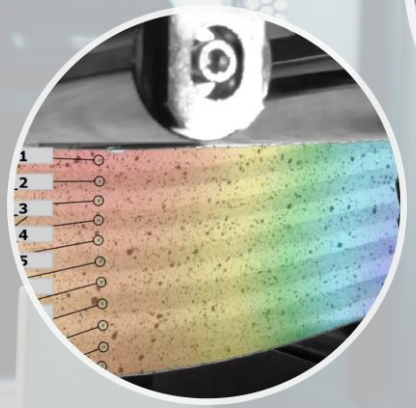
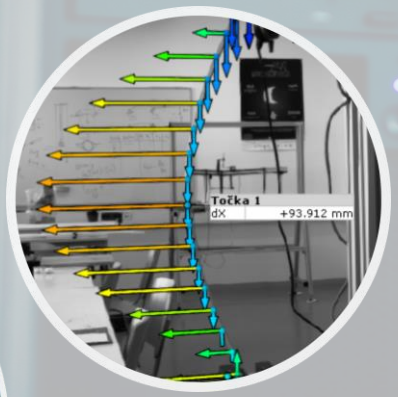
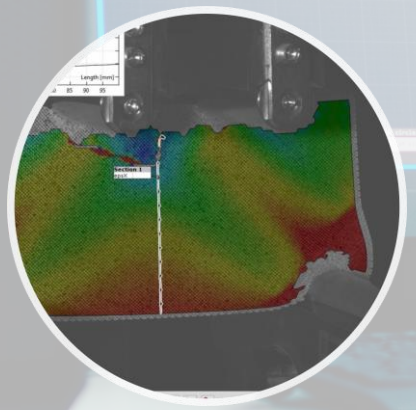
MINOR IN:

APPLIED MECHANICS

IN MODERN ENGINEERING PRACTICE







Sveučilište
u Rijeci
Građevinski
fakultet

MINOR IN:

APPLIED MECHANICS IN MODERN ENGINEERING PRACTICE

Can be enrolled as part of the Graduate study programme in **Civil Engineering** module **Structures**

4 optional courses in the 2. semester

Can be enrolled as a **life-long education programme** (available to non-students)

Carried out in **English language**

Improved **knowledge**, **skills** and **competences** + new **employment opportunities**

Certificate of an acquired minor degree in **Applied mechanics in modern engineering practice**

G F Sveučilište u Rijeci **Građevinski fakultet**

Academic graduate programme in CIVIL ENGINEERING

Module: **STRUCTURES**

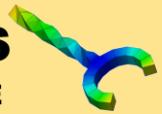
- I. Semester
- **II. Semester**
- III. Semester
- IV. Semester

Compulsory courses

- Steel Structures
- Timber Structures
- Dynamics of Structures

Optional courses

APPLIED MECHANICS
IN MODERN ENGINEERING PRACTICE



- Stability of Structures
- Plate and Shell Structures
- Energy Methods in Applied Mechanics
- Introduction to Plasticity and Damage Modeling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Assoc. Prof. **Dragan Ribarić**
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Stability of Structures

Stability of Structures

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There is practical need to analyse safety against the instabilities caused by structural geometry and internal forces combined.

The new technical discipline arises for that purpose – **stability of structures.**

Stability of Structures

Theory

The problem of the geometrical instability is expressed by unified differential equations as a result of combined kinematic and material expressions as well as equilibrium relations.

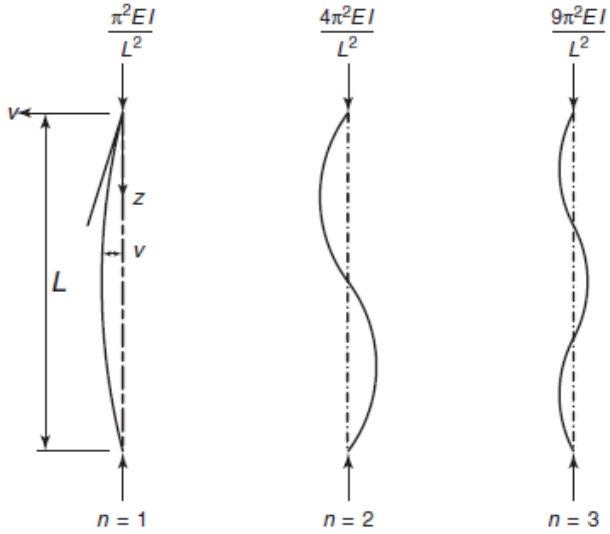
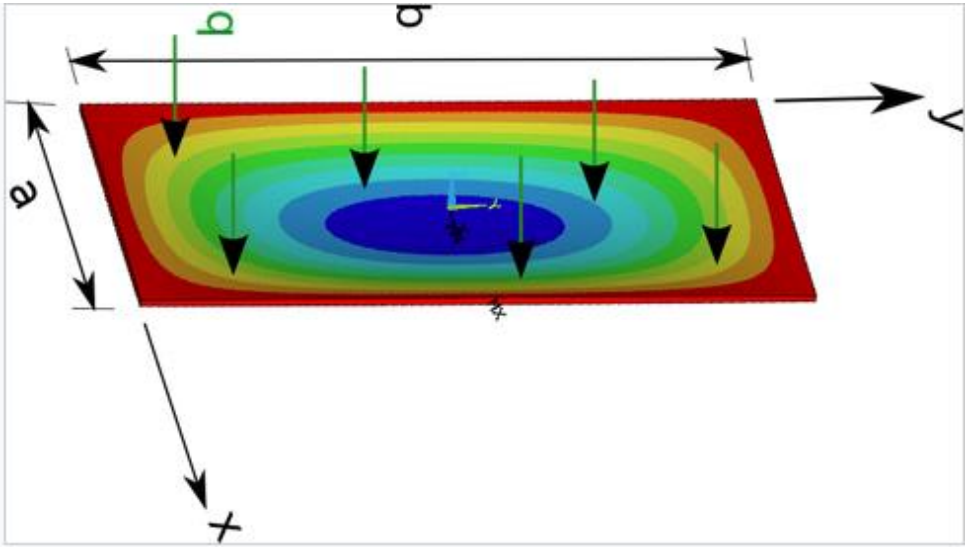


Fig. 2.5 Mode shapes of buckled column. [19]

$$\frac{d^4 w}{dx^4} + \frac{P}{EI}\frac{d^2 w}{dx^2} = \frac{q}{EI}$$



[18]

Leonhard Euler
(1707 – 1783)
mathematician

[20]

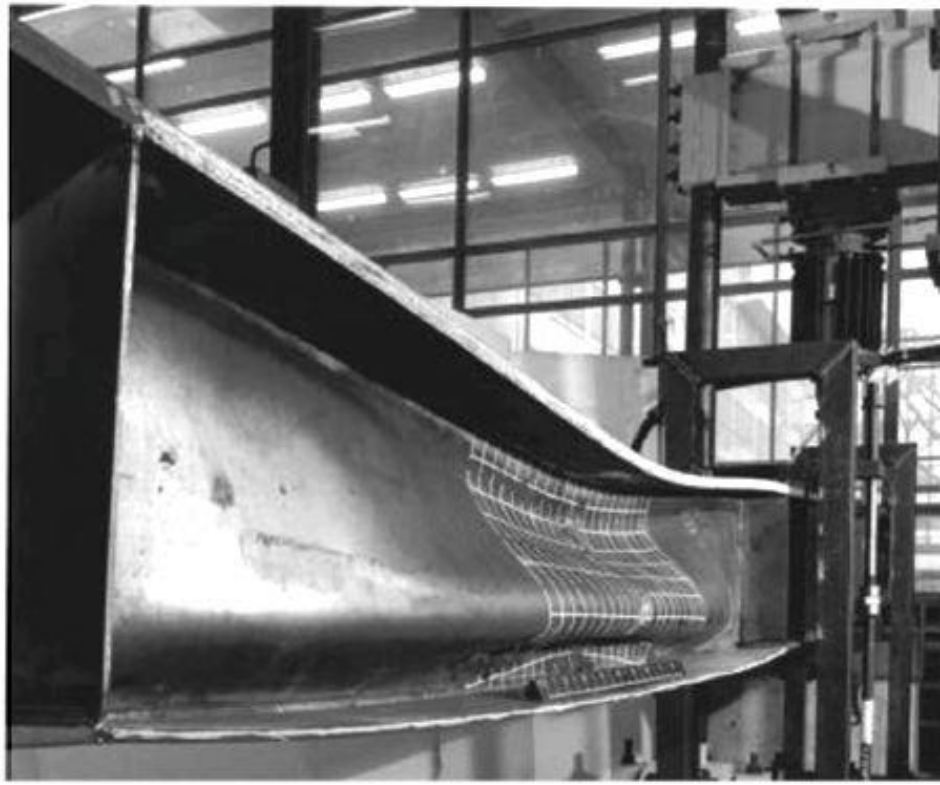
$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} + \left(\frac{n_x}{D}\frac{\partial^2 w}{\partial x^2} + 2\frac{\tau_x}{D}\frac{\partial^2 w}{\partial x \cdot \partial y} + \frac{n_y}{D}\frac{d^2 w}{dy^2}\right) = \frac{q}{D}$$

Stability of Structures

Experiments

Experimental setup models the practical problem and confirms the theoretical results.

