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[Continued on next page]

(54) Title: FLOATING OFFSHORE KITE POWERED GENERATOR

(57) Abstract: An offshore infrastructure for tropospheric aeolian generator is described, which comprises at least one floating platform (1) able to host a tropospheric aeolian generator (2) driven by tethered kites (3) and at least one mooring line (5) anchored to a sea bottom through at least one sinker (6).

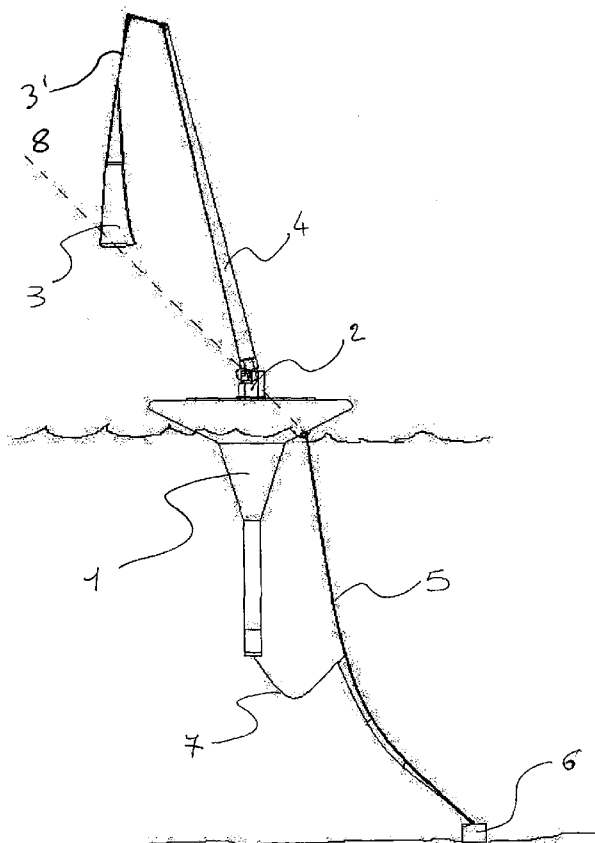


Fig 1



SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT,
TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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FLOATING OFFSHORE KITE POWERED GENERATOR

The present invention deals with an offshore infrastructure for a tropospheric aeolian generator.

The installation of windmills on board of floating platforms for deep offshore wind energy conversion is a difficult task because of the high thrust and heeling moment generated on the platform by a Horizontal Axis Wind Turbine (HAWT), by a Vertical Axis Wind Turbine (VAWT) or other kinds of wind energy systems during operations.

Several projects are ongoing around the world with companies involved in wind energy and oil and gas offshore technologies, mainly focused on the HAWT.

The more recent are actually HIWIND, WINDSEA, MIT-NREL, Float Wind - "Trifloater", BLUE H.

All these projects are fighting not only with the forces developed by the generator on duty, but also with the cross-action of the environment (wind and sea forces) on the infrastructure.

The general understanding is that the floating platform or spar must be tightly secured to the sea bottom and the displacements and rotations of the infrastructures must be limited as much as possible to avoid excessive unbalance and oscillation of the windmill.

These basic considerations lead to employ huge structures and heavy mooring lines, trying to counteract enormous loads but making the application absolutely not convenient in light of a profit and loss account analysis.

Object of the present invention is overcoming this inherent problem, by providing an offshore infrastructure for a tropospheric aeolian generator, which employs a novel and different concept for wind energy exploitation, by transferring and adapting to the offshore environment the emerging technology just developed for the high altitude wind generator of the Applicant of the present application.

The inventive generator employs highly efficient flying kites to intercept the high altitude wind energy, then it transfers the collected and noble mechanical energy through a couple of cables driving a set of electric generator/motors located at ground level.

The first prototype of the Applicant's generator dates back to 2006 and demonstrated for the first time the possibility to collect high altitude wind energy in an efficient and economically convenient way.

The Applicant's technology is now ready and available for inland operations and the first 1MW industrial generator is going to be installed on the ground and connected to the electric grid.

The latest developments are described, for instance, in Italian Patent Application T02008A000423.

The key concepts behind the offshore infrastructure's technology are:

- "dematerialization" and "delocalisation" of the aerodynamic surfaces, substituting the windmill's blades with light and efficient flying kites;
- force management, limiting the maximum loads through control;
- greater yearly availability when compared to windmills.

