INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

IJARIIT

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue5)
Available online at www.ijariit.com

Performance of Mixing Efficiency and Residence Time Distribution of Static Mixer in Liquid-Liquid and Gas-Liquid Mixture

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Abstract: In this experimental work the mixing efficiencies of immiscible fluids were studied with finding out the mixing index of the fluids at the different velocities and with different Reynolds's number. For finding the efficiencies of the immiscible fluids the pressure drop acts as an important role so as the pressure drop increases then the mixing efficiency of fluids increases. Also, pressure drop directly effects on to know the increasing the mixing efficiency. Also, residence time distribution is a key factor which is found in the mixing of the immiscible fluids in the static mixer which shows the time which remains in the static mixer to pass out the solution which is also important for the calculating the mixing efficiency of the fluids. The objective of the study is to design the static mixer for estimating the maximum mixing efficiency of immiscible fluids.

Keywords: Static Mixture, Physical and Chemical Properties, Immiscible Fluid, Mixing Index.

1. INTRODUCTION

The use of static mixers in the manufacture of dispersions of immiscible fluids has received much attention over the last two decades for progress in the hydrodynamics and the mixing performance of these systems. Process control and monitoring have been improved as well, especially in the chemical, petrochemical, food and cosmetics industries etc. Also, the static mixers have been widely used for a variety of applications in process industry such as continuous mixing, heat, and mass transfer processes and chemical reaction. There is a wide variety of static mixer that is optimized for the specific application. Different designs mainly depend on flow regimes and their various applications.

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2. LITERATURE REVIEW

There is a wide variety of static mixers that are optimized for specific applications. Different designs are proposed depending on the flow regime and the applications. In their review, Han E.H. Meijer at al4 listed the principal commercial static mixer designs and static mixer proposed correlation analysis which are listed in P Joshi at al8. In the literature liquid-liquid and gas-liquid in turbulent flows have been studied by Emelian Lobry at al2.

The micromixing efficiency of a static mixer in various flow regimes and optimization of the micro-mixing efficiency which are studied by J. Z. Fang at al5, Mrityunjay .K. at al7 and important study based on the Microcellular foams of PVDF in the static mixer which is mainly studied by Srinivas Siripurapu at al9.

The static mixer with a high-efficiency vortex in turbulent flow is investigated. This type of mixer generates coherent large-scale structures, enhancing momentum transfer in the bulk flow and hence providing favorable conditions for phase dispersion which are mainly studied by T. Lemenand at al10.

The considerable amount of work on residence time distribution (RTD) for single phase flow has been reported, whereas information on RTD of liquid phase for two-phase flow in the static mixer which are mainly studied by, K.D.P. Nigam6, Tirupati Reddy Keshav11. And Reactions and residence time distributions in motionless mixers which are studied by E. B. Nauman at al1.

The influence of heat and mass transfer rate on the liquid-liquid and gas-liquid mixture is greatest in the laminar flow on the basis of equal pressure drop, dispersion phenomena in high viscosity immiscible fluid system and application of static mixer which are studied by Haehold P. G at al3 and optimized heat transfer at lower aspect ratio for the mixing elements which are considering in static mixer which are studied by Wadley R at al12

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3. EXPERIMENTAL SECTION

3.1Experimental apparatus and methods for mixing

The schematic representation of experiment is shown as in figure 5.Two-phase flow experiments were performed using two immiscible fluids. The experimental setup consists of two similar feed loops, as shown in Fig.3.1.

