STUDY OF LIQUID FLOW FIELD IN DUAL IMPELLER GAS-LIQUID STIRRED TANK REACTOR

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Highlights

- A novel mixed impeller is employed at the top with a standard Rushton turbine at the bottom as a dual impeller combination in gas-liquid STR.
- Radioactive Particle Technique is used for liquid hydrodynamics of dual impeller gas-liquid STR.
- A notable S/D ratio effect was found on the liquid flow pattern and flow regime in dual impeller gas-liquid STR.

1. Introduction

The utilization of multiple impeller gas-liquid stirred tank reactor (STR) systems is popular in chemical and bio-process industries which include fermentation, polymerization, hydrogenation, waste water treatment etc. The multiple impeller configuration enhances the gas utilization in gas-liquid STRs due to the high residence time of the gas phase. Overall, gas dispersion in stirred tank reactors is a critical phenomenon because it affects the mass and heat transfer of the system. The hydrodynamics of multiple impeller gas-liquid STRs depends upon the impeller design, impeller configuration, spacing between the impellers, aspect ratio of the tank, impeller speed, and gas inlet velocity. Several studies are reported for multiple impellers gas-liquid STRs illustrating their mixing behavior, mass transfer coefficient and flow patterns with dual Rushton turbines [1-3]. However, the liquid flow field information is largely missing for the dual impeller system. Further, most of these studies are reported for either dual Rushton turbine system. In the present study, a detailed hydrodynamics study is performed for the Rushton turbine and novel mixed impeller configuration for three different spacings between the impellers. For each case, experiments are performed for different impeller speeds (300-500 rpm) and gas superficial velocities (2-6 mm/sec). The mean liquid velocities, rms velocities, and kinetic energy of turbulence are measured for all the cases by using the radioactive particle tracking (RPT) technique.

2. Methodology

Figure 1 shows the schematic diagram of the RPT setup of the dual impeller gas-liquid stirred tank reactor and impeller photographs used in the current study. Experiments are performed in a 0.19 m diameter and 0.4 m height STR made of Perspex. The impeller diameter (D) is kept at 0.063 m and the bottom to impeller distance is also maintained at 0.063 m. All the experiments are performed for an aspect ratio of 2. The effect of impeller spacing to impeller diameter ratio (S/D), impeller speed and gas inlet velocity on the liquid flow field is studied through the RPT technique. In RPT, a single radioactive tracer particle (gamma-ray source) is used as a marker of the phase of interest. The property of the tracer particle is kept the same as of the phase of interest. In the present case, the particle is made neutrally buoyant and hence, it follows the path of the liquid. A series of scintillation detectors are placed strategically around the reactor to record the photons emitted by the tracer particle. The lagrangian position of the tracer particle is reconstructed by using photon count time series data acquired at all the detectors. The same is used to calculate instantaneous lagrangian velocity, mean velocity, rms velocity and turbulent kinetic energy of the liquid phase.

3. Results and discussion

Experiments are performed for different gas velocities and S/D ratios. For all the conditions, the liquid velocity field is tracked by using the radioactive particle tracking technique. The instantaneous, mean and fluctuating velocity field of liquid is measured and processed to calculate rms velocities and turbulent kinetic energy. Figure 2 shows the liquid velocity vector field for three different S/D ratios for impeller speed of 300 rpm and gas superficial gas velocity of 4 mm/s. The results show that the flow pattern changes with a change in the S/D ratio. The distinguished flow circulation loops are found in all the cases. For S/D ratio 1 the flow circulation loop is limited in the lower region, for S/D ratio 2 the circulation loop is found in lower and middle regions and for S/D ratio 3 the flow circulation loop is found in lower, middle and upper regions. Hence, it can be concluded that the change in the S/D ratio affects and causes flow regime transition in gas-liquid STRs.

