Chemical and Catalytic Reaction Engineering

Practical 10 (second part) – a.a. 2023-2024

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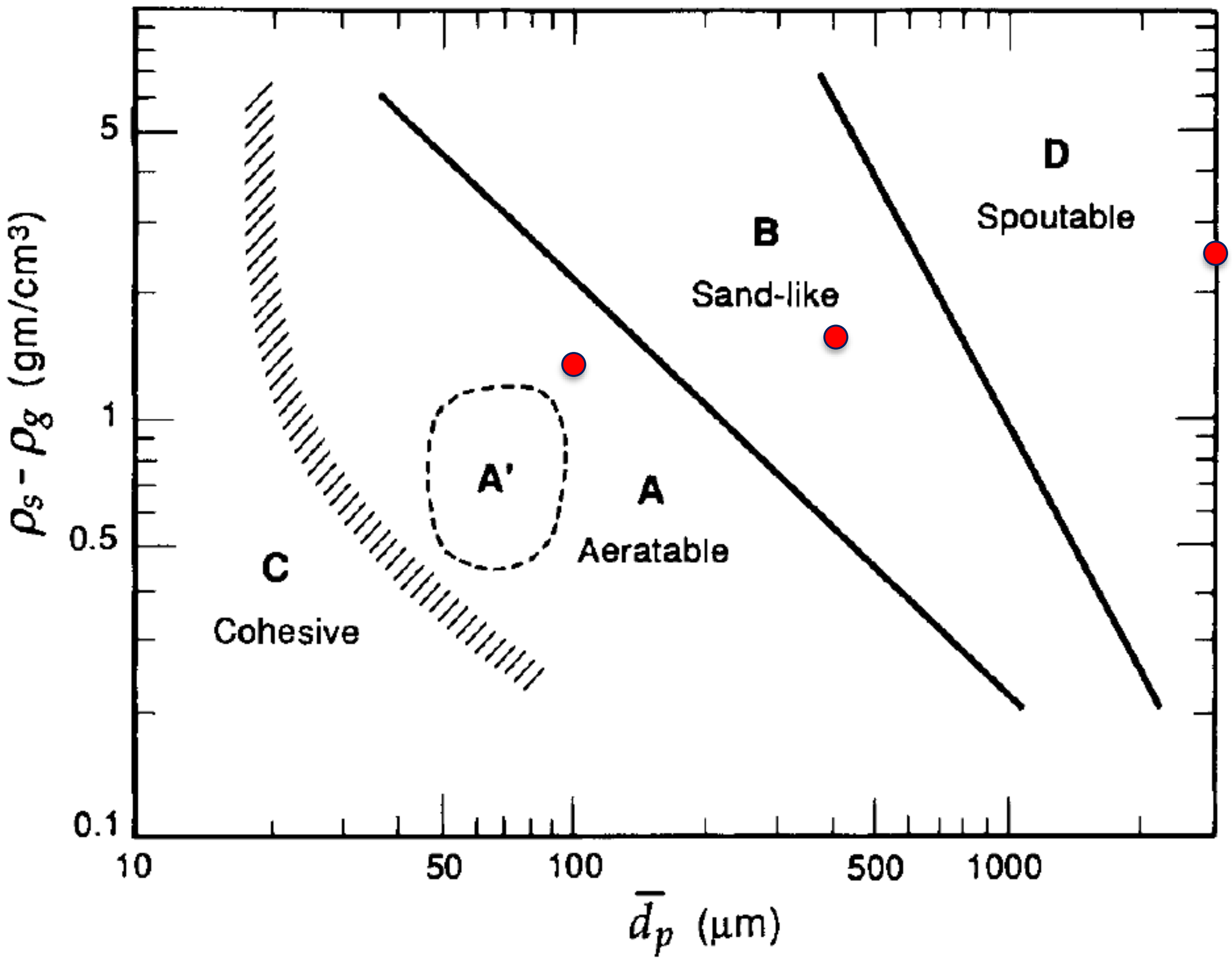
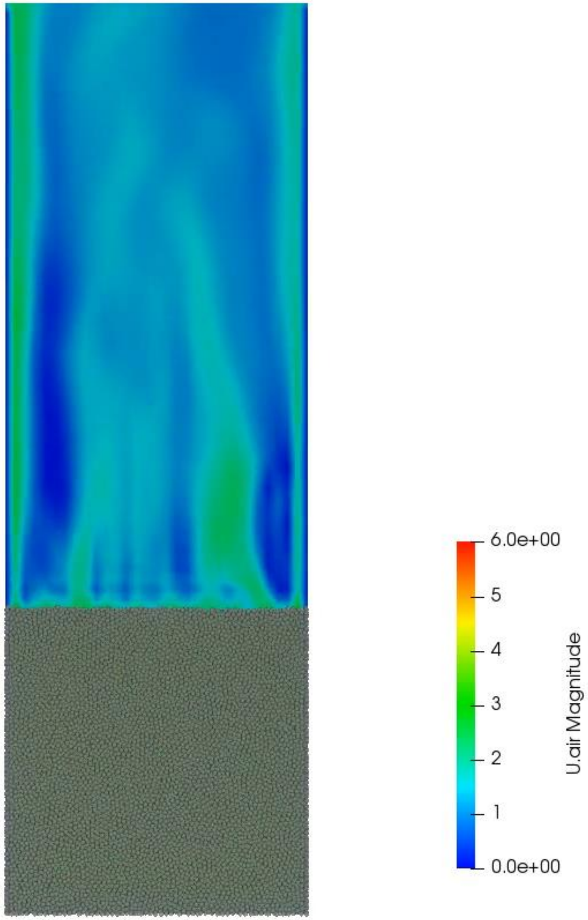
Particle Characteristic: Geldart Classification



