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• **DONG, Tingting**

Beijing 100190 (CN)

• **XING, Huifang**

Beijing 100190 (CN)

• **YU, Jiemiao**

Beijing 100190 (CN)

• **RONG, Meng**

Beijing 100190 (CN)

• **LIU, Huizhou**

Beijing 100190 (CN)

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(71) Applicant: **Institute of Process Engineering, Chinese Academy of Sciences Beijing 100190 (CN)**

(74) Representative: **Prinz & Partner mbB**

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Rundfunkplatz 2

80335 München (DE)

(72) Inventors:

• **YANG, Liangrong**

Beijing 100190 (CN)

(54) **WHOLE-PROCESS CONTINUOUS GAS-ASSISTED MAGNETIC SEPARATION SYSTEM**

(57) Disclosed is a whole-process continuous gas-assisted magnetic separation system, comprising an adsorption tank (1), an extraction column (2) connected to the adsorption tank (1), and a desorption column (3) connected to the extraction column (2). The extraction column (2) and the desorption column (3) each comprises a hollow gas floatation column (7). A magnetic roller (8) is provided on the top of each gas floatation column (7), a scraper (9) is provided on one side of the magnetic roller (8), and a gas inlet is provided at the bottom of each gas floatation column (7). Each of the gas floatation columns (7) of the extraction column (2) and the desorption column (3) is connected to a rinsing device, a rinsing opening of which is arranged opposite the scraper (9).

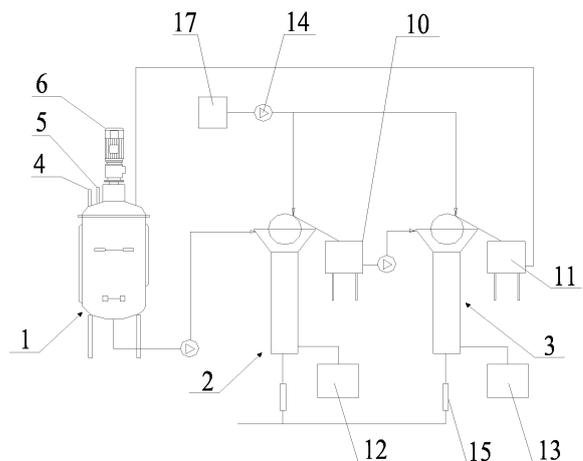


Figure 1

EP 3 424 600 A1

Description

Technical field

[0001] The present disclosure relates to the technical field of magnetic separation processing equipment, in particular to a whole process continuous gas-assisted magnetic separation system.

Background

[0002] The magnetic carrier separation technology is a novel separation technology that includes the steps of adsorbing target components by affinity ligands, hydrophobic groups, ion exchange groups and the like coupled to the surface of magnetic carriers, separating out the magnetic carriers loaded with the targets by use of a suitable magnetic separation device, and washing and eluting the magnetic carriers to directly and quickly separate the targets. Magnetic carrier separation technology has been developed since the 1970s and has achieved great development. Since this technology has the advantages of quick and simple separation, high selectivity, rapid separation and capability of being used directly to the separation of complex systems, etc., it has been proposed and widely studied for application to the fields such as immunoassay, cell labeling and separation, nucleic acid isolation, protein purification, wastewater treatment, natural product separation, and the like.

[0003] However, when the technology is used in the separation field, it is a huge challenge to appropriately increase the processing scale due to the separation object is a dilute solution or even a very dilute solution for most of the time. The existing magnetic separation devices either have too small processing scale to meet the requirements, or have insufficient space magnetic field intensity and gradient within the devices after enlargement, resulting in weak magnetic particles and ultrafine magnetic particles flowing in the space, especially the nanometer magnetic particles, which cannot be quickly and efficiently captured due to the too weak magnetic force. How to effectively process a large amount of dilute solution containing magnetic particles is a prominent problem in the application of the magnetic carrier separation technology.

Summary

[0004] The object of the present disclosure is to provide a whole process continuous gas-assisted magnetic separation system to solve the problem that weak magnetic particles and ultrafine magnetic particles, especially nanometer magnetic particles, within the space cannot be quickly and efficiently captured due to the insufficient magnetic field intensity and gradient after the enlargement of the device in the related technics.

