

Introduction

- Liquid–liquid mixing is a key operation in processes such as extraction, emulsification, and multiphase reactions, where performance is strongly influenced by **droplet size distribution and interfacial area**. In such systems, two competing phenomena—**droplet break-up and coalescence**—occur simultaneously, and their balance determines the overall mass transfer efficiency and process outcome.
- While achieving the desired emulsification is often feasible at the laboratory or pilot scale, **scaling up to industrial reactors introduces significant challenges**. Changes in vessel geometry, impeller design, and energy dissipation can alter local hydrodynamics, leading to variations in drop size, mixing time, and ultimately process performance.
- VisiMix provides a robust platform to analyze and predict mixing behavior by evaluating key parameters such as **stabilization time, drop size distribution, and specific mass transfer area**. This enables engineers to ensure that production-scale performance closely matches pilot-scale results, reducing risk and improving scale-up reliability.

Objective

The process aims to **scale up liquid–liquid mixing from a 30 L pilot reactor to a 6 kL production reactor** while maintaining consistent **emulsification quality, drop size distribution, and mass transfer performance**.

The objective is to ensure that key parameters such as **stabilization time and specific mass transfer area** remain comparable across scales by optimizing reactor configuration and operating conditions using VisiMix.

The Process

- The process involves a **liquid–liquid extraction system**, where an oil phase is dispersed into a continuous aqueous phase to form an emulsion. The mixing is governed by the simultaneous phenomena of **droplet break-up and coalescence**, which determine the final drop size and interfacial area.
- At the pilot scale, a **30 L reactor with 4 flat baffles and 67% liquid fill level** is used, achieving stable emulsification within a short time.

- During scale-up, the process is transferred to a **6 kL production reactor equipped with a single tubular baffle and 83% liquid fill level**.
- To ensure similar performance, maintaining comparable **hydrodynamic conditions and mixing intensity** is critical, as changes in reactor geometry and internals can significantly impact emulsification behavior.

VisiMix Simulation Approach

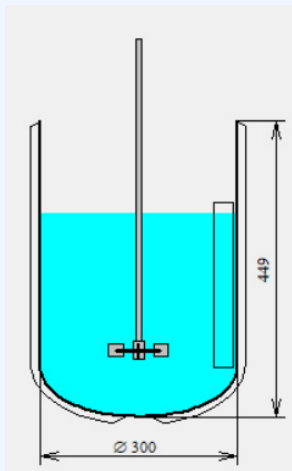
Step-I: Pilot Reactor Simulation

VisiMix Turbulent was first used to simulate the **30 L pilot reactor** to understand its hydrodynamics and emulsification behavior. All relevant physical properties of the liquid–liquid system were incorporated to accurately represent the process conditions.

The simulation evaluated key parameters such as **stabilization time, drop size distribution, specific mass transfer area, and flow patterns**, which govern droplet break-up and coalescence.

This established a clear baseline of the conditions that produced the desired **emulsification quality and mixing performance at pilot scale**, serving as a reference for subsequent scale-up to the production reactor.

VisiMix Analysis



TANK WITH ELLIPTICAL BOTTOM	
Inside diameter	300 mm
Total tank height	449.4 mm
Total volume	30 l
Level of media	307.9 mm
Volume of media	20 l

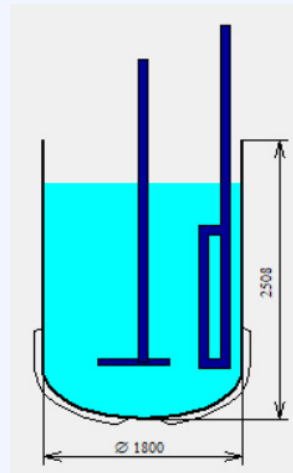
FLAT BAFFLE-2	
Number	4
Width	30 mm
Length	250 mm
Dist. from bottom	75 mm
Dist. from wall	5 mm
Angle to radius (fi)	0 deg

DISK TURBINE	
Tip diameter (D)	100 mm
Diameter of disk	75 mm
Number of blades	6
Pitch angle	90 deg
Width of blade	20 mm
Length of blade (L)	25 mm
Dist. from bottom	100 mm
Rotational speed	350 Rpm
Motor power	100 W
Pumping direction	down

