FDE 205 FLUID MECHANICS

Chapter 3. Principles of Momentum Transfer and Applications

1) FLOW PAST IMMERSED OBJECTS
(BATIK OBJELER ÜZERİNDE (ETRAFINDA) AKIŞ)

2) FLOW IN PACKED BEDS
(DOLGULU YATAKLARDA AKIŞ)

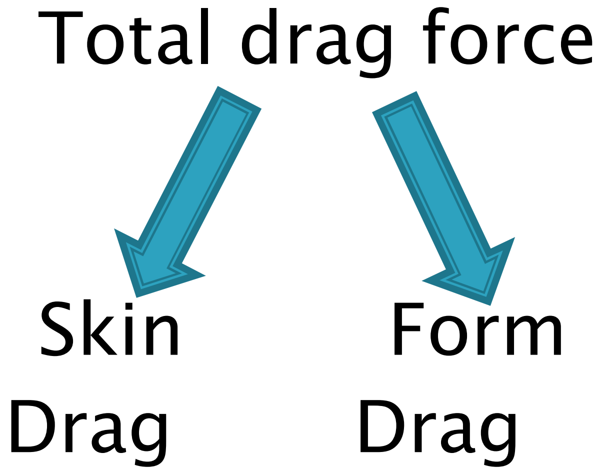
3) FLOW IN FLUIDIZED BEDS
AKIŞKAN YATAKLARDA AKIŞ

FLOW PAST IMMERSED OBJECTS

- We were concerned primarily with the momentum transfer and frictional losses for flow of fluids inside conduits or pipes.
- In this section we will consider the flow of fluid around solid, immersed objects.
- The flow of fluid outside immersed bodies appears in many engineering applications.
- Eg., flow through packed beds in drying, and filtration, flow past tubes in heat exchangers.

- When a fluid flows over a solid surface, it applies a force on the solid surface in the direction of flow. This force exerted by the fluid can be named as skin or wall drag (yüzey veya duvar sürüklemesi)
- For any surface in contact with a flowing fluid, skin friction will exist.
- In addition to skin friction, if the fluid is not parallel to the surface but must change direction to pass around a solid body such as a sphere, significant additional frictional losses will occur; This is called form drag. (Buna ek olarak akışkan eğer yüzeye paralel akmıyorsa veya geçiş için yön değiştirmesi gerekiyorsa ilave sürtünme kayıpları oluşur. Bu kayıplara şekil sürüklemesi denir).

- The total of these two forces is called total drag force (toplam sürükleme kuvveti).



Drag coefficient (Sürükleme katsayısı)

- The geometry of the solid is very important while determining the drag force.

$$C_D = \frac{F_D / A_p}{\rho v_0^2 / 2}$$

C_D: Drag coefficient (dimensionless)

F_D: Total drag force (N)

A_p: Projection Area (m^2)

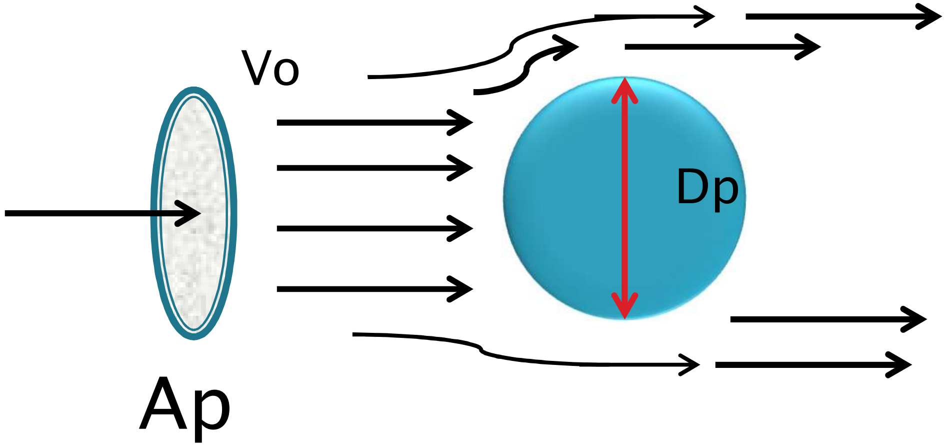
v_0: Free stream velocity (m/s)

ρ: Density of the fluid (kg/ m^3)

- The geometry of the solid is very important while determining the drag force since it is effective on projection area in the formula.

