Claims

1. A method for producing hydrogen peroxide, comprising the steps of:

1) feeding a working solution containing an alkylanthraquinone to a hydrogenation reactor and subjecting the alkylanthraquinone to a hydrogenation reaction in the presence of hydrogenation catalyst particles and hydrogen to obtain a slurry comprising a hydrogenated anthraquinone, a by-product and the hydrogenation catalyst particles, recovering the hydrogenation catalyst particles from the slurry to obtain a circulating slurry rich in hydrogenation catalyst particles and a hydrogenated solution substantially free of hydrogenation catalyst particles, and returning the circulating slurry to the hydrogenation reactor;

2) dividing the hydrogenated solution into two streams, and regenerating the first stream of the hydrogenated solution to convert at least a part of the by-product contained in the first stream of the hydrogenated solution into the alkylanthraquinone to obtain a regenerated hydrogenated solution;

3) contacting the second stream of the hydrogenated solution and the regenerated hydrogenated solution with an oxygen-containing gas for oxidation reaction to obtain an oxidized solution containing hydrogen peroxide and the alkylanthraquinone; and

4) carrying out extraction separation on the oxidized solution to obtain an extract liquor containing hydrogen peroxide and a raffinate containing the alkylanthraquinone, and returning the raffinate to the hydrogenation reactor for use as a part of the working solution;

wherein the ratio of the volume flow rate of the circulating slurry to that of the working solution is 6-20 : 1, preferably 8-18 : 1, and the ratio of the mass flow rate of the first stream of the hydrogenated solution to that of the second stream of the hydrogenated solution is 10-50 : 50-90, preferably 15-40 : 60-85;

the step 1) further comprises: carrying out a first cooling on the circulating slurry to obtain a first cooled solution, and returning the first cooled solution to the hydrogenation reactor; preferably, the temperature of the first cooled solution is 40 to 70 ºC.

2. The method according to claim 1, wherein in step 1), the hydrogenation reaction is carried out in a slurry bed reactor;

preferably, the conditions of the hydrogenation reaction include: a pressure of 0.03-0.35 MPa, preferably 0.05-0.2 MPa; a temperature of 40-70 ºC, preferably 45-65 ºC; a ratio

of the mass flow rate of the working solution to that of the hydrogenation catalyst of 25-700 : 1, preferably 30-500 : 1; a ratio of the standard volume flow rate of the hydrogen to the volume flow rate of the working solution of 4-14 : 1, preferably 5-10 : 1;

preferably, the hydrogenation reaction further produces a hydrogen-containing tail gas, and the step 1) further comprises discharging the hydrogen-containing tail gas and/or compressing the hydrogen-containing tail gas and returning it to the hydrogenation reactor.

3. The method according to any one of the preceding claims, wherein the temperature of the first cooled solution is 45 to 65 ºC.

4. The method according to any one of the preceding claims, wherein in step 2), the regeneration is carried out in the presence of a regeneration catalyst in a regeneration reactor selected from fixed bed reactor, slurry bed reactor or a combination thereof;

preferably, where the regeneration reactor is a fixed bed reactor, the regeneration catalyst is a modified alumina, and further preferably, the modified alumina is alumina modified by at least one metal selected from the group consisting of alkali metals, alkaline earth metals and rare earth metals;

preferably, where the regeneration reactor is a slurry bed reactor, the regeneration catalyst is a modified molecular sieve, and further preferably, the modified molecular sieve is a molecular sieve modified by at least one metal selected from the group consisting of alkali metals, alkaline earth metals and rare earth metals.

5. The method according to any one of the preceding claims, wherein the step 3) further comprises: before the oxidation reaction, combining the second stream of the hydrogenated solution and the regenerated hydrogenated solution to obtain a mixed solution, and carrying out a second cooling on the mixed solution to obtain a second cooled solution;

preferably, the step 3) further comprises: before the oxidation reaction, mixing the second cooled solution with a first pH regulator to obtain a regulated solution and optionally filtering the regulated solution.

6. The method according to any one of the preceding claims, wherein the extractant used in step 4) comprises water and optionally a second pH regulator;

preferably, the step 4) further comprises: carrying out a third cooling on the oxidized solution before the extraction to obtain a third cooled solution.

7. The method according to any one of the preceding claims, wherein the step 4)

further comprises: vacuum drying at least 10% by mass flow rate of the raffinate to obtain a residual liquor, and returning the residual liquor and the rest of the raffinate to the hydrogenation reactor;

preferably, at least 30% by mass flow rate of the raffinate is vacuum dried;

preferably, the vacuum drying further produces water and/or an organic matter, and the step 4) further comprises recycling the water and/or the organic matter.

8. A system for producing hydrogen peroxide, comprising a hydrogenation unit, a regeneration unit, an oxidation unit, and a separation unit;

the hydrogenation unit is configured to conduct a hydrogenation reaction on a working solution containing an alkylanthraquinone in the presence of hydrogenation catalyst particles and hydrogen to obtain a slurry comprising a hydrogenated anthraquinone, a by-product and the hydrogenation catalyst particles, recover the hydrogenation catalyst particles from the resulting slurry to obtain a circulating slurry rich in hydrogenation catalyst particles and a hydrogenated solution substantially free of hydrogenation catalyst particles, and recycle the circulating slurry;

the regeneration unit is configured to regenerate a part of the hydrogenated solution to convert at least a part of the byproduct contained therein to the alkylanthraquinone to produce a regenerated hydrogenated solution;

the oxidation unit is configured to contact the rest part of the hydrogenated solution and the regenerated hydrogenated solution with an oxygen-containing gas for oxidation reaction to obtain an oxidized solution containing hydrogen peroxide and the alkylanthraquinone;

the separation unit is configured to carry out extraction separation on the oxidized solution to obtain an extract liquor containing hydrogen peroxide and a raffinate containing the alkylanthraquinone, and return the raffinate to the hydrogenation unit; and

the hydrogenation unit further comprises a first cooler, the first cooler is connected between the circulating slurry outlet of the filter and the circulating slurry inlet of the hydrogenation reactor for cooling the circulating slurry before it is recycled to the hydrogenation reactor.

