NEWSLETTER

Continuous Flow Process: Impact of Feed Position in a Multistage Impeller Reactor on Reaction Performance

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Introduction

- Continuous flow reactors are widely used in the chemical and pharmaceutical industries due to their ability to provide consistent product quality, improved process control, and enhanced safety. In such systems, reactor performance is strongly influenced not only by reaction kinetics but also by hydrodynamic factors such as mixing efficiency, flow patterns, and feed inlet location.
- Multistage impeller configurations are commonly employed to improve axial circulation and reduce concentration gradients in tall reactors. However, the effectiveness of these systems depends significantly on how and where reactants are introduced into the vessel. Feed position can influence local reactant concentrations, mixing intensity, residence time distribution, and ultimately the balance between desired product formation and undesired by-product formation.
- This study uses VisiMix Chem to evaluate the influence of feed position in a continuous reactor equipped with a three-stage paddle agitator. By comparing different feed inlet locations while maintaining identical operating conditions, the study provides insight into the relationship between mixing dynamics, reactant conversion, product formation, and by-product generation.

Consider the following example, which includes both the main reaction and the side reaction leading to by-product formation.

Designation	Description
R1	Main reaction A + B <-> P
R2	 A + P <-> BP

Where ‘A’ and ‘B’ are reactants, ‘P’ is the main product and ‘BP’ is the by-product.

Objective

The objective of this study is to evaluate the influence of feed inlet location on the performance of a continuous flow reactor equipped with multistage impellers. The study investigates the concentration profiles of reactants, product, and by-product as a function of time and analyzes the corresponding reactant conversion rates.

Concentration and conversion profiles are generated to assess the impact of feed positioning on reaction kinetics and overall reactor performance.

Feed Location Configurations

Case-I: Feed 2 Located Near the Bottom Side of the Reactor

Feed 2 was introduced near the bottom side wall of the reactor at a height of 450 mm from the base. This configuration was used as the reference case to evaluate the influence of feed location on reaction performance.

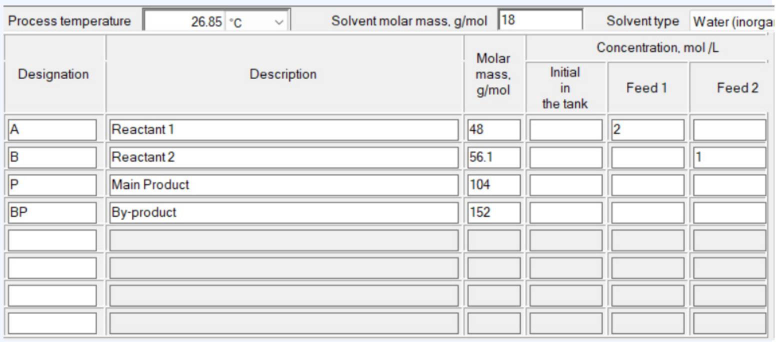
Case-II : Feed 2 Located Near the Top Side of the Reactor

Feed 2 was relocated to the top side wall of the reactor at a height of 1500 mm from the base, while all other process and reactor parameters remained unchanged. This configuration was evaluated to determine the effect of feed positioning on reactant conversion, product formation, and by-product generation.

VisiMix Model Setup

Case-I: Feed 2 Located Near the Bottom Side of the Reactor

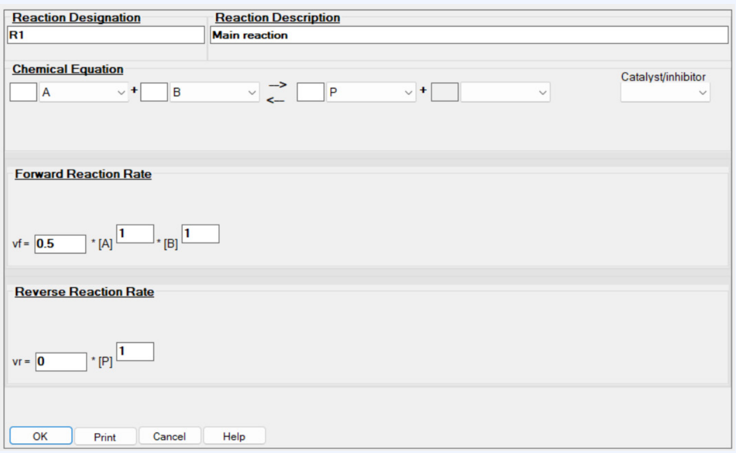
The study was performed using VisiMix Chem by defining the reaction kinetics, reactor geometry, impeller configuration, and feed locations as shown below.



