Date : Sep 6th, 2017

Mechanisms of Momentum Transport

Associated Readings: BSL 1.1, 1.2 and 1.7

Basic Definitions

Molecular Momentum Transport Due to molecular interactions

Fluid property determining this transport, μ = viscosity

Convective Momentum Transport → Transport of momentum due to bulk flow, fluid property : ρ = density

1. Newton's Law of Viscosity (Molecular Momentum Transport)

No slip condition → Relative velocity for a viscous fluid in contact with solid surface is zero.

REFER TO Other notes on Mechanisms of Momentum Transport

2. <u>Generalization of Newton's Law of Viscosity</u>: We generally encounter 3 dimensional flows in real situations, so we need to have a general form of equation that captures the role of viscosity in momentum transfer in fluid flow. This generalization involves some assumptions which needs to be emphasized (and remembered) when using the equation.

   Consider a very general flow pattern:

   There are two basic steps in this generalization approach: a) identifying all the forces that are acting on a fluid particle in general case and b) relating these forces to the velocity gradient in order to derive a relationship between forces and velocity profile. We will go over each of these steps now.

   Step a : Types of Forces in a Fluid in Motion

   Pressure and Viscous Forces

Step b : Relating the forces to velocity gradients

This is the part where generalization happens when we identify 81 coefficients. Assumptions then reduces it to 2 coefficients. We do not need to consider all the math underpinnings for this result.

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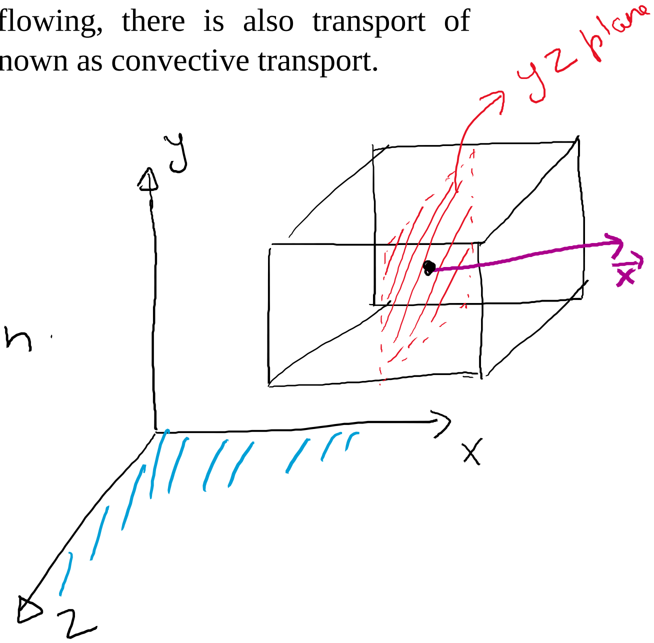
3. <u>Convective Momentum Transport:</u> When a fluid is flowing, there is also transport of momentum due to bulk flow (mixing) of fluid which is known as convective transport.

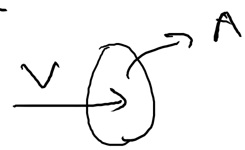


velocity in x-direction of fluid is v_x

→ Consider unit area of yz plane ⊥ar to which is the x direction.

Volumetric flow rate

$= v \times A$ on



$= \left(\frac{l}{time}\right) \times A$

$=$ Volume/time

Volumetric flow rate through yz plane of unit area

$= v_x$

Mass flow rate through yz plane of unit area

$= (\rho v_x)$

Convective Momentum transferred in <u>x-direction</u> due to x velocity

$= (\underline{\rho v_x} v_x)$

⊥ar to y-direction

$(\rho v_y) v_x$

$(\rho v_y) v_y$

$(\rho v_y) v_z$

ρv_y

ρv_z

$\rho \vec{v} \vec{v}$

$\underline{v_x}, v_y \; v_z$

General Expression for convective momentum transport

$= \rho \vec{v}\vec{v}$ (it will have 9 components) See table 1.7-1 in book)

Total Momentum transport

$$\underline{\Phi} = \underbrace{\pi}_{\text{molecular}} + \underbrace{\rho \vec{v}\vec{v}}_{\text{convect}}$$

$$\underline{\Phi}_{ij} = p\vec{\delta}_{ij} + \tau_{ij} + \rho \vec{v}\vec{v}$$

$\underline{\Phi}_{ij}$ = combined momentum flux of j^{th} momentum across a surface perpendicular to i^{th} direction due to molecular and convective mechanisms.