We will investigate three different kind of particles each one belonging to a different Geldart Class and reported in Figure by a red circle.

Geldart D particles

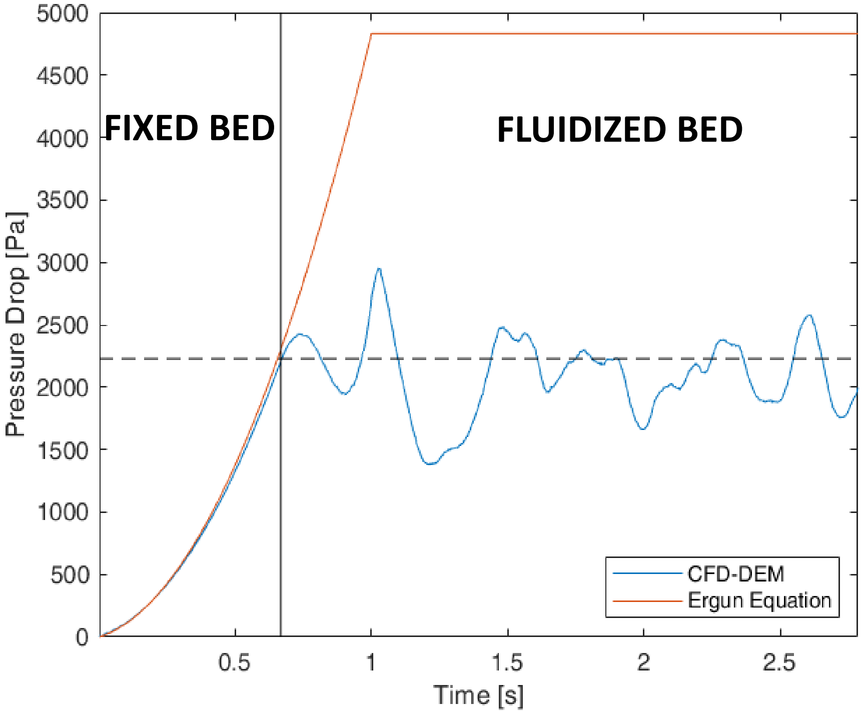


- **Large and dense particles**. The beds composed by these particles are **difficult to fluidize**, thus **high flow rates and minimum fluidization velocities are required** (in the order of m/s). Large bubbles are easily formed

- **Bubble rise velocity is lower than the one of the gas percolating through the emulsion**

- **They are undesirable for chemical operations** (high flow rate and poorer mixing with respect to finer particles) but **sometimes they cannot be avoided** when products are growing on the particles, e.g. in polimerizations

Geldart D particles



- **The drag exerted** by the gas on these kind of particles is prevalently related to **inertial forces**

- Therefore the Ergun equation shows a **parabolic dependence of reactor pressure drops on the inlet velocity** and in this case time (since velocity increases linearly with time from 0 to 1.5 Umf in 1s in the plot at the left)

$$\Delta P = \frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\boxed{\frac{150(1-\varepsilon)\mu}{d_p} U} + \boxed{1.75\rho_g U^2} \right) \cdot H_{bed}$$

