Finite Element Method for Stress Analysis summary

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Artificial Intelligence & Information Analysis Lab

Finite Element Method (FEM) for object/force modeling

- Finite Element Method
- Strain and Stress
- Basic concept of FEM
- FEA Steps
- Pre-Processing
- Solution
- Post-Processing
- Solution and Results
- Advantages and Limitations
- Applications

Finite element Method

The ***Finite Element Method***, or FEM, is a numerical method for solving differential equations of any physical phenomena and performing ***Finite Element Analysis*** or FEA

Applications:

Structural/***Stress analysis***, Heat transfer, Electromagnetics, Fluid Flow, Acoustics, Biomechanics.

Stress Analysis

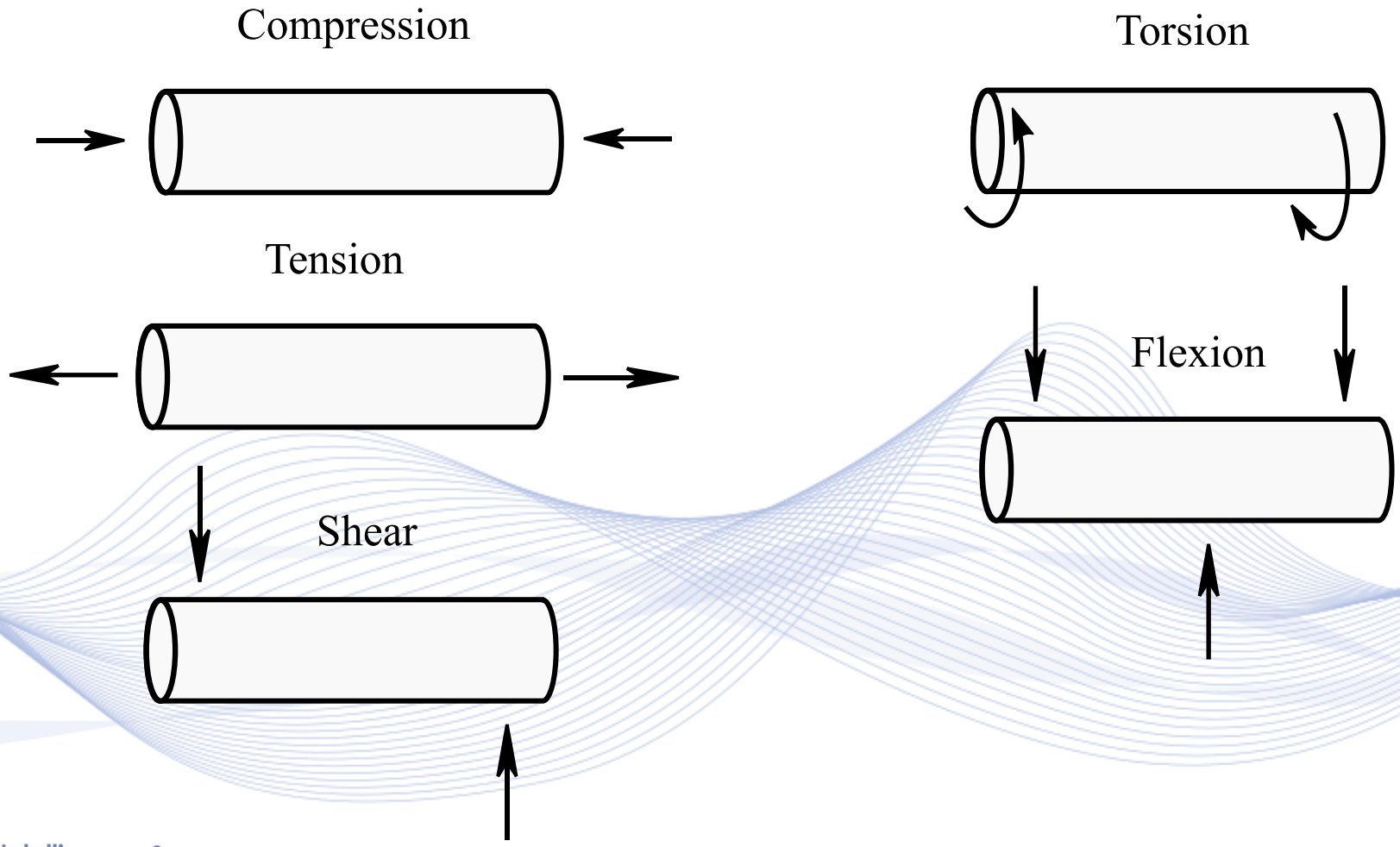
Stress analysis is used to determine the stress in materials and structures, which are subjected loads.