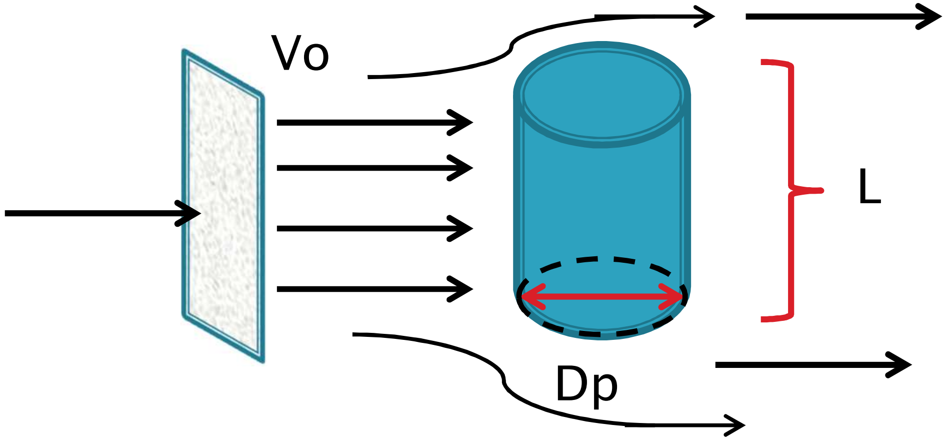
- The projection area is the area obtained by projecting the body on a plane perpendicular to the line of flow. (İzdüşüm alanı, cismin akış çizgisine dik düzlem üzerine yansıtılarak elde edilen alandır).

For sphere:



$$A_p = \frac{\pi D_p^2}{4}$$

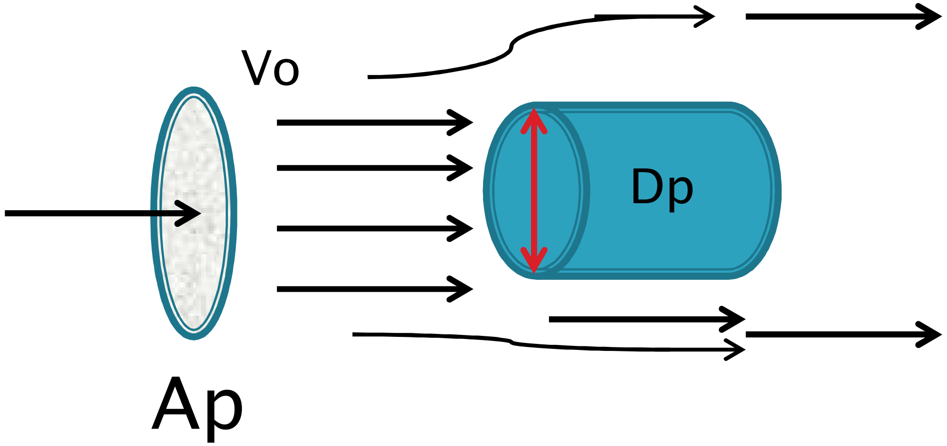
For perpendicular cylinder:



$$A_p = LD_p$$

Ap

For horizontal cylinder:



$$A_p = \frac{\pi D_p^2}{4}$$

- The total drag force can be calculated by:

$$F_D = C_D \frac{v_0^2}{2} \rho A_p$$

- The Reynolds number for a given solid immersed in a flowing liquid:

$$\mathrm{Re} = \frac{D_P v_0 \rho}{\mu}$$

Flow past sphere, long cylinder and disk

- For each particular shape of object and orientation of the object with respect to the direction of flow, a different relation of C_D versus Re exists. (Figure 3.1-2)