[0005] To achieve this object, the present disclosure adopts the following technical solutions:

A whole process continuous gas-assisted magnetic separation system comprises an adsorption tank, the adsorption tank is connected with an extraction column, and the extraction column is connected with a desorber;

a feed liquid inlet and a magnetic particle inlet are arranged at the top of the adsorption tank, a mixed liquid outlet is arranged at the bottom of the adsorption tank, and a stirring device is arranged inside the adsorption tank ;

the extraction column comprises a hollow air flotation column, a mixed liquid inlet and a raffinate outlet are arranged on the air flotation column, the mixed liquid inlet is connected with the mixed liquid outlet, and a magnetic roller is arranged at the top of the air flotation column, a scraper is arranged on one side of the magnetic roller, a mixture storage tank is arranged at the end of the scraper, and a gas inlet is arranged at the bottom of the air flotation column;

the desorber comprises a hollow air flotation column, a magnetic particle inlet and a product outlet are arranged on the air flotation column, and the magnetic particle inlet is connected with the mixture storage tank, a magnetic roller is arranged at the top of the air flotation column, a scraper is arranged on one side of the magnetic roller, a magnetic particle storage tank is arranged at the end of the scraper, the magnetic particle storage tank is connected with the adsorption tank, and a gas inlet is arranged at the bottom of the air flotation column;

the air flotation columns of the extraction column and the desorber are connected with a washing device, and the washing port of the washing device is arranged opposite to the scraper.

[0006] Further, the whole process continuous gas-assisted magnetic separation system comprises a plurality of extraction columns, and the plurality of extraction columns are connected in series through mixed liquid inlets and raffinate outlets;

wherein, the mixed liquid inlet of the extraction column at the head end is connected with the mixed liquid outlet, and the raffinate outlet of the extraction column at the tail end is connected with the raffinate storage tank.

[0007] Further, the whole process continuous gas-assisted magnetic separation system comprises a plurality of extraction columns, and the mixed liquid inlet of each extraction column is connected with the mixed liquid outlet, and the raffinate outlet of each extraction column is connected with the raffinate storage tank.

[0008] Further, the whole process continuous gas-assisted magnetic separation system comprises a plurality of desorbers, and the a plurality of desorbers are connected in series through magnetic particle inlets and

product outlets;

wherein, the magnetic particle inlet of the desorber at the head end is connected with the mixture storage tank, and the product outlet of the desorber at the tail end is connected with the product storage tank.

[0009] Further, the whole process continuous gas-assisted magnetic separation system comprises a plurality of desorbers, and the magnetic particle inlet of each desorbers is connected with the mixture storage tank, and the product outlet of each desorbers is connected with the product storage tank.

[0010] Further, the feed liquid inlet, the magnetic particle inlet and the stirring device are arranged on the tank cover of the adsorption tank, and the tank cover of the adsorption tank is connected with a lifting assembly.

[0011] Further, peristaltic pumps are arranged between the adsorption tank and the extraction column, between the extraction column and the desorber and between the washing device and the scraper.

[0012] Further, the whole process continuous gas-assisted magnetic separation system comprises a control device which includes a controller, the controller is connected with the stirring device, the magnetic roller, the lifting assembly and the peristaltic pump, and the controller is provided with a control button.

[0013] Further, the whole process continuous gas-assisted magnetic separation system comprises a gas supply line which is connected with the gas inlets of the extraction column and the desorber, respectively, and gas flowmeters are arranged at the gas inlets of the extraction column and the desorber.

[0014] Further, the magnetic roller comprises a magnetic arc region, and the arc of the magnetic arc region is 240°.

[0015] According to the present disclosure, a whole process continuous gas-assisted magnetic separation system is provided, when in use, extraction is performed in a adsorption tank to complete the adsorption of targets with magnetic particles, afterwards, they enter an extraction column where the magnetic particles are captured by rising bubbles and enriched to the liquid level to form a magnetic particle solution enrichment region where the magnetic particles are separated from the raffinate by a magnetic roller, then the magnetic particles enter a desorber that is provided with a desorption liquid for separating the targets from the magnetic particles. Similarly, the magnetic particles are captured by rising bubbles and enriched to the liquid level to form a magnetic particle solution enrichment region where the magnetic particles are separated from the desorption liquid by a magnetic roller, afterwards, the magnetic particles are continuously sent to the adsorption tank for recycling.