VISCOUS CONTRIBUTION

INERTIAL CONTRIBUTION

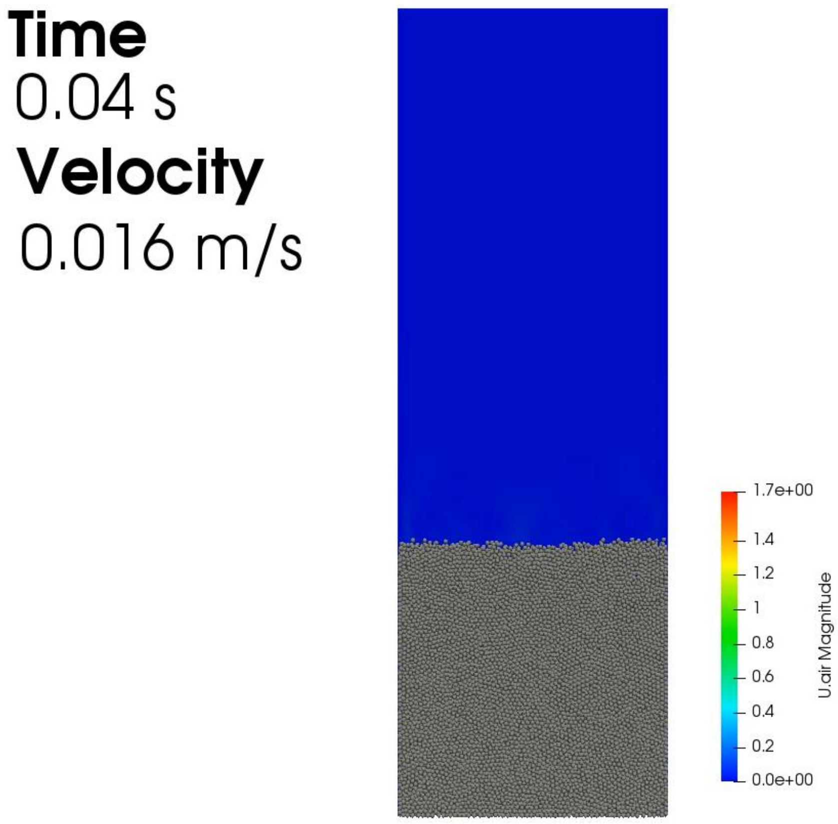
Class B particles

- **Fine «sand-like» particles**. The beds composed by these particles is easy to fluidize, thus **lower flow rates and minimum fluidization velocities are required** (in the order of few cm/s).

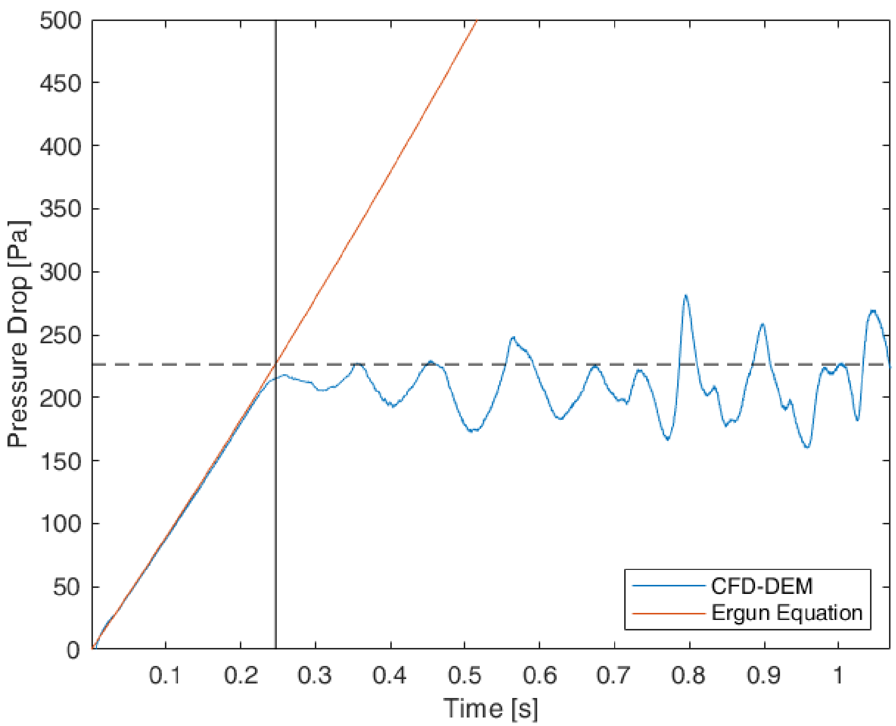
- **Bubble rise velocity is higher than the one of the gas percolating through the emulsion**

- **<u>The bed starts to bubble as soon as minimum fluidization condition is achieved</u>.** Bubble size grows roughly linearly with the distance from the inlet of the reactor. Smaller multiple bubbles are obtained with respect to D particles.

