Mixing dynamics in a large volume single use mixer — effect of tank shape and impeller quantity on salt settling and dispersion

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Mixing dynamics in a large volume single use mixer—effect of tank shape and impeller quantity on salt settling and dispersion

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Abstract

The purpose of this study was to present the effect of tank shape and impeller quantity on large volume single-use mixing dynamics for a given impeller design and a given impeller location (Fig. 1). Salt settling and dispersion phenomena were used to evaluate the mixing performance. Additionally the following post-processing plotting techniques were used to gain additional insights: velocity streamline, cloud height ratio, and velocity contours. Mixing in the corners is another critical aspect of large volume mixing that was explored as part of this study.

Introduction

Large volume single-use technology mixers can be used for mixing operations throughout the entire bioprocess workflow. Large volume mixers are mainly required in clinical three-scale and production-scale facilities where mixing efficiency is one of the key drivers of throughput efficiency. Upstream applications such as medium preparation and harvest requires fast and efficient mixing whereas downstream mixing operations used in purification and separation processes requires sensitive mixing.

Dispersion and settling were evaluated as part of this study, which provides a clear decision path on the tank shape and impeller quantity for a given impeller design and a given impeller location. Dissolution studies will be used in future to understand the liquid-liquid and powder-liquid mixing times along with zone mapping and test validation.

Fig 1. The Xcellerex™ XDUO 2500 mixer was one of the mixers evaluated in this study. It has a lateral cuboid design with dual impellers.

Materials and methods

Five different 2500 L tank shapes for a given impeller design and a given impeller location were evaluated as part of this study (Fig 2).

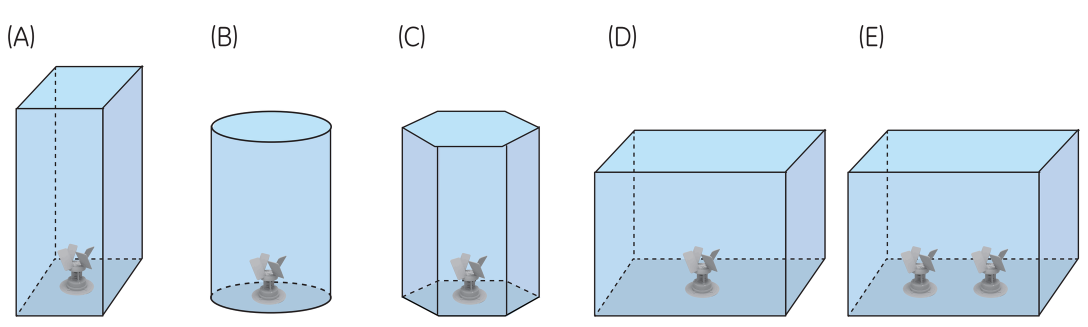

Fig 2. Tank shapes evaluated in this study (A) vertical cuboid single impeller; (B) cylindrical single impeller; (C) hexagonal single impeller; (D) lateral cuboid single impeller; (E) lateral cuboid dual impeller—XDUO 2500.

Initial conditions

Figure 3 shows the salt settling at tank bottom before the start of the impeller/-s.

Fluid in tank:	Water
Salt particle size:	1 mm
Particle density:	2160 kg/m^3
Speed of impeller:	300 rpm
Direction of pumping:	Downwards

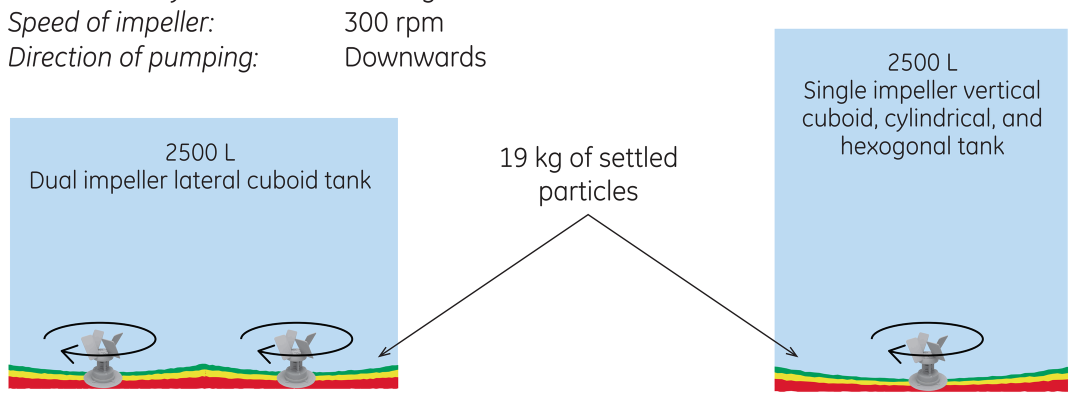

Fig 3. Initial salt settling at tank bottom before the start of impeller.

