FLOW AND MIXING CHARACTERISTICS OF JET-FLOW REACTOR

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ABSTRACT

A novel jet-flow reactor is designed, fabricated and tested for carrying out gas-liquid reactions. As all reactions between gas and Liquid are categorized as instantaneous, fast or slow and the mass transfer is also playing prominent role, it is necessary to carry out study on kinetics of reaction, mixing characteristics and mass transfer characteristic of the reactor. Jet flow reactor being novel, its characteristics related to the mixing and mass transfer are taken up for study separately.

This paper deals with study of flow and mixing in this Novel equipment i.e., Jet-flow reactor. Therefore, it undertakes the study of mixing characteristic in the reactor. Mixing characteristics can be better studied with fluid which is transparent and using tracer which are visible in this transparent fluid and are easily dragged or flown by the fluid under test. Thus, taking known volume of water and specially designed tracer like spike type tracer, water balls and poly-vinyl chloride (PVC) grains, are chosen to observe the axial flow as well as radial flow. To begin with, after completing Hydraulic and pneumatic test of the vessel, the study is carried out with known amount of liquid and known flow of gas. The movement of liquid, both in radial as well as axial direction, is observed by reflection of LED light focused from top on tracer particle. This manual observation by naked eye and photographs and videography reveal the flow pattern. The flow pattern is reproduced in the form of schematic diagram to better understand the flow behavior.

Having completed this study, qualitatively, further study is carried out for quantitative analysis using chemical system which can be analyzed by simple chemical methods. Thus, NaOH-CO_2 system is chosen and the mixing characteristics is checked. Both the observations, flow pattern and mixing are recorded.

Keywords: *Jet-flow reactor, flow pattern in mixer tank, mixing characteristics*

1. INTRODUCTION TO JET-FLOW REACTOR:

The novel jet flow reactor, is intended to carry out gas-liquid reaction without causing liquid and gaseous pollution by completely utilizing the raw material [1]. To understand and predict the performance of the reactor for various type of reactions, the study of flow and mixing is carried out. To explore the suitability of the equipment for various reactions, the data are compared with existing reactors.

2. JET FLOW REACTOR:

2.1 Construction of jet-flow reactor:

Jet flow reactor consists of jacketed tank with bottom-elliptical dished end and top flat end. Four baffles are mounted equidistance inside. Two pipes with jet nozzles are mounted at the bottom end along with the two baffles. The projection of this two jets are such that they make an angle of 45˚ with both radial direction and tangent to the tank circumference. The pipe carry gas and disperse gas through jet nozzle at bottom such that liquid acquires circular motion. The nozzle is convergent nozzle with 1.5 mm diameter at the narrow end and 12.5 mm at other. The

vessel has got one outlet at the bottom for material, one outlet for condensate from jacket, one inlet for jacket and three opening at the top flat end. Among the three-top opening, one rectangle opening is meant to rest the mist eliminator and other two are light glass and sight glass. The entire vessel is supported on the lug support. The gas inlet line is connected to the outlet of compressor through needle valve. Flow is distributed equally in both the pipes carrying nozzle by Tee-Joint. Proper observation is ensured by the light of LED from the light glass and observations and photography are performed from sight glass.

(a) Semi-batch reactor

(b) Top head of the reactor

(c) Bottom end of the reactor

(d) Internal configuration of reactor

Fig-1: Semi-batch Reactor & it's configuration

2.2 Tracers:

Three types of tracer are used (i) Floating PVC spherical grains of size 3 mm. Some grains are colored yellow, some green and some are yellowish green, (ii) Spike type tracer (arrow type) are the floating tracer exhibiting movement of fluid in axial direction and (iii) Water balls. (Refer fig.2)