- **They are suitable for chemical operations**



Class B particles



- **The drag exerted** by the gas on these kind of particles is prevalently related to **viscous forces**
- Therefore the Ergun equation shows a **linear dependence of reactor pressure drops on the inlet velocity** and in this case time (since velocity increases linearly with time from 0 to 6 Umf in 1s in the plot at the left)

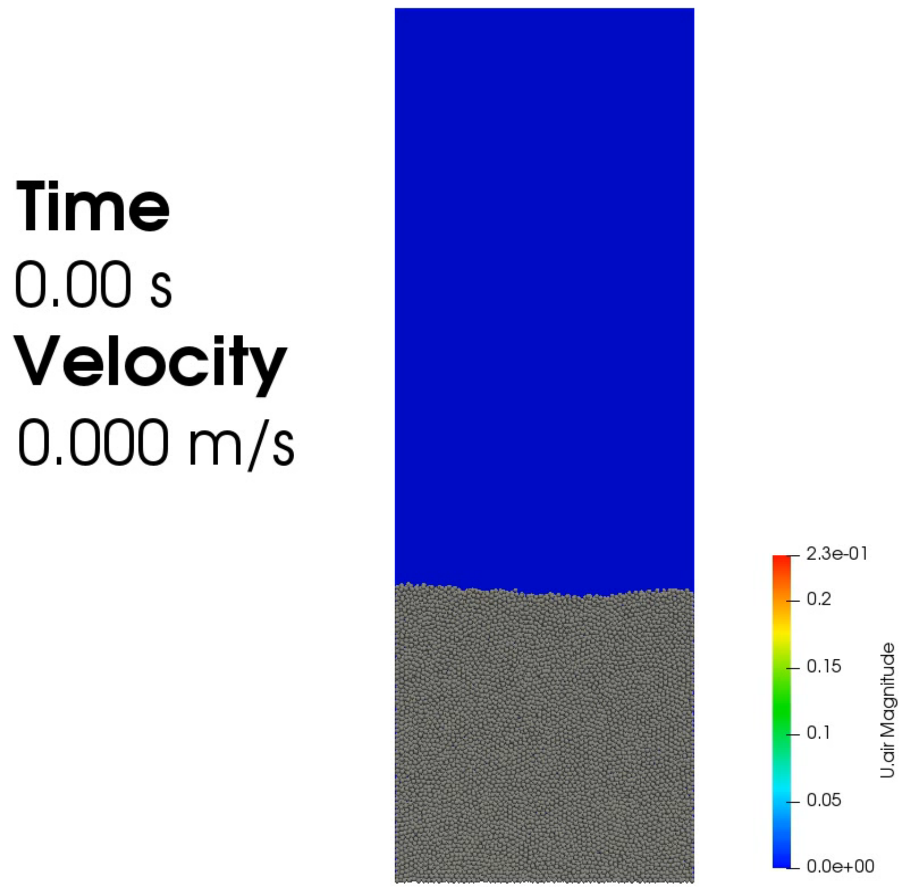
$$\Delta P = \frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\boxed{\frac{150(1-\varepsilon)\mu}{d_p} U} + \boxed{1.75 \rho_g U^2} \right) \cdot H_{bed}$$

