Optimization of a Multiphase Emulsion Mixer

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Abstract

Mixing is a very vital operation in the chemical and allied industries because the attainment of homogeneity revolves round Mixing. However, the mixing processes are influenced by many factors which include; types of impeller, vessel geometry, nature of reactants, speed of agitation, mixing time, among others. In this article , the significance of impellers in a mixing system to actualize a uniformity/homogeneity in a multiphase emulsion is investigated. This involves construction of a laboratory mixer, two different impellers, and performance of experiment and simulation of results. Running of study on laminar flow. The three bladed impeller produced a better correlation of the experimental results with simulated results. The three bladed form a more linear relationship between the two variables of temperature versus mixing time and concentration of mixture versus blending time. The two bladed required power than the three bladed to achieve the same results of mixing. Simulated result revealed that the three bladed impeller has the higher efficiency and optimally better in contributing to maintain a homogeneous solution than the two bladed impeller for a cylindrical mechanical agitated reactor.

Keywords: *Impeller Types, Mixer, Emulsion*

1. Introduction

The need to attain homogeneity in mixing operations is a major drive in the study of factors that can influence the extent of mixing.

Mixing operations are of major importance as they are employed in many Chemical and allied industries. It can occur naturally, through diffusion of liquids, although this is relatively slow. Chemical Engineers rely mostly on conventional methods which are commonly accomplished by introducing an agitator or driven impeller in the liquid content or mixture of a tank. The mixing quality of product in these conventional methods are based on impellers which is as a function position, size and power consumption, vessel design which is as a function of the number and size of baffles, bottom shape of tank and the bottom clearance

In the design of vessels, understanding the effect of impellers can go a long way in achieving fast, reliable scale up production, consistent physical and chemical properties. These effects can help manage variable batch size and multi product plants so as to meet production deadline. The relative performance of different types of impellers is a function of many variables including impeller type, vessel/tank diameter, geometry of vessel/tank, speed of rotation, power consumption of impellers, rheology of mixing system, clearance, and liquid level as in [1],[3].

The flow pattern in an agitated tank depend upon the fluid properties, the geometry of the tank, type of baffles in the tank, and the agitator itself as in [2],[4].

A dispersion application may require the presence of high intensity shear forces acting in a restricted flow area if agglomerates of fine particles are to be adequately distributed. No such requirement may exist in the mixing of reactants in a chemical reactor , although the viscosity of the mixing may increase markedly as the reaction proceeds as in [6].

In the design of an agitated vessel an important factor is the power required to drive the impeller. Power consumption P, is related to fluid density ρ, fluid viscosity, rotational speed N, and impeller diameter D_a by plot of power number N_P versus N_{RE}. The power number is $Np = P/\ell N^3 D_a^5$. These curves may be used for the operation of the respective impellers in un-baffled tanks when the Reynolds number is 300 or less. References [1],[2],[3],[9] show that when N_{Re} is greater than 300 however, the power consumption for an un-baffled tank is considerably less than for a baffled tank. When the impeller Reynolds number is less than 10, the flow induced by the impeller is laminar. Under these conditions the impeller drags fluid with it in a predominant circular pattern as in [3], [10].

The presence or absence of turbulence in an impeller vessel can be correlated with an impeller Reynolds number defined as $N_{Re} = D_a^2 N\ell / \mu$. Viscosity alone is not a valid indication of the type of flow to be expected and not only is the type of flow related to the impeller Reynolds number alone, but also by the following process performance characteristics; mixing time, impeller pumping rate, impeller power consumption, and heat and mass transfer coefficients as in [3], [9], [11].

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The turbulent shear rate (G) within a stirred tank is characterized using the spatially average gradient $G = (\epsilon/\nu)^{1/2.}$ Where ν is the kinematics viscosity of the mixing fluid. ϵ is the average turbulent energy dissipation rate. $\epsilon = N_p N^3 D^5/V$, where V is the tank volume.

This study develops a suitable model for solid/liquid that would accurately predict quantity like, the power consumption, the minimum agitation speed, the mixing time. The extent of homogeneity could not be measured accurately with the use of any standard Instrument but with visual inspection and approximate using pH-meter as a result slight differences could be noticed.

An incorrectly impelled tank on the other hand can lead to poor mixer performance which result in the mixer not being able may achieve the process result for which it was designed.

It is normally desirable to position the impellers perfectly in the tank to prevent solids or fluids from stagnating at any point. The optimum mixing arrangement, however, will vary from process to process and is dependent upon a variety of factors including, vessel geometry, vessel internals, specific power, the required surface effects, and viscosity.

Understanding the effect of impellers in a mixing stirred reactor can go a long way to achieving fast, reliable scale up production, consistent physical and chemical properties and impurity profiles. This effect in turn help to manage variable batch size and multi product plants and at the same time meet production deadlines. In the long run adding value to the company and saving money.

2. Methodology

In this study four step adopted were; design and fabrication of laboratory mixer, selection and fabrication of three different types of impellers, production of white emulsion paint, experiment on mixing using different impeller types.

