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(54) Benævnelse: **ANORDNING TIL OMDANNELSE AF KINETISK ENERGI FRA EN STRØMNING AF BØLGER, VIND- ELLER VANDSTRØMME TIL MEKANISK ROTATIONSENERGI**

(56) Fremdragne publikationer:
WO-A1-2005/061887
WO-A2-2014/111800
KR-A- 20110 107 881
US-A1- 2010 237 625
US-A1- 2011 254 275

DESCRIPTION

TECHNICAL FIELD

[0001] The invention relates generally to a low cost device that makes an efficient use of the energy from waves or water or wind currents, using cross-flow turbines and without the need of deflectors. It is especially suitable for pumping sea water and for generating electricity by harnessing energy from the sea waves.

STATE OF THE ART

[0002] Known are in the art the devices for converting kinetic energy from a flow of waves, wind or water currents into mechanical energy of rotation (for generation of electricity), comprising a cross flow turbine, the turbine being provided with fixed curved blades arranged in squirrel cage configuration about an axis of rotation.

[0003] Examples of these devices are described in documents WO 2014/111800, KR 2011 0107881, WO 2005/061887, US 2011 /254275, US 2010/237625 as well as KR100191636 B1 and KR101492768B1.

[0004] KR100191636 B1 discloses a turbine mounted on two floaters that maintain the lower half of the turbine immersed, thus causing that the flow that passes between the floaters rotates the turbine.

[0005] In KR101492768 B1 a turbine mounted on a floating device is shown, but the arrangement of the turbine is fully sunk. The device is complex, since it comprises a surrounding casing designed to channel water in the lower part of the turbine.

[0006] In general, the squirrel configuration turbines with fixed blades that operate in liquid fluids are provided with a deflector aimed at channeling the fluid through the outer portion of the turbine, and only through one side of the turbine.

[0007] Thus, in general the known devices that operate with squirrel configuration turbines are complex devices that do not allow to maximize the harnessing of the energy of the incident flow. In particular, these devices do not allow to optimally extract energy from the waves energy, namely at the level of the water surface, and in general their structure is complex and cumbersome.

DESCRIPTION OF THE INVENTION

[0008] To overcome the shortcomings of the prior art, the present invention proposes a device for converting kinetic energy of a flow from waves, wind or water currents into mechanical energy of rotation (for generation of electricity), comprising a plurality of cross flow turbines, each one comprising fixed curved blades arranged in squirrel cage configuration about an axis of rotation. According to the invention the turbines are mounted on a floating support on the water, directly placed in the fluid flow and arranged successively one after another with their axes parallel to each other and perpendicular to the fluid flow.

[0009] This device is specially adapted to make efficient use of energy from waves, wind and water currents (it is very robust and economic) since it makes use of low cost cross-flow turbines, without the need of costly deflectors, baffles or flow channeling means destined to channel the flow in only a part of the turbines. The successive turbines allow for successively diminishing the flow energy, and then, the energy remaining after the flow having gone through a turbine is harnessed in the subsequent one.

[0010] In particular, the invention is very advantageous for its use in harnessing wave energy. The wave front, when reaching the turbines, mainly involves a vertical movement of the particles, which can be harnessed by the turbine. As the wave front progresses through successive turbines, it breaks, which means that the movement of the flow acquires progressively a horizontal direction, which can then be exploited by the following turbines.

[0011] In the case of the waves devices, where the water particles oscillate vertically, describing trochoidal trajectories and creating powerful surface currents in the form of breakers, the turbines as used in the present invention will always rotate in the same rotating direction independently of the incident flow, which in turn allows simplifying the electrical elements or downstream power electronics that will eventually be connected to the turbines. It works as a reef of offshore turbines or onshore breaker.

[0012] According to several optional features that can be combined with each other whenever technically possible:

- When operating as a wave's device, the axes of the turbines are parallel and horizontally mounted on the floating hulls structure support. In particular, this has to be understood as that the axes of the turbines are mounted on the floating support such that the axes are arranged horizontally when the device is placed in the water. This arrangement is particularly suited to take advantage of the surface energy of a vertical and horizontal stream of water. It also implies a reduced space occupation in the vertical direction, allowing it to be used in shallow waters or as a breakwater. It also allows getting it in and out of the water with a tugboat.
- the axes of the turbines are contained in the same plane, thus allowing to optimally successively harnessing the waves flow energy.
- the floating support has a U-cross section profile that forms a channel, such that a bottom hull or wall and two side hulls or walls, the axes of the turbines being rotatably supported between the two side hulls. This structure allows the hulls simultaneously

supporting the turbines, to protect them inferiorly and to channel water to the turbines as well as an easy access to the turbines from above.

