Chemical Engineering & Processing: Process Intensification 148 (2020) 107794

Contents lists available at ScienceDirect

Chemical Engineering & Processing: Process Intensification

journal homepage: www.elsevier.com/locate/cep

Macromixing study for various designs of impellers in a stirred vessel

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ARTICLE INFO

Keywords:
Impeller design, clearance level
Energy dissipation rate
Mixing time
Nonlinear regression
ANFIS-Fuzzy C-means

ABSTRACT

The effect of the impeller designs and impeller clearance level (C/T) on power consumption, mixing time and air entrainment point in a single liquid phase under turbulent conditions (Re > 10^4) were investigated. Different impeller designs including conventional and new designs, were used to consider both axial and radial flow impellers. The electric conductivity method, suspended motor system and observation method were employed to determine the mixing time, the power consumption and the air entrainment point, respectively. The reduction in the impeller clearance level form T/3 to T/6 resulted in a decrease in power number values for up-flow pumping impellers while it was increased for down-flow pumping. The same trend was observed for the mixing time results. Moreover, axial flow impellers and specially HE3 are preferable for higher agitation speeds due to the less air entrainment. The results verified that the axial flow impellers and specifically down-flow impellers are more efficient than the radial flow impellers. ANFIS-Fuzzy C–means (ANFIS–FcM) and nonlinear regression were used to develop models to predict the mixing time based on the energy dissipation rate and clearance. The results verified that the model predictions successfully fit the experimental mixing time data.

1. Introduction

Mechanical agitation is widely employed in chemical process industries for heat and mass transfer applications or chemical reactions applications [1]. Precipitation, polymerization and hydrometallurgical processes are usually conducted using mechanical agitation. The efficiency of the mixing process is dependent on different internal parameters such as agitation speed, impeller type, tank geometry, geometrical ratios such as impeller to tank diameter (D/T), off-bottom clearance to tank diameter (C/T), liquid height to tank diameter (H/D), dispersed phase hold-up and fluid physical properties. Therefore, any small changes in vessel and impeller geometries has considerable effects on the power consumption, flow pattern, drop size distribution, mixing time and consequently on the mixing characteristics [2,3]. In last 60 years, several impellers have been designed and developed for better efficiency in various applications but Rushton turbine, pitched blade turbines and propellers were the most common employed impellers [4–10].

Power consumption and mixing time are two parameters with a significant role in evaluating the performance of stirred vessels. Power consumption is defined as the required amount of energy per unit of time and mixing time is understood as the time required to obtain a certain degree of uniformity in a stirred vessel [3]. The stirred vessel configuration has a direct effect on these parameters and consequent influence on operating cost and product quality [1,9,11,12]. Thus, the comparison of these parameters for various impeller designs and impeller off-bottom clearance level gives valuable information about the performance of the agitation systems [1,13]. Furthermore, it is also helpful to improve and develop the design of reactors especially when the geometrical design and the condition of experiments are comparable. However, achievement of desired level of mixing is expected at the lowest value of the power consumption [5].

Several studies have been accomplished on the effect of impeller designs and configurations on mixing parameters. Raghav Rao and Joshi [14] performed extensive experiments to study the effect of clearance for different design of impellers on the power consumption per unit volume of liquid and pointed out better efficiency for down-flow pitched blade turbine. They reported a reduction in mixing time with decreasing the clearance for disk turbine and pitched blade up-flow turbine while it was increased in the case of pitched-blade down-

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https://doi.org/10.1016/j.cep.2019.107794
Received 14 September 2019; Received in revised form 9 December 2019; Accepted 19 December 2019
Available online 19 December 2019
0255-2701/