(a) PVC grains

(b) Spike type tracer

(c) Water ball

Fig-2: Types of tracer

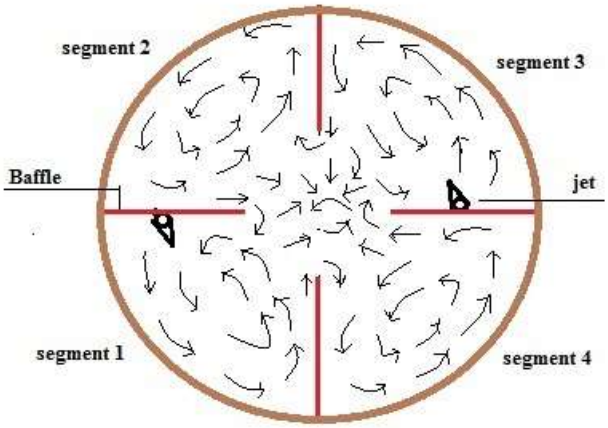

Fig-3: Movement of liquid in tank

2.3 Working of jet-flow reactor:

For conducting trial water and air are chosen. Water is filled up to required level (45 L) in the tank. The compressed gas (ambient air), compressed to 110 psi (this pressure of 110 psi is fixed after performing several trials to establish the steady-state) is then supplied through nozzle to maintain the steady state flow. Gas emerges out from nozzle as jet into the pool of liquid.

The experiments are divided into two categorize:

1. Qualitative analysis using water-air system
2. Quantitative analysis using NaOH-CO_2

2.3.1 Trial runs for flow pattern:

To carry out the study of flow pattern the total volume of tank is divided into four segments (Refer fig 4). The segment between the two consecutive baffles which includes the jet are called segment 1 and segment 3. The other segments are given number 2 and 4 such that sequence of the number is in clock-wise pattern as shown in fig. 4.

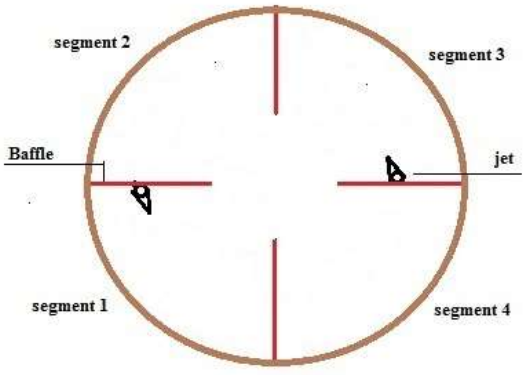

Fig-4: Segments in jet mix reactor

2.3.1.1 To decide the level of liquid:

This was decided by observing gas bubbles while dispersion of gas at 100 psi. Since the pressure was the limiting factor, the gas bubbles rose and burst out in atmosphere at higher rate of gas and lower liquid volume. The vessel is designed to accommodate 45 liters of liquid with 30% of the vapor space. Therefore, the flow rate, liquid level and the pressure of compressor were so chosen that the steady state can be maintained. Thus, total volume of liquid, 45 liters and pressure of compressor 110 psi gave the steady state performance with adequate dispersion and provision for observation.

2.3.1.2 To observe the axial movement:

In this step, the spike type tracer shown in fig. 2(b) were placed on the surface of the liquid at selected locations. The compressed gas was then started at steady state and dispersion of gas was done through two nozzles. The movement of spike showed "Down-to-top" at places between two baffles where jets were mounted i.e., segment 1 and 3 and the movement of spike showed "Top-to-down" at the center. The spike also showed movement of material from opposite segments, and also in other segments where jets were not there.

2.3.1.3 To observe the radial movement:

Water ball type tracer, fig. 2 (c), and PVC granules of different colors fig. 2 (a) were used. Placing the different color spherical particle in equal quantity in all segments, the experiment was started. Thus, having placed floating spherical particles distributed uniformly the gas purging was started at the rate which was used earlier. Particles of different colors showed movement at different rate. However, it showed the movement which appeared to be regular after some interval of time. All the observations were reported and photographed. From the photography and observations, the schematic diagram of flow pattern was prepared (Refer fig. 3).

2.3.1.4 Result and conclusions of flow pattern:

As a result of visual observation and photographs of all tracers' movement, the flow pattern was derived i.e., from movement of spike tracer axial flow and from movement of water ball type tracer and PVC grains, radial flow. Based on this observation the schematic diagrams are prepared which reveals the flow pattern of the liquid-gas mixture into the jet-flow reactor as shown in fig. 3.

