Engineering Project 9: SolidWorks parametric modeling + FEA analysis and stress calculation + ML prediction for manufacturability.

Problem statement

- Structural components with through-holes exhibit strong stress sensitivity to hole diameter.
- Running full FEA for every geometric variation is computationally expensive and slow.
- Early design stages lack fast, quantitative feedback on whether a geometry is mechanically manufacturable.
- A lightweight, data-driven approach is needed to predict failure risk using minimal simulation data.

The problem this project solves

- Converts a small set of FEA-derived von Mises stress results into a scalable dataset.
- Trains an ML surrogate model to predict maximum von Mises stress at the hole surface from hole diameter.
- Translates stress predictions into a clear manufacturability decision (PASS / FAIL) using a single physics-based criterion.
- Eliminates the need for repeated FEA runs during early design exploration.

Applications

- Early-stage mechanical design screening before detailed simulation.
- Parametric CAD → FEA → ML workflows in structural components with holes or cutouts.
- Rapid manufacturability assessment in brackets, bosses, fixtures, and load-bearing parts.
- Dataset generation and surrogate modeling for design optimization pipelines.
- Educational and portfolio demonstration of physics-informed ML in mechanical engineering.

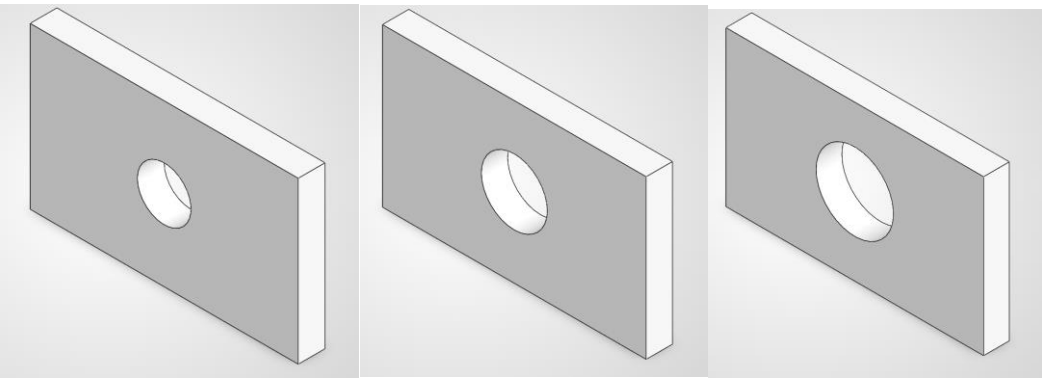
Why it's important

- Demonstrates integration of CAD parameters, FEA physics, and machine learning in a single workflow.
- Shows how limited simulation data can be amplified into predictive design intelligence.
- Reduces engineering iteration time and computational cost.
- Aligns with modern industry practices in digital twins, surrogate modeling, and AI-assisted design.
- Provides a clear, explainable decision rule grounded in mechanical stress theory.

Workflow:

Part 1: SolidWorks parametric model building.

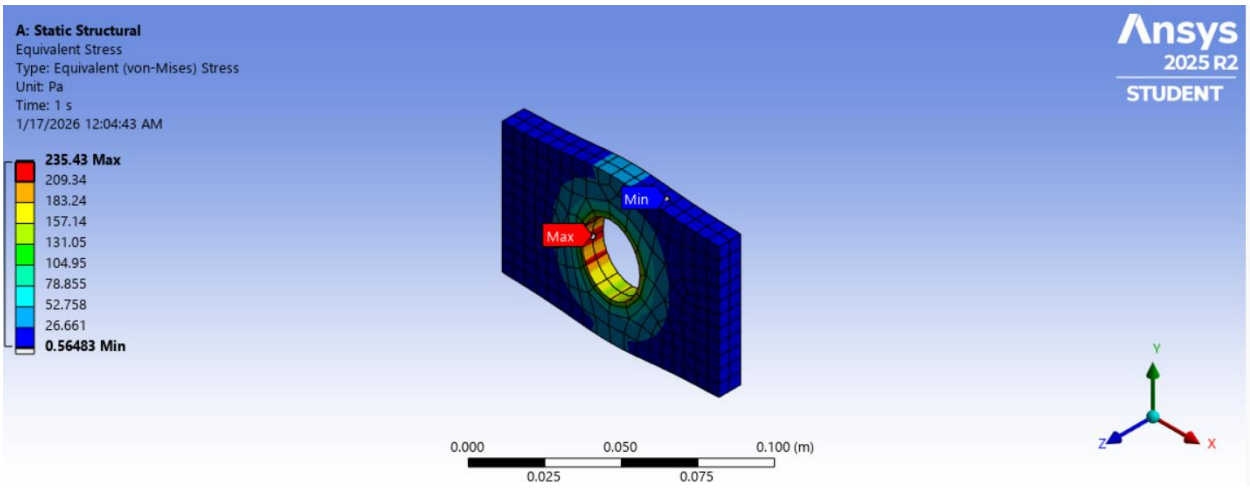
Example: 3 samples of rectangular part with through holes in the center with different diameter (20mm, 25mm, 30mm).