[21]

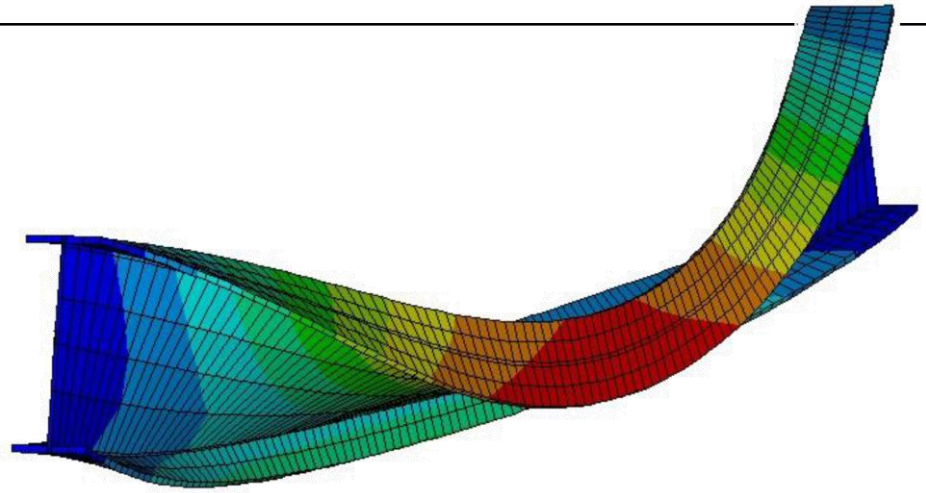


[14] **Figure 2. Vertical web buckling.**

Stability of Structures

Numerical solutions

Complex practical problems can be solved with numerical methods.
The most often used is Finite Element Method.



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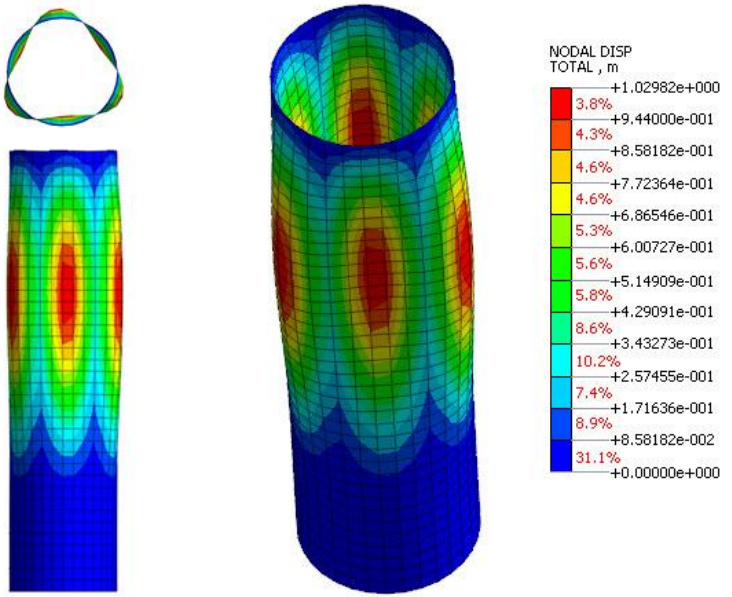

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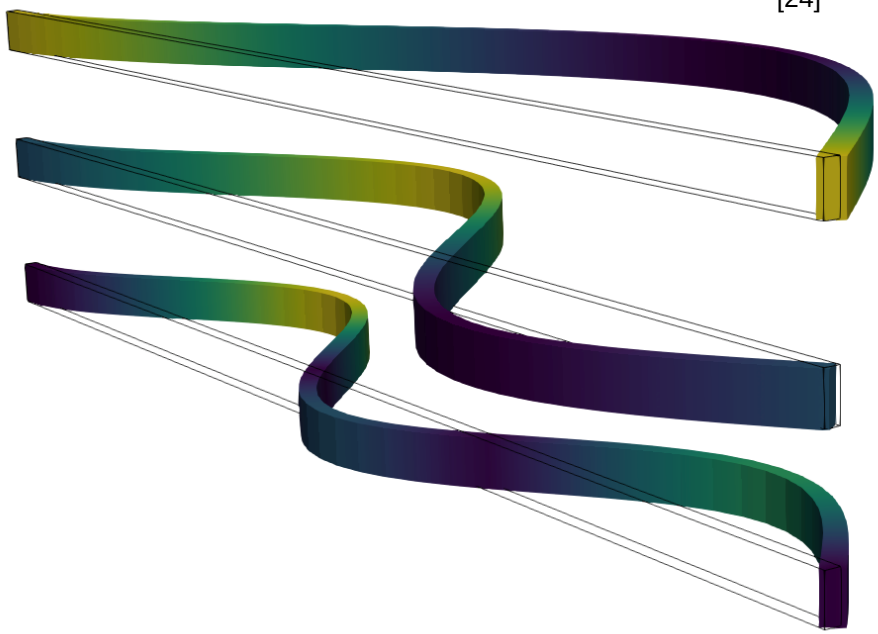

Plate and shell structures

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Asst. Prof. **Nina Čeh**
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Plate and shell structures


[26]


[27]


[60]


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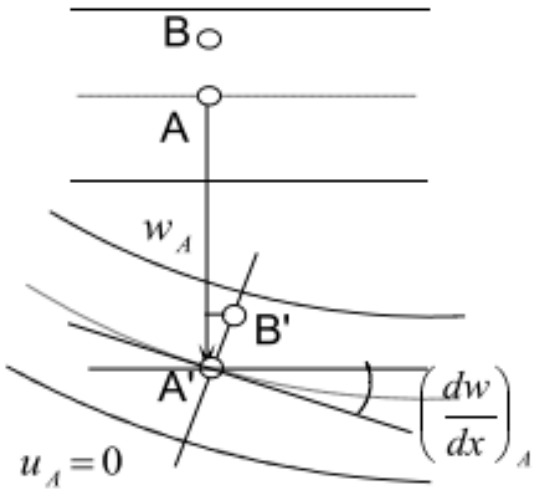
Different types of plate and shell structures in Civil Engineering: **walls, membranes, plates and shells.**

Plate and shell structures

What is the difference between **beams** and **plates**?

Beam structures

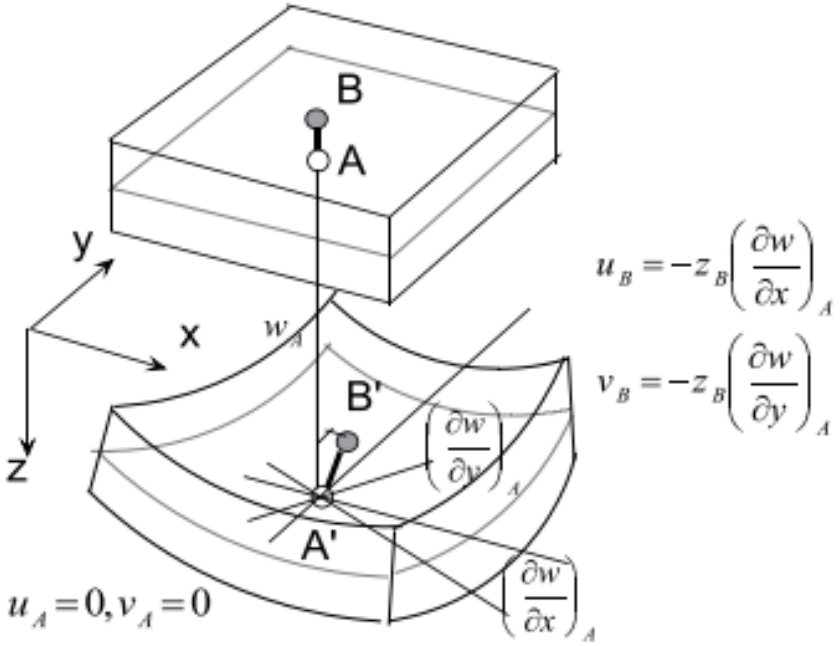


$$w_B = w_A$$

$$u_B = -z\left(\frac{dw}{dx}\right)_A$$

Displacements of all points are determined by the neutral axis displacement

Plate structures



Displacements of all points are determined by the neutral **plane** displacement

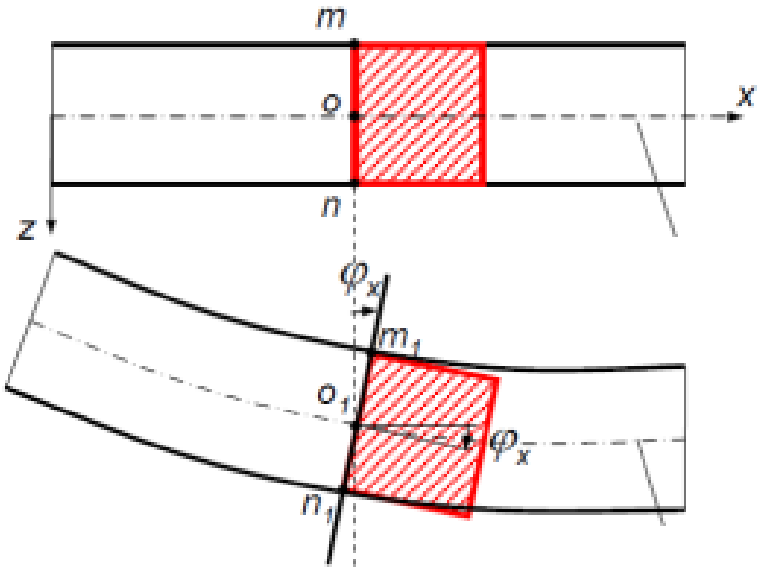
Plate and shell structures

What is the difference between **thin** and **thick plates**?