***Stress* (σ)** is a force per unit area applied to an object:

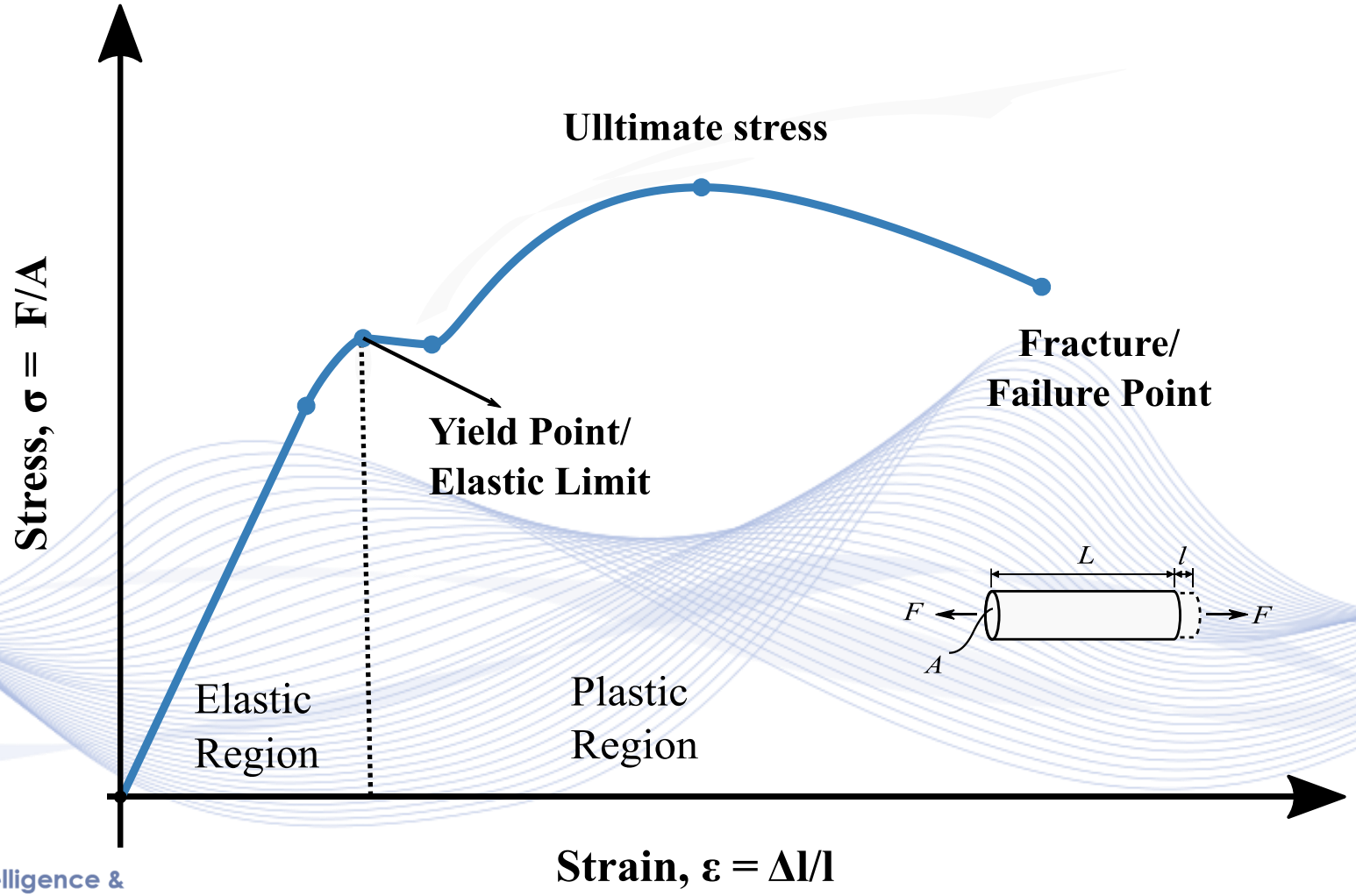
$$\sigma = \frac{Force}{Area}$$

Object's particles undergo a displacement compared to their unstressed arrangement. The normalized measure of this deformation called ***Strain* (ε)**.

Type of Stress

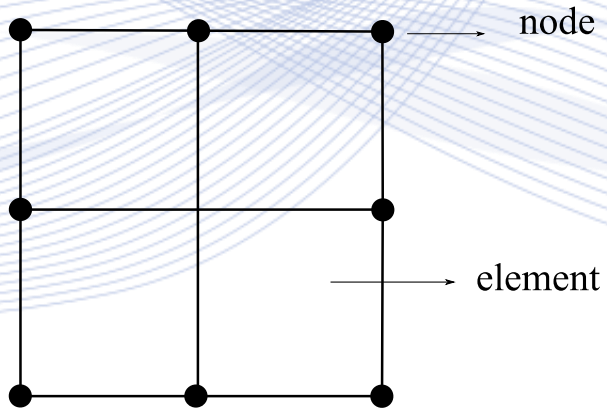


Strain-Stress curve (2)



Basic Concept of FEM (1)

- The FEM divides the domain into (finite) elements, connected by nodes.
- The governing equation is approximated by the method of ***Weighted Residuals*** (Galerkin's Method, Least Square Method) or ***variational method*** (Rayleigh-Ritz Method).
- The result is interpolated for the entire domain.



