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Sensitivity analysis of artificial neural networks for just-suspension speed prediction in solid-liquid mixing systems: Performance comparison of MLPNN and RBFNN

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ABSTRACT

Just-suspension speed (Njs) is an important parameter for stirred tank design using a solid-liquid mixing system in the chemical process industry. However, current correlations for Njs suffer from uncertainty from limited experimental databases and limitations due to many parameters that play an important role in Njs determination. A comprehensive computation of the radial basis function neural network (RBFNN) was developed based on solid-liquid mixing experiments, which contain 935 datasets for the prediction of Njs. The Njs values were obtained experimentally using Zwietering correlation with different solid loading percentages, solid particle density, solid particle diameter, mixing solvent density, number of impeller blades, impeller diameter, impeller blade hub angle, impeller blade tip angle, the width of the impeller blade and the ratio of the clearance between the impeller and the bottom of the tank with the tank diameter. The RBFNN proved to have a much better ability to accurately predict the desired Njs compared to MLPNN even after decreasing the number of input variables from 11 to 8. Thus, the computational RBFNN model results will be useful for extending the application of a solid-liquid mixing system for estimating the just-suspension speed for stirred tank design.

1. Introduction

Solid-liquid mixing stirred tank systems have been widely applied in the chemical process industry for solid dissolution, crystallization, precipitation and suspension of solid particles. In such a mixing system, the knowledge of the solid suspension distribution over the stirred tank is an important parameter required for scale-up and optimum mixing performance [1]. Generally, solid particles tend to settle as their density is higher than the mixing liquid. To operate the mixing system under optimized conditions, the surface area of the solid particles should be fully exposed in the liquid solution to maximize the mass transfer [2]. Optimization can be achieved via hydrodynamic conditions by retaining the solid particles under complete off-bottom suspension conditions. The impeller speed is the most important parameter that strongly affects the mass transfer and the power consumption on the overall mixing system through introduced drag and lift forces to move between the mixing solution and the solid particles. The impeller speed (rpm) at which solid particles complete off-bottom suspension conditions for more than 1 or 2 s is the definition of just-suspension speed (Njs) [3]. Zwietering [3] reported that the correlation for Njs that consists of solid particle properties, liquid solvent properties, impeller diameter and the constant S is a number function of the impeller and mixing tank geometry. The Njs equation is expressed as:

$$N_{js} = S\left(\frac{g(\rho_s - \rho_L)}{\rho_L}\right)^{0.45} \frac{X^{0.13} d_p^{0.2} v^{0.1}}{D^{0.85}} \tag{1}$$

where S is the number function of the geometry system, v is the viscosity of the mixing solution, D is the impeller diameter, d is the diameter of the solid particle, X is the weight fraction of the solid particles, g is the gravity acceleration constant, ρ_s is the density of the solid and ρ_L is the density of the mixing solution.

The accuracy of computing Njs is very important and influences the power consumption in a mixing system, as recorded in the handbook of industrial mixing for stirred tank design [4]. The design of the stirred tank reactor relies on the correlation obtained from the experimental data. However, these correlations suffer from uncertainty from the limited database to support them due to the current correlation, which is limited to the high solid loading opaque mixing system, but most

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