Mechanics of deformable bodies
COE – 3001
Shear
Homework #3

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Modeling assumptions

Unless otherwise stated, the following assumptions of strength of materials are adopted throughout this assignment:

- material is continuous, homogeneous, and isotropic,
- deformations are small,
- linear elastic behavior,
- stresses and strains are uniformly distributed,
- loads and supports are perfectly idealized.

Exercise I Questions on the course

Do you feel confident about your knowledge of shear loading? Please answer each question to assess your understanding.

1. Shear deformation corresponds to angular distortion.

☐ True ☐ False

2. Shear stress is caused by forces parallel to the cross section.

☐ True ☐ False

3. In pure shear, normal stresses are zero.

☐ True ☐ False

4. Shear strain is dimensionless.

☐ True ☐ False

5. For small deformations, shear strain is equal to the shear angle expressed in radians.

☐ True ☐ False

6. Shear modulus G relates shear stress and shear strain in the linear elastic regime.

☐ True ☐ False

7. Hooke's law in shear can be written $\tau = G\gamma$.

☐ True ☐ False

8. Shear stress and normal stress have the same physical unit.

☐ True ☐ False

9. In a simple shear test, shear stress is assumed uniform over the bonded area.

☐ True ☐ False

10. Pure shear produces no change in volume for an isotropic material.

☐ True ☐ False

11. Shear deformation modifies angles but preserves lengths to first order.

☐ True ☐ False

12. Shear stress always produces normal deformation.

☐ True ☐ False

13. In bonded joints, increasing the bonded area reduces the average shear stress.

☐ True ☐ False

14. Shear failure occurs when shear stress exceeds the shear strength of the material.

☐ True ☐ False

15. Safety factors are used to reduce allowable shear stress.

☐ True ☐ False

16. In pin connections, shear stress is often assumed uniformly distributed.

☐ True ☐ False

17. Contact pressure and shear stress represent the same physical quantity.

☐ True ☐ False

18. A material with a high shear modulus necessarily has a high shear strength.

☐ True ☐ False

19. Shear deformation can occur without normal stresses being applied.

☐ True ☐ False

20. The shear modulus G depends on the material but not on the specimen geometry.

☐ True ☐ False

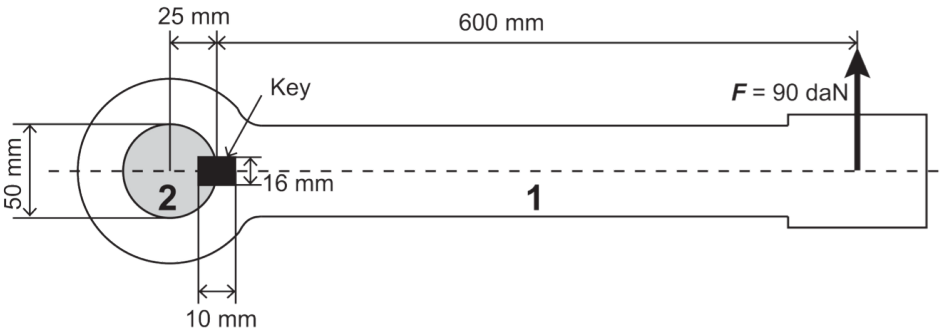

Figure 1: Torque transmission between a lever and a shaft using a rectangular key.

Exercise II Shear stress in a key

Torque transmission between a lever and a shaft is achieved by means of a rectangular key with a cross section

$$16\,\text{mm} \times 10\,\text{mm},$$

and a length $l_k = 30\,\text{mm}$ (see Figure 1).

A force $F = 900\,\text{N}$ is applied to the lever.

1. Draw the free body diagram of the system.
2. Compute the shear force acting on the key.
3. Deduce the corresponding average shear stress in the key.

Exercise III Shear deformation of an elastomer block

A rectangular elastomer block of dimensions

$$50 \times 100 \times 25 \text{ mm}$$

with a shear modulus $G = 800\,\text{MPa}$ is bonded between a rigid plate and a fixed support.

A shear force $T = 100\,\text{daN}$ is uniformly distributed over the block (see Figure 2).