Basic concept of FEM (2)

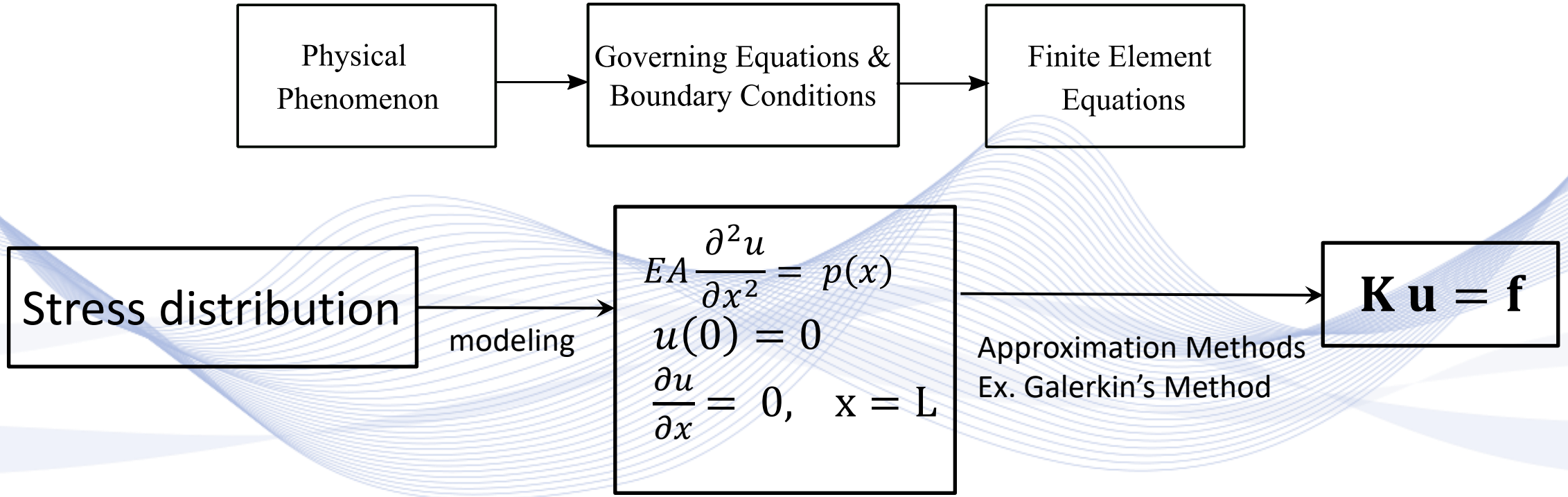
The ***strong form*** of system equations consists the set of governing partial difference equations (PDE's) with boundary conditions.

The ***weak form*** is preferred for obtaining an approximated solution and offers the finite element equations.

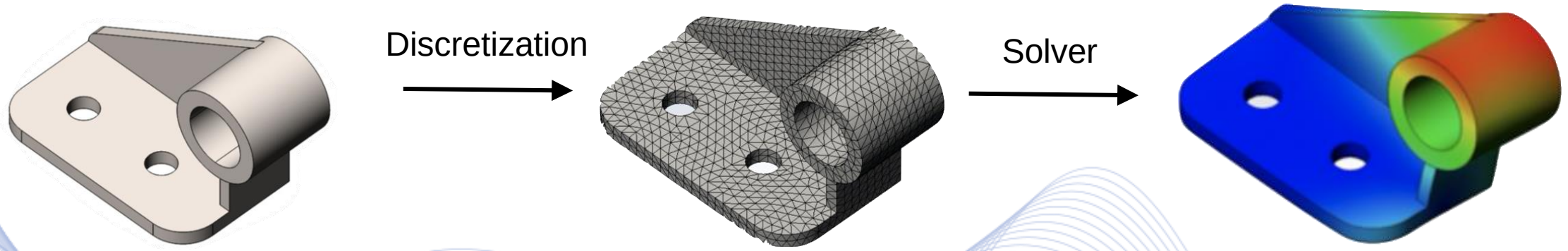
For example, ***Galerkin's method*** choose a finite-dimensional approximation to the solution, by choosing finite basis functions.

