

Fluidized Bed Reactor, and Apparatus and Method for Preparing Light Olefins

I. Field of the Invention

The present invention relates to the olefin preparation field, in particular to a fluidized
5 bed reactor, an apparatus for preparing light olefins, and a method for preparing light
olefins.

II. Background of the Invention

Light olefins, i.e., ethylene and propylene, are two important basic chemical raw
materials, and are in greater demand increasingly. Usually, ethylene and propylene are
10 produced through a petroleum route. However, the cost of producing ethylene and
propylene from petroleum resources becomes higher and higher, owing to the limited
supply and high prices of petroleum resources. In recent years, techniques for producing
ethylene and propylene from converted substitutional raw materials were developed
vigorously. Among those substitutional raw materials, a sort of important substitutional
15 raw materials for producing light olefins are oxygen-containing compounds, such as
alcohols (methanol, ethanol), ethers (dimethyl ether, methyl ethyl ether), esters (methyl
carbonate, methyl formate), etc., which can be converted from energy resources such as
coal, natural gas, and biomass, etc. Some oxygen-containing compounds can be
produced by mass production now. For example, methanol can be produced from coal
20 or natural gas with matured techniques at a production scale of mega tonnage. The
oxygen-containing compounds-to-olefins (OTO) process, especially the
methanol-to-olefins (MTO) process, receives more and more attention, owing to the

wide availability of oxygen-containing compounds and the economic efficiency of the conversion process for producing light olefins.

The US Patent Publication No. US4499327 has disclosed an application of silicoaluminophosphate molecular sieve catalyst in methanol-to-olefins (MTO) process, and has stated that SAPO-34 is a preferred catalyst for the MTO process. The SAPO-34 catalyst has very high selectivity to light olefins and has high activity as well, and can shorten the reaction time of methanol conversion to light olefins to a value smaller than 10 seconds, even to the range of reaction time in a riser.

The US Patent Publication No. US6166282 has disclosed a technique and a reactor for converting methanol into light olefins, wherein, a fast fluidized bed reactor is employed, and most of the entrapped catalyst is separated preliminarily with a special gas-solid separation device after the gas phase reacts in a dense-phase reaction zone at a low gas velocity and is lifted to a fast reaction sub-zone where the inner diameter of the reactor is reduced sharply. Since the product gas and the catalyst are separated from each other quickly after the reaction, the occurrence of secondary reaction is prevented effectively. The result of simulated calculation indicates that both the inner diameter of the fast fluidized bed reactor and the required reserve of catalyst are greatly reduced when compared with those in conventional bubbling fluidized bed reactors. However, that method has a drawback of low yield of light olefins.

The Chinese Patent Publication No. CN1723262A has disclosed a multi-stage riser reaction apparatus with a central catalyst loop applied in an oxides-to-light olefins process. The apparatus comprises a plurality of riser reactors, a gas-solid separation zone, and a plurality of offset elements, etc., wherein, each riser reactor is provided with

a catalyst injection port, and the catalyst injection ports are converged to the separation zone, where the catalyst and the product gas are separated from each other. With that method, the carbon-based yield of the light olefins is usually 75~80%; namely, that method also has a drawback of low yield of light olefins.

5 In the conventional methanol-to-light olefins (MTO) process, usually the entire fluidized bed reactor can be divided into inlet zone, reaction zone, lifting zone, and fast outlet separation zone. Conventionally, the regenerated catalyst and the spent catalyst enter into the reaction zone directly from the inlet zone to catalyze the reaction of the raw gas. The mixing result of the two catalyst streams has direct influences on the
10 selectivity to olefins. The gas and solid flow, the mixing result of gas and catalyst particles, and the reaction behavior in the inlet zone have remarkable influences on the efficacy of the entire reactor. However, the existing literatures haven't put forward a solution to the particle mixing in the inlet zone of the fluidized bed reactor and the efficiency of contact between gas and catalyst particles in the reaction zone.

15 **III. Contents of the Invention**

To overcome the drawbacks of the existing light olefins preparation apparatuses, such as uneven mixing of the catalysts and low light olefin yield, etc., the present invention provides a fluidized bed reactor, an apparatus for preparing light olefins, and a method for preparing light olefins.

20 The present invention provides a fluidized bed reactor, comprising a reaction zone provided with a draft tube that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube and a recirculating flow mixing zone B outside

the draft tube, and two catalyst inlets are arranged on the side wall of the reactor in the reaction zone.