Bernouli I + II: Kirchhoff

$$\varphi_x = \frac{\partial w}{\partial x} \qquad \varphi_y = \frac{\partial w}{\partial y}$$

Shear strain is neglected



Bernouli I: Reissner-Mindlin

$$\varphi_x = \frac{\partial w}{\partial x} + \gamma_{xz} \qquad \varphi_y = \frac{\partial w}{\partial y} + \gamma_{yz}$$

Shear strain is **NOT** neglected

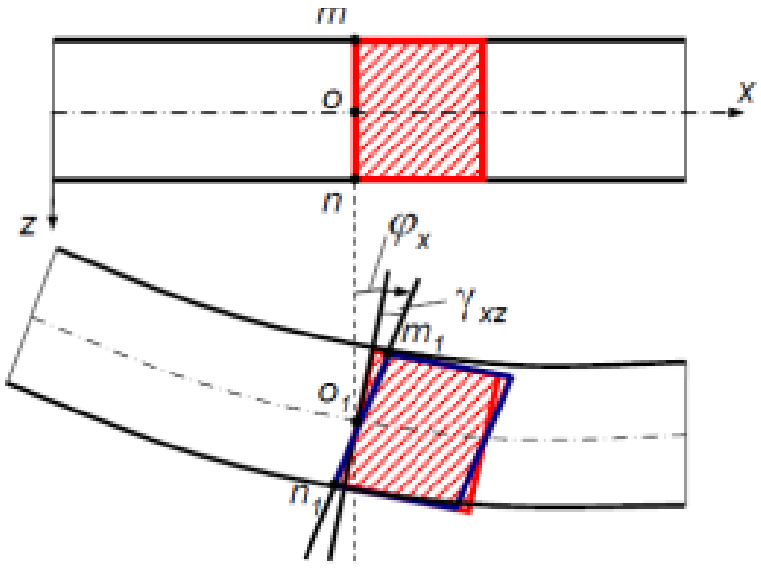


Plate and shell structures

How are **forces**, **displacements**, **strains** and **stresses** related?

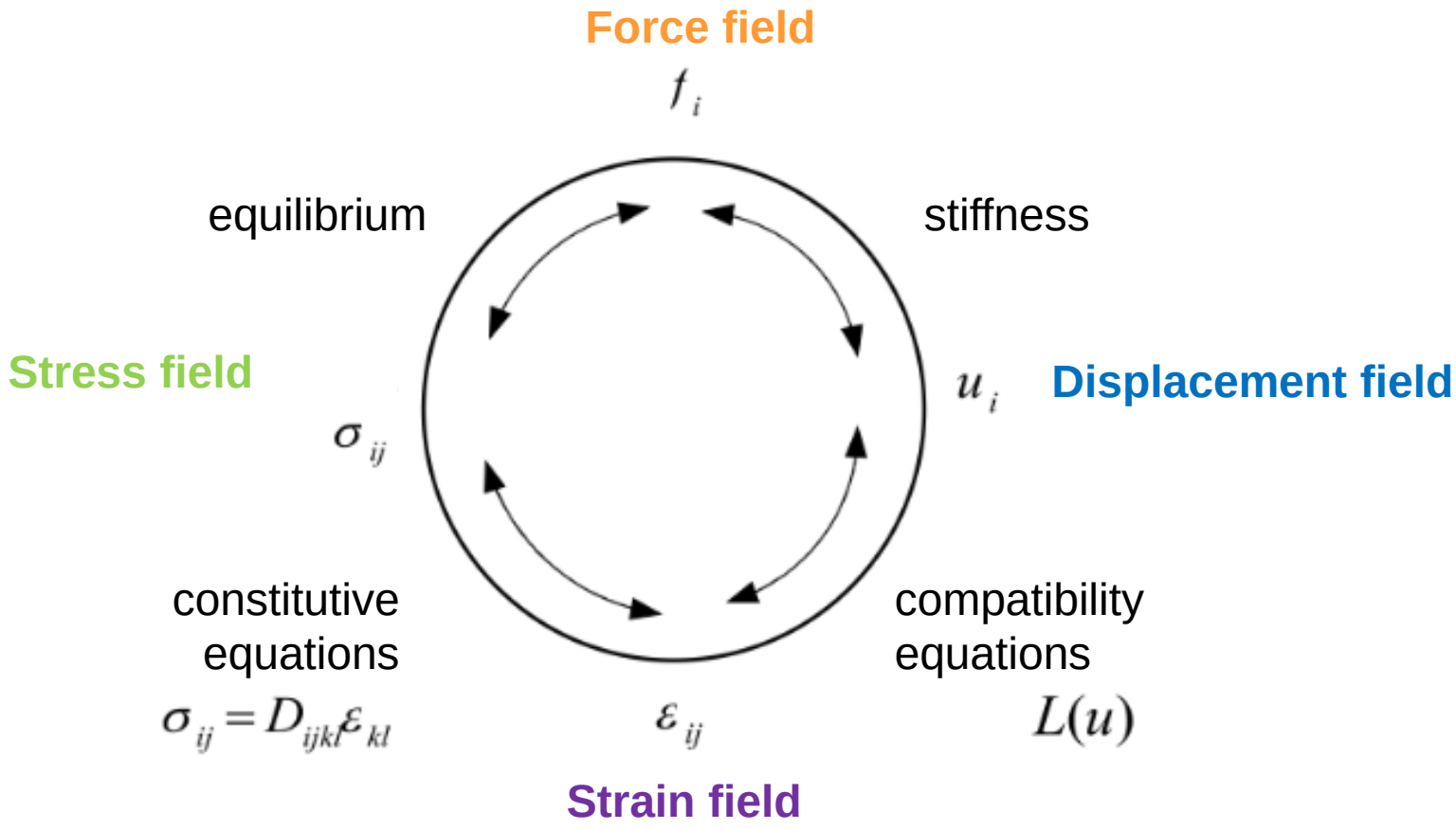
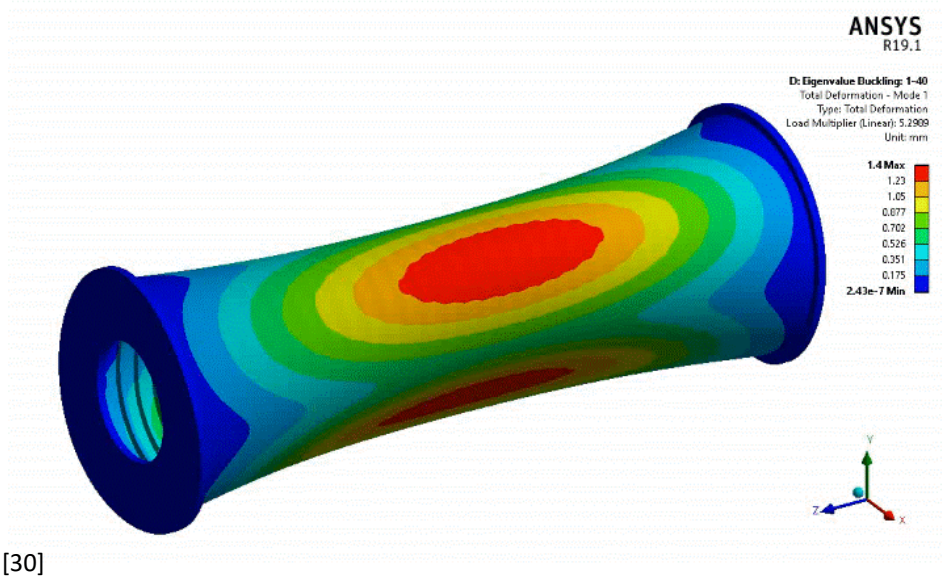


Plate and shell structures

Introduction to numerical methods for static and dynamic analysis of plate structures – **finite difference method, Rayleigh-Ritz method** and **the finite element method.**