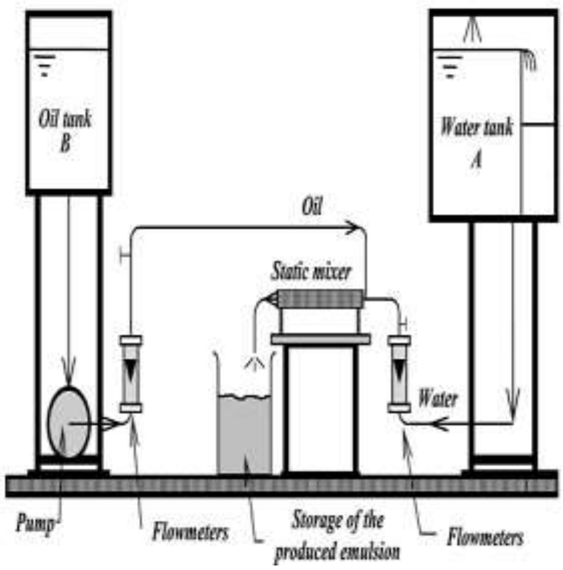


Fig3.1: Schematic diagram of mixing in static mixer

Each loop containing the working fluid. The oil is pumped with a centrifugal pump, while the water is supplied by a constant-level feed tank. Also for Gas-liquid mixing, the air is used with the help of compressor and the water is supplied by a constant-level feed tank. The flow rates are controlled by valves and measured with two flow meters with overlapping ranges. The working fluids are water for the continuous phase and technical sunflower oil without any additive for the dispersed phase which is used for the liquid-liquid mixing. And for gas-liquid mixing the water is used for continuous phase and the air is used in another loop as working fluid. The set-up allows running experiments corresponding to dispersed-phase mixing rates of up to 15%. With Reynolds numbers ranging from 500 to 15 000

3.2: Step of Finding out the mixing index for liquid-liquid mixture

1. First arranging the experimental set up as shown in fig. 5.1.
2. The two tanks which contain the working fluids fill in the tanks
   i) Water ii) Oil
3. Then start the oil flow rate and keep this flow rate constant throughout the mixing and water flow rate changes at the different velocities.
4. Add some sort of tracers which are changes from 1 to 5 wt %
5. The Output of the Tracers which are measured by the titration method.
6. So from the titration method Weight % of mixture com be calculated of the fluids.
7. So from the wt % of the mixture the standard deviation is calculated for each sample.

8. And from initial mixing or from the tracer wt % the Initial slandered deviation (6) which are calculated.
9. So from the known value of slandered deviation and initial slandered deviation, the mixing index is calculated.
8. So how Much mixing efficiency occurs in the process is known by the mixing Index.
9. The mixing Index is calculated by the different change in velocities used for process
10. From the various samples, it is observed that the change in mixing Index occurs.
11. So higher the Mixing Index the higher the mixing Efficiency.

3.3: Mixing Index for Gas-liquid Mixture

For Gas-Liquid mixture water and air are taken as a working Fluid the water is taken out in one tank and the air Compressor are connected at the static mixer simultaneously and the processer is carried.

5.3.1: Steps of Finding out Mixing Index for Gas-Liquid:

1. At Start Water are takes in one Tank and gas is taken from the air compressor.
2. The gas velocities are Kept Constant through Out the process and Liquid (Water) through the process
3. Tracers are added to know the mixing % in the static mixer
4. Then on the Valve of liquid tank and switch of Compressor and the both are passing from the Static Mixer
5. Offer the same Time the Whole Mixture is come out
6. So from the output mixture the trousers 0% are calculated and it measured by the titration Processer
7. So there Processers are carried at Different velocities of water and constant gas velocities
8. From there Weight % of Output Mixture Calculating the mixing Index of gas-liquid mixture
9. From these mixing Index, we know the efficiency of mixture of static mixture
10. So as the mixing index Increases the nixing efficiency increases.
11. So higher mixing index higher the mixing efficiency.

3.4: Calculation for Pressure Drop

The Pressure drop is an important concept in finding the mixing of fluid. So pressure Drop defines how much pressure which is used in the mixing of given process.

So for calculating pressure drop while the process is carried out the following formulae is useful for calculating the pressure drop,

$$\Delta P = \frac{4flv^2}{2d_e}$$

Where,
L = Length of static mixer
V =velocities of water
d_e= Equivalent Diameter
ΔP= Total pressure Drop
F= Friction factor

3.5 For Residence time distribution

Experiments were conducted to measure the RTD of the liquid phase in two-phase flow through Static Mixer using a step response technique. Air was used as the gas phase, and the liquid phase was water and aqueous solutions of carboxyl methyl cellulose (CMC) of different concentrations. The CMC solutions were prepared by dissolving CMC powder in water at 60 ◦C. Formaldehyde was added to prevent biological

Degradation of solutions (0.5 ml of formaldehyde per liter of CMC solution).The rheological behavior of CMC solutions was described by the power law model:

τ = Kγn.

