

# Analogy between Fluid Mechanics and Solid Mechanics

In general, the displacement field for both solids and fluids are represented as:

$$\vec{u} = u_i \hat{e}_i = u_1 \hat{e}_1 + u_2 \hat{e}_2 + u_3 \hat{e}_3$$

Assuming Cartesian coordinate system:

$$\vec{u} = u\hat{i} + v\hat{j} + w\hat{k}$$

Where strain is described as

$$\epsilon_{xx} = \frac{\partial u}{\partial x}, \quad \epsilon_{yy} = \frac{\partial v}{\partial y}, \quad \epsilon_{zz} = \frac{\partial w}{\partial z}, \quad \gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}, \quad \gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}, \quad \gamma_{zx} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}$$

Expressing the strain tensor and displacement vector using differential operator tensor:

$\vec{\epsilon} = \vec{\partial} \vec{u}$  where  $\vec{\sigma} = \vec{D} \cdot \vec{\epsilon}$  [As per Hooke's law for Linear Isotropic Elastic Material]

$$\vec{\epsilon} = \begin{Bmatrix} \epsilon_{xx} \\ \epsilon_{yy} \\ \epsilon_{zz} \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix}, \quad \vec{\sigma} = \begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix}, \quad \vec{D} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 & 0 & 0 \\ \nu & 1-\nu & \nu & 0 & 0 & 0 \\ \nu & \nu & 1-\nu & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1-2\nu}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1-2\nu}{2} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix}$$

Define:

$$\lambda = \frac{2\nu G}{2-2\nu} = \frac{\nu E}{(1+\nu)(1-2\nu)}, \quad G = \frac{E}{2(1+\nu)}$$

$\vec{B}$  = Distributed body force per unit volume

$\rho \vec{u}$  = Inertial forces applicable only when body is accelerating

Equilibrium equations:

$$\frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} + B_x = \rho \ddot{u}, \quad \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} + B_y = \rho \ddot{v}, \quad \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \sigma_{zz}}{\partial z} + B_z = \rho \ddot{w}$$

$$\Rightarrow \vec{\partial}^T \vec{\sigma} + \vec{B} = \rho \vec{u}$$

Where

# Solid Mechanics

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