9. The system according to claim 8, wherein:

the hydrogenation unit is provided with a working solution inlet, a hydrogen-containing gas inlet, a hydrogenated solution outlet and an optional hydrogen-containing

tail gas outlet;

the regeneration unit is provided with a hydrogenated solution inlet and a regenerated hydrogenated solution outlet;

the oxidation unit is provided with a hydrogenated solution inlet, an oxygen-containing gas inlet, an oxidized solution outlet and an oxygen-containing tail gas outlet;

the separation unit is provided with an oxidized solution inlet, an extractant inlet, an extract outlet and a raffinate outlet;

wherein the hydrogenated solution outlet of the hydrogenation unit is respectively communicated with the hydrogenated solution inlets of the regeneration unit and the oxidation unit, the regenerated hydrogenated solution outlet of the regeneration unit is communicated with the hydrogenated solution inlet of the oxidation unit, the oxidized solution outlet of the oxidation unit is communicated with the oxidized solution inlet of the separation unit, and the raffinate outlet of the separation unit is communicated with the working solution inlet of the hydrogenation unit.

10. The system according to claim 8 or 9, wherein the hydrogenation unit comprises a hydrogenation reactor in the form of a slurry bed reactor and a filter, the hydrogenation reactor comprises a reaction zone and a gas-liquid separation zone, and is provided with a working solution inlet, at least one hydrogen-containing gas inlet, a circulating slurry inlet, a slurry outlet and a hydrogen-containing tail gas outlet, the filter is provided with a slurry inlet, a circulating slurry outlet and a hydrogenated solution outlet, wherein the slurry outlet of the hydrogenation reactor is in communication with the slurry inlet of the filter, the circulating slurry outlet of the filter is in communication with the circulating slurry inlet of the hydrogenation reactor, and optionally the hydrogen-containing tail gas outlet of the hydrogenation reactor is in communication with one hydrogen-containing gas inlet of the hydrogenation reactor;

preferably, the hydrogenation unit further comprises a compressor, the compressor is connected between the hydrogen-containing tail gas outlet of the hydrogenation reactor and one hydrogen-containing gas inlet of the hydrogenation reactor for compressing the hydrogen-containing tail gas and recycling it to the hydrogenation reactor.

11. The system according to any one of claims 8-10, wherein the regeneration unit comprises a regeneration reactor having a hydrogenated solution inlet and a regenerated hydrogenated solution outlet;

preferably, the regeneration unit further comprises a heat exchanger, the heat exchanger is connected between the hydrogenated solution outlet of the hydrogenation unit, the hydrogenated solution inlet of the regeneration reactor and the regenerated hydrogenated solution outlet of the regeneration reactor for exchanging heat between the hydrogenated solution to be regenerated and the regenerated hydrogenated solution;

further preferably, the regeneration unit further comprises a heater, and the heater is connected between the hydrogenated solution outlet of the heat exchanger and the hydrogenated solution inlet of the regeneration reactor for heating the hydrogenated solution after the heat exchange.

12. The system according to any one of claims 8-11, wherein the oxidation unit comprises an oxidation reactor having a hydrogenated solution inlet, an oxygen-containing gas inlet, an oxidized solution outlet, and an oxygen-containing tail gas outlet;

preferably, the oxidation unit further comprises a second cooler, the second cooler is connected between the hydrogenated solution outlet of the hydrogenation unit, the regenerated hydrogenated solution outlet of the regeneration unit and the hydrogenated solution inlet of the oxidation reactor for cooling a mixed solution obtained by combining the rest of the hydrogenated solution and the regenerated hydrogenated solution;

further preferably, the oxidation unit further comprises a precision filter, and the precision filter is connected between the outlet of the second cooler and the hydrogenated solution inlet of the oxidation reactor for filtering the cooled mixed solution.

13. The system according to any one of claims 8-12, wherein the separation unit comprises an extraction column having an oxidized solution inlet, an extractant inlet, an extract outlet, and a raffinate outlet;

preferably, the separation unit further comprises a third cooler, the third cooler is connected between the oxidized solution outlet of the oxidation unit and the oxidized solution inlet of the extraction column for cooling the oxidized solution;

preferably, the separation unit further comprises a vacuum drying column, the vacuum drying column is connected between the raffinate outlet of the extraction column and the working solution inlet of the hydrogenation unit for carrying out vacuum drying on at least 10% by mass flow rate of the raffinate and returning the resulting residual liquor to the hydrogenation unit;

further preferably, the vacuum drying column is further communicated with the

extractant inlet or the oxidized solution inlet of the extraction column for returning the water and/or organic matter obtained by vacuum drying at least 10% by mass flow rate of the raffinate to the extraction column.