The main characteristics of the system make it particularly suitable for offshore applications.

Since the position of the centre of mass of the generator can be really close to the deck of the floating platform and the direction of the main loads, represented by the mechanical pull acting on the cables, is practically passing through the centre of mass of the generator, the weight of the generator and of the hosting offshore infrastructure can be a fraction of the weight of a floating windmill, with evident advantage in terms of cost saving.

A first important consideration is that there is no need for the tall tower supporting the hub and the blades of a classic windmill. The offshore infrastructure simply employs a take-off arm, called "stem", that can be extremely slender and light and can be oriented along the pull direction immediately after the take-off, so that no high bending loads can act on the arm during the operations.

The take-off arm can also be fully lowered for the periodical maintenance of the system and during extreme weather conditions, so that a better stability of the platform can be achieved in harsh environment.

The installation of an Applicant's generator onboard a floating platform presents many typical problems of marine structures and equipment, some of them can be solved relying on well established prior art solutions, but others need new solutions to grant the right amount of safety, reliability and profitability.

First of all, the floating platform will have an appropriate weight distribution and overall dimensions in order to give the necessary amount of buoyancy, stability and sea keeping qualities.

A preferential design employs a flared axis symmetric shape, similar to the 12-meter discus buoys successfully employed over the years for ocean monitoring, but with improved stability thanks to a calculated amount of submersed heavy ballast.

The platform comprises several watertight compartments for generator, electronics, pieces of equipment.

The hull's widening diameter upward and its consequent increasing displacement grant a desirable reduced variation between light waterline and load waterline when the vertical component of the kite's pull tends to lift the platform.

A key role in determining the dynamic behaviour on duty of the offshore tropospheric aeolian generator is played by the mooring line (typically a metal chain or a fibre rope), that is anchored

on the sea bottom with a sinker like commonly done, but is connected to the floating platform, for instance through a mooring yoke or a chain plate, in a position lying close to the estimated average direction of the pull of the kite's control cables, so that the resulting lever arm between the mooring line and the kite's control cables can generate only a negligible amount of overturning moment if compared with waves and wind effects on the platform stability.

Further, the tropospheric aeolian generator can tolerate bigger oscillations than HAWT, VAWT and other wind energy systems operating in offshore environment.

With this uncommon and particular layout, the mooring line and the kite's control cables under load always tend to align one each other and lie collinear on duty.

As a consequence, this particular arrangement of the mooring line and the axis symmetric design give the floating platform the possibility to orient itself accordingly to the kite's pulling direction, so that a certain amount of displacement can be not only tolerated, but even exploited to reduce the number and the size of the mooring lines, with evident technical advantage and cost saving.

The movements of the floating platform due to the waves can also be transformed in useful energy by the generator with the electronic control of the kite's control and power cables.

The movements of the floating platform on the sea surface can be seen like the composition of a short period rotation around the

platform's vertical axis, driven by the typical figure of eight kite's trajectories, and a long period rotation and translation around the projection of the dead weight on the sea surface, driven by the average wind direction and ocean current and limited by the mooring line length.

One of the advantages of the proposed solution is that the generator can rotate about the vertical axis without the need for a big and expensive bearing or a curved linear guide and the relative kinematic chains, which are mandatory for inland applications.

To avoid the risks of kinking of the mooring lines, the mooring yoke or the chain plate can rotate about the vertical axis of the platform thanks to a cost effective solution represented, for instance, by a rough bearing and suitable to operate in the marine environment realized through a series of wheels equipped with rubber tires free to rotate along a groove machined or added to the hull.

The electronic system needs to control mainly the elevation of the take-off arm, but can obviously modify the kite's trajectories so that the average pull direction can compensate drift and bad attitude of the platform due to marine current and wind load on the platform.

Considering an offshore wind farm, a big advantage must be kept in account. The spatial distribution of classic windmills requires typically a separation of 8-9 rotor diameters, that for a

5 MW windmills farm means approximately 1000 m of free space between each tower.

The offshore infrastructure of the present invention can use the third dimension (the altitude) to separate the air space of the flying wings so that they always find undisturbed wind front and the floating generators can be placed closer one each other.

