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# FLUIDIZED BED

## INTRODUCTION

The flow of fluids outside immersed bodies appears in many engineering applications and other processing applications. It is useful to be able to predict the frictional losses and/or the force on the submerged objects in these various applications.

### Types of fluidization in beds:

In a packed bed of small particles, when a fluid enters at sufficient velocity from the bottom and passes up through the particles, the particles are pushed upward and the bed expands and becomes fluidized. Two general types of fluidization, *particulate fluidization* and *bubbling fluidization* can occur.

In particulate fluidization, as the fluid velocity is increased the bed continues to expand and remains homogenous for a time. The particles move farther apart and their motion becomes more rapid. The average bed density at a given velocity is the same in all regions of the bed. An example is catalytic cracking catalysts fluidized by gases. This type of fluidization is very desirable in promoting intimate contact between the gas and solids. Liquids often give particulate fluidization.

In bubbling fluidization, the gas passes through the bed as voids or bubbles which contain few particles and only a small percentage of the gas passes in the spaces between individual particles. The expansion of the bed is small as gas velocity is increased. Sand and glass beads provide examples of this behavior. Since most of the gas is in bubbles, little contact occurs between the individual particles and the bubbles.

Another type of behavior, called slugging, can occur in bubbling since the bubbles tend to coalesce and grow as they rise in the bed. If the column is small in diameter with a deep bed, bubbles can become large and fill the entire cross section and travel up the tower separated by slugs of solid (Geankoplis, 2003).

### Minimum velocity and porosity for fluidization:

When a fluid flows upward through a packed bed of particles at low velocities, the particles remain stationary. As the fluid velocity is increased, the pressure drop increases according the Ergun equation (Eq.1). Upon further increases in velocity, conditions finally occur where the force of the pressure drop times the cross-sectional area just equals the gravitational force on the mass of particles minus the buoyant force of the displaced fluid. When the particles just begin to move, this is the onset of fluidization or minimum fluidization. The gas velocity at which fluidization begins is the minimum fluidization velocity $v'_{mf}$ in m/s based on the empty cross section of the tower (superficial velocity) (Geankoplis, 2003; McCabe et a., 1985; Perry et al., 1997).

$$\frac{\Delta P}{\Delta L} = \frac{150\mu v'(1-\varepsilon)^2}{\phi^2 D_p^2 \varepsilon^3} + \frac{1.75\rho(v')^2(1-\varepsilon)}{\phi D_p \varepsilon^3} \qquad (1)$$

Where; ΔP is pressure drop, Pa; L is the height of the bed, m; ν is the velocity of the fluid based on empty bed cross-section, m/s; ε is the porosity, ρ is the density of the fluid, kg/m$^3$; μ is the viscosity of the fluid, kg/m.s; $D_p$ is the diameter of the particles, m and ϕ is sphericity.

Porosity is the ratio of volume of voids to volume of bed. Many particles in beds are often irregular in shape. The equivalent diameter of a particle is defined as the diameter of a sphere having same volume as this particle. The sphericity shape factor ϕ of a particle is the ratio of the surface area of this sphere having the same volume as the particle to the actual surface area of the particle.

The porosity of the bed when the true fluidization occurs is the minimum porosity for the fluidization and is $\varepsilon_{mf}$. The bed expands to this voidage or porosity before particle motion appears. This minimum voidage can be experimentally determined by subjecting the bed to a rising gas stream and measuring the height of the bed $L_{mf}$, m. Generally, it appears best to use gas as the fluid rather than a liquid since liquids give somewhat higher values of $\varepsilon_{mf}$.

As stated earlier, the pressure drop increases as the gas velocity is increased until the onset of minimum fluidization. Then as the velocity is further increased, the pressure drop decreases very slightly and then remains practically unchanged as the bed continues to expand or increase in porosity with increases in velocity. The bed resembles a boiling liquid. As the bed expands with increase in velocity, it continues to retain its top horizontal surface. Eventually, as the velocity is increased much further, entrainment of particles from the actual fluidized bed becomes appreciable.

