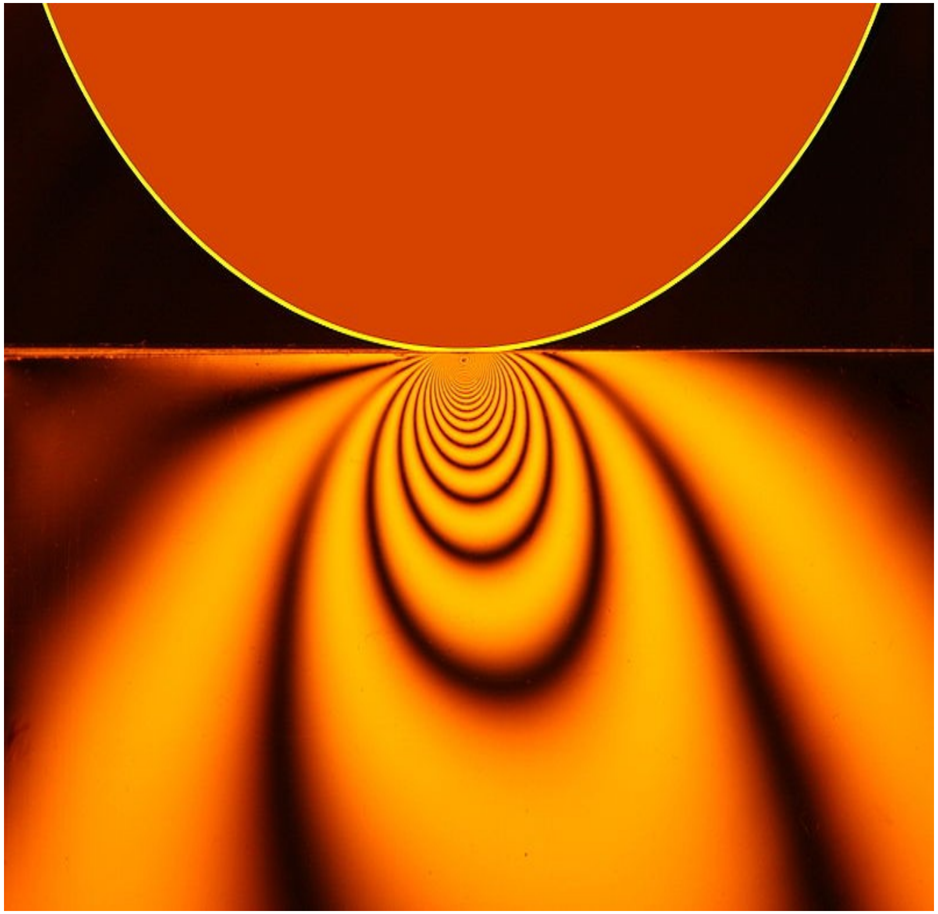
Flywheels!

- Flywheel – NASA G2
- Energy storage in rotational form
- Advanced flywheel energy storage – high strength carbon composite filaments with speeds of 20K to 50K rpms
- Image courtesy: wiki

Flywheels!