In the conservative hypothesis to divide by 4 the separation distance, assuming $D = 250$ m, it is possible to install, in the otherwise empty and unexploited squared km, 21 additional kites having 3 MW of rated power plus the 4 substituting the windmills at the corners.

That means a potential territorial peak power density of 75 W/m^2 instead of the 4 W/m^2 typical of windmills farms and, taking into account the yearly availability, an average territorial power density of 50 W/m^2 for the aeolian tropospheric generator wind farm versus the 2 W/m^2 of the HAWT wind farm.

A big economical advantage is the reduced length of the submarine electric cables constituting the farm's electric grid.

The electrical cables can follow the mooring line, and they will have the right length to compensate tide and waves effects.

Finally, to limit the damages deriving by extreme weather conditions, the weight of the sinker at the sea bottom is lower than the breaking strength of the mooring line and calculated so that, under the sea and wind action, over certain load limits, the sinker can be dragged along the sea bottom dissipating through friction the excess of energy.

The original position of the sinker can be restored by manual extraordinary maintenance or automatically through the kite's pull action or through bow thrusters installed on board.

The produced energy can be transmitted ashore with an electric line, preferably of the high voltage kind, or can be employed offshore for different purposes.

A preferential use of the generated energy is the extraction and separation of noble metals from the salted sea water, in particular uranium, directly onboard, or on board of another suitably equipped floating platform, or on board of a ship anchored to the sea bottom.

As an alternative, the generated energy can be used to generate fuels, to capture carbon dioxide, for the desalinisation of seawater and similar applications.

The processed liquid or gas can be stored on a floating tank.

The above and other objects and advantages of the invention, as will appear from the following description, are obtained with an offshore infrastructure for tropospheric aeolian generator as described in Claim 1. Preferred embodiments and non-trivial variations of the present invention are the subject matter of the dependent claims.

These and other features of the present invention will clearly appear from the following description of a preferred embodiment, provided as a non-limiting example, with reference to the enclosed drawings, in which:

- Figure 1 is a side view of the offshore infrastructure of a preferred embodiment of the tropospheric aeolian generator of the present invention in a step of its operating cycle;
- Figure 2 is a side view of the offshore infrastructure of the tropospheric aeolian generator of Figure 1 in a step of its operating cycle;
- Figure 3 is a schematic representation of the displacement of the offshore infrastructure under wind and sea loads; and
- Figure 4 is a perspective view of a part of the offshore aeolian generator according to a variation of the present invention.

With reference to Figure 1, the floating platform 1 hosting an aeolian tropospheric generator 2 driven by flying kites 3 (in turn driven by control cables 3') and equipped with a take-off arm 4 is anchored to the sea bottom through a mooring line 5 connected to a sinker 6.

The produced electric energy is transferred through a submarine electric cable 7 following the mooring line and connected to a switchbox (not shown).

The generator 2 is shown at rest and the kite 3 is hanging supported by the take-off arm 4.

The mooring line 5 is connected to the floating platform 1 in a position close to the line identifying the average pull direction 8 of the flying kite 3.

With reference to Figure 2, the generator 1 is shown on duty and the mooring line 5 is under tension and collinear with the kite's 3 pull direction.

With reference to Figure 3, the possible movements of the floating platform 1 are shown. The platform 1 can rotate (rotation direction 10) about its vertical axis 10' driven by the typical figure of eight kite's trajectories and can translate and rotate (along respective directions 11) around the projection 12 of the sinker 6 on the sea surface driven by the average wind and current direction.

According to a variation, shown in Figure 4, the mooring line 5 is connected to the hull of the floating platform 1 through a rough bearing realized with a rotating ring 17 and a series of rotating wheels 14 equipped with rubber tires 15. The wheels 14 roll in a groove 16 and the mooring line 5 is directly linked to the bearing with a mooring yoke 13.

According to a preferred embodiment, the water displacing hull of the floating platform 1 has an axis symmetrical shape, like the round one shown in the Figures, or, also as a non-limiting example, has a squared shape or the like.

Alternatively, the floating platform 1 is adapted to be placed on a ship (not shown) operating as a water displacing hull and anchored to the sea bottom.

As further alternative, the floating platform 1 has a ballast keel.

