Effect of aeration on mixing time in stirred tanks using dual PBTU30˚ impeller

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Abstract

In this work effects of aeration and impeller speed on mixing time in a stirred tank with PBT impellers is studied. All the experiments carried out in a stirred tank with two PBTU30˚. Conductivity Probe technique is used for obtaining of the mixing time. Results show with increasing the impeller speed in both; single- and two-phase systems cause decreasing the mixing time. Whereas, the aeration can lead to increase or decrease mixing time and even create negligible effect. Also, is shown that different flow regimes can affect the final concentration of conductometer.

Keywords: Stirred tank, PBT impeller, Mixing Time , Aeration,conductivity.

Introduction

Stirred tanks are widely used in different industries like pharmacies, foods, refineries and chemical process. Using these mixers need to be optimized in designing by applying and selecting the suitable impellers,impeller ratios with tank diameter and other stirred tank ratios. Mixing time is one of the parameters that lead to find the optimum flow regime. Mixing time is defined as the time required to gain a certain homogenity of two or more content of material that are mixed. For many high-volume industrial scale mixers, proper placement and sizing of impellers becomes critical in satisfying maximum allowable mixing time requirements which are dictated by reaction time. Reactants which react very fast must be accommodated by faster mixing times [1].

Traditionally, gas dispersion in agitated vessels is carried out using radial disc turbines, such as the Rushton turbine. With the aim of reducing the weaknesses of disc turbines in gas-liquid applications, an increased interest in axial flow impellers for such operations has evolved. Customarily, the axial impellers are used in the down-pumping mode and have provided significant advantages over radial flow agitators [2]. The pitched blade turbines (PBT) have a good balance of pumping and shear capabilities and therefore are considered to be a general-purpose impeller. The flow pattern with a PBT becomes closer to radial as the impeller

diameter is increased or liquid viscosity is increased [3]. Multiple impellers are used when liquid depth/tank diameter ratio is higher than 1.0. In that case, more circulation loops are formed. Radial flow impellers give two circulation loops with each impeller.
Marijn M. C. G. Warmoeskerken.[4] studied the gas-liquid dispertion with pitched balde turbines, they showed there are two distinct regimes by which gas leaving the sparger reaches the impeller: at low gas rates this is indirect via the recirculation loops, while at higher gas flow rates the flow is direct. Piero M. Armenante.[5] investigated on power consumption of 6PBT and obtained a correlation for power number. Firoz et al. [6] studied the strength of the trailing vortex structures close to the four-bladed 45◦ pitched blade turbine using vorticity maps. It is possible to minimize the vortex size and improve the axial flow efficiency of such impellers by proper designing of the blade tip shape. Kumaresan et al.[7] did an extensive investigation of impeller design effect on the flow pattern and mixing in stirred tanks with using axial impellers and showed that number of blades, blade width, blade angle and pumping direction influence on the mixing efficiency.

Experimental

All experiments carried out in a flat bottom stirred tank made of glass with inner diameter (T) 0.3 m. The setup are shown in Fig.1 . It's equiped with four baffles (width of 1/10th and thickness 1/100th of the tank diameter) and electromotor that lead to rotate the impellers. A sparger having perforated distributor of 7.5cm diameter and 31 orifices which is used for aeration that is placed 5 cm under the bottome impeller. Tow 6-blade pitched blade turbin (PBT) are mounted on the shaft. The specification of the PBT impeller is given in the Table.1. Gas aeration is provided by a compressor that flow rate of gas is measered by a calibrated flowmeter. The off – bottom clearance is C1 = 0.55T, and the upper impeller is placed ΔC = 0.7T above the lower one.The stirred tank is filled with water which its surface is C2 = 0.55T above the upper impeller. The stirring speed is measured using a calibrated digital oscilloscope. A tachometer was used to measure the impeller speed for certitude. A pulse trace of 60 ml of NaCl solution (100 gr/Lit) is injected vertically above the surface of water. The point of prob is selected at middle of tank to measure the final mixing time through varing the concentration to attain the final concentration within ±5% of the average final concentration.

