Claims

1. A process for producing propylene, comprising the steps of:

1) providing a starting material comprising olefin(s) having 4 or more carbon atoms;

2) pretreating the starting material to obtain a propylene precursor comprising olefin(s) having 3×2^n carbon atoms, wherein n is an integer greater than or equal to 1, preferably 1-3, more preferably 1-2; and

3) subjecting the propylene precursor to a catalytic cracking reaction to obtain a reaction product comprising propylene,

wherein the pretreating of step 2) comprises:

2a) optionally, separating the starting material to obtain one or more of the following fractions: a fraction comprising C_4 olefin, a fraction comprising C_5 olefin, a fraction comprising C_7 olefin, and a fraction comprising C_8 olefin, and optionally a first propylene precursor comprising C_6 olefin, wherein:

the fraction comprising C_4 olefin has a C_4 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_4 olefin,

the fraction comprising C_5 olefin has a C_5 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_5 olefin,

the fraction comprising C_7 olefin has a C_7 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_7 olefin,

the fraction comprising C_8 olefin has a C_8 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_8 olefin, and

the first propylene precursor has a C_6 olefin content of no less than 40 wt%, more preferably no less than 70 wt%, further preferably no less than 80 wt%, particularly preferably no less than 90 wt%, based on the weight of the first propylene precursor, and is most preferably consisted essentially of C_6 olefin; and

2b) subjecting the starting material or a fraction thereof to an olefin oligomerization reaction, and optionally separating the resulting oligomerization product, to obtain a second propylene precursor comprising C_{12} olefin, wherein m is an integer greater than or equal to 2, preferably 2 to 3, and the second propylene precursor has a C_{12} olefin content of no less than 40 wt%, more preferably no less than 70 wt%, further preferably no less than 80 wt%,

particularly preferably no less than 90 wt%, based on the weight of the second propylene precursor, and is most preferably consisted essentially of C_{12} olefin.

2. The process according to claim 1, wherein the pretreating of step 2) comprises the step 2a) and step 2b), and the oligomerization step 2b) comprises one or more of:

b1) subjecting the fraction comprising C_4 olefin of the starting material to an olefin oligomerization reaction, and optionally separating the resulting oligomerization product, to obtain the second propylene precursor that comprises C_{12} olefin;

b2) combining the fraction comprising C_5 olefin with the fraction comprising C_7 olefin of the starting material to obtain an oligomerization feedstock, subjecting the oligomerization feedstock to an oligomerization reaction, and optionally separating the resulting oligomerization product, to obtain the second propylene precursor that comprises C_{12} olefin; and

b3) combining the fraction comprising C_4 olefin with the fraction comprising C_8 olefin of the starting material to provide an oligomerization feedstock, subjecting the oligomerization feedstock to an oligomerization reaction, and optionally separating the resulting oligomerization product, to obtain the second propylene precursor that comprises C_{12} olefin.

3. The process according to claim 1 or 2, wherein the oligomerization reaction of each step is carried out independently in the presence of an oligomerization catalyst and under conditions including:

a temperature of 50-550 ºC, a pressure of 0.2-8.0MPa, and a weight hourly space velocity of 0.1-10 h^{-1}, and the oligomerization catalyst used in each step being independently selected from the group consisting of phosphoric acid catalysts, acidic resins, silica-alumina solid acid catalysts, zeolite solid acid catalysts, and combinations thereof;

preferably, in the oligomerization step b2), the weight ratio of C_5 olefin to C_7 olefin in the oligomerization feedstock is 1 : 0.7 to 1 : 3; and/or

preferably, in the oligomerization step b3), the weight ratio of C_4 olefin to C_8 olefin in the oligomerization feedstock is 1 : 0.5 to 1 : 3.

