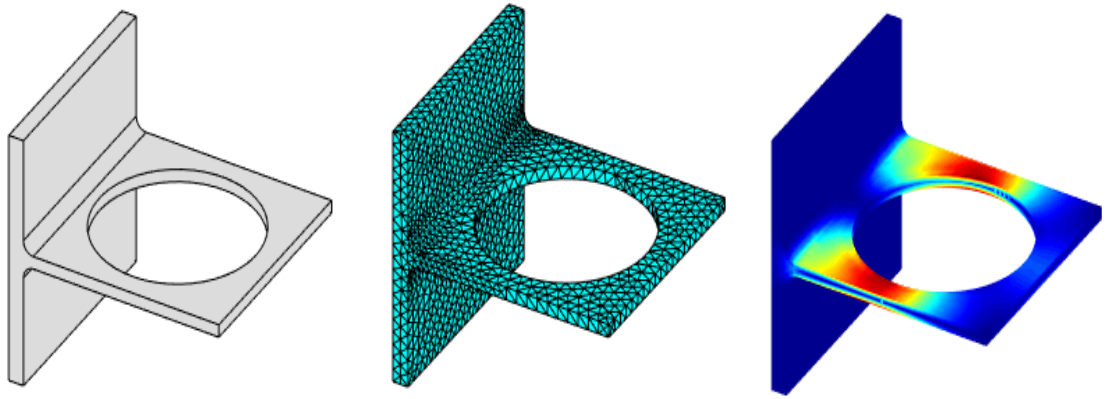
Structural and Thermal Analysis with MATLAB



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Agenda

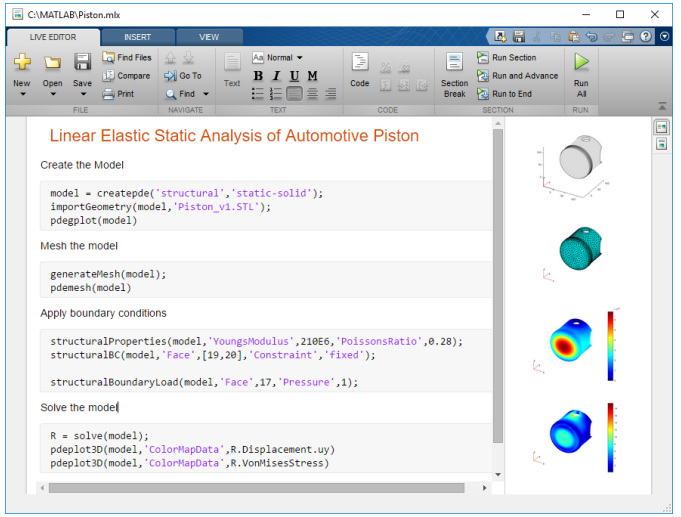
- Motivation
- MATLAB for Structural and Thermal Analysis
  - Workflow
  - Application Example 1: Heat Tolerance of Robotic Component [DEMO]
  - Application Example 2: Linear Elastic Study of Bracket [DEMO]
  - Application Example 3: Structural Dynamics of Tuning Fork [DEMO]
- Key Takeaways and Resources

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

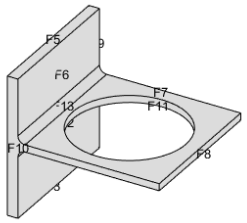
10 lines of code

```
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)
```

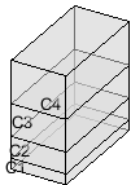
PDE Workflow

GEOMETRY → **DEVELOP MODELS** → **ANALYSIS** → **INTEGRATE AND SCALE** → **SHARE**

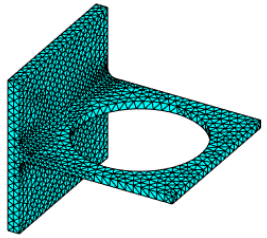
CAD (STL)