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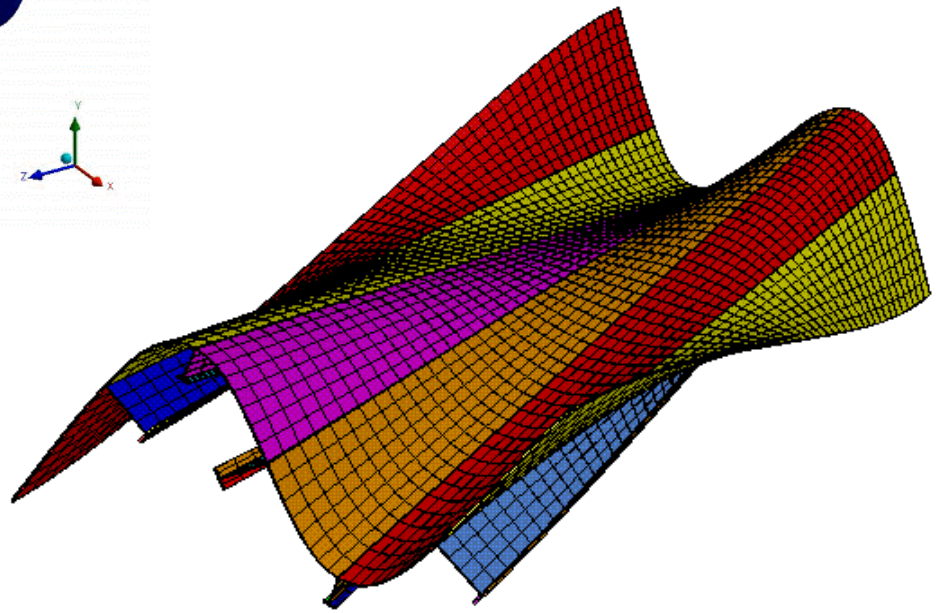

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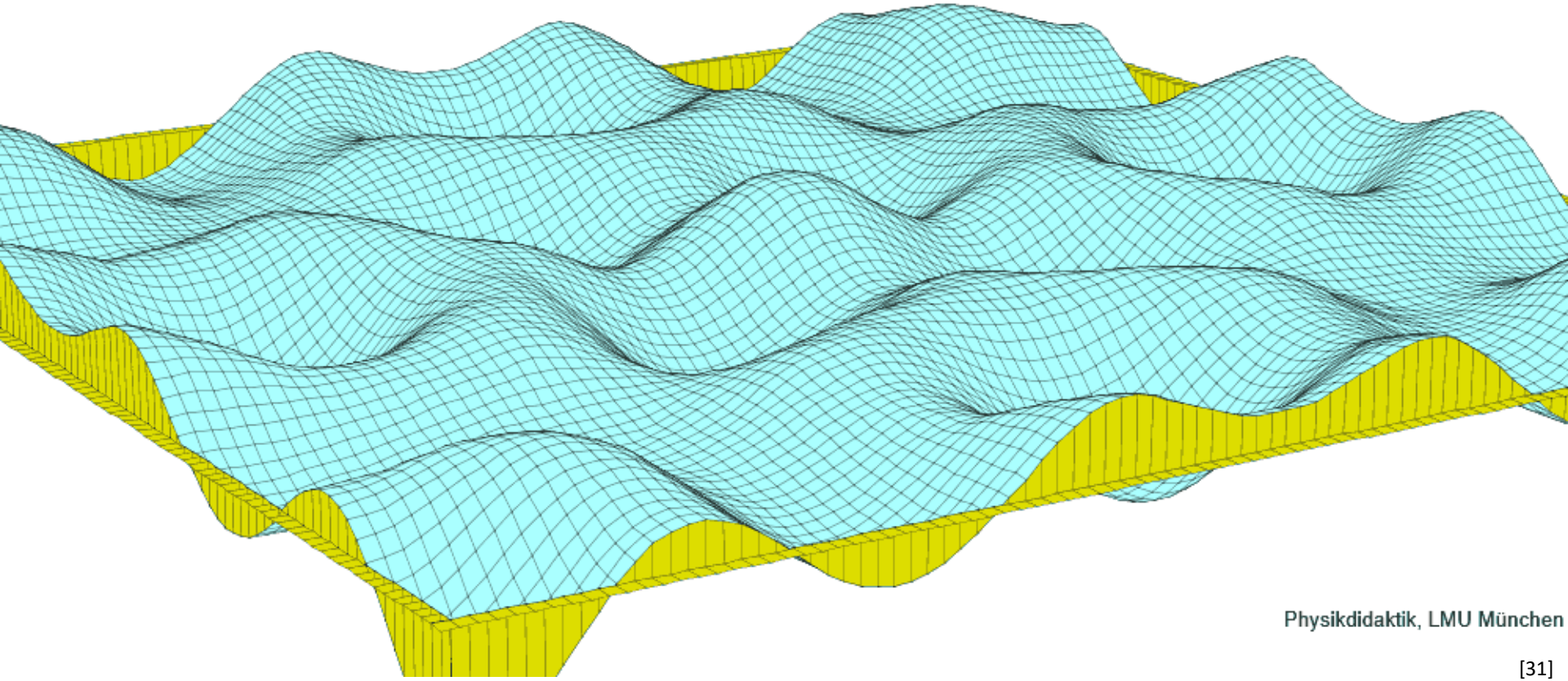
Plate and shell structures

Introduction to numerical methods for static and dynamic analysis of plate structures – **finite difference method, Rayleigh-Ritz method** and **the finite element method.**



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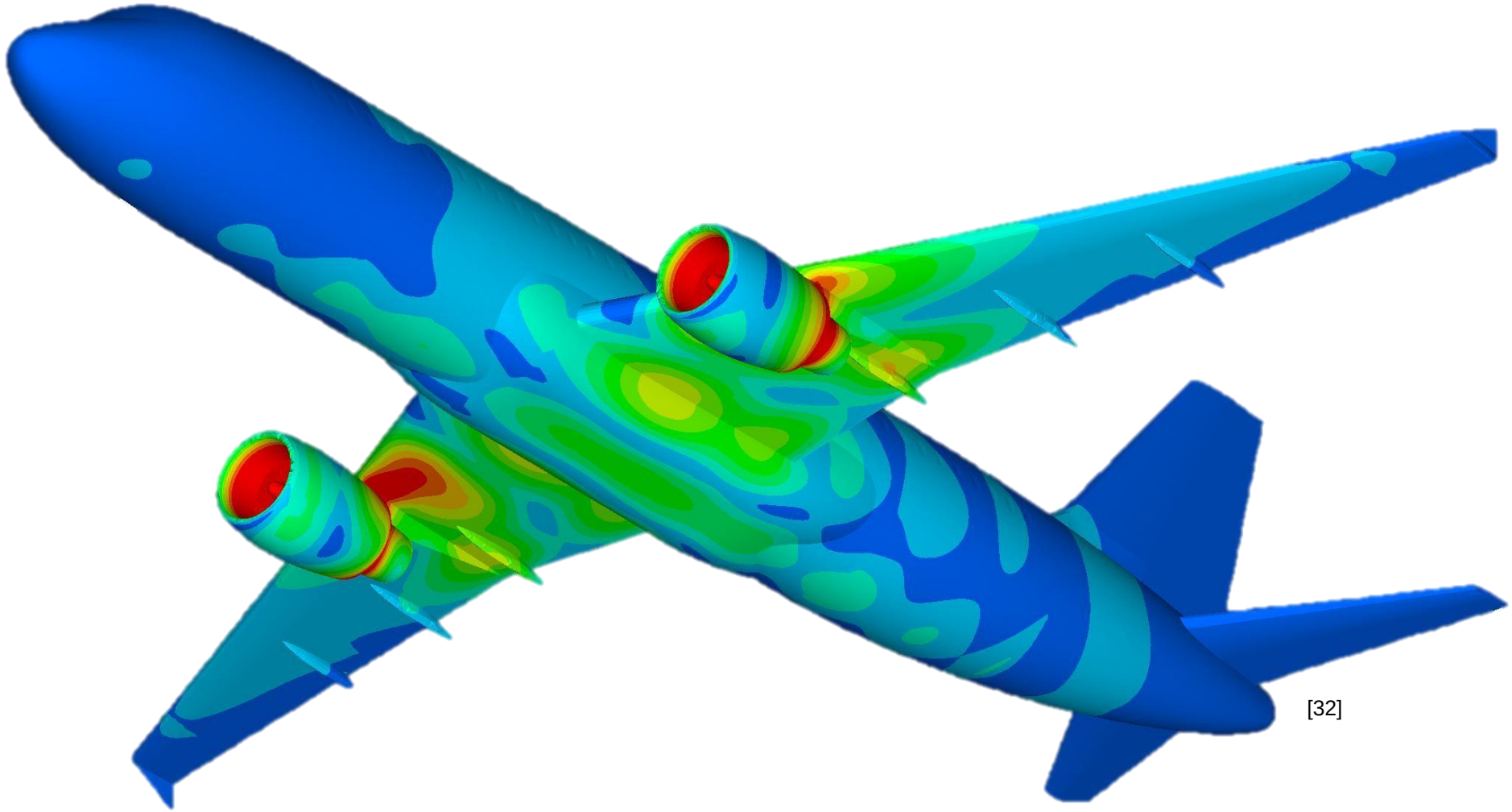
Energy Methods in Applied Mechanics