VISCOUS CONTRIBUTION

INERTIAL CONTRIBUTION

Geldart A

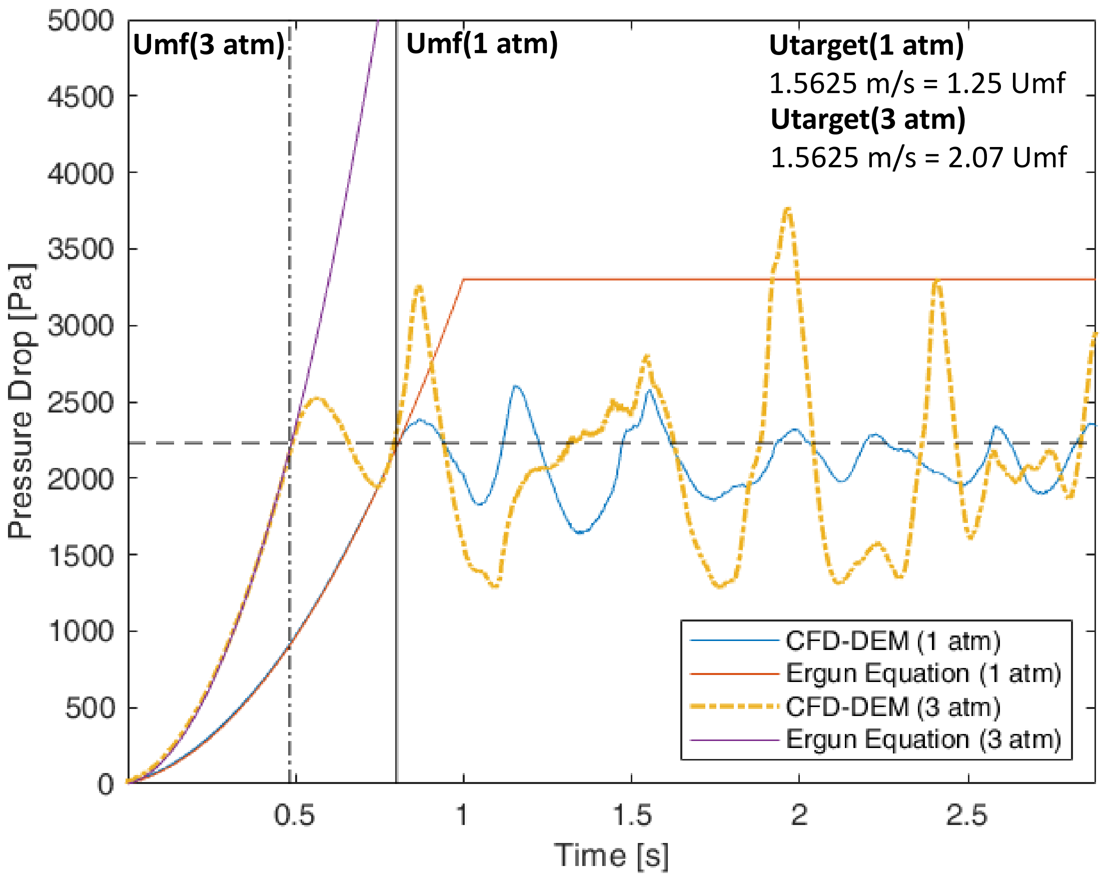
- **Fine aeratable particles**. The beds composed by these particles is easy to fluidize, thus **lower flow rates and minimum fluidization velocities are required** (in the order of few mm/s).
- Bubble rise velocity is higher than the one of the gas percolating through the emulsion
  - **A higher number of smaller bubbles** are observable **with respect to B particles**. Moreover, **the bed first homogeneously expand** just above minimum fluidization and, **then, starts to bubble above minimum bubbling velocity.**
- **They are suitable for chemical operations**



Minimum Fluidization Point (Geldart D): Pressure Dependence

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75 \rho_g U^2 \right) \cdot H_{bed} = m_{cat} g / A$$

Minimum Fluidization Point (Geldart D): Pressure Dependence



$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = m_{cat} g / A$$

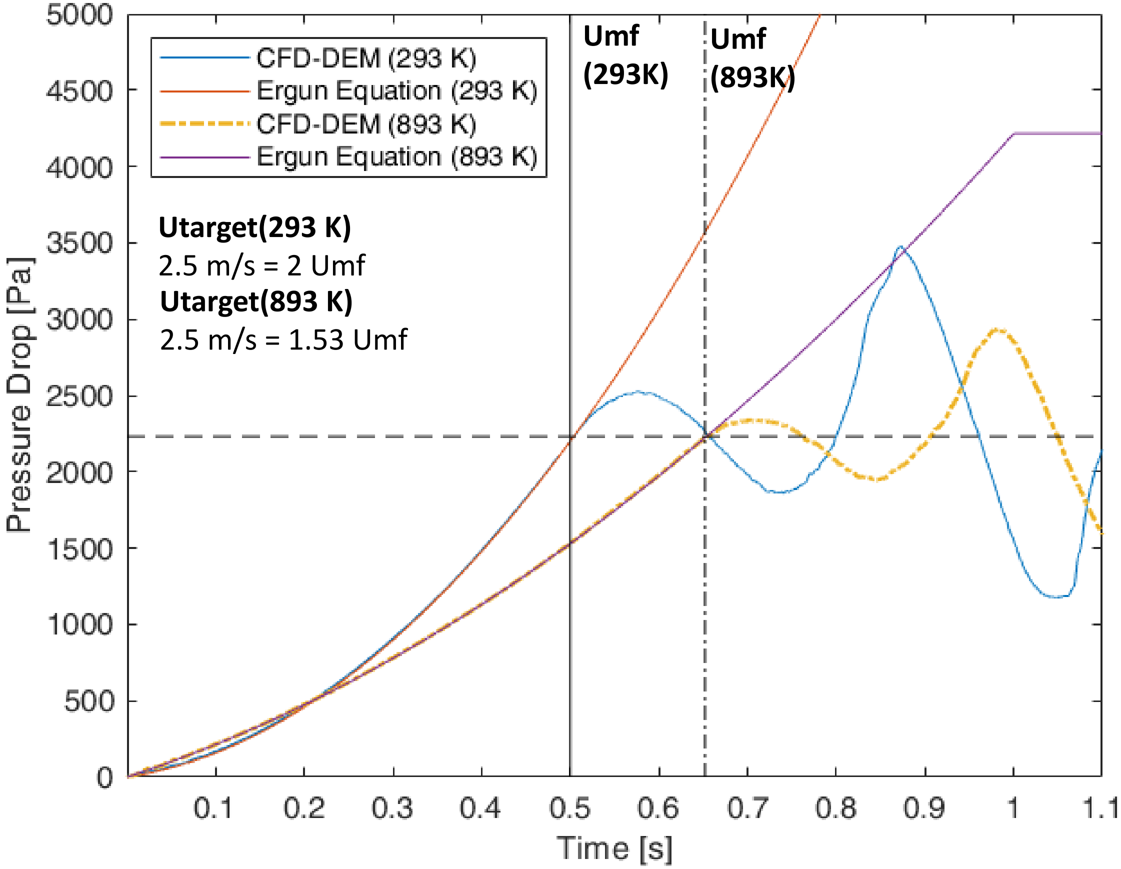
- The **weight** of the bed **does not change** with pressure
- The **density** of the gas **increases** linearly with pressure
- The **viscosity** of a gas is **poorly influenced by pressure**.