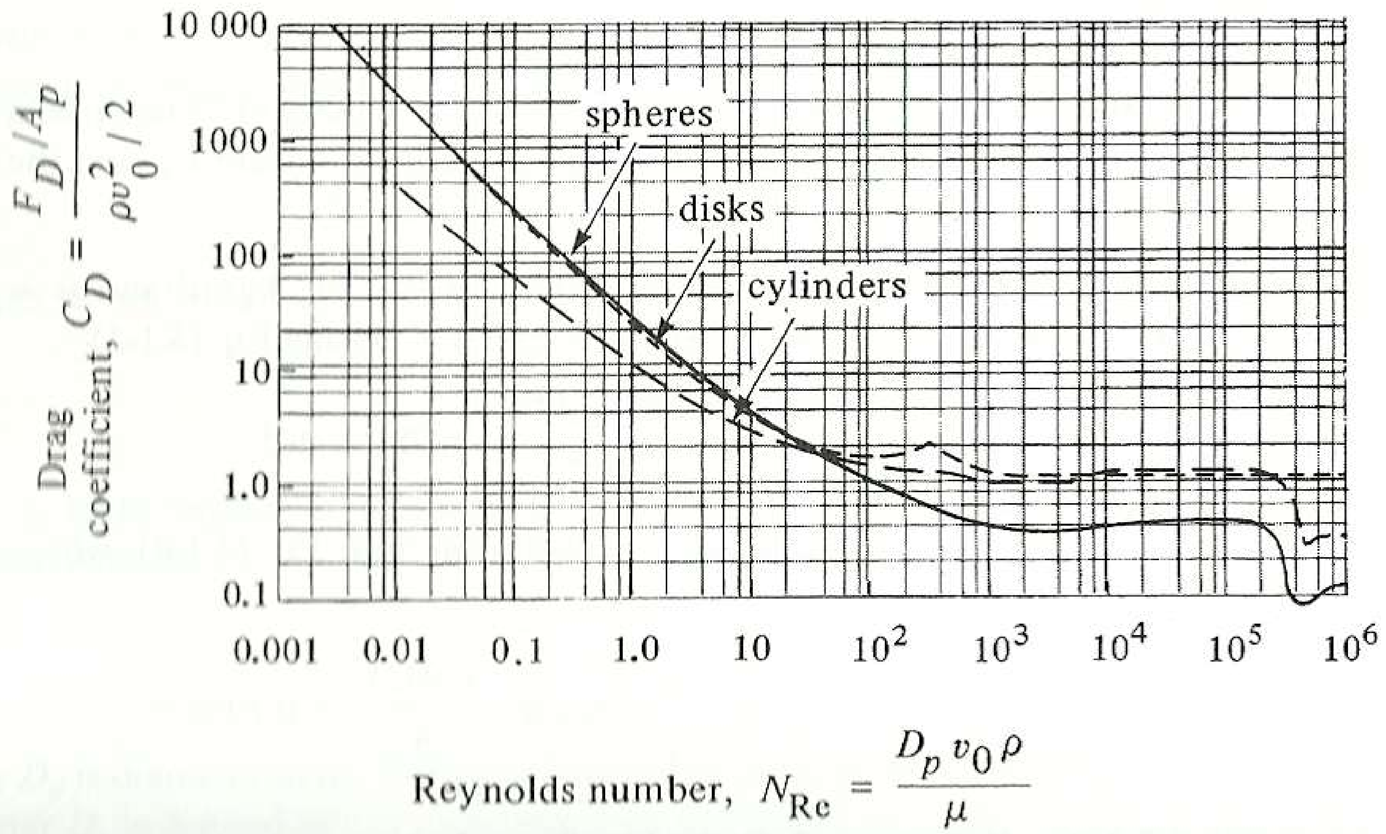
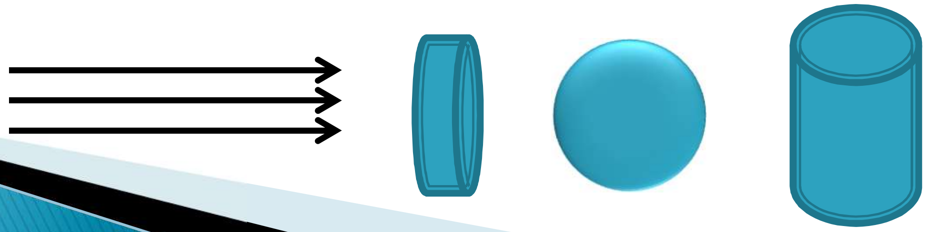


FIGURE 3.1-2. *Drag coefficients for flow past immersed spheres, long cylinders, and disks. (Reprinted with permission from C. E. Lapple and C. B. Shepherd, Ind. Eng. Chem., 32, 606 (1940). Copyright by the American Chemical Society.)*



The surface of the disc and the axis of the cylinder is perpendicular to the flow.

