(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 March 2011 (24.03.2011)

PCT

(10) International Publication Number
WO 2011/034409 A1

(51) International Patent Classification:
C10B 47/30 (2006.01) *C10J 3/00* (2006.01)

(21) International Application Number:
PCT/LV2010/000010

(22) International Filing Date:
17 September 2010 (17.09.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
P-09-157 18 September 2009 (18.09.2009) LV

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: REACTOR FOR PYROLYSIS OF BIOMASS

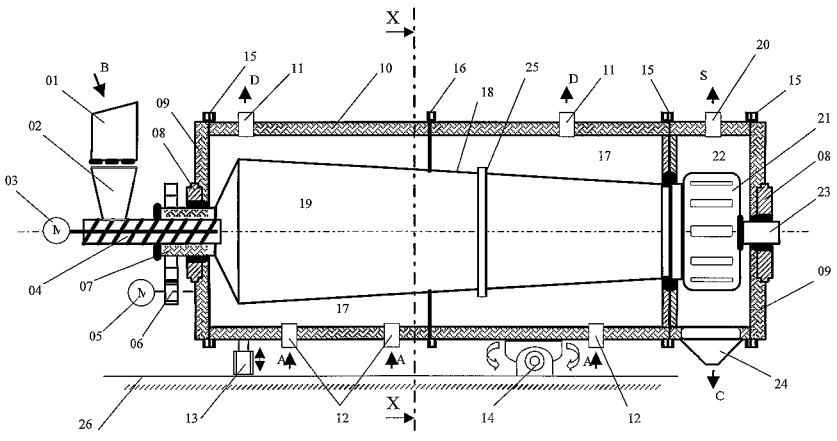


Fig. 1

(57) Abstract: A reactor for pyrolysis of biomass comprising a reactor chamber (18) having an entrance end, an opposing discharge end, a longitudinal axis about which the reactor chamber is rotatable, a heating chamber (17) disposed around the reactor chamber (18), an air-tight charging hopper (1, 2, 3, 4), an air-tight delivery chamber (22), and a drive unit (5, 6) for rotating the reactor chamber (18) about its longitudinal axis, whereas the reactor is mounted onto a base (26) in a swingable relation to each other so that a tilt angle of the reactor relative to the base (26) can be changed freely, thereby changing an orientation of the longitudinal axis of the reactor chamber in a vertical plane.

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REACTOR FOR PYROLYSIS OF BIOMASS

FIELD OF THE INVENTION

The present invention relates to biomass conversion into energy. More particular, the present invention relates to biomass pyrolytic conversion to fuels in rotary type reactor.

BACKGROUND OF THE INVENTION

Biomass resources can be used as bioenergy. Biomass in general is the biodegradable fraction of products, waste and residues from agriculture, including vegetal and animal substances, forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. Usage of biomass resources is developed in three ways: biomass for heating purposes (bio-heating); biomass for electricity production (bio-electricity); and biomass for transport fuels (transportation biofuels).

As mentioned, many types of biomass are available for conversion into energy. The efficiency of converting biomass into energy is determined by specific characteristics of the applied biomass technology.

At present, the following technologies are developed and applied for biomass conversion into electric energy:

- Firing in boilers (Fluid Beds as a rule) with generation of steam and its utilization in Rankin cycle; application of this method is limited by the necessity of gathering big amounts of biomass and by produced air pollution. Emission of the products of combustion contains large amounts of pollutants in spite of complex and costly purification and gas eliminating systems.
- Gasification of biomass and further firing of the gases in gas turbines or engines; low calorific value of the generated fuel gases seriously limits its efficiency.
- Pyrolysis of the biomass. This method, if successful, provides gaseous or liquid fuels with high calorific value for power generation and seems to be especially convenient for small power units destined for in situ heat generation.

Pyrolysis of biomass and in particular rotary reactors for pyrolysis are taught in the art. As an example, U.S. Pat. No. 5,688,117 "Rotatable Heating Chamber with

Internal Tubes for Waste" by May et al. describes a relatively long, rotating low-temperature carbonization drum that has many parallel heating tubes inside, in which the waste is heated largely to the exclusion of air. The low-temperature carbonisation chamber (pyrolysis reactor) converts the waste, which is fed through a waste conveyor into low-temperature carbonization gas and pyrolysis residue. Such heating method does not allow for control of temperature gradient along the drum length.

