International Journal of Industrial Engineering
http://ijie.gjpublications.com/
Vol. 1, No. 7, 2017. Page 227-231.
ISSN: 2456-8449.

Research Article

Experimental Investigation on Jet Mixing of Homogeneous Liquids

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Abstract

The term mixing implies taking at least two separate phases and causing them to distribute randomly through one another. In jet mixers, a fast moving jet stream of liquid is injected into a slow moving or stationary bulk liquid. The relative velocity between the jet and bulk liquid creates a turbulent mixing layer at the boundary. This mixing layer grows in the direction of the jet flow. A very few works have been reported on jet mixer with top entry nozzle. Hence, a systematic work has been undertaken to study the mixing time of jet mixer with top entry nozzle. Experiments were conducted using sodium hydroxide and sodium chloride as the tracer to find the mixing time for particular concentration by conductivity. The flow rates maintained in the jet mixers were 60, 70 and 80 LPM. The solid dosage of sodium hydroxide and sodium chloride added in the jet mixer were in the multiples of their molecular weight. The effect of flow rates, solid dosage and hold up on mixing time characteristics were studied. The results of the study showed that an increase in the flow rate was found to reduce the mixing time. Also, the mixing time decreases with increase in solid dosage value of sodium hydroxide and sodium chloride at higher flow rates i.e 80 LPM.

Keywords: Jet mixer; Mixing time; Mixing; Solid dosage; Conductivity.

Introduction

Mixing has been one of essential unit operations for chemical engineering processes [1]. Mixing can be defined as the reduction of inhomogeneity in order to achieve a desired process result. The inhomogeneity can be one of concentration, phase, or temperature. Secondary effects, such as mass transfer, reaction, and product properties are usually the critical objectives. Mixing plays a key role in a wide range of industries such as fine chemicals, pharmaceuticals, petrochemicals, biotechnology, polymer processing, paints and automotive finishes, cosmetics and consumer products, food, drinking water and wastewater treatment, pulp and paper, Mineral processing etc.,[2,3].

Most commonly, mixing is used to produce uniform mixtures of components. But in some cases, the objective of the operation involves movement or transfer of materials from or to the surfaces of particles or phases. Examples of such operations include dissolution, leaching, gas absorption, crystallization, and liquid-liquid extraction. A few mixing operations also involve transfer of a component to or from an equipment boundary or surface as in the case of electroplating [4]. Mixing can be achieved using mechanical mixers, fluid jet mixers, static mixers or pipe line with tees [5,6].Mixing is mainly done in vessel-type and pipe-type equipment. In vessel –type equipment, there is a circulation or back flow that moves fluid into all parts of the vessel. Examples for vessel-type equipments are cylindrical tanks stirred by rotating impellers or propellers, or by jet of fluids [7,8].

In pipe-type equipments, flow is predominantly in one direction. But there is a cross-flow pattern which moves fluid perpendicular to the axial or direction of the flow. The vessel rotates and tumbles the material to be mixed. Examples of pipe mixers are co-axial jets with turbulent flow in the pipe downstream of the jets and modified helical screws in a tube [9]. Mixing by impellers and jets are two known methods for fluid homogenization in the liquid phase [10,11]. The

Received: 19.10.2017; Received after Revision: 30.10.2017; Accepted: 30.10.2017; Published: 31.10.2017.

cost of the device as well as complexity of fabrication and operation would be increased by the addition of impellers and other complex internal geometries inside mixers to intensify fluid motion [12]. In order to avoid such difficulties, the industries are now preferably using the jet mixers. Jet mixing can be defined as a type of flow mixer or line mixer, depending on impingement of one liquid over another to produce mixing.

The jet mixers are cheap and can be easily installed when compared with the impeller mixers. A jet needs just a pump for circulating the fluid, a cheap nozzle and some simple piping works. In the jet mixing operation, a part of the liquid inside the tank is withdrawn through a pump and returned into the tank at a high velocity. Therefore, similar to impeller mixing, a circulating pattern is maintained in the tank by a jet leading to liquid homogenization [9,10]. Mixing time is an important parameter to evaluate the mixing efficiency of mixing devices [13,14]. Mixing time can be determined either with experiments or numerical modeling, such as computational fluid dynamics (CFD) [15]. The conductivity method requires a conductivity probe to present in the target system, which make it an intrusive method because the existence of the probe might change the mixing efficiency of the device. In the present work, conductivity method is used to find the mixing time for different solid dosage of sodium hydroxide and sodium chloride at different flow rates. The applications of jet mixing includes extraction, chemical reaction, absorption and desorption, dust collection, evaporative cooling, drying of high moisture content particles, mixing, reaction injection molding, side-dump combustion, etc.[16,17].