- These curves have been determined experimentally. However in the laminar region for low Re numbers, less than about 1, the experimental drag force for a sphere is the same as the theoretical Stokes Law equation as follows:

$$F_D = 3\pi\mu D_p v_0$$

$$F_D = 3\pi\mu D_p v_0$$

$$A_p = \frac{\pi D_p^2}{4}$$

$$C_D = \frac{F_D / A_p}{\rho v_0^2 / 2}$$

$$C_D = \frac{24}{\text{Re}}$$

Reynold Sayısı 1'den küçük durumlar için geçerli

Example:

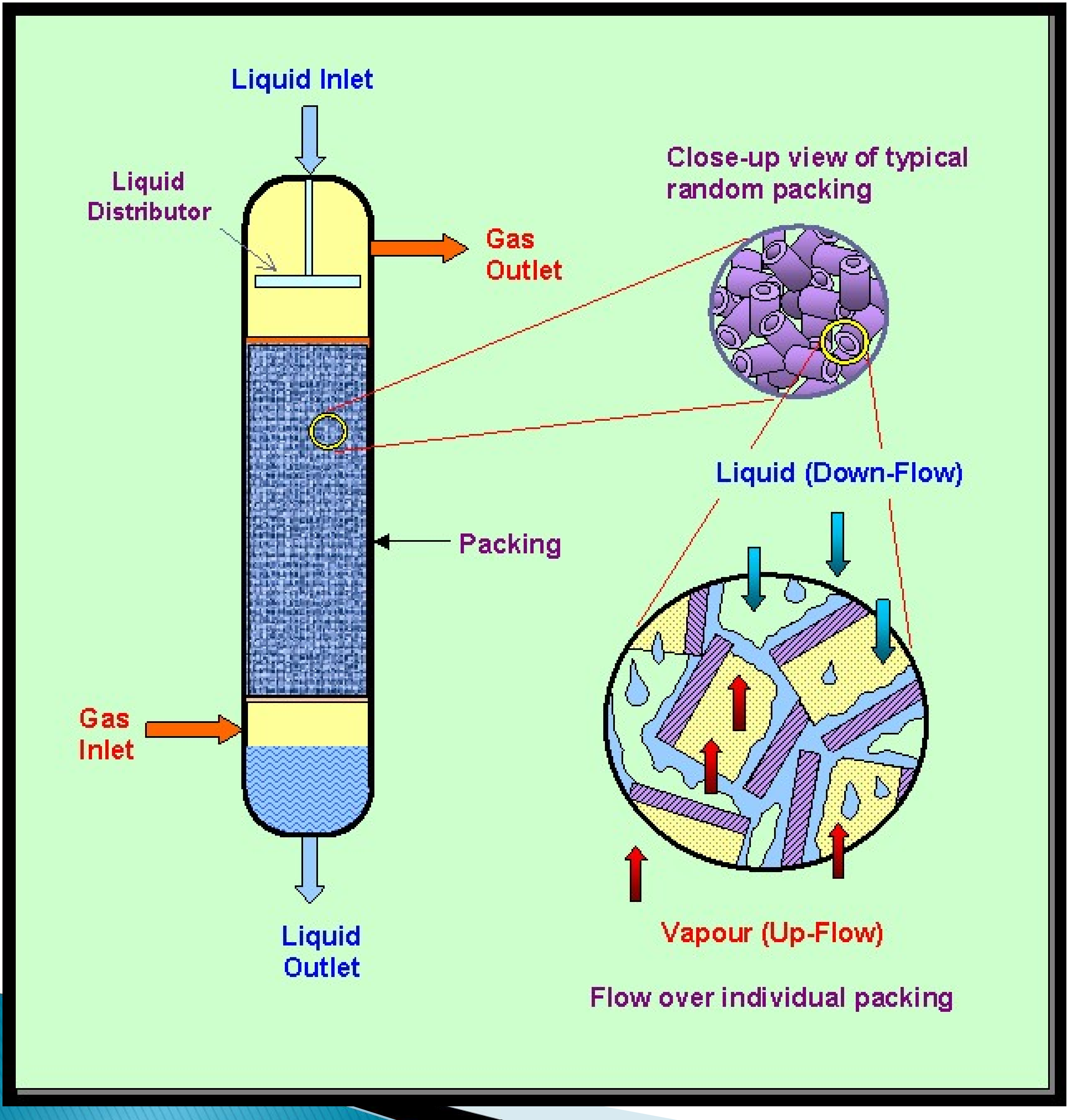
- Air at 37.8°C and 101.3 kPa absolute pressure flows at a velocity of 23 m/s past a sphere having a diameter of 42 mm. What are the drag coefficient and the force on the sphere?

