maintenance costs. In fact, the difficult environmental conditions to which they are subject coupled with moderate efficiency make the energy production cost uncompetitive compared to other renewable energies like solar or wind, whose technologies are now mature and have a production cost which keeps going down.

[8] In fact, the high expense items for a wave-energy conversion system installed at sea are located in the materials making up the wave-energy conversion system which must be capable of withstanding these environmental conditions and also in the installation thereof in a marine environment, for example involving anchoring.

[9] Consequently, there is still a need for proposing a low-cost solution capable of effectively converting the renewable energy generated by the movement of waves.

[10] Further, reducing the fuel consumption of powered ships is sought, and there is a need to propose a solution aiding propulsion which draws its energy from the energy of the swell.

## SUMMARY

[11] For that purpose, according to an aspect, a device is proposed here for propulsion and for recovery of the energy of the movement of waves comprising at least one floating structure, at least one keel mounted mobile on the floating structure, according to at least one sliding movement relative to said floating structure along a heaving axis,
characterized in that it comprises at least one flap connected by a hinged system both to the keel and also to the floating structure, where said flap is configured for being positioned under the surface of the water, laid out so as to follow the oscillations of said keel by oscillating rotation under the action of wave movements, and generating a propulsion force directed substantially towards the center of gravity of said floating structure.

[12] Because of these dispositions, the horizontal propulsion produced by the reciprocating flap serves for countercurrent swimming to counter the effect of the local wind and/or the effect of the sea current and/or the effect of the swell itself. In fact, advantageously, the oscillating rotation of the flap produces a propulsion in a direction counter to the direction of the swell. This propulsion with a substantially horizontal resultant is used to move the floating structure forward against the swell (and also against the current and/or the wind).

[13] Advantageously, when the floating structure is connected to the rear part (i.e. the stern), of a boat (e.g. ship, barge, etc.), the propulsion generated by the floating structure can lead to a reduction of the demand on other propulsion systems of the boat. For example, when the boat is equipped with a propeller

motor as first propulsion means, the use of the floating structure the stern of the boat may, advantageously, reduce the fuel consumption. According to another connected advantage, the oscillating keel may be coupled to a generator (e.g. electrical) with which to provide the boat electrical energy.

[14] Note that in the presence of swell, the flap forces relative movement between the keel and the floating structure by oscillating rotation, thus allowing recovery of the energy from the movement of the waves. Further, in reaction, the movement of the flap is also forced by the relative heaving of the keel and the floating structure, leading to two relative movements which are coupled and mutually amplifying one another.

[15] In the case where the floating structure is connected to an anchoring element, the generated propulsion may contribute to reducing the force exerted on the anchoring point. This reduction of the anchoring force has the advantage of allowing lighter and less costly anchoring solutions.

[16] In various examples, one and/or another of the following dispositions could further be used.

[17] According to an example, the hinged system may comprise a pivoting connection (A1) between the flap (3) and the keel. By these means, a robust and easy-to-implement connection results in order to allow the reciprocating of the flap relative to the keel.

[18] According to an example, the hinged system may comprise a connecting rod connection (4) between the flap (3) and the floating structure (1). This forms a simple and basic and robust mechanical connection which does not require maintenance. According to an alternative option, in place of a connecting rod system, there could be a guide using sliding of pins in openings or another auxiliary guiding system.

[19] According to an example, the hinge system may comprise a connecting element (4) connected to the floating structure (1) by a pivoting connection (A2) and connected to the flap (3) by a pivoting connection (A3). The connecting element in question is comparable to a connecting rod which allows a pivoting movement of the flap relative to the keel without major parasitic movement compared to the floating structure. Further, this forms a simple and basic and robust mechanical connection.

[20] According to an example, the flap (3) may further comprise a rear extension of the surface thereof (8), where said rear extension is connected to a front part of the flap (83) by a pivoting connection (A8).

[21] This serves to amplify the propulsion effect, since the reciprocating of the rear extension is slightly later in phase than the reciprocating of the front part of the flap.

[22] According to an example, the rear extension (8) may be returned to a neutral angular position relative to the front part of the flap (3) by a spring restoring system.

[23] It involves a simple and basic system, reliable and maintenance free. The restoring to the neutral position contributes to the effectiveness of the propulsion on meeting the swell.

[24] According to an example, the flap may further comprise a rear extension of the surface thereof (8), where said rear extension is flexible and fixed to the front part of the flap. Biomimetics is used in order to produce in that way a whale tail effect.

[25] According to an example, the flap (3) may further comprise a rear extension of the surface thereof (8), connected to a front part of the flap (83) by a pivoting connection (A8), where said front part is then shaped like control arms (36, 37).

[26] According to an example, the keel may comprise several flaps (3, 3+) arranged one under the other, mounted so as to remain parallel with each other. By these means, the characteristics of the site where the device is positioned may be reflected in the number of flaps present on said keel. Each arrangement serves to get a device more compact on the surface if a sufficient draft is available, where each flap extends less individually but the effects of the flaps add up power.

