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| **Activity 2.3.1: Stress/Strain Calculations** |

Purpose

On January 28, 1986, NASA launched a shuttle orbiter named Challenger. Approximately 73 seconds after launching, Challenger exploded, killing all seven of its crew members. Christa McAuliffe, a high school teacher, was one of the crew members aboard the Challenger. Why did the Challenger explode?

Engineers are technical problem solvers. The way in which engineers solve problems varies. In general engineers implement a logical approach, or method, in solving the problems that they encounter.

Procedure

You will learn about physical properties related to strengths of materials and apply this information to solve common engineering problems.

Axial stress is the stress in a solid member. Axial stress is symbolized by the Greek letter sigma (σ). Axial stress is defined as a force acting on a perpendicular cross-sectional area.

Shear stress is symbolized by the Greek letter Tau (τ). It is defined as the force parallel to the cross-sectional area of the member divided by the cross-sectional area.

When a body is subjected to an axial force, the body undergoes a deformation, which is termed as **total deformation** δ (delta).

**Normal Strain** ε (epsilon) is defined as the deformation per unit length. Note: This formula assumes the material is homogenous with a uniform cross section,

ε = δ/L0.

Symbols – σ is the axial stress, ε is the axial strain, and E is the constant of proportionality. This constant is called the **modulus of elasticity**. E is often referred to as Young’s modulus, after the scientist Thomas Young (1773-1829) who introduced the idea of the modulus of elasticity.

Elongation caused by a tensile load P on a prismatic bar, assuming linear elasticity, can be calculated using Hooke’s law (σ= E ε). By combining the formulas for stress (σ = F/A) and strain (ε = δ/L), we can determine deformation (δ = FL/EA).

Common Variable Names

Δ (delta) = the change in

*δ* (delta) = total deformation or elongation (in.)

σ (sigma) = stress (force per unit area, psi or lb/in.2)

ε (epsilon) = strain or unit deformation (in./in.)

*E* = modulus of elasticity (psi or lb/in.2)

F = axial force (lb, kip, ton)

A = cross-sectional area (unit²)

L = length (in.)

r = radius (in.)

d = diameter (in.)

Formulas:

Definition of normal stress:  = F/A

Definition of normal strain:  =  /L

Relationship between normal stress and strain: = *E*

A = πr2 (area of circle when using the radius)

A = πd2/4(area of circle when using the diameter)

By substitution we can combine the stress and strain in Hooke’s Law to get the formula for predicting the deformation of a material.

 = FL / A*E*

This equation shows that deformation is directly proportional to the Load (force = F) and the length L and is inversely proportional to the modulus of elasticity *E* and cross-sectional area A.

Five Step Problem-Solving Method

1. Identify *Knowns* (what you’re given) and *Unknowns* (what you want to find out). Assign variable names to the knowns and unknowns and specify each using the correct number and unit name. For example: diameter = d = 3m. *Note: If you are given units mixed in the English and metric systems, you should convert to one standard system of measurement.*
2. Draw a picture. Be sure to label all parts shown.
3. Find an *Equation* (or series of equations) that will provide the answer. Write it down. Manipulate the equation using algebraic principles, if necessary.
4. *Substitute* numbers and units into the equation and solve. Write your answer in terms of the variable name that you chose previously. Be sure to specify not only the numeric answer but the units as well. For example: F = 4N.
5. *Convert*, if necessary. Use the conversion method.
6. Study this example problem.

Example: A force of 150 lb pushes on a round plate with an area of 30 in.2. How much stress does the plate apply to the ground?

Step 1: Identify the Knowns and the Unknowns.

Knowns Unknowns

F= 150 lb =

A = 30 in.2

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| Step 2: Draw a picture. | P |

Step 3: Write an equation.



Step 4: Substitute and Solve.



Step 5: Convert, if necessary. In this problem, the result 5 lb/in.2 is in the form that we desire, so no additional conversion is necessary.

Calculations

Solve the following problems using the five step problem-solving method.

1. A weight of 18,000 lb is supported on a rectangular base plate that is 9 in. wide and 2 ft long. The base plate rests on a concrete slab. Determine the stress that the base plate exerts on the concrete slab. Express your answer in units of (a) lb/in.2 and (b) lb/ft2.
2. Determine the maximum load that a 0.50 in. diameter steel rod can support if the normal stress in the rod must not exceed 24,000 psi.
3. A 4 in. wide by 1.125 in. thick rectangular steel bar supports a load of P in tension. Determine:
4. The stress in the bar if P = 32,000 lb
5. The load P that can be supported by the bar if the axial stress must not exceed 25,000 psi.
6. A 35 ft long solid steel rod is subjected to a load of 8,000 lb. This load causes the rod to stretch 0.266 in. The modulus of elasticity of the steel is 30,000,000 psi. Determine the diameter of the rod.
7. A 100 ft long steel wire has a cross-sectional area of 0.0144 in.2. When a force of 270 lb is applied to the wire, its length increases by 0.75 in. Determine:
8. The stress
9. The strain
10. The modulus of elasticity of the steel
11. A 1.25 in. by 3 in. rectangular steel bar is used as a diagonal tension member in a bridge truss. The diagonal member is 20 ft long, and its modulus of elasticity is 30,000,000 psi. If the strain in the diagonal member is measured as 0.001200 in./in., determine:
12. The axial stress
13. The tension force in the bar
14. The elongation of the member
15. Two 40 ft long wires made of differing materials are supported from the ceiling of a testing laboratory. Wire (1) is made of material H and has a diameter of 3/8 in. Wire (2) is made of material K and has a diameter of 3/16 in. When a load of 225 lb is applied to its lower end, wire (1) stretches 0.10 in. When the same 225 lb load is applied to the lower end of wire (2), wire (2) stretches 0.25 in. Compare materials H and K. Which material has the greater modulus of elasticity? Which is the stiffer material?
16. A 9,000 lb load is suspended from the roof in a shopping mall with a 16 ft long solid aluminum rod. The modulus of elasticity of the aluminum is 10,000,000 psi. If the maximum rod elongation must be limited to 0.50 in. and the maximum stress must be limited to 30,000 psi, determine the minimum diameter that may be used for the rod.
17. A solid circular titanium control rod at 7,000 lb axial tension force, stress must not exceed 42,000 psi. Assume that the modulus of elasticity of the titanium is 16,500,000 psi and that the rod must elongate no more than 0.20 in. Determine (a) the minimum rod diameter *(precision 0.00)* and (b) the maximum rod length.