The mixer was constructed using iron material. The properties of Iron that enabled it to be used as material of construction is as follows: Iron as a material is the most readily available type of metal, thus making it one of the cheapest available, the nature of iron is such that it can easily be coated with an antirust paint, to prevent corrosion giving it an advantage over other metals, the rough surface of iron makes for better mixing because it increases interaction between molecules and increasing chances of better homogeneity during the mixing process. In order to obtain standard results the mixer was built to contain less than 4 liters of substances to be mixed.

The dimensions of the fabricated mixer is: Z =Height of the mixer, 300mm,T = Diameter of the mixer, 200mm,B = Baffle width, 45mm,D = Diameter of impeller, 66.7mm,C = Bottom Clearance, 75mm, Motor Power = 0.5 Kilowatts, 180 r.p.m

The material used in the construction of the impellers was iron for the same reasons it was used for the construction of the mixer. For the purpose of this experiment, different types of impellers shaped were constructed namely; simple Paddle, three Bladed Propeller

Each of these impellers had their different effect on the mixing processes

2.1 Experiments on Mixing Using Different Impeller Types.

The first batch of white emulsion paint was introduced into the mixer With three bladed impeller and the rotor switched on (at constant speed throughout the experiment), after 30 seconds titanium oxide and nitro sol were also introduced into the mixer (one after the other) and by visual inspection and stable pH-value of paint mixture, the extent of homogeneity was observed after 30 seconds, 60 seconds and 90 seconds respectively.

This same procedure was repeated for 2nd and 3rd batches with the simple paddle and anchor propeller respectively. All observations were obtained by visual inspection and pH-meter. This aids in determining the extent of mixing or homogeneity and all observations were recorded.

3. Results and Discussion

3.1 Figures

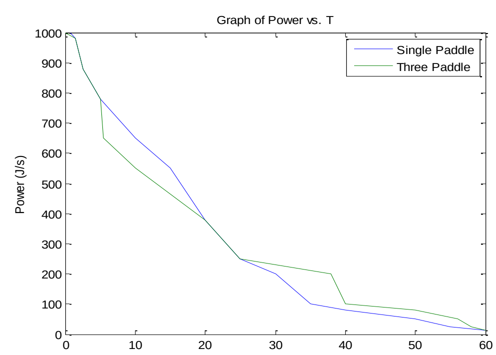

Fig. 1 Power Versus Time for Single and Three Paddle.

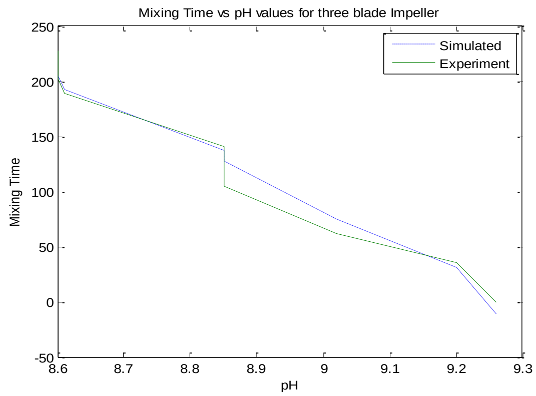

Fig. 2 Mixing Time Versus pH Value.

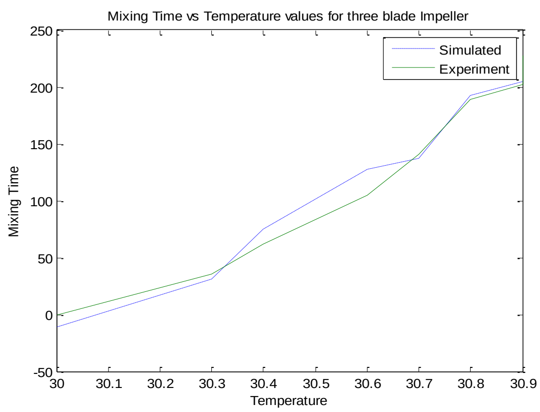

Fig. 3 Mixing Time Versus Temperature.

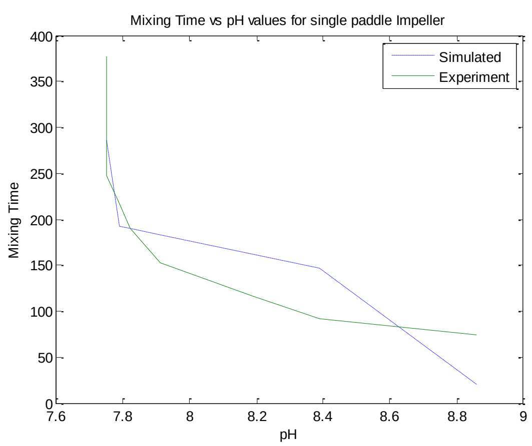

Fig. 4 Mixing Time Versus pH Value

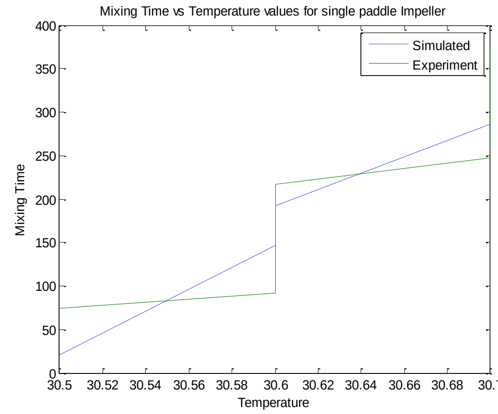

Fig. 5 Mixing Time Versus Temperature.