The present invention further provides an apparatus for preparing light olefins, comprising a fluidized bed reactor, a settler, and a regenerator, wherein, a reaction zone
5 of the fluidized bed reactor is provided with a draft tube that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube and a recirculating flow mixing zone B outside the draft tube, a catalyst outlet of the fluidized bed reactor communicates with the settler, a recirculation outlet on the lower part of the settler communicates with the recirculating flow mixing zone B, a spent catalyst outlet
10 on the lower part of the settler communicates with the regenerator, and a regenerated catalyst outlet of the regenerator communicates with the recirculating flow mixing zone B.

The present invention further provides a method for preparing light olefins, comprising:
subjecting reaction raw materials, spent catalyst from a settler, and regenerated catalyst
15 from a regenerator to react in a fluidized bed reactor, wherein, a reaction zone of the fluidized bed reactor is provided with a draft tube that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube and a recirculating flow mixing zone B outside the draft tube, the reaction raw materials are supply to the fast reaction zone A and the recirculating flow mixing zone B, and the spent catalyst
20 and the regenerated catalyst are supplied to the recirculating flow mixing zone B;

treating the product obtained through the reaction by fast gas-solid separation and settling separation, treating the catalyst obtained through settling separation by gas

stripping, and then lifting the catalyst into the settler through a riser under the lifting action of a lifting medium; and

returning a part of the spent catalyst treated by settling separation in the settler directly to the recirculating flow mixing zone B, feeding the other part of the spent catalyst into
5 the regenerator for regeneration, and injecting the obtained regenerated catalyst into the recirculating flow mixing zone B.

According to the fluidized bed reactor and the apparatus for preparing light olefins provided in the present invention, a draft tube is arranged in the reaction zone of the fluidized bed reactor to separate the reaction zone into a fast reaction zone A and a
10 recirculating flow mixing zone B, the spent catalyst from the settler and the regenerated catalyst from the regenerator are pre-mixed and pre-react in the recirculating flow mixing zone B, and then enter into the fast reaction zone A for further reaction; thus, not only thorough mixing between catalysts different in carbon content is realized, but also full reaction is achieved, and thereby an objective of improving the yield of light olefins
15 is attained; specifically, the yield ratio of light olefins can be as high as 89.32wt%.

The apparatus for preparing light olefins described in the present invention can be used for minute-level deactivation reactions, and can be applied in methanol-to-olefins, methyl benzene alkylation, olefin cracking, and naphtha cracking fields, etc. Especially, the apparatus can be used for reactions with catalysts different in carbon content at a
20 specific mix ratio, in which the catalysts different in carbon content can be mixed homogeneously. For example, when the apparatus is applied for methanol-to-olefins reactions, a regenerated catalyst regenerated in a regenerator can be mixed homogeneously with a spent catalyst recirculated via a settler in a recirculating flow

mixing zone of a fluidized bed reactor, the mixed catalyst reacts preliminarily with methanol fed into the recirculating flow mixing zone, and then the catalyst is entrained and entrapped in the materials and carried by the materials to a fast reaction zone and reacts with methanol further, so as to attain the objective of improving the yield of light
5 olefins. In a preferred case, in which the catalyst separated from the fluidized bed reactor is gas-stripped and then injected into a settler via a riser and the lifting medium in the riser is a low-carbon alcohol (e.g., ethanol or propanol), the methanol-to-olefins process can be combined with a low-carbon alcohol dehydration process for producing olefins, since the low-carbon alcohol can be converted into light olefins by dehydration.
10 In another embodiment, in which the material inputted into the fluidized bed reactor is C4 hydrocarbons and the lifting medium in the riser is methanol, the carbon-free catalyst in the fluidized bed reactor has an olefins cracking reaction with the C4 hydrocarbons, and the carbon-containing catalyst produced through the reaction is utilized in the MTO reaction; thus, the MTO process is combined with an olefin
15 cracking reaction. Hence, with the apparatus disclosed in the present invention, multiple processes can be coupled. Thus, the application scope of the apparatus is greatly widened, and the apparatus has an advantage of high yield of light olefins.

Other features and advantages of the present invention will be further detailed in the embodiments hereunder.

20 IV. Description of the Drawings

The accompanying drawings are provided here to facilitate further understanding on the present invention, and constitute a part of this document. They are used in conjunction with the following embodiments to explain the present invention, but shall not be

comprehended as constituting any limitation to the present invention. Among the drawings:

Fig. 1 is a schematic diagram of the apparatus for preparing light olefins according to the present invention;

- 5 Fig. 2 is a schematic diagram of gas distribution holes of the gas distribution device in the apparatus for preparing light olefins according to the present invention.