Computational fluid dynamics (CFD) settings

- Eulerian granular multiphase model
- Phase interaction: Drag-Gidaspow turbulent dispersion force-Simonin
- Drag modification: Brucato factor = 0.0008766.

Results

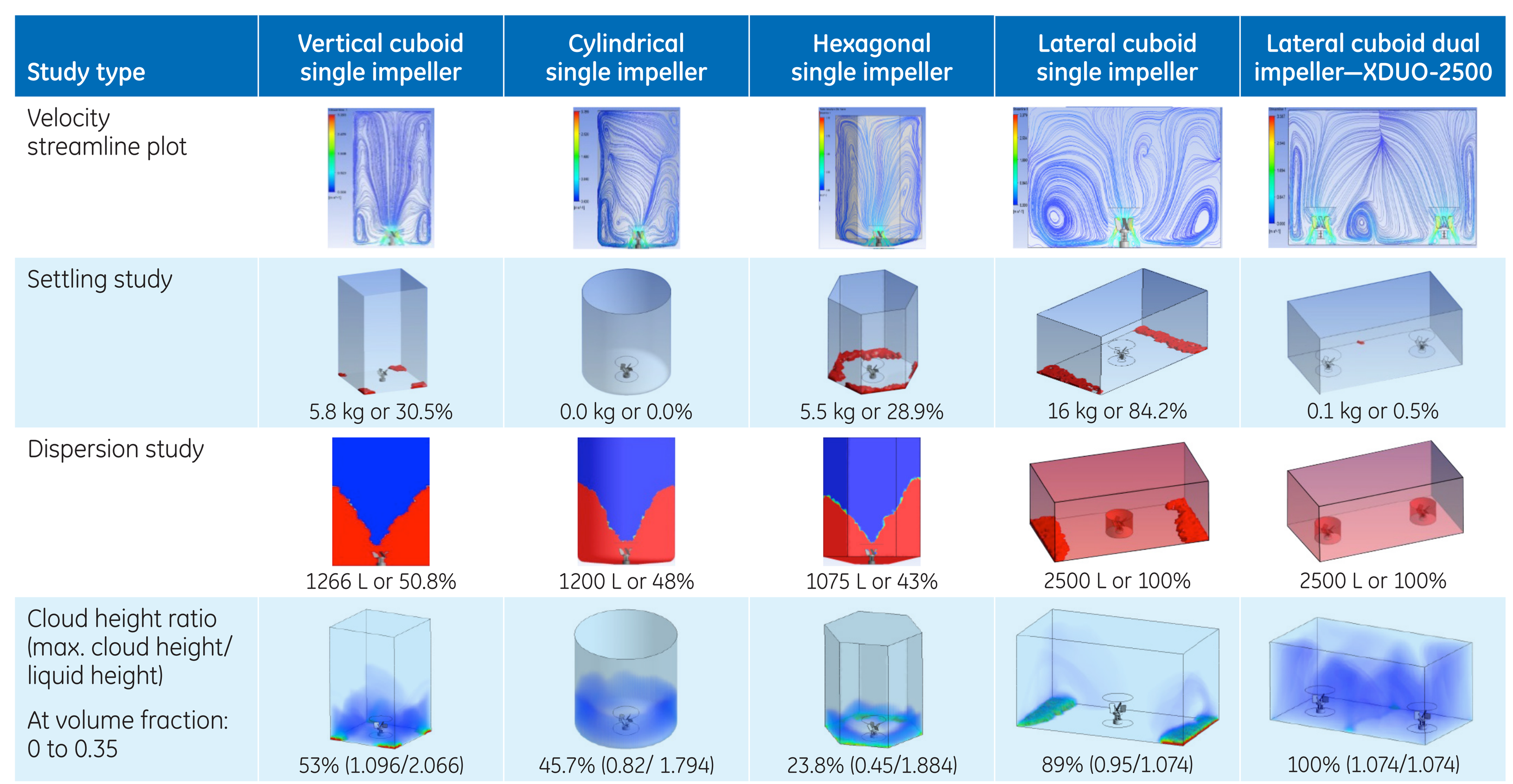

Fig 4. Settling and dispersion characterization in different tank shapes.