- the structure comprises floating control means so that the device is movable between a lower position where the turbines are completely sunk and an upper position where the turbines are arranged completely above the water level. Thus, the turbines can be accessed for maintenance and the device can be moved along waters of varying depth. Thus, when placed in the waves the device will operate as a reef or a breakwater and it will be possible to adjust its vertical position to optimize the performance or to minimize the impact of storms.
- the floating control means are floodable floats.

[0013] In another variant of the invention, the axes of the turbines are vertically mounted with respect to the floating support. In this variant, the axes of the turbines can be arranged above the floating support for harnessing wind energy or placed under the level of the floating structure to operate as a water current power plant.
In all the variants described, it is envisaged that optionally:

- the axes of the turbines are arranged at regular intervals.
- the blades of the turbines have a cylindrical envelope.
- the floating support comprises means for anchoring it to the seabed, to prevent any takeoff but allowing some rotation around the anchor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] To complete the description and in order to provide for a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the description and illustrate embodiments of the invention, which should not be interpreted as restricting the scope of the invention, but just as examples of how the invention can be carried out. The drawings comprise the following figures:

FIG. 1 shows the theoretical pressure distribution on the surface of a circular cylinder according to the classis theory.

FIG. 2 shows the experimental pressure distribution on the surface of a circular cylinder.

FIG. 3 shows the theoretical pressure distribution on an outboard aerodynamic shaped circular cylinder.

FIG. 4 shows the cross section of a crossflow turbine with bent sheet blades.

FIG. 5 shows the cross section of a crossflow turbine with aerodynamic blades.

FIG. 6 shows the arrangement of several turbines supported on an anchored hull floating base to harness the energy of a wave front.

FIG. 7 shows the above arrangement in a transverse or profile view, to indicate the oscillating level of the water in the presence of waves.

FIG. 8 shows the flow characteristics affected by an aerodynamic shaped outboard edged circular cylinder according to researches related to the invention, emphasizing the boundary zone between the uniform outer flow and the altered zone or affected by the solid.

FIG. 9a shows the arrangement of the floating support and turbines to extract energy from a water stream.

FIG. 9b is a profile showing a series of turbines mounted with their axes in the same plane to extract energy from the waves.

FIG. 9c is analogous to FIG. 9a but in the case of its application to wind, with the turbines on the upper part.

FIG. 10 to 12 show a side elevated view, a plan view and a frontal elevated view respectively of a preferred embodiment of the present invention.

DESCRIPTION OF A WAY OF CARRYING OUT THE INVENTION

[0015] As it can be seen in FIG. 1, according to the classical theory and in the case of a perfect fluid, there would be no resistance or drag a solid placed in a moving fluid because of the equilibration of the pressures in the front and back sides of the solid 1. Therefore, this theory gives rise to the D'Alembert's paradox, consisting in that theoretically the drag force is zero on a body moving with constant velocity relative to the fluid, in direct contradiction to the observation of substantial drag on bodies moving relative to fluids.

[0016] Consequently, always according to the classical theory, if the solid were a cylinder there would not be a pressure difference between the two halves of the cylinder. This would apply to a turbine squirrel cage, whose envelope is cylindrical, so that according to this theory, there would be no possibility of extracting energy from the turbines placed fully facing the flow, i.e. without deflectors or water channeling means to the halves of the turbines 9 as disclosed in the documents of the prior art.

[0017] Instead, the practical implementation of the invention has led to industrially well tested experimental results, in particular it has been determined that an existing suction action by the downstream flow prevents from the theoretical existence of positive pressures on the back of the cylinder 1, as shown in FIG. 2 for a cylinder or an outboard edged cylinder as shown in FIG.3.

[0018] This formulation developed for cylinders and other simple shapes, clearly states that the pressure distribution as shown in 2-FIG. 3 has a pressure gradient in the outside flow direction 3 enabling forcing the fluid flow in a cylindrical turbine without deflectors or distributors.

[0019] Any fluid passing through the cylindrical turbine area, as shown in 8-FIG. 4, is deflected by the curvature of the blades thus creating a reaction in the blades with respect to the axis always of the same sign and consequently the turbine 9 will always rotate in the same direction independently of the flow. This facilitates its practical implementation jointly with rotary pumps or generators, in practice better than the alternative ones.