2.3.2 Trial runs for degree of mixing:

2.3.2.1 Experimental:

To, determine the time of mixing, experiment were carried out with dilute solution of NaOH and air [2]. Thus, 45 liters of 0.1 N NaOH was taken into the vessel and the compressed air(ambient) at 110 psi was introduced through jets in the vessel. The samples were collected at regular time intervals and were analyzed for its content: strong alkali and weak alkali.

2.3.2.2 Analysis:

The samples were analyzed by neutralizing with 0.1 N HCl and using phenolphthalein and Methyl orange as indicator. It means that two samples of 10 ml each were taken separately and were analyzed with 0.1N HCl using Phenolphthalein for one sample and Methyl orange for another. The results are tabulated.

Table 1: Observation with NaOH-CO_2 system

Time (min.)	B.R using phenolphthalein	B.R using Methyl orange	Equivalent of strong alkali	C_A / C_{AO}

	V_1 (ml)	V_2 (ml)	$C_A = \frac{(V_2-V_1)}{1000}$	(C_{AO} = 0.1 N)
0	14.6	21.1	0.065	1.5384
1	14.8	20.2	0.054	1.8518
2	14.9	19.0	0.041	2.4390
4	15.2	18.3	0.031	3.2258
6	15.2	18.2	0.030	3.3333
8	15.0	18.1	0.031	3.2258
10	15.0	18.3	0.033	3.0303
12	15.5	18.2	0.027	3.7037
14	15.6	18.0	0.024	4.1666
16	15.5	18.1	0.026	3.8461
18	14.9	18.0	0.031	3.2258
20	15.1	18.1	0.03	3.3333
22	15.5	18.8	0.033	3.0303
27	16.0	19.3	0.033	3.0303
32	16.4	19.2	0.028	3.5714
37	16.8	19.1	0.023	4.3478
42	15.6	18.1	0.025	4
47	15.4	18.2	0.028	3.5714
52	15.2	18.1	0.029	3.4482
57	15.0	18.4	0.034	2.9411
62	15.4	18.5	0.031	3.2258

2.3.2.3 Result of experiment for mixing:

The plot of 'concentration of NaOH' and 'time' showed sharp decline initially, followed by cyclic rise and fall with slight deviation during subsequent period as shown in fig. 5.

