Jesmond ENGINEERING

Cyclone Separator

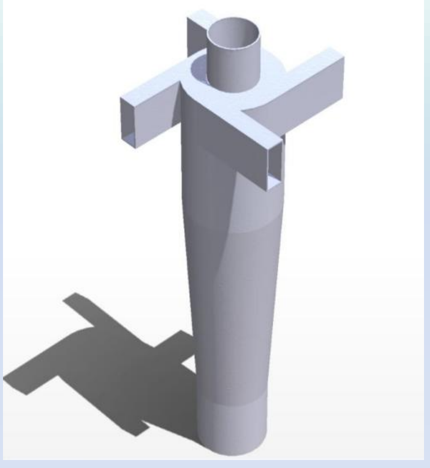

Figure 1 CAD model of a cyclone. Cyclones can have no moving parts, with separation driven entirely by fluid vortices within.

Summary

Jesmond Engineering conducted an optimization analysis for the design of a cyclone intended to separate out carbon black from the products of a reactor. The task was to balance the size of the cyclone with the flow rate to maximize the capture efficiency.

The design parameters needed to be precisely balanced so that the desired particle escaped through the gas vent while waste products dropped out of the bottom under gravity.

Problem

Particles of varying size and density escape the reactor, and the client required the extraction of a single type of particle - carbon black. The flow field inside the cyclone is complex, formed of inner and outer vortices, and this must be simulated accurately to correctly determine how the reactor products move within the separator. As two design elements were variable, the number of possible designs to simulate is large so preliminary work was necessary to reduce the size and cost of the project.

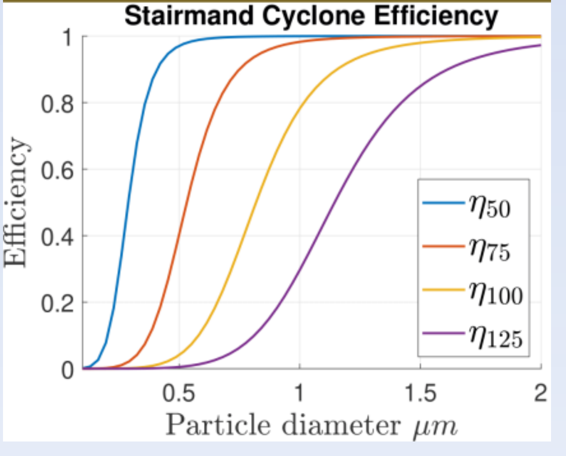

Figure 2 Typical efficiency curves for cyclones of various sizes.

$$\mathrm{Stk} = \frac{d_p^2 \rho_p V_{in}}{18 \mu D_{in}}$$

d_p	Particle diameter
ρ_p	Particle density
V_{in}	Inlet velocity
μ	Fluid viscosity
D_{in}	Cyclone diameter

Figure 3 Equation for the Stokes number for a particle inside the cyclone. A large value indicates the particle will detach from streamlines, while a small value means the particle follows the flow.

Solution

Before beginning simulations, Jesmond Engineering conducted a mathematical analysis of the problem and determined theoretically what the optimum cyclone design would be. The key parameter was the particle Stokes number, characterizing the tendency of a particle to follow the streamlines of the gas flow. With a theoretical solution, only one Computational Fluid Dynamics (CFD) simulation was required to verify the results, and Jesmond Engineering were able to reliably suggest a new cyclone design, which was more efficient to run than the client's previous design.

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Conclusion

CFD provided a powerful, insightful and time-saving alternative to iterative physical testing, which may require building many prototypes and consuming resources. The mathematical analysis conducted by our CFD engineers sidestepped the need even for iterative simulation, landing the process much closer to the final optimized design. This reduced time and cost for the client who were then provided with a highly efficient cyclone design that could operate at lower running costs than their original design. Jesmond Engineering furthered the expertise of the client while providing confident and clear implementations for their product.

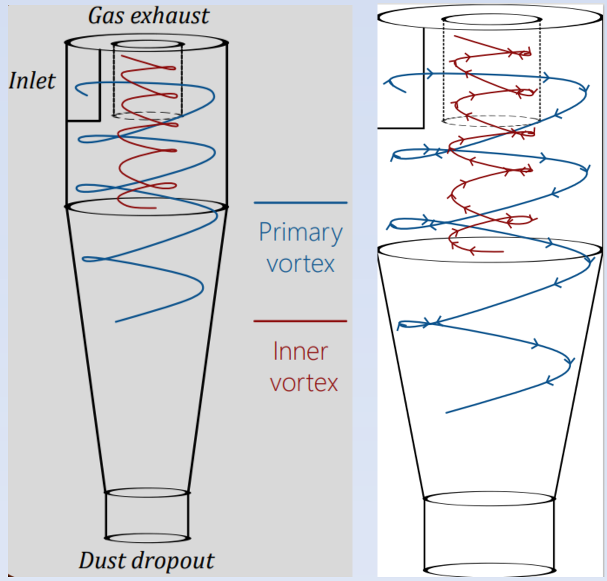
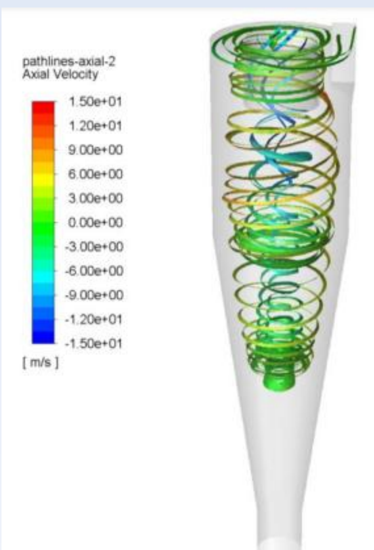


Figure 3 *Sketches of the cyclone produced by Jesmond Engineering for consultations with the client.*

CFD Results



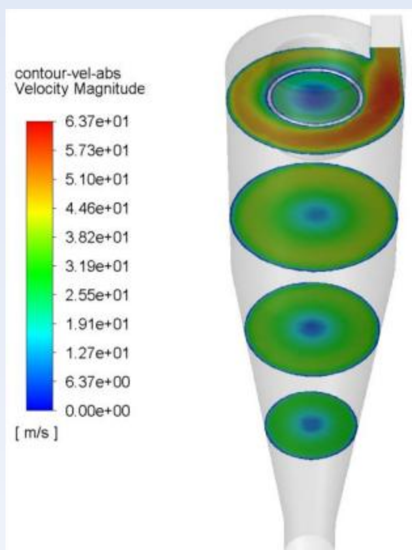


Figure 3 *CFD simulation results. Left: particle pathlines through the cyclone coloured by velocity magnitude showing the descent of particles before being driven up by the inner cyclone. Middle: Plot of velocity magnitude through 4 cross-sections of the cyclone. The flow is fastest near the boundaries and there is a central quiescent core through which particles may fall. Right: A still from a 3D animation of the flow with a custom flow visualization developed by Jesmond Engineering.*

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