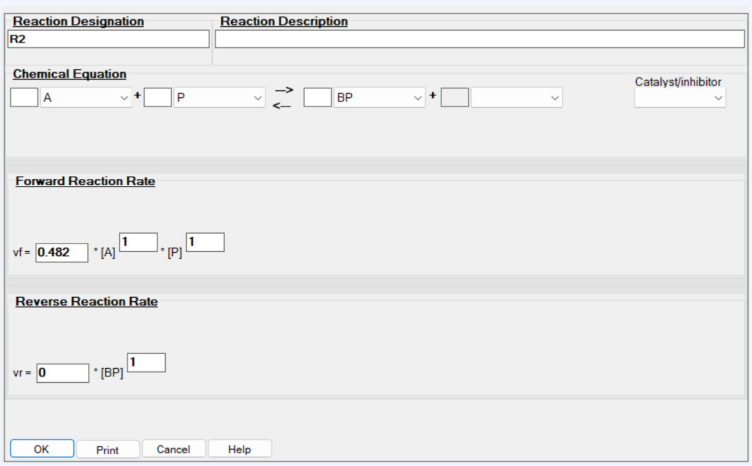
Process temperature 26.85 °C | Solvent molar mass, g/mol 18 | Solvent type Water (inorga

Designation	Description	Molar mass, g/mol	Concentration, mol /L: Initial in the tank	Feed 1	Feed 2
A	Reactant 1	48		2	
B	Reactant 2	56.1			1
P	Main Product	104			
BP	By-product	152			