[0020] The inventive energy recovery device 19 in its most general form consists of arranging several crossflow type cylindrical turbines 9, as shown in FIG. 4 and in FIG. 5, with their axes parallel, spaced apart, interposing the water flow as shown in FIG. 7, which based in the physical principle described above, impinges on the curved blades 5-FIG. 4 and 6-FIG. 5, such that the turbine always rotates in the same direction 7-FIG.4 regardless of the direction or characteristics of the flow 8-FIG. 4. In particular, FIG. 9b, in the case of waves 13, all the turbines will rotate with the same rotation direction. In this case, the front of energy is represented by the water level 18.

[0021] The implementation of the invention was inspired using the velocity distribution obtained analytically, as shown in FIG. 8. In particular, the fluid area affected by the cylinder 17-FIG. 8 indicates that the active fluid front 3 is defined as a close and finite environment.

[0022] The cylindrical crossflow turbines 9, which does not unfavorably interfere with each other, will be arranged with their axes in parallel, as shown in FIG. 6, interposed in the energy flow 16, as shown in FIG. 7, FIG. 9a and 9c.

[0023] The rotational energy in the turbine, with low angular speed and high torque, will then be transformed by conventional means into electrical, hydraulic or mechanical energy.

[0024] To maintain a maximum turbine 9 resistance against the impulse of the fluid, in the case of the waves energy recovering system (vertical and horizontal flow) an anchor 14 and a horizontal stabilizer are also necessary. Flooding tubes arranged in the side hulls 12A, 12B allow adjusting the vertical position. Specifically, it will allow to sink the turbines 9 in cases of storms or to take them out from the water for maintenance. In the case of recovering energy from currents any known anchoring system is usable.

[0025] This floating support 10 can have water passage slits to destabilize the wave together with the effect of turbines and make the wave breaks.

[0026] The type of waves to be found in the installation site, and the cost's and capacity's installation will condition the size, number and arrangement of the turbines, as well as its funding. Its physical effect will be that of a reef in a floating off shore installation. If its location is made by a breakwater on the coast, its effect will be like a breakwater one.

[0027] Given the high torque and uneven rotation provided by the waves, it can be very useful and economical to pump seawater at high pressure to a reservoir on land or then turbinate or pump sea water to a desalination unit by reverse osmosis, or any other known type of use that avoids energy transformation stages. The auxiliary equipment may be located within the floating support 10-FIG. 7 or on land, to where the desalinate water, compressed air, water or oil pressure or electric power, would head according to the chosen design.

[0028] In all cases preferably cylindrical turbines 9 will be arranged as in FIGS. 4, 5, 6 and 7, in the device 19, of the type used in crossflow turbines. They consist of a series of curved blades preferably arranged in a squirrel cage as shown in FIGS. 4 and 6, reacting to the passage of fluid with a torque always the same sign, even with a changing direction of flow on the blade.

[0029] The preferred shape of the profiles will be such as the described in the patent ES2074010 by the same inventor, like the profiles shown in FIG. 5, or may be a simple bent plate or any curved surface 5-FIG. 4 for economy purposes.

[0030] The cylindrical turbine will have the side faces or bases of the cylinder closed to the flow with two disks which also support the blades and the mechanical axis, comprising also other intermediate discs to stiffen the blades, as it is usual in this type of turbine. The diameter and height of the cylindrical turbine will depend on the flow characteristics and power requirements and available space, its calculation preferably developed through the equations described for example in Doria J.J., Granero F. TEORIA INNOVADORA EN AERODINAMICA. PROTOTIPOS Y PATENTES Actas III Congreso Internacional de Ingenieria de Proyectos. 1.996 Barcelona.

[0031] The shaft, as described, is arranged perpendicular to the foreseeable and variable flow directions and it is connected to any known power transmitting means 15 (pump, generator, compressor, gear...).

[0032] FIG. 9a shows an embodiment of the device 19 for the harnessing of a water stream, illustrated as a rectangular front 18. Here, the turbines are placed with their axes vertical, under the floating support 10, which is in turn supported by two hulls 20. Only the first turbine of each row is shown, the successive turbines are placed behind.

[0033] FIG. 9c shows an embodiment of the device 19 analogous to that shown in FIG. 9a, but destined to harness the energy of a wind stream, and therefore the turbines are placed with their axes above the floating support.