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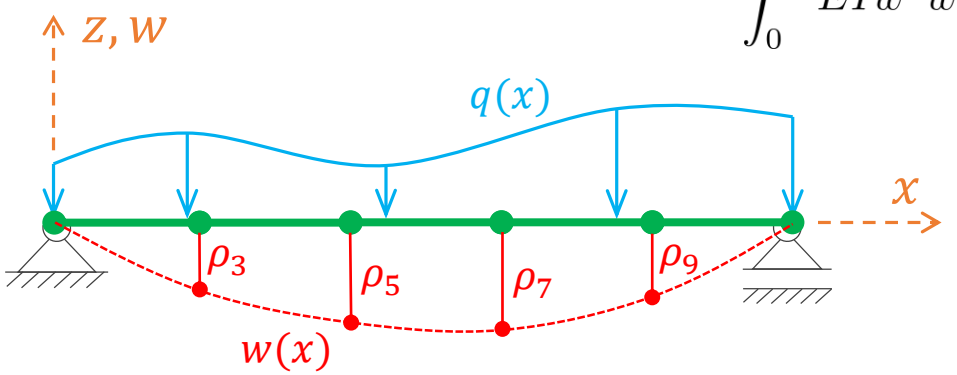
Energy Methods in Applied Mechanics

Strong form of the governing equation

$$EIw^{IV} = q$$

$$w(0) = 0$$
$$w(L) = 0$$
$$w''(0) = 0$$
$$w''(L) = 0$$



Weak form of the governing equation

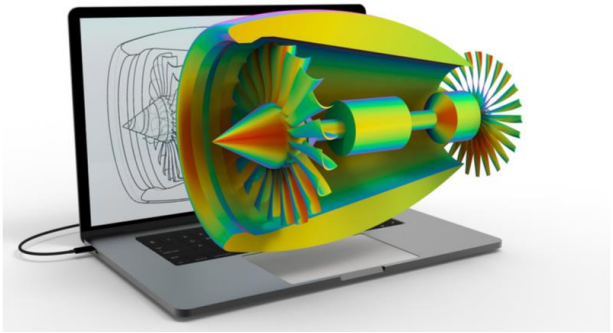
$$\int_0^L EIw''\bar{w}''\,dx - \int_0^L q\bar{w}''\,dx = 0$$

Finite element method approximation of the governing equation

$$\begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{21} & k_{22} & \cdots & k_{2n} \\ \vdots & \vdots & \ddots & \\ k_{n1} & k_{n2} & & k_{nn} \end{bmatrix} \begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_n \end{bmatrix} = \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_n \end{bmatrix}$$

$$\mathbf{K}\boldsymbol{\rho} = \mathbf{F} \rightarrow \boldsymbol{\rho} = \mathbf{K}^{-1}\mathbf{F}$$

Practical for computer implementation (Finite element method)



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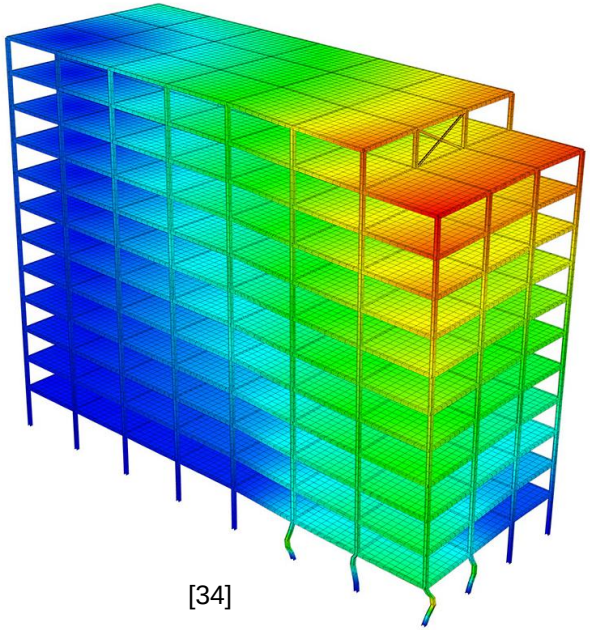
Procedures for approximate solutions satisfying the weak form will be described, with emphasis on the Finite element method

Energy Methods in Applied Mechanics



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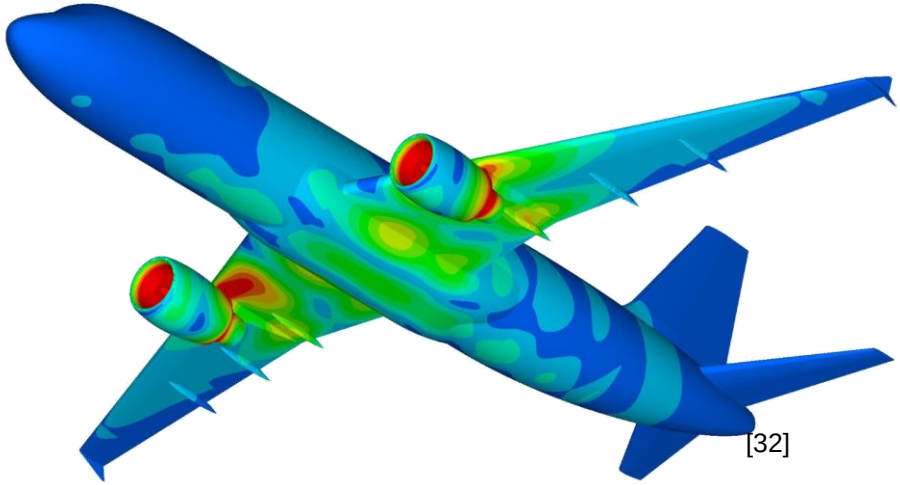

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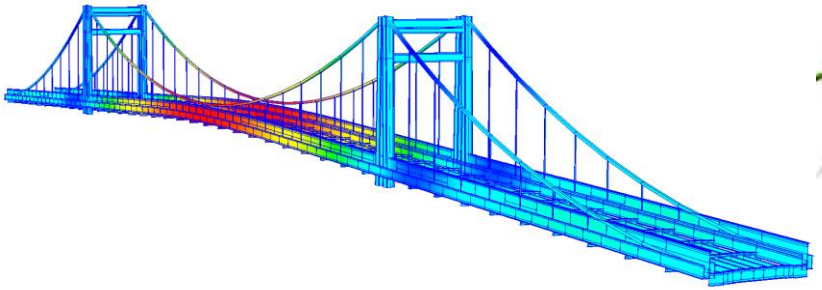

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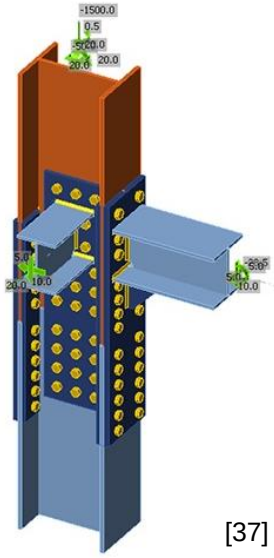
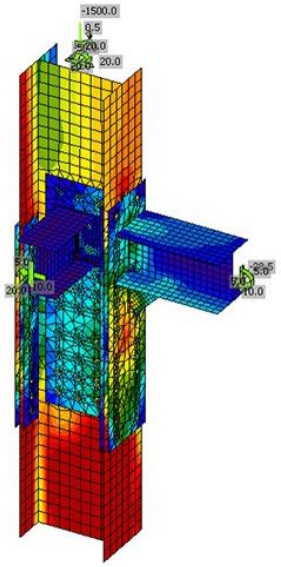
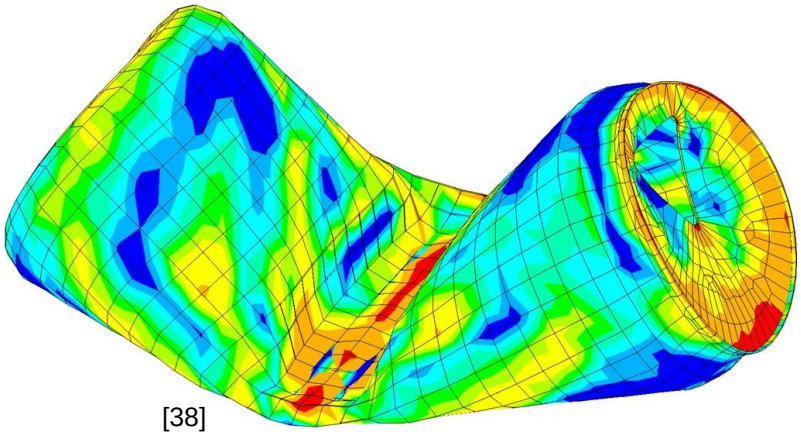




[37]

A wide variety of complex mechanical problems can be analysed with software implementing the Finite element method

