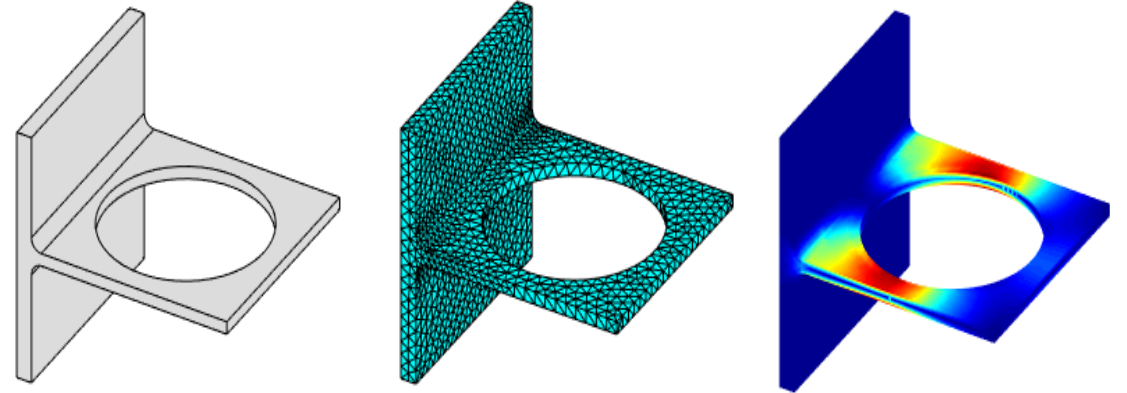


Structural and Thermal Analysis with MATLAB

Sergio Obando Quintero – Application Engineer
Sarah Palfreyman – Technical Marketing & Product Management



Agenda

- Motivation
- MATLAB for Structural and Thermal Analysis
 - Workflow
 - Application Example 1: Heat Tolerance of Robotic Component [[DEMO](#)]
 - Application Example 2: Linear Elastic Study of Bracket [[DEMO](#)]
 - Application Example 3: Structural Dynamics of Tuning Fork [[DEMO](#)]
- Key Takeaways and Resources

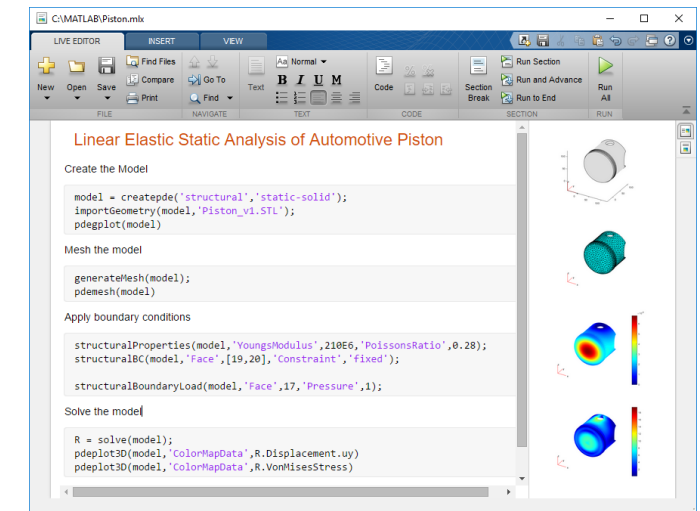
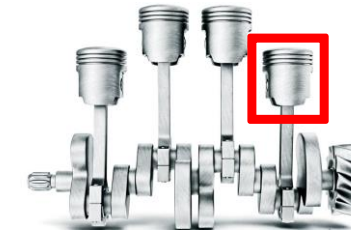
Motivation

Structural and Thermal Analysis lets you ...

... assess a component for ...

- Deformation, stress and strain related to loading
- Failure under loading to determine its fitness-for-use
- Vibration and resonance
- Thermal response to applied heat sources

- **Finite Element Analysis (FEA)** is a popular approach for solving the underlying PDEs which capture the physics.

