Claims

1. A heavy oil hydrotreating system, comprising a prehydrotreating reaction zone, a transition reaction zone, and a hydrotreating reaction zone that are connected in series, and sensor units and a control unit, wherein the sensor units are arranged to detect pressure drop in each prehydrotreating reactor in the prehydrotreating reaction zone, and the control unit is arranged to receive pressure drop signals from the sensor units;

   in the initial reaction stage, the prehydrotreating reaction zone includes 3-6 prehydrotreating reactors connected in parallel, and, in the initial reaction stage, the transition reaction zone doesn't include any prehydrotreating reactor;

   in the reaction process, the control unit is arranged to control material feeding to and material discharging from the prehydrotreating reactors in the prehydrotreating reaction zone according to pressure drop signals of the sensor units, so that:

   when the pressure drop in one prehydrotreating reactor reaches a predetermined value, the prehydrotreating reactor is switched from the prehydrotreating reaction zone to the transition reaction zone, and is named as a cut-out prehydrotreating reactor I, and the prehydrotreating reaction zone, the cut-out prehydrotreating reactor I, and the hydrotreating reaction zone are connected in series successively;

   when the pressure drop in the next one prehydrotreating reactor reaches the predetermined value, the prehydrotreating reactor is switched from the prehydrotreating reaction zone to the transition reaction zone, and is named as a cut-out prehydrotreating reactor II, and the prehydrotreating reaction zone, the cut-out prehydrotreating reactor II, the cut-out prehydrotreating reactor I, and the hydrotreating reaction zone are connected in series successively;

   the other prehydrotreating reactors are treated in the above-mentioned method, till all of the prehydrotreating reactors are connected in series;

   preferably, the predetermined value of pressure drop in the prehydrotreating reactor is 50%-80% of a design upper limit of pressure drop for the prehydrotreating reactors, more preferably is 60%-70% of the design upper limit of pressure drop.

2. The system according to claim 1, wherein in the initial reaction stage, the prehydrotreating reaction zone includes 3-4 prehydrotreating reactors;
the hydrotreating reaction zone includes 1-5 hydrotreating reactors connected in series, more preferably includes 1-2 hydrotreating reactors connected in series.

3. The system according to claim 1 or 2, wherein in the prehydrotreating reaction zone, the discharge outlet of any one prehydrotreating reactor is connected through a pipeline with a control valve to the feed inlets of other prehydrotreating reactors and the feed inlet of the hydrotreating reaction zone, the feed inlet of any one prehydrotreating reactor is connected through a pipeline with a control valve to a supply source of mixed flow of heavy oil raw material and hydrogen, wherein the control unit controls material feeding and discharging by controlling the control valves corresponding to the prehydrotreating reactors.

4. A heavy oil hydrotreating method, comprising: mixing the heavy oil raw material with hydrogen, and then feeding the mixture through the prehydrotreating reaction zone, transition reaction zone, and hydrotreating reaction zone that are connected in series; wherein, sensor units are arranged to detect pressure drop in each prehydrotreating reactor in the prehydrotreating reaction zone, and in the reaction process, a control unit is arranged to receive pressure drop signals from the sensor units;
in the initial reaction stage, the prehydrotreating reaction zone includes 3-6 prehydrotreating reactors connected in parallel, and in the initial reaction stage, the transition reaction zone doesn't include any prehydrotreating reactor;
when the pressure drop in one prehydrotreating reactor reaches the predetermined value, the prehydrotreating reactor is switched from the prehydrotreating reaction zone to the transition reaction zone, and is named as a cut-out prehydrotreating reactor I, and the prehydrotreating reaction zone, the cut-out prehydrotreating reactor I, and the hydrotreating reaction zone are connected in series successively;
when the pressure drop in the next one prehydrotreating reactor reaches the predetermined value, the prehydrotreating reactor is switched from the

prehydrotreating reaction zone to the transition reaction zone, and is named as a cut-out prehydrotreating reactor II, and the prehydrotreating reaction zone, the cut-out prehydrotreating reactor II, the cut-out prehydrotreating reactor I, and the hydrotreating reaction zone are connected in series successively;

the other prehydrotreating reactors are treated in the above-mentioned method, till all of the prehydrotreating reactors are connected in series;

wherein the predetermined value of pressure drop in the prehydrotreating reactors is 50%-80% of a design upper limit of pressure drop for the prehydrotreating reactors, preferably is 60%-70% of the design upper limit of pressure drop.

5. The method according to claim 4, wherein in the initial reaction stage, the prehydrotreating reaction zone includes 3-4 prehydrotreating reactors.

