NEWSLETTER

Sensitivity Analysis for Optimizing Liquid–Solid Mixing Using VisiMix

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VISIMIX NEW PRODUCT: SENSITIVITY ANALYSIS

The **Sensitivity Analysis** module in VisiMix is designed to help engineers systematically evaluate how variations in a single process parameter impact overall process performance. In this module, multiple simulations are run in identically designed mixing tanks, where all parameters remain constant except for the one chosen **sensitivity variable.** Users can select this variable from a predefined list, allowing a focused study on its effect. The module generates comprehensive **output tables and charts** that present side-by-side comparisons of key process characteristics, enabling a clear understanding of how changes in the sensitivity variable influence results.

In **liquid–solid mixing,** Sensitivity Analysis is particularly useful, as these systems are highly influenced by factors such as impeller speed, solid concentration, and reactor occupancy, which directly affect suspension quality, uniformity, and overall mixing efficiency.By systematically analyzing these effects, engineers can identify the optimal operating range of the sensitivity parameter, enhance mixing performance, minimize experimental trials, and ensure scalable, robust processes.

The Challenge

Let’s consider scaling up from a **1 L flat-bottom lab reactor** to a **6 KL elliptical-bottom industrial reactor.**

The **goal** is to achieve **good suspension** and maintain **axial and radial uniformity of solids** in the 6 KL industrial reactor, comparable to the performance observed in the 1 L lab reactor.

Key Challenges:

- **Geometric differences:** Lab reactor is flat-bottomed; industrial reactor is elliptical, affecting flow patterns and particle suspension.
- **Mixing efficiency:** Impeller type, size, and speed must be adjusted; power input doesn’t scale linearly.
- **Particle settling:** Larger tanks increase the risk of solids settling at the bottom or corners.

Axial and radial uniformity of solids:

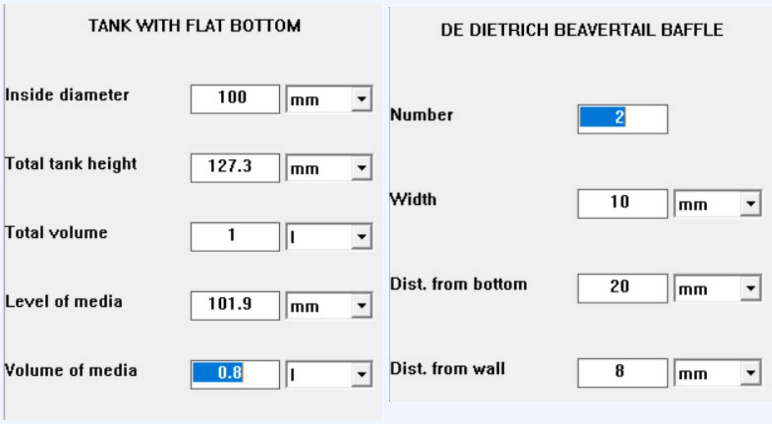
- **Axial:** Ensuring uniform particle distribution from top-to-bottom to prevent settling or surface concentration.
- **Radial:** Ensuring uniform distribution from tank center to walls to avoid dead zones and uneven shear.

The Solution

To address the scale-up challenge, **VisiMix Turbulent with Sensitivity Analysis** is used to simulate both the laboratory and industrial systems and determine the critical parameters before actual plant trials.

Step-1: Laboratory simulation:

The laboratory setup was first modeled in VisiMix. Input the details of tank, baffles (thermowell and pH electrode) and the impeller.