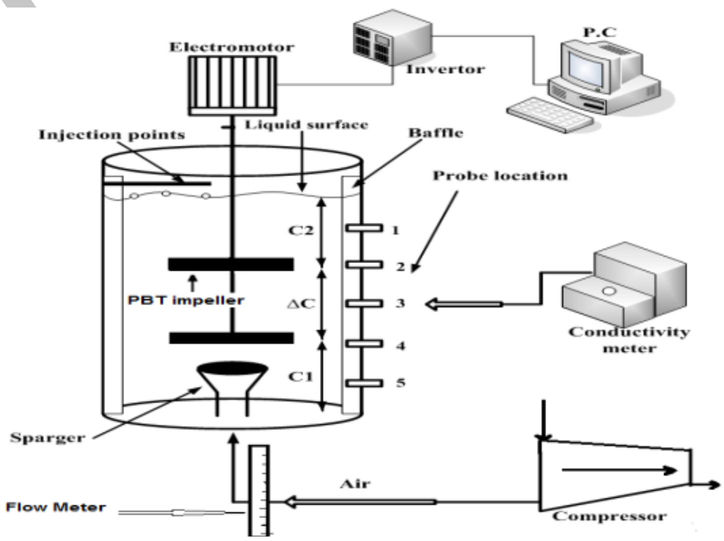

Fig.1 - Experimental setup

Table.1 – specification of the used PBT impeller in experiments

Impeller	Diameter	Blade thickness	Blade width	Blade length	Hub diameter	Hub height
PBTU30°	100 mm	2 mm	20 mm	32 mm	36 mm	22 mm

Mixing time via conductometery prob technique

Conductivity measurement method with NaCl solution as a tracer fluid has been used to measure the mixing time. The density of the tracer fluid has the average of 1078 kg/m3 by dissolving an appropriate quantity of sodium chloride in water.

The prob point of 3 that is located in middle space of two impeller is used for prob location. The conductometer is normalized for each set of experiments; Each normalized signal starts from concentration C (t=0) =0 and changes over time to the final concentration of C (t=∞). The variance is then defined as [8] : for one probe :

$$\sigma^2 = (C'(t) - 1)^2 \tag{1}$$

and:

$$C'(t) = \frac{C(t) - C_0}{C(\infty) - C_0} = \frac{C(t)}{C(\infty)} \tag{2}$$

Where C′(t) is the current value of the normalized response at time t.

The mixing time is then defined as a time when the variance reaches 95% from its final value. In Fig.2, a plot of the calculated variance is obtained in a semi-log scale. The variance indicates the decay of the concentration fluctuations after the addition of the tracer. In a semi-log scale the variance can vary from zero for an unmixed system, to −∞ for a perfectly mixed system. Then, the mixing time is easy to define at 95% homogeneity as the time when the last concentration fluctuation crosses the line log (σ^2) = -2.6

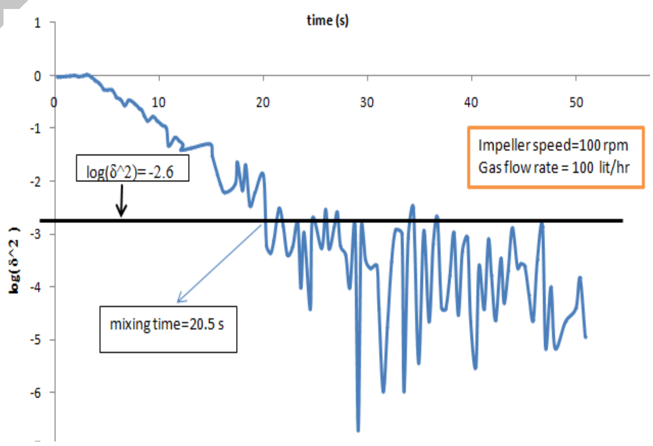

Fig.2 – Mixing time achieved with log variance in PBTU30° impeller

Results and Discussion

1.Effect of impeller rotational speed

Impeller speed plays a major role in flow regime and by increasing the impeller speed, circulation loops and turbulency of fluid is observed. Minimizing the mixing time in mixing systems is one of the main pourposes for optimum design[9]. Fig.3, shows that mixing time (for one phase system) , decreases exponentially by increasing of the impeller rotaional speed and equation (3) is fitted with it accurately. Satish, Pandit and Jafari [10,9], have reported the same observation even by combination of different impeller, incresing the impeller speed, cause reducing of mixing time.