The relation between bed height L and porosity ε is as follows for a bed having a uniform cross-sectional area A. Since the volume LA(1- ε) is equal to the volume of solids if they existed as one piece (Geankoplis, 2003; McCabe et a., 1985).

$$L_1 A(1-\varepsilon_1) = L_2 A(1-\varepsilon_2) \qquad (2)$$

Where $L_1$ is height of the bed with porosity $\varepsilon_1$ and $L_2$ is height with porosity $\varepsilon_2$.

**Pressure drop and minimum fluidizing velocity:**

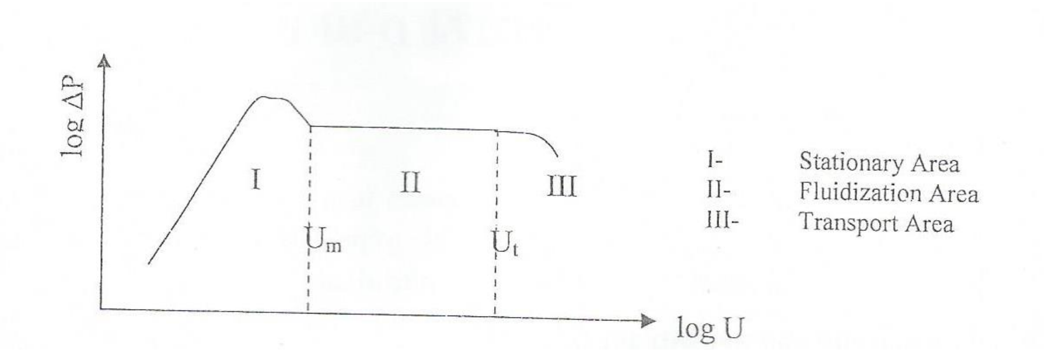
The force obtained from the pressure drop times the cross sectional area must equal the gravitational force exerted by the mass of the particles minus the buoyant force of the displaced fluid (Geankoplis, 2003; McCabe et a., 1985).

$$\Delta P = L_{mf}(1-\varepsilon_{mf})(\rho_p - \rho)g \tag{3}$$

The minimum fluidization speed can be calculated by Equation 4 which is the combination of Equations 1 and 3.

$$\frac{1.75(N_{\mathrm{Re},mf})^2}{\phi\varepsilon_{mf}^3} + \frac{150(1-\varepsilon_{mf})(N_{\mathrm{Re},mf})}{\phi^2\varepsilon_{mf}^3} - \frac{D_p^3\rho(\rho_p-\rho)g}{\mu^2} = 0 \tag{4}$$

$$N_{\mathrm{Re},mf} = \frac{D_p v'_{mf}\rho}{\mu} \tag{5}$$



## OBJECTIVE

The objective of the experiment is to investigate the fluidization phenomena and to compare the experimental results for the variation of pressure loss as a function of fluid velocity, with the theoretical values in a laboratory scale fluidized bed.

## EXPERIMENTAL PROCEDURE

### Apparatus:

The fluidization system contains a fan which supplies air to the system, a valve for adjusting the air speed and U-manometer. The liquid in the manometers is water. Pressure loss in the bed can be measured by the U-manometer which is connected between beginning and end of the bed. Materials in the bed are green coffee particles.

**Set-up:**

1. Control the electrical connections of the bed.
2. Open the valve partially.
3. Control the air flow rate by observing the manometer.
4. Close the valve slowly until observing a one or two centimeter difference on the manometer.
5. Starting from this point, open the valve gradually for 10 different positions.

**Data to be recorded:**

Record pressure difference in the U-manometer, velocity of air and height of the bed for 10 different positions

## CALCULATIONS AND CONCLUSION

1. Plot the graph between air velocity and pressure drop in bed (Experimental log P vs log $\nu$)
2. Plot the graph between air velocity and theoretical pressure drop (Theoretical log P vs log $\nu$)
3. Calculate the minimum fluidization velocity ($\nu_{mf}$) and compare it with experimental $\nu_{mf.}$

## FURTHER STUDY

Write your recommendations to minimize the errors during experiment.

## REFERENCES

Geankoplis, C.J., 2003. Transport Processes and Separation Process Principles, 4th Ed., Prentice Hall, USA.

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