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Hydrodynamic Studies on Air-Inducing Impeller System

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Abstract : Attempts have been made to convert a conventional mechanically agitated vessel into an air-inducing reactor and to simplify the mechanism and fabrication of self-air inducing impeller system. A specially designed tube-bundle fabricated using L-shaped tubes was used as the primary impeller for inducing air which when attached to the impeller-shaft of a conventional agitated vessel converted it into an air-inducing reactor. Two different tube-bundles (3-Ltubes and 6-L tubes) were used for this study. A straight turbine and disc-turbine with six-blades were used as the secondary impellers. The primary impellers were used separately and combined with one secondary impeller at a time. Critical speed for the induction of air, gas holdup and power consumption per unit volume of the working fluid were observed by varying the impeller combination, bottom clearance, submergence depth of the orifice and inter-impeller distance in order to observe the hydrodynamic aspects and performance of the proposed system. It was found that the critical speed for induction of air into the reactor increased with increase in submergence depth of the orifice and decreased with bottom clearance when water was used as the working fluid.
Keywords: Air-inducing impeller; Self-ingesting reactor; Gas holdup; Hydrodynamics.

Introduction:

Aeration is the most important and indispensable unit operation unit for a variety of processes including the treatment of wastewater using activated sludge[1].Stirred tank reactors are widely used to perform gas–liquid reactions and gas–liquid–solid reactions involving dispersion and dissolution of reactant gas into the liquid phase. The processes requiring gas–liquid contact include alkylation, ozonolysis, ethoxylation, catalytic hydrogenation, suspension polymerization, oxidative leaching of ores, waste water treatment, chlorination, ammonolysis, oxidation, etc., where it is very much important to have complete utilization of the solute gas. However, in these processes, only a small fraction of the feed gas is absorbed in a single pass and the remaining disengages into the headspace of the reactor. In order to overcome this problem, gas liquid contactor with self-inducing impeller is an attractive alternative option[1-3]. In situations, where internal recycle of unreacted gas is desirable, gas-inducing impellers are advantageous[4]. A characteristic feature of gas-inducingimpellers is that the flow and dispersion of gas within theliquid only take place after a critical rotational speed – thespeed at which the pressure at the impeller orifice just falls below the pressure of the reactor head space – isexceeded[5,6] .In establishing the efficiency of a reactor system,power consumption is one of the most important parameters[7].Self-inducing reactor is a safer alternative for reactions involving expensive and/or hazardous solute gases as it minimizes the risk of leaks. In general, aself-inducing reactorcould work on four mechanisms viz., (i) surface aeration in a partially baffled, or unbaffled, vessel[8]; (ii) gas-induction through a hollow-bladed shaft and impeller[6]; (iii) self–induction through a rotor-stator device and concentric standpipe[2]; or (iv) ingestion of gas through the formation of surface vortices. The present work has been carried out to minimize the specific power consumption of air–inducing impeller system for suction and distribution of atmospheric air into water in a baffled agitated vessel using an air-inducing impeller.

Experimental:

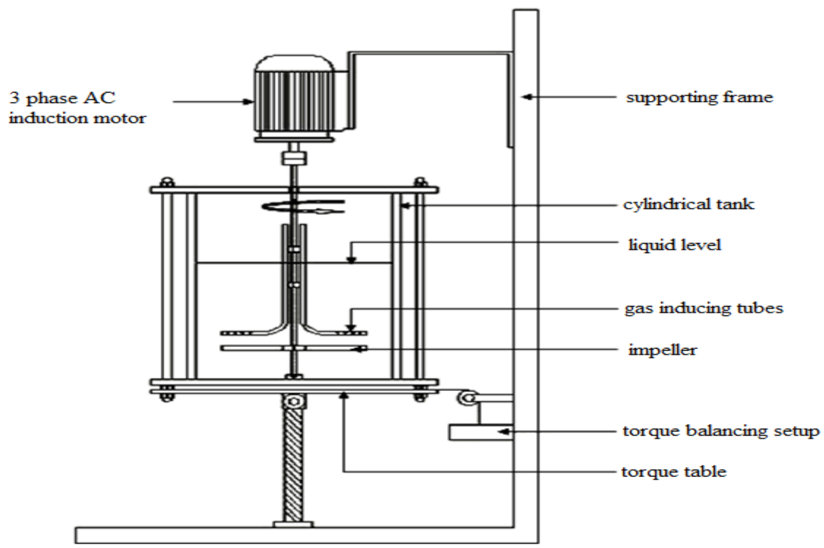

Fig. 1: Experimental setup of the conventional baffled agitated vessel retrofitted with the proposed air-inducing impeller system

