Mixing Characterization in Batch Rotor-Stator Mixer

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Abstract

- Mixing characterization of existing batch rotor-stator mixer (RSM) is studied at different rotor speeds (2000, 4000 and 6000 rpm) for two different geometries with different stator heads, such as circular and square.
- Flow parameters such as mass flow rate, Power number and energy dissipation rate have been investigated in both geometries.

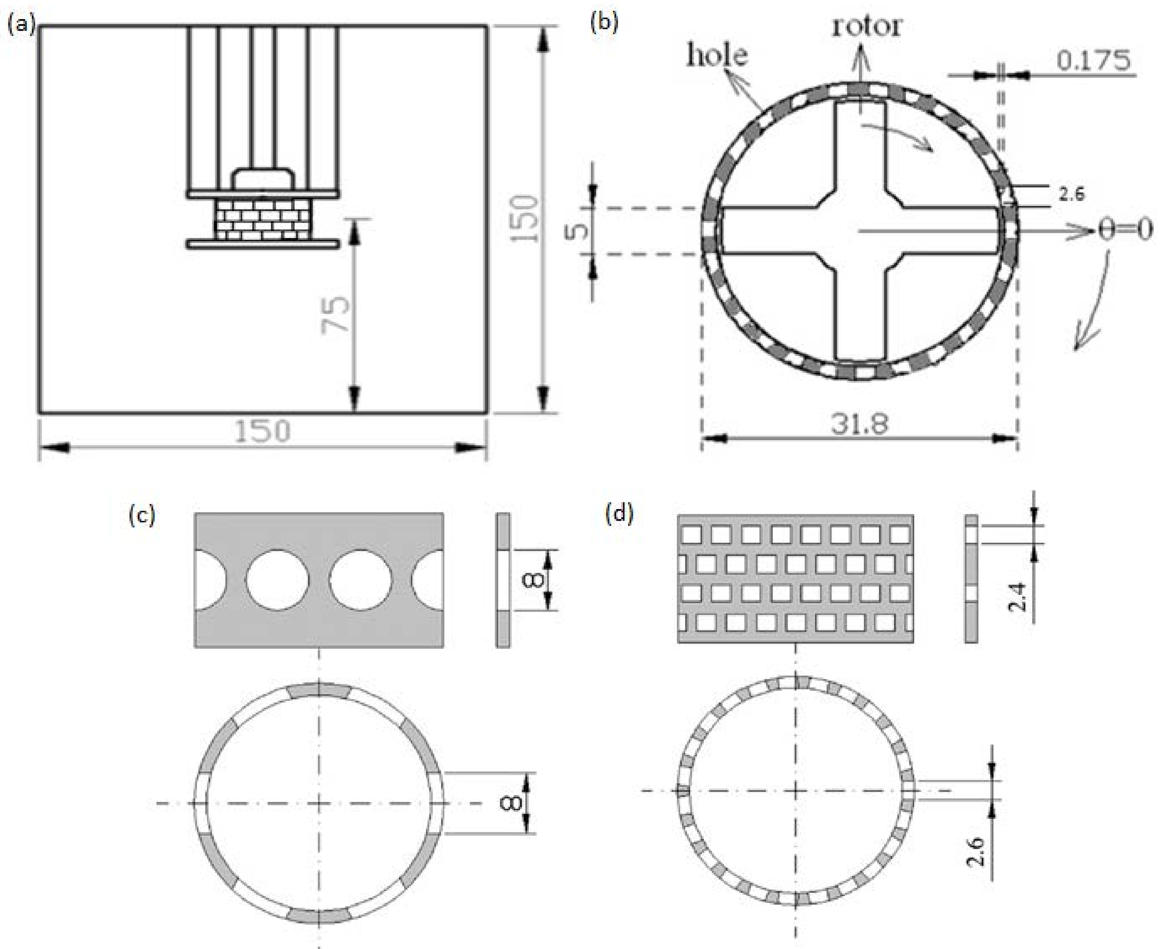

Figure (a) Tank with L4RT Silverson mixer, (b) Top view of L4RT Silverson mixer, (c) Circular head stator with 6 holes, and (d) Square head with 92 holes. (Source: Utomo et al., 2009)