CLAIMS

- 1) Offshore infrastructure for a tropospheric aeolian generator, **characterized in that** it comprises at least one floating platform (1) able to host a tropospheric aeolian generator (2) driven by tethered kites (3) and at least one mooring line (5) anchored to a sea bottom through at least one sinker (6).
- 2) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the mooring line (5) is connected to the platform (1) in a position laying close to a pull direction of control cables (3') of a kite (3) so that the mooring line (5) and the control cables (3') of the kite (3) tend to align one each other under load limiting the overturning moment on the platform (1).
- 3) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the mooring line (5) is a fibre rope.
- 4) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the mooring line (5) is a metal chain.
- 5) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the water displacing hull of the floating platform (1) has an axis symmetrical shape.
- 6) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the floating

- platform (1) has a water displacing hull with a squared shape.
- 7) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the floating platform (1) is adapted to be placed on a ship operating as a water displacing hull and anchored to the sea bottom.
 - 8) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the floating platform (1) has a ballast keel.
 - 9) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the floating platform (1) can be oriented and towed by the combined action of the pull acting on the control cables (3') of the kite (3), of the wind and of the marine current.
 - 10) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the weight of the sinker (6) on the sea bottom is lower than the breaking strength of the mooring line (5) and calculated so that the sinker (6) can be dragged in case of extreme weather conditions in order to avoid damages to the infrastructure itself.
 - 11) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the position of the sinker (6) can be actively maintained or restored through the action of a pull action on the kite (3).

12) Offshore infrastructure for a tropospheric aeolian generator according to claim 1, **characterized in that** the mooring line (5) is connected to the floating platform (1) through a mooring yoke (13) or a plate chain connected to a series of wheels (14) equipped with rubber tires (15) free to rotate about the hull's vertical axis along a groove (16) machined or added to the hull.