A conventional baffled agitated vessel was retrofitted with a specially designed air-inducing tube-bundle and the schematic diagram of the experimental setup is shown in Fig.1.A flat-bottomed cylindrical agitated vessel made up of acrylic material, was mounted on a torque-table fixed to the floor. Four vertical baffles were fitted to seizethe vortex formation and ensure effective mixing of the working fluid. The impeller, mounted on a vertical solid shaft, was driven by a 2 hpalternating current (AC) induction motor (Monark, India). The rotational speed of the impeller was regulated by a speed control drive (Commander SK, India) and the power consumed by the motor was measured using two digital watt meters (Ampere, India). The shaft power was calculated from the counter weight on a load cell which was connected to the torque table. The impeller speed was measured using a digital tachometer. Two tube bundles (with 3-tubes and 6-tubes) were fabricated by bending the tube to L-shape and attaching them to the impeller shaft and used to induce the air into the vessel. During the experiment, for a given level of liquid in the tank,the impeller immersion depth and bottom clearance were fixed by adjusting the position of the impeller. The rotational speed ofimpeller was gradually increased using speed-control-drive until the start of the suction of air and the corresponding speed (critical speed) was measured using tachometer.Critical speed, gas holdup and power consumption (both motor power and shaft power) were measured by varying the total liquid height, orifice submersion depth, impeller combinationand bottom clearance.

Results and Discussion:

1. Critical speed

From the results, it was observed that the critical speed was found to increase with increase in impeller immersion depth for all the impeller assemblies used in this study. This is due to the fact that an increase in impeller immersion depth increases the centrifugal force required to overcome the stagnation pressure. The impeller immersion depth decreases as the bottom clearance increases and hence the critical speed decreases with increase in bottom clearance.

2. Power consumption

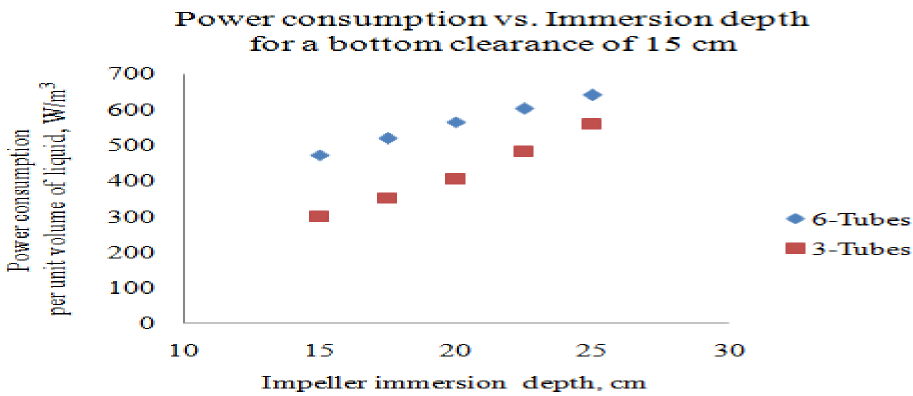

Fig. 2: Effect of impeller immersion depth on power consumption per unit volume of liquid for a bottom clearance of 15 cm

Since the increase in impeller immersion depth increases the hydrostatic pressure at the orifice of the primary impeller and leads to higher critical speed and higher power consumption.Fig.2 shows the effect of impeller immersion depth on power consumption per unit volume of liquid for a bottom clearance of 15 cm.The addition of secondary impeller, irrespective of the type of assembly, increases the total mass of the rotor and hence the power consumption is also increased. For a givenliquid level in the tank, the power consumption decreases with increase in bottom clearance of the primary impeller for all the impeller assemblies studied.