Development of FE equations

The development of finite element equations:



FEA Steps(5)

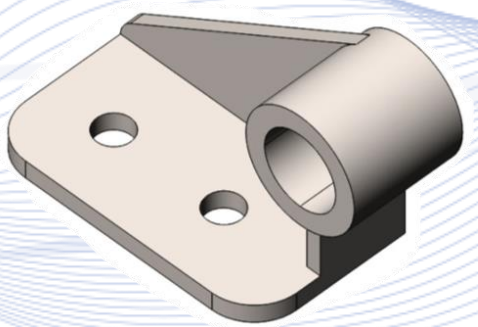

Discretization
Solver
CAD model
FEA model
FEA results
1.Pre-Processing
2.Solution
3.Post-Processing

Meshing(1)

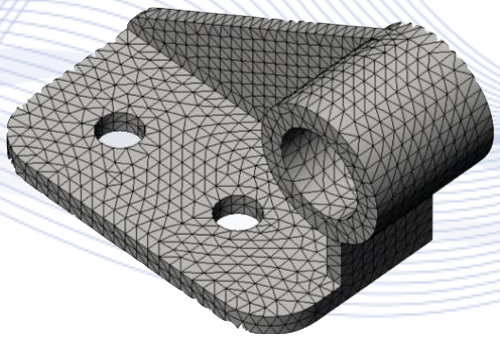
The numerical methods, such as FEM, follow discrete methods.

A principal step of pre-processing is the meshing procedure, which affects the results accuracy from a FEA model.

Meshing is discretization of a continuous system.



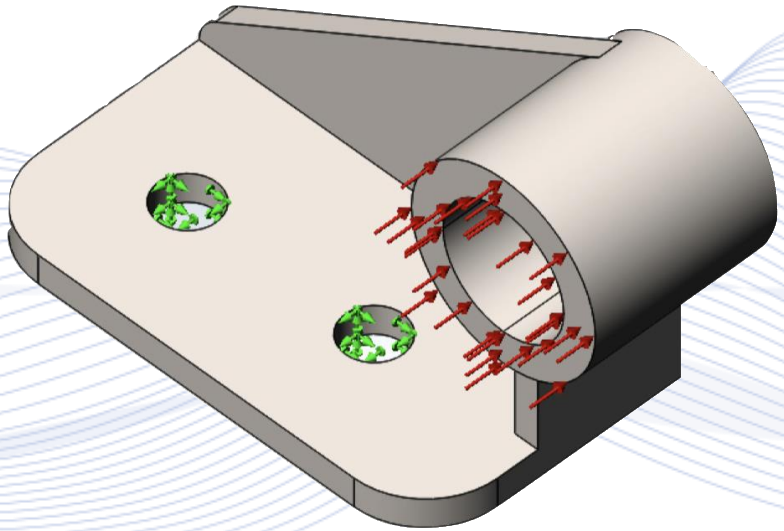
Continuous domain



Discretized domain

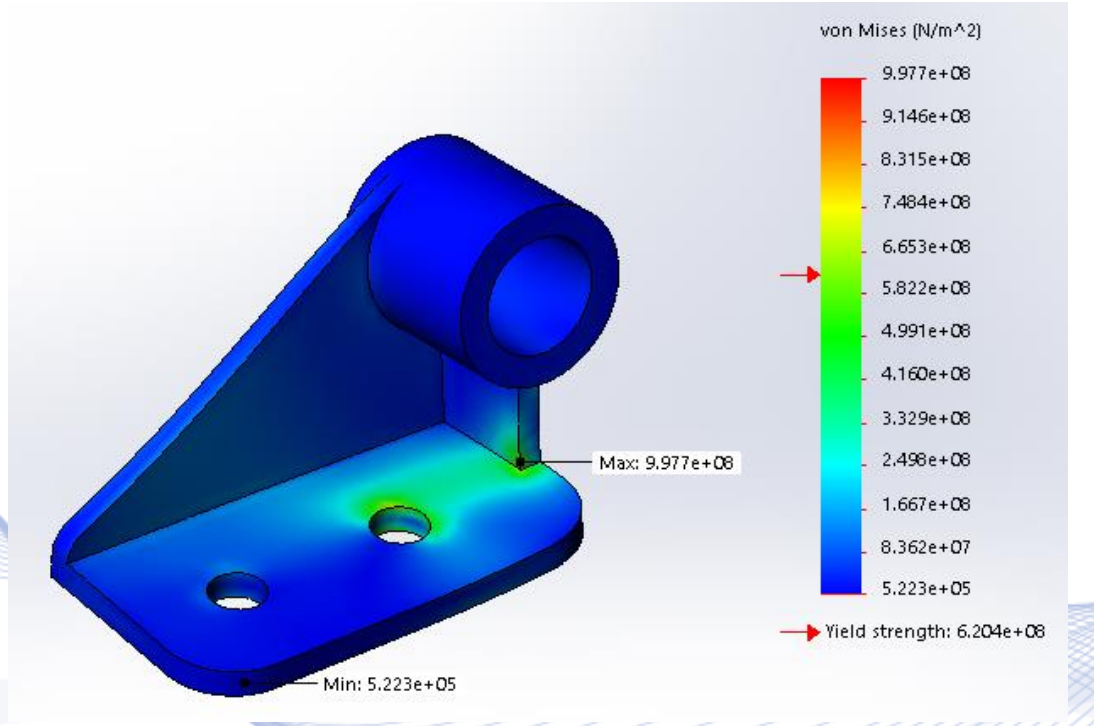
Load Application

Apply force as: concentrated or distributed load, force on line, pressure and vacuum, blending moments and torque, hydrostatic, temperature, gravity loading etc