As a consequence the minimum fluidization velocity can only decrease with a pressure increment

Minimum Fluidization Point (Geldart D): Temperature Dependence

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = m_{cat} g / A$$

Minimum Fluidization Point (Geldart D): Temperature Dependence



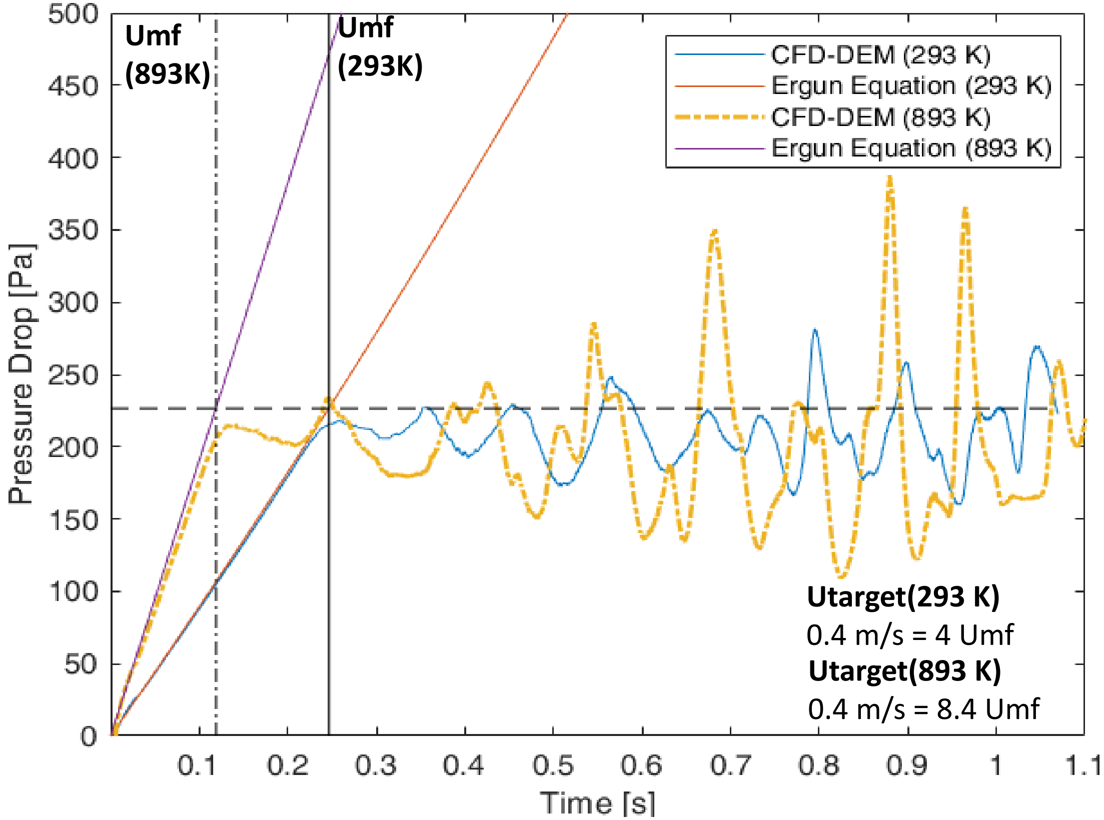
$$\frac{1}{d_p}\cdot\frac{1-\varepsilon}{\varepsilon^3}\cdot\left(\frac{150(1-\varepsilon)\mu}{d_p}U+1.75\rho_g U^2\right)\cdot H_{bed}=m_{cat}g/A$$

- The **weight** of the bed **does not change** with temperature
- The **density** of the gas **decreases** with temperture (from 1.2 to 0.39 kg/m3)
- The **viscosity** of the gas **increases** with temperature (from 1.82e-5 to 3.965e-5 Pa*s)

As a consequence the minimum fluidization velocity increases with a temperature increment.