4. The process according to claim 3, wherein:

the phosphoric acid catalyst is one or more selected from the group consisting of a catalyst formed by loading phosphoric acid on diatomite, a catalyst formed by loading

phosphoric acid on activated carbon, a catalyst formed by phosphoric acid-soaked quartz sand, a catalyst formed by loading phosphoric acid on silica gel and a catalyst formed by loading copper pyrophosphate on silica gel;

the silica-alumina solid acid catalyst is a catalyst formed by loading metal ion(s) on alumina and/or an amorphous silica-alumina carrier, wherein the loaded metal ion(s) can be selected from Group VIII metals, Group IVA metals or a combination thereof; and

the zeolite solid acid catalyst comprises 10-100 wt% of a zeolite and 0-90 wt% of a matrix, based on the weight of the zeolite solid acid catalyst, wherein the zeolite is one or more selected from the group consisting of one-dimensional zeolites, two-dimensional zeolites, and three-dimensional zeolites, preferably the one-dimensional zeolite is selected from the group consisting of MTW (ZSM-12), MTT (ZSM-23), and TON (ZSM-22), the two-dimensional zeolite is selected from the group consisting of FER (ferrierite), MFS (ZSM-57), MWW (MCM-22), and MOR (mordenite), and the three-dimensional zeolite is selected from the group consisting of beta zeolites.

5. The process according to any one of claims 1 to 4, wherein the step 1) further comprises subjecting a hydrocarbon feedstock to a catalytic conversion reaction to obtain a reaction product comprising olefin(s) having 4 or more carbon atoms as the starting material,

preferably, the hydrocarbon feedstock is selected from petroleum hydrocarbons, other mineral oils, or a combination thereof, wherein the petroleum hydrocarbon is one or more selected from the group consisting of vacuum gas oils, atmospheric gas oils, coker gas oils, deasphalted oils, vacuum residues, atmospheric residues, and heavy aromatic raffinate oils; said other mineral oil is one or more selected from the group consisting of coal liquefaction oil, oil sand oil and shale oil.

6. The process according to claim 5, wherein the catalytic conversion reaction of step 1) and the catalytic cracking reaction of step 3) are carried out in separate reaction units, and the reaction units used in step 1) and step 3) are each independently a fluidized bed reactor; or

alternatively, the catalytic conversion reaction of step 1) and the catalytic cracking reaction of step 3) are carried out in the same or different parts of the same reaction device, that is preferably a fluidized bed reactor,

preferably, the fluidized bed reactor is a riser reactor or a composite reactor comprising a riser in combination with a dense phase bed, wherein the riser reactor is an equal-diameter riser reactor or a diameter-transformed riser reactor.

7. The process according to claim 5 or 6, wherein the catalytic conversion reaction of step 1) and the catalytic cracking reaction of step 3) are carried out in the presence of a same catalyst comprising 1-50 wt% of a zeolite, 5-99 wt% of an inorganic oxide, and 0-70 wt% of a clay, based on the weight of the catalyst, wherein the zeolite is selected from the group consisting of mesoporous zeolites, macroporous zeolites, or a combination thereof, the mesoporous zeolite is selected from the group consisting of ZSM series zeolites, ZRP zeolites or a combination thereof, and the macroporous zeolite is one or more selected from the group consisting of REY zeolites, REHY zeolites, ultrastable Y zeolites and high-silica Y zeolites; or

alternatively, the catalytic conversion reaction of step 1) and the catalytic cracking reaction of step 3) are carried out in the presence of different catalysts, and the catalysts used in step 1) and step 3) each independently comprise 1-50 wt% of a zeolite, 5-99 wt% of an inorganic oxide, and 0-70 wt% of a clay, based on the weight of the catalyst, wherein the zeolite is selected from the group consisting of mesoporous zeolites, macroporous zeolites, or a combination thereof, the mesoporous zeolite is selected from the group consisting of ZSM series zeolites, ZRP zeolites or a combination thereof, and the macroporous zeolite is one or more selected from the group consisting of REY zeolites, REHY zeolites, ultrastable Y zeolites and high-silica Y zeolites.

8. The process according to any one of claims 5 to 7, wherein the catalytic conversion reaction of step 1) is carried out in a fluidized bed reactor under reaction conditions including: a reaction temperature of 420-650 ºC, a reaction time of 0.05-20 seconds, and a catalyst-to-feedstock weight ratio of 3 : 1 to 15 : 1, a steam-to-feedstock weight ratio of 0.03 : 1 to 0.5 : 1;

preferably, the reaction conditions include: a reaction temperature of 480-600 ºC, a reaction time of 0.1-15 seconds, a catalyst-to-feedstock weight ratio of 4 : 1 to 12 : 1, and a steam-to-feedstock weight ratio of 0.05 : 1 to 0.3 : 1.