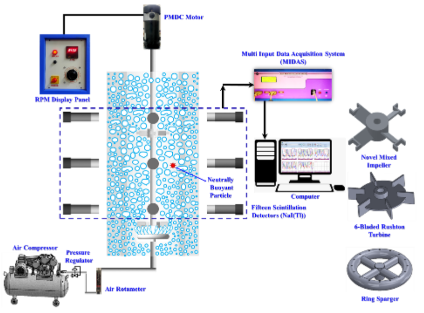

Figure 1. Schematic diagram of RPT Setup of dual impeller gas-liquid STRs

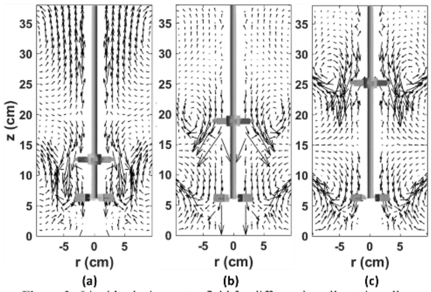

Figure 2. Liquid velocity vector field for different impeller to impeller spacing arrangement for N = 300 rpm, V_{sg} = 4 mm/s (a) S/D = 1, (b) S/D = 2, and (c) S/D = 3

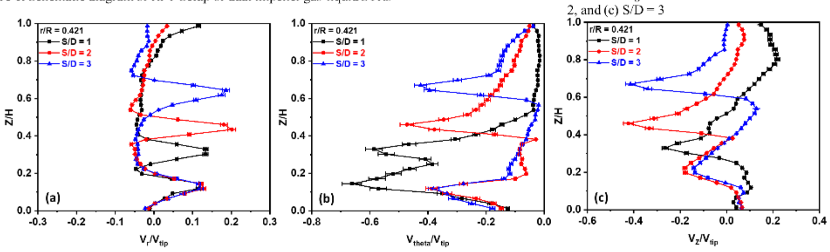

Figure 3. Effect of S/D ratio on mean liquid velocity for N = 300 rpm, V_{sg} = 4 mm/s (a) radial (b) tangential, and (c) axial velocity

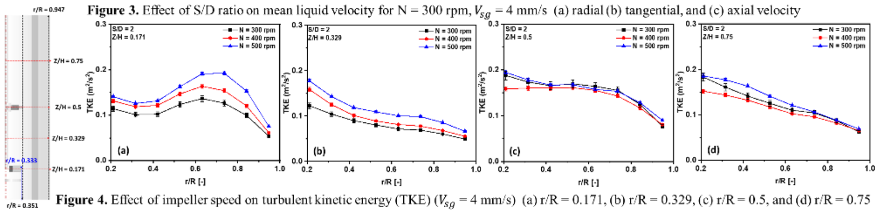

Figure 4. Effect of impeller speed on turbulent kinetic energy (TKE) (V_{sg} = 4 mm/s) (a) r/R = 0.171, (b) r/R = 0.329, (c) r/R = 0.5, and (d) r/R = 0.75

Figures 3 (a) to (c) show the effect of the S/D ratio on the radial, tangential and axial mean velocity of liquid. It was observed that varying the S/D ratio changes the velocity profile peak position for radial, tangential and axial velocities. The radial velocity peaks were observed at both impeller positions. Figures 4 (a) to (d) show the effect of impeller speed at a constant superficial gas velocity of 4 mm/s on turbulent kinetic energy (TKE) at different axial locations of Z/H = 0.171, 0.329, 0.5, and 0.75 respectively. Increasing the impeller speed results in an increase of turbulent kinetic energy at all axial heights. Further, turbulent kinetic energy increases with axial height for all the impeller speeds. This shows that the top section of STR is more violent.

4. Conclusion

Dual impeller gas-liquid flow hydrodynamics is studied in the present study using radiotracer-based techniques for different operating conditions. It is found that the S/D ratio has a significant effect on liquid flow dynamics in dual impeller gas-liquid STRs. The change in the S/D ratio can change the operating regime. Further, gas inlet velocity and impeller speed also affect the performance of STR significantly and can lead to regime change. The full manuscript will present similar results for different gas inlet velocities and kinetic energy data for all the conditions will be presented.

References

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Keywords

Dual impeller configuration, Gas-liquid STRs, Radioactive Particle tracking (RPT) technique