Introduction and Motivation

- Rotor-stator mixers (RSMs), also referred as high shear mixers, are characterized by high shear and energy dissipation, and comprised of moving (rotor) and stationary (stator) parts.
- Extensively used for liquid–liquid dispersion and uniform mixing in various process industries due to enhanced mixing and uniform dispersion of dispersed medium into continuous medium.
- Mixing is a very significant unit operation in all major process industries, energy, minerals mining, chemical industries, pharmaceuticals production, food and metallurgical processing, etc. Limited research has been done to study the mixing in rotor-stator mixers.

Type of Device	Energy Dissipation rate (W/Kg) or m^2/s^3	Typical Size Range (μm)	Comments
Static mixers	10 – 1000	50 –1000	Narrower DSD (drop size distribution) than agitated Vessel
Agitated vessel	0.1 – 100	20 – 500	With Rushton turbine in a fully baffled vessel; usually, broad DSD
High speed rotor–stator (high shear mixer)	1000 – 100000	0.5 –100	Can be smaller with the correct Chemistry
Valve homogenizer	~	0.5 – 1	Requires high pressure, 5000 to 10 000 psi
Ultrasonics	~	0.2 – 0.5	Sonification devices

Modeling approach

- Standard k-ε turbulent with transient sliding mesh was used to predict the hydrodynamics and mixing characteristics.
- Water was used as a working fluid at different rotor speeds of 2000, 4000 and 6000 rpm.
- 100 rotations were performed for flow characterization and validation.
- For mixing characterization, species transport model without reaction was used.
- Tracer properties were used similar to the liquid.
- The density of the tracer has been varied according to the volume-weighted-mixing-law and the viscosity remains constant as of water.
- 300 rotations were run to predict mixing characteristics (Flow time = 6 sec).
- The tracer was monitored at seven different points with time at different rotor speeds.
- The governing species equation of the tracer was solved by using the QUICK scheme.

Results & discussion

Power number (Po) = $P/\rho N^3 D^5$ where ρ is density of the fluid, P is the power required to turn the motor, N is the rotor speed and D is the rotor diameter.