The purpose of this CFD was to compare different mixing parameters with different tank shapes (Fig 4).

- The velocity streamline plot shows the pattern of flow and vortex in the tanks.
- The settling study plots shows the location and quantity of particles getting settled (shown in red) in different tank shapes.
- Dispersion study plots shows pictorially what is the volume of the tank where the particles are dispersed (shown in red).
- When the particles are dispersed in the tank, it disperses in the form of a cloud and tend to dwell in the cloud. The 3D cloud height plot shape of the cloud and its height in different tanks.

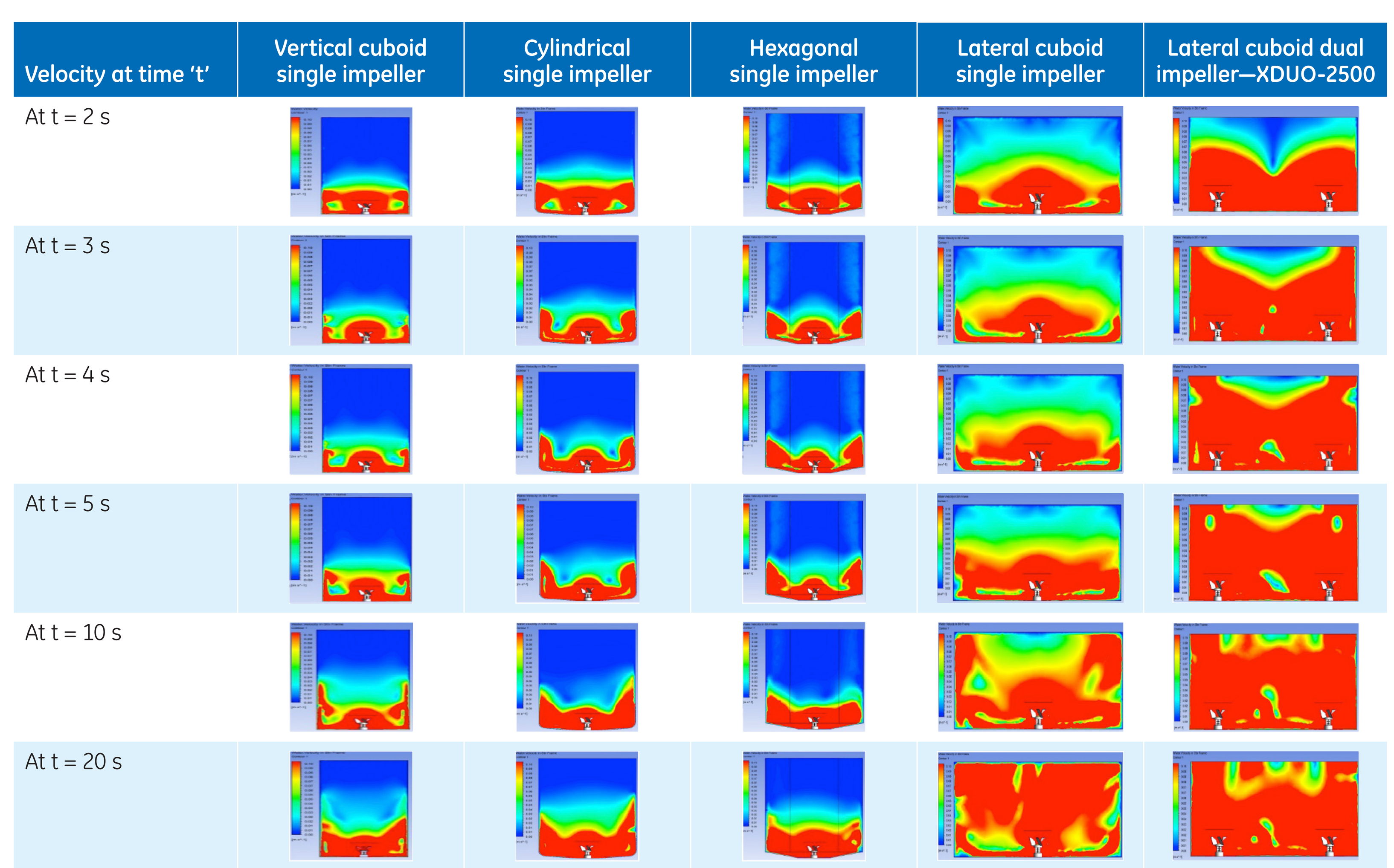

Fig 5. Momentum transfer characterization in different tank shapes. Velocity contours (red = 0.1 m/s and above, blue = stagnant region).

The velocity contours (Fig. 5) shows how quickly the momentum is transferred from the impeller and reaches the top of the tank. For this, a velocity of 0.1 m/s was considered and the results were monitored to see how quickly this velocity reaches the top of the tank. The region of the tank where the color is red shows that the velocity is greater than 0.1 m/s. In the tank with lateral cuboidal dual impeller shape, the velocity of 0.1 m/s was able to reach the top of the tank within 4 s.