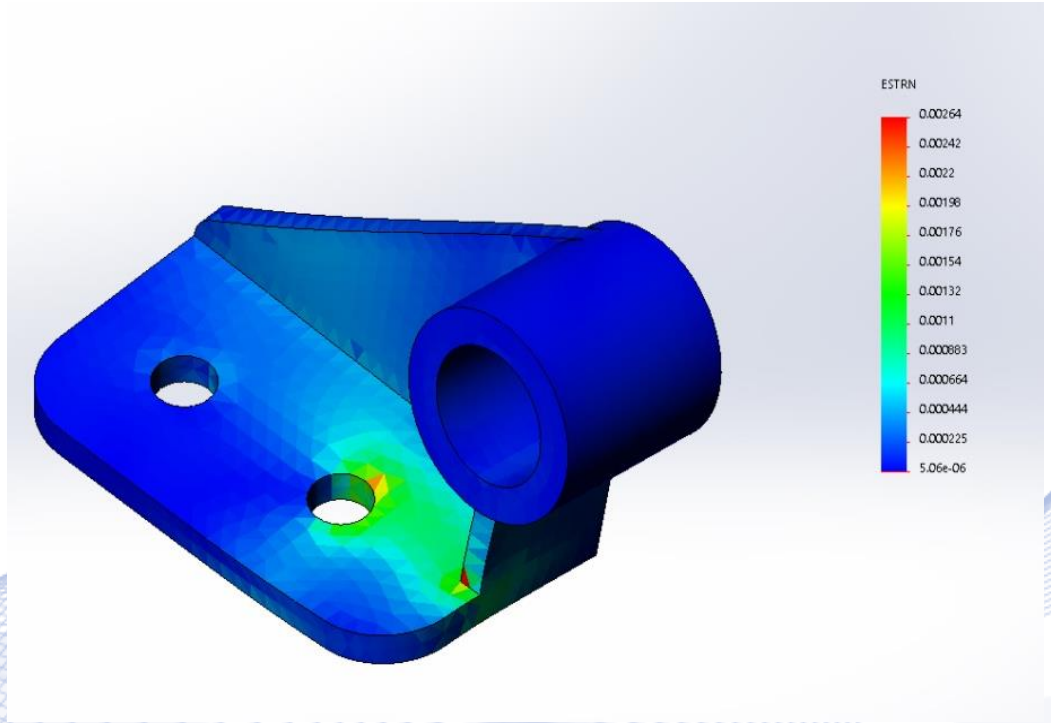


Boundary conditions: Forces (red) and constraints (green).