Energy Methods in Applied Mechanics



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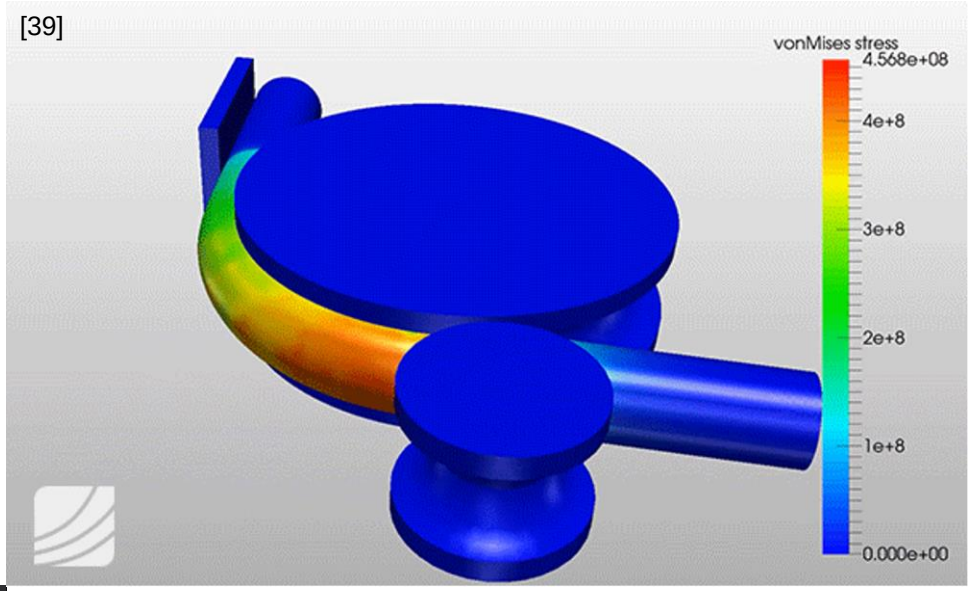

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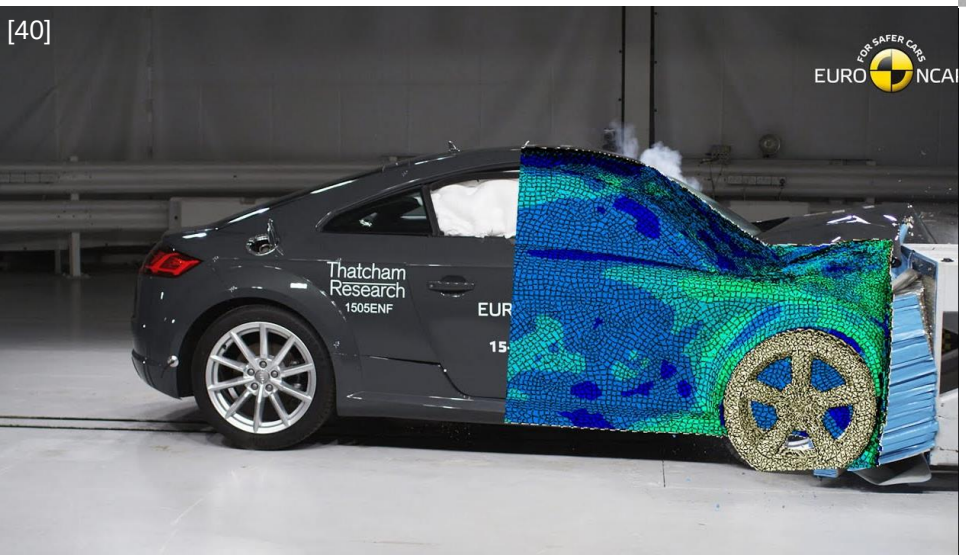

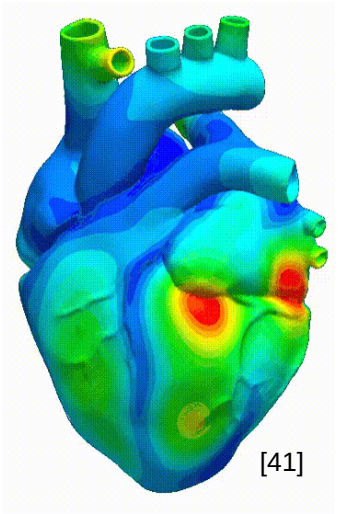

[41]

A wide variety of complex mechanical problems can be analysed with software implementing the Finite element method

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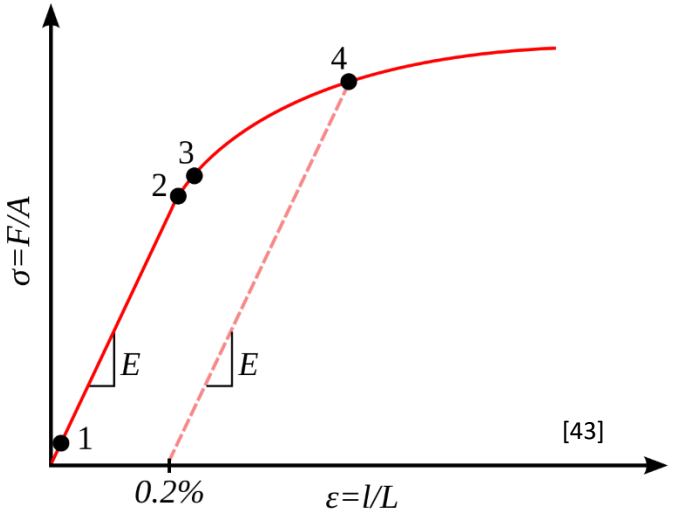
[42]

Introduction to plasticity and damage modelling

Introduction to plasticity and damage modelling

UNIAXIAL STRESS STATE

- Plastic deformations



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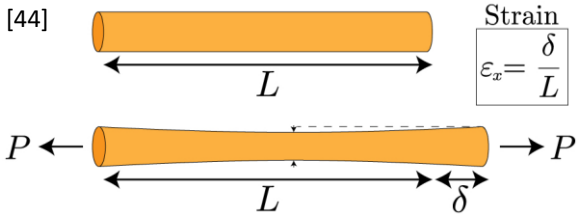

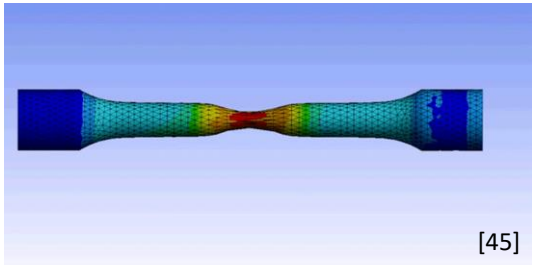

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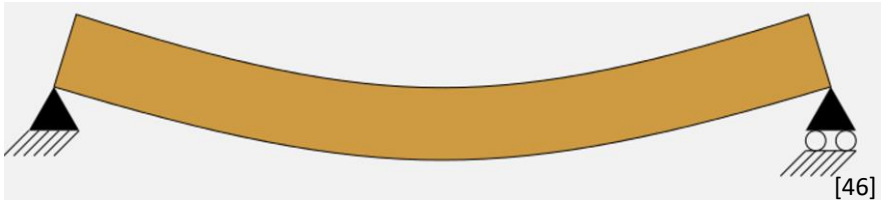
ELASTO-PLASTIC BENDING

- cross-section gradual plastification and plastic joint development



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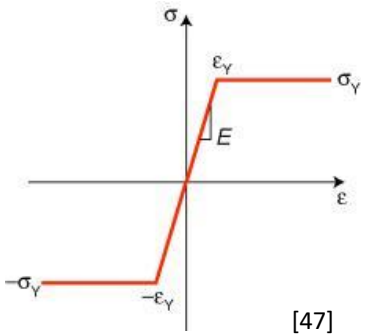

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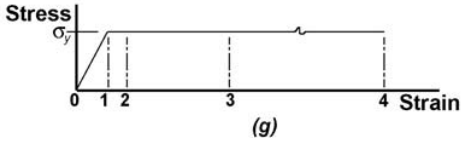
Prandtl model



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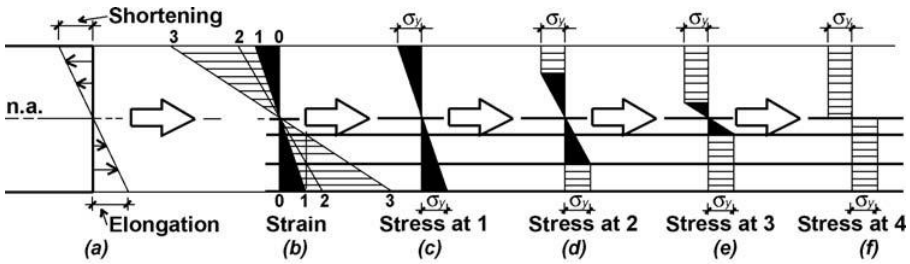
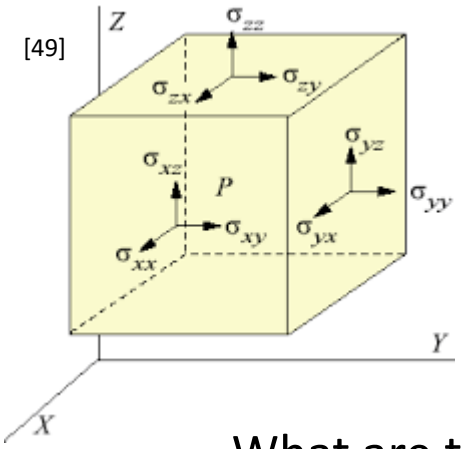
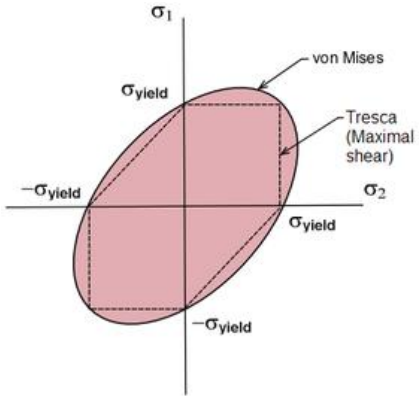


Introduction to plasticity and damage modelling

MULTI-AXIAL STRESS STATE – when does yielding/plastification occur?