Description of the Symbols

1 Gas outlet pipeline of settler	2 Product gas outlet pipeline
3 Exhaust gas outlet pipeline	4 Cyclone separator
5 Spent catalyst flow control valve	6 Settler
7 Spent catalyst outlet	8 Recirculation outlet
9 Sloped spent catalyst tube	10 Cyclone separator
11 Regenerator	12 Regenerating medium feeding pipeline
13 Cyclone separator	14 Stripper
15 Fluidized bed reactor	15a catalyst inlet of fluidized bed reactor
15b catalyst inlet of fluidized bed reactor	16 Catalyst recirculation pipe
17 Fast gas-solid separation device	18 Stripping medium feeding pipeline
19 Sloped stripping tube	20 Recirculated catalyst flow control

	valve	
21	Regenerated catalyst flow control valve	22 Sloped regenerated catalyst tube
23	Raw material feeding pipeline	24 Stripped catalyst flow control valve
25	Riser	26 Lifting medium feeding pipeline
27	Settling section of reactor	28 Gas distributor
29	Fluidizing medium feeding pipeline of settler	30 Sloped tube
31	Gas distribution device	32 Draft tube

V. Detailed Description of the Embodiments

Hereunder some embodiments of the present invention will be detailed. It should be appreciated that the embodiments described here are only provided to describe and
 5 explain the present invention, but shall not be deemed as constituting any limitation to the present invention.

The ends points and any value in the ranges disclosed in the present invention are not limited to the exact ranges or values. Instead, those ranges or values shall be comprehended as encompassing values that are close to those ranges or values. For
 10 numeric ranges, the end points of the ranges, the end points of the ranges and the discrete point values, and the discrete point values can be combined to obtain one or more new numeric ranges, which shall be deemed as having been disclosed specifically in this document.

In this document, unless otherwise specified, the terms of orientation are used as follows: for example, "top" and "bottom" refer to "top" and "bottom" indicated in the accompanying drawings; "inside" and "outside" refer to "inside" and "outside" in relation to the outlines of the components.

5 As shown in Fig. 1, the reaction zone of the fluidized bed reactor 15 according to the present invention is provided with a draft tube 32 arranged axially, and two catalyst inlets 15a,15b are arranged on the side wall of the reactor in the reaction zone, wherein, the draft tube 32 separates the reaction zone into a fast reaction zone A inside the draft tube 32 and a recirculating flow mixing zone B outside the draft tube 32. In the
10 fluidized bed reactor, a spent catalyst and a regenerated catalyst are injected via the two catalyst inlets 15a,15b, the spent catalyst and the regenerated catalyst are pre-mixed and pre-react with the materials in the recirculating flow mixing zone B, and then the mixed catalyst enters into the fast reaction zone A and further reacts with the materials; thus, not only thorough mixing between the catalysts different in carbon content is realized,
15 but also full reaction is achieved, so as to attain the objective of improving the yield of light olefins.

In the fluidized bed reactor according to the present invention, the ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone in the fluidized bed reactor 15 may be 0.1~0.5:1.

20 Preferably, the fluidized bed reactor 15 is further provided with a gas distribution device 31 in it. The gas distribution device 31 has separate gas distribution holes corresponding to the fast reaction zone A and the recirculating flow mixing zone B respectively. As shown in Fig. 2, the gas distribution device 31 preferably is a one-piece distributor, in

which the gas distribution hole corresponding to the fast reaction zone A and the gas distribution hole corresponding to the recirculating flow mixing zone B are arranged on the same component.

More preferably, the diameter of the gas distribution hole corresponding to the fast reaction zone A is smaller than the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B; preferably, the ratio of the diameter of the gas distribution hole corresponding to the fast reaction zone A to the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B is 1:1.5~10, more preferably is 1:2~5. In the preferred case, the linear speed of the materials in the fast reaction zone A is higher than that of the materials in the recirculating flow mixing zone B; preferably, the linear speed of the materials in the fast reaction zone A is 1.5~5m/s, and the linear speed of the materials in the recirculating flow mixing zone B is 0.3~0.6m/s.