3. Gas holdup

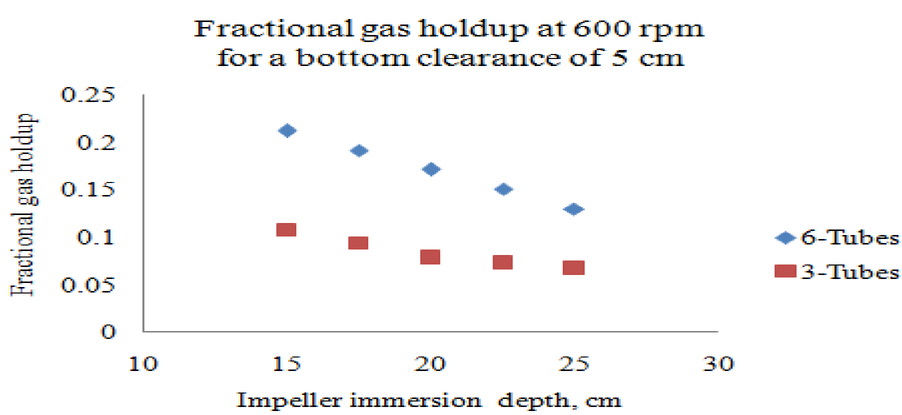

Fig. 3: Effect of impeller immersion depth on fractional gas holdup at 600 rpm for a bottom clearance of 5 cm

The gas holdup increases with increase in impeller speed due to higher induction rate if air. Fig. 3 shows the dependence of fractional gas holdup on impeller speed for an immersion depth of 15 cm. At all rotational speeds of the impeller greater than the critical speed fora givenliquid level, the increase in orifice submergence leads to decrease in the gas holdup in the vessel. The gas holdup was observed for both the tube sets (tube sets with 3 tubes and 6 tubes) for all the immersion depths studied. It was noticed that the gas holdup was more for tube set with 6 tubes as compared with the tube setwith 3 tubes. Fig. 4 shows the effect of impeller immersion depth on fractional gas holdup at 600 rpm for a bottom clearance of 5 cm.

Conclusions:

The hydrodynamic characteristics of the proposed air-inducing impeller system were investigated for suction and distribution of atmospheric air into the working fluid (water). Two L-shaped tube-sets, one with 3-tubes and 6-tubes, were fabricated and used as the primary impeller for inducing air and the results were found to be satisfactory. Critical speed for the suction of air, gas holdup and power consumption per unit volume of the working fluid were observed by varying the impeller assembly, bottom clearance and submergence depth of the orifice in order to observe the characteristics and performance of the proposed impeller system. It was found that the critical speed for suction of air into the reactor increased with increase in submergence depth of the orifice and decreased with increase in bottom clearance when water was used as the working fluid. It has been found that the gas holdup increased with both decrease in orifice submersion depth and increase in bottom clearance. The addition of a secondary impeller improves the gas holdup in the vessel, which is due to effective dispersion and distribution of the induced air in the liquid.

References:

1. Jyh-Herng Chen, Yung-Chien Hsu, Y.-F. Chen, Chih-Chu Lin, Application of gas-inducing reactor to obtain high oxygen dissolution in aeration process, Water research, 37, 2003, 2919 – 2928.
2. Ashwin W. Patwardhan, Jyeshtharaj B. Joshi, Design of gas-inducing reactors, Ind. Eng. Chem. Res.38, 1999,49–80.
3. N. A. Deshmukh, S. S. Patil, J. B. Joshi, Gas induction characteristics of hollow Self-inducing impeller, Trans IChemE, Part A, Chem. Eng. Res. Des., 84(A2) 2006, 124–132.
4. B.N. Murthy, N.A. Deshmukh, A.W. Patwardhan, J.B. Joshi, Hollowself-inducing impellers: Flowvisualization and CFD simulation, Chem. Eng. Sci., 62, 2007, 3839–3848.
5. Fan Ju, Zhen-Min Cheng, Jian-Hua Chen, Xiao-He Chu, Zhi-Ming Zhou, Pei-Qing Yuan, A novel design for a gas-inducing impeller at the lowest critical speed, Chem. Eng. Res.Des., 87, 2009, 1069–1074.
6. S.E. Forrester, C.D. Rielly, K.J. Carpenter, Gas-inducing impeller design and performance characteristics, Chem. Eng. Sci., 53 (4) 1998, 603–615.
7. Mousa Jafari, Jafar S. Soltan Mohammadzadeh, Power consumption and onset speed for gas induction in a gas-induced contactor, Chem. Eng. J, 103, 2004, 1–5.
8. P. C. Lines, Gas-liquid mass transfer using surface-aeration in stirred vessels, with dual impellers, Trans IChemE, Part A, 78, 2000, 342–347.

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