Materials and methods

Experimental set-up

The experimental set up consists of a cylindrical borosilicate glass tank of 500 mm diameter and 600 mm height in which a nozzle is installed at the centre of the tank. A centrifugal pump is used to maintain a recycling condition which withdraws fluid from the storage tank and deliver it through the nozzle where the fluid is ejected to the mixing tank as a jet stream. The experimental set-up is shown in Fig. 1. The borosilicate tank is equipped with sensors to measure conductivity of the solution. The inlet flow rate is measured by recalibrated rotameter (35-50 LPM) and (10-100 LPM). The jet mixer specification is given in the table 1.

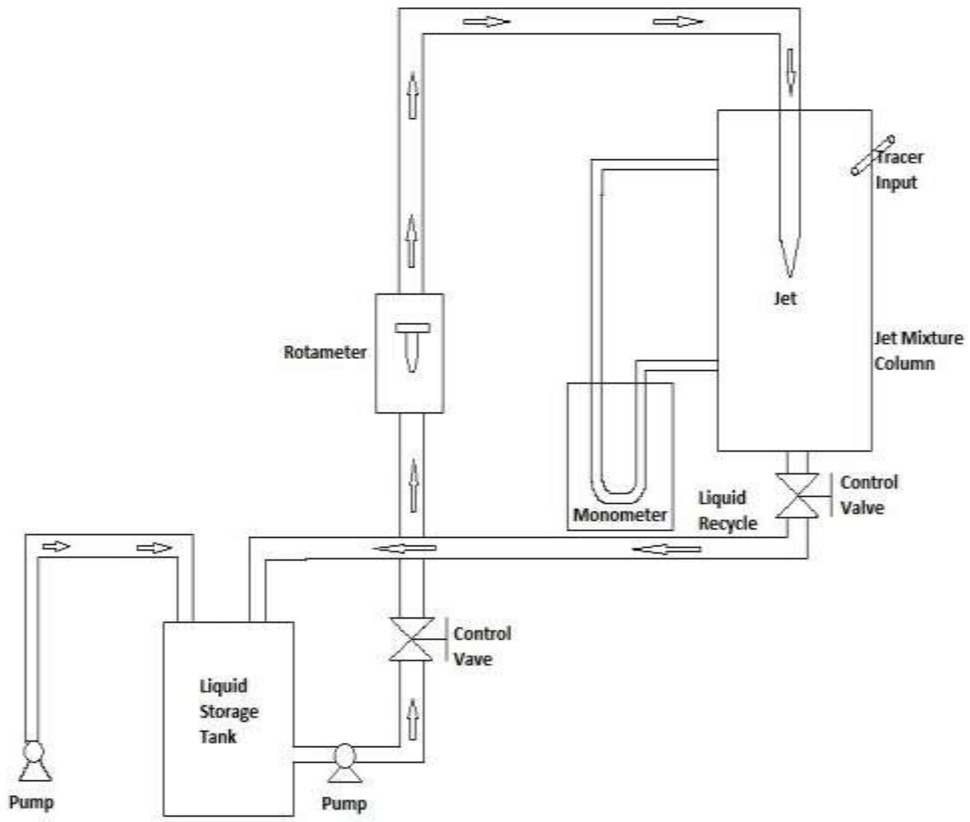

Fig. 1. Schematic of experimental set up

Table 1. Jet mixer specification

Column diameter	500 mm
Column height	600 mm
H/D ratio	1.2
Rotameter rating	10-100 LPM

Experimental procedure

The fluid from storage tank was pumped into the mixing tank through a nozzle. The output flow rate was adjusted to maintain the initial liquid holdup. After attaining the steady state, the initial holdup was noted. By maintaining a constant hold up, 100 ml of 10 N NaOH is added into the jet mixer. The conductivity readings are noted for every 5 seconds. The conductivity value is taken till a constant value is reached. Then 100 ml of 10 N of NaOH is added into the jet mixer from the centre of the tank. Again the conductivity value is noted down. The addition of NaOH is continued upto 1000 ml. The experiment is done for three flow rates i.e 60 lpm, 70 lpm, 80 lpm respectively. The above procedure is repeated for NaCl.

Results and discussion

The graphs were drawn between conductivity and mixing time for different operating conditions like flow rate, solid dosage, holdup etc., The solid dosage of sodium hydroxide added in the jet mixer are in the ratio 40, 80, 120, 160, 200, 240, 280, 320, 360 and 400 gm. For sodium chloride, the solid dosage varied in the ratio of 59, 118, 177, 236, 295, 354, 413, 472, 531 and 590 g. The effect of mixing time on different solid dosage of sodium chloride at different flow rate and the corresponding conductivity value is represented in Fig. 2 and Fig. 3. It can be observed that the mixing time decreases with increase in flow rates at different solid dosage.