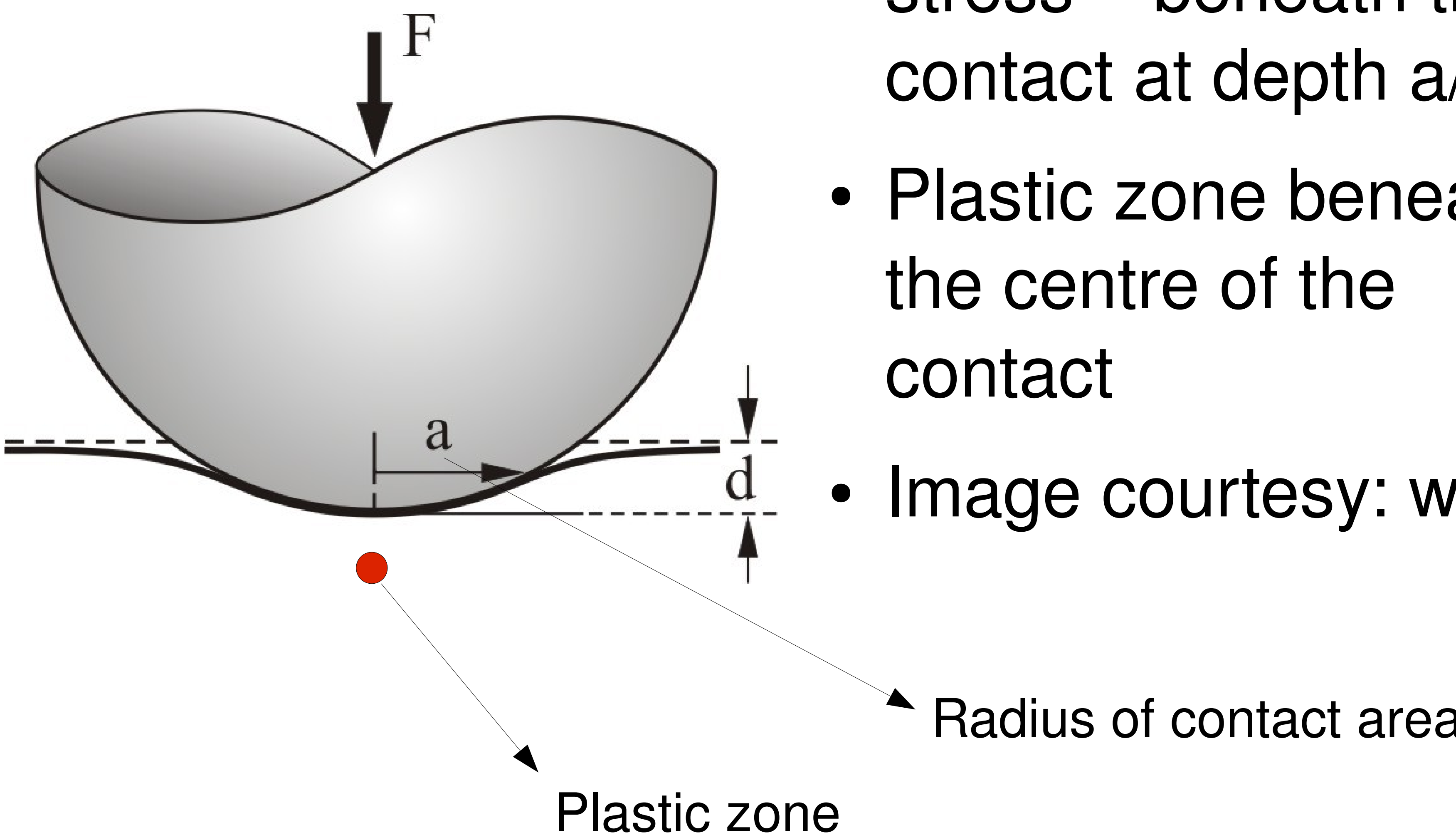
- Vacuum enclosure
- Magnetic bearings to reduce energy loss
- A very efficient and clean way of storing electricity!
- Trains, buses, ...
- Main limitation: strength!

Contact stresses



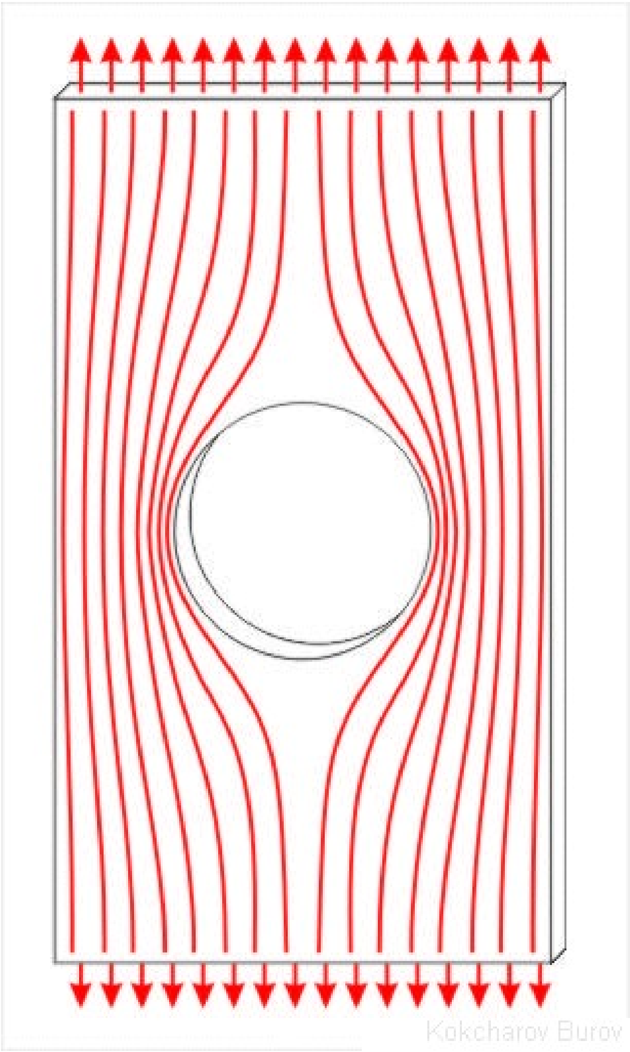
- Hertzian contact
- On loading contact areas grow
- Stress beneath the contact – first analysed by Hertz
- Failure in contact: shear stress maximum
- Image courtesy: wiki

