EDEXCEL NATIONAL CERTIFICATE/DIPLOMA

FURTHER MECHANICAL PRINCIPLES AND APPLICATIONS
UNIT 11 - NQF LEVEL 3

OUTCOME 2 - STRESS AND STRAIN

TUTORIAL 1 - SHEAR

CONTENT

Be able to determine the stress in structural members and joints

Single and double shear joints*:* fastenings e.g. bolted or riveted joints in single and double shear; joint parameters e.g. rivet or bolt diameter, number of rivets or bolts, shear load, expressions for shear stress in joints subjected to single and double shear, factor of safety

Structural members*:* members e.g. plain struts and ties, series and parallel compound bars made from two different materials; loading e.g. expressions for direct stress and strain, thermal stress, factor of safety

It is assumed that the student has studied Mechanical Principles and Applications Unit 6 and is already familiar with basic stress and strain.

1. SHEAR STRESS τ

Shear force is a force applied sideways on to the material (transversely loaded). This occurs typically:

(i) When a pair of shears cuts a material

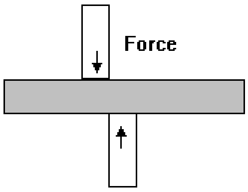


Figure 1

(ii) When a material is punched

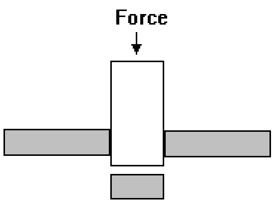


Figure 2

(iii) When a beam has a transverse load.

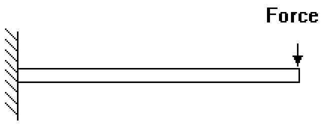


Figure 3

(iv) When a pin carries a load.

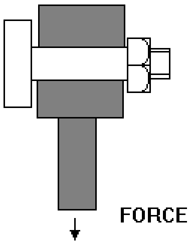


Figure 4

Shear stress is the force per unit area carrying the load. This means the cross sectional area of the material being cut, the beam and pin respectively. Shear stress $\tau = F/A$.
The symbol τ is called Tau. The sign convention for shear force and stress is based on how it shears the materials and this is shown below.

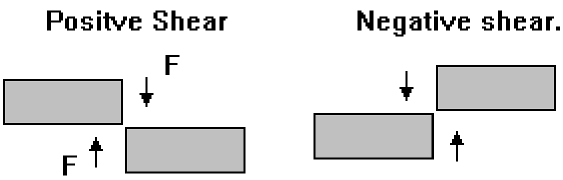


Figure 5

In order to understand the basic theory of shearing, consider a block of material being deformed sideways as shown.

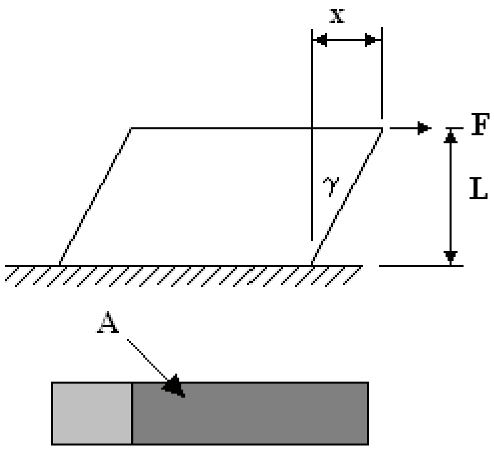


Figure 6

2. SHEAR STRAIN γ

The force causes the material to deform as shown. The shear strain is defined as the ratio of the distance deformed to the height x/L.

The end face rotates through an angle γ. Since this is a very small angle, it is accurate to say the distance x is the length of an arc of radius L and angle γ so that

$$\gamma = x/L$$

It follows that γ is the shear strain. The symbol γ is called Gamma.

3. MODULUS OF RIGIDITY G

If we were to conduct an experiment and measure x for various values of F, we would find that if the material is elastic, it behave like a spring and so long as we do not damage the material by using too big a force, the graph of F and x is a straight line as shown.

