Shear stress formula pdf

Shear stresses are a very important parameter in mechanical design and an engineer must understand the phenomena of shear stress. Maximum shear stress must be calculated for a cross-section to see whether the design is safe or not. Here, we will show you how to find shear stress on a certain point of a cross-section. You can understand it very easily. Shear stresses are the result of the vertical bending forces, acting from the perpendicular direction of the part axis. And we want to calculate the shear stress on a cross-section that shear force acting upon it. Actually, it has a very basic principle. First of all, you need to understand the neutral plane on this cross-section. In certain cross-sections, the neutral axis or neutral plane passes through the center of gravity of the cross-sectional area. And, you want to calculate the shear stress that occurs on a certain point on this cross-section, because of the shear force acting on this cross-section. Cross-section example to understand shear stress calculation for cross-sections(Image Source:D. K. Singh – Strength of Materials-Springer, 2020, pg.228). Take a look at the cross-section example above. There is a shear force acting upon this cross-section say it is ‘F’. CD line is the line that contains our point that we want to calculate the shear stress. Also, you can see that the neutral axis is very straightforward above. And the center of gravity of the area above the CD line is shown with ‘G’. The distance between this ‘G’ and the neutral axis is denoted as ‘y(prime)’. The distance between the CD line and neutral axis is denoted as ‘y’. Calculate The Moment Of Inertia First of all, you need to calculate the moment of inertia of the whole cross-section concerning the neutral axis. You will use this moment of inertia value in shear stress calculations. Calculate The Area Then you need to calculate the area above the line which contains the point that you want to calculate shear stress(which is CD in the example above). Calculate The Moment Area Then you need to multiply this area with the distance(y(prime)) of the center of gravity(which is G in the example above) of this area to the neutral axis. This will give you the first moment of the area. Put The Values Into The Equation To Find Shear Stress If you put the values that you find, you will find the shear stress on that line. In here, ‘b’ is the thickness of the part or cross-section which is perpendicular to shear force. Conclusion You can apply this principle to each type of cross-section. Do not forget to leave your comments and questions below about the shear stress calculations in cross-sections in mechanics. Your precious feedbacks are very important for us. Component of stress coplanar with a material cross section Shear stressCommon symbolsτSI unitpascalDerivations fromother quantitiesτ = 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. Shear stress, often denoted by τ (Greek: tau), is the component of stress coplanar with a material cross section. It arises from the shear force, the component of force vector parallel to the material cross section. Normal stress, on the other hand, arises from the force vector component perpendicular to the material cross section on which it acts. General shear stress The formula to calculate average shear stress is force per unit area.:[1] τ = F A , {\displaystyle \tau ={F \over 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] τ = γ G {\displaystyle \tau =\gamma G\,} where G is the shear modulus of the isotropic material, given by G = E 2 (1 + ν) . {\displaystyle G={\frac {E}{2(1+u)}}.} 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. τ = f Q I b , {\displaystyle \tau ={fQ \over Ib},} where f = total shear force at the location in question; Q = statical moment of area; b = thickness (width) 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 Further information: Shear flow 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 Constructions in soil can also 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: τ = 2 U G V , {\displaystyle \tau ={\sqrt {2UG \over V}},} where U = change in kinetic energy; G = shear modulus; V = volume of rod; and U = Urotating + Uapplied; Urotating = 1/2Iω2; Uapplied = Tθdisplaced; I = mass moment of inertia; ω = angular speed. Shear stress in fluids See also: Viscosity, Couette flow, Hagen-Poiseuille equation, Depth-slope product, and Simple shear Any real fluids (liquids and gases included) moving along a solid boundary will incur a shear stress at that boundary. The no-slip condition[5] dictates that the speed of the fluid at the boundary (relative to the boundary) is zero; although at some height from the boundary the flow speed must equal that of the fluid. The region between these two points is 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. For non-Newtonian fluids, the viscosity is not constant. The shear stress is imparted onto the boundary as a result of this loss of velocity. For a Newtonian fluid, the shear stress at a surface element parallel to a flat plate at the point y is given by: τ (y) = μ ∂ u ∂ y {\displaystyle \tau (y)=\mu {\frac {\partial u}{\partial y}}} where μ is the dynamic viscosity of the flow; u is the flow velocity along the boundary; y is the height above the boundary. Specifically, the wall shear stress is defined as: τ w ≡ τ (y = 0) = μ ∂ u ∂ y | y = 0 . {\displaystyle \tau _{\mathrm {w} }\equiv \tau (y=0)=\mu \left.