Shear stress

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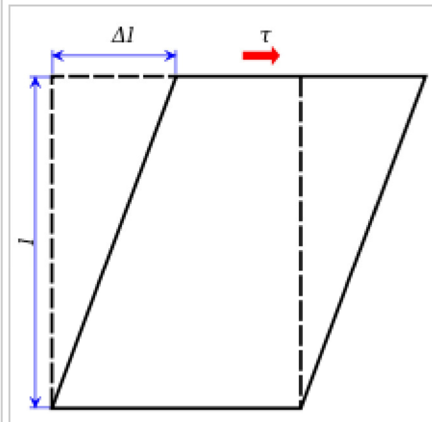
A **shear stress**, denoted τ (Greek: tau), is defined as the component of stress coplanar with a material cross section. Shear stress arises from the force vector component parallel to the cross section. Normal stress, on the other hand, arises from the force vector component perpendicular to the material cross section on which it acts.

Shear stress	
Common symbols	τ
SI unit	pascal
Derivations from other quantities	τ = *F* / *A*



A shearing force is applied to the top of the rectangle while the bottom is held in place. The resulting shear stress, τ, deforms the rectangle into a parallelogram. The area involved would be the top of the parallelogram.

Contents

General shear stress

The formula to calculate average shear stress is force per unit area.:[1]

$$\tau = \frac{F}{A},$$

where:

τ = the shear stress;
F = the force applied;
A = the cross-sectional area of material with area parallel to the applied force vector .

Other forms

Pure

Pure shear stress is related to pure shear strain, denoted γ, by the following equation:[2]

$$\tau = \gamma G$$

where G is the shear modulus of the material, given by

$$G = \frac{E}{2(1+\nu)}.$$

Here E is Young's modulus and ν is Poisson's ratio.

Beam shear

Beam shear is defined as the internal shear stress of a beam caused by the shear force applied to the beam.

$$\tau = \frac{VQ}{It},$$

where

V = total shear force at the location in question;

Q = statical moment of area;

t = thickness in the material perpendicular to the shear;

I = Moment of Inertia of the entire cross sectional area.

The beam shear formula is also known as Zhuravskii Shear Stress formula after Dmitrii Ivanovich Zhuravskii who derived it in 1855.[3][4]

Semi-monocoque shear

Shear stresses within a semi-monocoque structure may be calculated by idealizing the cross-section of the structure into a set of stringers (carrying only axial loads) and webs (carrying only shear flows). Dividing the shear flow by the thickness of a given portion of the semi-monocoque structure yields the shear stress. Thus, the maximum shear stress will occur either in the web of maximum shear flow or minimum thickness.

Also constructions in soil can fail due to shear; e.g., the weight of an earth-filled dam or dike may cause the subsoil to collapse, like a small landslide.

Impact shear

The maximum shear stress created in a solid round bar subject to impact is given as the equation:

$$\tau = 2\left(\frac{UG}{V}\right)^{\frac{1}{2}},$$

where

U = change in kinetic energy;

G = shear modulus;

V = volume of rod;

and

$$U = U_{rotating} + U_{applied}\,;$$
$$U_{rotating} = \frac{1}{2} I \omega^2\,;$$
$$U_{applied} = T\theta_{displaced}\,;$$

I = mass moment of inertia;

ω = angular speed.

Shear stress in fluids

Any real fluids (liquids and gases included) moving along solid boundary will incur a shear stress on that boundary. The no-slip condition[5] dictates that the speed of the fluid at the boundary (relative to the boundary) is zero, but at some height from the boundary the flow speed must equal that of the fluid. The region between these two points is aptly named the boundary layer. For all Newtonian fluids in laminar flow the shear stress is proportional to the strain rate in the fluid where the viscosity is the constant of proportionality. However for non-Newtonian fluids, this is no longer the case as for these fluids the viscosity is not constant. The shear stress is imparted onto the boundary as a result of this loss of velocity. The shear stress, for a Newtonian fluid, at a surface element parallel to a flat plate, at the point y, is given by:

$$\tau(y) = \mu \frac{\partial u}{\partial y}$$

where

μ is the dynamic viscosity of the fluid;

u is the velocity of the fluid along the boundary;

y is the height above the boundary.

Specifically, the wall shear stress is defined as:

$$\tau_{\mathrm{w}} \equiv \tau(y=0) = \mu \left.\frac{\partial u}{\partial y}\right|_{y=0} \quad .$$

In case of wind, the shear stress at the boundary is called wind stress.

Measurement with sensors

Diverging fringe shear stress sensor

This relationship can be exploited to measure the wall shear stress. If a sensor could directly measure the gradient of the velocity profile at the wall, then multiplying by the dynamic viscosity would yield the shear stress. Such a sensor was demonstrated by A. A. Naqwi and W. C. Reynolds.[6] The interference pattern generated by sending a beam of light through two parallel slits forms a network of linearly diverging fringes that seem to originate from the plane of the two slits (see double-slit experiment). As a particle in a fluid passes through the fringes, a receiver detects the reflection of the fringe pattern. The signal can be processed, and knowing the fringe angle, the height and velocity of the particle can be extrapolated. The measured value of wall velocity gradient is independent of the fluid properties and as a result does not require calibration. Recent advancements in the micro-optic fabrication technologies have made it possible to use integrated diffractive optical element to fabricate diverging fringe shear stress sensors usable both in air and liquid.

Micro-pillar shear-stress sensor

A further technique is that of slender wall-mounted micro-pillars made of the flexible polymer PDMS, which bend in reaction to the applying drag forces in the vicinity of the wall. The sensor thereby belongs to the indirect measurement principles relying on the relationship between near-wall velocity gradients and the local wall-shear stress.[7][8]

See also

- Direct shear test
- Shear rate
- Shear strain
- Shear strength
- Shear and moment diagrams
- Tensile stress
- Triaxial shear test
- Critical resolved shear stress

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