$$\text{Mixing time}(t) = 26.976\exp(-.002N) \quad (3)$$

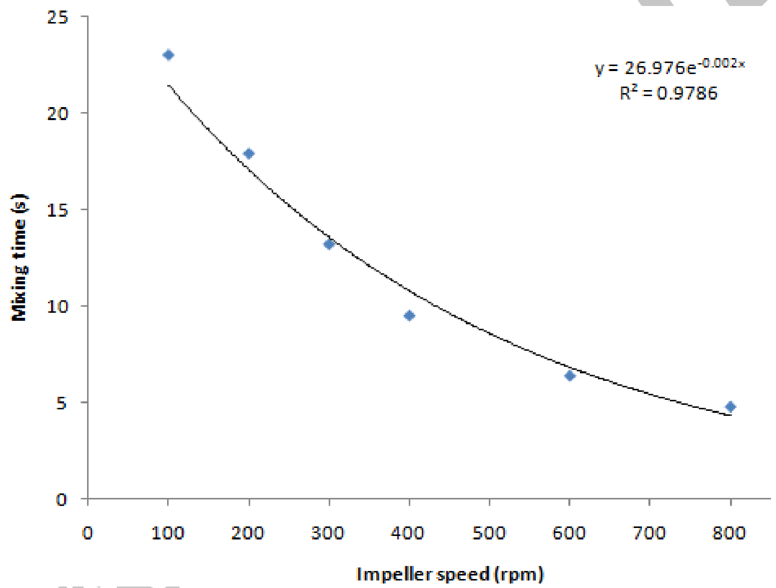

Fig.3 – Effect of impeller speed on mixing time in one phase system

It's noticeabe that start region of the curve (N<300rpm), has a sharp slope of variation, whereas for higher N(impeller speed), has lower value of curve slope. This case indicates that variation of mixing time at high speed is slow and lower. Fig.4, is shown the mixing time variation with impeller speed in different gas flow rates. The space between above line(100 lit/hr) and lowest line(600 lit/hr), in 100 rpm point, is noticeable enough; but this space is reduced by increasing of impeller speed which implies having low effect of aeration on mixing time in high impeller speeds. It's realizable that by different gas flow rate, increasing of impeller speed lead to decrease mixing time.

The dimensionless mixing time, $N.t_{m,}$ will remain constant if the impeller speed remains just in the turbulent region. Fig.5, shows that for Re>25000, nondimentional mixing time is almost constant. For Re<25000 has the lowest value that in comparison with others work shows proper results. As comparison, Wang Zheng et al[11]. (CFD), present the 66.5 with rushton turbin for nondimentional mixing time. Supposed that the mixing process is affected by the rate of the Reynolds number , several empirical equations can be used to predict the mixing time, for example, Moo-Young et al[12]. proposed: equation (4)

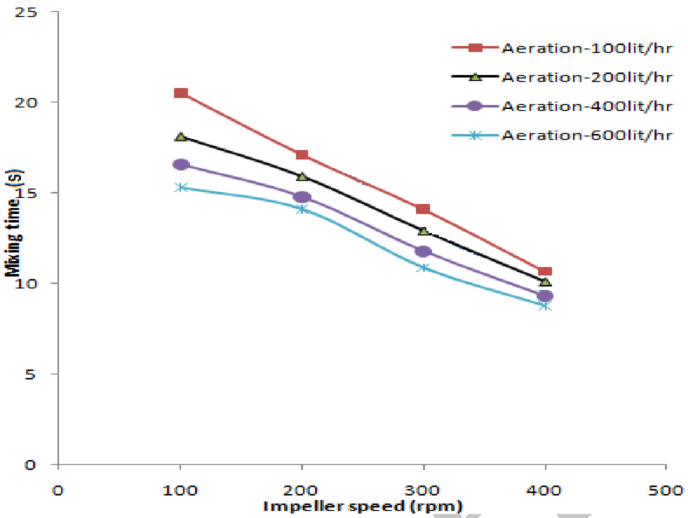

Fig.4 –Effect of impeller speed under aeration system(two phase)

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$$N.t_m = \alpha \operatorname{Re}^{\beta} \qquad (4)$$

Where $\operatorname{Re} = NT^2 / 9\upsilon$, β and α are the experimental proportional coefficients.