{\frac {\partial u}{\partial y}}\right|_{y=0}~~.} The Newton's constitutive law, for any general geometry (including the flat plate above mentioned), states that shear tensor (a second-order tensor) is proportional to the flow velocity gradient (the velocity is a vector, so its gradient is a second-order tensor): τ (u →) = μ ∇ u → {\displaystyle \mathbf {\tau } ({\vec {u}})=\mu abla {\vec {u}}} and the constant of proportionality is named dynamic viscosity. For an isotropic Newtonian flow it is a scalar, while for anisotropic Newtonian flows it can be a second-order tensor too. The fundamental aspect is that for a Newtonian fluid the dynamic viscosity is independent on flow velocity (i.e., the shear stress constitutive law is linear), while non-Newtonian flows this is not true, and one should allow for the modification: τ (u →) = μ (u →) ∇ u → {\displaystyle \mathbf {\tau } ({\vec {u}})=\mu ({\vec {u}})abla {\vec {u}}} The above formula is no longer the Newton's law but a generic tensorial identity: one could always find an expression of the viscosity as function of the flow velocity given any expression of the shear stress as function of the flow velocity. On the other hand, given a shear stress as function of the flow velocity, it represents a Newtonian flow only if it can be expressed as a constant for the gradient of the flow velocity. The constant one finds in this case is the dynamic viscosity of the flow. Example Considering a 2D space in cartesian coordinates (x,y) (the flow velocity components are respectively (u,v)), the shear stress matrix given by: (τ x x τ x y τ y x τ y y) = (x ∂ u ∂ x 0 0 − t ∂ v ∂ y) {\displaystyle {\begin{pmatrix}\tau _{xx}&\tau _{xy}\\\tau _{yx}&\tau _{yy}\end{pmatrix}}={\begin{pmatrix}x{\frac {\partial u}{\partial x}}&0\\0&-t{\frac {\partial v}{\partial y}}\end{pmatrix}}} represents a Newtonian flow, in fact it can be expressed as: (τ x x τ x y τ y x τ y y) = (x 0 0 − t) ⋅ (∂ u ∂ x ∂ u ∂ y ∂ v ∂ x ∂ v ∂ y) {\displaystyle {\begin{pmatrix}\tau _{xx}&\tau _{xy}\\\tau _{yx}&\tau _{yy}\end{pmatrix}}={\begin{pmatrix}x&0\\0&-t\end{pmatrix}}\cdot {\begin{pmatrix}{\frac {\partial u}{\partial x}}&{\frac {\partial u}{\partial y}}\\{\frac {\partial v}{\partial x}}&{\frac {\partial v}{\partial y}}\end{pmatrix}}} , i.e., an anisotropic flow with the viscosity tensor: (μ x x μ x y μ y x μ y y) = (x 0 0 − t) {\displaystyle {\begin{pmatrix}\mu _{xx}&\mu _{xy}\\\mu _{yx}&\mu _{yy}\end{pmatrix}}={\begin{pmatrix}x&0\\0&-t\end{pmatrix}}} which is nonuniform (depends on space coordinates) and transient, but relevantly it is independent on the flow velocity: μ (x , t) = (x 0 0 − t) {\displaystyle \mathbf {\mu } (x,t)={\begin{pmatrix}x&0\\0&-t\end{pmatrix}}} This flow is therefore newtonian. On the other hand, a flow in which the viscosity were: (μ x x μ x y μ y x μ y y) = (1 u 0 0 1 u) {\displaystyle {\begin{pmatrix}\mu _{xx}&\mu _{xy}\\\mu _{yx}&\mu _{yy}\end{pmatrix}}={\begin{pmatrix}{\frac {1}{u}}&0\\0&{\frac {1}{u}}\end{pmatrix}}} is Nonnewtonian since the viscosity depends on flow velocity. This nonnewtonian flow is isotropic (the matrix is proportional to the identity matrix), so the viscosity is simply a scalar: μ (u) = 1 u {\displaystyle \mu (u)={\frac {1}{u}}} 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.[7] Micro-pillar shear-stress sensor A further measurement 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.[8][9] Electro-Diffusional method The Electro-Diffusional method measures the wall shear rate in the liquid phase from microelectrode under limiting diffusion current condition. A potential difference between an anode of a broad surface (usually located far from the measuring area) and the small working electrode acting as a cathode leads to a fast redox reaction. The ion disappearance occurs only on the microprobe active surface, causing the development of the diffusion boundary layer, in which the fast electro-diffusion reaction rate is controlled only by diffusion. The resolution of the convective-diffusive equation in the near wall region of the microelectrode lead to analytical solutions relying the characteristics length of the micro-probes, the diffusional properties of the electrochemical solution and the wall shear rate.[10] See also Critical resolved shear stress Direct shear test Shear and moment diagrams Shear rate Shear strain Shear strength Tensile stress Triaxial shear test References ^ Hibbeler, R.C. (2004). Mechanics of Materials. New Jersey USA: Pearson Education. p. 32. ISBN 0-13-191345-X. ^ "Strength of Materials". Eformulae.com. Retrieved 24 December 2011. ^ Лекция Формула Журавского [Zhuravskii's Formula]. Сопромат Лекции (in Russian). Retrieved 2014-02-26. ^ "Flexure of Beams" (PDF). Mechanical Engineering Lectures. 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