[49]





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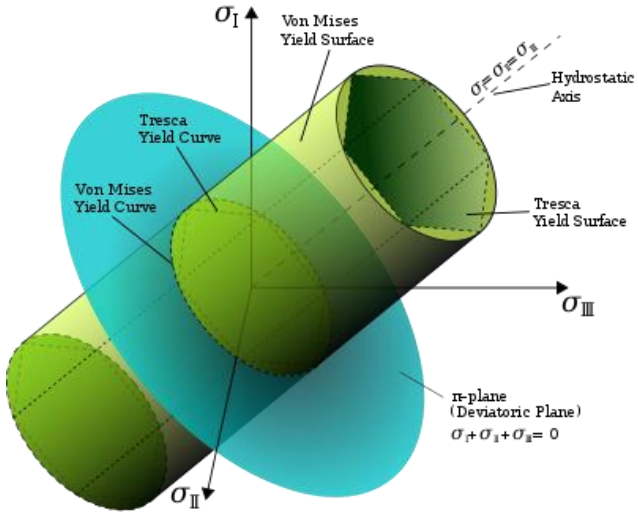
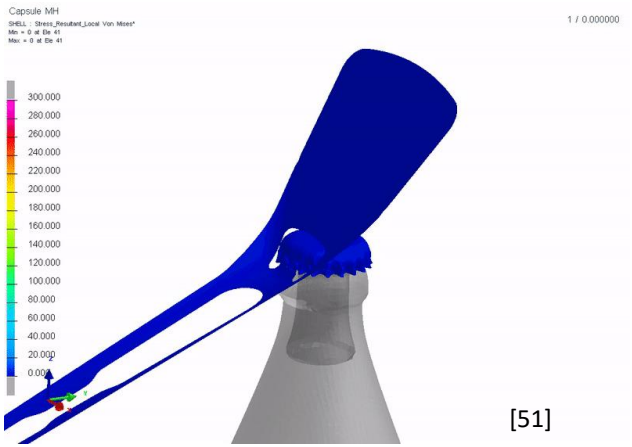


What are the yield/plastification criteria?

Application in computer simulations



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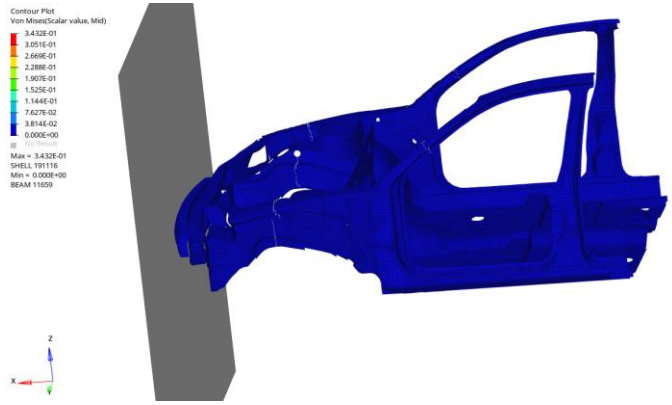
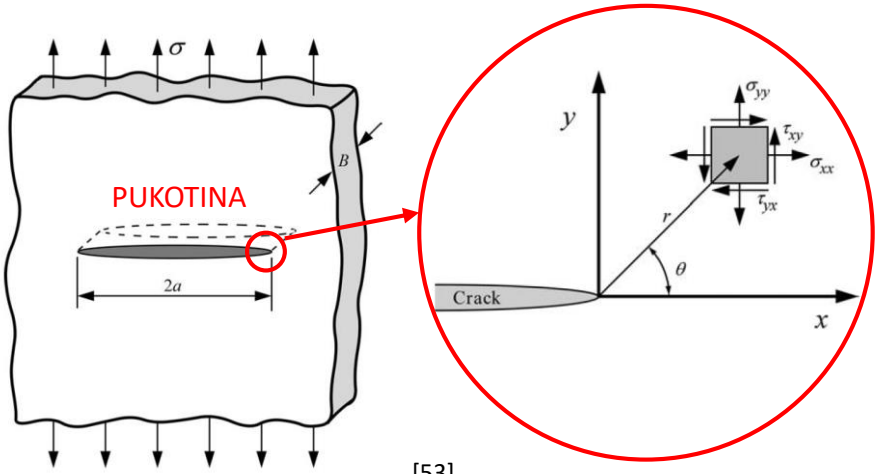


[52]

Introduction to plasticity and damage modelling

FRACTURE MECHANICS – when and why does a crack develop in a material?



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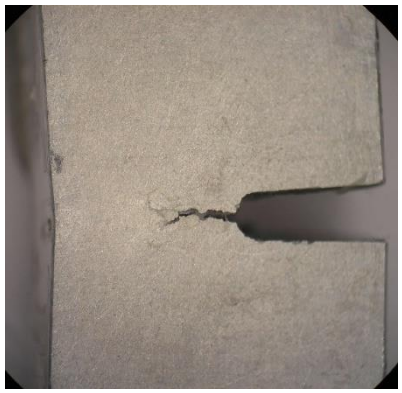

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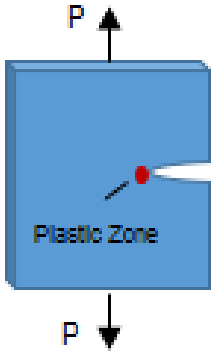

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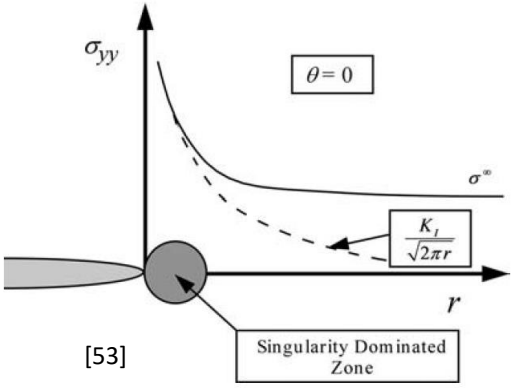
Linear elastic fracture mechanics – brittle material fracture

Ductile fracture of the material – a plastic zone (damage) forms behind the crack



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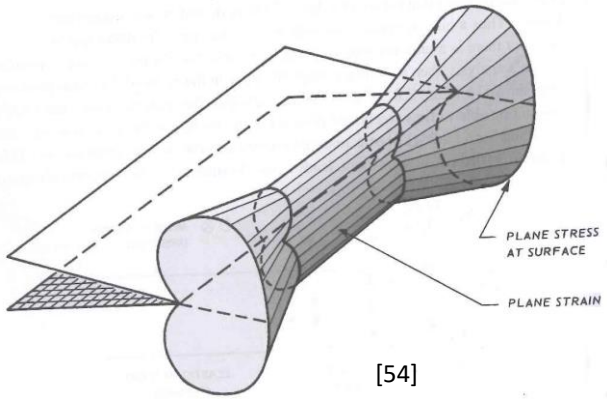
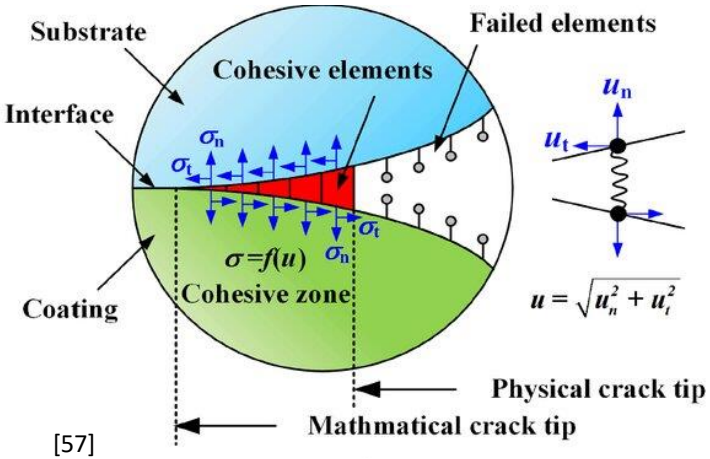


[54]

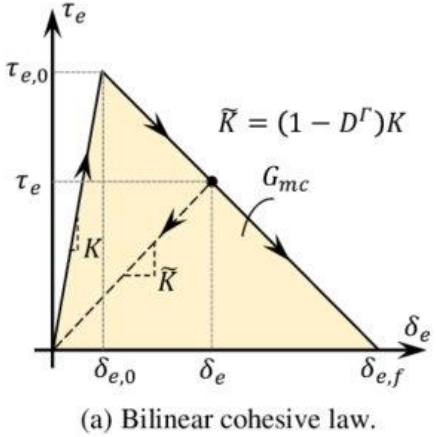
Introduction to plasticity and damage modelling

DAMAGE MECHANICS

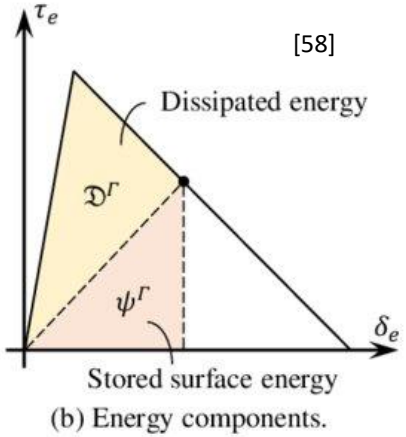
- Models of progressive damage (softening) leading to material failure



[57]



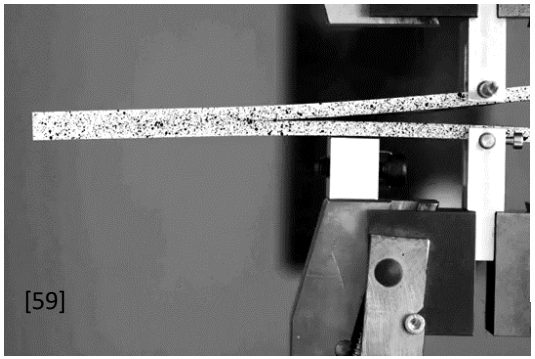
(a) Bilinear cohesive law.