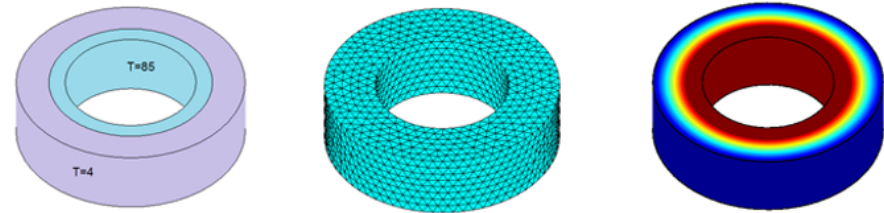


Applications

Thermal Analysis | Structural Analysis | General PDEs

- Conduction dominant heat transfer
- Linear static deflection and stress analysis
- Modal analysis
- Transient linear dynamics
- General PDE formulations

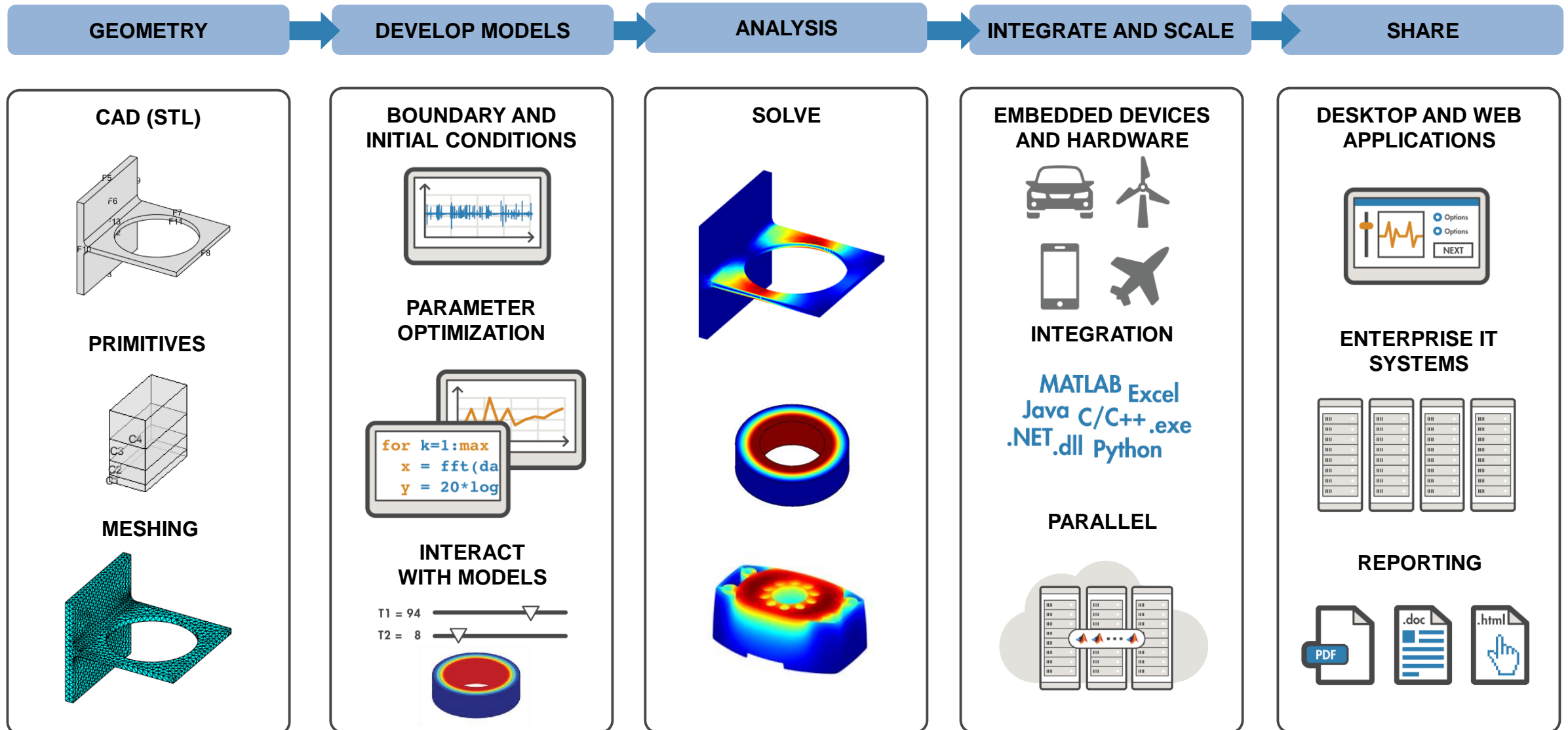
Heat Transfer in a Pipe



10 lines
of code

```
pdem = createpde('thermal');  
gm = multicylinder([20,25,35], 20, 'Void', [1,0,0]);  
pdem.Geometry = gm;  
generateMesh(pdem);  