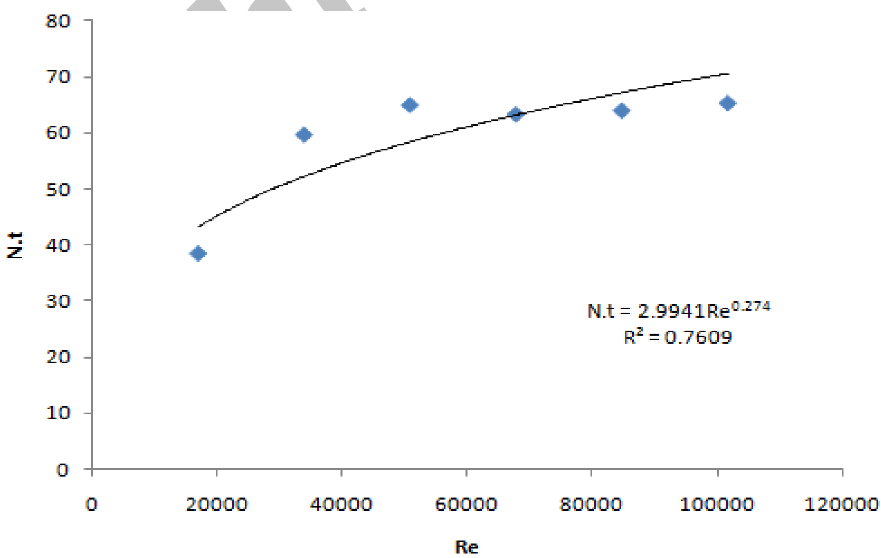

Fig.5 – Variation of nondimentional mixing time(N.t) with Re

Also the formed flow regime, influence the final value of conductometer(Fig.6-a), but drawing of the condutometer result in nondimentional form, lead to have fluctuation around the same line after a special time(Fig.6-b). However, obtained mixing time curve depend on its final concentration for each impeller speed, seperately.

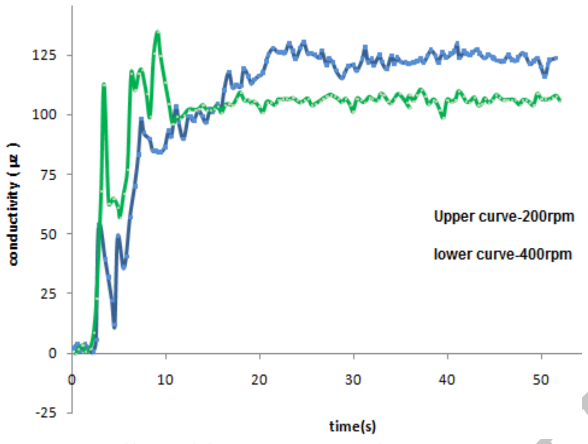

Fig.6-a, Effect of flow regime on final conductivity

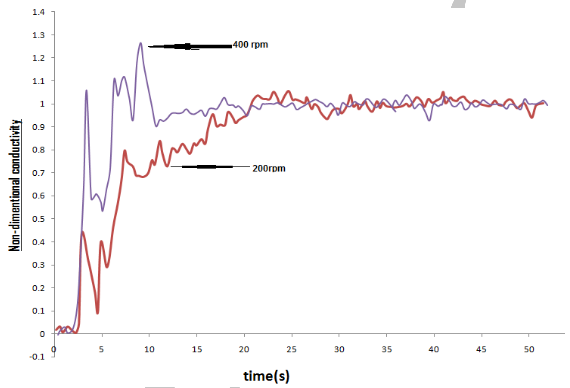

Fig.6-b, Nondimentional form of conductivity result in different flow regime

2.Effect of gas flow rate

Aeration increases the rate of mixing at a given shaft power, especially at high gas flow rates. Inconsistencies in the literature on the effect of aeration on the mixing time are satisfactorily resolved if the potential energy input from gas aeration is considered[13].

It is obvious from Fig.7, that in low impeller speeds, by incresing gas flow rate, the mixing time is decreased subsequently. In impeller speed of 100 rpm, a primary sharp slope is observed which can be due to the low created turbulency through mechanical power; however, starting aeration lead to creat a portion of turbulency and circulation flow via bubble distribution. By increasing of aeration, the curve slope becomes lower. Increasing of aeration rate in higher rate of aeration, has less effect on mixing time, due to low flow circulation and low power number in lower impeller speeds, so that the distribution of bubbles doesn't happen in whole volume.