[27] According to an example, it is intended that a resting position of the flap is defined by a reference angle, where said reference angle is defined by the surface of said flap and the longitudinal axis (X) perpendicular to the keel. In the case of a substantially flat flap, this serves to bring the main body of the flap closer to the surface of the water.

[28] According to an example, it is intended that said reference angle be included between 0 and 30°. By these means, the adjustment of the reference angle serves to position the end of the flap closest to the surface of the water where the efficiency of said flap is optimal.

[29] According to an example, the body of the flap extends mainly in a work plane and the transverse width of the flap increases going away from a zone where the hinged system connects the flap to the keel. The parts farthest from the hinge have the advantage of a larger lever arm and that way their force is optimized relative to a set surface area of the flap.

[30] If the reference resting condition is such that the flap is “flat,” then the working plane of the flap is perpendicular to the heaving axis (Z).

[31] According to an example, the floating structure and the flap are made with at least one composite material. The use of this type of material has the advantage

of allowing the reduction of the total weight of the device and thus the total cost thereof.

[32] According to an example, it is intended that the composite material be a polyepoxide or polyester matrix comprising carbon fibers or fiberglass. By these means, this solution has good performance in mechanical and chemical robustness.

[33] According to an example, the device may further comprise at least one means for transmission of the relative movement of said keel to at least one electric converter in order to convert the mechanical energy of said movement into electrical energy, where the device then has a function of conversion of the energy of the movement of the waves. Note that the flap forces relative movement between the keel and the floating structure by oscillating rotation, thus allowing conversion of the energy from the movement of the waves into another form of energy.

[34] According to an example, the device further comprises a control unit (9) configured for driving the power collection rate in the electrical converter so as to thus balance between the propulsion produced by the countercurrent swimming and the transformed energy from the swell.

[35] The electrical converter (via the transmission means) constitutes a damper on the oscillatory movement of the flap. The control unit may modulate the energy collection taken by the electrical converter in order to keep enough energy for countercurrent swimming, according to the actual conditions of current, wind and swell.

[36] According to an example, the device may be usable and effective for a range of swell periods. By means of which, the device is profitably used even when the swell period does not correspond to the resonant period thereof and may convert energy from the movement of the waves over a very long range of swell periods.

[37] The energy conversion chain may act as a damper controlled in real time, simulating an artificial spring, which serves to change the resonant period of the system when the chain is not acting in purely resistive mode (in addition to acting as a damper, it can then act as a spring and as a mass).

[38] According to an example, the range of swell periods can be included between 3 and 16 seconds, preferably included between 6 and 12 seconds.

[39] According to an example, the device may comprise a hydraulic cylinder (6) as transmission means.

[40] According to an example, the electrical converter may be an electrical generator coupled to a hydraulic motor.

[41] According to an example, the device may be connected to at least one anchoring element, for example to a buoy or any floating element with substantially fixed position. The effective anchoring force is reduced in this way; lighter weight and less costly anchoring solutions may thus be chosen. Further, reduced dimensions of the anchoring, and also of the lash onto the device lead to solutions that are easier to install and therefore less costly. They are more durable and experience less wear in comparison to passive anchorings.

[42] According to an example, the device may be fixed to the stern of a boat or incorporated in the stern of a boat. The fuel consumption of powered ships is thus reduced with such a solution aiding propulsion by drawing its energy from the energy of the swell.

[43] According to an example, the device may comprise a restoring spring between the floating structure (1) and the keel (2).

[44] According to an example, the flap may have a rectangular or triangular or trapezoidal shape.

[45] According to another example, a device is proposed for propulsion and for conversion of the energy from the movement of waves comprising at least one floating structure connected to at least one anchoring element, at least one keel mounted mobile on the floating structure, along at least one sliding movement relative to said floating structure along a heaving axis, at least one means for transmission of the relative movement of said keel to at least one electrical converter for converting the mechanical energy of said movement into electrical energy,
characterized in that it comprises at least one flap connected by a hinged system to the keel and to the floating structure, where said flap is configured for being positioned under the surface of the water, laid out so as to follow the oscillations of said keel by oscillating rotation under the action of wave movements, and generating a propulsion force directed substantially towards the center of gravity of said floating structure.

[46] Most of the optional characteristics described above can be used in combination with the device disclosed in the preceding paragraph.

[47] According to another aspect, a device for propulsion and for recovery of the energy of the movement of waves is proposed comprising:
- at least one floating structure;
- at least one keel mounted mobile on the floating structure, according to at least one sliding movement relative to said floating structure along a heaving axis,
characterized in that it comprises at least one flap connected by a hinged system both to the keel and also to the floating structure, where said flap is configured for generating a propulsion force directed

substantially towards the center of gravity of said floating structure, and in that the hinged system comprises at least one control arm mounted in rotation on the keel by a first pivoting connection, and at least one linkage connected to the floating structure by a second pivoting connection and connected to said control arm(s) by a third pivoting connection, where the flap is mounted in rotation on said control arm(s) by means of a hinge arranged in a rear position cantilevered relative to the third pivoting connection.

[48] Most of the optional characteristics described above can be used in combination with the device disclosed in the preceding paragraph, in particular the elastic restoring applied to the hinge (A8) of the flap.