[58]

(b) Energy components.

Experimental determination of parameters that describe the fracture resistance of materials



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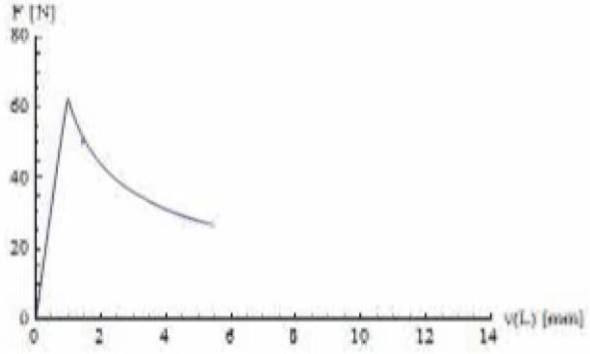

APPLIED MECHANICS
IN MODERN ENGINEERING PRACTICE

Detailed description of the courses can be found on *www.gradri.hr*:
https://gradri.uniri.hr/en/lifelong-education/

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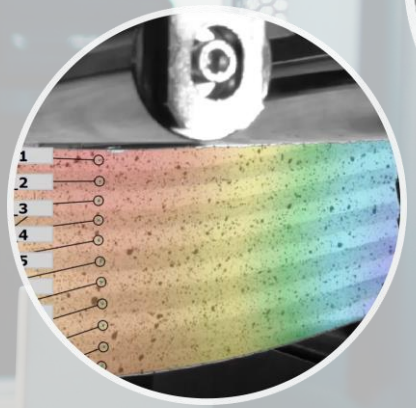
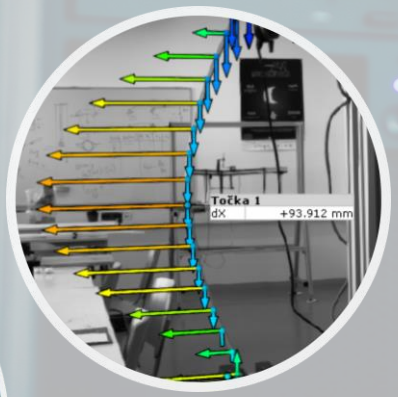
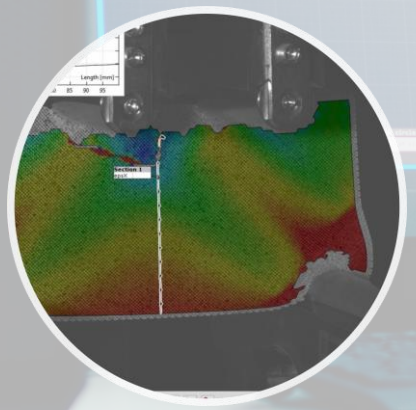
REMARK: As part of the graduate study program it is possible to choose only part of the Minor courses, but then the Minor cannot be acquired.

APPLIED MECHANICS

IN MODERN ENGINEERING PRACTICE







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References:

1. http://brookreport.com/best-colleges-for-civil-engineering-majors-2022/
2. https://veryrealandrew.com/site-visits/2019/12/16
3. https://www.utilitydesign.co.uk/blog/celebration-modern-architecture-styles/
4. https://edition.cnn.com/style/article/famous-buildings-dubai/index.html
5. https://www.grandtouringautos.com/model/rimac-nevera/
6. https://en.wikipedia.org/wiki/Differential_%28mechanical_device%29
7. https://mlrit.ac.in/wp-content/uploads/2022/03/istock-541144900_0.jpeg
8. https://www.automotiveplastics.com/automotive-plastics-today/chassis/
9. https://images.unsplash.com/photo-1559023234-1e773470544f?ixlib=rb-4.0.3&ixid=M3wxMjA3fDB8MHxzZWFyY2h8Mnx8cGxhbmUlMjB0YWtlb2ZmfGVufDB8fDB8fHww&w=1000&q=80
10. https://www.skyfilabs.com/blog/list-of-major-design-projects-for-mechanical-engineering-students
11. https://csb-scb.com/
12. https://centralgaheart.com/need-know-heart-stent/
13. https://www.perfectbracesacademy.com/uploads/products/t/l-p-91-p-24-4tnhw.png
14. https://www.pinterest.com/
15. https://www.pinterest.com/
16. https://www.pinterest.com/
17. https://www.pinterest.com/
18. https://www.pinterest.com/
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21. https://www.pinterest.com/
22. https://www.pinterest.com/
23. https://www.pinterest.com/
24. https://www.pinterest.com/
25. https://seele.com/references/strasbourg-railway-station
26. https://www.civilprojectsonline.com/tag/lotus-temple-as-a-shell-structure/
27. https://www.novilist.hr/rijeka-regija/rijeka/oporavak-stizu-prve-naznake-boljih-vremena-luka-rijeka-u-sedam-mjeseci-povecala-promet/
28. https://pdh-pro.com/course/materials-for-embankment-dams/
29. https://www.sintef.no/projectweb/isogeometric-analysis/collaborators/projects/icada/results/
30. Linear elastic buckling of ring-stiffened cylindrical shell (https://www.finglowconsultants.co.uk/2023-fcl-busy-week)
31. https://www.en.didaktik.physik.uni-muenchen.de/multimedia/waves/animations/index.html
32. https://www.stressebook.com/finite-element-analysis-in-a-nut-shell/
33. https://www.imeche.org/news/news-article/modern-finite-element-analysis-achieves-accurate-results-with-little-effort
34. https://aecmag.com/simulation/msc-software-partners-with-ingeciber-to-boost-simulation/
35. https://www.midasbridge.com/en/project-application/three-sisters-bridges
36. https://www.researchgate.net/figure/The-FE-model-of-the-studied-wind-turbine_fig5_277009482
37. https://www.h-conner.co.th/Article/Detail/151373
38. https://www.linkedin.com/pulse/shells-vs-solids-finite-element-analysis-quick-review-kuusisto-p-e-
39. https://commons.wikimedia.org/wiki/File:Bending_Analysis_of_an_Aluminium_Pipe.gif
40. https://i.ytimg.com/vi/lol15USYnDw/maxresdefault.jpg
41. https://www.cies.unsw.edu.au/scaled-boundary-finite-element-method-2a
42. https://www.foxnews.com/us/north-carolina-official-says-completely-severed-crack-roller-coaster-was-visible-days-closing
43. https://en.wikipedia.org/wiki/Plasticity_(physics)
44. https://www.bu.edu/moss/mechanics-of-materials-strain/
45. https://yasincapar.com/
46. https://benjdd.com/courses/cs110/spring-2019/pas/bridge_deflection/index.html
47. https://www.doitpoms.ac.uk/tlplib/beam_bending/plastic.php
48. https://jonochshorn.com/structuralelements/book/1.08-strength.html
49. https://www.efunda.com/formulae/solid_mechanics/mat_mechanics/stress.cfm
50. https://en.wikipedia.org/wiki/Von_Mises_yield_criterion
51. https://www.reddit.com/r/fea/comments/smm5x3/is_this_still_a_trend/
52. https://skill-lync.com/student-projects/assignment-6-frontal-crash-simulation-challenge-51
53. Ted L. Anderson, Fracture Mechanics: Fundamentals and Applications, Fourth Edition, CRC Press, 2017
54. https://pdfs.semanticscholar.org/42f2/b3e97ce3f8bcaffacd808c8209dfe6e7e0f7.pdf
55. https://www.metallurgyfordummies.com/tag/fracture-mechanics-concepts.html
56. https://mechanicalc.com/reference/fracture-mechanics
57. https://www.researchgate.net/publication/352136601_Monitoring_of_Crack_Initiation_at_CoatingSubstrate_Interface_by_Residual_Magnetic_Field_Measurement/figures?lo=1
58. https://www.researchgate.net/publication/334303096_Adaptive_Discrete-Smeared_Crack_A-DiSC_Model_for_Multi-Scale_Progressive_Damage_in_Composites/figures?lo=1
59. https://www.youtube.com/watch?v=ssy9ReoC46Y
60. https://www.birdair.com/technology/tensile-architecture/aesthetics-design/