As shown in Fig. 1, the apparatus for preparing light olefins according to the present invention comprises a fluidized bed reactor 15, a settler 6, and a regenerator 11, wherein, the reaction zone of the fluidized bed reactor 15 is provided with a draft tube 32 that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube 32 and a recirculating flow mixing zone B outside the draft tube 32, a catalyst outlet of the fluidized bed reactor 15 communicates with the settler 6, a recirculation outlet 8 on the lower part of the settler 6 communicates with the recirculating flow mixing zone B via the catalyst inlet 15b of the reactor 15, a spent catalyst outlet 7 on the lower part of the settler 6 communicates with the regenerator 11, and a regenerated

catalyst outlet of the regenerator 11 communicates with the recirculating flow mixing zone B via the catalyst inlet 15a of the reactor 15.

In the apparatus for preparing light olefins according to the present invention, the ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone in the fluidized bed reactor 15 may be 0.1~0.5:1.

Preferably, the fluidized bed reactor 15 is further provided with a gas distribution device 31 in it. The gas distribution device 31 has separate gas distribution holes corresponding to the fast reaction zone A and the recirculating flow mixing zone B respectively. As shown in Fig. 2, the gas distribution device 31 preferably is a one-piece distributor, in which the gas distribution hole corresponding to the fast reaction zone A and the gas distribution hole corresponding to the recirculating flow mixing zone B are arranged on the same component.

More preferably, the diameter of the gas distribution hole corresponding to the fast reaction zone A is smaller than the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B; preferably, the ratio of the diameter of the gas distribution hole corresponding to the fast reaction zone A to the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B is 1:1.5~10, more preferably is 1:2~5. In the preferred case, the linear speed of the materials in the fast reaction zone A is higher than that of the materials in the recirculating flow mixing zone B; preferably, the linear speed of the materials in the fast reaction zone A is 1.5~5m/s, and the linear speed of the materials in the recirculating flow mixing zone B is 0.3~0.6m/s.

In the present invention, the apparatus for preparing light olefins may further comprise a stripper 14 and a riser 25, wherein, the catalyst outlet of the fluidized bed reactor 15 communicates with a catalyst inlet of the stripper 14, a catalyst outlet of the stripper 14 communicates with a catalyst inlet of the riser 25, and the riser 25 communicates with
5 the settler 6. The solid catalyst separated from the fluidized bed reactor is fed through a sloped tube 30 into the stripper 14, and is stripped under the action of a stripping medium injected through a stripping medium feeding pipeline 18; the stripped solid catalyst is injected through a sloped stripping tube 19 provided with a flow control valve 24 into the riser 25, and then is lifted to the settler 6 under the action of a lifting medium
10 (e.g., water vapor or low-carbon alcohol, etc.) injected through a lifting medium feeding pipeline 26.

In the apparatus for preparing light olefins according to the present invention, the fluidized bed reactor 15 may be any conventional fluidized bed reactor in the art. A fast gas-solid separation device 17 is arranged above the reaction zone of the fluidized bed
15 reactor 15, and is configured to carry out fast gas-solid separation for the materials after the reaction. In the fast gas-solid separation process, the linear speed of the materials may be 1~1.5m/s. The mixture obtained through fast gas-solid separation is injected into a settling section 27 of the reactor for settling separation; the separated solid catalyst is injected into the follow-up stripper 14 via a catalyst outlet on the lower part of the
20 settling section 27 of the reactor through a sloped tube 30. A cyclone separator 13 is arranged in the upper part of the reaction zone, and the product (e.g., light olefins) separated from the cyclone separator 13 is discharged via the product gas outlet pipeline 2.

In the apparatus for preparing light olefins according to the present invention, the communicating pipeline between the recirculation outlet 8 on the lower part of the settler 6 and the recirculating flow mixing zone B and/or the communicating pipeline between the regenerated catalyst outlet of the regenerator 11 and the recirculating flow
5 mixing zone B are/is usually provided with a flow control valve. To inject the catalyst at certain pulse frequency into the fluidized bed reactor 15 so as to reduce bed pressure fluctuations, preferably the flow control valve employs a pulse control valve.

In a preferred embodiment, a draft tube is arranged in the reaction zone of the fluidized bed reactor, a one-piece distributor is arranged below the reaction zone, and the flow
10 rates of the spent catalyst and the regenerated catalyst entering into the reaction zone are regulated with the pulse control valves; thus, the particle pre-mixing effect can be enhanced effectively, the axial density distribution can be improved, the bed pressure fluctuation can be reduced, the gas-solid contact efficiency can be improved, and thereby the yield of light olefins can be improved effectively.