Post-Processing Results

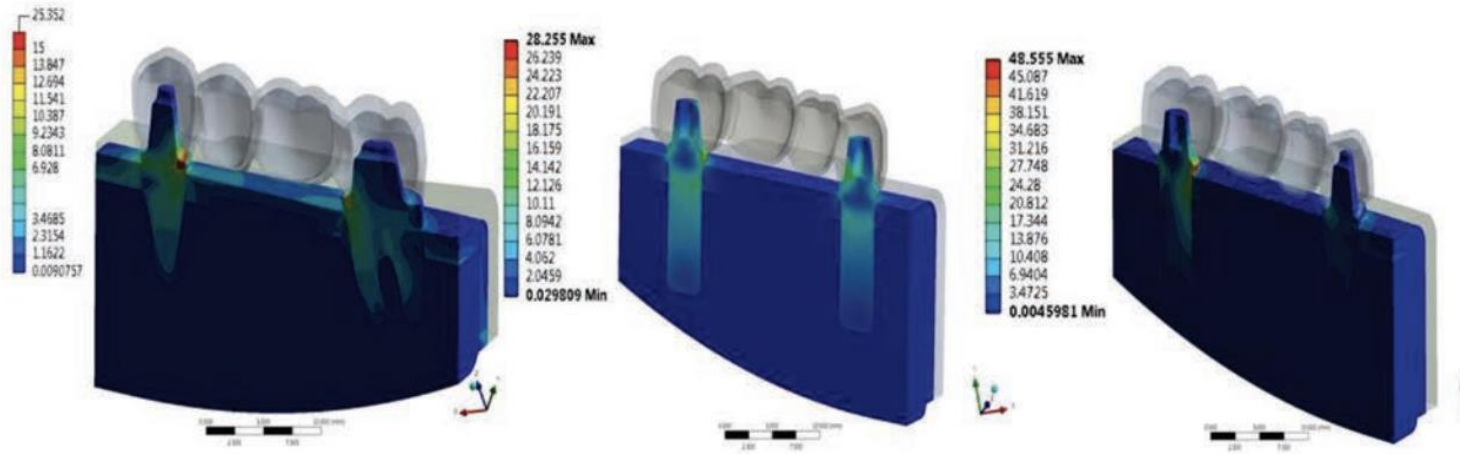


Von Misses stress

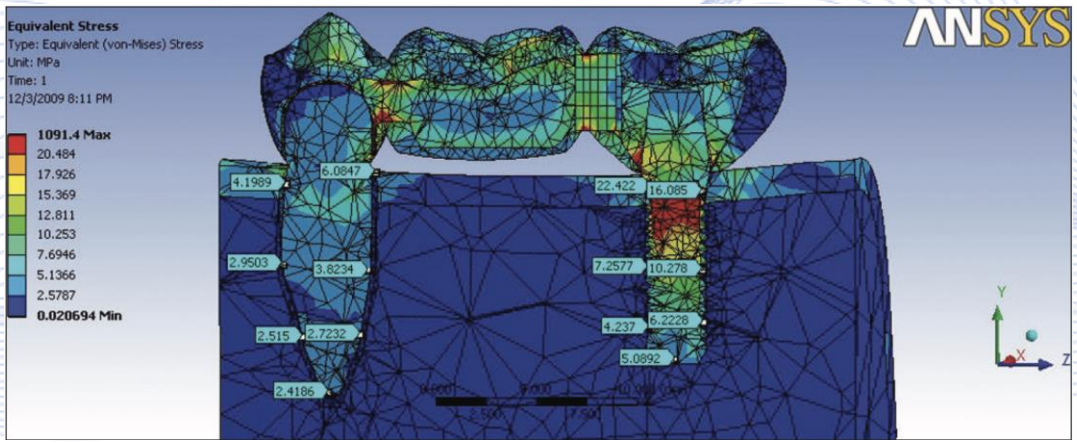


Equivalent Strain

Dental Implant Application



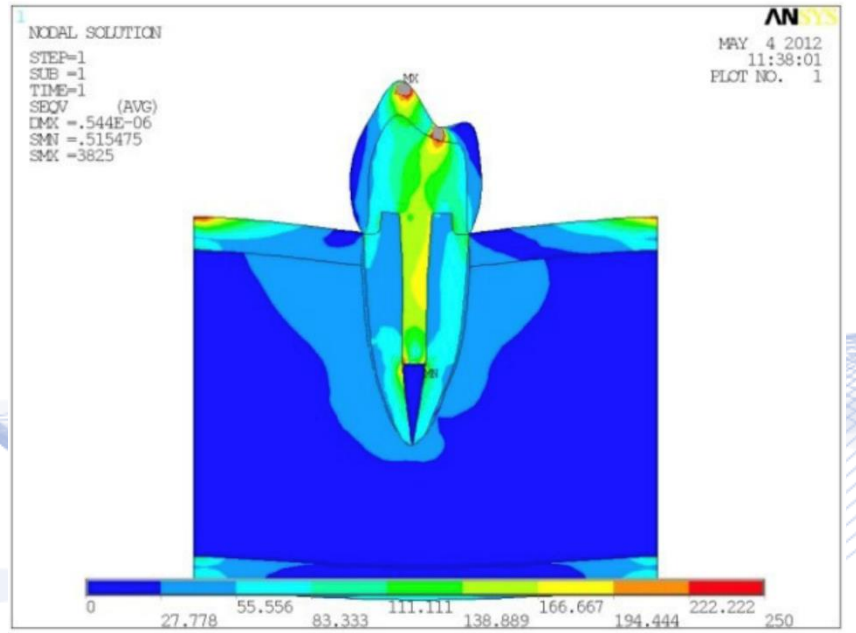
Tooth-tooth, implant-implant and tooth-implant supporting dentures. [GRB2017]