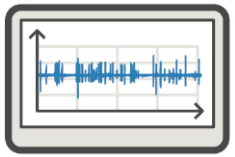
PRIMITIVES



MESHING

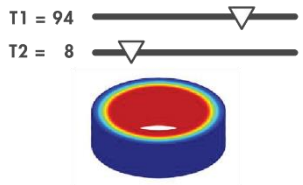


BOUNDARY AND INITIAL CONDITIONS

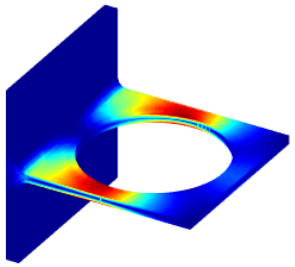


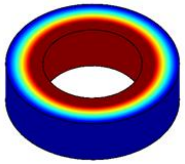
PARAMETER OPTIMIZATION

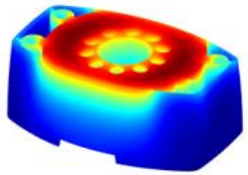
INTERACT WITH MODELS



SOLVE







EMBEDDED DEVICES AND HARDWARE

INTEGRATION

MATLAB Excel
Java C/C++ .exe
.NET .dll Python

PARALLEL

DESKTOP AND WEB APPLICATIONS

ENTERPRISE IT SYSTEMS

REPORTING

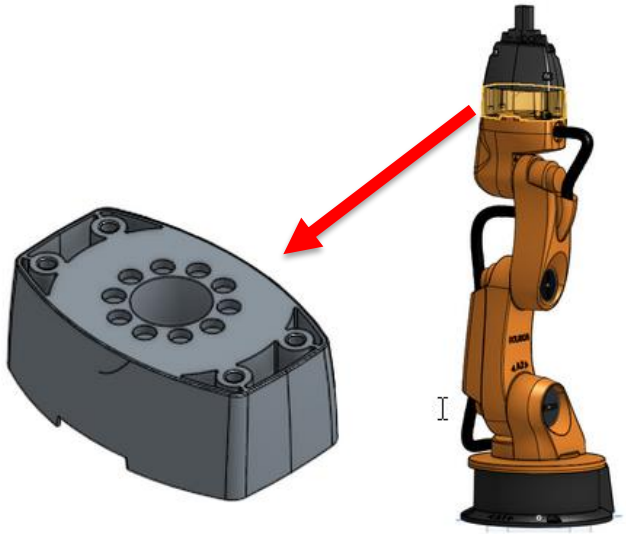
Application Example 1

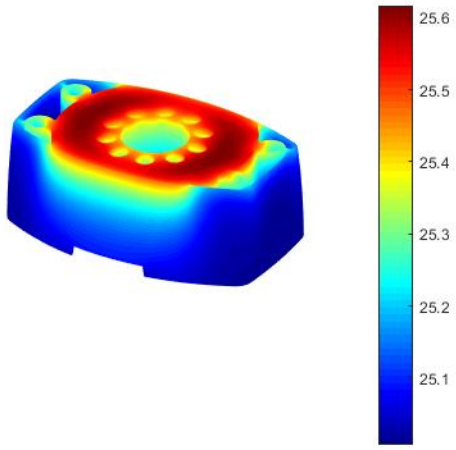
Parametric Thermal Analysis

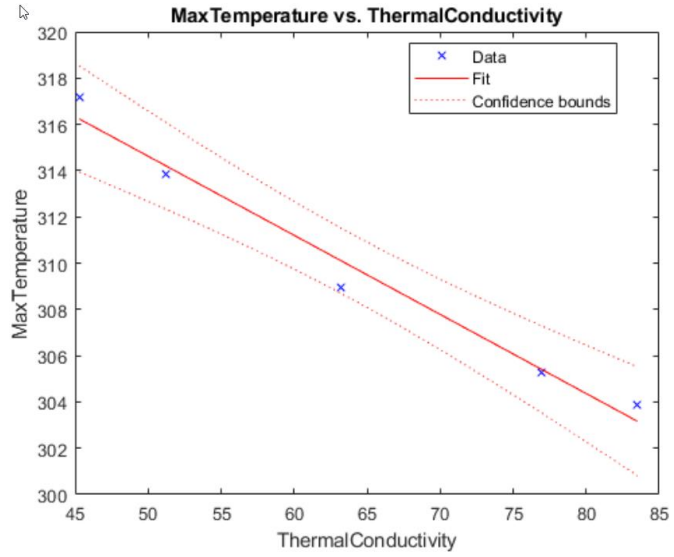
Heat Tolerance of Components Exposed to Electronics

Objective:

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







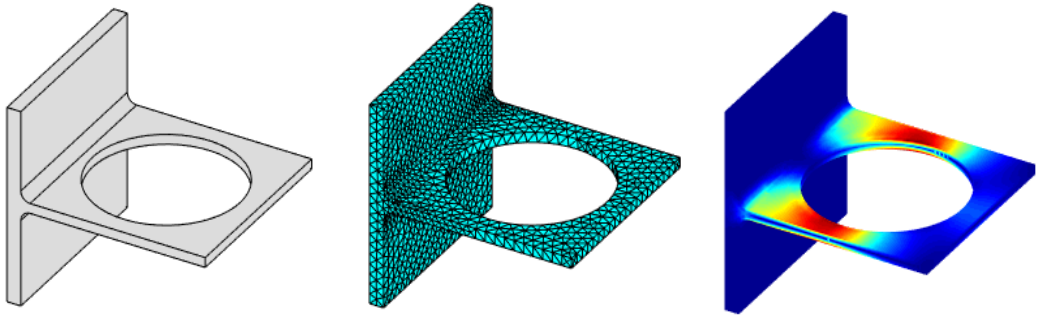
Application Example 2

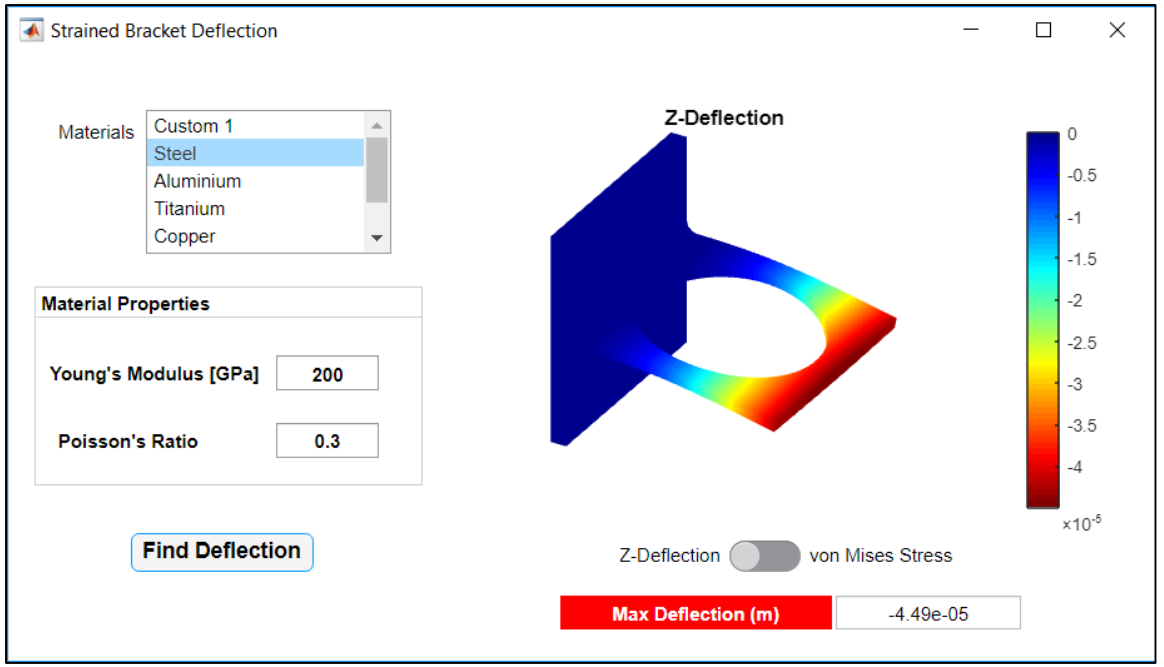
Structural Analysis

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

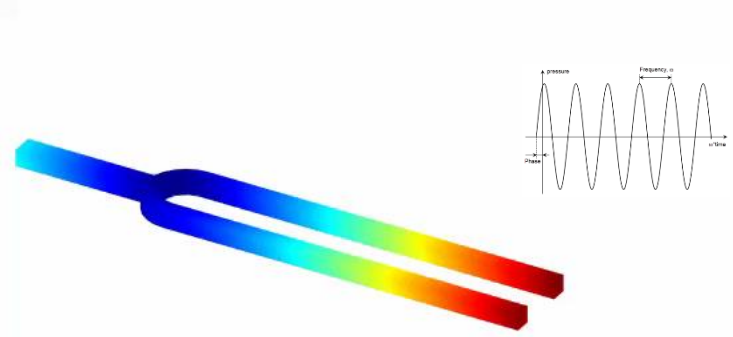




Application Example 3

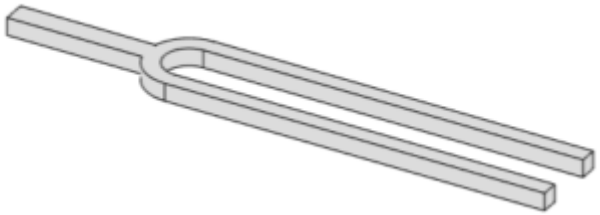
Modal and Transient Linear Dynamics

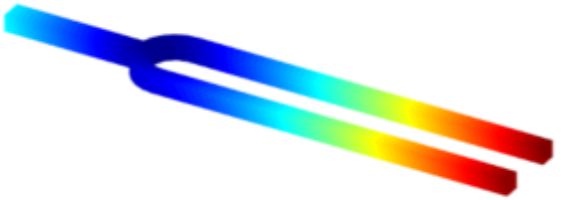
Structural Dynamics of Tuning Fork



Objective:

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



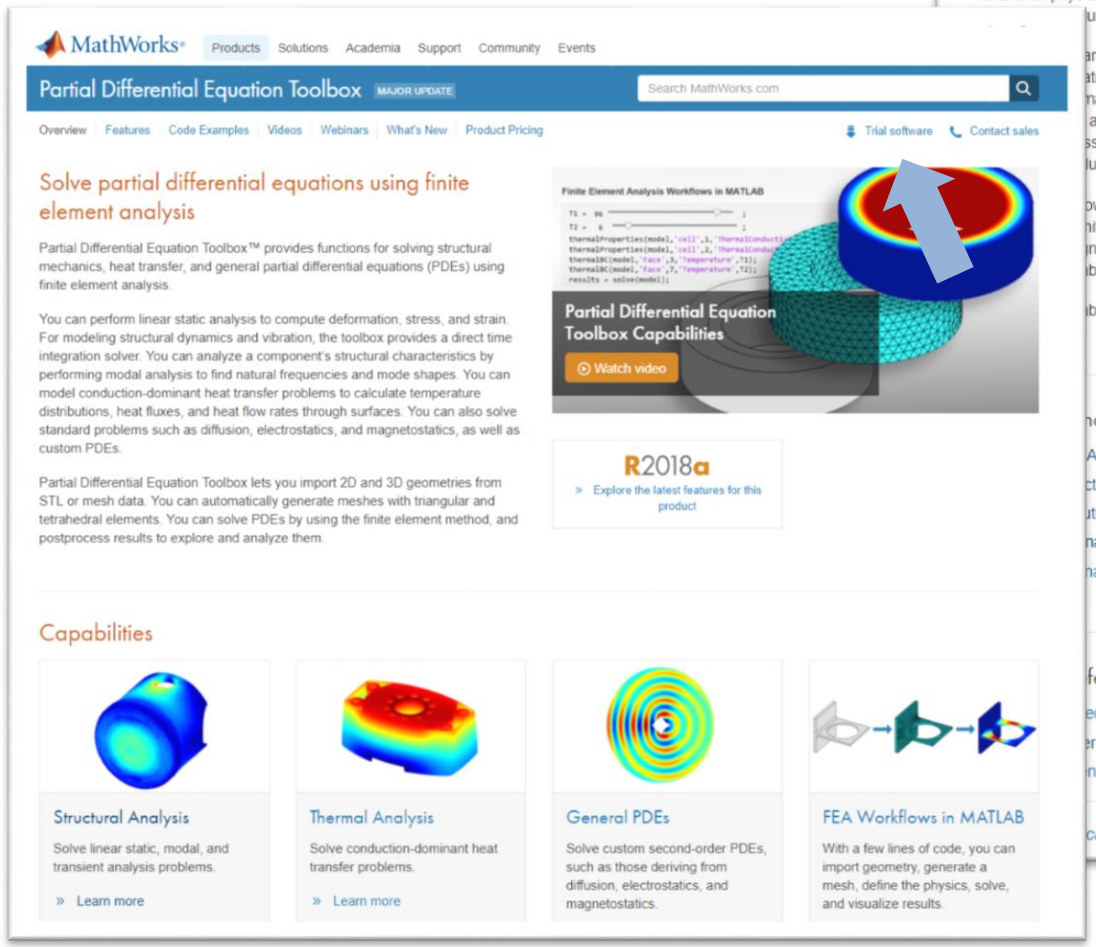


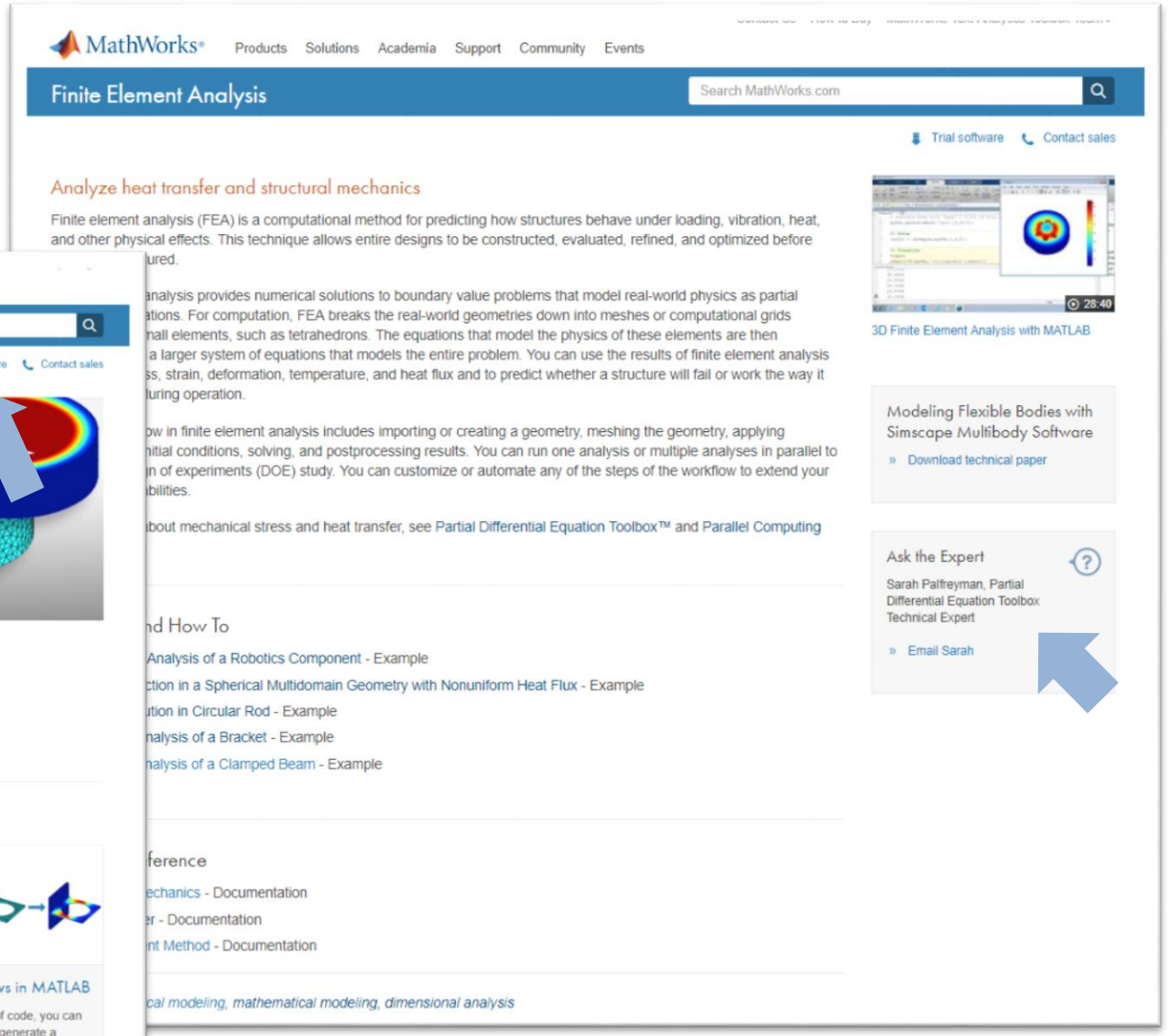
Mode	Frequency
1	0.0039119
2	0.0053546
3	0.0055787
4	0.0082541
5	0.0083016
6	0.0086049
7	467.27
8	714.48