Another example, U.S. Pat. No. US patent No. 5,657,705 to Martin et al describes a furnace for effecting pyrolysis of waste material that includes an essentially cylindrical cavity for effecting pyrolysis of the waste material rotating around its lengthwise axis, a combustion chamber located around the cavity and injectors for introducing fuel and comburant into the combustion chamber.

The available solutions that are brought herein as references as well as other solutions fail to provide an efficient pyrolyser for biomass conversion into energy. Moreover, in the prior art apparatus an optimal performance can be achieved only for certain type of biomass, and because of variation in the biomass product the prior art apparatus operational characteristics are far from optimal.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a reactor for biomass pyrolytic conversion to energy such as electric power and heat generation.

It is an object of the present invention to provide a reactor for biomass pyrolytic conversion with an improved efficiency of the system for processing of biomass with different chemical and physical characteristics.

It is another object of the present invention to provide a reactor for biomass pyrolytic conversion to energy that is in situ and eliminate the high cost involved in biomass transportation.

The objects of the invention are attained through a reactor for pyrolysis of biomass that comprises a reactor chamber for pyrolytic conversion of biomass having an entrance end, an opposing discharge end, and a longitudinal axis about which the reactor chamber is rotatable; a heating chamber disposed around the reactor chamber for heating the biomass in the reactor chamber; an air-tight charging hopper in communication with the entrance end of the reactor chamber for feeding the biomass

into the reactor chamber; an air-tight delivery chamber in communication with the discharge end of the reactor chamber for extracting products of the biomass pyrolysis; a drive unit for rotating the reactor chamber about its longitudinal axis, the reactor being characterized in that the reactor is mounted onto a base in a swingable relation to each other so that a tilt angle of the reactor relative to the base can be changed freely, thereby changing an orientation of the longitudinal axis of the reactor chamber in a vertical plane.

Preferably the reactor comprises a tilting mechanism for changing the tilt angle.

Preferably the substantial part of the reactor chamber has a progressively decreasing cross-section. For example, the reactor chamber may be of an essentially conical shape, or essentially pyramidal shape, or any other shape that has a progressively decreasing cross-section.

In a preferred embodiment of a reactor comprises a hand-basket disposed in the delivery chamber and being in communication with the discharge end of the reactor chamber.

Preferably, the reactor comprises a plurality of pads disposed on an inner surface of the reactor chamber for facilitating advancement and mixing of the biomass.

According to one aspect of the invention the tilting mechanism comprises and axis and pusher.

According to another aspect of the invention the tilting mechanism is electronically controlled.

According to still another aspect of the invention the drive unit for rotating the reactor is adopted for continually changing a rotation velocity and direction.

According to further aspect of the invention the drive unit is electronically controlled.

In a preferred embodiment the reactor comprising an electronic controller for changing a rotation velocity, direction, and the orientation of the longitudinal axis to control the advancement of the biomass hereby adjusting parameters of a pyrolytic reaction.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is longitudinal cross-sectional view of a reactor according to the present invention.

FIG. 2 is cross-sectional view of the reactor taken along the line X-X

FIG. 3 is enlarged view of an inner wall of the rotary reactor

DETAILED DESCRIPTION OF THE INVENTION

Referring to the Fig. 1 and Fig. 2 it is seen that the biomass B is pressed in the vibrating hopper 1 and feeding chamber 2 so to reduce hardly anything the presence of air (O_2). The feeding of the biomass material through cochlea 4 is continuous and uninterrupted so that to prevent the presence of the air in reactor chamber 18. In the cochlea 4 the biomass material is preheated and pushed further into the reactor chamber 18. The cochlea 4 is actuated by the motor 3. The hopper 1, feeding chamber 2 and cochlea forms an air-tight charging hopper that is in communication with the entrance end of the reactor chamber 18 for feeding the biomass into the reactor chamber 18.

The rotatable reactor chamber 18 or rotor can have the shape of cylinder, conic or pyramid, so that to process the biomass with reference of his characteristics (specific gravity, granulation, etc.). In the preferred embodiment the reactor chamber has a shape that progressively narrows down towards the discharge end.

