

# 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:

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

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

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:

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

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

Where

# Solid Mechanics

**Ying Liu**



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## **Table of Contents Solid Mechanics**

1. Understanding the eBook Solid Mechanics
  - The Rise of Digital Reading Solid Mechanics
  - Advantages of eBooks Over Traditional Books
2. Identifying Solid Mechanics
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Solid Mechanics
  - User-Friendly Interface
4. Exploring eBook Recommendations from Solid Mechanics
  - Personalized Recommendations
  - Solid Mechanics User Reviews and Ratings
  - Solid Mechanics and Bestseller Lists
5. Accessing Solid Mechanics Free and Paid eBooks
  - Solid Mechanics Public Domain eBooks
  - Solid Mechanics eBook Subscription Services
  - Solid Mechanics Budget-Friendly Options
6. Navigating Solid Mechanics eBook Formats

- ePub, PDF, MOBI, and More
  - Solid Mechanics Compatibility with Devices
  - Solid Mechanics Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Solid Mechanics
    - Highlighting and Note-Taking Solid Mechanics
    - Interactive Elements Solid Mechanics
  8. Staying Engaged with Solid Mechanics
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Solid Mechanics
  9. Balancing eBooks and Physical Books Solid Mechanics
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Solid Mechanics
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Solid Mechanics
    - Setting Reading Goals Solid Mechanics
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Solid Mechanics
    - Fact-Checking eBook Content of Solid Mechanics
    - Distinguishing Credible Sources
  13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development
    - Exploring Educational eBooks
  14. Embracing eBook Trends
    - Integration of Multimedia Elements
    - Interactive and Gamified eBooks

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