

Description

Reactor for chemical process technology

The present invention relates to an apparatus having a reactor for conducting at least one chemical process.

Reactors, catalysts, heat exchangers and evaporators are used in many fields of chemical process engineering in order to split or synthesize substances. A basic principle of such plants is based on the spatial separation of streams of matter and the transfer of thermal energy through the reactor structure. Frequently, activation of these processes requires high temperatures, optionally elevated pressures and a catalyst.

The materials used are subject to high demands with regard to corrosion resistance and chemical stability at high temperatures and under the media influence of the starting materials and reaction products. If heating is effected with a burner, an additional requirement is resistance to an oxidizing atmosphere. Activating and maintaining of endothermic processes requires supply of thermal energy, for example by means of an electrical heater or a burner.

In all cases, heat has to be transferred in the form of conducted heat and, if appropriate, radiated heat. In principle, this is subject to losses, either as a result of conduit losses (in the case of external burners) and/or as a result of heat transfer losses (in the case of indirect electrical heating in an electrically heated furnace environment).

Although integrated gas burners for heat generation can reduce conduit losses, there is an increase in the complexity of the system. Owing to the difficulty of accessibility, there may also be an increase in maintenance complexity and hence in plant downtime in the event of a fault.

A main requirement on the heating of a reaction space is thus to achieve matched heat transfer performance with maximum efficiency or minimum heat losses.

In a multitude of chemical processes, the heat is supplied by means of gas burners or electrical heating. The reactor systems

frequently comprise a furnace having a tube system which conducts starting media and reaction products through the furnace. In the case of catalytically assisted processes, beds of catalytically coated material may be present in the tube system.

Figure 1 shows such a reactor system 100, which has a furnace 110 and a tube system 120 arranged at least partly therein. The furnace 110 is heated by means of an electric heater 111.

The tube system 120 is designed, by way of example, as a double tube comprising a reactant section 121 through which a reactant E or reactant is conducted on one side into and through the furnace 110, and a product section 122 through which, following the chemical process, the product P is passed through and out of the furnace 110 on the same side. The reactant section 121 and the product section 122 are designed as a tube-in-tube construction. An alternative possible construction is one in which the tube system 120 is designed as a simple tube and the reactant section 121 and the product section 122 are guided out of the furnace 110 on opposite sides.

In the lower region of the reactant section 121, a catalyst K has been introduced as a bed of a catalytic material. In this way, the reactor system 100 is divided into a heat exchanger section 101 and a catalyst section 102.

Depending on the external thermal insulation, greater or lesser heat losses will occur via the outer wall of the furnace 110.

Figure 1 shows only one tube system 120, but a plurality of tube systems 120 can be installed in the furnace 110. Within the furnace 110, the individual tube systems 120 or reactor tubes should be supplied with very substantially equal heat flows in order to ensure equal conversion rates. Therefore, both in the case of convective heating by hot gas and in the case of the electrical heating shown in figure 1, a minimum distance is required between the tube systems 120 in order to achieve very substantial uniformity of flow of hot gas around the tubes or to transfer the radiant heat of electrical heaters 111 very

substantially uniformly to the individual tubes. It follows from this that the furnace volume has to be substantially greater than the tube volume, as a result of which power density is limited.

It is an object of the invention to provide an improved apparatus having a reactor for conducting a chemical process.

This object is achieved by an apparatus having the features of claim 1. Advantageous developments follow from the dependent claims, the description of the invention that follows and the description of preferred working examples.

The apparatus of the invention serves to conduct at least one chemical process. The apparatus is employed in chemical process technology, for example for cleavage, synthesis or other production or conversion of substances.

The apparatus comprises a reactor which has a reactor housing defining a reactor space and is set up to execute the at least one chemical process.

According to the invention, the reactor housing, for heating of the reactor space, has at least one resistance-heated section designed as an electrical resistance heater. In other words, heating of the reactor space is achieved by integration of the heating function into the geometry forming the reactor space, i.e. by integration of the heating function into the reactor housing.