[0034] FIGS. 10 to 12 show an embodiment of the invention comprising four rows, each provided with six successive turbines 9, arranged with their axes horizontal and in the same plane. The floating support 10 is basically a catamaran wherein the two hulls 10A, 10B support the axes of the turbines 9. Four rigid sails/ wings 10C fixed on the ends of the hulls 10A, 10B serve for orienting the base. The hulls 10A, 10B have floodable spaces inside that can extend in reservoirs placed inside the wings, which then contribute to control the water level. Although, there are six turbines in each row, it is obvious that more turbines can be provided to harness the maximum energy from the waves or current.

[0035] In this text, the term "comprises" and its derivations (such as "comprising", etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

[0036] The invention is obviously not limited to the specific embodiments described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

References

[0037]

(1) Circular cylinder, without blades.

(2) Pressure distribution.

(3) Uniform speed flow wherein the cylinder is submerged.

(4) Outboard shaped cylinder.

(5) Bent sheet blades

(6) Aerodynamic blades

(7) Rotating direction.

(8) Flow direction between blades.

(9) Cross-flow cylindrical Turbines.

(10) Floating support.

(10A, 10B) Hulls.

(10C) Rigid sails.

(11) Water surface oscillating (waves) with respect to the turbines.

(12) Bottom hull.

(12A, 12B) Side Hulls.

(13) Waves approaching the device.

(14) Anchorage.

(15) Means for conveying energy from an axis to another power type of energy.

(16) Incoming waves.

(17) External limit surface.

(18) Useful frontal fluid flux.

(19) Device for generation of electricity.

(20) Hulls.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO2014111800A **[0003]**
- KR20110107881 **[0003]**
- WO2005061887A **[0003]**
- US2011254275A **[0003]**
- US2010237625A **[0003]**
- KR100191636B1 **[0003]** **[0004]**
- KR101492768B1 **[0003]**
- ES2074010 **[0029]**

Non-patent literature cited in the description

- **DORIA J.J.GRANERO F.**TEORIA INNOVADORA EN AERODINAMICA. PROTOTIPOS Y

PATENTESActas III Congreso Internacional de Ingenieria de Proyectos, 1996, [0030]

PATENTKRAV

1. Anordning (19) til omdannelse af kinetisk energi fra en strømning (16, 18) af bølger, vind- eller vandstrømme til mekanisk rotationsenergi, der omfatter en flerhed af tværstrømsturbiner (9), der hver omfatter faste buede blade (5, 6)) arrangeret i egernburskonfiguration omkring en rotationsakse (A), hvor turbinerne (9) er monteret på en flydende understøtning (10) på vandet, således at de kan placeres direkte i væskestrømmen (18) og arrangeres successivt efter hinanden med deres akser (A) parallelle med hinanden og vinkelret på strømmen (18), hvor den flydende understøtning (10) har U-formet tværsnitsprofil, der danner kanalen hvor den flydende understøtning (10) har en U-tværsnitsprofil, der danner kanalen, således at et nederste skrog (12) og to sideskrog (12A, 12B) er defineret, akserne (A) af turbinerne (9) er roterbart understøttet mellem de to sideskrog (12A, 12B), og hvor flydende styreorganerne er overflydelige flydere, således at anordningen er bevægelig mellem en nedre stilling, hvor turbinerne (9) er fuldstændigt nedsænket og en øvre position hvor turbinerne (9) er anbragt helt over vandstanden.

2. Anordning ifølge krav 1, hvor akserne (A) af turbinerne er placeret i samme plan.

3. Anordning ifølge ethvert af de foregående krav, hvor akserne (A) af turbinerne er arrangeret med regelmæssige mellemrum.

4. Anordning ifølge ethvert af de foregående krav, hvor bladets sæt af turbinerne (9) har en cylindrisk indhylling.

5. Anordning ifølge ethvert af de foregående krav, hvor understøtningen (10) omfatter organer til forankring af den i havbunden.