So for finding the total residence time distribution the equation which are,

$$\bar{t}=\frac{\sum tiCi\Delta ti}{\sum Ci\Delta ti}=\frac{\sum tiCi}{\sum ci}$$

4. RESULT AND DISCUSSION

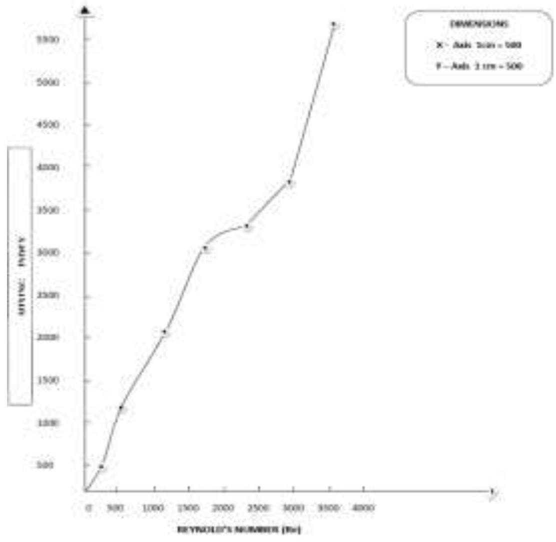
In the present work the σ, I_{LL}, I_{GL}, and ΔP were measured experimentally. So mixing index of liquid-liquid and gas-liquid, pressure drop, and RTD which are defined by the graph.

So for finding the mixing Index of liquid-liquid and gas-liquid the following equation are used,

$$\textbf{Standard deviation } (\sigma) = \sigma = \sqrt{\frac{\sum_1^n (xi-\bar{x})^2}{N-1}}$$

$$= \sqrt{\frac{\sum_{i=1}^n xi^2 - \bar{x}\sum_{i=1}^n xi}{N-1}}$$

Initial Standard Deviation (σ_0) = $\sqrt{\mu(1-\mu)}$



GRAPH OF REYNOLD'S NUMBER VS MIXING INDEX OF GAS-LIQUID

Mixing Index (I) $= \frac{\textbf{Initial Standered deviation}}{\textbf{Standered deviation}}$

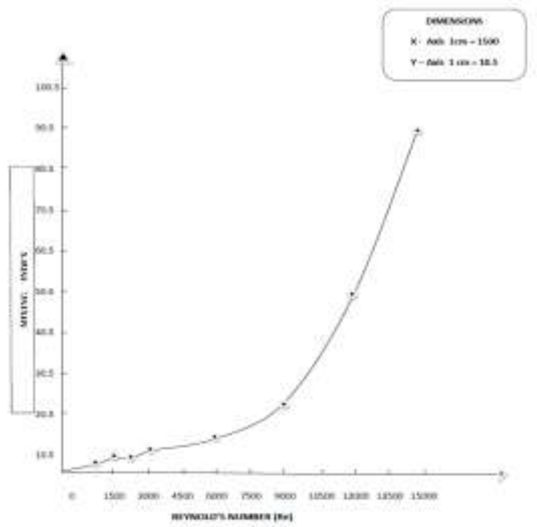
4.1 Mixing index of liquid-liquid mixing: So for finding the mixing index of liquid-liquid mixing following equation is used,

Standard deviation $(\boldsymbol{\sigma}) = \boldsymbol{\sigma} = \sqrt{\frac{\sum_1^n (xi - \bar{x}\ )^2}{N-1}}$

$$= \sqrt{\frac{\sum_{i=1}^n xi^2 - \bar{x}\sum_{i=1}^n xi}{N-1}}$$

Initial Standard Deviation **(σ_0) =** $\sqrt{\mu(1-\mu)}$

Mixing Index $(I_{LL}) = \frac{\text{Initial Standered deviation}}{\text{Standered deviation}}$



GRAPH OF REYNOLD'S NUMBER VS MIXING INDEX OF LIQUID –LIQUID MIXING

From the graph, it is clearly seen that the higher Reynolds's number of liquid-liquid fluid the mixing index of the liquid-liquid($\boldsymbol{I_{LL}}$) increases gradually.