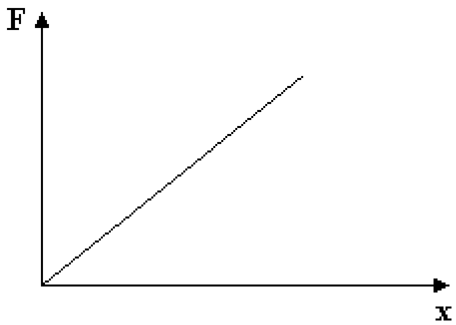


Figure 7

The gradient of the graph is constant so F/x = constant and this is the spring stiffness of the block in N/m.

If we divide F by the area A and x by the height L, the relationship is still a constant and we get

$$\frac{F}{A} \div \frac{x}{L} = \frac{FL}{Ax} = \text{constant}$$

But F/A = τ and x/L = γ so $\frac{F}{A} \div \frac{x}{L} = \frac{FL}{Ax} = \frac{\tau}{\gamma} = \text{constant}$

This constant will have a special value for each elastic material and is called the Modulus of Rigidity with symbol G.

$$\frac{\tau}{\gamma} = G$$

4. ULTIMATE SHEAR STRESS

If a material is sheared beyond a certain limit it becomes permanently distorted and does not spring all the way back to its original shape. The elastic limit has been exceeded. If the material is stressed to the limit so that it parts into two(e.g. a guillotine or punch), the ultimate limit has been reached. The ultimate shear stress is τ_u and this value is used to calculate the force needed by shears and punches.

WORKED EXAMPLE No. 1

Calculate the force needed to guillotine a sheet of metal 5 mm thick and 0.8 m wide given that the ultimate shear stress is 50 MPa.

SOLUTION

The area to be cut is a rectangle 800 mm x 5 mm

$A = 800 \times 5 = 4000\ \text{mm}^2$ The ultimate shear stress is $50\ \text{N/mm}^2$

$$\tau = \frac{F}{A} \quad \text{so} \quad F = \tau \times A = 50 \times 4000 = 200\,000\ \text{N or } 200\ \text{kN}$$

WORKED EXAMPLE No. 2

Calculate the force needed to punch a hole 30 mm diameter in a sheet of metal 3 mm thick given that the ultimate shear stress is 60 MPa.

SOLUTION

The area to be cut is the circumference x thickness = $\pi d \times t$

$A = \pi \times 30 \times 3 = 282.7\ \text{mm}^2$ The ultimate shear stress is $60\ \text{N/mm}^2$

$$\tau = \frac{F}{A} \quad \text{so} \quad F = \tau \times A = 60 \times 282.7 = 16965\ \text{N or } 16.965\ \text{kN}$$

5. SAFETY FACTOR

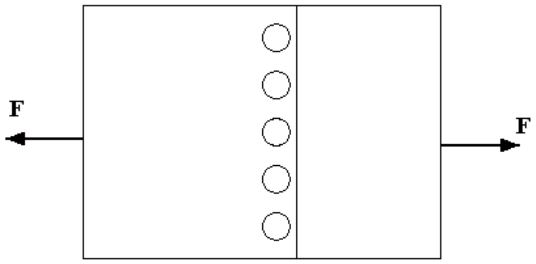
It is normal to err on the side of safety when working out the forces and stresses in shear joints so a safety factor is used. This is defined as:

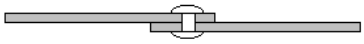
$$\text{Safety Factor} = \frac{\text{Ultimate Stress}}{\text{Working Stress}}$$

The use of the safety factor is shown in the next example.

WORKED EXAMPLE No. 3

Two sheets of steel are riveted together with 5 rivets as shown. Each rivet is 8 mm diameter. Calculate the maximum force required to break the joint in shear given that the ultimate shear stress is 60 MPa and a safety factor of 1.5 is to be used..





SOLUTION

The area to be sheared in each rivet is the circular area $A = \frac{\pi d}{4} = \frac{\pi \times 8^2}{4} = 50.26 \text{mm}^2$

The total area is 5 x 50.26 = 251.3 mm^2 The ultimate shear stress is 60 N/mm^2

Working stress = 60 ÷ safety factor = 60/1.5 = 40 N/mm^2

$\tau = \frac{F}{A}$ so $F = \tau \times A = 40 \times 251.3 = 10052$ N or 10.052 kN

SELF ASSESSMENT EXERCISE No. 1

1. A guillotine must shear a sheet of metal 0.6 m wide and 3 mm thick. The ultimate shear stress is 45 MPa. Calculate the force required. (Answer 81 kN)