15 According to an embodiment of the present invention, as shown in Fig. 1, the apparatus for preparing light olefins in the present invention mainly comprises a fluidized bed reactor 15, a draft tube 32, a fast reaction zone A, a recirculating flow mixing zone B, a settler 6, a regenerator 11, a stripper 14, and a riser 25, wherein, a spent catalyst outlet 7 on the bottom of the settler 6 is connected to the upper part of the regenerator 11
20 through an sloped tube 9 provided with a flow control valve 5, the lower part of the regenerator 11 is connected to the lower part of the recirculating flow mixing zone B through a sloped regenerated catalyst tube 22 provided with a flow control valve 21, a recirculation outlet 8 on the bottom of the settler 6 is connected to the lower part of the

recirculating flow mixing zone B through a catalyst recirculation pipe 16 provided with a flow control valve 20, a settling section 27 of the reactor is connected to the upper part of the stripper 14, the lower part of the stripper 14 is connected to the lower part of the riser 25, and the upper part of the riser 25 is connected to the upper part of the settler 6.

5 In this embodiment, the settler 6 has two catalyst outlets, i.e., the spent catalyst outlet 7 on the bottom of the settler and the recirculation outlet 8 on the bottom of the settler, wherein, one stream of catalyst flows out of the spent catalyst outlet 7 on the bottom of the settler, is regenerated in the regenerator 11, and then flows back to the bottom of the recirculating flow mixing zone B, and the other stream of catalyst flows out of the

10 recirculation outlet 8 on the bottom of the settler, and directly returns to the bottom of the recirculating flow mixing zone B; the ratio of the mass flow rate of the catalyst that directly returns from the settler 6 to the bottom of the recirculating flow mixing zone B to the mass flow rate of the catalyst that is regenerated in the regenerator 11 and then returns to the bottom of the recirculating flow mixing zone B may be 1~10:1; the ratio

15 of the diameter of the fast reaction zone A to the diameter of the recirculating flow mixing zone B may be 0.1~0.5:1; a catalyst distributor 28 is arranged on the bottom of the settler 6; a gas distribution device 31 is arranged on the bottom of the fluidized bed reactor 15, and the gas distribution device 31 has two separate gas distribution holes, which enter into the fast reaction zone A and the recirculating flow mixing zone B

20 respectively. In this embodiment, the reaction raw materials (e.g., low-carbon alcohols, C4 hydrocarbons, etc.) are fed through a pipeline 23 via the gas distribution device 31 into the recirculating flow mixing zone B and the fast reaction zone A of the fluidized bed reactor 15 respectively, and contact with the catalyst, the gas-phase product produced through the reaction is discharged through the pipeline 2, the spent catalyst is

gas-stripped in the stripper 14 and then is lifted through the riser 25 to the settler 6, and is recirculated in the settler 6 in two loops, wherein, one stream of catalyst flows down through a sloped spent catalyst tube 9 to the regenerator 11 and contacts with a regenerating medium (e.g., air) fed through a regenerating medium feeding pipeline 12 so as to produce a regenerated catalyst, the regenerated catalyst flows through the sloped regenerated catalyst tube 22 to the recirculating flow mixing zone B of the fluidized bed reactor 15 via the catalyst inlet 15a, and the exhaust gas generated through the reaction is exhausted through a pipeline 3; the other stream of catalyst flows through the sloped recirculation tube 16 to the recirculating flow mixing zone B of the fluidized bed reactor 15 via the catalyst inlet 15b, is mixed with the regenerated catalyst to form a catalyst that contains certain coke deposit amount, and the mixed catalyst reacts with the reaction raw materials fed through the pipeline 23; thus, an objective of continuous reaction-regeneration is attained.

The present invention further provides a method for preparing light olefins, comprising: subjecting reaction raw materials, spent catalyst from a settler, and regenerated catalyst from a regenerator to react in a fluidized bed reactor, wherein, a reaction zone of the fluidized bed reactor is provided with a draft tube that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube and a recirculating flow mixing zone B outside the draft tube, the reaction raw materials are supply to the fast reaction zone A and the recirculating flow mixing zone B, and the spent catalyst and the regenerated catalyst are supplied to the recirculating flow mixing zone B;

treating the product obtained through the reaction by fast gas-solid separation and settling separation, treating the catalyst obtained through settling separation by gas

stripping, and then lifting the catalyst into the settler through a riser under the lifting action of a lifting medium; and

returning a part of the spent catalyst treated by settling separation in the settler directly to the recirculating flow mixing zone B, feeding the other part of the spent catalyst into
5 the regenerator for regeneration, and injecting the obtained regenerated catalyst into the recirculating flow mixing zone B.