Discussion

Percentage of particles dispersed (not settled) and percentage of 2500 L volume where particles are dispersed should be evaluated together to conclude the effectiveness of the tank shape and impeller quantity (Fig. 6).

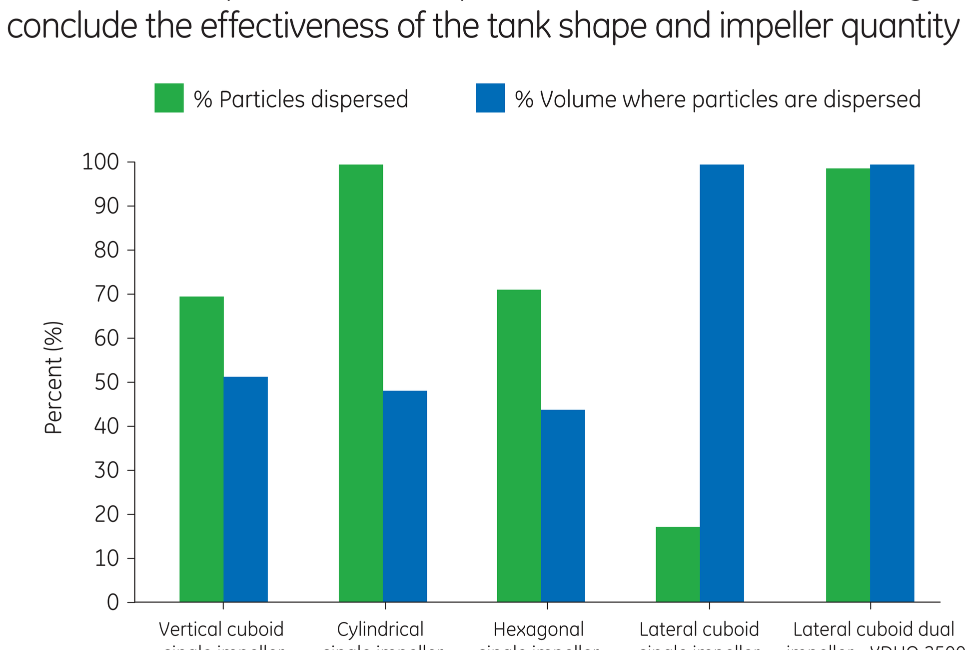

Fig 6. Percentage of particles dispersed (not settled) and percentage of 2500 L volume where particles are dispersed in the studied mixer shapes.

References

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Conclusion

- It is clear from the comparison bar chart that the lateral cuboid tank shape with dual impeller is very good at dispersing the particles all over the tank with negligible settling compared with other tank shapes.
- The velocity streamline and contour plots clearly demonstrates that a lateral cuboid tank shape with dual impeller enables fast and complete momentum transfer all the way to the top of the tank.
- CFD proved to be a valuable tool to understand the complex mixing dynamics in a large volume mixer.
- Dissolution studies will be used in future to understand the liquid-liquid and powder-liquid mixing times along with zone mapping and test validation.

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