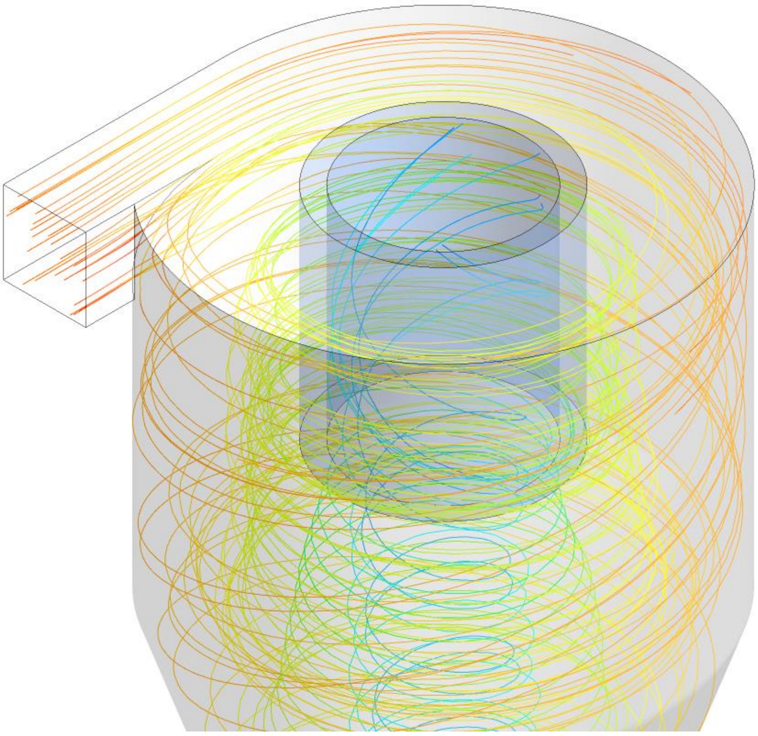
Computational fluid dynamics in metallurgy

Cyclone design optimization for particle collection efficiency



Summary

Several metallurgical reactors are equipped with cyclones in the gas treatment section. Their task is to remove particles from the gas stream, in order to:

- Collect products which are in the form of a powder
- Clean the gas stream from impurities in the form of solid residues or liquid droplets

In many cases, the cyclone takes care of a rough cleaning, and a filter system removes the last traces of solids. Some set-ups may require the cyclones to remove the solid particles up to a targeted gas cleanliness.

The particle collection efficiency, typically a function of the particle size, is therefore an important parameter to understand.
Optimizing the cyclone design for the particle collection efficiency can be done for various reasons and lead to many improvements:

- Lowering loading on the subsequent bag plant, to increase dust handling capacity
- Improving impurity removal, leading to higher product qualities
- Reaching off-gas cleanliness targets and achieving tightened environmental constraints
- Separating certain impurities to a targeted stream and creating different dust or powder product qualities

Challenges

It is well-known that cyclone separation is based on centrifugal forces on the particles, and hence on the creation of a strong and stable vortex. It is therefore important to not only study the particle collection in steady state, but also to find indications on the size and stability of the vortex.

Theoretically, many aspects of the cyclone design can be varied: inlet shape and location, outlet diameter, vortex finder thickness and length, angle of conicity, etc. In practice, redesigning a cyclone separator for retrofit applications requires dealing with constraints on the available space, off-gas fan power, maintenance and material handling. These will often require trade-offs to be made. An experienced engineer will set-up targeted calculations in order to find an improved or even optimal design within these constraints.

Technology used

- Geometry preparation and parametrization: ANSYS Spaceclaim
- Mesh preparation: ANSYS Meshing
- Computational Fluid Dynamics (CFD) software: ANSYS Fluent

Engineering Solution

- Depending on the particle loading, a coupled or uncoupled discrete phase model (DPM) is used to simulate the particulate flow.
- Appropriate turbulence models and structured wall meshes are used to account for turbulent flow and boundary layers at the wall.
- The geometry is parametrized in order to automate design optimization.
- A particle size distribution function (PSD) is applied at the inlet, and the particle collection efficiency is calculated from the resulting PSD at the outlet.

Benefits

- **Geometry could be created from existing CAD files, and many modifications could be evaluated (e.g. Figure 1).**

- **Determine the flow (Figure 2) and vortex stability as a function of the design.**
- **Determine the resulting particle collection efficiency as a function of particle size (Figure 3).**
- **Behaviour of sub-micron particles could be calculated.**
- **Use the gained knowledge to optimize not only the design but also the process conditions, in order to improve the particle collection.**
- **Avoid standard design and use optimal design for typical solids loading, gas properties, and constraints in the actual plant.**