[0016] The whole process continuous gas-assisted magnetic separation system combines an air flotation separation technology with a magnetic carrier separation technology, and still has a higher magnetic separation effect after an increase in the scale of the device; meanwhile, since the adsorption tank, the extraction column

and the desorber arranged in series are used for continuous magnetic separation of the adsorption, washing and desorption processes of the targets, respectively, and in combination with a continuous implementation of these three processes themselves, a whole process continuous separation of the target isolates can be achieved ultimately. At the same time, the system can not only achieve a whole process continuity of the target isolates, but also enable a whole process continuity and a direct recycling utilizability of the magnetic particle carriers.

Brief Description of the Drawings

[0017]

Figure 1 is a schematic flow diagram of a whole process continuous gas-assisted magnetic separation system provided by the present disclosure;

Figure 2 is a main view at the magnetic roller of a whole process continuous gas-assisted magnetic separation system provided by the present disclosure.

[0018] In the Figures:

1. adsorption tank; 2. extraction column; 3. desorber; 4. feed liquid inlet; 5. magnetic particle inlet; 6. stirring device; 7. air flotation column; 8. magnetic roller; 9. scraper; 10. mixture storage tank; 11. magnetic particle storage tank; 12. raffinate storage tank; 13. product storage tank; 14. peristaltic pump; 15. gas flowmeter; 16. magnetic arc region; 17. washing liquor storage tank.

Detailed Description

[0019] The technical solution of the present disclosure will be further described below by way of specific embodiments in combination with accompanying drawings.

[0020] As shown in Figure 1 and Figure 2, a whole process continuous gas-assisted magnetic separation system is provided by this example, the system comprises an adsorption tank 1, the adsorption tank 1 is connected with an extraction column 2, and the extraction column 2 is connected with a desorber 3;

a feed liquid inlet 4 and a magnetic particle inlet 5 are arranged at the top of the adsorption tank 1, a mixed liquid outlet is arranged at the bottom of the adsorption tank 1, and a stirring device 6 is arranged inside the adsorption tank 1;

the extraction column 2 comprises a hollow airflotation column 7, a mixed liquid inlet and a raffinate outlet are arranged on the air flotation column 7, the mixed liquid inlet is connected with the mixed liquid outlet, and a magnetic roller 8 is arranged at the top of the air flotation column 7, a scraper 9 is arranged on one side of the magnetic roller 8, a mixture storage tank 10 is arranged

at the end of the scraper 9, and a gas inlet is arranged at the bottom of the air flotation column 7;

the desorber 3 comprises a hollow air flotation column 7, a magnetic particle inlet and a product outlet are arranged on the air flotation column 7, and the magnetic particle inlet is connected with the mixture storage tank 10, a magnetic roller 8 is arranged at the top of the air flotation column 7, a scraper 9 is arranged on one side of the magnetic roller 8, a magnetic particle storage tank 11 is arranged at the end of the scraper 9, the magnetic particle storage tank 11 is connected with the adsorption tank, and a gas inlet is arranged at the bottom of the air flotation column 7;

the air flotation columns 7 of the extraction column 2 and the desorber 3 are connected with a washing device, and the washing port of the washing device is arranged opposite to the scraper 9.

[0021] The adsorption tank 1 in the system has a larger capacity, that is, it can be used to prepare a sufficient amount of adsorbed raw material liquid at one time for subsequent continuous use, and also provides high-capacity storage to easily realize the closed-loop circulation. A glass-made manhole and liquid level observation hole are arranged on the adsorption tank 1 so as to observe the materials and the liquid level in the adsorption tank 1.

[0022] The washing device comprises a washing liquor storage tank 17 which is connected with the washing port, wherein the extraction column 2 and the desorber 3 use the same washing liquor storage tank 17, or the extraction column 2 and the desorber 3 are separately provided with a washing liquor storage tank 17.

