

Hole_plate_Test1

Prompt >>

[Task 1] Using the contents of {experimental_introduction}, {experimental_goals}, {model shape} and {parameters}, carry out the following tasks

1. Explain what you're trying to do
 - (1) Overview
 - (2) Purpose and Objective
 - (3) Plan for Implementation
2. For each response variable, we estimate the importance ranking of the sensitivity of the design variable and explain the engineering basis for that estimation using equations and etc..
(Example: $a > b \dots$)

[Model Information]

{experimental_introduction} = "Perform a structural analysis on a planar plate with a hole"

{experimental_goals} = "examine the correlation between the design variables and response variables and estimate the sensitivity of each design variable."

{model shape} = a rectangular thin plate shape with a center hole

{parameters} =

1. design variable
 - length: 250mm - 300mm
 - width: 100mm - 110mm
 - diameter: 20mm - 90mm
 - thickness = 5mm ※fixed variable
 2. response variable
 - max stress, max displacement
 3. constraints
 - the entire left side = fixed
 - the entire right side = vertical tensile stress 1,000N
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Answer >>

1. Explanation of the Analysis

(1) Overview

The study aims to perform a structural analysis on a rectangular thin plate with a central hole. The objective is to assess how design variables (plate length, width, and hole diameter) influence maximum stress and maximum displacement under a specified tensile load. The analysis seeks to determine the sensitivity ranking of each design variable in relation to these response variables.

(2) Purpose and Objective

The main goal is to analyze the correlation between design variables and response variables in a planar plate with a hole subjected to a vertical tensile stress. Specifically, the study intends to:

- Understand how variations in plate length, width, and hole diameter affect maximum stress and maximum displacement.
- Identify the relative importance of each design variable in influencing the response variables.
- Provide an engineering explanation for the sensitivity ranking based on structural mechanics principles.

(3) Plan for Implementation

The analysis will utilize a Finite Element Method (FEM) approach, involving the following steps:

1. **Model Construction:** Generate a 2D rectangular thin plate with a center hole.
2. **Boundary and Loading Conditions:**
 - The left edge of the plate will be fully fixed.
 - A tensile stress of 1,000N will be applied vertically on the right edge.
3. **Design Variable Variation:**
 - Length: 250mm - 300mm
 - Width: 100mm - 110mm
 - Hole Diameter: 20mm - 90mm
 - Thickness will be fixed at 5mm.
4. **Finite Element Analysis (FEA):** Compute maximum stress and maximum displacement for various combinations of design variables.
5. **Sensitivity Analysis:** Assess the impact of each design variable on the response variables and rank them based on their influence.

2. Sensitivity Ranking of Design Variables

The importance ranking of sensitivity is determined by analyzing the impact of length (L), width (W), and hole diameter (D) on maximum stress (σ_{max}) and maximum displacement (δ_{max}).

(A) Sensitivity Analysis on Maximum Stress (σ_{max})

Using stress concentration theory, the maximum stress in a plate with a hole under tensile stress can be estimated by the equation:

$$\sigma_{max} = K_t \cdot \sigma_{applied}$$

Where:

- σ_{max} = Maximum stress
- $\sigma_{applied}$ = Applied tensile stress (1,000 N)
- K_t = Stress concentration factor, which depends on the hole diameter and plate width.

For a rectangular plate with a hole, the stress concentration factor is approximated by:

$$K_t = 1 + 2\sqrt{\frac{D}{W}}$$

- **Effect of Hole Diameter (D):** As the hole diameter increases, K_t increases, leading to higher maximum stress. This suggests that D has the most significant influence on σ_{max} .
- **Effect of Plate Width (W):** A larger width reduces the stress concentration factor, leading to a decrease in σ_{max} .
- **Effect of Plate Length (L):** The length primarily affects global deformation rather than stress concentration near the hole.

Sensitivity Ranking for Maximum Stress:

$$D > W > L$$

(B) Sensitivity Analysis on Maximum Displacement (δmax)

The maximum displacement of a plate under tension can be approximated using beam theory for thin plates:

$$\delta_{max} \approx \frac{\sigma_{applied} L^2}{Et}$$

Where:

- δmax = Maximum displacement
- E = Elastic modulus
- t = Plate thickness (Fixed at 5mm)
- L = Plate length
- **Effect of Plate Length (L):** Since δmax is proportional to L², increasing the length significantly increases maximum displacement³³. Thus, L is the most dominant factor.
- **Effect of Plate Width (W):** A larger width provides more stiffness, reducing δmax, but its effect is smaller than that of L.
- **Effect of Hole Diameter (D):** The hole diameter has a relatively minor effect on global displacement.

Sensitivity Ranking for Maximum Displacement:

$$L > W > D$$

Final Sensitivity Rankings

Response Variable	Sensitivity Ranking
Maximum Stress (σmax)	D>W>L
Maximum Displacement (δmax)	L>W>D

This analysis provides an engineering-based justification for how design variables influence the structural response of a plate with a hole under tensile stress.