Determination of Particle Penetration from Knowledge of the Fully Developed Concentration Profile in Laminar Flow Tubes

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The fully developed particle number concentration profile in a laminar flow tube is given by (Alonso, Huang and Alguacil, 2010)

$$n^*(r^*, x^*) = 1.477e^{-3.659\beta x^*}\left[1 - \frac{1}{11}\left(18r^{*2} - 9r^{*4} + 2r^{*6}\right)\right] \quad (1)$$

where n^* is the particle number concentration referred to that at the entrance of the tube, r^* and x^* are the dimensionless radial and axial coordinates, and $\beta = DL/\langle u_x \rangle R^2$ is the dimensionless particle diffusion coefficient (D: diffusivity; L: tube length; $\langle u_x \rangle$: mean axial flow velocity; R: tube radius).

The fraction of surviving particles at the outlet of the tube (panetration) can be estimated from the above expression as

$$P = \frac{\int_0^1 r^* u^*_x (r^*) n^*(r^*,1) dr^*}{\int_0^1 r^* u^*_x (r^*) dr^*}, \quad (2)$$

resulting in

$$P = 0.846e^{-3.659\beta}. \quad (3)$$

This approximate expression is compared in Figure 1 with the Gormley-Kennedy (1949) equation

$$P_{GK} = 0.819e^{-3.657\beta} + 0.098e^{-22.3\beta} + 0.033e^{-57\beta}$$

for $\beta \geq 0.031$

and

$$P_{GK} = 1 - 2.56\beta^{2/3} + 1.2\beta + 0.177\beta^{4/3}, \text{ for } \beta < 0.031.$$

The agreement between both expressions is excellent except for very small values of the dimensionless diffucion coefficient β. Note also that eq.(3) is quite similar to the first term of the Gormley-Kennedy equation for $\beta \geq 0.031$, but the constant factor is a bit larger in eq.(3).

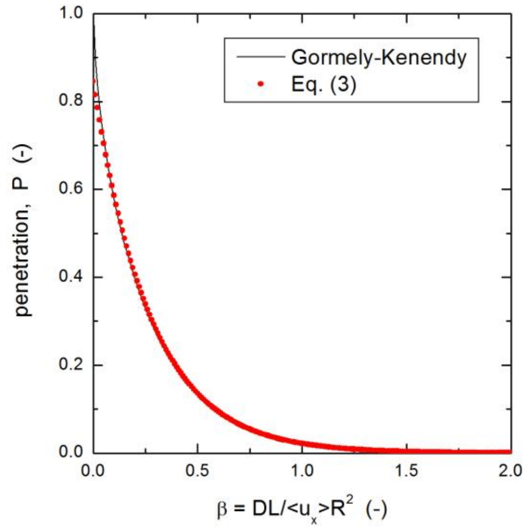

Figure 1. Comparison between the Gormley-Kennedy equation and the approximate equation (3) derived from knowledge of the fully developed particle concentration profile.

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Alonso, M., Alguacil, F.J., and Huang, C.H. (2010) *J. Aerosol Sci.*, **41**, 413-417.

Gormley, P.G., and Kennedy, M. (1949) *Proc. Royal Irish Acad.*, **52A**, 163-169.