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DEPARTMENT OF AEROSPACE ENGINEERING

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Course	:	**19ASE310 FATIGUE AND FRACTURE MECHANICS**			

LECTURE NOTES

TOPIC: SN CURVES

Introduction

Fatigue failure is a critical concern in engineering applications, particularly in components subjected to cyclic loading. To assess the fatigue life of materials, fatigue testing is performed, and the results are represented using **S-N curves** (Stress-Number of Cycles curves). These curves help engineers predict the lifespan of materials under varying stress levels. The study of fatigue is essential in industries such as aerospace, automotive, civil engineering, and biomedical engineering, where structures are subjected to repeated loading conditions.

Definition

An **S-N curve** is a graphical representation of the relationship between the applied cyclic stress amplitude (S) and the number of cycles to failure (N) for a given material. The curve is obtained from fatigue tests conducted under controlled laboratory conditions. The vertical axis represents the applied stress, while the horizontal axis is a logarithmic scale depicting the number of cycles. This curve is crucial in determining the fatigue behavior of materials, enabling engineers to set design parameters to ensure durability and safety.

Significance of S-N Curves

S-N curves provide valuable insights into:

- The fatigue strength of materials under cyclic loading conditions.
- The endurance limit, if applicable, beyond which materials can theoretically sustain infinite life.
- The expected lifespan of a material under varying stress levels.
- The safe design limits for mechanical components to prevent premature fatigue failure.
- The role of material properties, surface finish, temperature, and environmental influences on fatigue performance.

Fatigue Testing and S-N Curve Construction

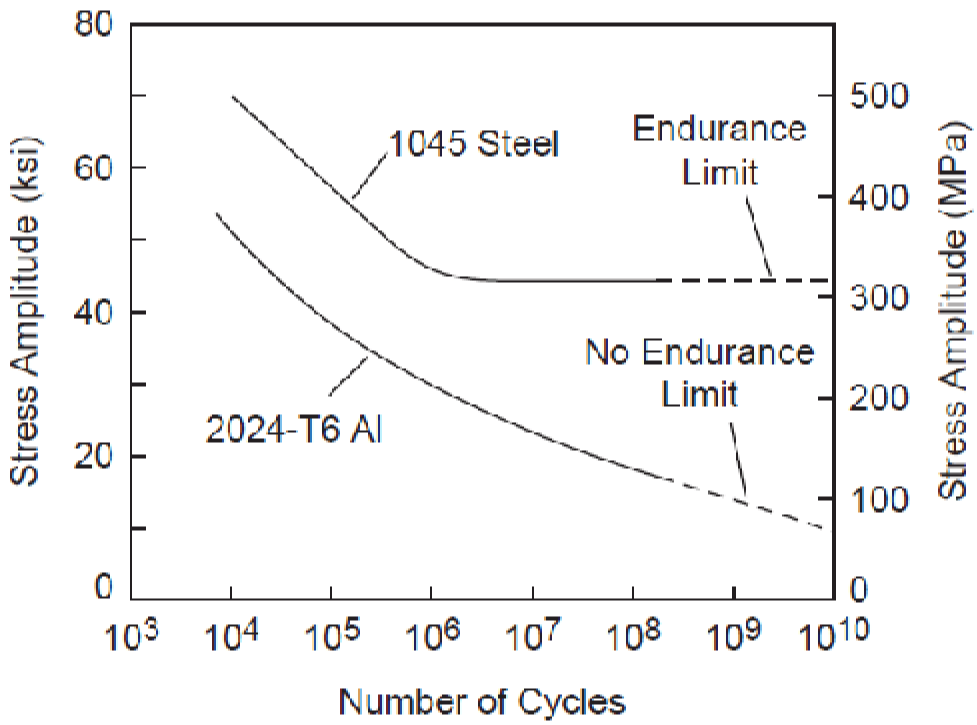
Fatigue testing is conducted using various methodologies, including rotating beam tests, axial loading tests, and bending tests. The procedure for constructing an S-N curve involves:

- Subjecting a standardized specimen to cyclic loading at a constant stress amplitude.
- Recording the number of cycles required for failure.
- Repeating the test at different stress levels to determine the fatigue life of the material.
- Plotting the recorded data on a logarithmic scale with stress (S) on the y-axis and number of cycles (N) on the x-axis to generate the curve.