Part 2: FEA analysis and calculation of Mises stress (ANSYS static structural simulation).

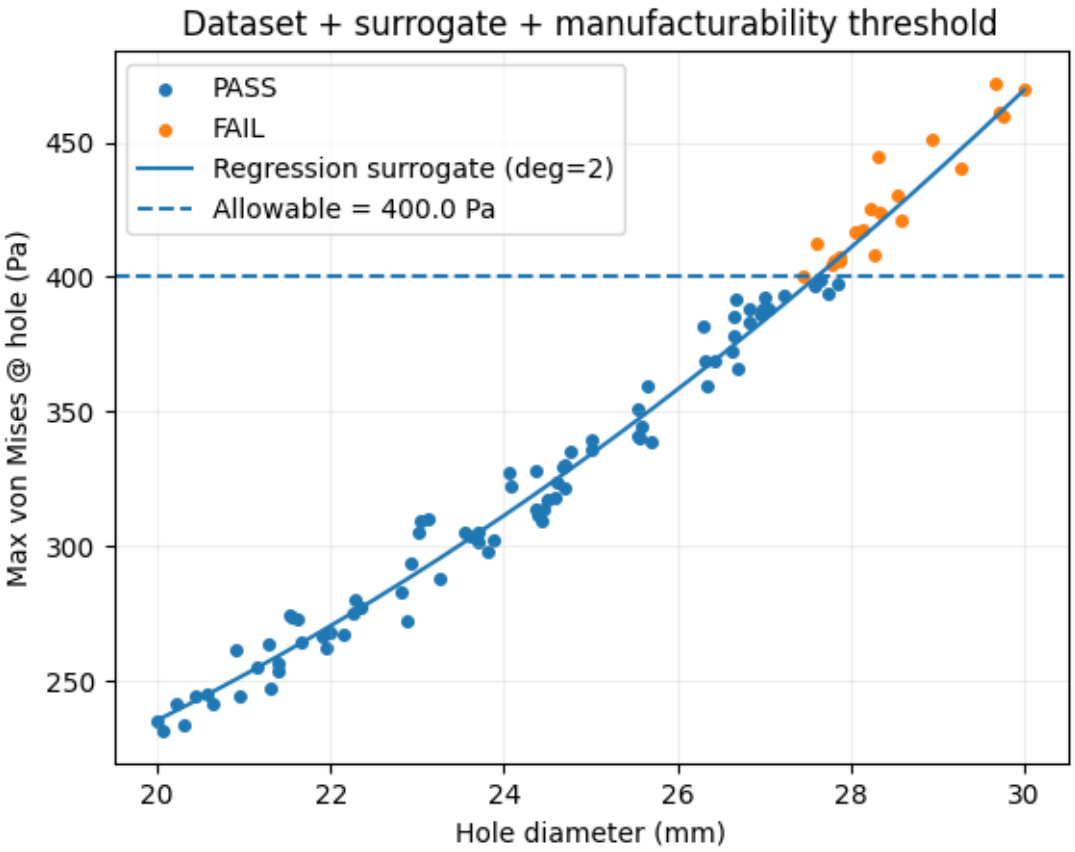
Boundary conditions: Left and right edges are fixed, and 100Pa pressure is applied in the internal surface of the hole.

Example: Von Mises stress for hole dia=20mm.



Part 3: Prediction of manufacturability based on failure criteria (Maximum Von Mises Stress >400Pa): Imagine you have 100 samples and corresponding von Mises stress values. You can predict manufacturability by running a simple ML algorithm.

N.B. refer to the .ipynb file for detail script.


Dataset + surrogate + manufacturability threshold
PASS
FAIL
Regression surrogate (deg=2)
Allowable = 400.0 Pa
Max von Mises @ hole (Pa)
Hole diameter (mm)
250
300
350
400
450
20
22
24
26
28
30