The apparatus designed in this way makes it possible to reduce the volume to be heated by direct heating of the reactor space by comparison, for example, with furnace systems that are operated with gas burners or electric heaters. This results in a reduction in external surface area and in heat loss flows. The apparatus enables a particularly high power density and control dynamics, i.e. rapid adjustability of power, with a small installation space requirement, through which a large scalability range and in particular small structural sizes are achievable. This also results in a comparatively low weight of

the apparatus, which is advantageous in particular in non-stationary applications.

A further technical contribution of the apparatus lies in a high efficiency through reduction of heat losses owing to a small outer surface area.

The apparatus enables a modular construction with which scaling for a broad performance spectrum is achievable.

The compact design of the apparatus, which is achieved by the synergistic utilization of the reactor housing as resistance heating, results in a reduction in manufacturing costs and operating costs or resource consumption as a result of a lower energy requirement for the activation and maintenance of endothermic processes.

The reactor is preferably designed as a traversable tube or as a traversable double tube or tube-in-tube concept, as a result of which the apparatus is implementable in a particularly compact manner in terms of mechanical engineering.

The reactor preferably comprises a reactant section through which a reactant is conductable into and at least partly through the reactor, and a product section through which, following the at least one chemical process, a product is conductable at least partly through and out of the reactor. In this way, a continuous process is conductable in a compact construction of the reactor. A catalyst can be provided in the reactor space for performance and/or assistance of the at least one chemical process.

The catalyst may be implemented, for example, in the form of beds of a catalytic material and/or a catalytically coated material. Alternatively or additionally, the reactor space may be provided with a catalytic coating.

The reactor preferably has two electrical terminals that are connected to the reactor housing and are set up to supply the reactor housing with electrical power, wherein the resistance-heated section is between the two terminals. In this way, the reactor housing is connectable directly to a power supply.

Preferably, one electrical insulator in each case is installed on the opposite side of the electrical terminals from the resistance-heated section. The electrical insulators may be provided directly next to the electrical terminals or further to the outside, as a result of which any regions of the reactor that are not to be heated are electrically insulated from the resistance-heated section.

Preferably, at least the resistance-heated section of the reactor housing is made of reaction-bonded silicon-infiltrated silicon carbide. In this way, rapid heating characteristics owing to the thermomechanical material properties of SiSiC and hence a low switch-on delay are achievable, as a result of which the use of the apparatus in cyclically operated plants, for example, is enabled. The apparatus also has a high corrosion resistance to a multitude of media, in particular to the influence of steam, ammonia, hydrogen and nitrogen.

The reactor has preferably been manufactured by continuous casting, slip casting or an additive method, as a result of which the apparatus is producible in a structurally simple and reliable manner.

The resistance-heated section of the reactor space preferably contains a honeycomb body, preferably an extruded honeycomb body, an alternative geometric structure with an elevated surface area, in particular fins, and/or a filling, in particular a ceramic bed. In this way, it is possible to increase the heat transfer area in the reactor space.

The apparatus preferably comprises a thermal insulation which at least partly surrounds the reactor, in particular the resistance-heated section, which achieves the principle of a hot reactor core with a temperature level decreasing in the outward direction. Since the heat is generated in the reactor core or reactor space itself, there are no resultant introduction losses of a heat stream fed in from the outside.

Further advantages and features of the present invention are apparent from the description of preferred working examples that

follows. The features described therein can be implemented alone or in combination with one or more of the features set out above, to the extent that the features are not mutually exclusive. The description of preferred working examples that follows is given with reference to the accompanying drawings.

Brief description of the figures

Preferred further embodiments of the invention are elucidated in detail by the description of the figures that follows. The figures show:

Figure 1 a schematic of a conventional reactor system having an electrically heated furnace and a tube system;

Figure 2 a schematic of an apparatus for conducting a chemical process with a resistance-heated reactor according to one working example;

Figure 3 a perspective section view of an apparatus for conducting a chemical process according to a further working example;

Figure 4 a schematic of an apparatus for conducting a chemical process according to a further working example.