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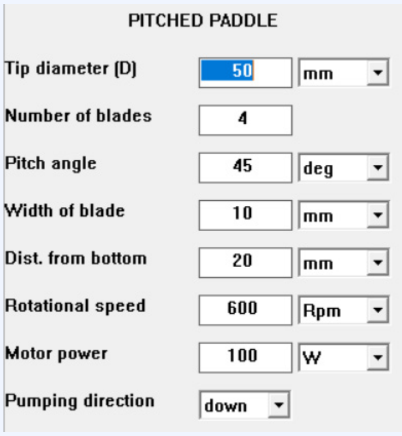
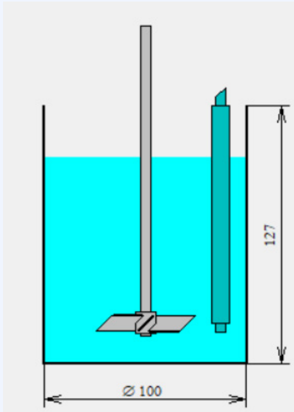
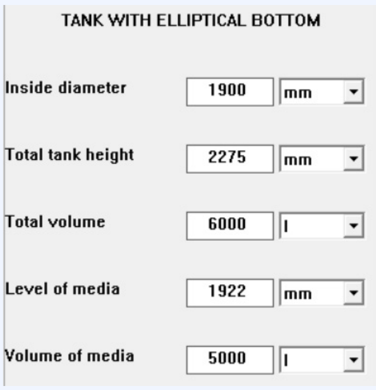
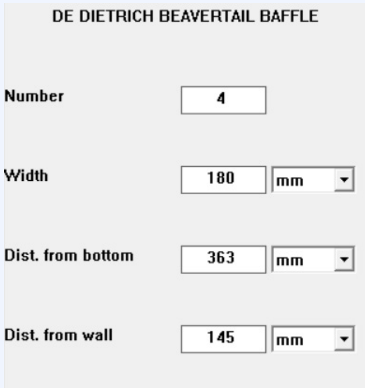


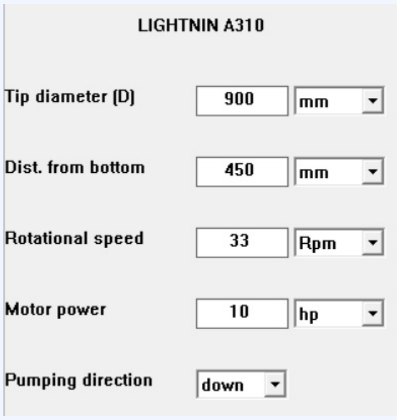


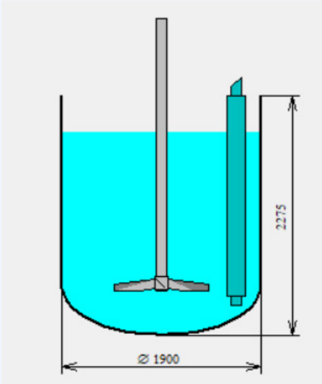
Step-2: Creating the industrial model:

Next, input the details of the 6 KL reactor







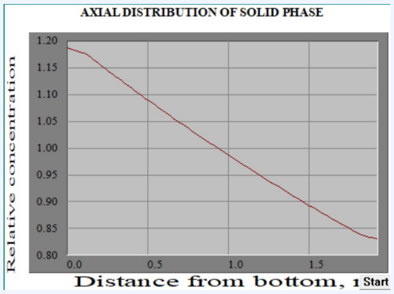


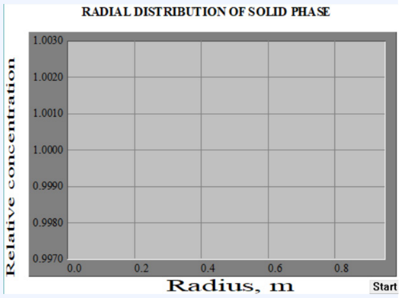
Simulation Results:

At lab scale, complete suspension was achieved. The measured non-uniformity was **10.2%** in the axial direction and **2%** in the radial direction.

In the current plant setup, the liquid–solid mixing is operated at 33 RPM. Preliminary observations and simulations indicate that under these conditions, achieving complete suspension of solids is challenging.To quantify the mixing performance, axial and radial uniformity of solids were analyzed, highlighting regions where suspension is suboptimal and non-uniformity is significant.

- Complete suspension is **questionable.**
- Maximum degree of **non-uniformity-axial% - 18.7%**
- Maximum degree of **non-uniformity-radial% - 0.266%**





Axial and Radial distribution of Solid phase at plant scale

To address the suspension and uniformity challenges, **VisiMix Sensitivity Analysis** was performed with **Impeller rotation speed** selected as the sensitivity variable over a range of **20–120 RPM**. The simulation generated mixing performance, suspension behavior, and axial/radial uniformity at intermediate RPM values, allowing direct comparison and identification of conditions that achieve complete suspension and uniform solids distribution.

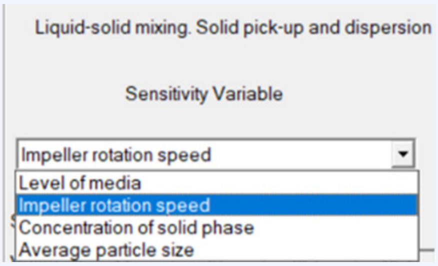


Figure: Sensitivity variables available for liquid–solid mixing simulations.

