Evaluation of cyclones cutoff diameters for blow-by gas cleaning applications

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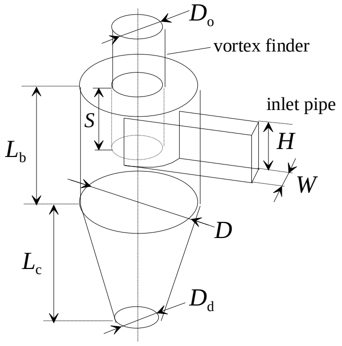
Cyclone separators are commonly used in industry to remove solid or liquid particles from a gas stream. These devices are frequently applied to large-scale processes. Small cyclones are also widely used in the automotive industry, particularly in internal combustion engines for the separation of oil mist from blow-by gases. These so-called “blow-by gases” result from leakages between the combustion chamber and the crankcase. The resulting oil mist has to be cleaned up, for pollution control, oil consumption reduction and also to avoid oil deposit in the intake line. This is an important feature of crankcase venting systems, and the design of the sampling cyclone is of great importance for its collection efficiency: a reduction of the cyclone diameter produces an increase of the collected oil flow, but also results in increased pressure drops.

The aim of this experimental study is to investigate the separation performances of a set of small cyclones. The diameter of these cyclones spans the range of 20 to 45 mm, which is the typical size of these devices when they are used for the separation of oil mist from blow-by gases, in internal combustion engines.



Dimensionless ratios
$(L_b + L_c)/D$ =2,
L_b/D =1, S/D =0.62,
W/D =0.22,
H/D =0.48,
D/D_o =2.23

Cyclone size
D variable (20, 25, 30, 35, 40, 45 and 50 mm)

To reproduce the flow rates and temperature operating conditions (80°C) of combustion engines, we developed a temperature controlled flow bench, with a polydisperse aerosol generator (PALAS PLG 2010) producing engine oil droplets with diameter in a 0.3-10 µm range. Measurements of the aerosol particle concentrations with an optical particle counter (WELAS) upstream and downstream of the cyclone permitted the determination of the particle collection efficiency, for the six devices that were tested, with flow rates ranging from 18 to 500 Nl.min^{-1}.

Pressure losses were measured separately with the cyclones exhaust at the atmosphere as recommended by Hoffman (2002) who reports that this is the best way to evaluate pressure losses in the vortex finder with highly swirling flow. As illustrated in figure 1, pressure losses were found to be in good agreement with Muschelknautz’s model (Muschelknautz, 2010), with an average deviation of 12%.

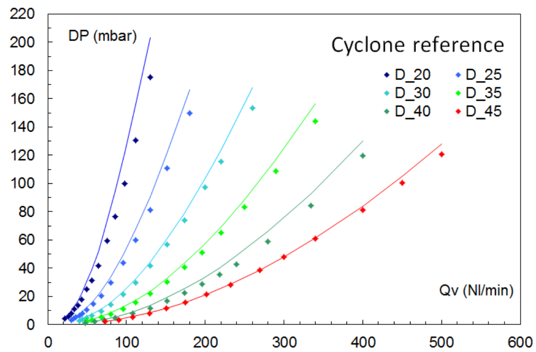


Figure 1. Pressure losses evaluation (point: measurements, line : Muschelknautz model).

Collection efficiency curves were also measured, and these efficiencies were plotted against Ξ, the slip-corrected particle size normalised to the experimentally determined slip-corrected cut-off sizes.

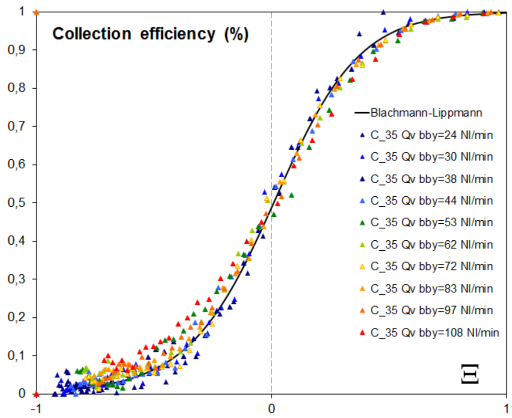


Figure 2. Fractional efficiency (cyclone with D=35 mm)

As illustrated in figure 2 for an intermediate cyclone size, a quadratic Blachman-Lippmann model can be used to interpolate the data, with a reasonable scattering.

Muschelknautz, U. (2010) *L3.4 Cyclones for the Precipitation of Solid Particles.* 1226-1237, VDI Verlag GmbH Heat Atlas, 2ème. ed, Ed Springer, Düsseldorf

Hoffmann, A. C. and Stein, L. E. (2002) *Gas Cyclones and Swirl Tubes. Principles, Design and Operation.* Springer, New York.