Process Chemistry

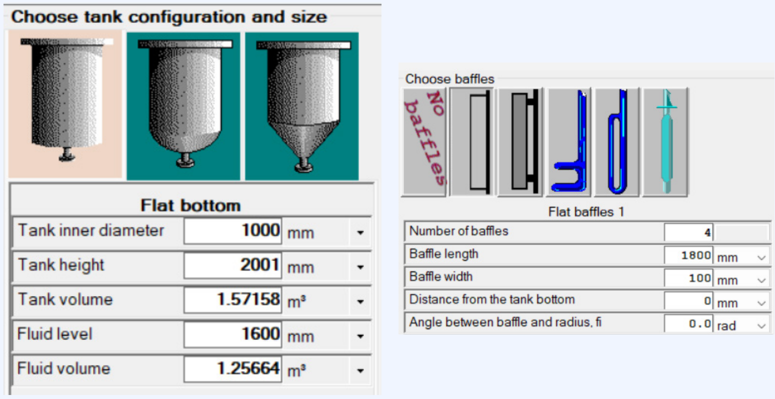


Main Reaction Kinetics

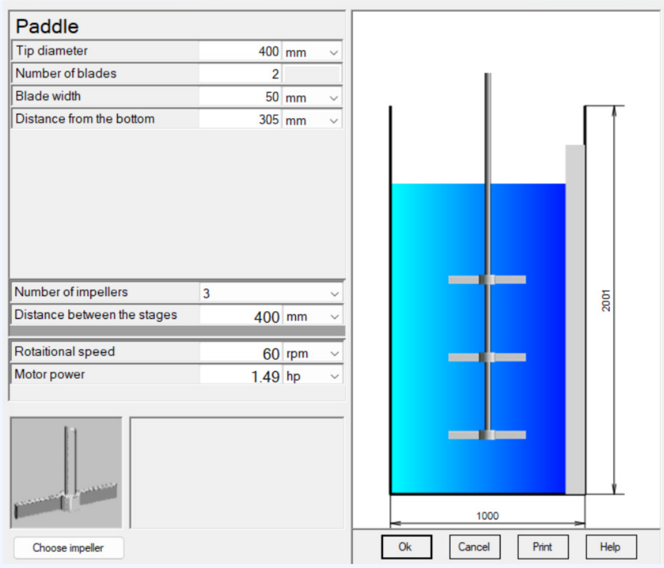


Side Reaction Kinetics

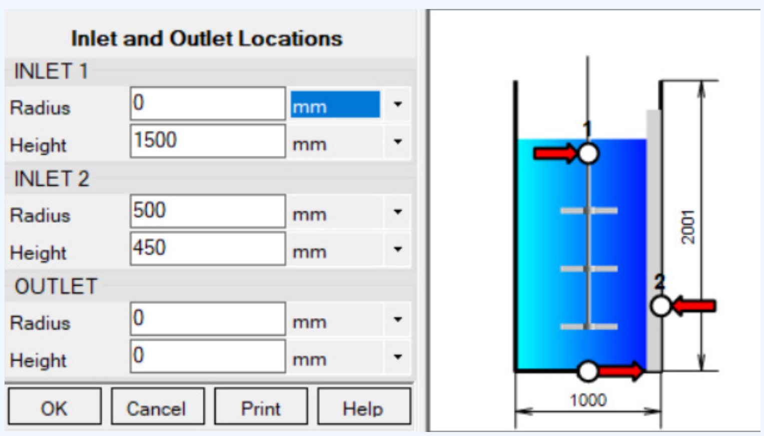
Next, the reactor was modeled as a 1000 mm internal diameter flat-bottom tank with a 1600 mm working fluid height, equipped with four flat baffles.



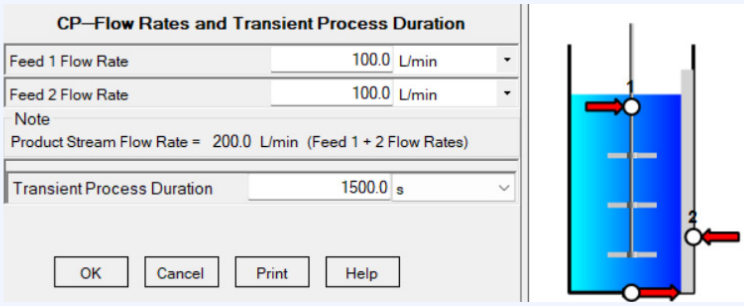
Reactor and Baffle Configuration



Multistage Paddle Impeller Configuration



Feed and Outlet Locations



Feed Flow Rates and Process Duration

Simulation Results - Case-I

Continuous Flow Process—Average Concentrations, mol/L

At the end of the transient process of requested duration

Reactant Designation	Actual Reactor–Tank	Actual Reactor–Product Stream	Reactor with Perfect Macromixing
A	0.5855	0.09603	0.08615
B	0.0162	0.03434	0.02895
P	0.01437	0.04022	0.02826
BP	0.3253	0.4193	0.4334

Average concentration in the reactor mol/L

Continuous Flow Process—Concentration Non-Uniformities in Actual Reactor, mol/L

At the end of the transient process of requested duration

Reactant Designation	Local Concentration Standard Deviation	Difference between the Maximum and Minimum Local Concentrations	Average Concentrations
A	0.3665	0.9339	0.5855
B	0.02298	0.08736	0.0162
P	0.01776	0.04096	0.01437
BP	0.07039	0.1869	0.3253

Concentration Non-Uniformities in Actual Reactor, mol/L

Continuous Flow Process—Reactant Conversion

At the end of the transient process of requested duration

Reactant Designation	Actual Reactor–Product Stream	Reactor with Perfect Macromixing
A	0.904	0.9138
B	0.9313	0.9421
P		
BP		

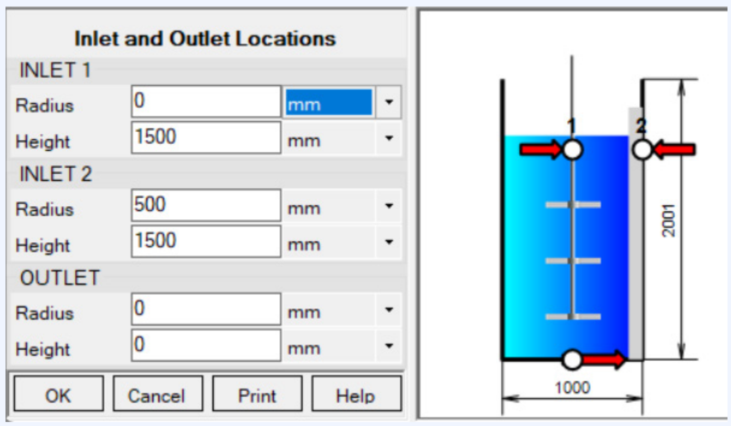
Reactant conversion

Reactant A achieves a conversion of **0.904** in the actual reactor, slightly below the ideal reactor's **0.914,** while Reactant B achieves **0.93,** compared to the ideal reactor's **0.94.** This difference is likely due to non-ideal flow dynamics, localized mixing zones, or dead zones hindering its efficiency.

The product concentration in the actual reactor is **0.04 mol/L** with the by-product concentration at **0.42 mol/L,** indicating increased by-product formation. This is likely due to suboptimal flow patterns or insufficient local mixing, leading to side reactions.

