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Research Article

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Case Study of Design of Oscillatory Baffled Reactor

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Abstract The aim of this paper is to case study of design the continuous Oscillatory Baffled flow Reactor on the laboratory scale. It presents the prediction of the number of serially arranged ideal stirred tank reactors, that will have an equivalent performance as an Oscillatory baffled flow reactor using tanks in Series Model approach. It would be more economical to use a single Oscillatory baffled flow reactor than using about the number Continuous stirred tank reactor for the given reaction.

Keywords Oscillations, Baffles, Reactor

Introduction

Continuous Oscillatory Baffled reactors (COBR) consist of tubes fitted with equally spaced orifice plate baffles. A through flow is applied to the reactor, and an oscillatory fluid motion is superimposed on the entire volume of the fluid in the reactor, such that the interaction of the fluid with the baffle geometry generates highly effective mixing within each inter baffle cavity, as well as along the length of the reactor as a whole [1]. When a liquid is pushed up through the tube, eddies are created around the baffles, enabling significant radial motion. On a down stroke, eddies are created on the opposite side and the intensity of eddy generation and cessation can be controlled precisely thus very effective mixing is created [3]. COBR offers a means to perform reactions which require long reaction times (of order hours) in a reactor of greatly reduced length-to-diameter ratio. This is achieved while maintaining plug-flow residence time distribution (RTD) characteristics, effective mixing, and high heat- and mass-transfer rates. Such requirements are difficult to achieve (for long reaction time processes) in tubular reactors relying on throughput alone to achieve mixing. These features make it possible to consider performing certain reactions continuously, which previously were only possible in batch. Many advantages have been characterized for oscillatory flow mixing, such as efficient dispersion for immiscible fluids, uniform particle suspension, gas-in-liquid dispersions and multiphase mixing [1].

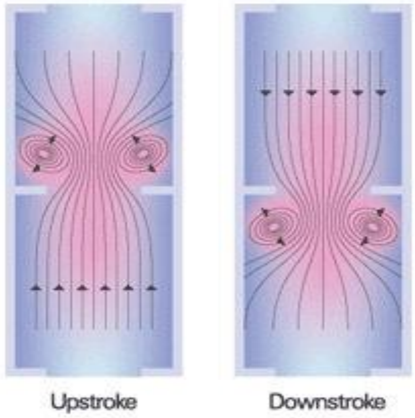

Figure 1: Formation of eddies Due to baffles in COBR

Materials and Methods

Plug Flow Reactor

The plug flow reactor model (PFR, sometimes called continuous tubular reactor, CTR, or piston flow reactors) is a model used to describe chemical reactions in continuous, flowing systems of cylindrical geometry. The PFR model is used to predict the behavior of chemical reactors of such design, so that key reactor variables, such as the dimensions of the reactor, can be estimated. Fluid going through a PFR may be modeled as flowing through the reactor as a series of infinitely thin coherent "plugs", each with a uniform composition, traveling in the axial direction of the reactor, with each plug having a different composition from the ones before and after it. The key assumption is that as a plug flows through a PFR, the fluid is perfectly mixed in the radial direction but not in the axial direction (forwards or backwards). As it flows down the tubular PFR, the residence time of the plug is a function of its position in the reactor. The PFR model works well for many fluids: liquids, gases, and slurries. The PFR model can be used to model multiple reactions as well as reactions involving changing temperatures, pressures and densities of the flow [2].