WHAT WILL HAPPEN IN CASE OF A GELDART B POWDER?

Minimum Fluidization Point (Geldart B): Temperature Dependence



$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75 \rho_g U^2 \right) \cdot H_{bed} = m_{cat} g / A$$

- The **weight** of the bed **does not change** with temperature
- The **density** of the gas **decreases** with temperture (from 1.2 to 0.39 kg/m3)
- The **viscosity** of the gas **increases** with temperature (from 1.82e-5 to 3.965e-5 Pa*s)

The effect of temperature on density and viscosity is the same as for Geldart D particles. However B particles are finer and dominated by viscous effects as shown by linear Ergun equation, thus **MINIMUM FLUIDIZATION DECREASES WITH TEMPERATURE!**

Investigation of the
minimum fluidization point in case of:

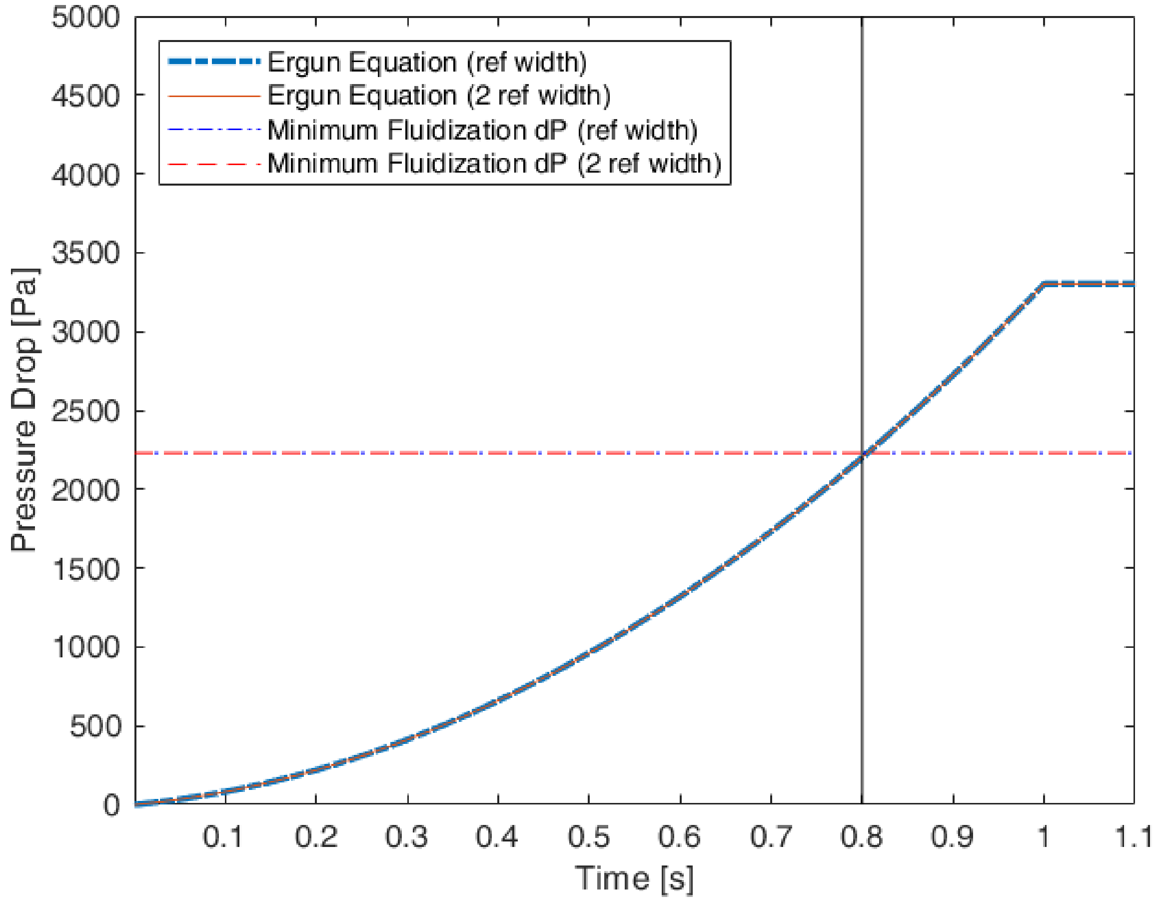
- a pseudo-2D reactor (D particles) which has 2 times the width of a reference test case
- a pseudo-2D reactor which has 2 times the packed bed height of a reference test case