thermalProperties(pdem,'cell',1,'ThermalConductivity',40);  
thermalProperties(pdem,'cell',2,'ThermalConductivity',0.15);  
thermalBC(pdem,'Face',3,'Temperature',85);  
thermalBC(pdem,'Face',7,'Temperature',4);  
result = solve(pdem);  
pdeplot3D(pdem,'ColormapData',result.Temperature)
```

PDE Workflow



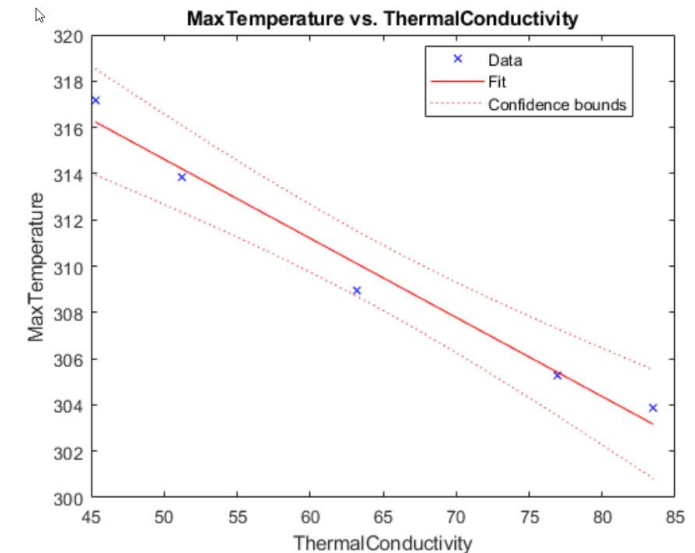
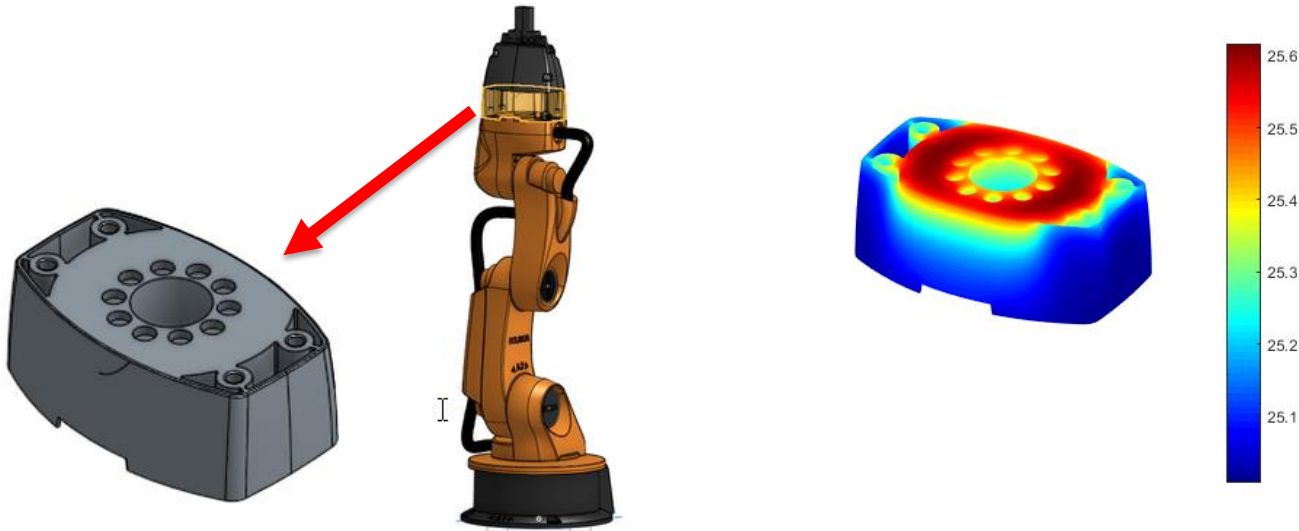
Application Example 1

Parametric Thermal Analysis

Heat Tolerance of Components Exposed to Electronics

Objective:

- Calculate Max and Bulk body temperatures
- Test different materials for the robotic component
- Model relationship between thermal conductivity and max temperature



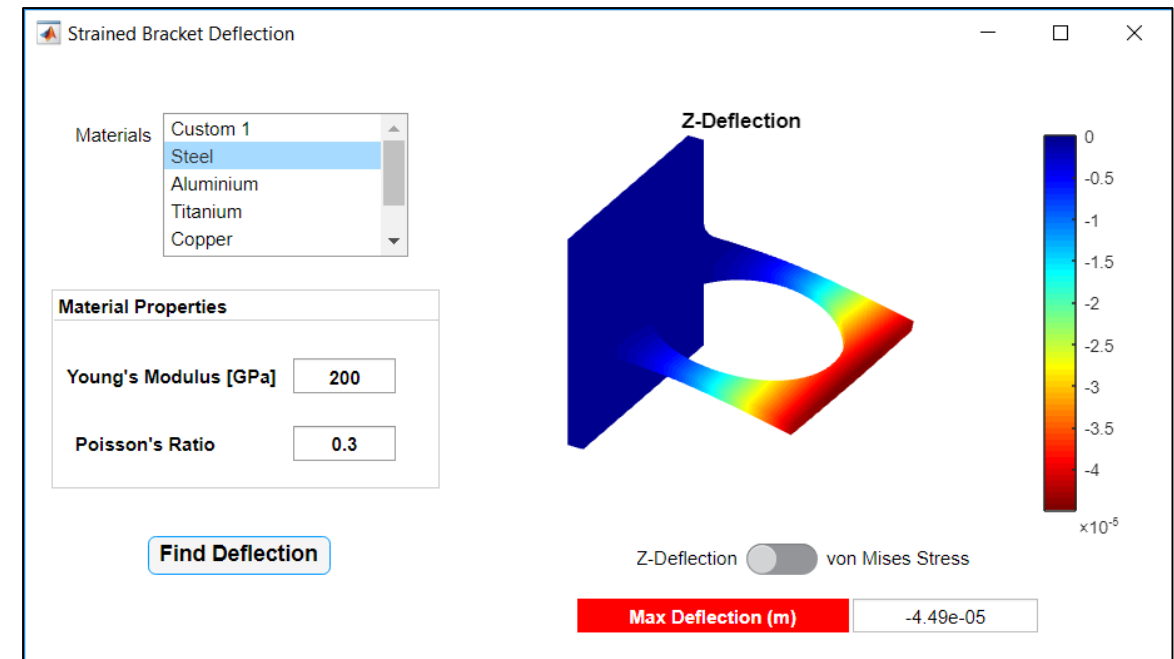
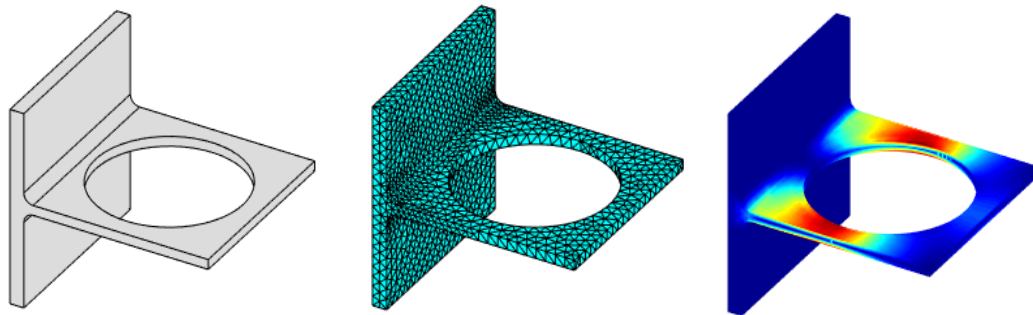
Application Example 2

Structural Analysis

Linear Elastic Deformation Parametric Study of Bracket with a Hole

Objective:

- Determine maximum deflection of bracket under load
- Parametric study of multiple materials
- Compute load deflection curves
- Integrate analysis into App for deployment



