Prosimy cytować jako: Inż. Ap. Chem. 2009, 48, 4, 108-109

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Distribution of suspension concentration in mixing equipment with a draught tube

Introduction

Large tall vessels with a draught tube (shown in Figure 1) are used for mixing of suspensions especially when high homogeneity is desirable. Short shaft and small ground area are also advantages of this configuration.

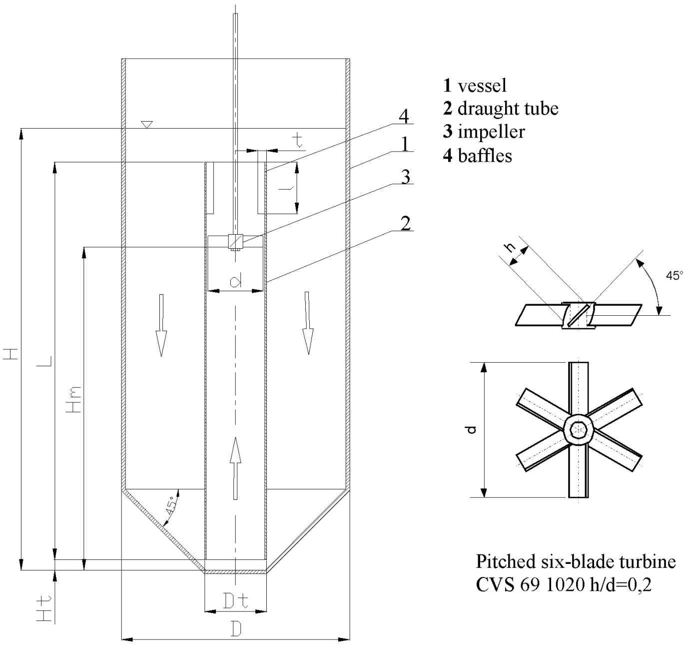

Fig. 1. Mixing vessel with a draught tube

Theoretical

The concentration in annular space between draught tube and vessel wall c_m and concentration in draught tube c_t can be obtained by solution of the following set of equations.

Solid-phase material balance:

$$S_m c_m + S_t c_t = (S_m + S_t)c \tag{1}$$

Equation of continuity:

$$u_m S_m = u_t S_t \tag{2}$$

Solid-phase equation of continuity:

$$[u_m + u_\infty (1-c_m)^m] c_m S_m = [u_t - u_\infty (1-c_t)^m] c_t S_t \tag{3}$$

Mean velocity in draught tube:

$$u_t = Kpnd^3 / S_t \tag{4}$$

Terminal settling velocity of single particle:

$$u_\infty = Re_p \frac{\mu}{d_p \rho} \tag{5}$$

where (see [1])

$$Re_p = \left[\left(\frac{18}{Ar} \right)^{0,8} + \left(\frac{0,3}{Ar} \right)^{0,4} \right]^{-1,25} \tag{6}$$

and exponent (see [2])

$$m = 4,7 \frac{1 + 0,15 Re_p^{0,687}}{1 + 0,253 Re_p^{0,687}} \tag{7}$$

The other adequate methods for particle settling velocity calculation can be found e.g. in [1].

Results

The above set of equations was solved numerically and the graphical form of results is shown in the following figures.

The dependence of c_t resp. c_m on c for water suspension of glass particles with diameter d_p = 0,47 mm in vessel characterized by ratio S_m/S_t =16,2 and agitator speed n = 1280 1/min is shown in Fig. 2. From this figure it can be seen that particle concentration in draught tube is higher than concentration in annular space between draught tube and vessel wall c_m. It was also confirmed experimentally using GTT (Gamma Transmission Tomography) method [3].

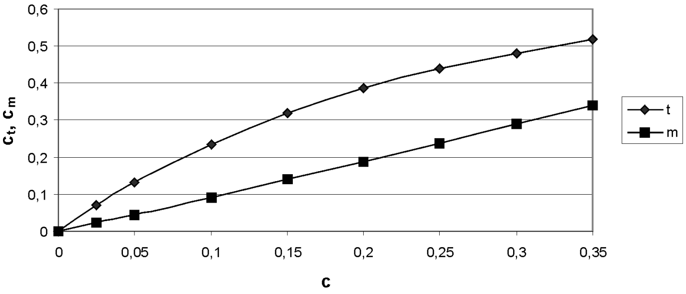

Fig. 2. Dependence of concentrations in draught tube c_t and in annular space c_m on mean concentration c

Fig.3 shows that particle concentration in the draught tube c_t is much higher than mean concentration c and the ratio of both concentrations decreases with increasing mean concentration, the concentration in annular space between draught tube and vessel wall c_m differs from mean concentration c only slightly due to high ratio S_m/S_t.

From Fig. 4 it can be seen that the difference between both concentrations increases with increasing particle size (ratio S_m/S_t =16,2 and agitator speed n = 1280 1/min are the same).

