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**DEPARTMENT OF AEROSPACE ENGINEERING**

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| Year & Branch | : | **III AERO** | Semester | : | **VI** |
| Course | : | **19ASE310 FATIGUE AND FRACTURE MECHANICS** | | | |

**LECTURE NOTES**

# TOPIC: Notched S-N Curves

## 1. Introduction

Fatigue failure is a critical consideration in engineering design, especially for components subjected to cyclic loading. Notched S-N curves are used to evaluate the fatigue strength of materials containing stress concentrators, such as notches, grooves, holes, or keyways. These curves provide valuable insights into the fatigue life of real-world components, which often have geometric discontinuities.

## 2. Definition

A **Notched S-N curve** is a graphical representation of the relationship between the number of cycles to failure (N) and the applied stress amplitude (S) for a material with a notch or stress concentration. It accounts for the reduction in fatigue strength due to the presence of notches, as compared to smooth specimens.

## 3. Importance of Notched S-N Curves

- **Realistic Fatigue Analysis:** Most engineering components have stress concentrations. Notched S-N curves help in predicting the actual fatigue life.

- **Design Optimization:** Helps in improving the durability of components by considering notch effects during the design stage.
- **Failure Prevention:** Assists in selecting materials and geometries that minimize premature fatigue failure.
- **Material Comparison:** Enables engineers to compare different materials under fatigue conditions, considering notch sensitivity.

# 4. Factors Affecting Notched S-N Curves

- **Notch Geometry:** The shape, size, and depth of the notch influence stress concentration and fatigue life.
- **Material Properties:** Ductility, strength, and microstructure affect notch sensitivity.
- **Surface Finish:** Rougher surfaces tend to reduce fatigue strength.
- **Environmental Effects:** Corrosion, temperature, and humidity can degrade fatigue performance.
- **Loading Conditions:** The type of cyclic loading (axial, bending, torsional) influences the fatigue behavior.

# 5. Advantages of Using Notched S-N Curves

- More accurate fatigue life predictions for real components.
- Helps in evaluating the effect of different notch geometries.
- Provides insights into material behavior under cyclic loading.
- Useful in structural integrity assessments and safety evaluations.

# 6. Limitations of Notched S-N Curves

- Requires extensive experimental data for different notch configurations.
- Does not directly account for variable amplitude loading conditions.
- Fatigue life estimation is influenced by environmental and operational uncertainties.
- Limited applicability for highly complex geometries with multiple stress risers.

# 7. Applications of Notched S-N Curves

- **Aerospace Industry:** Analysis of fatigue performance in aircraft structures with riveted and bolted joints.
- **Automotive Engineering:** Evaluation of fatigue life in engine components, shafts, and suspension systems.

- **Structural Engineering:** Predicting fatigue failure in bridges, offshore platforms, and welded structures.
- **Biomedical Engineering:** Analysis of fatigue behavior in orthopedic implants with stress concentrators.

Notched S-N curves are essential tools in fatigue analysis, providing engineers with a means to predict the lifespan of components with geometric discontinuities. Their application in design, testing, and failure prevention makes them indispensable in various engineering fields. While they offer valuable insights, it is crucial to consider their limitations and complement them with other fatigue analysis techniques for comprehensive evaluations.

## Problem 1: Effect of Notch on Fatigue Life

A steel component is tested for fatigue with and without a notch. The **unnotched** specimen has a fatigue strength of **300 MPa** for **$10^6$ cycles.** A notched specimen with a notch sensitivity factor ($q$) of **0.85** and a theoretical stress concentration factor ($K_t$) of **2.5** is tested under the same conditions. Determine the fatigue strength of the notched specimen at **$10^6$ cycles.**

**Solution:**

The fatigue strength reduction factor ($K_f$) is given by:

$$K_f = 1 + q(K_t - 1)$$

$$K_f = 1 + 0.85(2.5 - 1) = 1 + 0.85(1.5) = 2.275$$

Now, the notched fatigue strength is:

$$S_{\text{notched}} = \frac{S_{\text{unnotched}}}{K_f}$$

$$S_{\text{notched}} = \frac{300}{2.275} = 131.8\, MPa$$

**Answer:** The fatigue strength of the notched specimen at **$10^6$ cycles** is **131.8 MPa.**

## Problem 2: Estimating Fatigue Life for a Notched Component

A **notched** aluminum component is subjected to a cyclic stress amplitude of **120 MPa.** The material follows the Basquin equation for fatigue life:

$$N_f = CS^{-b}$$

where

- $C = 1.5 \times 10^{12}$,
- $b = 3.5$,
- The notched fatigue strength at **$10^6$ cycles** is **150 MPa.**

Estimate the fatigue life ($N_f$) of the component.

**Solution:**

Using Basquin's equation:

$$N_f = 1.5 \times 10^{12} \times (120)^{-3.5}$$

$$N_f = 1.5 \times 10^{12} \times (3.472 \times 10^{-7})$$

$$N_f = 5.21 \times 10^5 \text{ cycles}$$

**Answer:** The fatigue life of the notched component is approximately **521,000 cycles.**

### Problem 3: Fatigue Life Comparison Between Smooth and Notched Specimens

A smooth steel specimen has a fatigue limit of **250 MPa** at $10^7$ **cycles.** A notched version of the same material is tested under identical conditions, with a notch sensitivity factor ($q$) of **0.75** and a theoretical stress concentration factor ($K_t$) of **3.**

Determine the expected fatigue limit of the **notched specimen.**

**Solution:**

Using the fatigue strength reduction factor:

$$K_f = 1 + q(K_t - 1)$$

$$K_f = 1 + 0.75(3 - 1) = 1 + 0.75(2) = 2.5$$

Now, the notched fatigue limit is:

$$S_{\text{notched}} = \frac{S_{\text{smooth}}}{K_f}$$

$$S_{\text{notched}} = \frac{250}{2.5} = 100\, MPa$$

**Answer:** The fatigue limit of the notched specimen is **100 MPa.**