Case-II : Feed 2 Located Near the Top Side of the Reactor

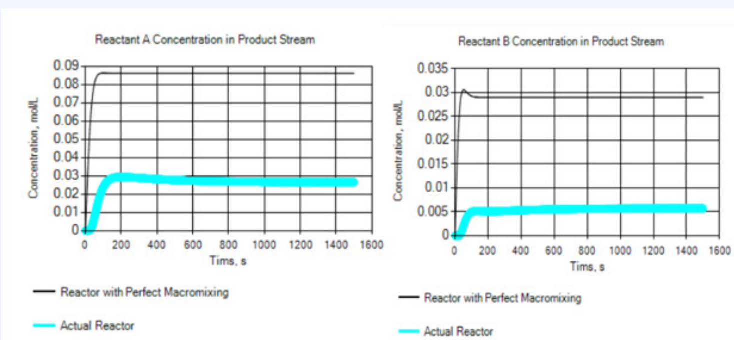
To evaluate the influence of feed inlet position, Feed 2 was relocated to the top side of the reactor while all other process conditions remained unchanged. This change helps us understand how feed location affects mixing, conversion, and by-product formation. The results are compared with the previous configuration to assess the impact on reaction performance and process yield.

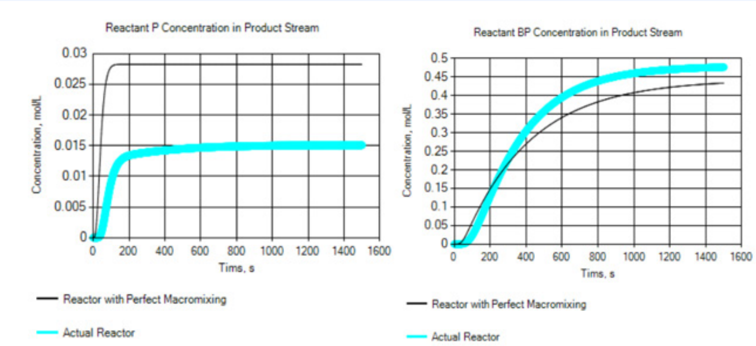


Feed 2 Position Modification

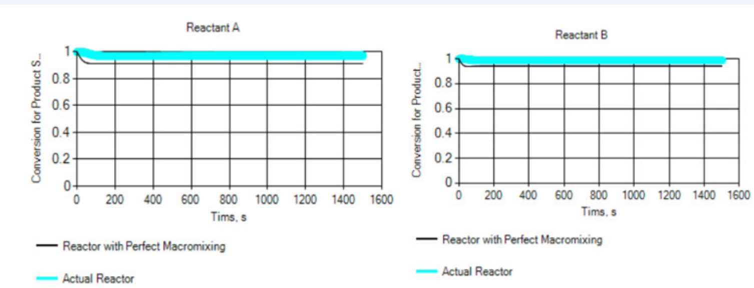
Simulation Results- Case-II

Concentration Profiles





Conversion Profiles



Relocating Feed 2 to the top side of the reactor resulted in higher reactant conversions, with Reactant A and Reactant B achieving conversions of **0.973** and **0.988,** respectively. However, the product concentration in the product stream was **0.015 mol/L,** while the by-product concentration reached **0.476 mol/L,** indicating that the modified feed location promoted the secondary reaction pathway.

COMPARATIVE ANALYSIS

Parameter	Case-I (Feed 2 near the bottom of the reactor)	Case-II (Feed 2 near the top of the reactor)
Feed concentration of A (mol/L)	2	2
Feed concentration of B (mol/L)	1	1
Reactant A conversion	0.9	0.97
Reactant B conversion	0.93	0.988
Product concentration in the Product stream (mol/L)	0.04	0.015
By-product concentration in the Product stream (mol/L)	0.42	0.47

The comparison demonstrates that feed location has a significant impact on reactor performance. While positioning Feed 2 near the top of the reactor improved reactant conversion, it also increased by-product formation and reduced product concentration. This highlights the importance of balancing conversion and selectivity when optimizing feed placement in continuous flow reactors.

CONCLUSION

This study demonstrates that feed positioning is a critical design parameter in continuous flow reactors equipped with multistage impellers. Although relocating Feed 2 to the top region enhanced reactant conversion, it also favored by-product formation. Therefore, feed location should be optimized based on both conversion and product selectivity to achieve the desired process outcome.

Please refer: **Feed position near the bottom in multi stage impeller**
Feed position near the top in multistage impeller