The plurality of pads 19 disposed on an inner surface of the reactor chamber 18 provides the continuous mixing of the biomass and its progressive transfer along the reactor chamber 18 towards hand-basket 21 and the delivery chamber 22. The pads 19 are arranged on the internal wall of the reactor chamber 18 and are fixed according to helicoidal lines and the sizes defined in the project. Their pyramidal shape, shown in enlarge view on Fig. 3, with different slope of the surfaces, allow the mixing and the push along the longitudinal axis of the biomass material while, with opposite rotation of the reactor chamber 18, it slow down the advancement of the biomass material.

The hand-basket 21 disposed in the delivery chamber 22 and being in communication with the discharge end of the reactor chamber 18 is built with a particular grating to keep for some time the solid phase char before to collect it in the hopper 24. Thus facilitating further separation of syngas from char. The unloading of the hopper 24 is continuous and is regulated so as to impede the loss of the syngas S with the char. The syngas is pumped out through the valve 20 and sent to a general plant for the use.

The rotatable reactor chamber 18 is composed with several elements arranged with flanges 25. The length of each element can be from 3.000 to 5.000 mm., its diameter

can be from 1.500 to 4.000 mm depending on the requested production and the kind of biomass to process. The reactor chamber 18 is fixed with the bearings 8, refrigerated and hermetic as to impede the loss of hot gas from heating chamber 17. The drive unit 6 that comprises the motor 5 rotates the reactor chamber 18 about its longitudinal axis. The drive unit 6 allows changing the rotation speed and direction.

The heating chamber 17 is composed with the multi-layered thermo-insulated elements 10 connected by the joints 16. The length of the element can be from 3.000 to 6.000 mm depending on the diameter of the project.

The temperature of the heating chamber 17 is adjusted with the quantity of hot gas supplied through valves 12, 11 (A – D).

The reactor can modify the slope or tilt of its longitudinal axis with the rotation around the fulcrum 14 with the action of the group 13. In the preferred embodiment the group 13 is a tilting mechanism comprising the fulcrum 14 or an axis and a pusher.

In operation.

The process of "pyrolysis gasification" occurs in the reactor chamber 18, cylindrical, conical or pyramidal, rotating inside the heating chamber 17.

The biomass is fed in continuously by means of a group of a vibrating hopper 1 and cochlea 4, with a heated chamber. This system prevents the presence of the air (O_2) in the reactor.

The circulation of hot gas in the heating chamber 17 is provided by means of a series of modular valves 11-12, arranged on the cylindrical surface and distributed along the longitudinal axis thus to make the gradient of temperature in the various phases of process of the pyrolysis.

The whole reactor can rotate or tilt in the vertical plane by means of tilting mechanism 13, 14 in the both directions (+/-) in relation to horizontal so that to control the advancement of the biomass and the production of the gas (syngas) and the derivates: char (solid fraction) and tar (liquid fraction).

Depending on the quantity and the characteristics of processed biomass, the following parameters of working of reactor and the control of process of pyrolysis are regulated:

- the rotating speed of the reactor chamber 18 with the possibility to reverse its motion;
- the gradient of temperature along the heating chamber 17.

- the tilt or slope (+/-) of the reactor in the vertical plan.
- the quantity and the crossed circulation of the burnt gas.

The pyrolysis (scission by heating of the organic material) can made in the range of temperature of 400 to1.000 °C in the requested time for the production of expected quantity of the gas.

In the last part of the reactor is arranged a special chamber 22 to collect the syngas and the secondary products of pyrolysis, char and tar, combustibles utilized in the general plant to produce more energy.

The materials used for the construction of the prototype reactor are special steel for high temperature, stainless steel, fireproof materials, components with high heating resistance and the abrasion of the components of biomass.

The scheme of reactor of Fig.1 is indicative. The dimensions of the reactor change acting as the quantity and the characteristics of the biomass.

The process of "pyrolysis" is verified by sensors for the measure of the temperature in the 3 zones of the hot chamber, of the char and the syngas produced.

An electronic controller (computer), in the preferred embodiment of PLC (Programmable Logic Controller) type, with appropriate software, manages all the process and the signals of anomalies of functioning. The set program manages in full the process acting in accordance with the kind of biomass to use.

The regulations are automatics:

- the range of the burnt gas.
- the rotating speed and the tilt of the reactor.
- the quantity of the biomass.
- temperature, pressure, etc..

By means of continuous analysis of the mixer of produced gas (syngas) the electronic controller controls and corrects the characteristic parameters of the process (gradient of the temperature and the time of heating of the biomass).