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

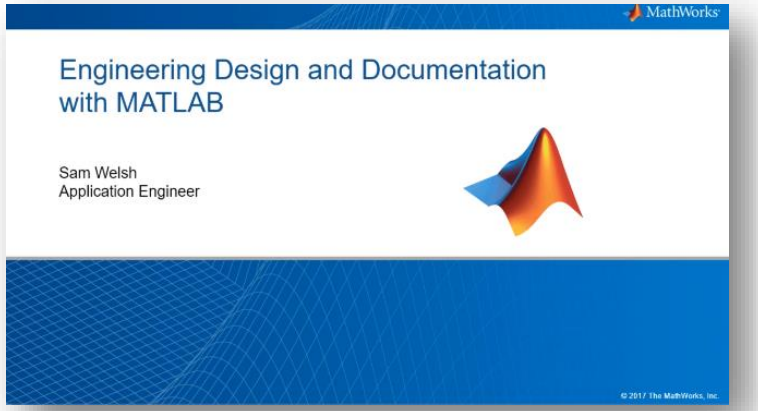




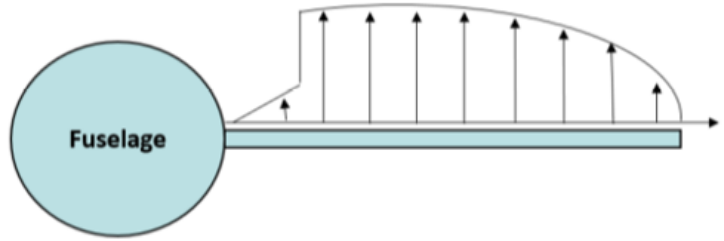
https://www.mathworks.com/discovery/finite-element-analysis.html

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

Resources
https://www.mathworks.com/videos



[Engineering Design and Documentation]




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

TotalLoad =

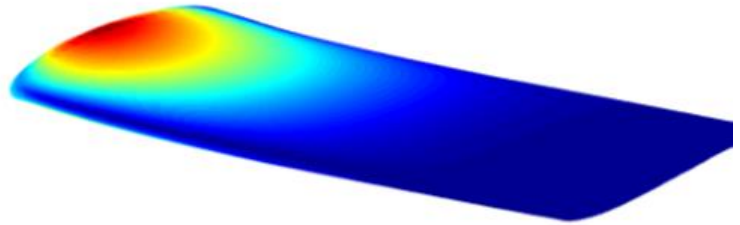
$$\begin{cases} \frac{9375\left(\frac{X}{4}-\frac{66}{25}\right)}{104}\,\frac{\mathrm{N}}{\mathrm{m}}+\frac{328125\left(\frac{2X}{5}-\frac{3429}{125}\right)}{258064}\,\frac{\mathrm{N}}{\mathrm{m}}+\frac{1000000\sqrt{\frac{145161}{625}-X^2}}{16129\,\pi}\,\frac{\mathrm{N}}{\mathrm{m}} & \text{if } X \le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

Symbolic Analytical load

Modeling an Aircraft Wing Load

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

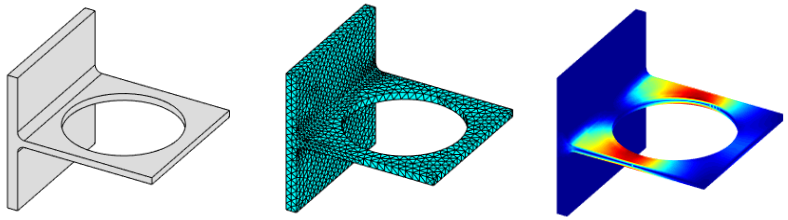
- Symbolic Math Toolbox
- Partial Differential Equation Toolbox
- MATLAB Report Generator



3D Structural Mechanics

Structural and Thermal Analysis with MATLAB

Thermal



Linear Elastic

Transient Dynamics