An Improved Correlation to Predict "Just Suspension" Speed for Solid-Liquid Mixtures with Axial Flow Impellers in Stirred Tanks

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Abstract

In the design of agitators for solid-liquid mixing processes there are two important design criteria. The first is "uniform distribution" where the particles are distributed throughout the liquid phase so that, at each axial location, the solids concentration is very close to the calculated average. The second is "just suspended" where all the particles are in motion on the base of the vessel but not necessarily uniformly distributed.

The correlation proposed by Zwietering (1958, *Chem. Eng. Sci.*, **8**, 244) has been widely used for estimating the "just suspension" speed, N_{JS} and is recommended for agitator design in the *Handbook of Industrial Mixing* (2004, Atiemo-Obeng *et al.* eds., Wiley). But we believe that Zwietering's correlation has a number of problems. For example:

- Zwietering predicts that N_{JS} is proportional to the liquid's kinematic viscosity raised to the 0.1 power. There is no physical explanation nor is there experimental data to support this.
- Zwietering predicts that the power input per mass required for an impeller to operate at N_{JS} decreases on scale-up. Experimental data do not support this and Zwietering recommends that scale-up should be made on constant power input per mass because "it is on the safe side".
- Zwietering found that the exponent on impeller diameter ranged from -0.78 to -0.94 yet chose an exponent -0.85 for all impellers tested.

Baldi *et al.* (1978, *Chem. Eng. Sci.*, **33**, 21) and Davies (1986, *Chem. Engng. Proc.*, **20**, 175) have proposed a model in which turbulent eddies of the scale of the particles are responsible for suspension. This model can be re-arranged into two dimensionless numbers; the Reynolds number of the turbulent eddies and Archimedes number for the particles:

$$\frac{Re_E}{\sqrt{Ar}} = K$$

The constant, K, is dependent on the impeller type and its clearance above the vessel base.

The Fluid Mixing Processes consortium made measurements of N_{JS} for pitched blade and hydrofoil impellers of two diameters and four clearances at a range of scales and liquid viscosities. The new data can be fit to the Davies / Baldi model and show that N_{JS} is independent of viscosity and that the scale-up should be made at constant power input per unit volume (for the same geometry).