Detailed description of preferred working examples

Preferred working examples are described hereinafter with reference to the figures. Identical, similar or equivalent elements in the figures are given identical reference numerals, and repeated description of these elements is dispensed with to some extent in order to avoid redundancy.

Figure 2 shows an apparatus 1 for conducting a chemical process, which comprises a resistance-heated reactor 10. The apparatus 1 is used in chemical process engineering, for example for cleavage, synthesis or other production or conversion of substances.

In the present case, the reactor 10 takes the form of a simple traversable tube. However, other geometries are also suitable, for example a double-tube construction or a tube-in-tube construction similar to that of figure 1. The reactor 10 has a reactor housing 11 that defines a reactor space 12 (cf. figure

3). In the case of a tubular design of the reactor 10, the reactor housing 11 is implemented by the (hollow-cylindrical) tube wall.

The reactor 10 comprises a reactant section 13, by means of which a reactant E is conducted into and at least partly through the reactor 10, and a product section 14, by means of which, following a chemical process, a product P is conducted through and out of the reactor 10.

A catalyst 15 may have been provided in the reactor space 12 for conducting of the chemical process. The catalyst 15 may be designed, for example, as beds of a catalytic material and/or a catalytically coated material. Alternatively or additionally, the reactor space 12 may have been provided with a catalytic coating.

The aim of heat loss-minimized heating of the reactor space 12 is achieved by integration of the heating function into the geometry forming the reactor space 12. In other words, the reactor geometry itself, i.e. the reactor housing 11, is designed at least in sections as electrical resistance heating. The principle of integrated resistance heating is shown in figure 2 in the form of a simple geometric variant of the traversed tube. The reactor 10 has two electrical terminals 16, 17 connected to the reactor housing 11, by means of which the reactor housing 11 can be supplied directly with electrical power. At least the middle region of the reactor housing 11 between the two electrical terminals 16, 17, also referred to herein as resistance-heated section 18, has been manufactured from a material suitable for converting the electrical energy provided by the terminals 16, 17 to thermal energy.

An electrical insulator 19 may be installed immediately adjacent to the electrical terminals 16, 17 (on the opposite side from the resistance-heated section 18) or further outward.

Such resistance heating of the reactor geometry significantly reduces the heated volume, compared, for example, to a reactor tube heated in a combustion chamber or furnace. Further

efficiency benefits also arise from minimization of the heat loss areas and improvement of heat transfer. The reduced energy requirement results in lower operating costs.

The integration of the electrical resistance heating function into the reactor geometry or into the reactor housing 11 is associated with particular material demands. A high thermal stability, a high strength level at high temperatures and a high thermal shock resistance are required or desired, as are high HT corrosion resistance and a suitable specific electrical resistivity. In order to ensure leaktightness, the material of the reactor housing 11 should be free of pores.

The required or desired material properties of the reactor 10 are satisfied in particular by reaction-bonded silicon-infiltrated silicon carbide (SiSiC). The shaping can be effected by ceramic shaping methods, for instance continuous casting or slip casting, and by additive methods (3D printing), which results in a broad spectrum of degrees of freedom of geometry of the reactor 10.

In order to increase the heat transfer area in the reactor space 12, the resistance-heated section 18 may comprise an extruded honeycomb body 20, as shown in the working example of figure 3, or another geometric structure with elevated surface area (for example fins). The heat transfer area can also be increased by filling with a ceramic bed.

The resistance-heated reactor 10 may be combined with a thermal insulation 30, cf. working example of figure 4, which achieves the principle of a hot reactor core with a temperature level decreasing in the outward direction. Since the heat is generated in the reactor core or reactor space 12 itself, there are no resultant introduction losses of a heat stream fed in from the outside.

The apparatuses 1 set out above enable a reduction in the volume to be heated by direct heating of the reactor space 12 by comparison, for example, with furnace systems that are operated with gas burners or electric heaters. This results in a reduction

in external surface area and in heat loss flows. The apparatus 1 enables a particularly high power density and control dynamics, i.e. rapid adjustability of power, with a small installation space requirement, through which a large scalability range and in particular small structural sizes are achievable.