[0023] In the whole process continuous gas-assisted magnetic separation system, a plurality of extraction columns 2 and a plurality of desorbers 3 can be employed respectively, specifically a plurality of extraction columns 2 are included, and the plurality of extraction columns 2 are connected in series through mixed liquid inlets and raffinate outlets;

wherein, the mixed liquid inlet of the extraction column 2 at the head end is connected with the mixed liquid outlet, and the raffinate outlet of the extraction column 2 at the tail end is connected with the raffinate storage tank 12.

[0024] Alternatively, the whole process continuous gas-assisted magnetic separation system comprises a plurality of extraction columns 2, the mixed liquid inlet of each extraction column 2 is connected with the mixed liquid outlet, and the raffinate outlet of each extraction column 2 is connected with the raffinate storage tank 12.

[0025] The above two forms are the plurality of extraction columns 2 being connected in series and in parallel, respectively, wherein, when the extraction columns 2 are connected in series, they can be used for multi-stage magnetic separation, so that the magnetic particles in the raffinate can be separated more sufficiently; while when they are connected in parallel, a plurality of extraction columns 2 can be used at the same time, resulting in higher magnetic separation efficiency.

[0026] Similarly, the desorbers 3 can also be connected in series or in parallel, that is, a plurality of desorbers 3 can be included, and the plurality of desorbers 3 are connected in series through magnetic particle inlets and product outlets;

wherein, the magnetic particle inlet of the desorber 3 at the head end is connected with the mixture storage tank 10, and the product outlet of the desorber 3 at the tail end is connected with the product storage tank 13.

[0027] Alternatively, the whole process continuous gas-assisted magnetic separation system comprises a plurality of desorbers 3, the magnetic particle inlet of each desorber 3 is connected with the mixture storage tank 10, and the product outlet of each desorber 3 is connected with the product storage tank 13.

[0028] The desorbers 3 connected in series are more sufficient for the recovery of the magnetic particles and reduce the circulation loss of the magnetic particles; while the desorbers 3 connected in parallel can improve the recovery efficiency of the magnetic particles.

[0029] The feed liquid inlet 4, the magnetic particle inlet 5 and the stirring device 6 are arranged on the tank cover of the adsorption tank 1, and the tank cover of the adsorption tank 1 is connected with a lifting assembly.

[0030] The adsorption tank 1 can be lifted and lowered by arranging a lifting assembly, which facilitates the maintenance and overhaul of the interior of the device in the later period, wherein, the lifting assembly is a telescopic cylinder, a hydraulic cylinder, and an electric hoist, etc.

[0031] Preferably, peristaltic pumps 14 are arranged between the adsorption tank 1 and the extraction column 2, between the extraction column 2 and the desorber 3 and between the washing device and the scraper 9, wherein, the flow rate of the peristaltic pump 14 is adjusted in a range of 3 to 6800 mL/min.

[0032] This example further comprises a control device which includes a controller, the controller is connected with the stirring device 6, the magnetic roller 8, the lifting assembly and the peristaltic pump 14, and the controller is provided with a control button. The control device is arranged in the lower part of the system, which is easy to operate. The control device is provided with corresponding control buttons, which facilitates the unified manipulation of the operator.

[0033] This example further comprises a gas supply line which is connected with the gas inlets of the extraction column 2 and the desorber 3, respectively, and gas flowmeters 15 are arranged at the gas inlets of the extraction column 2 and the desorber 3.

[0034] The extraction column 2 and the desorber 3 perform a unified gas supply operation through the gas supply line, wherein a corresponding gas flowmeter 15 is arranged at the gas inlet, and the measurement range of the gas flowmeter 15 is set at 6 to 60 L/h.

[0035] The magnetic roller 8 comprises a magnetic arc region 16, and the arc of the magnetic arc region 16 is 240°. The surface of the magnetic arc region 16 of the magnetic roller 8 is made to have a relatively uniform

capturing force on the magnetic particles. In the design of the magnetic circuit system, a certain amount of small-size rubidium ferboron rare earth permanent magnets are arranged in an annular shape at a certain distance along the surface of a sleeve, so that a uniform magnetic field intensity on the surface of the sleeve can be generated.