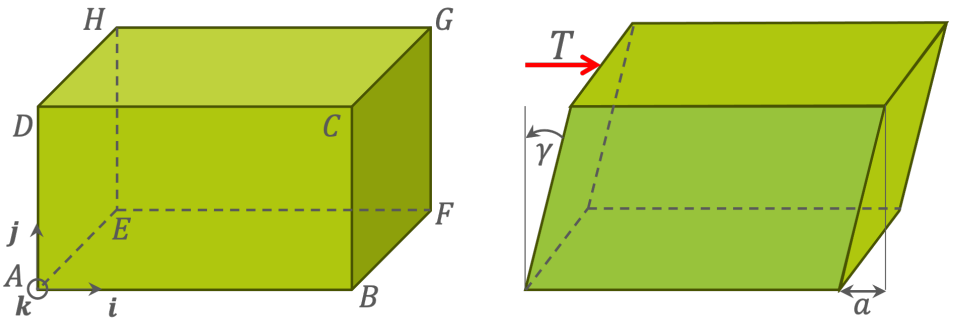

Figure 2: Shear deformation of an elastomer block bonded between two rigid surfaces.

1. Express the shear strain γ as a function of the lateral displacement a and the height h.
2. Compute the shear strain.
3. Determine the corresponding lateral displacement.

Exercise IV Shear stress in a bonded block

A rectangular block of dimensions

$$50 \times 160 \times 40 \text{ mm}$$

and shear modulus $G = 600\,\text{MPa}$ is bonded between two rigid plates.

The upper plate undergoes a horizontal displacement of $0.8\,\text{mm}$, while the lower plate remains fixed (see Figure 2).

1. Sketch the schematic diagram of the system.
2. Compute the average shear stress in the block.
3. Determine the magnitude of the applied shear force.

Exercise V Shear strength of pins

The rigid bar BCD is connected by three pins (see Figure 3). Pins at B and D have a diameter of $8\,\text{mm}$, while the pin at C has a diameter of $12\,\text{mm}$.

The shear yield strength of the steel is $\tau_y = 300\,\text{MPa}$. A safety factor $s = 3$ is required.

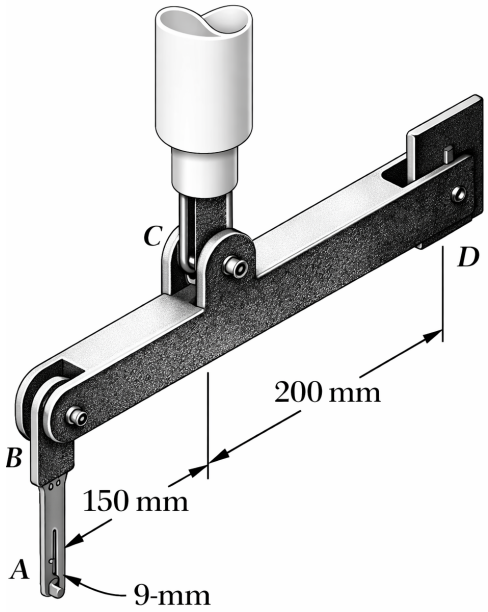

Figure 3: Rigid bar connected by three pins subjected to shear loading.

Determine the maximum vertical force P that can be applied at point C without exceeding the allowable shear stress in any pin.

Exercise VI Key design under torsional loading

A shaft transmits torque to a hub through a rectangular key (see Figure 4).

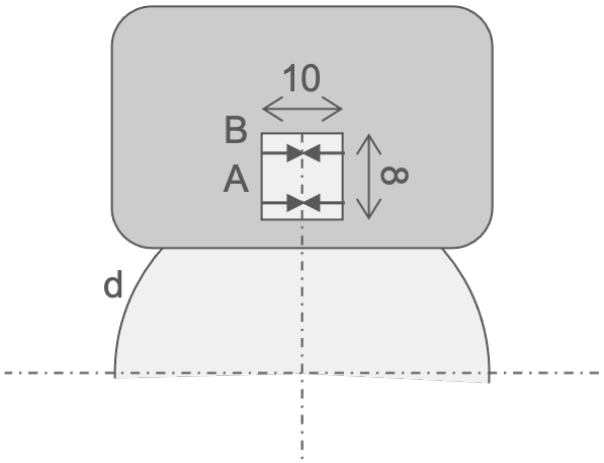

Figure 4: Shaft–hub connection using a rectangular key under torsional loading.

The shaft diameter is $d = 32\,\text{mm}$ and the transmitted torque is $M = 65\,\text{N m}$.

The key dimensions are 10×8 mm and its allowable shear strength is $\tau_e = 108\,\text{MPa}$. The allowable contact pressure is $p_m = 30\,\text{MPa}$.

1. Compute the magnitude of the contact force acting on the key.

2. Determine the minimum required key length based on the bearing stress criterion.

3. Verify the design using the shear stress criterion and conclude.