The present invention further provides a method for preparing light olefins with the apparatus for preparing light olefins according to the present invention.

In the method provided in the present invention, the linear speed of the materials in the
10 fast reaction zone A may be 1.5~5m/s, and the linear speed of the materials in the recirculating flow mixing zone B may be 0.3~0.6m/s.

In the method provided in the present invention, the linear speed of the materials in the fast gas-solid separation process may be 1~1.5m/s.

In the method provided in the present invention, the ratio of the flow rate of the spent
15 catalyst that returns to the recirculating flow mixing zone B directly to the flow rate of the regenerated catalyst that is injected into the recirculating flow mixing zone B via the regenerator may be 1~10:1, preferably is 2~8:1, more preferably is 3~6:1.

In the method provided in the present invention, the ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone of the fluidized bed reactor 15
20 may be 0.1~0.5:1.

In the method provided in the present invention, preferably the flow rates of the spent catalyst and the regenerated catalyst injected into the recirculating flow mixing zone B are controlled by means of pulse control valves.

In the method provided in the present invention, the coke deposit amount in the spent catalyst injected into the recirculating flow mixing zone B may be 1.5~5wt%, and the coke deposit amount in the regenerated catalyst injected into the recirculating flow mixing zone B may be 0.01~2.5wt%.

In the method provided in the present invention, the reaction raw materials may be oxygen-containing compounds and/or C4 hydrocarbons, and the lifting medium may be C1-C4 alcohols and/or water vapor. In the present invention, the oxygen-containing compounds may be C1-C4 alcohols, such as methanol, ethanol, propanol or butanol.

In the method provided in the present invention, the catalyst may comprise aluminosilicophosphate molecular sieve, in which the molar ratio of $\text{SiO}_2/\text{Al}_2\text{O}_3$ may be 10~100.

Hereunder the present invention will be further detailed in some examples, but the protection scope of the present invention is not limited to these examples.

Example 1

In the reaction-regeneration apparatus as shown in Fig. 1, the catalyst is SAPO-34, the reaction raw material is methanol at 99.5% purity, a part of the methanol raw material contacts and reacts preliminarily with the catalyst in the recirculating flow mixing zone B; after the reaction, the catalyst is entrained and entrapped in the reaction materials and carried by the materials into the fast reaction zone A and reacts further with methanol; after the reaction, the spent catalyst flows into the stripper 6, is stripped there, and then

is lifted to the settler 6; the catalyst is recirculated in the settler 6 in two loops, wherein, one stream of catalyst flows down through the sloped spent catalyst tube to the regenerator 11, contacts with air fed through an air distribution pipe in a counter-current manner in the regenerator 11, so that the coke on the catalyst surface is burnt off and a regenerated catalyst is obtained, and then the regenerated catalyst flows through the sloped regenerated catalyst tube to the recirculating flow mixing zone B of the fluidized bed reactor 15; the other stream of catalyst flows through the sloped recirculation tube to the recirculating flow mixing zone B of the fluidized bed reactor 15, is mixed with the regenerated catalyst to form a catalyst that contains certain coke deposit amount, and the mixed catalyst reacts with the methanol, wherein, the mass ratio of the regenerated catalyst to the spent catalyst flowing into the fluidized bed reactor 15 is 10:1. The ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone of the fluidized bed reactor is 0.5:1, the linear speed of the materials in the fast reaction zone A is 5m/s, the linear speed of the materials in the recirculating flow mixing zone B is 0.6m/s, the lifting medium is water vapor, the regenerating medium is air, the regeneration temperature is 620°C, the reaction temperature in the fluidized bed reactor 15 is 470°C, and the mass space velocity of the methanol is 6h^{-1} . The coke deposit amount in the regenerated catalyst is 0.05wt%, and the coke deposit amount in the spent catalyst returning from the settler 6 to the fluidized bed reactor 15 is 2.65wt%. The gas-phase product obtained in the top part of the reactor is analyzed by online gas chromatography. The carbon-based yield (ethylene and propylene in the gas-phase product) is 83.75wt%.

