cyclone Problems

1.For the following particle size distribution, calculate the efficiency of a Lapple conventional cyclone with a body diameter of 0.50 meters. The particulate density $\rho_p = 1200\ \mathrm{kg/m^3}$, the gas density $\rho_g = 0.90\ \mathrm{kg/m^3}$, the gas viscosity $\mu = 1.67 \times 10^{-5} Pa \cdot s$, and the inlet gas velocity $V_i = 25\ \mathrm{m/s}$.

Size Range, μm	Mass Percent in Size Range
$0-4$	3.0
$4-10$	10.0
$10-20$	30.0
$20-40$	40.0
$40-80$	15.0
>80	2.0

Solution

Lapple conventional cyclone（Table 4.1）

H/D=0.5　W/D=0.25　L_b/D=2.0　Lc/D=2.0

H=0.5×0.5=0.25　W=0.25×0.5=0.125　L_b=2.0×0.5=1.0　Lc=2.0×0.5=1.0

$$N_e = \frac{1}{H}\left[L_b + \frac{L_c}{2}\right] = \frac{1}{0.25}\left[1.0 + \frac{1.0}{2}\right] = 6$$

$$d_{pc} = \left[\frac{9\mu W}{2\pi N_e V_i(\rho_p - \rho_g)}\right]^{1/2} = \left[\frac{9 \times 1.67 \times 10^{-5} \times 0.125}{2 \times 3.14 \times 6 \times 25 \times (1200 - 0.9)}\right]^{1/2} = 4.08 \times 10^{-6} m = 4.08 \mu m$$

$$\eta_1 = \frac{1}{1 + \left(d_{pc}/\bar{d}_{p_j}\right)^2} = \frac{1}{1 + (4.08/2)^2} = 0.1939$$

Size Range, μm	$\bar{d}_{pj}, \mu m$	η_j	m_j, %	$\eta_j m_j$, %
$0-4$	2	0.1939	3.0	0.0058
$4-10$	7	0.7466	10.0	0.0747
$10-20$	15	0.9312	30.0	0.2793
$20-40$	30	0.9819	40.0	0.3927
$40-80$	60	0.9954	15.0	0.1493
>80	80	0.9974	2.0	0.0199

$$\eta_o = \sum_{j=1}^{6} \eta_j m_j = 92.18\%$$

2. Design a Lapple conventional cyclone to clean a dusty airstream flowing at $180000\,m^3/h$ (at $90\,°\mathrm{C}$ and 1 atm). The required efficiency must be between 75% and 85% with a maximum allowable pressure drop of $3000\mathrm{Pa}$. The particle density is $1200\ \mathrm{kg/m^3}$ and the particle size distribution is given below.

Particle Size Range, μm	Mass Percent in Size Range
$0-5$	10
$5-15$	30
$15-30$	40
$30-50$	15
>50	5

Solution

Since the problem specifies a conventional Lapple cyclone, choose a type 3 cyclone from Table 4.1; the dimensional relationships are:

$H=0.5D \quad W=0.25D \quad D_e=0.5D \quad L_b=2D \quad L_c=2D$

$Q=180000\,m^3/h=180000/3600=50\,m^3/s$

$V_i=\frac{Q}{HW}=\frac{50}{0.5D\times0.25D}=\frac{400}{D^2}$ m/s

$$H_v=K\frac{HW}{D_e^2}=16\times\frac{(0.5\mathrm{D})(0.25\mathrm{D})}{(0.5\mathrm{D})^2}=8$$

From Appendix B, Table B. 2 the density of air is $0.0606\ \mathrm{lbm/ft^3}=0.97\mathrm{kg/m^3}$; the gas viscosity $\mu=0.0517\,\mathrm{lbm/(hr\cdot ft)}=2.14\times10^{-5}Pa\cdot s$

$\Delta P=\frac{1}{2}\rho_g V_i^2 H_v=\frac{1}{2}\times0.97\times(\frac{400}{D^2})^2\times8=\frac{620800}{D^4}$ Pa

$$N_e=\frac{1}{H}\left[L_b+\frac{L_c}{2}\right]=\frac{1}{0.25D}\left[1.0D+\frac{1.0D}{2}\right]=6$$

$$d_{pc}=\left[\frac{9\mu W}{2\pi N_e V_i(\rho_p-\rho_g)}\right]^{1/2}=\left[\frac{9\times2.14\times10^{-5}\times0.25D}{2\times3.14\times6\times\frac{400}{D^2}\times(1200-0.97)}\right]^{1/2}$$

$$=1.6323\times10^{-6}\times D^{1.5}=1.6323D^{1.5}\ \mu m$$

$$\eta_j=\frac{1}{1+\left(d_{pc}/\bar{d}_{pj}\right)^2}$$

经过试算，无法设计出这样一台旋风除尘器，既满足除尘效率在75%~85%之间，又满足阻力降小于 3000Pa。径试算，分成 6 台旋风并联处理，每台处理风量 30000m^3/h，于是，有：

$$Q=30000\,m^3/h=30000/3600=\frac{25}{3}m^3/s$$

$V_i = \frac{Q}{HW} = \frac{\frac{25}{3}}{0.5D \times 0.25D} = \frac{200}{3D^2}$ m/s

$$H_v = K\frac{HW}{D_e^2} = 16 \times \frac{(0.5\mathrm{D})(0.25\mathrm{D})}{(0.5\mathrm{D})^2} = 8$$

$\Delta P = \frac{1}{2}\rho_g V_i^2 H_v = \frac{1}{2} \times 0.97 \times (\frac{200}{3D^2})^2 \times 8 = \frac{155200}{9D^4}$ Pa

$$N_e = \frac{1}{H}\left[L_b + \frac{L_c}{2}\right] = \frac{1}{0.25D}\left[1.0D + \frac{1.0D}{2}\right] = 6$$

$$d_{pc} = \left[\frac{9\mu W}{2\pi N_e V_i(\rho_p - \rho_g)}\right]^{1/2} = \left[\frac{9 \times 2.14 \times 10^{-5} \times 0.25D}{2 \times 3.14 \times 6 \times \frac{200}{3D^2} \times (1200 - 0.97)}\right]^{1/2}$$

$$= 3.998 \times 10^{-6} \times D^{1.5} = 3.998D^{1.5}\ \mu m$$

经试算，当 D=1550mm 时，$d_{pc} = 7.7\mu m$，可达到要求.

Size Range, $\boldsymbol{\mu m}$	$\overline{\boldsymbol{d}}_{pj}, \boldsymbol{\mu m}$	η_j	$\boldsymbol{m}_j$, %	$\eta_j \boldsymbol{m}_j$, %
$0-5$	2.5	0.095	10.0	0.095
$5-15$	10	0.627	30.0	0.188
$15-30$	22.5	0.895	40.0	0.358
$30-50$	40	0.964	15.0	0.145
>50	50	0.977	5.0	0.049

$$\eta_o = \sum_{j=1}^{5} \eta_j m_j = 92.18\%$$

$\Delta P == \frac{155200}{9 \times 1.55^4} = 2988$ Pa