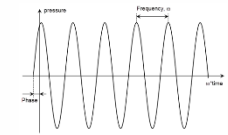
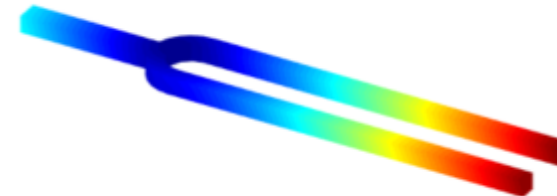
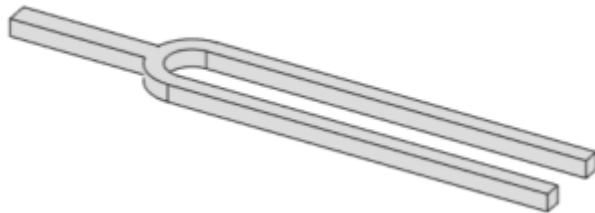
Application Example 3

Modal and Transient Linear Dynamics

Structural Dynamics of Tuning Fork

Objective:

- Find natural frequencies and mode shapes
- Visualize and animate results
- Simulate dynamics of fork
- Visualize displacement and spectrum



Mode	Frequency
1	0.0039119
2	0.0053546
3	0.0055787
4	0.0082541
5	0.0083016
6	0.0086049
7	467.27
8	714.48

Key Takeaways

- MATLAB offers an easy-to-use FEA workflow
- MATLAB tools which can be used for structural and thermal analysis
 - Live Editor
 - App Designer
 - Partial Differential Equation Toolbox
- Leverage MATLAB environment and tools to extend your mathematical analysis
 - Parallel Computing Toolbox
 - Symbolic Math Toolbox
 - Statistics and Machine Learning Toolbox
 - MATLAB Compiler

Resources

Finite Element Analysis

MathWorks® Products Solutions Academia Support Community Events

Partial Differential Equation Toolbox MAJOR UPDATE

Search MathWorks.com

Overview Features Code Examples Videos Webinars What's New Product Pricing Trial software Contact sales

Solve partial differential equations using finite element analysis

Partial Differential Equation Toolbox™ provides functions for solving structural mechanics, heat transfer, and general partial differential equations (PDEs) using finite element analysis.

You can perform linear static analysis to compute deformation, stress, and strain. For modeling structural dynamics and vibration, the toolbox provides a direct time integration solver. You can analyze a component's structural characteristics by performing modal analysis to find natural frequencies and mode shapes. You can model conduction-dominant heat transfer problems to calculate temperature distributions, heat fluxes, and heat flow rates through surfaces. You can also solve standard problems such as diffusion, electrostatics, and magnetostatics, as well as custom PDEs.

Partial Differential Equation Toolbox lets you import 2D and 3D geometries from STL or mesh data. You can automatically generate meshes with triangular and tetrahedral elements. You can solve PDEs by using the finite element method, and postprocess results to explore and analyze them.

Capabilities

Structural Analysis

Solve linear static, modal, and transient analysis problems.

» Learn more

Thermal Analysis

Solve conduction-dominant heat transfer problems.

» Learn more

General PDEs

Solve custom second-order PDEs, such as those deriving from diffusion, electrostatics, and magnetostatics.

FEA Workflows in MATLAB

With a few lines of code, you can import geometry, generate a mesh, define the physics, solve, and visualize results.

MathWorks® Products Solutions Academia Support Community Events

Finite Element Analysis

Search MathWorks.com

Trial software Contact sales

Analyze heat transfer and structural mechanics

Finite element analysis (FEA) is a computational method for predicting how structures behave under loading, vibration, heat, and other physical effects. This technique allows entire designs to be constructed, evaluated, refined, and optimized before being manufactured.

FEA provides numerical solutions to boundary value problems that model real-world physics as partial differential equations. For computation, FEA breaks the real-world geometries down into meshes or computational grids of small elements, such as tetrahedrons. The equations that model the physics of these elements are then assembled into a larger system of equations that models the entire problem. You can use the results of finite element analysis to predict stress, strain, deformation, temperature, and heat flux and to predict whether a structure will fail or work the way it is intended.

How to perform finite element analysis includes importing or creating a geometry, meshing the geometry, applying boundary conditions, solving, and postprocessing results. You can run one analysis or multiple analyses in parallel to perform a design of experiments (DOE) study. You can customize or automate any of the steps of the workflow to extend your capabilities.

For more information about mechanical stress and heat transfer, see Partial Differential Equation Toolbox™ and Parallel Computing Toolbox™.

