NEWSLETTER

Beyond Top-Mounted Agitators: Modeling Inclined and Off-Centre Bottom-Entering Shafts Using VisiMix

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Introduction

Mixing performance is strongly influenced not only by impeller type and speed, but also by **shaft orientation and entry location.** While **top-mounted agitators** are commonly used, many industrial processes—such as low and high-viscosity mixing, crystallization, and solid-handling operations—often require inclined or bottom-entering shaft configurations due to process, mechanical, or space constraints.

VisiMix is not limited to conventional top-mounted agitators. The software enables detailed evaluation of **top-mounted, inclined, and off-centre bottom-entering shaft configurations** which is **particularly critical for low viscosity applications,** where shaft orientation and impeller position strongly influence flow patterns and mixing performance. In this study, VisiMix is used to compare flow patterns, shear distribution, power consumption, and dead zones for different shaft orientations within the same vessel and process conditions. This approach provides clear insights into how agitator configuration influences mixing efficiency and supports informed design and scale-up decisions.

Objective

The objective of this study was to compare the hydrodynamic and turbulence characteristics of **off-centre bottom-entering, inclined and top-mounted agitator configurations** using VisiMix simulations under **identical vessel and operating conditions.**

The study focuses on understanding how **shaft orientation and entry location** influence **flow patterns, shear distribution, power consumption**, and dead zone formation, there by supporting informed agitator selection and scale-up decisions.

Configurations Evaluated

- Off-Centre Bottom-Entering Shaft
- Inclined Shaft
- Top-Mounted Shaft

VisiMix Simulation Approach

A **5 KL stirred reactor** operating at **80% working volume** was considered for this study. The vessel was fitted with **four baffles** and equipped with a **disk blade turbine** impeller, operating at **125 RPM**, under identical process conditions for all configurations.

All simulations were performed under **identical vessel geometry, fluid properties, and operating conditions,** with **shaft orientation and entry location** being the only variables across the cases. This ensures that observed differences arise solely from shaft configuration and not from changes in operating or geometric parameters.

TANK WITH ELLIPTICAL BOTTOM

Inside diameter	1800	mm
Total tank height	2200	mm
Total volume	5217	l
Level of media	1722	mm
Volume of media	4000	l

FLAT BAFFLE-2

Number	4	
Width	160	mm
Length	1700	mm
Dist. from bottom	450	mm
Dist. from wall	50	mm
Angle to radius (fi)	0	deg

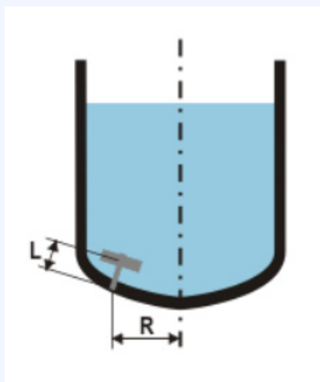
DISK TURBINE

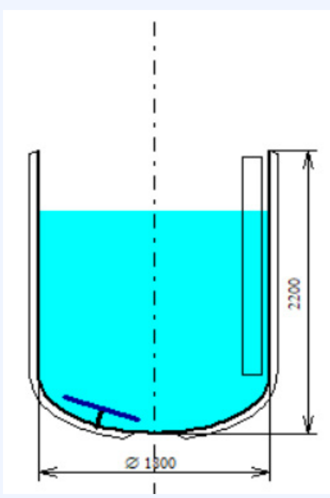
Tip diameter	600	mm
Diameter of disk	450	mm
Number of blades	6	
Pitch angle	90	deg
Width of blade	125	mm
Length of blade	150	mm
Dist.from shaft end	150	mm

Rotational speed	125	Rpm
Motor power	10	hp

Case-I: Off-centre bottom entering shaft

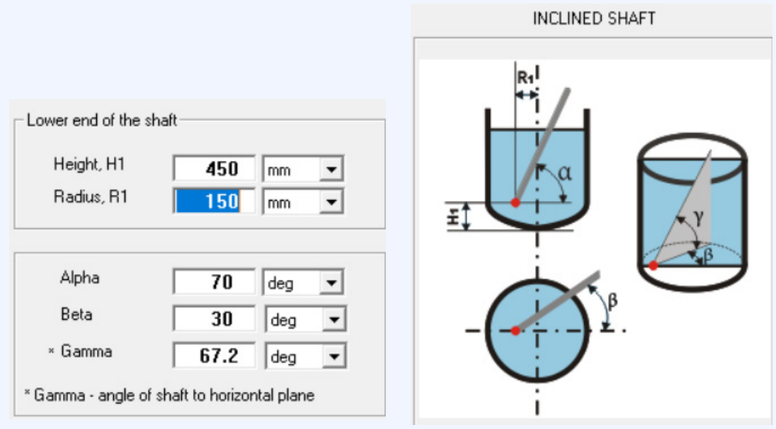
The off-centre bottom-entering shaft configuration was modeled in VisiMix by defining a radial offset (R) from the vessel centreline and the corresponding shaft length (L), while keeping the impeller type and operating conditions constant. This configuration is particularly relevant for low-viscosity applications, where impeller position plays a key role in breaking flow symmetry, enhancing bulk circulation, and reducing dead zones.