Fig. 4 and Fig. 5 indicate the variation in mixing time on different solid dosage of sodium hydroxide at different flow rates. It can be clearly observed that the mixing time decreases with increase in flow rate at different solid dosage. Fig. 4 and Fig. 5 indicate the variation in mixing time on different solid dosage of sodium hydroxide at different flow rates. It can be clearly observed that the mixing time decreases with increase in flow rate at different solid dosage.

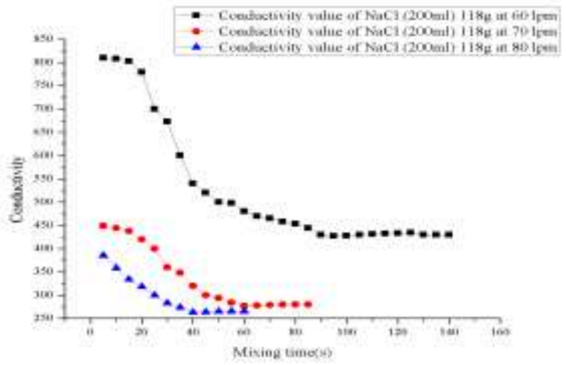

Fig. 2. Mixing time versus conductivity of NaCl at 118 g

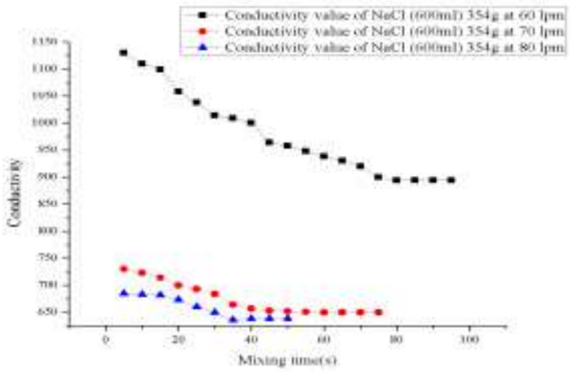

Fig. 3. Mixing time versus conductivity of NaCl at 354 g

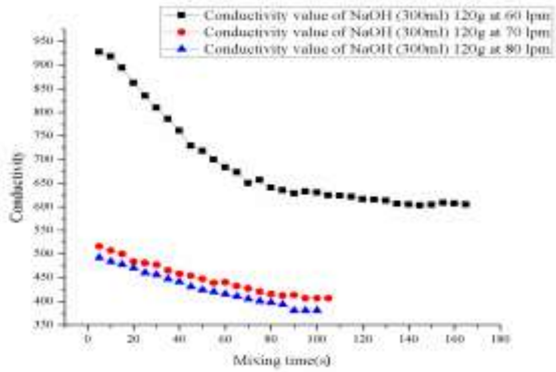

Fig. 4. Mixing time versus conductivity at 120 g

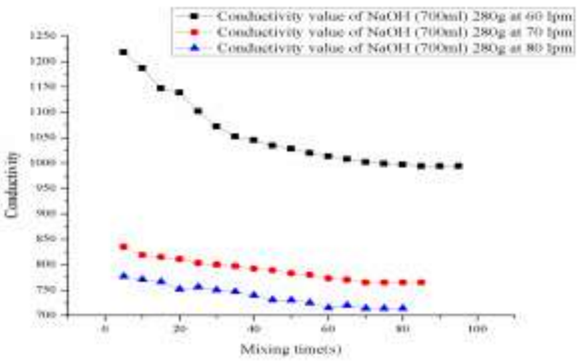

Fig. 5. Mixing time versus conductivity at 280 g

The effect of mixing time on different solid dosage of sodium hydroxide and sodium chloride for 60 LPM, 70 LPM, 80 LPM is given in Fig. 6, Fig. 7, and Fig. 8 respectively. It can be observed from the Fig.6 that mixing time decreases with increase in concentration of NaOH and NaCl. Fig, 6, Fig. 7 and Fig .8 indicates that the mixing time decreases with increase in flow rates at different solid dosage.