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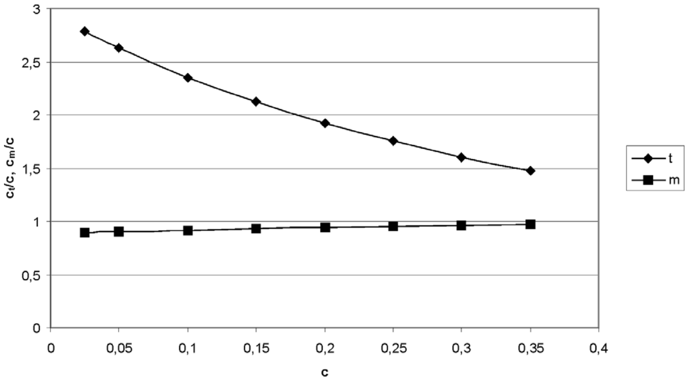

Fig. 3. Dependence of concentration ratios c_t/c and.c_m/c on mean concentration c

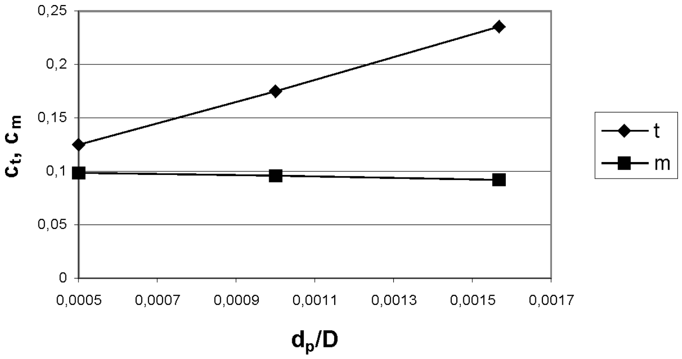

Fig. 4. Dependence of concentrations c_t and c_m on ratio d_p/D

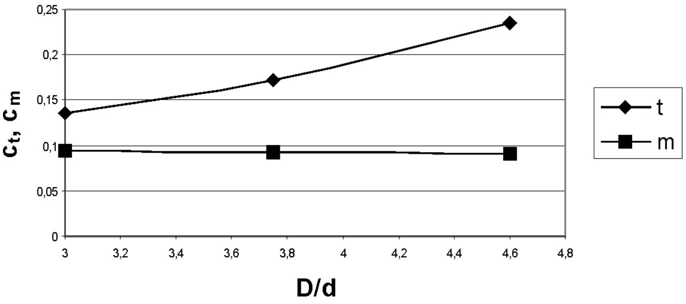

Fig. 5. Dependence of concentrations c_t and c_m on ratio D/d

From Fig. 5 it can be seen that the difference between both concentrations increases also with increasing vessel to draught tube diameters ratio (d_p = 0,47 mm and n = 1280 1/min).

From Fig.6 it can be seen that the difference between both concentrations decreases with increasing agitator speed (S_m/S_t=16,2 and d_p = 0,47 mm).

Conclusion

Concentration in draught tube must be controlled because it can be limiting for suspension fluidity and the successful operation of mixing equipment.

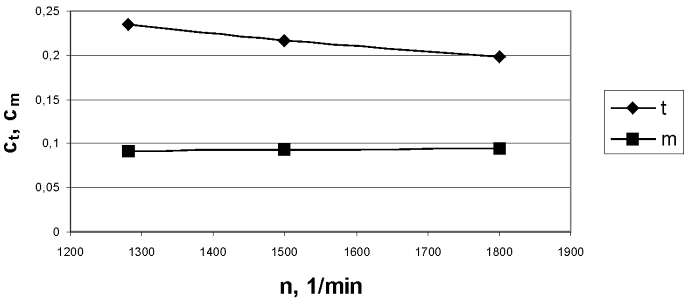

Fig. 6. Dependence of concentrations c_t and c_m on agitator speed n

List of symbols

$Ar = \frac{d_p^3 \rho g \Delta\rho}{\mu^2}$ – *Archimedes* number,
c – mean volumetric solid-phase concentration,
c_m – solid-phase concentration in annular space between draught tube and vessel wall,
c_t – solid-phase concentration in draught tube,
d – agitator diameter,
d_p – particle diameter
Kp – flow rate number,
$Kp = \frac{\dot{V}}{nd^3}$ – agitator speed.
m – exponent calculated from eq.(7)
$Re_p = \frac{u_\infty d_p \rho}{\mu}$ – particle *Reynolds* number,
S_m – cross-section of annular space between draught tube and vessel wall
S_t – cross-section of draught tube
u_m – mean velocity in annular space between draught tube and vessel wall
u_t – mean velocity in draught tube
u_∞ – terminal settling velocity of single particle
$\dot{V}$ – volumetric flow rate
μ – viscosity,
ρ – liquid density
$\Delta\rho$ – solid-liquid density difference

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3. *J. BroŽ* Ph.D. dissertation, Faculty of Mechanical Engineering, Czech Technical University in Prague, 2008.

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