The user can select one variable to study its impact on suspension and uniformity.

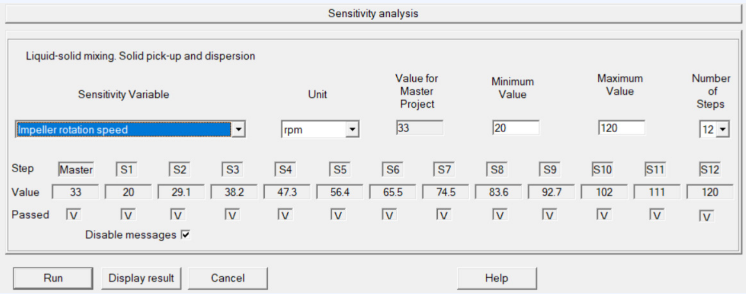


Figure: Sensitivity Analysis setup in VisiMix with impeller rotation speed (20–120 RPM) as the variable, showing incremental steps used to evaluate suspension and mixing uniformity.

Results from Sensitivity analysis

Run the simulation and click on 'Display Results.' The results are displayed as shown in the figure below and can be directly exported to Excel for further analysis.

Parameter	4	5	6	7	8	9	10
Project Name	53..	...S4..	...S5..	...S6..	...S7..	...S8..	...S9..
=== SENSITIVITY VARIABLES							
Media depth, mm	20	1920	1920	1920	1920	1920	1920
Rotational speed, rpm	.2	47.3	56.4	65.5	74.5	83.6	92.7
Average particle diameter, mm	)8	0.08	0.08	0.08	0.08	0.08	0.08
Mass concentration of solid phase, kg/m^3	0	100	100	100	100	100	100
=== TARGET PARAMETERS							
Complete/incomplete suspension	complete	incomplete	incomplete	complete	complete	complete	complete
Maximum relative axial non-uniformity, %	.1	12.9	10.7	9.22	8.07	7.17	6.45
Maximum relative radial non-uniformity, %	266	0.266	0.266	0.266	0.267	0.267	0.267
Maximum local concentration of solid phase, kg/m^3	8	114	112	110	109	108	107
Minimum local concentration of solid phase, kg/m^3	.2	87	89	90.4	91.5	92.4	93.1
Average concentration of solid phase in continuous flo...	8	114	112	110	109	108	107
Maximum energy of particle collisions, J	56e-13	1.16e-12	1.65e-12	2.22e-12	2.88e-12	3.63e-12	4.46e-12
Frequency of collisions with the maximum energy, 1/s	)0248	0.00307	0.00366	0.00425	0.00484	0.00543	0.00602
=== MAJOR DESIGN PARAMETERS							
Tank diameter, mm	00	1900	1900	1900	1900	1900	1900
Type of impeller	ghtnin A...	Lightnin A...	Lightnin A...	Lightnin A...	Lightnin A...	Lightnin A...	Lightnin A...
Impeller tip diameter, mm	0	900	900	900	900	900	900
Number of impellers		1	1	1	1	1	1
Presence of baffles	ES	YES	YES	YES	YES	YES	YES

Figure: Sensitivity Analysis results in VisiMix showing complete suspension achieved at 65 RPM

The output from VisiMix Sensitivity Analysis displayed the predicted suspension and mixing uniformity at each impeller speed. It was observed that 65 RPM was identified as the critical speed at which complete suspension of solids was achieved, with significantly improved axial and radial uniformity.

Key Observations:

The consolidated output displayed all results from 20 to 120 RPM, allowing quick comparison of suspension and mixing performance at different speeds.

- **33 RPM (existing case):** Complete suspension was not achieved, with axial non-uniformity of 18.7% and radial non-uniformity of 0.266%.
- **65 RPM:** Complete suspension was achieved, with axial non-uniformity reduced to 9.22% and radial non-uniformity maintained at 0.266%, indicating improved uniformity compared to the lab-scale results (axial 10.2%, radial 2%).

Conclusion:

The sensitivity analysis across a broad RPM range (20–120) enabled rapid identification of the optimal operating conditions, showing that complete suspension and uniform solids distribution are achieved at 65 RPM, comparable to lab-scale observations.