Packed bed reactors

Packed bed reactors can be used in chemical reactions in chemical industries. These reactors are tubular and are filled with solid catalyst particles, most often used to catalyze gas reactions.[2] The chemical reaction takes place on the surface of the catalyst. The advantage of using a packed bed reactor is the higher conversion per weight of catalyst than other catalytic reactors. The conversion is based on the amount of the solid catalyst rather than the volume of the reactor.

Theory

The Ergun equation can be used to predict the pressure drop along the length of a packed bed given the fluid velocity, the packing size, and the viscosity and density of the fluid.

The Ergun equation, while reliable for systems on the surface of the earth, is unreliable for predicting the behavior of systems in microgravity. Experiments are currently underway aboard the International Space Station to collect data and develop reliable models for on orbit packed bed reactors.

Monitoring of packed columns/beds

The performance of a packed bed is highly dependent on the flow of material through it, which in turn is dependent on the packing and how the flow is managed. Electrical tomography may be used to observe the distribution of liquids at different cross sections of the vessel, or indeed the flow pattern throughout the packed column. Depending on the nature of the materials, capacitance or resistance tomography may be used.

Design of packed bed reactors: guides to catalyst shape, size, and loading selection

The engineering design of packed bed-based unit operations is very much influenced by the structure of the packing matrix, which in turn is governed by the shape, dimensions and the loading of the constituent particles. For, say, reactor applications, optimum design of catalyst pellet in terms of shape configuration, internal pores and available surface area can promote catalytic activity and the prevailing transport properties of the system. Moreover, at the design stage, fabrication cost, resistance to crushing and abrasion, as well as dust build-up should also be taken into account. Knowledge of the underlying factors should enable designers to engineer the optimum design for a given system with prescribed conditions. However, in view of the significance of pellet/packing design, this paper addresses certain issues, which would elucidate the task.

Really, What Is a Packed Bed Reactor?

The chemical industry is considerably important to economies around the world, playing a critical role in processes ranging from the production of clean drinking water to the manufacture of pharmaceutical products. Chemical engineers are faced with the challenge of ensuring profitability in a rapidly growing and evolving market. Packed bed reactors are one of the most common reactors used in the chemical industry due to their high conversion rate per catalyst weight compared to other catalytic reactors.

How a Packed Bed Reactor Works

Packed bed reactors are very versatile and are used in many chemical processing applications such as absorption, distillation, stripping, separation processes, and catalytic reactions. Across the diverse applications in which they are used, the physical dimensions of the beds can vary greatly. Typical reactors consist of a chamber, such as a tube or channel that contains catalyst particles or pellets, and a liquid that flows through the catalyst. The liquid interacts with the catalyst across the length of the tube, altering the chemical composition of the substance.

Design Challenges of Packed Bed Reactors

When designing a packed bed reactor, the design must include mass transfer (or species transport) in the bed as well as heat transfer and chemical reactions. Understanding and optimizing the heat transfer through packed beds is important in order to decrease the cost of running the equipment. The packed catalyst is also critically important to the successful modeling of the device; the catalyst can be modeled as a porous structure, which leads to particle transport with different orders of magnitude, making the analysis of mass and energy transport a challenging task.

Another challenge when designing these devices lies in the pressure drop that occurs across the length of the reactor. The pressure drop can be reduced by using larger catalyst particles, but this causes lower intraparticle diffusion, making the reaction progress slower. The trade-off here is to find a particle size that is large enough to limit the pressure drop and small enough to allow the reaction to proceed at a fast-enough rate. A catalyst particle radius is typically in the order of magnitude of 1 millimeter. The space located between particles is described as microporous structure of the bed, while pores inside the catalyst themselves form what is known as the microstructure.

Various Applications

Depending on the application at hand, many different variations of the device can be designed. Examples of this could include different temperature and inlet concentration of the reactants, changes that can affect the reaction rate and the conversion that occurs. Additionally, depending on the application, there are many different packing shapes available for packed bed reactors that can affect the rate of the reaction.

Design variables that might change depending on the application: the catalyst diameter (active surface area per unit volume of material), structural strength, constructability, manufacturing cost, micro- and microporous volume, and transport properties, to name a few.

The most important characteristic of a PBR is that material flows through the reactor as a plug; they are also called plug flow reactors (PFR). Ideally, all of the substrate stream flows at the same velocity, parallel to the reactor axis with no back -mixing. All material present at any given reactor cross -section has had an identical residence time. The longitudinal position within the PBR is, therefore, proportional to the time spent within the reactor; all product emerging with the same residence time and all substrate molecule having an equal opportunity for reaction. The conversion efficiency of a PBR, with respect to its length, behaves in a manner similar to that of a well -stirred batch reactor with respect to its reaction time. Each volume element behaves as a batch reactor as it passes through the PBR. Any required degree of reaction may be achieved by use of an idea PBR of suitable length.

- Packed bed reactor (fixed bed reactor) consists of a cylinder of large diameter with multiple catalyst beds or many tubes in parallel packed with catalysts and encased in a large shell.
- Gas flows continuously through a stationary bed of catalyst. When low pressure drop is accounted for, large size catalysts particles are employed. The catalyst particles include: granular, pelleted, cylindrical or spherical shaped.
- Packing is used to provide a good contact between the contacting phases.
- Packed bed reactors most often are used to catalyze gas reactions
- Chemical reactions take place on the surface of the catalyst
- The advantage of using a packed bed reactor is the higher conversion per weight of catalysts than other catalytic reactors
- Packed beds of solid particles are also used in absorption and distillation columns to increase interfacial area of contact between gas and liquid
- The catalysts regeneration proce is a serious problem. It is not practically isothermal and does not carry over catalysts particles thus does not require recovery units. Cannot alo use very small size catalysts particles due to plugging and high pressure drop.It uses relatively large size particles for low pressure drop

APPLICATION: Absorption, ion exchange, distillation, humidification, and waste water treatment

The discovery of solid catalysts led to a breakthrough of the chemical process industry. Today most commercial gas-phase catalytic processes are carried out in fixed packed bed reactors1. A fixed packed bed reactor consists of a compact, immobile stack of catalyst pellets within a generally vertical vessel. On macroscopic scales the catalyst bed behaves as a porous media. The fixed-beds are thus employed as continuous tubular reactors in which the reactive species in the mobile fluid (gas) phase are reacting over the catalyst surface (interior or exterior) in the stationary packed bed. Compared to other reactor types or designs utilizing heterogeneous catalysts, the fixed packed bedreactors are preferred because of simpler technology and ease of operation.

Packed Bed Reactor Design - Typical for strongly exothermic processes, at some location in the reactor, an extreme temperature difference occurs, frequently named the hotspot. In some processes with very strong exothermic reactions the hotspot temperature can raise beyond permissible limits. This phenomenon is called **runaway**. An important task in reactor design and operation is thus to limit the hotspot and avoid excessive sensitivity of the reactor performance to variations in the temperature. The value of the temperature at the hotspot is determined mainly by the reaction rate sensitivity to changes in temperature, the heat of reaction potential of the process, and the heat transfer potential of the heat exchanger units employed. A heat exchanger is characterized by the heat transfer coefficient and heat transfer areas. The selection of an appropriate fixed bed reactor design for a given process is performed assessing the main limitations of these reactors. The fixed packed bed reactors can be malfunctioning due to in-proper temperature control, pressure drop for processes with low tolerance, and deactivation of the catalyst. To optimize the performance of the fixed bed reactor operation several constructions of fixed bed reactors have been investigated over the years. Three of the most common reactor designs are:

•single-bed units

•multi-bed units

•multi-tube units