In the process of pyrolysis the biomass is thus decomposed resulting in solid and gaseous phases where the gaseous phase is burnt with generation of exhaust gases in amounts much lower than in other processes; for instance, in waste incineration process.

The solid phase is rendered inert using part of the generated gases in the process of glassification, at the same time recovering most of the energy contained in coal, which is the main component of the solid phase.

The process is flexible and can be easily controlled at all stages. The efficiency factor may exceed 70%.

PARTS LIST

1 - vibrating hopper of load of the biomass

2 - chamber of feeding of the cochlea

3 - motor for the actuation of the cochlea

4 - cochlea of feeding of biomass

5 - motor with inverter for the actuation of the drive unit

6 – drive unit for the rotation of the reactor chamber

7 - insulated multi-layered elements for the thermal insulation of the reactor

8 - group of refrigerated bearing of rotation of the reactor chamber

9 - insulated element of the heating chamber

10 - thermo-insulated multi-layered element

11 - valves of the flow and the recycling of the hot gas

12 - valves of the forcing into of the hot gas

13 – pusher for regulation of the tilt of the reactor chamber

14 - clasp (fulcrum) for tilting of the reactor

15 - flanged joints to fixing

16 - joint of connection of the elements of heating chamber

17 - heating chamber

18 - reactor chamber

19 - pads on the inner surface of the reactor chamber

20 - valves of digging out of syngas

21 - hand-basket with grating to collect the char

22 - delivery chamber to collect the products of pyrolysis

23 - shaft of rotation of rotor's group

24 - hopper to collect the char

25 - flanges of the connection of reactor chamber elements

26 - base.

CLAIMS

1. A reactor for pyrolysis of biomass comprising:

a reactor chamber for pyrolytic conversion of biomass having an entrance end, an opposing discharge end, and a longitudinal axis about which the reactor chamber is rotatable;

a heating chamber disposed around the reactor chamber for heating the biomass in the reactor chamber;

an air-tight charging hopper in communication with the entrance end of the reactor chamber for feeding the biomass into the reactor chamber;

an air-tight delivery chamber in communication with the discharge end of the reactor chamber for extracting products of the biomass pyrolysis;

a drive unit for rotating the reactor chamber about its longitudinal axis, **characterized in that**

the reactor is mounted onto a base in a swingable relation to each other so that a tilt angle of the reactor relative to the base can be changed freely, thereby changing an orientation of the longitudinal axis of the reactor chamber in a vertical plane.

2. The reactor according to claim 1, comprising a tilting mechanism for changing the tilt angle.

3. The reactor according to claim 1, wherein the substantial part of the reactor chamber has a progressively decreasing cross-section.

4. The reactor according to claim 1, comprising a hand-basket disposed in the delivery chamber and being in communication with the discharge end of the reactor chamber.

5. The reactor according to claims 1-4, comprising a plurality of pads disposed on an inner surface of the reactor chamber for facilitating advancement and mixing of the biomass.

6. The reactor according to claim 2, wherein the tilting mechanism comprises an axis and a pusher.

7. The reactor according to claim 2, wherein the tilting mechanism is electronically controlled.

8. The reactor according to claim 1 or 7, wherein the drive unit for rotating the reactor is adopted for continually changing a rotation velocity and direction.

9. The reactor according to claim 8, wherein the drive unit is electronically controlled.

10. The reactor according to claim 9, comprising an electronic controller for changing a rotation velocity, direction, and the orientation of the longitudinal axis to control the advancement of the biomass hereby adjusting parameters of a pyrolytic reaction.