9. The process according to claim 8, wherein the catalytic conversion reaction of step 1) is carried out to the extent that a gaseous product having the following characteristics is

obtained:

a mass fraction ratio of liquefied gas (C_3 and C_4) to dry gas (C_2 or lower) of not less than 7, preferably not less than 10;

a methane yield of no greater than 2.0%, preferably no greater than 1.0%;

a mass fraction ratio of propylene to propane in the liquefied gas of not less than 3.5, preferably not less than 5.0; and/or

a mass fraction ratio of isobutylene to isobutane of not less than 1.5, preferably not less than 4.0.

10. The process according to any one of claims 5 to 9, wherein the catalytic conversion reaction of step 1) is carried out in a diameter-transformed riser reactor comprising, from bottom to top, a first reaction zone and a second reaction zone having a larger diameter than the first reaction zone,

wherein the reaction conditions in the first reaction zone include: a reaction temperature of 510-650 ºC, a reaction time of 0.05-1.0 second, a catalyst-to-feedstock weight ratio of 3 : 1 to 15 : 1, and a steam-to-feedstock weight ratio of 0.03 : 1 to 0.3 : 1; and preferably include: a reaction temperature of 520-600 ºC, a reaction time of 0.1-1 second, a catalyst-to-feedstock weight ratio of 4 : 1 to 12 : 1, and a steam-to-feedstock weight ratio of 0.05 : 1 to 0.2 : 1;

the reaction conditions in the second reaction zone include: a reaction temperature of 420-550 ºC, and a reaction time of 1.5-20 seconds; and preferably include: a reaction temperature of 460-530 ºC and a reaction time of 2-10 seconds.

11. The process according to any one of claims 5 to 10, wherein the separating step 2a) comprises:

a1) separating from the catalytic conversion product obtained in step 1) used as the starting material a fraction having a distillation range <145 ºC, a fraction having a distillation range of 145-260 ºC, a fraction having a distillation range >260 ºC, optionally a propylene product and a fraction comprising C_4 olefin;

a2) separating from the fraction having a distillation range <145 ºC the first propylene precursor that comprises C_6 olefin, and/or one or more of the following fractions: a fraction comprising C_5 olefin, a fraction comprising C_7 olefin and a fraction comprising C_8 olefin;

a3) optionally, separating from the fraction having a distillation range <145 ºC n-paraffins and iso-paraffins, and recycling the n-paraffins and iso-paraffins to the catalytic conversion reaction of step 1) or to other reaction device(s);

a4) optionally, recycling the fraction having a distillation range of 145-260 ºC to the catalytic conversion reaction of step 1) or sending it to other reaction device(s); and

a5) optionally, subjecting the fraction having a distillation range >260 ºC to a hydrotreatment and then recycling it to the catalytic conversion reaction of step 1) or sending it to other reaction device(s),

preferably, the hydrotreatment is carried out in the presence of a hydrotreating catalyst and under conditions including: a hydrogen partial pressure of 3.0-20.0 MPa, a reaction temperature of 300-450 ºC, a hydrogen-to-oil volume ratio of 300-2000, and a volume space velocity of 0.1-3.0 h^{-1};

wherein the hydrotreating catalyst comprises a carrier, a metallic component supported on the carrier, and optionally an additive, wherein the carrier is selected from alumina, amorphous silica-alumina or a combination thereof, the metallic component is selected from Group VIB metal, Group VIII metal or a combination thereof, the additive is one or more selected from the group consisting of fluorine, phosphorus, titanium and platinum, the Group VIB metal is selected from Mo, W or a combination thereof, and the Group VIII metal is selected from Co, Ni or a combination thereof; and

wherein the additive is present in an amount of 0-10 wt%, the Group VIB metal is present in an amount of 12-39 wt%, and the Group VIII metal is present in an amount of 1-9 wt%, based on the weight of the hydrotreating catalyst.