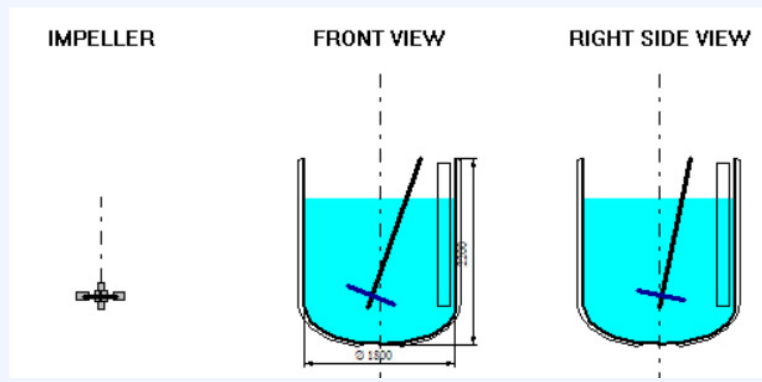




Case-II: Inclined shaft

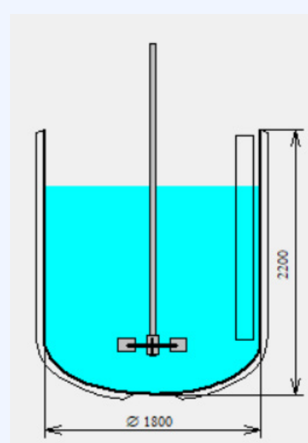
The inclined shaft configuration was modeled by defining the shaft inclination angle and spatial position relative to the vessel centreline in VisiMix. The impeller was positioned at the same clearance from the vessel bottom as the reference case, while the shaft inclination (α, β, ɣ) was varied to introduce asymmetry in the flow field.





Case-III: Top mounted agitator

The top-mounted agitator configuration was simulated in VisiMix under identical vessel geometry and operating conditions, as illustrated in the figure below.



KEY SIMULATION RESULTS

The table below summarizes key hydrodynamic and turbulence parameters obtained from VisiMix simulations for different agitator configurations under identical operating conditions.

Parameter	Units	Bottom entering shaft	Inclined shaft	Top-mounted agitator
Mixing power	W	4880	3870	3460
Reynolds number for flow		4.18e+05	5.09e+05	5.78e+05
Energy dissipation-maximum value	W/kg	330	257	241
Energy dissipation-average value	W/kg	1.22	0.968	0.865
Energy dissipation near baffles	W/kg	0.25	0.393	0.572
Energy dissipation in the bulk volume	W/kg	0.0964	0.157	0.248
Turbulent shear rate near the impeller blade	1/s	18200	16100	15600
Turbulent shear rate near the baffle	1/s	502	630	758
Turbulent shear rate in the bulk volume	1/s	312	398	500
Macromixing time	s	47.6	18.4	21.5
Characteristic time of micro mixing	s	3.22	2.52	2.01

Key Observations

- The **bottom-entering shaft** exhibits the **highest mixing power** and **maximum energy dissipation,** indicating strong localized agitation near the impeller region.
- The **top-mounted agitator** operates at the **highest Reynolds number,** suggesting a more globally turbulent flow regime compared to bottom-entering and inclined configurations.
- **Energy dissipation near the impeller blade** is highest for the bottom-entering shaft, while energy dissipation in the bulk volume and near baffles increases progressively from bottom-entering to inclined and is highest for the top-mounted agitator.
- **Turbulent shear rates** near the impeller blade are highest for the bottom-entering shaft, whereas shear rates near baffles and in the bulk volume are highest for the top-mounted agitator, indicating better distribution of turbulence away from the impeller.
- The **inclined shaft configuration** offers a balanced **hydrodynamic performance**, with moderate power input, enhanced bulk mixing, and significantly reduced macromixing time compared to the bottom-entering shaft.
- The **shortest macromixing time** is observed for the inclined shaft, highlighting its effectiveness in achieving faster overall mixing.
- The **top-mounted agitator** shows the lowest characteristic micro-mixing time, making it potentially more suitable for processes sensitive to micromixing, such as fast reactions or crystallization.
- Overall, **Bottom-entering shafts** favor high local shear, i**nclined shafts** provide optimal macromixing efficiency, and **top-mounted agitators** enhance bulk turbulence and micromixing performance.

In summary, the results indicate that agitator configuration plays a critical role in defining mixing performance. Each configuration exhibits distinct hydrodynamic and turbulence advantages, and the selection of an optimal agitator should be guided by the dominant process requirement, such as local shear intensity, bulk mixing efficiency, or micromixing performance. **VisiMix** enables informed and application-specific agitator selection during design and scale-up.

Conclusion

- Agitator configuration has a **significant impact on mixing hydrodynamics,** influencing power input, turbulence distribution, and overall mixing efficiency.
- **Bottom-entering shafts** generate **high localized shear near the impeller,** making them suitable for applications requiring intense local mixing.
- **Inclined shaft configurations** provide a **balanced hydrodynamic performance,** supporting effective bulk mixing with moderate energy input compared to bottom entering shafts.
- **Top-mounted agitators** deliver **superior bulk turbulence and the fastest micromixing,** making them well suited for micromixing-sensitive processes.
- No single agitator design is universally optimal; **selection should be driven by specific process requirements** such as shear sensitivity, mixing time, and scale-up considerations.
- VisiMix simulations enable **quantitative comparison** of agitator options, supporting informed and efficient equipment selection during process design and scale-up.

Through **VisiMix simulations,** engineers can analyze and select a wide range of agitator configurations, including top-mounted, inclined, and bottom-entering designs.

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