6. Anordning ifølge ethvert af de foregående krav som ikke omfatter prelplader eller afbøjningsplader.

DRAWINGS

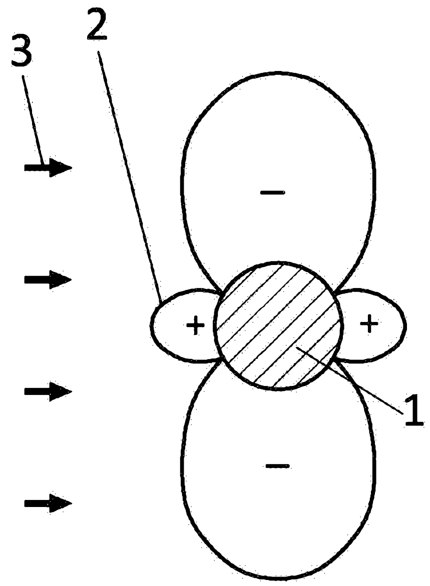

FIG. 1

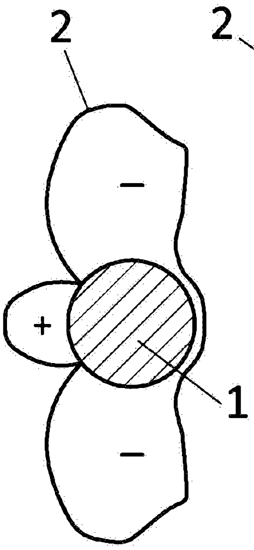