So at the turbulent flow, the total mixing index rate of liquid-liquid fluids gradually increases.

4.2. Mixing Index of gas-liquid mixing: For finding the gas-liquid mixing index following equation is used,

Standard deviation $(\boldsymbol{\sigma}) = \boldsymbol{\sigma} = \sqrt{\frac{\sum_1^n (xi - \bar{x})^2}{N-1}}$

From the graph, it is seen that in gas-liquid mixing the higher Reynold's number higher the mixing index of the fluid.
So at the turbulent flow, the total mixing index rate of gas-liquid fluids gradually increases.

4.3: Finding out pressure drop of liquid-liquid mixing

So for finding the pressure drop the following equation is used,

Pressure drop=$\Delta P = \frac{2fLv^2}{D_e}$

Where,

ΔP= Pressure drop.

F = $\frac{16}{Re}$= friction factor.

D_e= Equivalent diameter=0.03.

L = Length of mixer=600mm

= 0.6m

AS the total pressure drop of the fluid increases Reynold's number increases the total pressure drop of fluids increases.

So it is clearly seen that at turbulent flow the total pressure drop of liquid-liquid mixing increases.
And as the total pressure drop increases the mixing efficiency increases in the given liquid-liquid mixing.

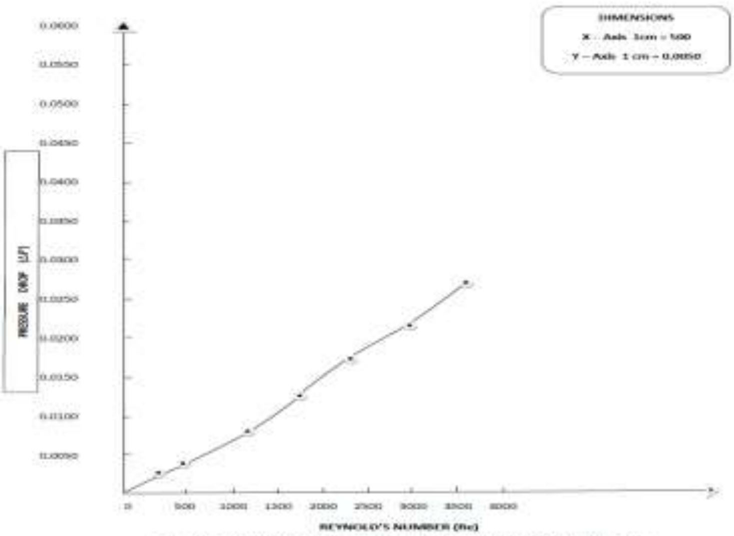


FIG- TOTAL REYNOLDS NUMBER VS PRESSURE DROP OF LIQUID-GAS

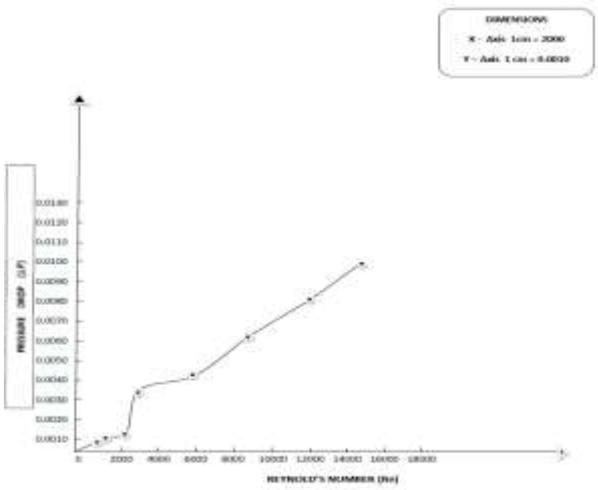


FIG- TOTAL REYNOLDS NUMBER VS PRESSURE DROP OF LIQUID-LIQUID

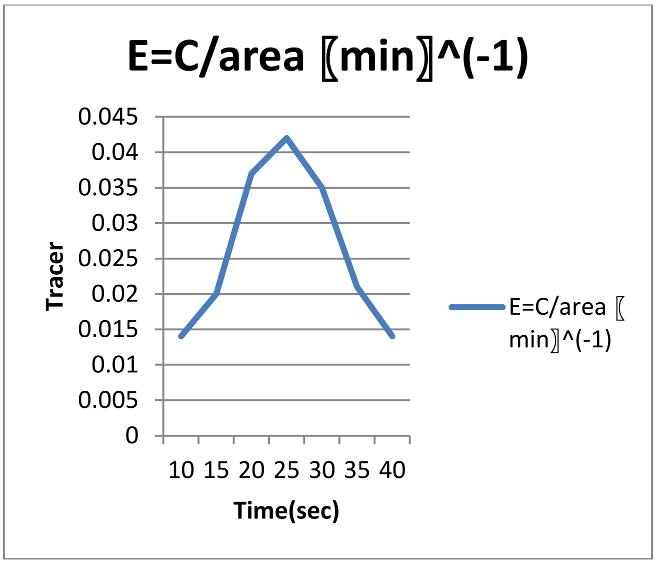
4.4. Finding the pressure drop of gas-liquid mixing
As Reynolds's number increases the total pressure drop of gas-liquid fluids gradually increases. So it is clearly seen that at turbulent flow the total pressure drop increases. And as the total pressure drop increases the mixing efficiency increases in the given gas-liquid mixing.

4.5. Finding out residence time distribution: So for finding out residence time distribution (RTD) the following equations are used