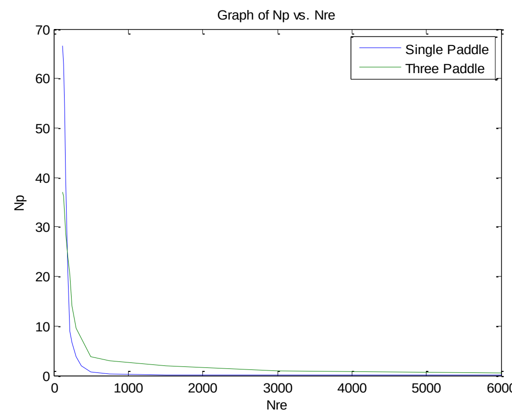

Fig. 6 Plot of Np Versus Reynolds Number

4. Discussion of Results

1 Impeller Flow Patterns and Circulation Time

Figure 1 shows the impeller power versus blending time for both single and three bladed impellers. The 3-bladed impeller produces flow combining axial and radial patterns, directed downward from the vertical axis. As a result, for a constant shear rate *G*, the circulation time of the 3-blade is in between those of the axial and radial flow impellers. After 40 min, most of the smallest clusters have been ‘‘swept out’’ and incorporated into the structure of the larger flocs, although some remain. Visual observations at this stage of the experiment indicate that the turbidity of the suspension has dropped drastically from that of the previous sample, indicating a significant drop in the particle number concentration. Also, for a constant shear rate the single bladed impeller results in the higher shear rate and required more power than the bladed impeller for the solution to attain the same homogeneity [1]- [4].

The pH value considerably falls as mixing time increases. This can be attributed to the loss of basicity of the blend due to mixing. After 200 secs the blend tends to maintain constant pH value of 8.60 which is the maximum mixing state that could be achieved by such impeller. However, for single blade impeller the constant pH value of 7.75 is maintained, since pH is a function of concentration, these show that the negative log function of the concentration mixture is decreasing with blending time. In laminar flow, bulk diffusion and molecular diffusion are the mechanism of concentration and temperature difference reduction [3], [11].

Statistical methods are used to describe the uniformity of the data in the mixing operations, the time to bring composition or properties with range or spread in values indicated as a measure of mixing performance for three bladed impeller than the single bladed. [1], [3].

This could be compared to the experimental data which shows a good correlation and agreement with the simulated data.

Figures 5 and 1 show the power number effects versus the Reynolds number, and the power effects against time for both single and three paddles respectively. The power number decreases as the Reynolds number increases which is confirmed by the other graph which indicates that the power decreases as time increases for both single and three paddle mixers.

2 Temperature and Mixing Time

The blend mixture shows considerable increase in temperature with increasing mixing time. The temperature increases gradually from initial point (30 ^{0}C) to a maximum when the mixing time is above 200 secs as shown in Figures 2 and 4.

The change in temperature could be due to agitation based on molecular interaction between the mixing components. Since molecular collision will increase with agitation. Shear forces due to bulk movement could also be responsible for the change in temperature. Likewise with the friction effect of the container wall could be a factor for temperature change.

The experimental result seems to form a more linear relationship between the two variables but the simulated result shows a regressed pattern on the experimental results.

The effect of the single blade impeller approximate the experimental data, the change in pH value increases drastically with blending time. This can be due to the vertically flatted head of the impeller which covers reasonable space to enhance mixing. The simulated result has good agreement towards midpoint of the experiment.

The temperature effect is not well correlated. First shows a steady rise and then an unprecedented rise. Between 56-230 sec the temperature of the mixture is maintained at 30.6 ^{o}C above this result to a gradual increase then a sharp end effects, this may be due to experimental error base on improper mixing and data collection.

5. Conclusion

It is obvious that for agitation to be effective it must be carefully tailored to the particular result desired. Optimum mixing result is usually obtained by using the right impeller, although other parameter influences the overall performance of the system: the immeasurable role of impellers cannot be overemphasized.

Various types of paddle impellers are often used at low speeds. Single bladed and three bladed are used in this experiment. At low speeds mild agitation is obtained in an un-baffled vessel. At higher speeds baffles are used since without baffles the liquid is simply swirled around with little actual mixing. The three bladed impeller produces flow which is a combination of axial and radial flow pattern. Also the three bladed form a more linear relationship between the two variables of temperature versus mixing time.

However the concentration of the mixture decreasing with blending time shows a good correlation of the experimental data compared with the simulated data.

In conclusion the three bladed impeller has the highest efficient and optimally homogenized for a cylindrical mechanically agitated vessel.

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