[0036] The mixture storage tank 10, the magnetic particle storage tank 11, the raffinate storage tank 12, the product storage tank 13, and the washing liquor storage tank 17 used in the whole process continuous gas-assisted magnetic separation system are all made of stainless steel, the shape of which is generally set to be a cuboid shape. At the same time, multiple spare storage tanks can be provided to configure and store the washing clear liquid and the desorption liquid.

[0037] Specifically, when in use, the magnetic carriers (i.e., magnetic particles) and the solution containing the target isolates are mixed in the adsorption tank 1 and fully stirred by the stirring device 6 to accelerate the extraction process of the targets by the magnetic particles and promote the full suspension of the magnetic particles, then the mixture is pumped into the extraction column 2 (taking two extraction columns 2 as an example, only one of them can be used, or they can be used simultaneously or alternately or in series), and the magnetic particles are fully captured by the magnetic roller 8 with the aid of the air flotation column 7. The magnetic particles on the magnetic roller 8 are washed off by the washing liquor pumped from the washing liquor storage tank 17 and collected into the mixture storage tank 10, and the raffinate is collected into the raffinate storage tank 12, the suspension inside the mixture storage tank 10 is pumped into the desorber 3, and desorption liquid is contained in the desorber 3, the targets desorb from the magnetic particles and enter the product storage tank 13, the desorbed magnetic particles are captured by the magnetic roller 8 and washed off by the washing liquor, and then enter the magnetic particle storage tank 11, the magnetic particles can be returned to the adsorption tank for recycling, and form a continuous closed-loop circulation.

[0038] The technical principle of the present disclosure has been described above in combination with the specific examples. These descriptions are merely illustrative of the principles of the present disclosure and are not to be construed in any way as limiting the protection scope of the present disclosure. Based on the explanation herein, those skilled in the art will be able to think of other specific embodiments of the present disclosure without giving any creative labor, which will fall within the protection scope of the present disclosure.

Claims

1. A whole process continuous gas-assisted magnetic separation system, wherein it comprises an adsorp-

tion tank (1), the adsorption tank (1) is connected with an extraction column (2), and the extraction column (2) is connected with a desorber (3); a feed liquid inlet (4) and a magnetic particle inlet (5) are arranged at the top of the adsorption tank (1), a mixed liquid outlet is arranged at the bottom of the adsorption tank (1), and a stirring device (6) is arranged inside the adsorption tank (1); the extraction column (2) comprises a hollow air flotation column (7), a mixed liquid inlet and a raffinate outlet are arranged on the air flotation column (7), the mixed liquid inlet is connected with the mixed liquid outlet, and a magnetic roller (8) is arranged at the top of the air flotation column (7), a scraper (9) is arranged on one side of the magnetic roller (8), a mixture storage tank (10) is arranged at the end of the scraper (9), and a gas inlet is arranged at the bottom of the air flotation column (7); the desorber (3) comprises a hollow air flotation column (7), a magnetic particle inlet and a product outlet are arranged on the air flotation column (7), and the magnetic particle inlet is connected with the mixture storage tank (10), a magnetic roller (8) is arranged at the top of the air flotation column (7), a scraper (9) is arranged on one side of the magnetic roller (8), a magnetic particle storage tank (11) is arranged at the end of the scraper (9), the magnetic particle storage tank (11) is connected with the adsorption tank, and a gas inlet is arranged at the bottom of the air flotation column (7); the air flotation columns (7) of the extraction column (2) and the desorber (3) are connected with a washing device, and the washing port of the washing device is arranged opposite to the scraper (9).

2. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein it comprises a plurality of extraction columns (2), and the plurality of the extraction columns (2) are connected in series through mixed liquid inlets and raffinate outlets; wherein, the mixed liquid inlet of the extraction column (2) at the head end is connected with the mixed liquid outlet, and the raffinate outlet of the extraction column (2) at the tail end is connected with the raffinate storage tank (12).
3. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein it comprises a plurality of extraction columns (2), and the mixed liquid inlet of each extraction column (2) is connected with the mixed liquid outlet, and the raffinate outlet of each extraction column (2) is connected with the raffinate storage tank (12).
4. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein it comprises a plurality of desorbers (3), and the

plurality of the desorbers (3) are connected in series through magnetic particle inlets and product outlets; wherein, the magnetic particle inlet of the desorber (3) at the head end is connected with the mixture storage tank (10), and the product outlet of the desorber (3) at the tail end is connected with the product storage tank (13). 5

5. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein it comprises a plurality of desorbers (3), and the magnetic particle inlet of each desorber (3) is connected with the mixture storage tank (10), and the product outlet of each desorber (3) is connected with the product storage tank (13). 10 15

6. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein the feed liquid inlet (4), the magnetic particle inlet (5) and the stirring device (6) are arranged on the tank cover of the adsorption tank (1), and the tank cover of the adsorption tank (1) is connected with a lifting assembly. 20

7. The whole process continuous gas-assisted magnetic separation system according to claim 6, wherein peristaltic pumps (14) are arranged between the adsorption tank (1) and the extraction column (2), between the extraction column (2) and the desorber (3) and between the washing device and the scraper (9). 25 30

8. The whole process continuous gas-assisted magnetic separation system according to claim 7, wherein it further comprises a control device which includes a controller, the controller is connected with the stirring device (6), the magnetic roller (8), the lifting assembly and the peristaltic pump (14), and the controller is provided with a control button. 35 40

9. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein it further comprises a gas supply line which is connected with the gas inlets of the extraction column (2) and the desorber (3), respectively, and gas flowmeters (15) are arranged at the gas inlets of the extraction column (2) and the desorber (3). 45

10. The whole process continuous gas-assisted magnetic separation system according to claim 1, wherein the magnetic roller (8) comprises a magnetic arc region (16), and the arc of the magnetic arc region (16) is 240°. 50

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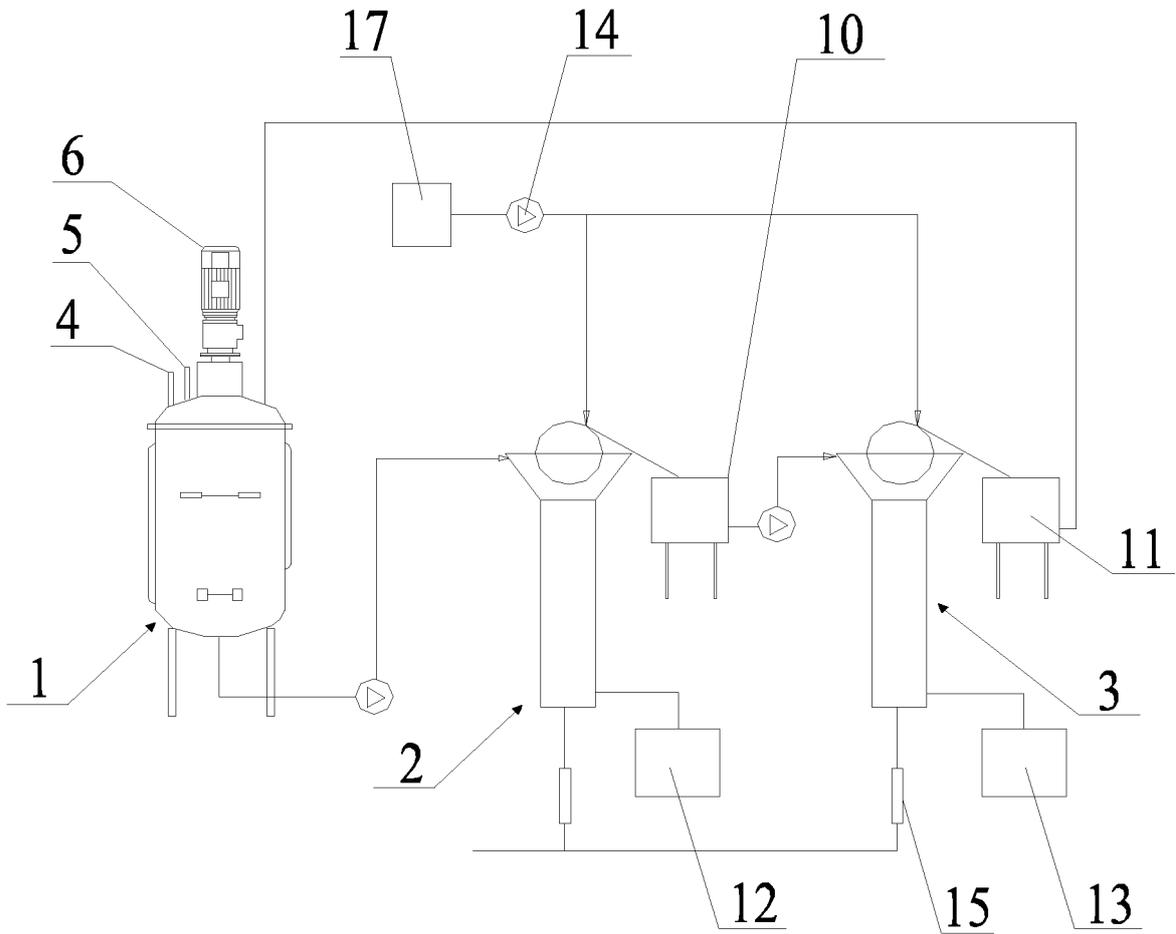