## BRIEF DESCRIPTION OF THE DRAWINGS

[49] Other aspects, goals and advantages of the invention will appear upon reading the following description of several embodiments thereof, given as nonlimiting examples. The invention will also be better understood in light of the attached drawings on which:

[50] Figure 1 is a schematic view of the propulsion device positioned in open sea.

[51] Figure 2 is a sectional schematic view of the propulsion device.

[52] Figure 3 is a top view of the propulsion device.

[53] Figure 4 is an operating diagram of a hydraulic cylinder coupled to a hydraulic motor.

[54] Figure 5 shows an output power curve as a function of the period of the swell, and also the available horizontal propulsion because of the countercurrent swimming.

[55] Figure 6 shows a curve of possible operating points according to the energy collection balancing control.

[56] Figure 7 shows a variant relating to the means of transmission of the relative movement of the keel.

[57] Figure 8 shows, in one or more embodiments, a section view of an alternative of the propulsion device.

[58] Figure 9 shows, in one or more embodiments, a top view of an alternative of the propulsion device.

[59] Figure 10 shows, according to an embodiment, the integration of the propulsion and/or conversion device into a boat type floating structure.

[60] Figure 11 shows, according to another embodiment, an alternative to the integration of the propulsion and/or conversion device into a boat type floating structure.

# CLAIMS

**Claim 1.** A device for propulsion and for recovery of the energy of the movement of waves comprising:

- at least one floating structure;

- at least one keel mounted mobile on the floating structure, according to at least one sliding movement relative to said floating structure along a heaving axis,

characterized in that it comprises at least one flap connected by a hinged system both to the keel and also to the floating structure, where said flap is configured for being positioned under the surface of the water, arranged so as to follow the oscillations of said keel by oscillating rotation under the action of wave movements, and generating a propulsion force directed substantially towards the center of gravity of said floating structure.

**Claim 2.** The device according to claim 1, characterized in that the hinged system comprises a pivoting connection between the flap and the keel.

**Claim 3.** The device according to any one of claims 1 to 2 characterized in that the hinged system comprises a connecting rod connection between the flap and the floating structure.

**Claim 4.** The device according to any one of claims 1 to 2 characterized in that the hinge system comprises a connecting element connected to the floating structure by a pivoting connection and connected to the flap by a pivoting connection.

**Claim 5.** The device according to any one of the preceding claims, characterized in that the flap further comprises a rear extension where said rear extension is connected to a front part of the flap by a pivoting connection.

**Claim 6.** The device according to claim 5, characterized in that said rear extension is returned to a neutral angular position relative to the front part of the flap by a spring restoring system.

**Claim 7.** The device according to any one of claims 1 to 4 characterized in that the keel comprises several flaps arranged one under the other, mounted so as to remain parallel with each other.

**Claim 8.** The device according to any one of claims 1 to 5 characterized in that a resting position of the flap is defined by a fixed angle, where said fixed angle is defined by the surface of said flap and the longitudinal axis perpendicular to the keel.

**Claim 9.** The device according to any one of claims 1 to 6 characterized in that the body of the flap extends mainly in a work plane and the width of the flap

increases going away from a zone where the hinged system connects the flap to the keel.

**Claim 10.** The device according to any one of claims 1 to 9 further comprising at least one means for transmission of the relative movement of said keel to at least one electric converter in order to convert the mechanical energy of said movement into electrical energy, where the device then has a function of conversion of the energy of the movement of the waves.

**Claim 11.** The device according to claim 10, further comprises a control unit configured for driving the power collection rate in the electrical converter so as to thus balance between the propulsion produced by the countercurrent swimming and the transformed energy from the swell.

**Claim 12.** The device according to any one of claims 10 to 11, characterized in that the transmission means is at least one hydraulic cylinder.

**Claim 13.** The device according to one of claims 10 to 12, characterized in that the electric converter is an electrical generator coupled to a **hydraulic motor**.

**Claim 14.** The device according to any one of the preceding claims, characterized in that it is connected to at least one anchoring element.

**Claim 15.** The device according to any one of claims 1 to 13, characterized in that it is fixed to the stern of a boat or incorporated in the stern of a boat.

**Claim 16.** A device for propulsion and for recovery of the energy of the movement of waves, comprising:
- at least one floating structure;
- at least one keel mounted mobile on the floating structure, according to at least one sliding movement relative to said floating structure along a heaving axis,

characterized in that it comprises at least one flap connected by a hinged system both to the keel and also to the floating structure, where said flap is configured for generating a propulsion force directed substantially towards the center of gravity of said floating structure, and in that the hinged system comprises at least one control arm mounted in rotation on the keel by a first pivoting connection, and at least one linkage connected to the floating structure by a second pivoting connection and connected to said control arm(s) by a third pivoting connection, where the flap is mounted in rotation on said control arm(s) by means of a hinge arranged in a rear position cantilevered relative to the third pivoting connection.

**Claim 17.** The device according to claim 16, wherein the flap is returned to a neutral angular position relative to the control by a spring restoring system.