Further technical contributions of the apparatus 1 lie in a high efficiency by reduction of heat losses on account of a low outer surface area, rapid heating behavior on account of the thermomechanical material properties, in particular of SiSiC, and hence a low switch-on delay, which enables utilization in cyclically operated plants, for example. Furthermore, the apparatus 1 has a comparatively low weight, in particular by utilization of SiSiC, which is advantageous in particular in non-stationary applications. The apparatus 1 also has a high corrosion resistance to a multitude of media, in particular to the influence of steam, ammonia, hydrogen and nitrogen.

The apparatus 1 enables a modular construction with which scaling for a broad performance spectrum is achievable.

The compact design of the apparatus 1 and the synergistic utilization of the reactor housing 11 as resistance heating result in a reduction in manufacturing costs and operating costs or resource consumption as a result of a lower energy requirement for the activation and maintenance of endothermic processes.

Where applicable, all the individual features shown in the working examples can be combined with and/or exchanged for one another without leaving the scope of the invention.

List of reference symbols

1	apparatus for conducting a chemical process
10	reactor
11	reactor housing
12	reactor space
13	reactant section
14	product section
15	catalyst
16	electrical terminal
17	electrical terminal
18	resistance-heated section
19	insulator
20	honeycomb body
30	thermal insulation
100	reactor system
101	heat exchanger section
102	catalyst section
110	furnace
111	electric heater
120	tube system
121	reactant section
122	product section
E	reactant
P	product
K	catalyst

Claims

1. An apparatus (1) for conducting at least one chemical process, wherein the apparatus (1) has:
a reactor (10) which has a reactor housing (11) defining a reactor space (12) and is set up to execute the at least one chemical process; wherein
the reactor housing (11), for heating of the reactor space (12), has at least one resistance-heated section (18) designed as an electrical resistance heater.
2. The apparatus (1) as claimed in claim 1, characterized in that the reactor (10) is designed as a traversable tube, double tube or tube-in-tube concept.
3. The apparatus (1) as claimed in claim 1 or 2, characterized in that the reactor (10) comprises a reactant section (13) through which a reactant (E) is conductable into and at least partly through the reactor (10), and a product section (14) through which, following the at least one chemical process, a product (P) is conductable at least partly through and out of the reactor (10).
4. The apparatus (1) as claimed in any of the preceding claims, characterized in that a catalyst (15) is provided in the reactor space (12).
5. The apparatus (1) as claimed in claim 4, characterized in that the catalyst (15) is implemented as beds of a catalytic material and/or a catalytically coated material and/or in that the reactor space (12) has been provided with a catalytic coating.
6. The apparatus (1) as claimed in any of the preceding claims, characterized in that the reactor (10) has two electrical terminals (16, 17) that are connected to the reactor housing (11) and are set up to supply the reactor housing (11) with electrical power, where the resistance-heated section (18) is positioned between the two terminals (16, 17).

7. The apparatus (1) as claimed in claim 6, characterized in that one electrical insulator (19) in each case is installed on the opposite side of the electrical terminals (16, 17) from the resistance-heated section (18).
8. The apparatus (1) as claimed in any of the preceding claims, characterized in that at least the resistance-heated section (18) has been manufactured from reaction-bonded silicon-infiltrated silicon carbide.
9. The apparatus (1) as claimed in any of the preceding claims, characterized in that the reactor (10) has been manufactured by continuous casting, slip casting or an additive method.
10. The apparatus (1) as claimed in any of the preceding claims, characterized in that the resistance-heated section (18) of the reactor space (12) contains a honeycomb body (20), preferably extruded honeycomb body (20), an alternative geometric structure with elevated surface area, preferably fins, and/or a filling, preferably a ceramic bed.
11. The apparatus (1) as claimed in any of the preceding claims, characterized in that the apparatus (1) has a thermal insulation (30) which at least partly surrounds the reactor (10), preferably the resistance-heated section (18).