PROPERTIES OF CONTINUOUS AND DISPERSE LIQUID PHASES.	
Continuous phase	
Density	1000 kg/cub.m
Dynamic viscosity	1 cP
Disperse phase	
Volume fraction	0.15
Density	940 kg/cub.m
Dynamic viscosity	30 cP
Interfacial surface tension	
0.03 N/m	
Index of repulsing pressure	
0	
-1 - 0.5 - coagulants (de-emulsifiers) -0.5 - 0.1 - 2- and 3-valent ions of electrolytes -0.1 - 0.1 - no significant admixtures (pure oil - water) 0.1 - 0.25 - electrolytes 0.25 - 0.5 - small quantities of detergents > 0.5 - detergents, emulsifiers	
OK	Cancel
Print	Help

Step-II: Production Simulation

Similarly, a second VisiMix model was developed for the 6 kL production reactor to evaluate key scale-up parameters and assess differences in the mixing environment compared to the pilot scale.



TANK WITH ELLIPTICAL BOTTOM	
Inside diameter	1800 mm
Total tank height	2508 mm
Total volume	6000 l
Level of media	2115 mm
Volume of media	5000 l

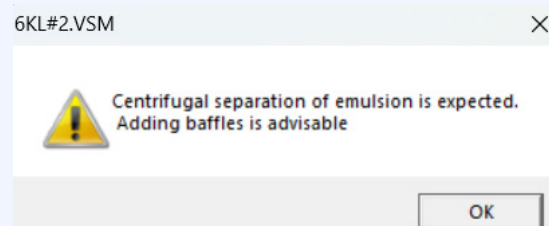
TUBULAR BAFFLE-2	
Number	1
Tube diameter (D)	100 mm
Length (L)	1300 mm
Dist. from bottom	450 mm
Dist. from wall	100 mm
Angle to radius (fi)	0 deg

GLASS LINED IMPELLER 1	
Tip diameter (D)	800 mm
Number of blades	3
Width of blade	80 mm
Dist. from bottom	500 mm
Rotational speed	100 Rpm
Motor power	1e+04 W

Summary of Simulation Results

• 6 KL (One Baffle) - VisiMix Warning

During the simulation of the 6 Kl reactor with one baffle, VisiMix generates the following warning message:



VisiMix warns that "Centrifugal separation of emulsion is expected. Adding baffles is advisable".

It is suggested to add one more baffle (i.e., use two baffles in total) in the 6 KL reactor to improve flow distribution and enhance emulsification performance.

Key Scaling up parameters

Comparison of Pilot and Production Performance

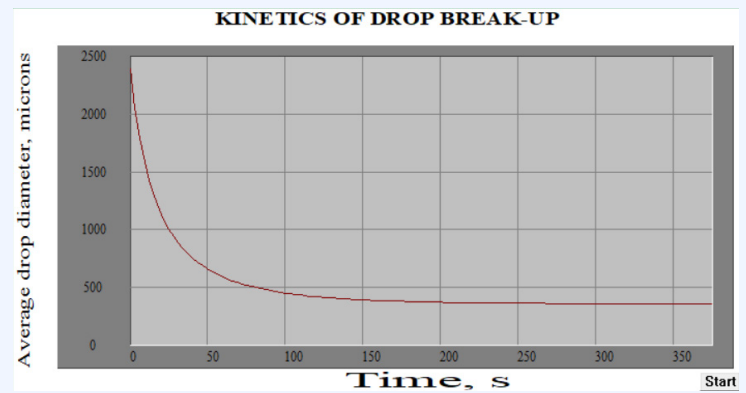
Parameters	Units	Pilot reactor (30 L)	Production (6 KL, one baffle)	Production (6 KL, 2 baffles)
Complete/incomplete Emulsification		No separation of emulsion is expected	Centrifugal separation of emulsion is expected. Adding baffles is advisable	No separation of emulsion is expected
Mean drop size	μm	355		348
Specific mass transfer area	m ² /m ³	3450		3520

The comparison of pilot and production-scale simulations highlights the importance of reactor configuration on emulsification performance:

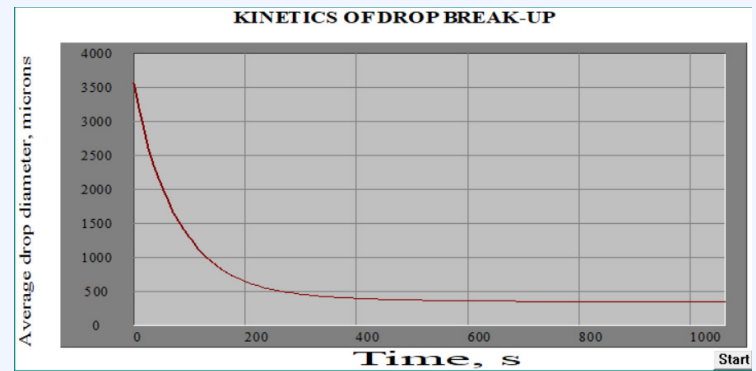
- In the initial **production case (6 kL, one baffle)**, the system showed **centrifugal separation**, indicating **poor emulsification and inadequate mixing conditions**. VisiMix recommended increasing the number of baffles.
- After modification to **two baffles**, the system achieved **complete emulsification**, consistent with the pilot-scale behavior (**30 L reactor**), where no phase separation was observed.
- The **mean drop size** remained comparable across scales, reducing slightly from **355 μm (pilot) to 348 μm (optimized production)**, indicating similar droplet break-up efficiency.
- The **specific mass transfer area** was also maintained at a similar level, increasing from **3450 m²/m³ (pilot) to 3520 m²/m³ (production)**, ensuring effective interfacial area for mass transfer.

Kinetics of Drop Break up

30 L Reactor



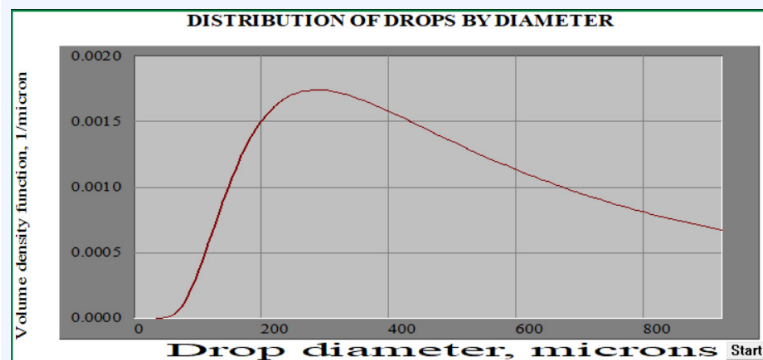
6 KL Reactor (2 baffles)



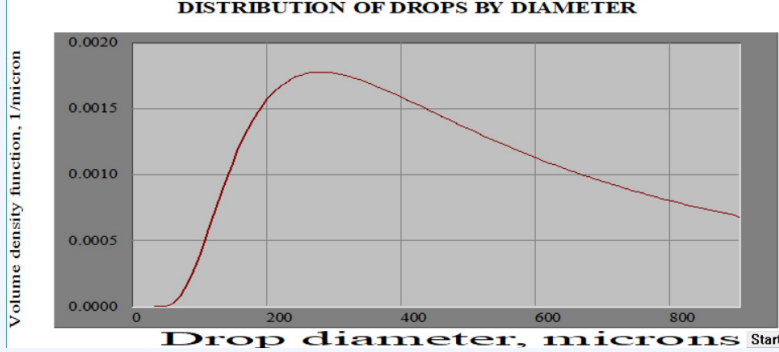
- At the pilot scale (30 L), stabilization is achieved rapidly (~3 minutes), indicating efficient dispersion.
- After optimization (2 baffles), the stabilization time improves (~5–6 minutes), aligning closely with the pilot-scale trend.

Distribution of Drops by Diameter

30 L Reactor



6 KL Reactor (2 baffles)



The drop size distribution further confirms the scale-up performance:

- The pilot reactor shows a narrow and stable distribution, indicating uniform droplet formation.
- The optimized production reactor achieves a similar distribution profile, confirming consistent emulsification quality.

Conclusion

- Scale-up from **30 L to 6 kL** requires matching **hydrodynamic conditions**, rather than relying only on geometric similarity, as changes in flow patterns can significantly impact mixing performance.
- **Reactor configuration, particularly baffle design**, plays a critical role in improving flow distribution and achieving stable emulsification in large-scale systems.
- The optimized system maintained **consistent drop size, specific mass transfer area, and stabilization time**, ensuring similar droplet break-up behavior, effective interfacial area, and comparable process performance across scales.
- VisiMix enabled **identification of design limitations and guided targeted optimization**, reducing scale-up risk and supporting reliable and efficient process transfer to production.

Please refer: [Drop Size.Scaling Up](#)

Start Your Free Trial of VisiMix Today

Want to model your own process and avoid costly mistakes?

[Click here to download your free trial of VisiMix](#)