$$\bar{t} = \frac{\sum ti \times ci \times \Delta ti}{\sum ci \times \Delta ti}$$

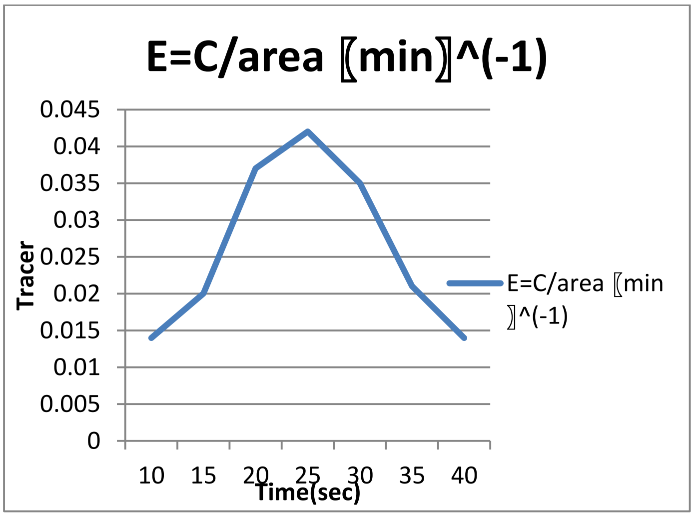
Where,
$\bar{t}$ = Mean residence time distribution of liquid mixture.

So residence time distribution of liquid-liquid mixing is:



So from the graph, it is shown that as the residence time of liquid-liquid mixing is higher than the total mixing of fluids increases. And the residence time distribution of the fluid is $\bar{t}$= **39sec.**

Finding out residence time distribution of Gas-liquid



So from the graph, it is shown that as the residence time of gas-liquid mixing is higher than the total mixing of fluids increases. And the residence time distribution of the fluid is $\bar{t}$= 24.63sec.

5. CONCLUSION

Mixing efficiency increases as Reynolds's number is higher. From the above experimental work, the effect of laminar flow and the turbulent flow of both fluids such as liquid-liquid and gas-liquid mixing are examined. In such laminar and turbulent flows which are common effects on the mixing efficiency or mixing index of fluids. Also, it shows that Reynolds's number increases then mixing efficiency increases. The holdup ratio of oil is taken as (1 to 9%) for liquid-liquid and (1 to 8%) for liquid gas.

Another term which is examined in experimental work is a pressure drop. The pressure drops which are mainly effects on mixing efficiency of fluids and it shows that as pressure drop increases the mixing efficiency also increases. The residence time distribution which mainly depends on the total time taken in the static mixer to pass out the solution. So higher the residence time than higher the mixing of fluids, and which depends on flow pattern in the mixing. The hold-up ratio of fluids is present in the inlet stream of liquid-liquid and gas-liquid flows. Higher the hold-up percent in the mixture then higher the residence time of fluids.

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