Doubling the width

Reference Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75 \rho_g U^2 \right) \cdot H_{bed} = m_{cat} g / A_{ref}$$

Doubling the width



Reference Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = m_{cat} g / A_{ref}$$

New Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = 2m_{cat} g / (2A_{ref})$$

No difference of Umf

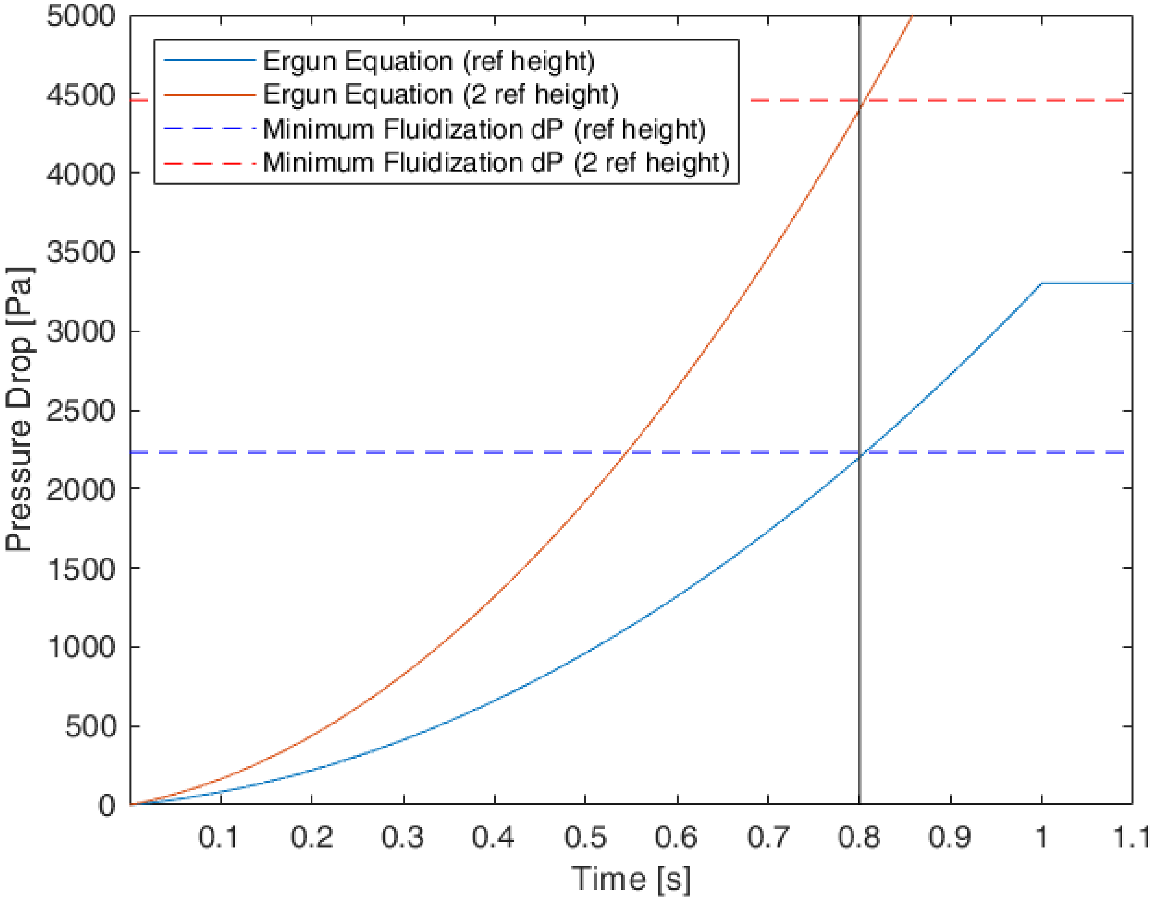
No difference of dp_{mf}

Doubling the height

Reference Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = m_{cat} g / A_{ref}$$

Doubling the height



Reference Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot H_{bed} = m_{cat} g / A_{ref}$$

New Reactor

$$\frac{1}{d_p} \cdot \frac{1-\varepsilon}{\varepsilon^3} \cdot \left(\frac{150(1-\varepsilon)\mu}{d_p} U + 1.75\rho_g U^2\right) \cdot 2H_{bed} = 2m_{cat} g / A_{ref}$$

No difference of Umf

Different dp_{mf}