12. A system for producing propylene, comprising a pretreatment unit configured to pretreat a starting material comprising olefin(s) having 4 or more carbon atoms to obtain a propylene precursor comprising olefin(s) having 3×2^n carbon atoms, wherein n is an integer greater than or equal to 1, preferably 1 to 3, more preferably 1 to 2, and a reaction unit configured to catalytically crack the propylene precursor to obtain a reaction product comprising propylene,

wherein the pretreatment unit comprises an oligomerization unit and optionally a first separation unit, and wherein the first separation unit is configured to separate the starting material to obtain one or more of the following fractions: a fraction comprising C_4 olefin, a

fraction comprising C_5 olefin, a fraction comprising C_7 olefin, and a fraction comprising C_8 olefin, and optionally a first propylene precursor comprising C_6 olefin, wherein:

the fraction comprising C_4 olefin has a C_4 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_4 olefin,

the fraction comprising C_5 olefin has a C_5 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_5 olefin,

the fraction comprising C_7 olefin has a C_7 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_7 olefin,

the fraction comprising C_8 olefin has a C_8 olefin content of 40-100 wt%, based on the weight of the fraction comprising C_8 olefin, and

the first propylene precursor has a C_6 olefin content of no less than 40 wt%, more preferably no less than 70 wt%, further preferably no less than 80 wt%, particularly preferably no less than 90 wt%, based on the weight of the first propylene precursor, and is most preferably consisted essentially of C_6 olefin; and

the oligomerization unit is configured to carry out an olefin oligomerization reaction on the starting material or a fraction thereof, and optionally separate the resulting oligomerization product, to obtain a second propylene precursor comprising C_{12} olefin, wherein m is an integer greater than or equal to 2, preferably 2 to 3, and the second propylene precursor has a C_{12} olefin content of no less than 40 wt%, more preferably no less than 70 wt%, further preferably no less than 80 wt%, particularly preferably no less than 90 wt%, based on the weight of the second propylene precursor, and is most preferably consisted essentially of C_{12} olefin.

13. The system according to claim 12, wherein the pretreatment unit comprises the first separation unit and the oligomerization unit, and the oligomerization unit is configured to carry out an olefin oligomerization reaction on the fraction comprising C_4 olefin, an oligomerization feedstock obtained by combining the fraction comprising C_5 olefin with the fraction comprising C_7 olefin and/or an oligomerization feedstock obtained by combining the fraction comprising C_4 olefin with the fraction comprising C_8 olefin, respectively, and optionally separating the resulting oligomerization product, to obtain the second propylene precursor that comprises C_{12} olefin.

14. The system according to claim 12 or 13, wherein the reaction unit comprises a

catalytic conversion reaction device, an oil-catalyst separation device, and a regenerator,

wherein the catalytic conversion reaction device is configured to perform a catalytic conversion reaction on a hydrocarbon feedstock in the presence of a catalyst to obtain a reaction effluent comprising a catalytic conversion product and a spent catalyst, wherein the catalytic conversion product comprises olefin(s) having 4 or more carbon atoms and optionally propylene,

the oil-catalyst separation device is configured to separate the catalytic conversion product from the spent catalyst in the reaction effluent, and transport the catalytic conversion product to the pretreatment unit to serve as the starting material;

the regenerator is configured to regenerate the spent catalyst and recycle the regenerated catalyst to the catalytic conversion reaction device; and

the pretreatment unit is configured to pretreat the starting material to obtain the propylene precursor comprising olefin(s) having 3×2^n carbon atoms and optionally a propylene product, and recycle the propylene precursor to the catalytic conversion reaction device.

15. The system according to claim 14, wherein the pretreatment unit comprises a first separation unit comprising a product separation unit and an olefin separation device, and an oligomerization unit comprising at least one oligomerization reactor and at least one rectifying column,

wherein the product separation unit is configured to fractionate the catalytic conversion product comprising olefin(s) having 4 or more carbon atoms and optionally propylene serving as the starting material to obtain a fraction having a distillation range <145 ºC, optionally a propylene product and a fraction comprising C_4 olefin,

the olefin separation device is configured to separate the fraction having a distillation range <145 ºC to obtain one or more of the following fractions: a fraction comprising C_5 olefin, a fraction comprising C_7 olefin and a fraction comprising C_8 olefin, and optionally the first propylene precursor that comprises C_6 olefin,

the one or more oligomerization reactors are configured to carry out an olefin oligomerization reaction on the fraction comprising C_4 olefin, an oligomerization feedstock obtained by combining the fraction comprising C_5 olefin and the fraction comprising C_7 olefin and/or an oligomerization feedstock obtained by combining the fraction comprising

C_4 olefin and the fraction comprising C_8 olefin, respectively, to obtain an oligomerization product comprising C_{12} olefin,

the one or more rectifying columns are configured to separately separate the oligomerization products from the one or more oligomerization reactors to obtain the second propylene precursor that comprises C_{12} olefin.