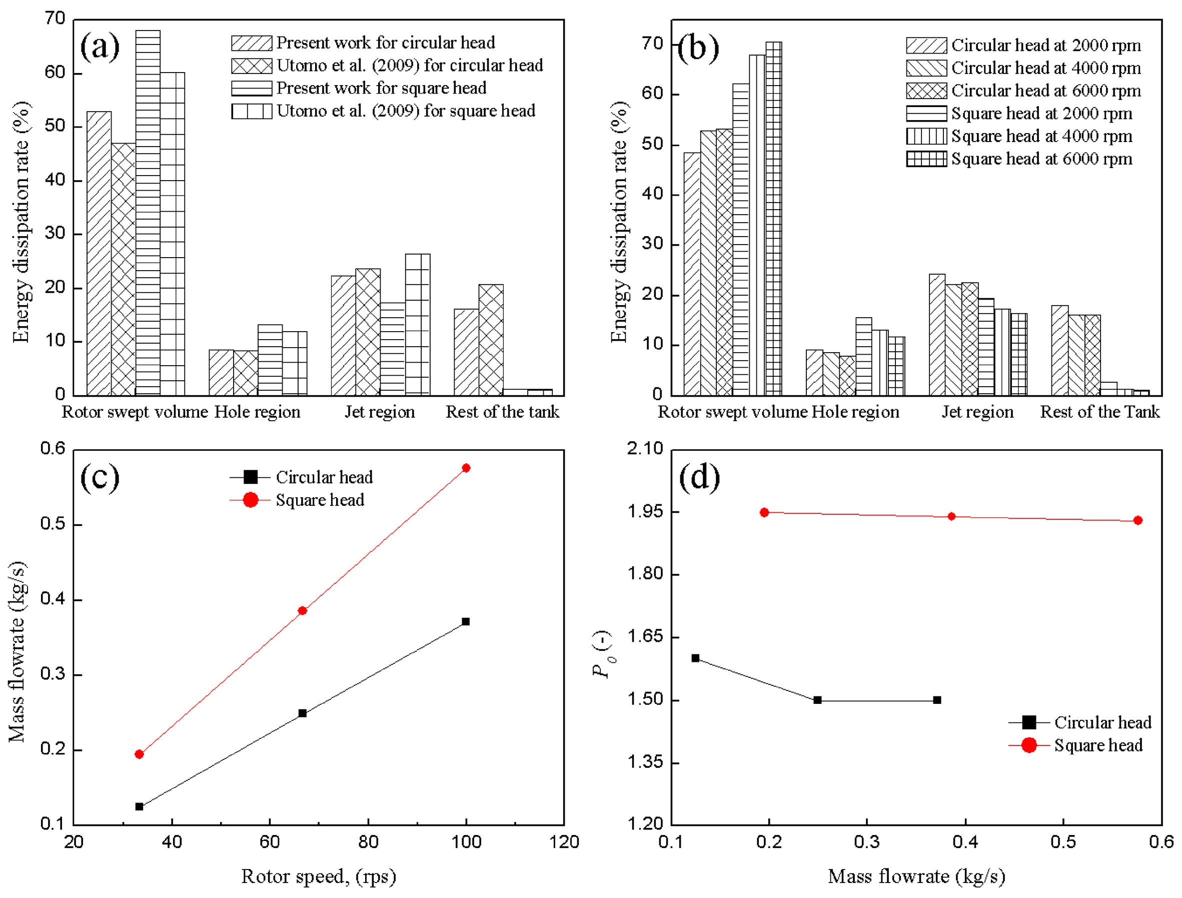

Figure (a) Comparison of energy dissipation rate at rotor speed of 4000 rpm, (b) energy dissipation rate in present work at different rotor speed, (c) mass flow rate variation with rotor speed and, (d) power number variation with mass flowrate.