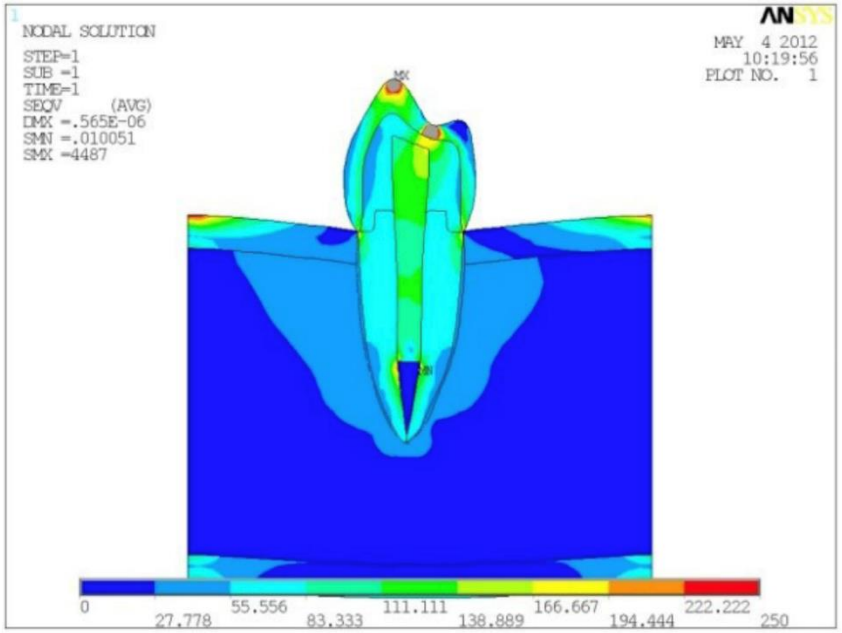
Implant structure stress concentration. [KUM2011]

Endodontic

Endodontic structures stress distribution analysis: The internal stresses of mandibular premolar using cast metal core are higher than using glass fiber post, when axial load applied.

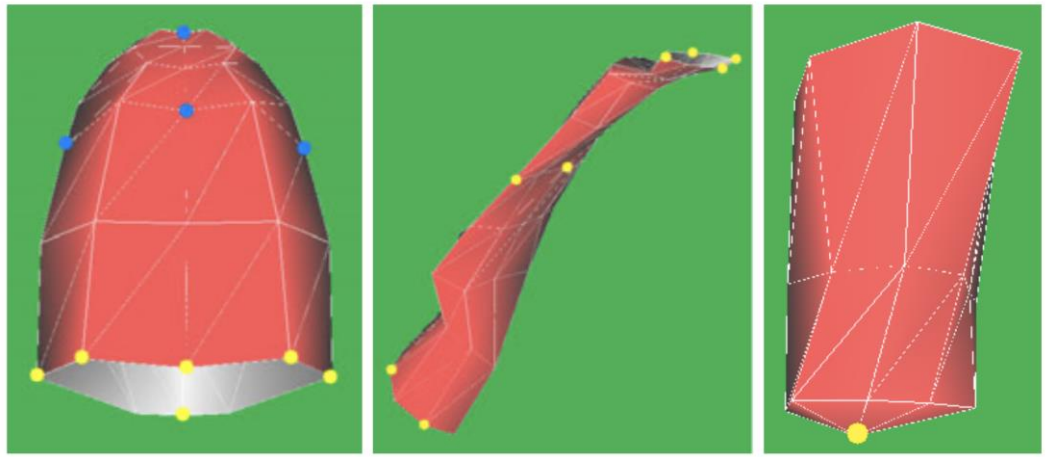


Metal core [NEG2017]

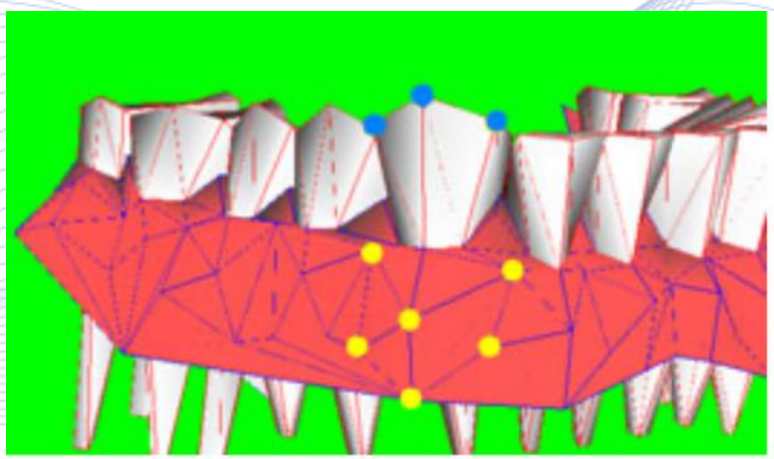


Glass fiber post [NEG2017]

Other Applications



[MOS2011]