Figure 1

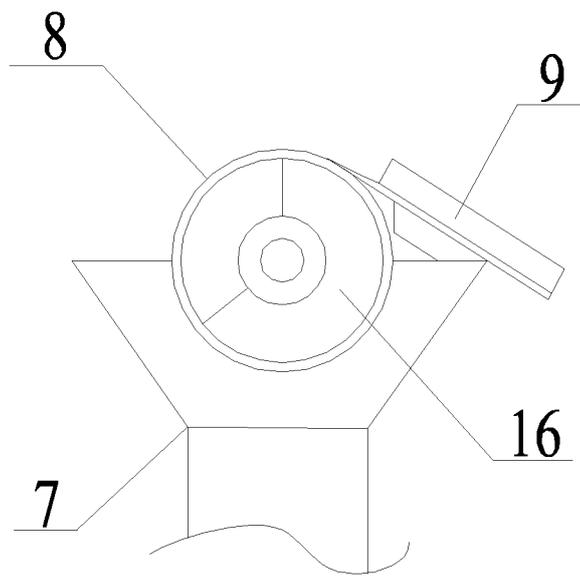


Figure 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/074332

5 A. CLASSIFICATION OF SUBJECT MATTER		
B03C 1/32 (2006.01) i According to International Patent Classification (IPC) or to both national classification and IPC		
10 B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) B03C; B01D		
15 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNABS, CNKI, SIPOABS, WPI: 磁, 分离, 颗粒, 吸附, 萃取, 解吸, 气浮, 刮板 magneti+, separat+, particle, grain, adsorb, extract, desorb, gas, air, scraper		
20 C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
25 X	CN 101164700 A (INSTITUTE OF PROCESS ENGINEERING, CHINESE ACADEMY OF SCIENCES), 23 April 2008 (23.04.2008), claim 1, description, page 2, line 10 to page 4, 4th line from the bottom, and figure 1	1-10
A	CN 105301265 A (SHANXI NORMAL UNIVERSITY), 03 February 2016 (03.02.2016), entire document	1-10
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30 A	CN 204017444 U (NINGBO MUNICIPAL CENTER FOR DISEASE CONTROL & PREVENTION), 17 December 2014 (17.12.2014), entire document	1-10
A	JP 2005074371 A (TSUKISHIMA KIKAI CO.), 24 March 2005 (24.03.2005), entire document	1-10
35 <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents:		
40 "A"	document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
45 "L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed	
50 Date of the actual completion of the international search 25 September 2017		Date of mailing of the international search report 30 September 2017
Name and mailing address of the ISA State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451		Authorized officer LIU, Hui Telephone No. (86-10) 62084774
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Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
 Information on patent family members

International application No. PCT/CN2017/074332

	Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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10	CN 105301265 A	03 February 2016	CN 105301265 B	30 June 2017
	CN 102500460 A	20 June 2012	CN 102500460 B	30 April 2014
	CN 204017444 U	17 December 2014	None	
	JP 2005074371 A	24 March 2005	JP 4353466 B2	28 October 2009
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