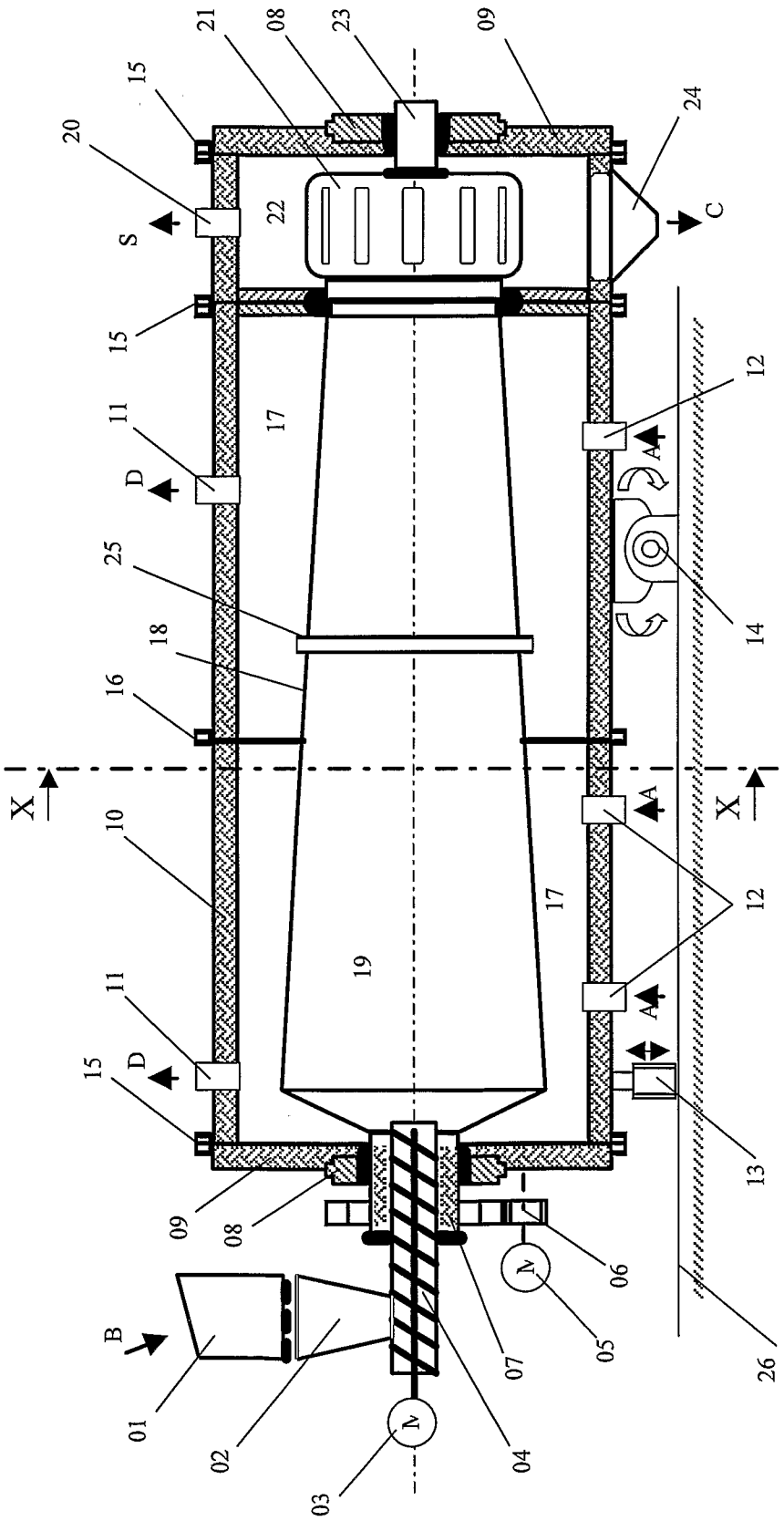

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Fig. 1

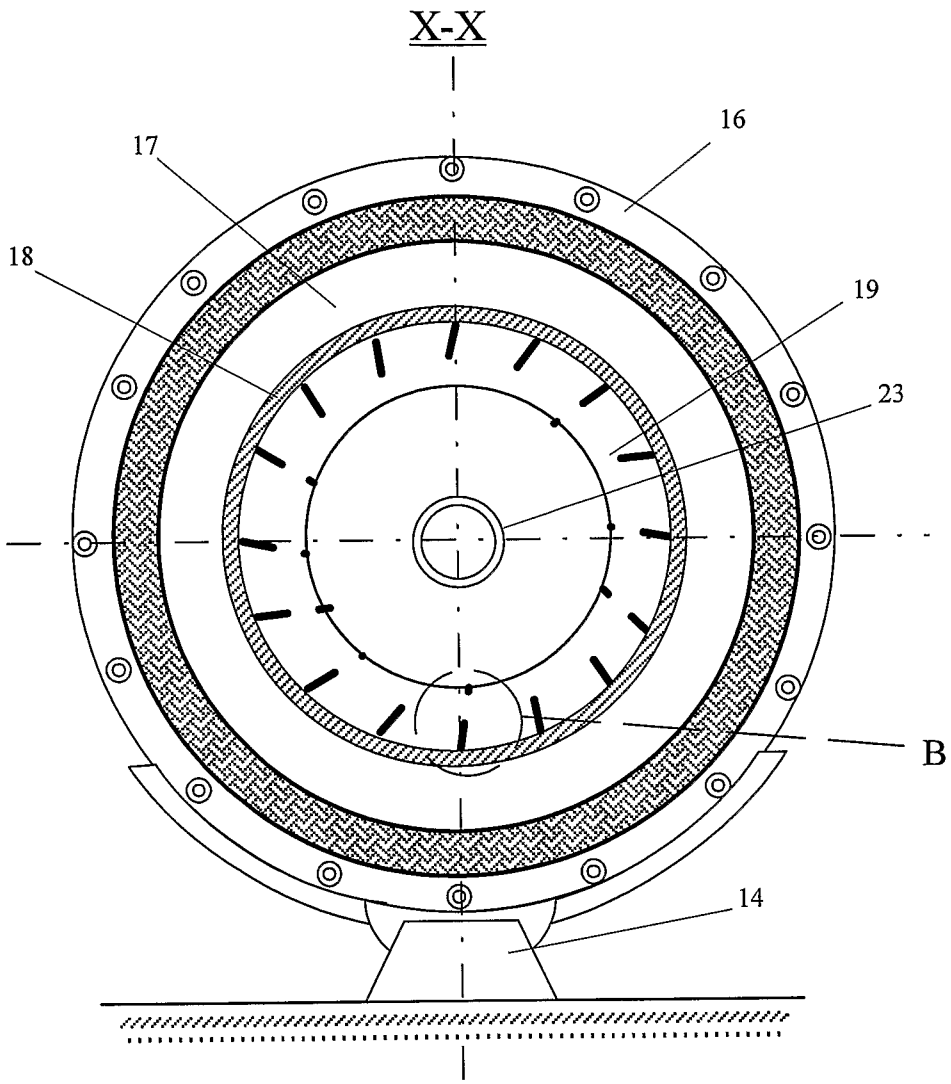


Fig.2

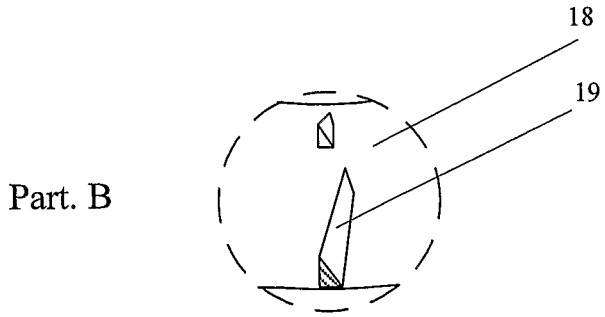


Fig.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/LV 2010/000010

A. CLASSIFICATION OF SUBJECT MATTER ***C10B 47/30*** *(2006.01)*
C10J 3/00 *(2006.01)*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10B 1/00-1/10, 47/00, 47/30, 53/00, 57/00, 57/14, C10J 3/00, 3/02, 3/20, 3/72, C10L 1/00, F23G 5/00, 5/20, F27B 7/00, 7/20, 7/22

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)
PAJ, Esp@cenet, PCT Online, USPTO DB, RUPTO, EAPO, DEPATISNET

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5688117 A (SIEMENS AKTIENGESELLSCHAFT) 18.11.1997, abstract, p. 2, lines 15-63, p. 4, line 35-p. 5, line 11, fig. 1, 2	1-10
A	DE 102006013617 A1 (UNIVERSITAT KASSEL) 27.09.2007, abstract, par. 7, 8, 13, 19, 20, 24, 27, fig. 1	1-10
A	US 5657705 A (INSTITUT FRANCAIS DU PETROLE) 19.08.1997, abstract, fig. 1	1-10
A	RU 2346026 C2 (OBSCHESTVO S OGRANICHENNOI OTVETSTVENNOSTYU "ALTERNATIVNYE ENERGETICHESKIE SISTEMY") 10.02.2009, abstract	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 December 2010 (24.12.2010)	27 January 2011 (27.01.2011)

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