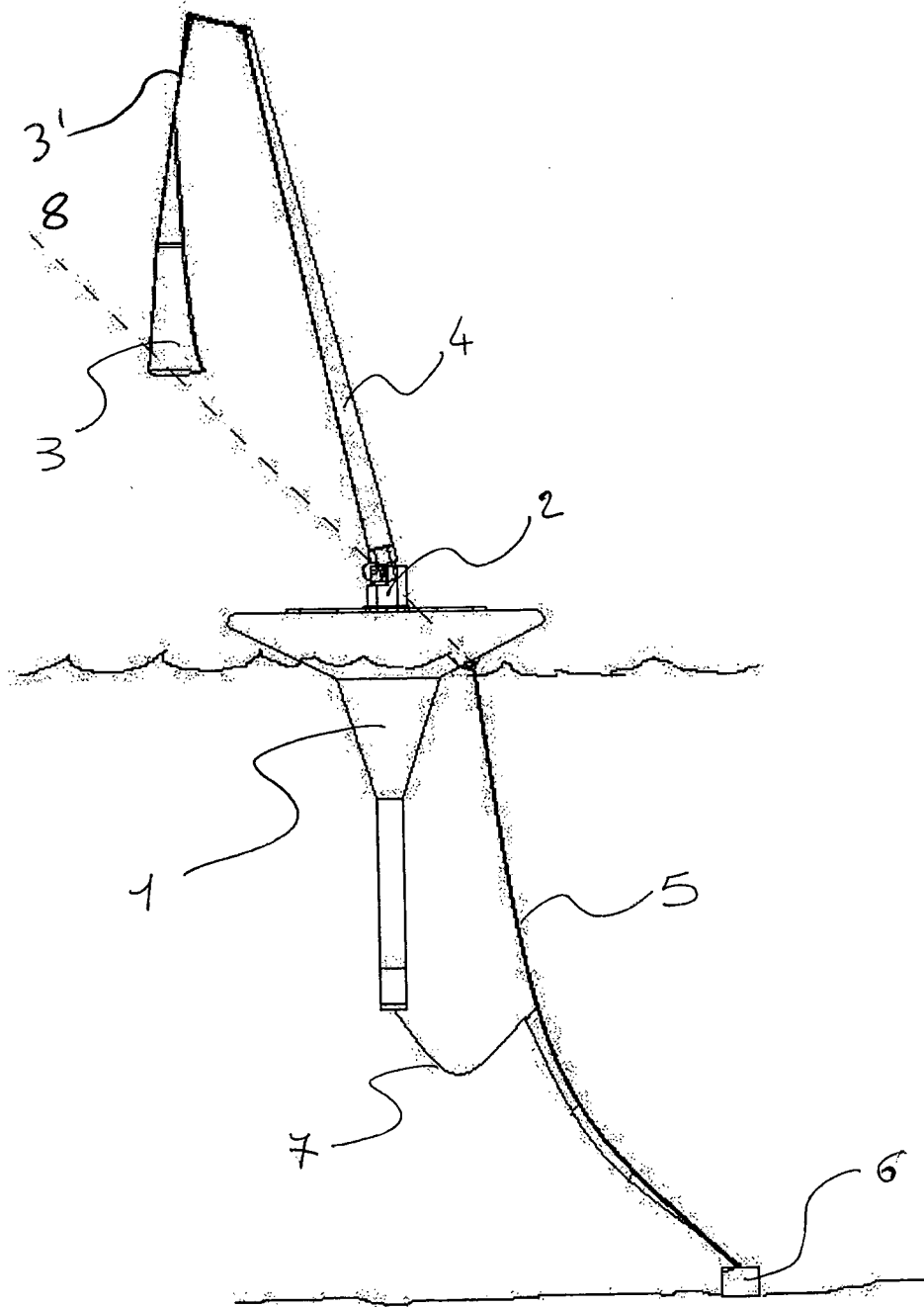


Fig 1/4

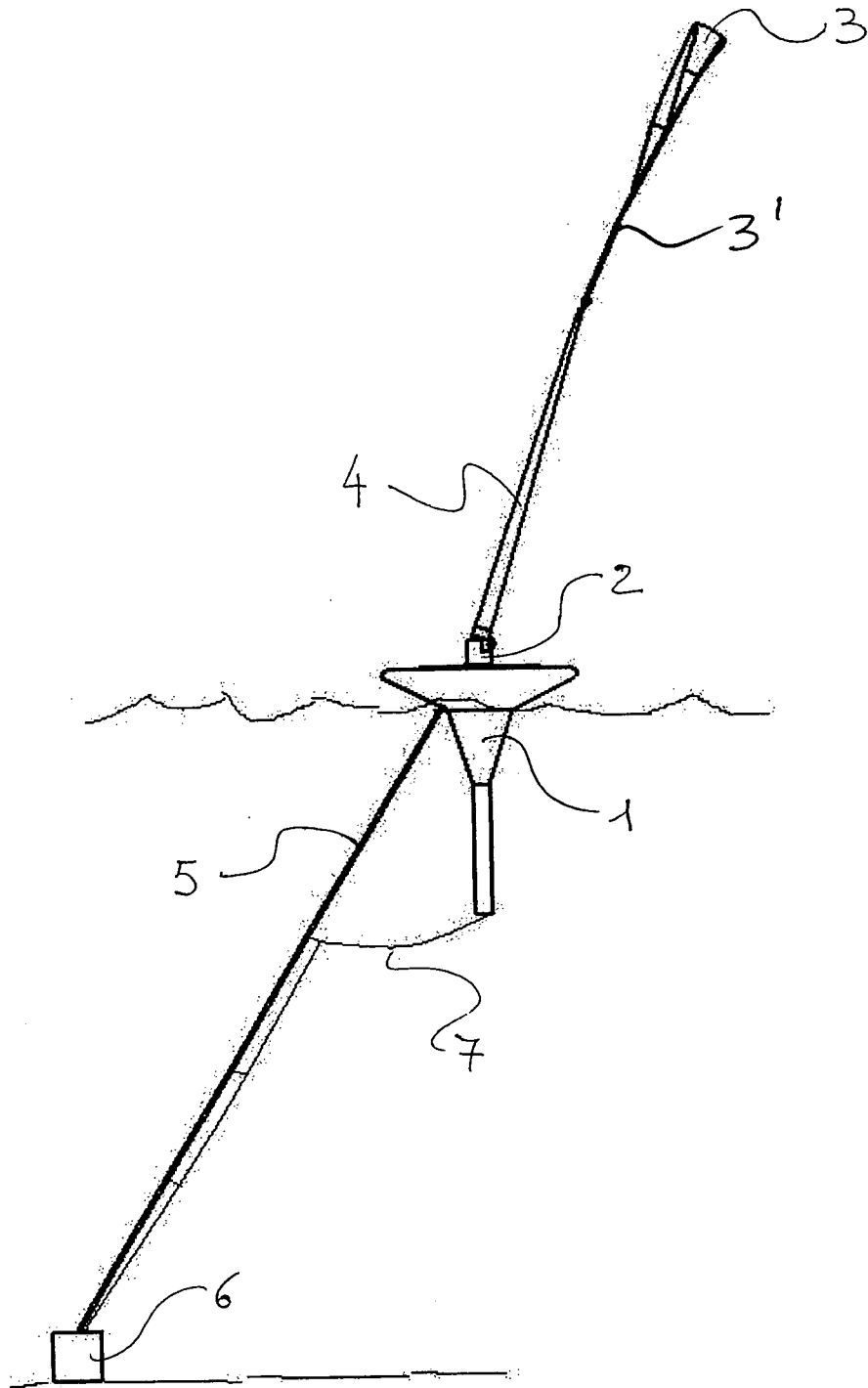


Fig 2/4

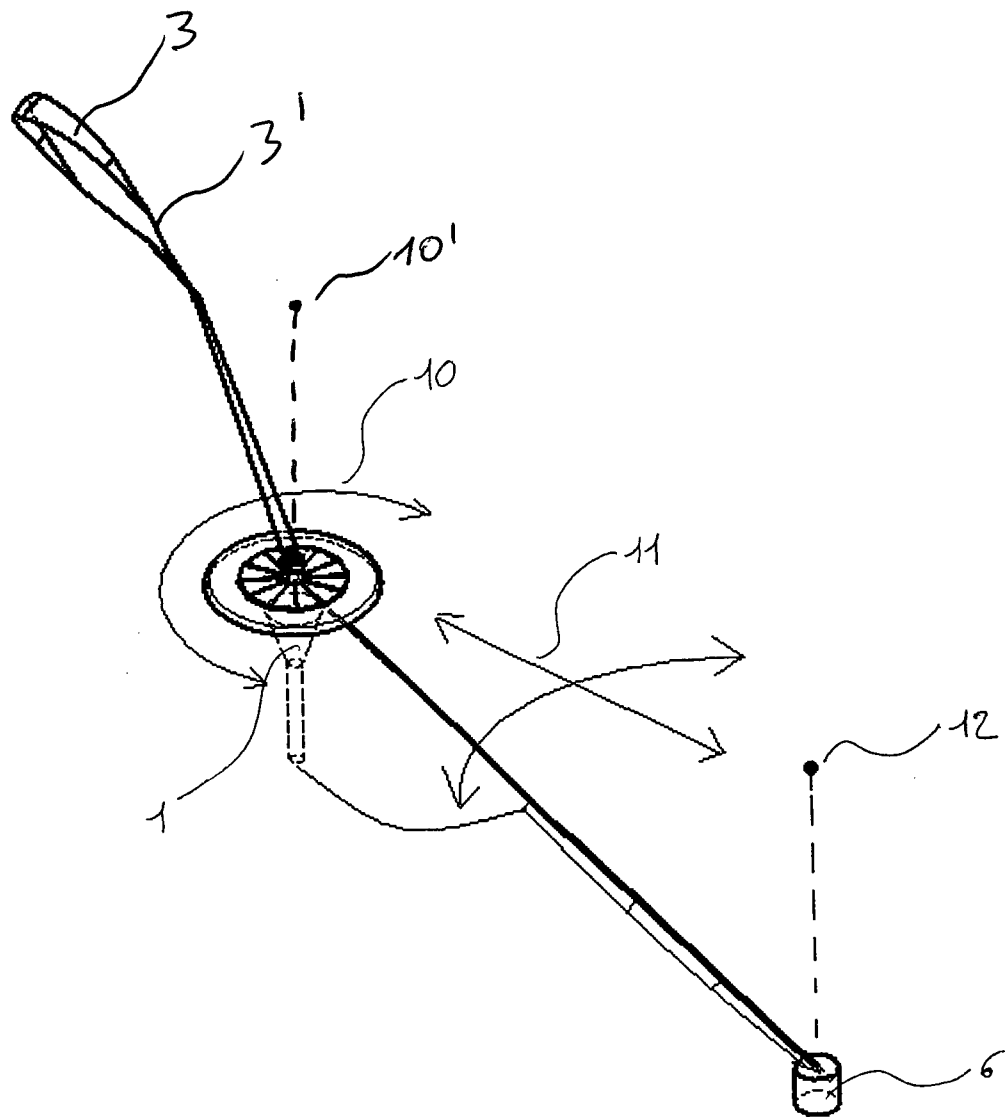


Fig 3/4

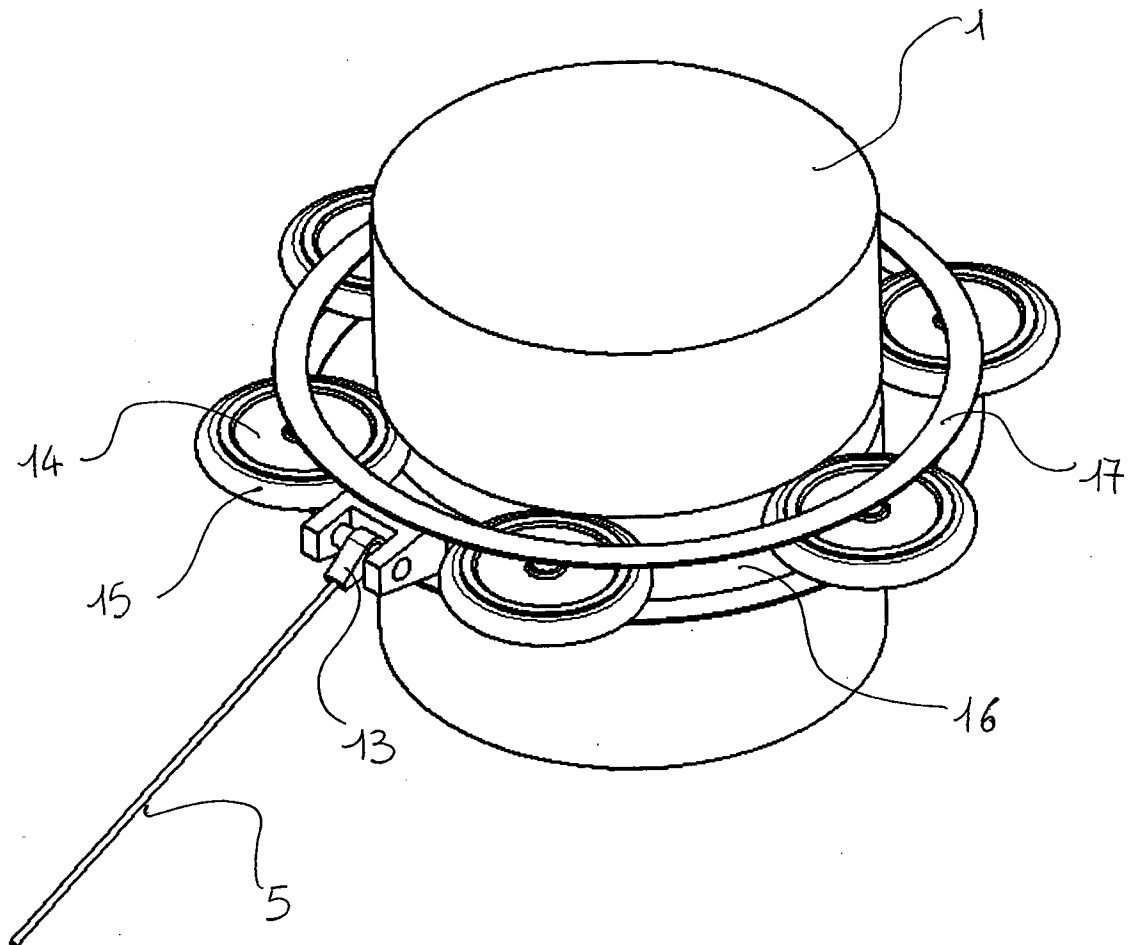


Fig 4/4

INTERNATIONAL SEARCH REPORT

International application No

PCT/IT2009/000260

A. CLASSIFICATION OF SUBJECT MATTER

INV. F03D5/06

ADD.

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)

F03D

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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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

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/IT2009/000260

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IT2009/000260

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