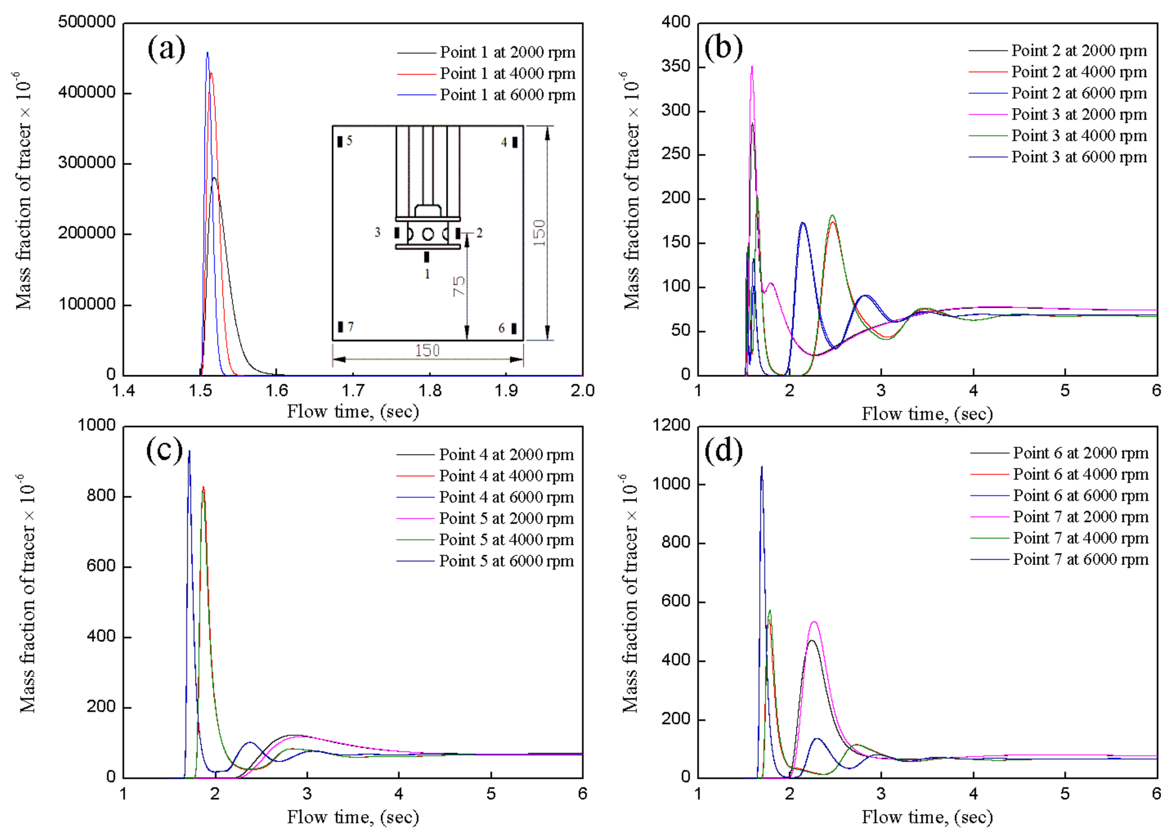

Figure Comparison of mass fraction of tracer with respect to flow time at (a) point 1, (b) point 2 and 3, (c) points 4 and 5, and (d) points 6 and 7 (depicted in Fig. 2.a) for circular head RSM at different rotor speeds.