Contact stresses



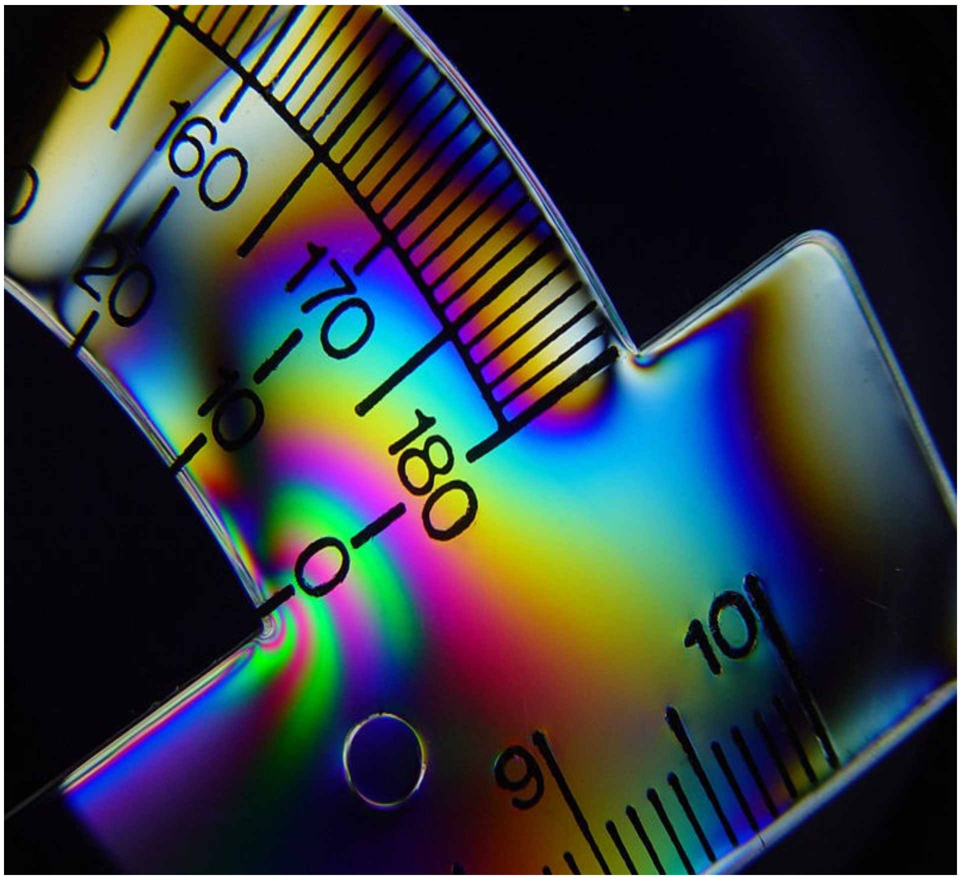
- Maximum shear stress – beneath the contact at depth a/2
- Plastic zone beneath the centre of the contact
- Image courtesy: wiki

Stress concentration



- Holes, slots, threads and changes in section concentrate stress locally!
- Why? Stress lines get bunched up!
- Image courtesy: wiki

Photoelasticty



- Tension lines in a plastic protractor under cross polarised light
- Stress concentration at the notches and corners
- Image courtesy: wiki

Stress concentration factor

$$K_{sc} = \sigma_{max} / \sigma_{nom} = 1 + \alpha (c / \rho_{sc})^{1/2}$$

- Maximum local stress σ_{max}
- Nominal stress – load divided by cross-section ignoring the features that cause stress concentration σ_{nom}
- Characteristic dimension of the stress-concentrating feature c
- Minimum radius of curvature of the stress-concentrating feature ρ_{sc}
- α: Roughly 2 for tension, ½ for torson and bending

Stress concentration factor

$$K_{sc} = \sigma_{max} / \sigma_{nom} = 1 + \alpha \left(c / \rho_{sc} \right)^{1/2}$$

How much does a circular hole concentrate stress?

How about an elliptic one?