2. A punch must cut a hole 30 mm diameter in a sheet of steel 2 mm thick. The ultimate shear stress is 55 MPa. Calculate the force required. (Answer10.37 kN)

3. Two strips of metal are pinned together as shown with a rod 10 mm diameter. The ultimate shear stress for the rod is 60 MPa. Determine the maximum force required to break the pin. (Answer 4.71 kN)

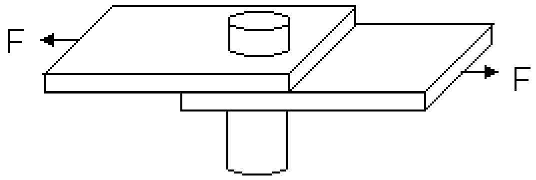


Figure 8

4. A riveted joint must withstand 20 kN in shear. The rivets are 5 mm diameter and have an ultimate shear stress of 80 MPa. If a safety factor of 2 is to be used, how many rivets are required?

(Answer 26)

5. DOUBLE SHEAR

Consider a pin joint with a support on both ends as shown. This is called a CLEVIS and CLEVIS PIN. If the pin shears it will do so as shown.

By balance of forces, the force in the two supports is F/2 each.

The area sheared is twice the cross section of the pin so it takes twice as much force to break the pin as for a case of single shear. Double shear arrangements doubles the maximum force allowed in the pin.

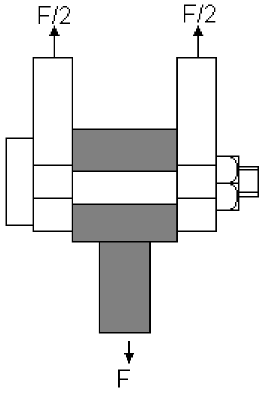


Figure 9

WORKED EXAMPLE No. 4

A pin is used to attach a clevis to a rope. The force in the rope will be a maximum of 60 kN. The maximum shear stress allowed in the pin is 40 MPa. Calculate the diameter of a suitable pin.

SOLUTION

The pin is in double shear so the shear sress is $\tau = \dfrac{F}{2A}$

$$A = \frac{F}{2\tau} = \frac{60000}{2 \text{ x } 40\text{x}10^{6}} = 750 \text{ x } 10^{-6} \text{ m}^2$$

$$A = 750 \text{ mm}^2 = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4 \text{ x } 750}{\pi}} = 30.9 \text{ mm}$$

SELF ASSESSMENT EXERCISE No. 2

1. A clevis pin joint as shown above uses a pin 8 mm diameter. The shear stress in the pin must not exceed 40 MPa. Determine the maximum force that can be exerted. (Answer 4.02 kN)

2.

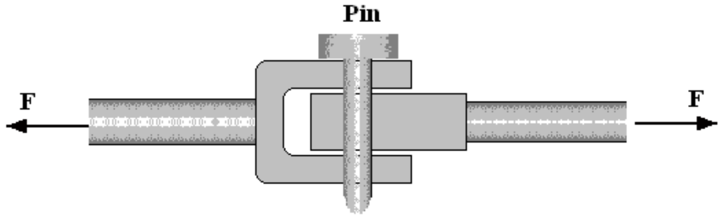


Figure 10

A rope coupling device shown uses a pin 5 mm diameter to link the two parts. If the shear stress in the pin must not exceed 50 MPa, determine the maximum force allowed in the ropes. (Answer 1.96 kN)

3. Three metal plates are joined together with steel M8 screws as shown along one edge. Find the root diameter of M8 screws and a typical ultimate shear stress for steel screws. Based on a safety factor of 1.5, calculate the number of screws needed withstand a shearing force of 40kN.

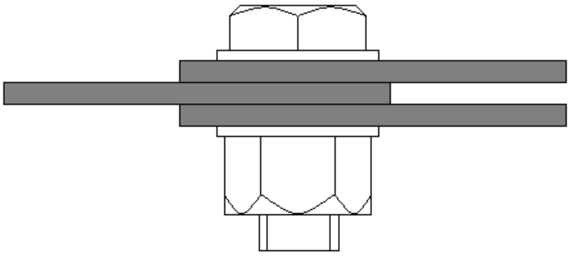


Figure 11

(Answer approximately 14)