Results & discussion

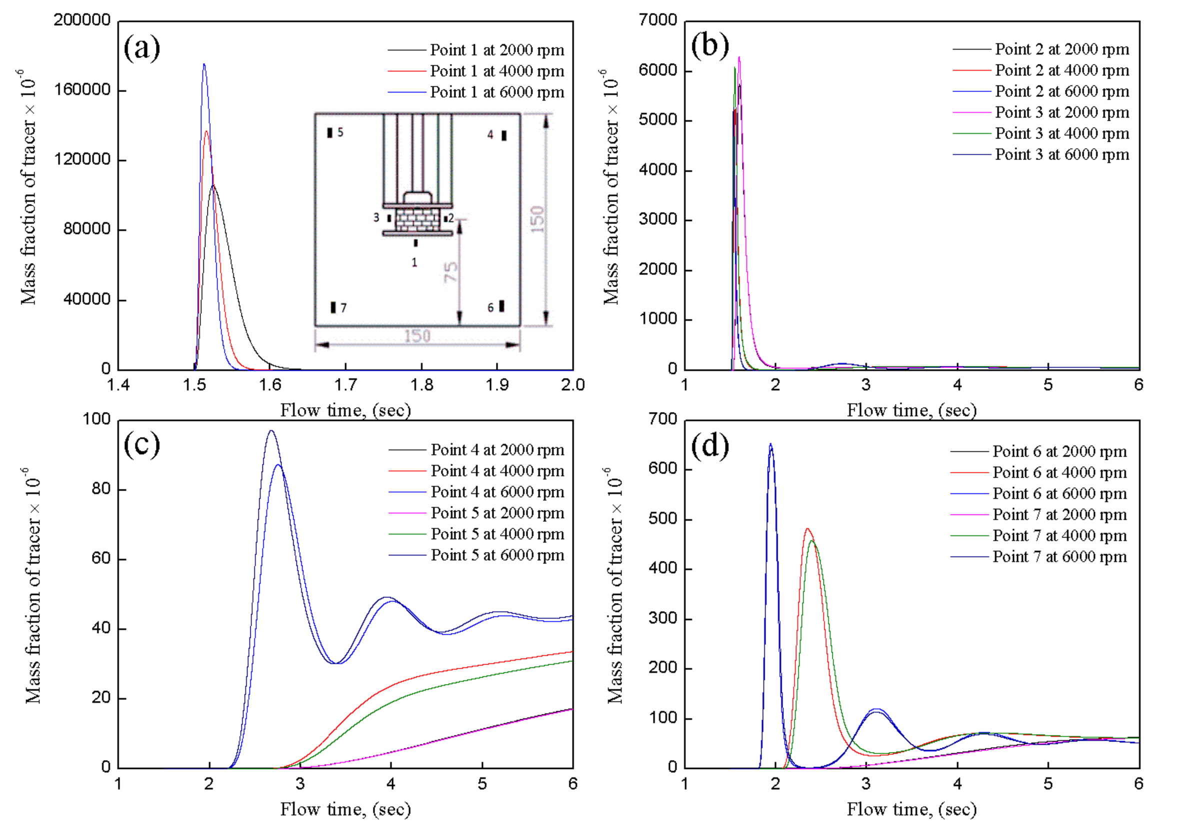

Figure Comparison of mass fraction of tracer with respect to flow time at (a) point 1, (b) point 2 and 3, (c) points 4 and 5, and (d) points 6 and 7 (depicted in Fig. 2.a) for square head RSM at different rotor speeds.

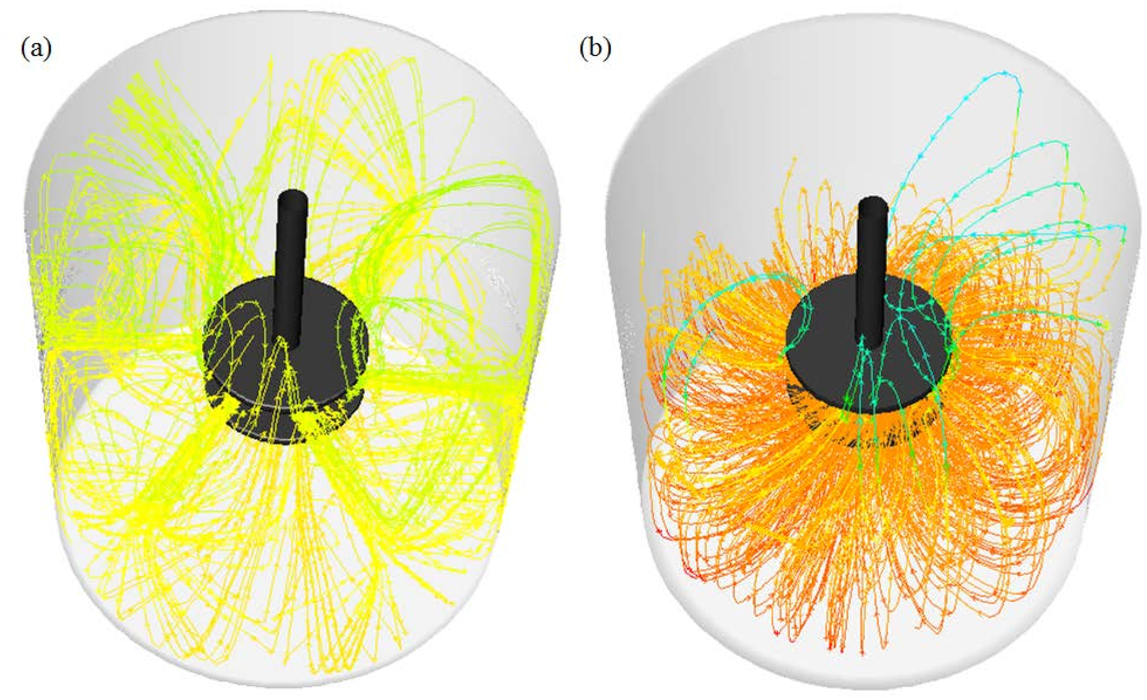

Figure Pathlines of tracer at a rotor speed of 2000 rpm (a) circular head, and (b) square head RSM.