FIG. 2

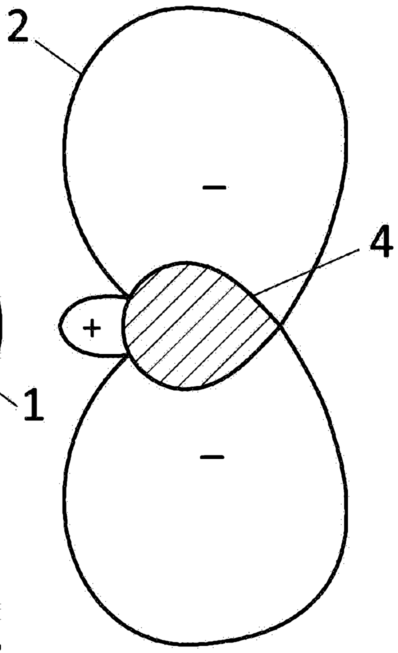

FIG. 3

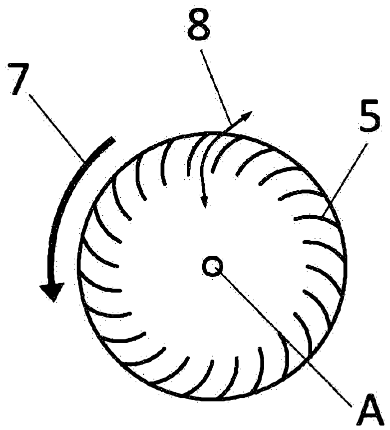

FIG. 4

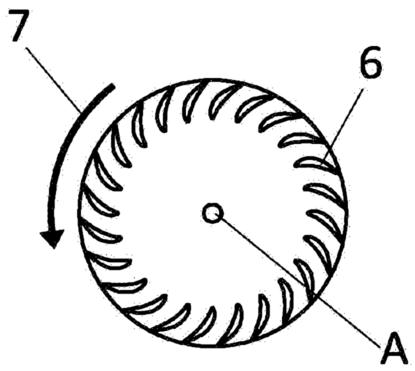

FIG. 5

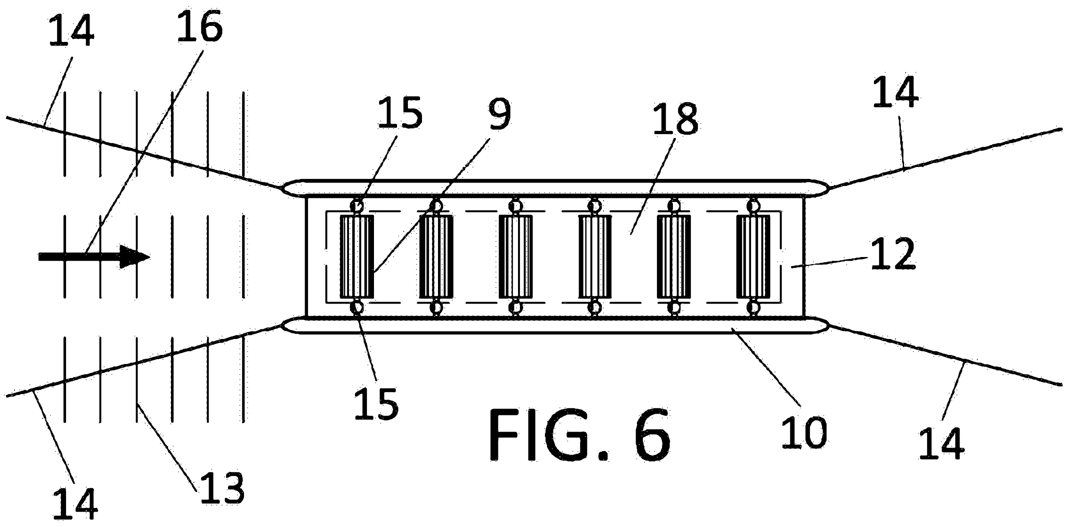