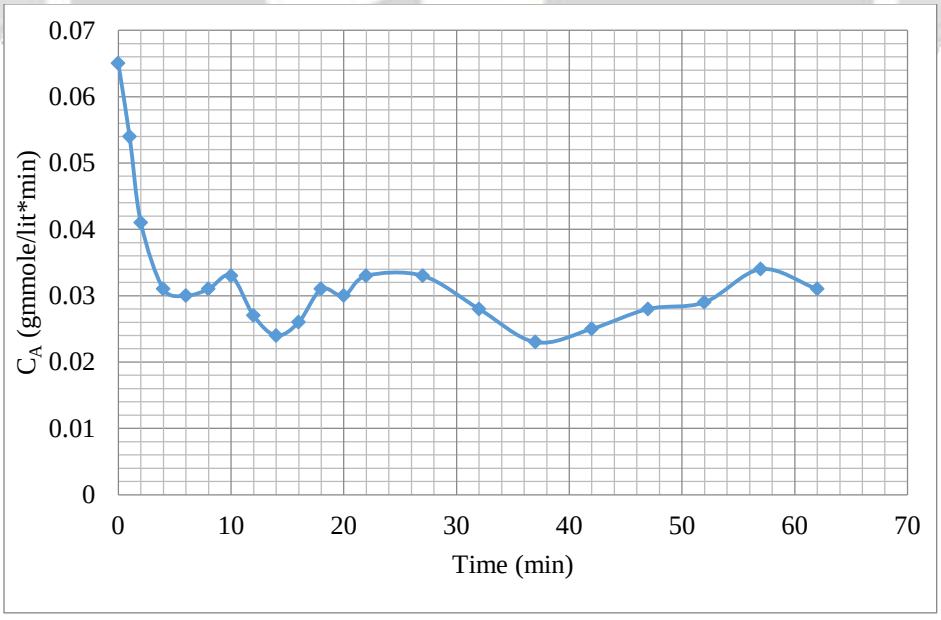

Fig-5: Concentration of NaOH and time

If the reaction between NaOH and CO_2 is considered fast than the reaction product can be considered as tracer emerging out at tip of jet and that can be considered as injection of tracer. Again, rate of formation of product is same as rate of conversion of reactant from stoichiometry. Hence, the depletion rate of NaOH can be taken as

combined effect of reaction and mixing. Thus, the plot of C_A vs t, in true sense, represents 'effect of mixing' super imposed on 'effect of drop in concentration due to the reaction'. The anticipated drop in concentration of C_A is the elongation of the initial part of the curve when extended. The cyclic variation, subsequently in the observation of 'concentration' vs 'time' then, represents the mixing characteristics or the exit edge distribution of the material.

With this approximation, the data of table 1, when converted in form of C_A/C_{AO} vs t, offers us a plot of tracer signal (Refer fig. 6). This tracer signal resembles to the "closed recirculating system", for which as depicted in fig. 6, $\bar{t}$ = 7 min., $2\bar{t}$ = 14 min., $3\bar{t}$ = 20 min., etc.…... showing that the mean residence time is 7 min. [3].

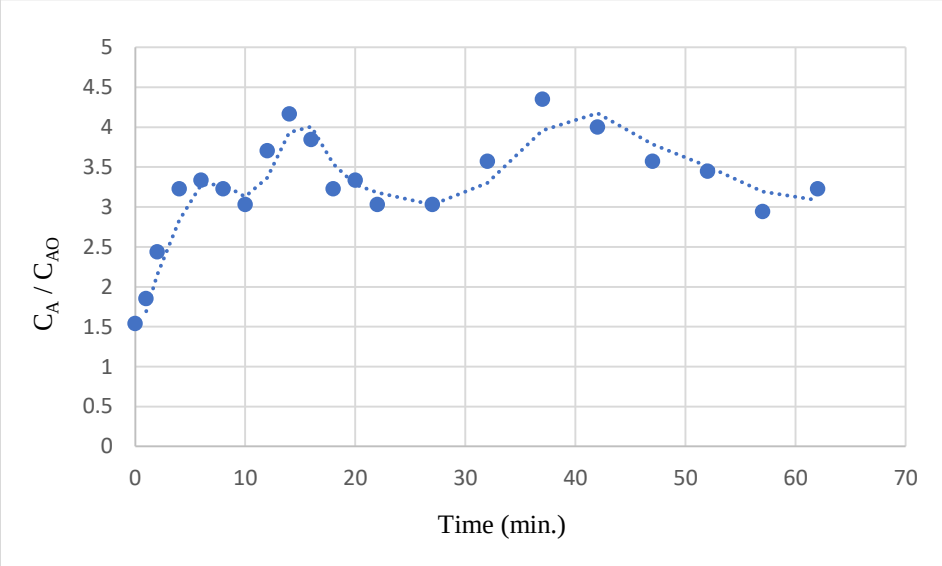

Fig-6: Cyclic pattern of variation of C_A with t

2.3.2.4 Conclusion of experiment of mixing:

Cyclic pattern of variation of C_A with t, with lower amplitude and crust points seen in Fig. 4, and also cyclic pattern of 'C_A/C_{AO}' vs 't', in fig. 6, resembles the flow behavior of n-tank in series or repeated pattern of flow in one tank [3] Hence, it was concluded that the liquid completes mixing in first phase within very short time and shows the movement of bulk of liquid moving in the established pattern subsequently. The time required to complete one cycle is 7 min., two cycles is 14 min., and so on.

3. CONCLUSION:

The conclusion derived out of these experimental work is that the flow pattern in jet-flow reactor is as shown in fig. 3 and as for the mixing, under given conditions it takes 7 min. to have the complete mixing.

4. REFERENCE:

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