Example 2

The conditions and steps described in the example 1 are used, the catalyst is SAPO-34, the mass ratio of the regenerated catalyst to the spent catalyst flowing into the fluidized bed reactor 15 is 1:1, the ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone of the fluidized bed reactor is 0.1:1, the linear speed of the materials in the fast reaction zone A is 1.5m/s, the linear speed of the materials in the recirculating flow mixing zone B is 0.3m/s, the lifting medium is ethanol and water, the ethanol at 99.6% purity is heated up to 176°C and then mixed with water vapor and fed into the riser 25, the raw material is methanol at 99.5% purity, the regenerating medium is air, the regeneration temperature is 620°C, the reaction temperature in the riser 25 is 455°C, the mass space velocity of the ethanol is 18h^{-1} , the reaction temperature in the fluidized bed reactor 15 is 470°C, and the mass space velocity of the methanol is 6h^{-1} . The fed mass ratio of ethanol to methanol is 1:3, and the gas-phase product obtained in the top part of the reactor is analyzed by online gas chromatography. The carbon-based yield (ethylene and propylene in the gas-phase product) is 88.13wt%.

Example 3

The conditions and steps described in the example 1 are used, the catalyst is SAPO-34, the mass ratio of the regenerated catalyst to the spent catalyst flowing into the fluidized bed reactor 15 is 3:1, the ratio of the inner diameter of the draft tube 32 to the inner diameter of the reaction zone of the fluidized bed reactor is 0.25:1, the linear speed of the materials in the fast reaction zone A is 3.5m/s, the linear speed of the materials in the recirculating flow mixing zone B is 0.4m/s, the lifting medium is ethanol, propanol and water, a mixture of ethanol and propanol at 99.6% purity is heated up to 205°C and then mixed with water vapor and fed into the riser 25, the weight ratio of water vapor to

ethanol to propanol is 0.2:1:1, the raw material is methanol at 99.5% purity, the regenerating medium is air, the regeneration temperature is 630°C, the reaction temperature in the riser 25 is 450°C, the total mass space velocity of ethanol and propanol is 21h⁻¹, the reaction temperature in the fluidized bed reactor 15 is 475°C, and
5 the mass space velocity of the methanol is 6h⁻¹. The weight ratio of ethanol and propanol to methanol is 2:5, and the gas-phase product obtained in the top part of the fluidized bed reactor is analyzed by online gas chromatography. The carbon-based yield (ethylene and propylene in the gas-phase product) is 89.32wt%.

Example 4

10 The conditions and steps described in the example 1 are used, the catalyst is SAPO-34, the mass ratio of the regenerated catalyst to the spent catalyst flowing into the fluidized bed reactor 15 is 6:1, the ratio of the fast reaction zone A to the recirculating flow mixing zone B is 0.4:1, the linear speed of the materials in the fast reaction zone A is 2.5m/s, the linear speed of the materials in the recirculating flow mixing zone B is
15 0.5m/s, the lifting medium is methanol at 99.5% purity and water, the methanol at 99.5% purity is heated up to 170°C and then mixed with water vapor and fed into the riser 25, weight ratio of water vapor to methanol is 0.2:1, the raw material is C4 hydrocarbons, in which the content of C4 hydrocarbons is 86wt%, the regenerating medium is air, the regeneration temperature is 630°C, the reaction temperature in the
20 riser 25 is 470°C, the mass space velocity of the methanol is 16h⁻¹, the reaction temperature in the fluidized bed reactor 15 is 550°C, and the mass space velocity of the C4 hydrocarbons is 10h⁻¹. The weight ratio of C4 hydrocarbons to methanol is 0.5:1, and the gas-phase product obtained in the top part of the reactor is analyzed by online

gas chromatography. The carbon-based yield (ethylene and propylene in the gas-phase product) is 86.25wt%.

Comparative example 1

5 The conditions and steps described in the example 1 are used, but no draft tube is arranged, the fluidized bed reactor is not separated into a recirculating flow mixing zone and a fast reaction zone; instead, the regenerated catalyst and the recirculated catalyst are directly mixed in the bottom part of the reactor and react with methanol. The carbon-based yield of light olefins at the outlet of the reactor is 79.83wt%.

10 It can be seen from the result of comparison between the examples and the comparative example: the apparatus provided in the present invention can attain an objective of improving the yield ratio of light olefins, has great technical advantages, and is applicable to industrial production of light olefins.