Example:

- Water at 24°C is flowing past along a cylinder at a velocity of 1.0 m/s in a large tunnel. The axis of the cylinder is perpendicular to the direction of the flow. The diameter of the cylinder is 0.09m. What is the force per meter length on the cylinder?

Flow in Packed Bed

- In chemical processing, a packed bed is a hollow tube, pipe, or other vessel that is filled with a packing material.
- The purpose of a packed bed is typically to improve contact between two phases in a chemical or similar process. Packed beds can be used in a chemical reactor, a distillation process, or a scrubber.


Liquid Inlet
Liquid
Distributor
Gas
Outlet
Close-up view of typical
random packing
Liquid (Down-Flow)
Packing
Gas
Inlet
Liquid
Outlet
Vapour (Up-Flow)
Flow over individual packing

Packing Material

- Packing material can be in different size, shape and geometry depending on the process.

Flow in Packed Bed

- Certain geometric relations for particles in packed beds are used in the derivation for flow.
- Void fraction: (Boşluk kesri)

$$\varepsilon = \frac{\text{Yataktaki boşlukların toplam hacmi}}{\text{Yatağın toplam hacmi}}$$

$$\frac{\text{Volume of voids in bed}}{\text{Total volume of voids (voids and solids)}}$$

- The specific surface of a particle (Taneciğin (dolgu malzemesinin) özgül yüzey alanı)
- $a_v \quad (m^{-1})$

$$a_v = \frac{S_p}{V_p}$$

S_p : surface area of a particle (m^2)

V_p : the volume of a particle (m^3)

- The specific surface area of a spherical particle
- Küresel bir tanecik için özgül yüzey alanı:

$$a_v = \frac{4\pi r^2}{\frac{4}{3}\pi r^3} = \frac{3}{r} = \frac{3}{D_p/2} = \frac{6}{D_p}$$

- Effective particle diameter for non-spherical objects (Küresel olmayan dolgu malzemeleri için etkin tanecik çapı): (m)

$$D_p = \frac{6}{a_v}$$

- Є : void fraction in packed bed (boşluk kesri)
- (1– Є) : volume fraction of particles in the bed (dolgulu yatakdaki tanecikler tarafından doldurulan hacim kesri olduğuna göre)

$$a: \quad \frac{\text{toplam tanecik yüzey alanı}}{\text{yatağın toplam hacmi}} \ (m^{-1})$$

a is the ratio of total surface area in the bed to total volume of bed

$$a = a_v(1-\varepsilon) = \frac{6}{D_p}(1-\varepsilon)$$

Example 3.1-3

- A packed bed is composed of cylinders having a diameter D=0.02 m and a length h= D. The bulk density of the overall packed bed is 962 kg/m^3 and the density of solid cylinders is 1600 kg/m^3:

a) Calculate the void fraction

b) Calculate the effective diameter of the particles

c) Calculate the value *a*

Hint: do the calculations for a unit volume (birim hacimdeki dolgulu yatak için hesaplamaları yapınız)