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Chapter 4
CONSERVATION OF MOMENTUM
(Forces Due to Fluids in Motion)

by
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Learning Outcomes

Upon completing this chapter, the students are expected to be able to:

1. *State the concept of conservation of momentum.*
2. *Derive the general momentum equation.*
3. *Calculate the force of moving fluid on stationary plane plate.*
4. *Calculate the force of moving fluid on stationary curved blades/vanes.*
5. *Calculate the force of flowing fluid in pipe bends.*

4.1) Introduction

- Conservation of momentum – another conservation law comparable to conservation of mass.
- Momentum cannot be created or destroyed.
- During fluid motion, some of the momentum may be converted into impulse-force.
- Momentum = mass x velocity ($M = mv$)

4.2) Momentum Equation

- Conservation of momentum that utilized the Newton's second law for a flowing fluid leads to the derivation of momentum equation.

- The total forces of fluid acting in the flow direction are equal to the rate of change of momentum of the fluid flow.

$$\sum F = \frac{\Delta M}{\Delta t} = \frac{m(\Delta v)}{\Delta t}$$

Since $\overset{o}{m} = \frac{m}{\Delta t}$, then

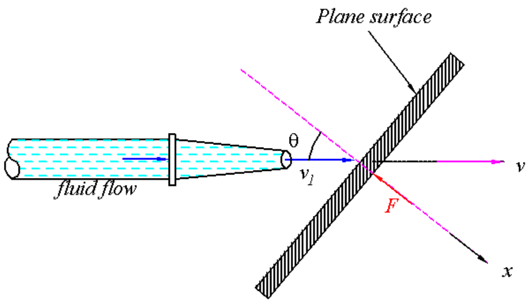
$$\sum F = \overset{o}{m}(v_2 - v_1)$$

$$\boxed{\sum F = \rho Q(v_2 - v_1)}$$ ⟵ **Momentum equation**

where v_1 = flow velocity coming into the control volume.
v_2 = flow velocity going out of the control volume.

4.3) Force of Moving Fluid on Plane Surfaces

4.3.1) Stationary Surfaces



where

θ = angle between the fluid flow and the line perpendicular to the plate.

F_x acts normal to the plate.

Using momentum equation, $F_x = \rho Q(v_{2x} - v_{1x})$

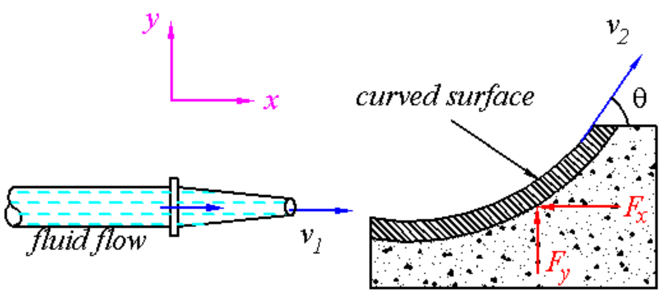
$$F_x = \rho Q(0 - v_1 \cos\theta) \quad \longleftarrow \quad \text{plane plate, } v_2 = 0$$

4.3.2) Moving Surfaces

- Not in the Syllabus -

4.4) Force of Moving Fluid on Curved Blades/Vanes

4.4.1) Stationary Blades



Turbine curved blades.

v_1 = fluid velocity approaching the blade (or vane)
v_2 = fluid velocity leaving the blade (or vane)
Two force components:

(i) x – component

$$F_x = \rho Q(v_{2x} - v_{1x})$$

$$F_x = \rho Q(v_2 \cos\theta - v_1)$$

(ii) y – component

$$F_y = \rho Q(v_{2y} - v_{1y})$$

$$F_y = \rho Q(v_2 \sin\theta - 0)$$

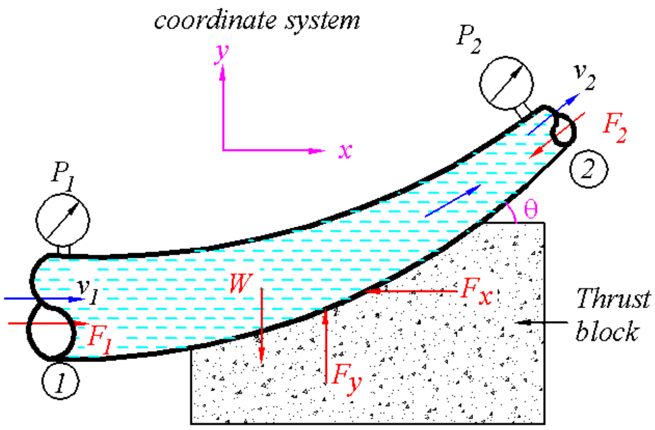
(iii) Resultant Force

$F = \sqrt{F_x^2 + F_y^2}$ at an angle $\alpha = \tan^{-1}\left(\frac{F_y}{F_x}\right)$ from horizontal

4.4.2) Moving Blades

- Not in the Syllabus -

4.5) Force of Flowing Fluid on Pipe Bends



Two force components:

(i) x – Component

$$\sum F_x = \rho Q(v_{2x} - v_{1x})$$

$$F_1 - F_x - F_2 \cos\theta = \rho Q(v_2 \cos\theta - v_1)$$

$F_2 = P_2 A_2$ (due to pressure at 2)

$F_1 = P_1 A_1$ (due to pressure at 1)

(ii) ***y*** **– Component**

$$\sum F_y = \rho Q(v_{2y} - v_{1y})$$

$$F_y - W - F_2 \sin\theta = \rho Q(v_2 \sin\theta - 0)$$

$W = \rho g V$ (weight of fluid in the pipe bend)
(True when the pipe bend is installed in **vertical plane**, that is *y* vertical and *x* horizontal)

V = volume of the pipe bend

Note: ***W*** **= 0** if the pipe bend is installed in **horizontal plane** (*x* horizontal and *y* also horizontal).

4.6 The PIPEBEND Computer Program

PIPEBEND stands for Pipe Bend is a medium sized executable computer program to solve forces problems on pipe bends. It is developed by Mr. Amat Sairin Demun using MS DOS based Fortran programming language. It is able to calculate the forces and the reaction forces of fluid flow acting on different orientations and conditions of pipe bends. The students can copy the file from Mr. Amat Sairin Demun at no cost. To run the computer program, the students will have to double click the PIPEBEND file and just follow the instructions appear on the computer screen. If you have difficulties running the computer program, please feel free to contact Mr. Amat Sairin Demun.