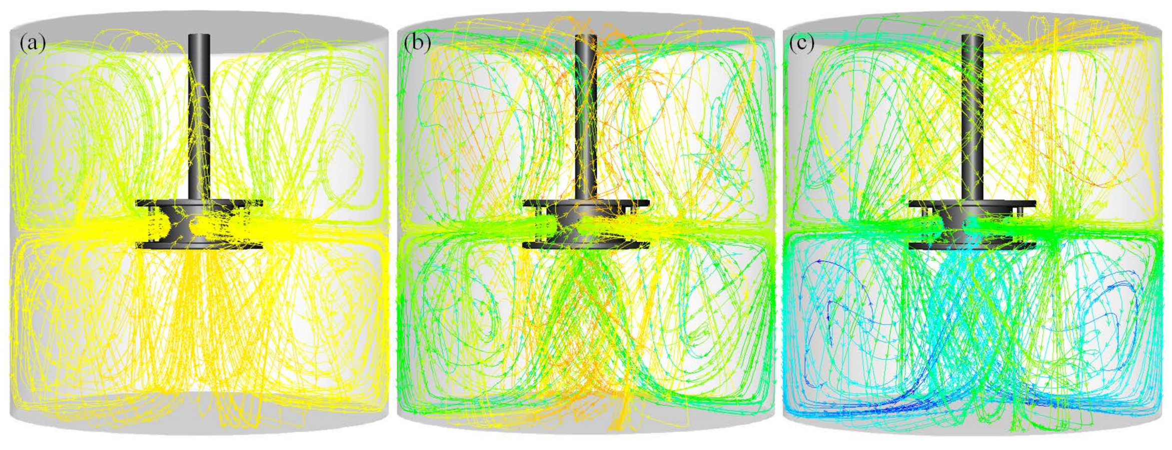

Figure Pathlines of tracer at different rotor speed (a) 2000 rpm, (b) 4000 rpm, (c) 6000 rpm, for circular head RSM.

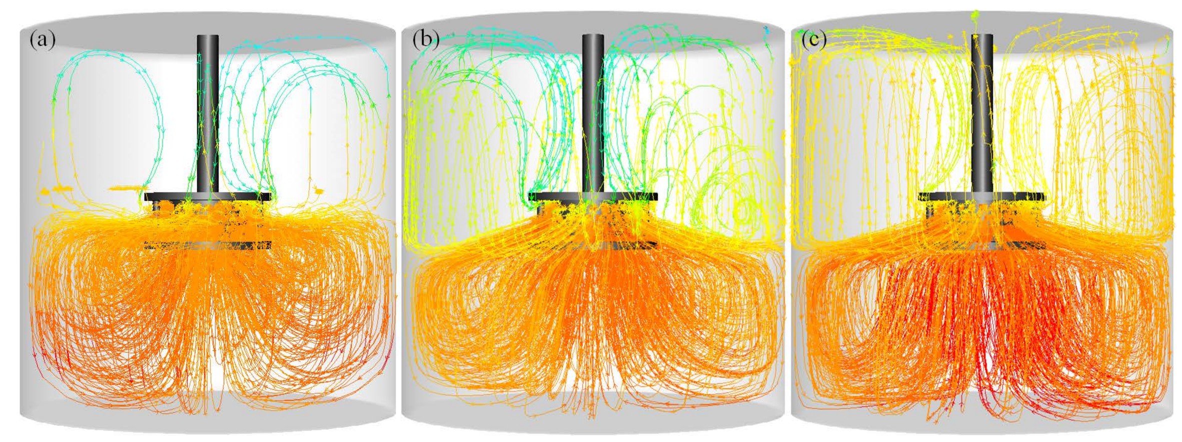

Figure Pathlines of tracer at different rotor speed (a) 2000 rpm, (b) 4000 rpm, (c) 6000 rpm, for square head RSM.

Conclusion

- Maximum energy dissipation occurred in rotor swept volume (area inside the stator).
- Mass flowrate increased with an increase in rotor speed and power number is less affected by the rotor speed in both RSMs.
- Stator with small opening and more number of stator holes has high energy dissipation rate and Power number in rotor swept volume area.
- Constant and uniform mixing inside the tank was greatly affected by the size of the stator hole and location of tracer input.
- Larger the size of stator holes, smaller the flow time for constant mixing. Therefore, mixing was faster in stator with large opening.
- Fluctuation in mixing near the stator holes jet was less in small opening stator head

Selected References

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