Plug flow reactors are used for some of the following applications:

- Large-scale production
- fast reactions
- Homogeneous or heterogeneous reactions
- Continuous production
- High-temperature reactions

Continuous Stirred Tank Reactor

The continuous flow stirred-tank reactor (CSTR), also known as vat or back mix reactor is a common ideal reactor type in chemical engineering. A CSTR often refers to a model used to estimate the key unit operation variables when using a continuous agitated-tank reactor to reach a specified output. The mathematical model works for all fluids: liquids, gases, and slurries. The behavior of a CSTR is often approximated or modeled by that of a Continuous Ideally Stirred-Tank Reactor (CISTR). All calculations performed with CISTRs assume perfect mixing. In a perfectly mixed reactor, the output composition is identical to composition of the material inside the reactor, which is a function of residence time and rate of reaction. If the residence time is 5-10 times the mixing time, this approximation is valid for engineering purposes. The CISTR model is often used to simplify engineering calculations and can be used to describe research reactors. In practice it can only be approached, in particular in industrial size reactors [3].

Continuous Oscillatory Baffled Reactor

Requirements

For the designing of COBR we requires, hollow glass cylinder, oscillator, circular baffles, connecting rods, pipes, valves, rotameter, two solution tank, linear bearings etc.

Design

A standard COBR consists of a 10-150mm ID tube with equally spaced baffles throughout. There are typically two pumps in a COBR; one pump is reciprocating to generate continuous oscillatory flow and a second pump creates net flow through the tube. This design offers a control over mixing intensity that conventional tubular reactors cannot achieve. Each baffled cell acts as a CSTR and because a secondary pump is creating a net laminar flow, much longer residence times can be achieved relative to turbulent flow systems. With conventional tubular reactors, mixing is accomplished through stirring mechanisms or turbulent flow conditions, which is difficult to control. By changing variable values such as baffle spacing or thickness, COBRs can operate with much better mixing control. For instance, it has been found that a spacing of 1.5 times tube diameter size is the most effective mixing condition; furthermore, vortex deformation increases with increase in baffle thickness greater than 3mm [2]. Based on these standards we have designed a model of COBR as shown in figure.

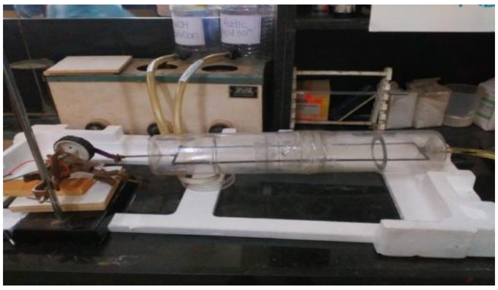

Figure 2: LAB Model of COBR

Biological Application

The low shear rate and enhanced mass transfer provided by the COBR makes it an ideal reactor for various biological processes. For shear rate, it has been found that COBRs have an evenly distributed, five-fold reduction in shear rate relative to conventional tubular reactors; this is especially important for biological process given that high shear rates can damage microorganisms. For the case of mass transfer, COBR fluid mechanics allows for an increase in oxygen gas residence time. Furthermore, the vortexes created in the COBRs causes a gas bubble break-up and thus an increase in surface area for gas transfer. For aerobic biological processes, therefore, COBRs again present an advantage. An especially promising aspect of the COBR technology is its ability to scale-up processes while still retaining the advantages in shear rate and mass transfer [2].

Limitations

Though the prospect for COBR applications in fields like bioprocessing are very promising, there are a number of necessary improvements to be made before more global use. Clearly, there is additional complexity in the COBR design relative to other bioreactors, which can introduce complications in operation. Furthermore, for bioprocessing it is possible that fouling of baffles and internal surfaces becomes an issue. Perhaps the most significant needed advancement moving forward is further comprehensive studies that COBR technology can indeed be useful in industry. There are currently no COBRs in use at industrial bioprocessing plants and the evidence of its effectiveness, though very promising and theoretically an improvement relative to current reactors in industry, is limited to smaller laboratory scale experiments.

Conclusion and Result

In this article, I have studied the concept of COBRs – from the fundamentals to applications in the real world. I hope to help chemical engineers regain their confidence in COBRs, while assisting them in establishing a clearer understanding of the concept, and helping them realise the significance of COBRs and the benefits it can bring to processes. It is clear that the benefits offered by COBRs have wide implications for the fine, speciality, pharmaceutical and process industries.

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