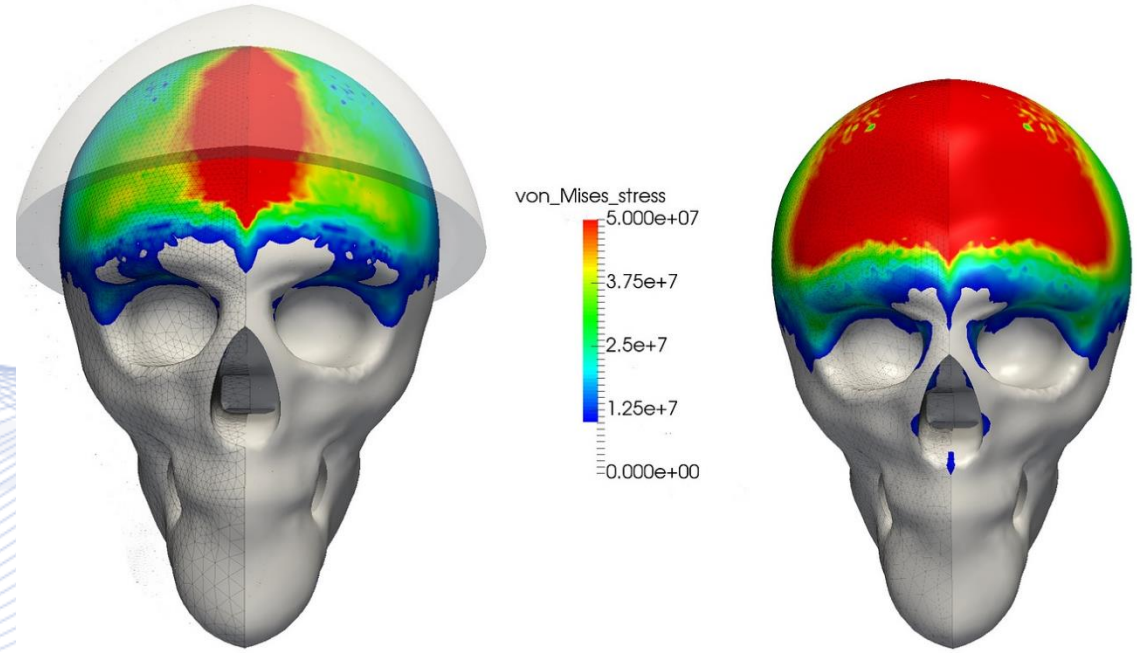


[MOS2011]

Skull with and without Helmet(1)

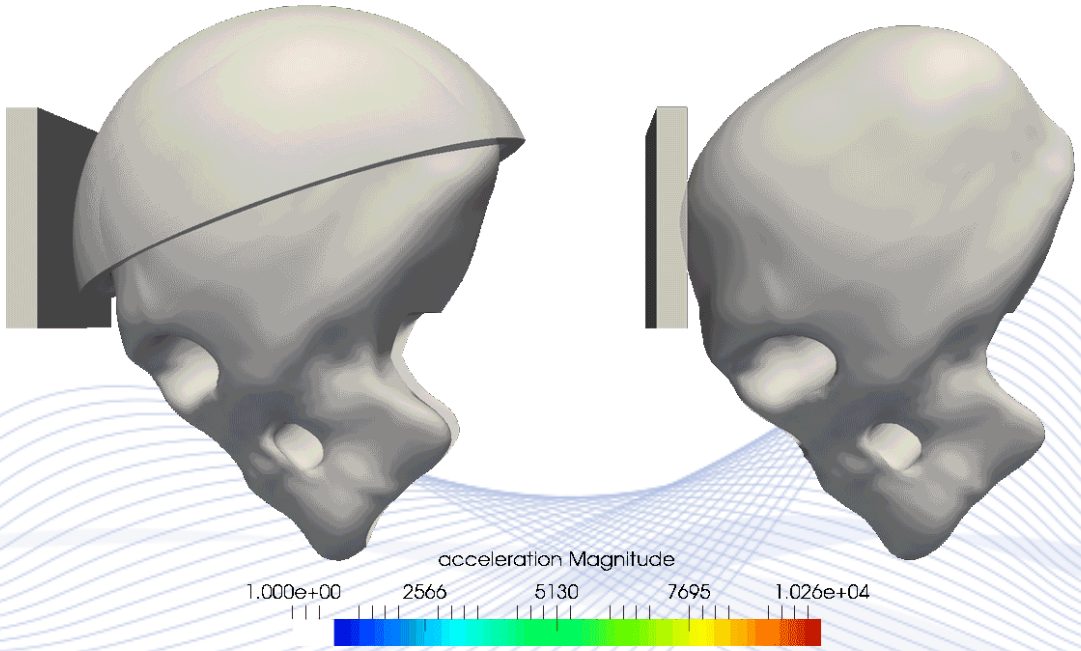
Non-linear dynamic analysis to simulate the skull during a crash with a wall, with initial velocity 25 km/h.

Mesh [SIM]



von Mises Stress on the skull with helmet and without helmet [SIM]

Skull with and without Helmet(2)



Skull Wall Crash (animation) [SIM]

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Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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