FIG. 6

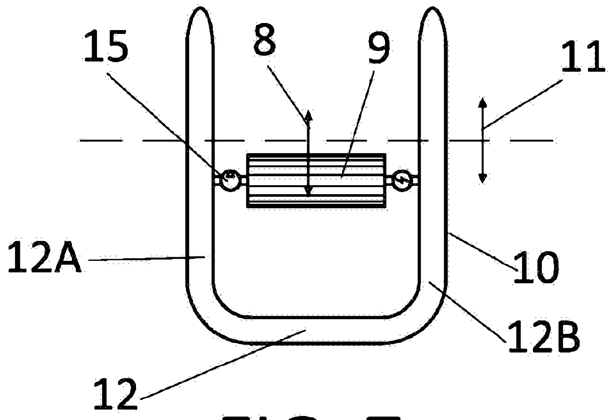

FIG. 7

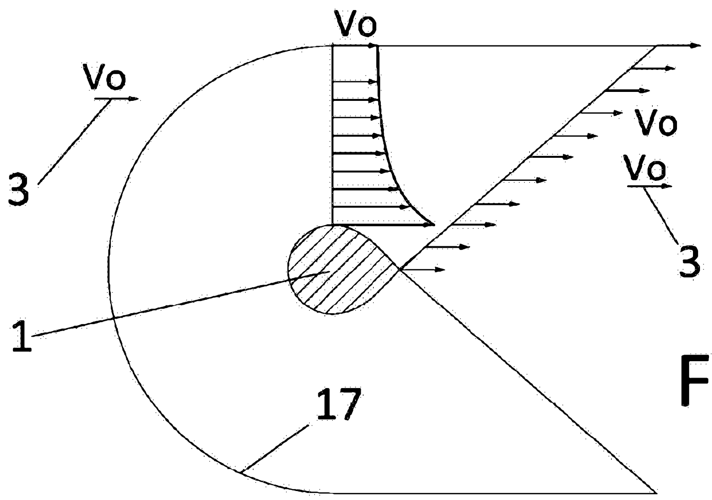

FIG. 8

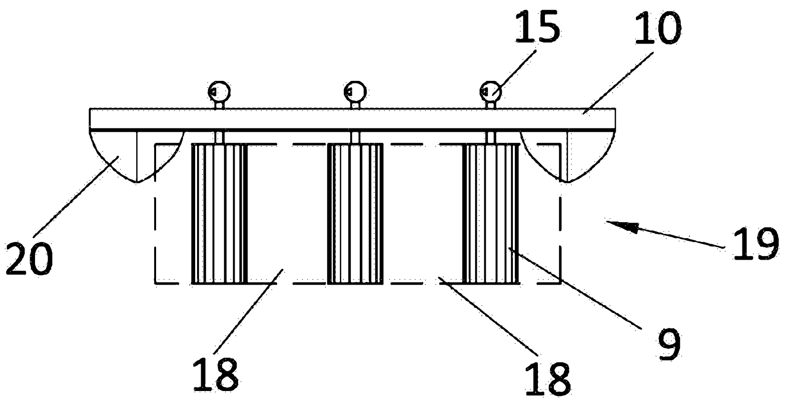

FIG. 9a

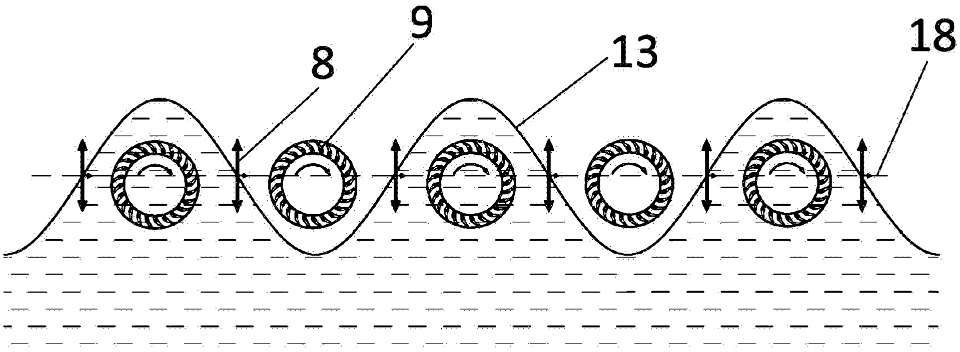

FIG. 9b