And How To

- Analysis of a Robotics Component - Example
- Conduction in a Spherical Multidomain Geometry with Nonuniform Heat Flux - Example
- Conduction in a Circular Rod - Example
- Analysis of a Bracket - Example
- Analysis of a Clamped Beam - Example

Reference

- Mechanics - Documentation
- Thermal - Documentation
- Finite Element Method - Documentation

Mathematical modeling, mathematical modeling, dimensional analysis

3D Finite Element Analysis with MATLAB

Modeling Flexible Bodies with Simscape Multibody Software

» Download technical paper

Ask the Expert

Sarah Palfreyman, Partial Differential Equation Toolbox Technical Expert

» Email Sarah

<https://www.mathworks.com/discovery/finite-element-analysis.html>

<https://www.mathworks.com/products/pde.html>

Resources

<https://www.mathworks.com/videos>

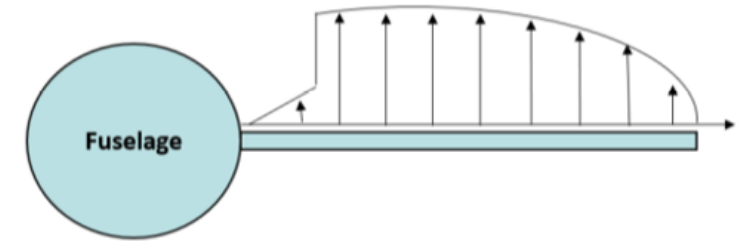


[Engineering Design and Documentation](#)

Modeling an Aircraft Wing Load

Estimate stress and deformation of a 3D aircraft wing using Finite Element Analysis (FEA) based on analytical loading calculations.

- Symbolic Math Toolbox
- Partial Differential Equation Toolbox
- MATLAB Report Generator

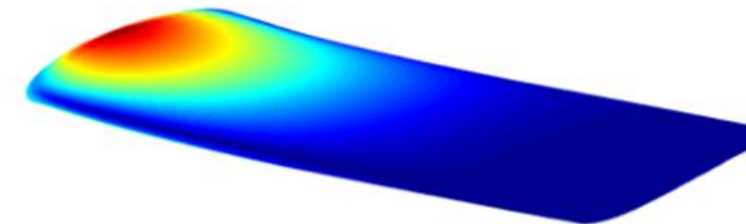


```
TotalLoad = subs(q_t, Vars, Values)
```

TotalLoad =

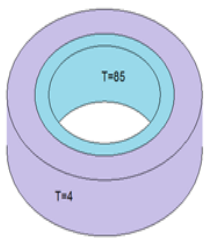
$$\begin{cases} \frac{9375 \left(\frac{X}{4} - \frac{66}{25} \right)}{104} \frac{N}{m} + \frac{328125 \left(\frac{2X}{5} - \frac{3429}{125} \right)}{258064} \frac{N}{m} + \frac{1000000 \sqrt{\frac{145161}{625} - X^2}}{16129 \pi} \frac{N}{m} & \text{if } X \leq \frac{12}{5} \\ \frac{328125 \left(\frac{2X}{5} - \frac{3429}{125} \right)}{258064} \frac{N}{m} + \frac{1000000 \sqrt{\frac{145161}{625} - X^2}}{16129 \pi} \frac{N}{m} & \text{otherwise} \end{cases}$$

Symbolic Analytical load

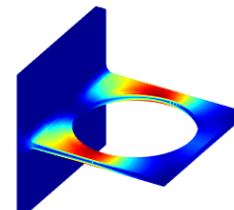
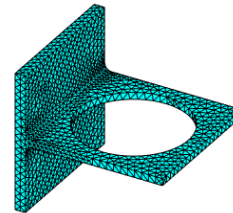
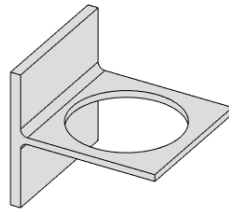
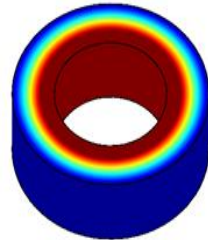


3D Structural Mechanics

Structural and Thermal Analysis with MATLAB



Thermal



Linear Elastic



Transient Dynamics