Claims

1. A nitro compound hydrogenation reaction process, comprising a hydrogenation step, a regeneration step, an optional activation step and a recycling step, which is characterized in that in the hydrogenation step, a nitro compound as the reaction raw material is contacted with hydrogen gas and a hydrogenation catalyst in a reactor, referred to as hydrogenation reactor, to obtain a reaction product and a spent catalyst; in the regeneration step, the spent catalyst is regenerated in a reactor, referred to as regeneration reactor, to obtain a regenerated catalyst; in the optional activation step, the regenerated catalyst is activated in a reactor, referred to as activation reactor, to obtain an activated catalyst; in the recycling step, the regenerated catalyst and/or the activated catalyst are recycled to the hydrogenation step; wherein there exists at least one step of degassing the spent catalyst, referred to as hydrogenation degassing step, between the hydrogenation step and the regeneration step, and(1) in the case that the activation step exists, there exists at least one step of degassing the regenerated catalyst, referred to as first regeneration degassing step, between the regeneration step and the activation step, optionally there exists at least one step of degassing the activated catalyst, referred to as activation degassing step, between the activation step and the recycling step, and optionally there exists at least one step of degassing the regenerated catalyst, referred to as second regeneration degassing step, between the regeneration step and the recycling step; or(2) in the case that the activation step is absent, there exists at least one step of degassing the regenerated catalyst, referred to as third regeneration degassing step, between the regeneration step and the recycling step, wherein assuming that the average mass flowrate, the unit is kg/h, of the spent catalyst being transported from the hydrogenation step to the hydrogenation degassing step is A1, the average mass flowrate, the unit is kg/h, of the spent catalyst being transported from the hydrogenation degassing step to the regeneration step is B1, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the regeneration step to the first regeneration degassing step is A2, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the first regeneration degassing step to the activation step is B2, the average mass flowrate, the unit is kg/h, of the activated catalyst being transported from the activation step to the activation degassing step is A3, the average mass flowrate, the unit is kg/h, of the activated catalyst being transported from the activation degassing step to the recycling step is B3, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the regeneration step to the second regeneration degassing step is A4, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the second regeneration degassing step to the recycling step is B4, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the regeneration step to the third regeneration degassing step is A5, the average mass flowrate, the unit is kg/h, of the regenerated catalyst being transported from the third regeneration degassing step to the recycling step is B5, the average mass flowrate, the unit is kg/h, of the regenerated catalyst or the activated catalyst being transported from the recycling step to the hydrogenation step is A6, then all of A1 to A6 and B1 to B5 are 5-100 kg/h.

2. The hydrogenation reaction process as claimed in Claim 1, wherein said nitro compound is nitrobenzene, and/or said hydrogenation reactor is a fluidized bed reactor, and/or said reaction product is aniline, and/or said regeneration reactor is a fluidized bed reactor, and/or said activation

reactor is a fluidized bed reactor, and/or the regenerated catalyst and/or the activated catalyst are recycled with a lifting pipe to the hydrogenation step, and/or all of A1 to A6 and B1 to B5 are 10-30 kg/h.

3. The hydrogenation reaction process as claimed in Claim 1, wherein assuming the particle volume fraction, the unit is %, in the transportation pipeline of the spent catalyst being transported from the hydrogenation step to the hydrogenation degassing step is C1, the particle volume fraction, the unit is %, in the transportation pipeline of the spent catalyst being transported from the hydrogenation degassing step to the regeneration step is D1, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the regeneration step to the first regeneration degassing step is C2, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the first regeneration degassing step to the activation step is D2, the particle volume fraction, the unit is %, in the transportation pipeline of the activated catalyst being transported from the activation step to the activation degassing step is C3, the particle volume fraction, the unit is %, in the transportation pipeline of the activated catalyst being transported from the activation degassing step to the recycling step is D3, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the regeneration step to the second regeneration degassing step is C4, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the second regeneration degassing step to the recycling step is D4, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the regeneration step to the third regeneration degassing step is C5, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst being transported from the third regeneration degassing step to the recycling step is D5, the particle volume fraction, the unit is %, in the transportation pipeline of the regenerated catalyst or the activated catalyst being transported from the recycling step to the hydrogenation step is C6, then all of C1 to C6 and D1 to D5 are 0.1-15%.