Sander Arnout, PhD
Modelling expert
InsPyro NV
Leuven, Belgium

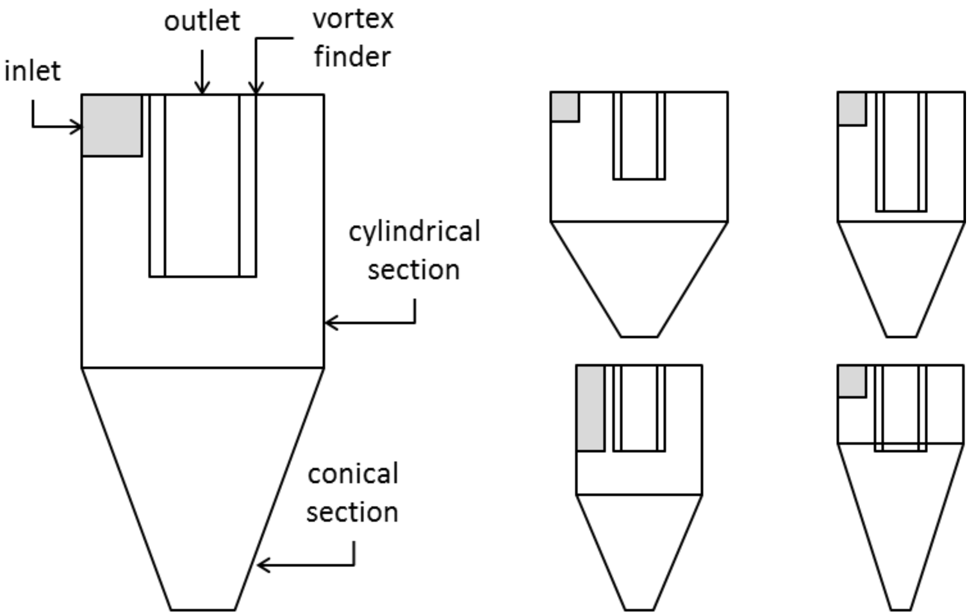


Figure 1: Typical cyclone layout and examples of design modifications*

*Hypothetical designs are used in this article.

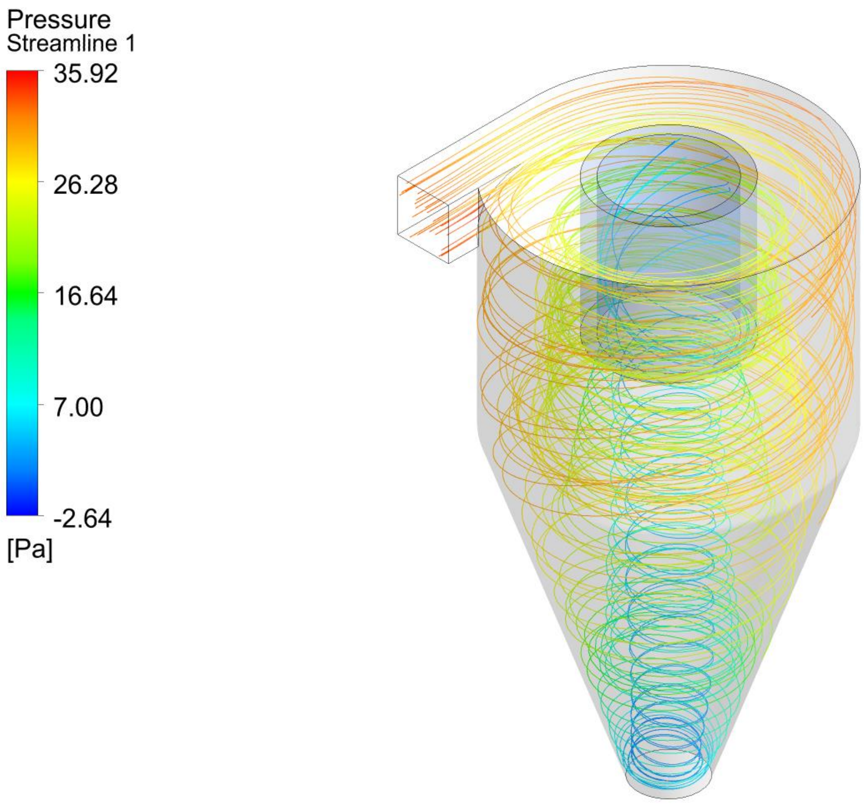


Figure 2: Flow of the gas phase in a cyclone (colored by pressure)

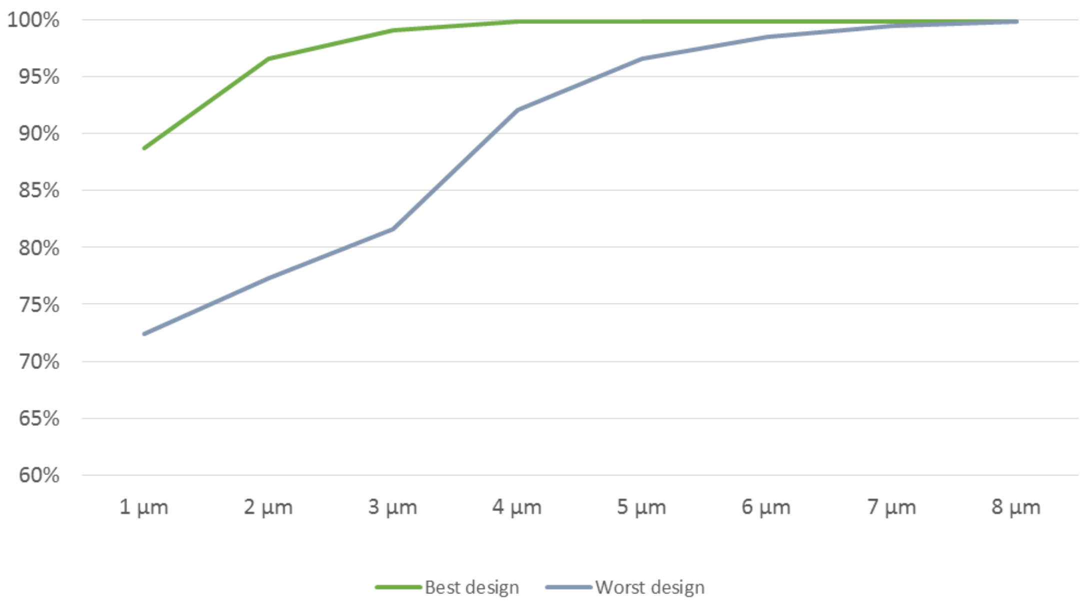


Figure 3: Cyclone collection efficiency as a function of particle size for two different set-ups