Fatigue testing may be conducted under fully reversed loading, zero-to-tension loading, or variable amplitude loading conditions. The resulting S-N curve enables engineers to design components with appropriate fatigue strength and predict their durability under real-world conditions.

Characteristics of S-N Curves

- **Endurance Limit**: Certain materials, such as ferrous metals and titanium alloys, exhibit a distinct endurance limit. Below this stress level, the material can theoretically withstand an infinite number of load cycles without failure.
- **Finite Life Region**: At higher stress levels, failure occurs within a limited number of cycles, typically characterized by a rapid decrease in fatigue life with increasing stress amplitude.
- **Infinite Life Region**: In materials with a defined endurance limit, stress levels below this threshold enable the material to sustain infinite life under cyclic loading conditions.
- **Scatter in Results**: Variations in fatigue life are attributed to material heterogeneities, surface finish, environmental factors, and residual stresses, leading to scatter in S-N data.



Factors Influencing S-N Curves

- **Material Composition**: The microstructure, alloying elements, and heat treatment of a material significantly influence its fatigue properties.
- **Surface Finish**: Rough surfaces promote crack initiation, reducing fatigue life, whereas polished surfaces enhance fatigue resistance.
- **Environmental Conditions**: Corrosive environments accelerate fatigue failure due to material degradation mechanisms such as corrosion fatigue.
- **Residual Stresses**: Induced residual stresses from manufacturing processes, such as shot peening or welding, affect fatigue strength.
- **Loading Conditions**: The type of loading, whether fully reversed, fluctuating, or variable amplitude, impacts the fatigue response of materials.

Advantages of S-N Curves

- Provides an empirical approach to determine the fatigue resistance of materials.
- Aids in designing fatigue-resistant components and structures.
- Enables estimation of safe working stress ranges for cyclic loading conditions.
- Serves as a valuable tool for material selection in fatigue-critical applications.
- Enhances the reliability and safety of engineering structures by minimizing unexpected fatigue failures.

Limitations of S-N Curves

- Does not explicitly account for crack initiation and propagation mechanisms in fatigue failure.
- Results depend on test conditions, including loading frequency, temperature, and surface treatment.
- Cannot accurately predict fatigue behavior under complex, variable amplitude loading scenarios.

- Does not consider the effects of mean stress unless modified Goodman or Gerber diagrams are used.
- Variability in test results due to inherent material properties, environmental conditions, and manufacturing inconsistencies.

Applications of S-N Curves

- **Aerospace Engineering**: Design and testing of aircraft structures, turbine blades, and landing gear components to ensure fatigue resistance under cyclic loading.
- **Automotive Industry**: Development of fatigue-resistant engine components, suspension systems, and chassis structures subjected to dynamic loads.
- **Civil Engineering**: Fatigue life assessment of bridges, railway tracks, and high-rise buildings exposed to repetitive traffic and wind loads.
- **Marine and Offshore Engineering**: Structural integrity assessment of offshore platforms, ship hulls, and propeller shafts under wave-induced loading.
- **Biomedical Applications**: Fatigue evaluation of orthopedic implants, prosthetics, and dental materials subjected to cyclic physiological loads.
- **Rotating Machinery**: Fatigue testing of gears, shafts, and bearings in turbines, compressors, and industrial machinery.

S-N curves serve as a fundamental tool in fatigue testing and the design of engineering components subjected to cyclic loading. They provide crucial information for predicting fatigue life, optimizing material selection, and enhancing the safety and durability of structural and mechanical systems. While S-N curves offer valuable empirical data, engineers must consider additional factors such as mean stress effects, crack growth behavior, and environmental influences to develop comprehensive fatigue life predictions. By integrating advanced fatigue analysis techniques and testing methodologies, industries can mitigate fatigue-related failures and improve the performance and longevity of engineering components.