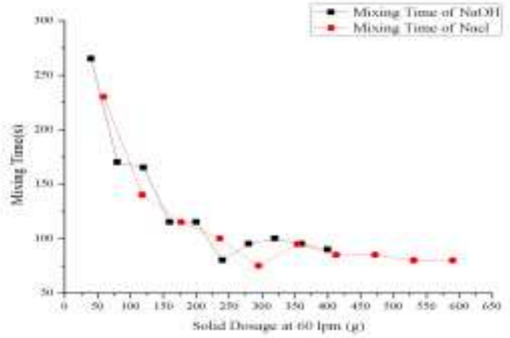

Fig. 6. Comparison of mixing time with solid dosage at 60 LPM

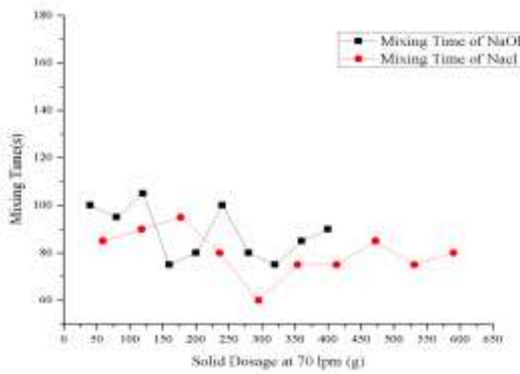

Fig. 7. Comparison of mixing time with solid dosage at 70 LPM

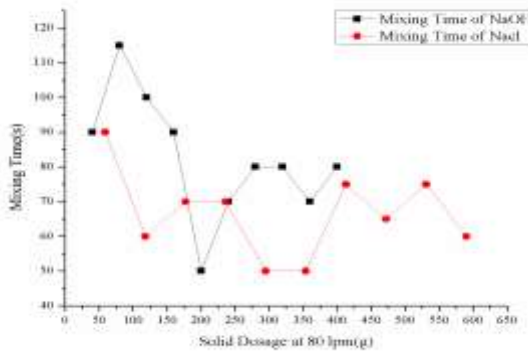

Fig. 8. Comparison of mixing time with solid dosage at 80 LPM

There was a gradual decrease in mixing time when compared to flow rate of 80 LPM with 70 LPM. Fig. 9 and Fig. 10 represent the effect of mixing time with different solid dosage of sodium chloride and sodium hydroxide at various flow rates. It is clearly understood from the Fig. 9 that mixing time decrease with increase in flow rates. It can be observed that the final mixing time value in NaCl is 80 s at 70 LPM and 60 s at 80 LPM. Fig. 10 indicates the final mixing time in NaOH as 90 s at 70 LPM and 80 s at 80 LPM.

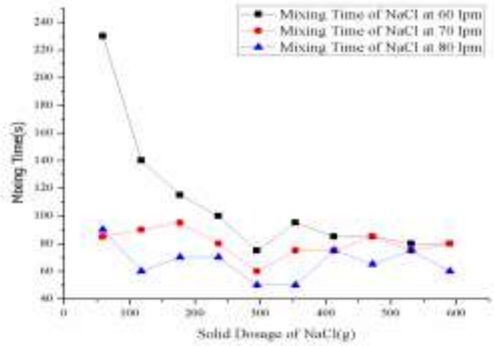

Fig. 9. Effect of mixing time with solid dosage of NaCl at various flow rates

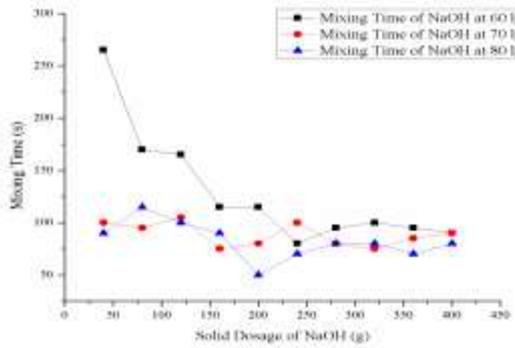

Fig. 10. Effect of mixing time with solid dosage of NaCl at various flow rates

Conclusions

Experiments were conducted in the jet mixer for studying the mixing characteristics of jet mixer under various operating conditions. The mixing time was taken as the time required for attaining uniformity in tracer concentration of the liquid. The concentration of the liquid was measured using conductivity meters. The parameters studied were flow rate of the liquid through nozzle and solid dosage of two tracers viz., sodium chloride and sodium hydroxide. It was found that the mixing time decreased with increase in circulation rate of liquid for all the operating conditions. It was also noticed that the mixing time was found to decrease with increase in solid dosage for all the operating conditions for both sodium chloride and sodium hydroxide. It was observed that the mixing time was found to be less for sodium chloride than that for sodium hydroxide for a given operating condition. Hence, it can be concluded that both increase in circulation rate of the liquid and increase in solid dosage reduces the mixing time effectively which, in turn, could save the power required for mixing.

Conflicts of interest

Authors declare no conflict of interest.

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