4. The hydrogenation reaction process as claimed in Claim 3, wherein all of C1 to C6 and D1 to D5 are 0.5-5%.

5. The hydrogenation reaction process as claimed in Claim 1, wherein the reaction conditions of the hydrogenation step comprise: the superficial gas velocity is 0.2-0.8 m/s, the molar ratio of hydrogen gas to the reaction raw material is 6-21, the reaction temperature is 220-280°C, the reaction pressure is 0.05-1 MPa, gauge pressure, and/or, the reaction conditions of the regeneration step comprise: in the presence of oxygen-containing gas, the superficial gas velocity is 0.1-0.6 m/s, the reaction temperature is 350-450°C, the reaction pressure is 0.05-1 MPa, gauge pressure, and/or, the reaction conditions of the activation step comprise: in the presence of hydrogen gas, the superficial gas velocity is 0.1-0.6 m/s, the reaction temperature is 200-250°C, the reaction pressure is 0.05-1 MPa, gauge pressure.

6. The hydrogenation reaction process as claimed in Claim 5, wherein the superficial gas velocity is 0.3-0.6 m/s, and/or said reaction raw material is nitrobenzene, and/or said

oxygen-containing gas is air or oxygen gas, and/or the superficial gas velocity is 0.2-0.4 m/s.

7. The hydrogenation reaction process as claimed in Claim 1, wherein the dimensionless particle diameter of the hydrogenation reactor is in the range of 1-60, and/or, the dimensionless particle diameter of the regeneration reactor is in the range of 1-40, and/or, the dimensionless particle diameter of the activation reactor is in the range of 1-30, wherein the dimensionless particle diameter is determined by the following equation:

$$Dimensionless\ particle\ diameter = Average\ particle\ diameter \times \sqrt[3]{\frac{Gas\ density \times Gas - solid\ density\ difference \times g}{Gas\ kinetic\ viscosity^2}},$$

wherein, the average particle diameter is the volume average particle diameter, the unit is m, of solid particles in the reactor, the gas density is the density, the unit is kg/m^3, of the gas in the reactor, the gas-solid density difference is the difference of the density, the unit is kg/m^3, of solid particles minus the density, the unit is kg/m^3, of the gas in the reactor, the gas kinetic viscosity is the kinetic viscosity, the unit is Pa·s, of the gas in the reactor, and g is the absolute value of the gravity acceleration, 9.8 m/s^2.

8. The hydrogenation reaction process as claimed in Claim 1, which further comprises a step of transporting a supplement hydrogenation catalyst to at least one of the hydrogenation step, the regeneration step, the optional activation step and the recycling step.

9. The hydrogenation reaction process as claimed in Claim 8, which comprises a step of transporting a supplement hydrogenation catalyst to the activation step, referred to as catalyst supplement step.

10. The hydrogenation reaction process as claimed in Claim 9, wherein in the catalyst supplement step, the ratio of the average mass flowrate of the supplement hydrogenation catalyst being transported to the hydrogenation catalyst inventory in the hydrogenation reactor, the unit is kg, is 0-10h^{-1}.

11. The hydrogenation reaction process as claimed in Claim 10, wherein the ratio of the average mass flowrate of the supplement hydrogenation catalyst being transported to the hydrogenation catalyst inventory in the hydrogenation reactor, the unit is kg, is 0.00002-0.001h^{-1}.

12. The hydrogenation reaction process as claimed in Claim 9, wherein the hydrogenation reactor is a fluidized bed reactor, the fluidized bed reactor comprise a dense phase reaction zone (4), at least one dynamic pressure measuring point is mounted on the side wall of the dense phase reaction zone (4) to measure the instantaneous pressure fluctuation in the dense phase reaction zone (4), when the standard deviation of the instantaneous pressure fluctuation is greater than 600Pa, the catalyst supplement step is initiated, and/or, the hydrogenation reactor is a fluidized bed reactor, the fluidized bed reactor comprises a dense phase reaction zone (4), when the catalyst particles having a particle diameter of less than 100μm comprise greater than 3wt% by mass percent of all catalyst particles in the dense phase reaction zone (4), the catalyst supplement step is initiated.