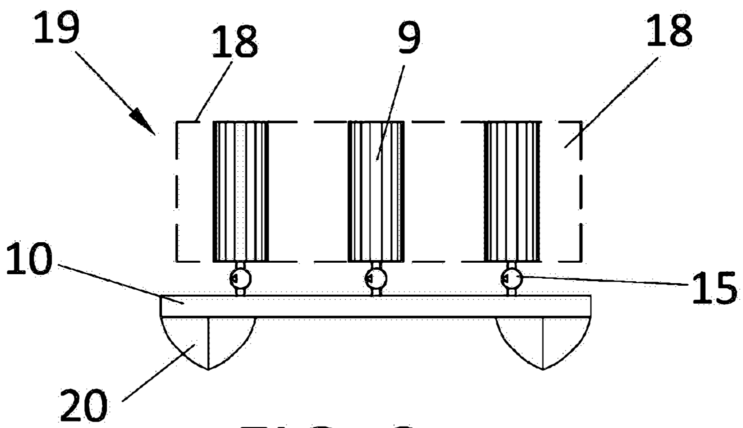

FIG. 9c

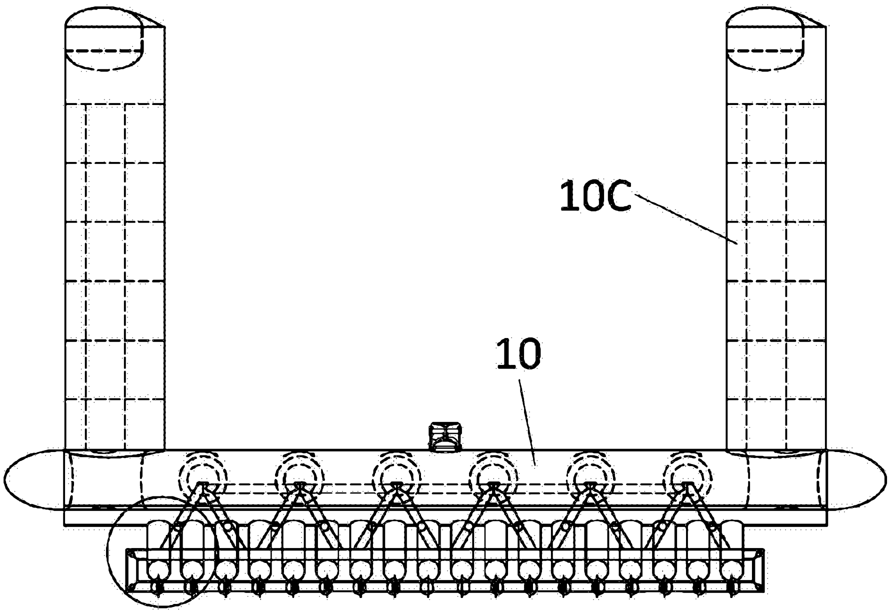

FIG. 10

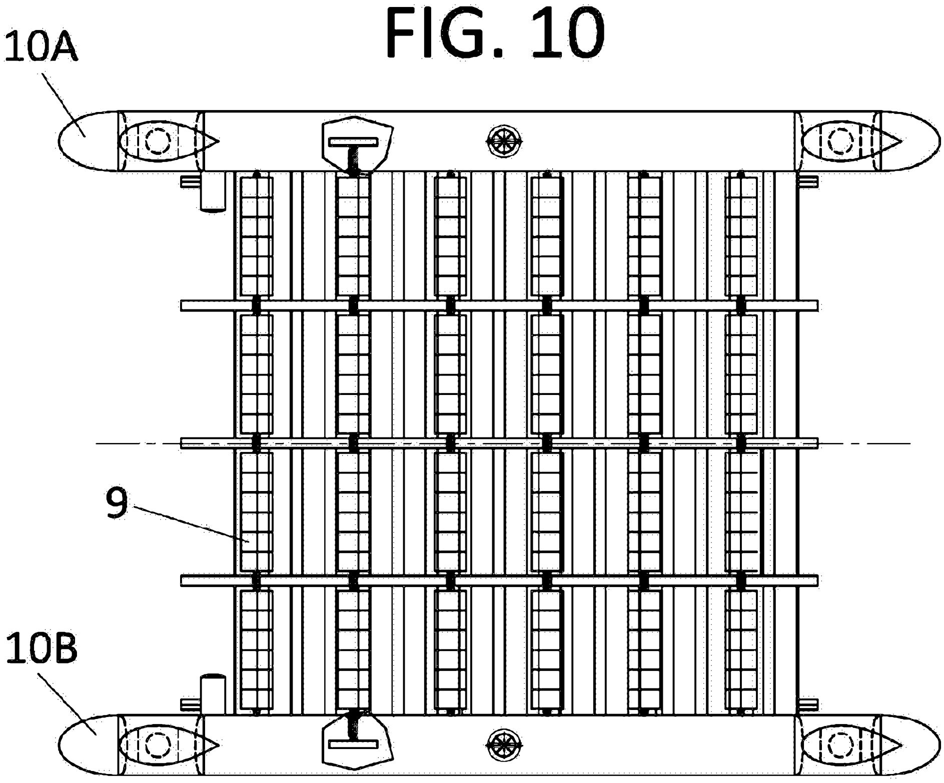

FIG. 11

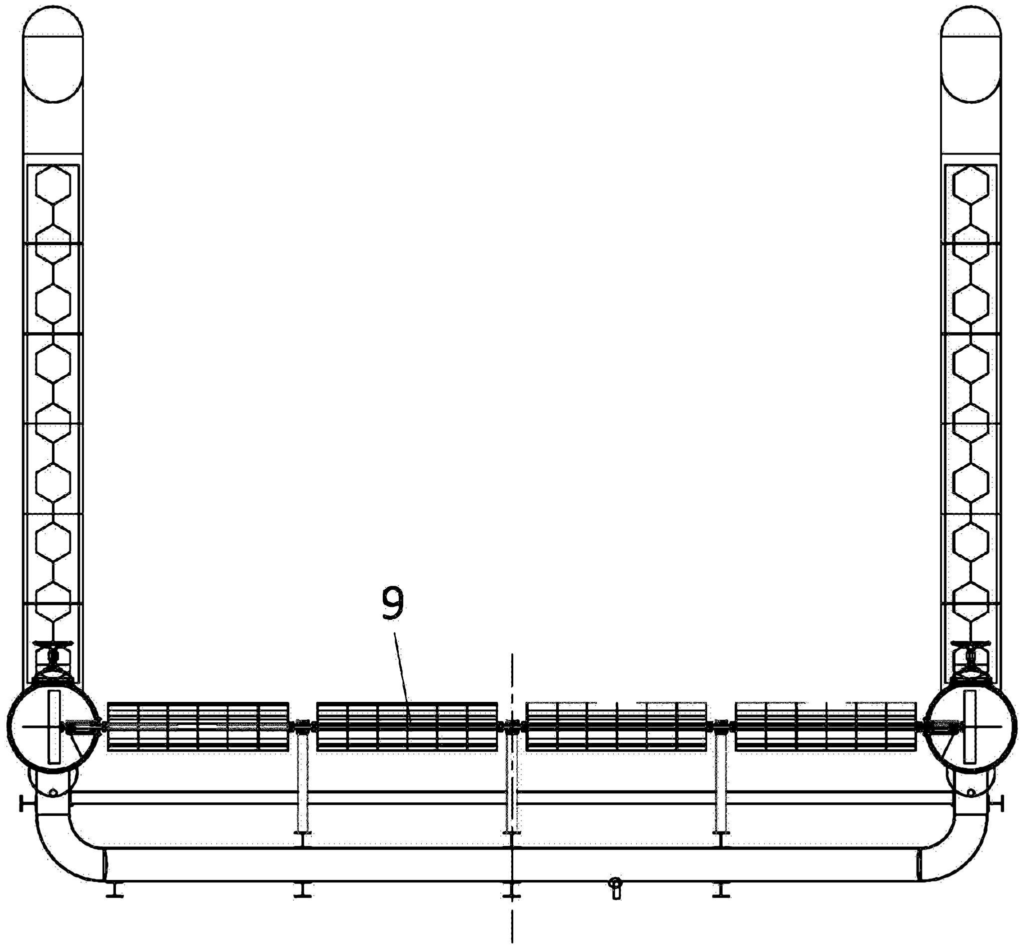

FIG. 12