6. The method according to claim 4 or 5, wherein the pressure drops in all of the prehydrotreating reactors are controlled so that they don't reach the predetermined value at the same time, and preferably the time difference between the times when the pressure drops in two adjacent prehydrotreating reactors in which the pressure drops are closest to the predetermined value of pressure drop reach the predetermined value of pressure drop is not smaller than 20% of the entire running period, preferably is 20%-60% of the entire running period.

7. The method according to claim 6, wherein the pressure drops in each prehydrotreating reactor in the prehydrotreating reaction zone are controlled so that they don't reach the predetermined value of pressure drop at the same time by setting operating conditions and/or utilizing the differences in the properties of the catalyst bed layers,

preferably, the pressure drops in each prehydrotreating reactor in the prehydrotreating reaction zone are controlled so that they don't reach the predetermined value of pressure drop at the same time, by controlling one or more of different catalyst packing heights in each prehydrotreating reactor, different feed rates of each prehydrotreating reactor, different properties of the

feed materials, different operating conditions, and different catalyst packing densities under a condition of the same packing height.

8. The method according to claim 7, wherein in the case that the approach of controlling different catalyst packing densities in each prehydrotreating reactor under a condition of the same catalyst packing height is used, in each prehydrotreating reactors connected in parallel in the prehydrotreating reaction zone, the maximum packing density is 400kg/m^3-600kg/m^3, preferably is 450kg/m^3-550kg/m^3; the minimum packing density is 300kg/m^3-550kg/m^3, preferably is 350kg/m^3-450kg/m^3;
   preferably, the difference between catalyst packing densities of two prehydrotreating reactors in which the packing densities are the closest to each other is 50-200kg/m^3, preferably is 80-150kg/m^3.

9. The method according to claim 7, wherein in the case that the approach of controlling different feed rates of each prehydrotreating reactor is used, the ratio of volumetric space velocities of material feeding to two prehydrotreating reactors of which the feed rates are the closest to each other is 1.1-3:1, preferably is 1.1-1.5:1;
   or, in the case that the approach of controlling the properties of feed materials in each prehydrotreating reactor is used, the difference between metals contents in the feed materials in two prehydrotreating reactors of which the properties of feed materials are the closest to each other is 5-50μg/g, preferably is 10-30μg/g.

10. The method according to claim 7, wherein in the case that the approach of controlling the different operating conditions in each prehydrotreating reactor is used, in the operating conditions of two prehydrotreating reactors in which the operating pressures and volumetric space velocities are controlled to be the closest, the difference in operating temperature is 2-30℃, preferably is 5-20℃; or in the operating conditions of two prehydrotreating reactors in which the operating pressure and operating temperature are controlled to be the closest, the difference in volumetric space velocity is 0.1-10h^{-1}, preferably is 0.2-5h^{-1}.

11. The method according to claim 4 or 5, wherein in the material flow direction, hydrogenation protectant, hydro-demetalization catalyst, and optional hydro-desulfurization catalyst are charged in each prehydrotreating reactor in sequence; hydro-desulfurization catalyst and hydro-denitrogenation residual carbon conversion catalyst are charged in the reactors in the hydrotreating reaction zone in sequence.

12. The method according to claim 4 or 5, wherein the operating conditions of the prehydrotreating reaction zone include: temperature: 370℃-420℃, preferably 380℃-400℃; pressure: 10MPa-25MPa, preferably 15MPa-20MPa; volume ratio of hydrogen to oil: 300-1,500, preferably 500-800; liquid hour space velocity (LHSV) of raw oil: $0.15h^{-1}$-$2h^{-1}$, preferably $0.3h^{-1}$-$1h^{-1}$.

13. The method according to claim 4, wherein the hydrotreating reaction zone includes 1-5 hydrotreating reactors connected in series, preferably includes 1-2 hydrotreating reactors connected in series.

14. The method according to claim 4 or 13, wherein the operating conditions of the hydrotreating reaction zone include: temperature: 370℃-430℃, preferably 380℃-410℃; pressure: 10MPa-25MPa, preferably 15MPa-20MPa; volume ratio of hydrogen to oil: 300-1,500, preferably 400-800; liquid hour space velocity (LHSV) of raw oil: $0.15h^{-1}$-$0.8h^{-1}$, preferably $0.2h^{-1}$-$0.6h^{-1}$.

15. The method according to claim 4 or 5, wherein the heavy oil raw material is selected from atmospheric heavy oil and/or vacuum residual oil;
preferably, the heavy oil raw material is blended with at least one of straight run wax oil, vacuum wax oil, secondary processed wax oil, and catalytic recycle oil.