Claims

1. An apparatus for preparing light olefins, comprising a fluidized bed reactor (15), a settler (6), and a regenerator (11), wherein, a reaction zone of the fluidized bed reactor (15) is provided with a draft tube (32) that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube (32) and a recirculating flow mixing zone B outside the draft tube (32), a catalyst outlet of the fluidized bed reactor (15) communicates with the settler (6), a recirculation outlet (8) on the lower part of the settler (6) communicates with the recirculating flow mixing zone B, a spent catalyst outlet (7) on the lower part of the settler (6) communicates with the regenerator (11), and a regenerated catalyst outlet of the regenerator (11) communicates with the recirculating flow mixing zone B.
2. The apparatus according to claim 1, wherein, the fluidized bed reactor (15) further comprises a gas distribution device (31) in it, which has separate gas distribution holes corresponding to the fast reaction zone A and the recirculating flow mixing zone B respectively.
3. The apparatus according to claim 2, wherein, the gas distribution device (31) is a one-piece distributor, and the ratio of the diameter of the gas distribution hole corresponding to the fast reaction zone A to the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B is 1:1.5~10.
4. The apparatus according to claim 3, wherein, the ratio of the diameter of the gas distribution hole corresponding to the fast reaction zone A to the diameter of the gas distribution hole corresponding to the recirculating flow mixing zone B is 1:2~5.

5. The apparatus according to any one of claims 1-4, wherein, the communicating pipeline between the recirculation outlet (8) on the lower part of the settler (6) and the recirculating flow mixing zone B and/or the communicating pipeline between the regenerated catalyst outlet of the regenerator (11) and the recirculating flow mixing zone B are/is provided with a pulse control valve.
6. The apparatus according to any one of claims 1-5, wherein, the ratio of the inner diameter of the draft tube (32) to the inner diameter of the reaction zone of the fluidized bed reactor (15) is 0.1~0.5:1.
7. The apparatus according to any one of claims 1-6, further comprising a stripper (14) and a riser (25), wherein, the catalyst outlet of the fluidized bed reactor (15) communicates with a catalyst inlet of the stripper (14), a catalyst outlet of the stripper (14) communicates with a catalyst inlet of the riser (25), and the riser (25) communicates with the settler (6).
8. A method for preparing light olefins, comprising:
subjecting reaction raw materials, spent catalyst from a settler, and regenerated catalyst from a regenerator to react in a fluidized bed reactor, wherein, a reaction zone of the fluidized bed reactor is provided with a draft tube that is arranged axially and separates the reaction zone into a fast reaction zone A inside the draft tube and a recirculating flow mixing zone B outside the draft tube, the reaction raw materials are supply to the fast reaction zone A and the recirculating flow mixing zone B, and the spent catalyst and the regenerated catalyst are supplied to the recirculating flow mixing zone B;
treating the product obtained through the reaction by fast gas-solid separation and settling separation, treating the catalyst obtained through settling separation by gas stripping, and then lifting the catalyst into the settler through a riser under the lifting action of a lifting medium; and

returning a part of the spent catalyst treated by settling separation in the settler directly to the recirculating flow mixing zone B, feeding the other part of the spent catalyst into the regenerator for regeneration, and injecting the obtained regenerated catalyst into the recirculating flow mixing zone B.

5

9. The method according to claim 8, wherein, the linear speed of the materials in the fast reaction zone A is 1.5~5m/s, and the linear speed of the materials in the recirculating flow mixing zone B is 0.3~0.6m/s.

10 10. The method according to claim 8 or 9, wherein, the flow ratio of the spent catalyst directly returned to the recirculating flow mixing zone B to the regenerated catalyst injected into the recirculating flow mixing zone B via the regenerator is 1~10:1.

15 11. The method according to any one of claims 8-10, wherein, the ratio of the inner diameter of the draft tube (32) to the inner diameter of the reaction zone of the fluidized bed reactor (15) is 0.1~0.5:1.

20 12. The method according to any of claims 8-11, wherein, the flow rates of the spent catalyst and the regenerated catalyst injected into the recirculating flow mixing zone B are controlled by means of pulse control valves.

25 13. The method according to any one of claims 8-12, wherein, the coke deposit amount in the spent catalyst injected into the recirculating flow mixing zone B is 1.5~5wt%, and the coke deposit amount in the regenerated catalyst injected into the recirculating flow mixing zone B is 0.01~2.5wt%.

30 14. The method according to any one of claims 8-13, wherein, the reaction raw materials are oxygen-containing compounds and/or C4 hydrocarbons, and the lifting medium is C1-C4 alcohols and/or water vapor.

15. The method according to claim 14, wherein, the oxygen-containing compounds are C1-C4 alcohols.
- 5 16. The method according to any one of claims 8-15, wherein, the catalyst comprises aluminosilicophosphate molecular sieve, in which the molar ratio of $\text{SiO}_2/\text{Al}_2\text{O}_3$ is 10~100.