At higher speed(N>300rpm), mixing time has more amount than one phase system, for low aeration rates. This can be due to the low gas volume dispersion in volume content. In the other word, suitable mechanical turbulency distribute the bubbles in whole volume conetnt but it last time to disperse bubbles due to lack of gas volume and low number of bubbles, so that by increasing of aeration, the mixing time is decreased again because of extend gas volume.

Pandit and Joshi[14] have assumed two different regimes separated by a critical impeller speed for gas-phase dispersion *(NCD*) for a specific gas flow rate (Q_G) and have reported that the mixing time decreases with an increase in the Q_G at any impeller speed which is less than *NCD* and the mixing time increases with an increase in the Q_G at any impeller speed which is greater than *NCD*.

Fig.7, is indicated for N<250 rpm, increasing of aeration lead to deacresing mixing time and for gas flow rate(Q_G > 150 lit/hr), increasing of impeller speed lead to decreasing mixing time, too. Also, it's noticeable that for high impeller rotational speed (N>400rpm), the effect of aeration rate on mixing time is negligible. So, it's noticeable that the proper regime is the aeration rate between 150 and 550lit/hr and impeller speed (N) between 200 and 500rpm.

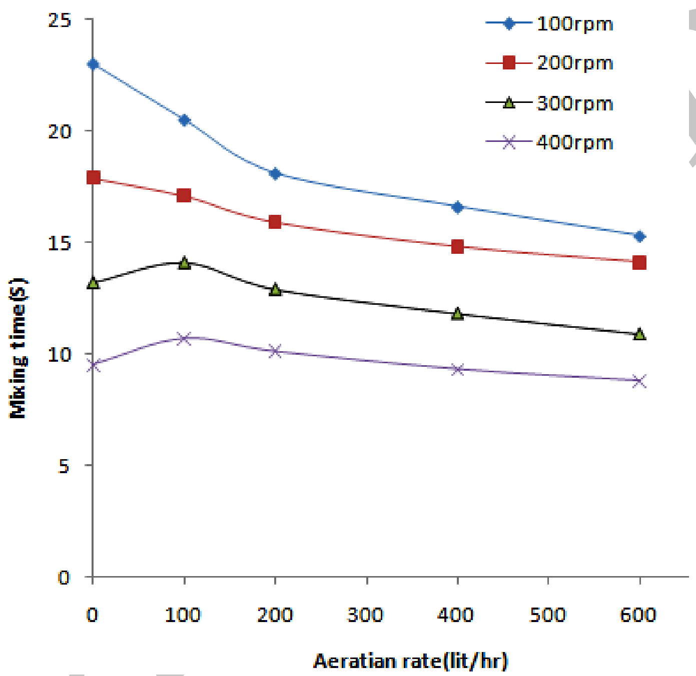

Fig. 7- Effect of gas flow rate on mixing time for dual PBT impeller system.

Conclusions

In this work, the effect of impeller speed and aeration rate on mixing time are investigated. It's obvious from results that mixing time is decreased by increasing of impeller speed. The rate of aeration has inconsinstence results on mixing time due to direct or indirect effect of gasses pumping capacity. For low impeller speed, aeration lead to reducing of mixing time but for high impeller speed, low aeration lead to increasing of mixing time. Then, more aeration creat two direct pumping capacity and decreasing of mixing time, consecuently. Also, the final results of conductometery , almost affected by flow regime but for each final concentration obtain the accurate mixing time, seperatly.

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بررسی اثر هوادهی بر زمان اختلاط در مخازن همزندار با پروانه PBTU30°

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چکیده
این تحقیق برای بررسی اثرات هوادهی و سرعت پروانه بر زمان اختلاط در تانک‌های همزندار همراه با پروانه PBT انجام شده است. کلیه آزمایشات در یک مخزن همزندار بافل دار با دو پروانه PBTU30° انجام شده است. از تکنیک هدایت سنجی برای بدست آوردن زمان اختلاط استفاده شد. نتایج نشان می دهد که در حالت یک‌فازی و دوفازی، افزایش سرعت پروانه باعث کاهش زمان اختلاط می‌شود، در حالی که هوادهی می‌تواند باعث افزایش یا کاهش زمان اختلاط شود و یا حتی اثر آن ناچیز باشد. تغییر غلظت نهایی هدایت سنج تحت تاثیر رژیم جریان، نشان داده شده است.

واژه‌های کلیدی: مخازن همزندار، پروانهPBT،زمان اختلاط،شدت هوادهی،هدایت-سنجی.