13. The hydrogenation reaction process as claimed in Claim 12, wherein the response frequency is not less than 100Hz, and/or when the standard deviation of the instantaneous pressure fluctuation is greater than 1500Pa, the catalyst supplement step is initiated, and/or, when the catalyst particles having a particle diameter of less than 100μm comprise greater than 5wt% by mass percent of all catalyst particles in the dense phase reaction zone (4), the catalyst supplement step is initiated.

14. The hydrogenation reaction process as claimed in Claim 8, wherein the supplement hydrogenation catalyst is selected from at least one of a copper-based loaded catalyst, a nickel-based loaded catalyst and a noble metal-based loaded catalyst, having an average particle diameter of 5-150μm.

15. The hydrogenation reaction process as claimed in Claim 14, wherein the average particle diameter of the hydrogenation catalyst is 20-70μm.

16. The hydrogenation reaction process as claimed in Claim 1, wherein the hydrogenation catalyst is selected from at least one of a copper-based loaded catalyst, a nickel-based loaded catalyst and a noble metal-based loaded catalyst, and/or, the hydrogenation catalyst has a bulk density of 300-1200 kg/m^3, and/or, the hydrogenation catalyst has an average particle diameter of 30-800μm, and the catalyst particles having a particle diameter of less than 80μm comprise not less than 2wt% by mass percent of all catalyst particles, and/or, the nitro compound is selected from at least one of the compounds represented by the following formula (1),

$R\text{-}NO_2$ (1)

in the structural formula (1), R is an optionally substituted $C_{2\text{-}20}$ straight, branched or cyclic hydrocarbyl.

17. The hydrogenation reaction process as claimed in Claim 16, wherein the hydrogenation catalyst has an average particle diameter of 40-500μm or 50-600μm, and/or the catalyst particles having a particle diameter of less than 80μm comprise 5-15 wt% by mass percent of all catalyst particles, and/or, In the structural formula (1), R is an optionally substituted $C_{4\text{-}20}$ cyclic hydrocarbyl or an optionally substituted $C_{6\text{-}20}$ aryl or an optionally substituted phenyl.

18. A hydrogenation reaction apparatus of the nitro compound, comprising a hydrogenation reactor, a regeneration reactor, an activation reactor and a recycling unit, the hydrogenation reactor is communicated with the regeneration reactor via at least one spent catalyst degasser through transportation pipelines, the regeneration reactor is communicated with the activation reactor via at least one regenerated catalyst degasser through transportation pipelines, the activation reactor is communicated with the recycling unit through transportation pipelines or communicated with the recycling unit via at least one activated catalyst degasser through transportation pipelines, the recycling unit is communicated with the hydrogenation reactor through transportation pipelines, wherein the solid particle inventory, the unit is kg, of the hydrogenation reactor: the solid particle inventory, the unit is kg, of the regeneration reactor: the solid particle inventory, the unit is kg, of the activation reactor = (10-200):(0.1-20):(0.1-20).

19. The hydrogenation reaction apparatus of Claim 18, wherein said hydrogenation reactor is a fluidized bed reactor, and/or said regeneration reactor is a fluidized bed reactor, and/or said activation reactor is a fluidized bed reactor, and/or said recycling unit is a lifting pipe, and/or wherein the solid particle inventory, the unit is kg, of the hydrogenation reactor: the solid particle inventory, the unit is kg, of the regeneration reactor: the solid particle inventory, the unit is kg, of the activation reactor = (20-100):(0.5-8):(0.5-8).

20. The hydrogenation reaction apparatus of Claim 18, wherein the hydrogenation reactor has a height of 5-60m, and a diameter of 0.5-12m, and/or, the regeneration reactor has a height of 1-15m, and a diameter of 0.1-3m, and/or, the activation reactor has a height of 1-15m, and a diameter of 0.1-3m, and/or, the inner diameters of the transportation pipelines are, identical to or different from each other, each independently 30-400mm.

21. The hydrogenation reaction apparatus of Claim 20, wherein the hydrogenation reactor has a height of 10-30m, and a diameter of 1-8m, and/or, the regeneration reactor has a height of 3-6m, and a diameter of 0.3-1m, and/or, the activation reactor has a height of 3-6m, and a diameter of 0.3-1m, and/or, the inner diameters of the transportation pipelines are, identical to or different from each other, each independently 50-300mm.