Sept. 29, 1959 F. M. M. B. SALOMON 2,906,230

SHIP STABILIZING APPARATUS

Filed Jan. 29, 1957 4 Sheets-Sheet 1

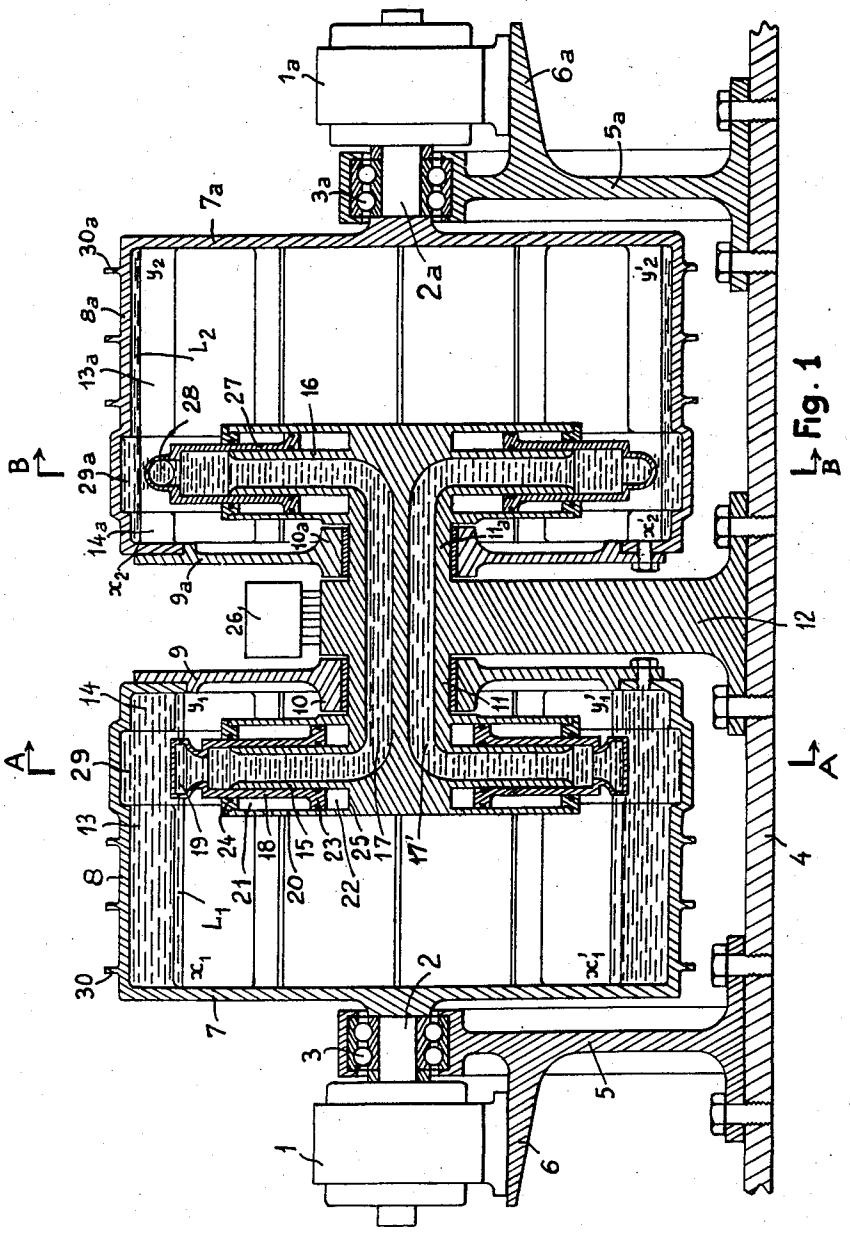


Fig. 1

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SHIP STABILIZING APPARATUS

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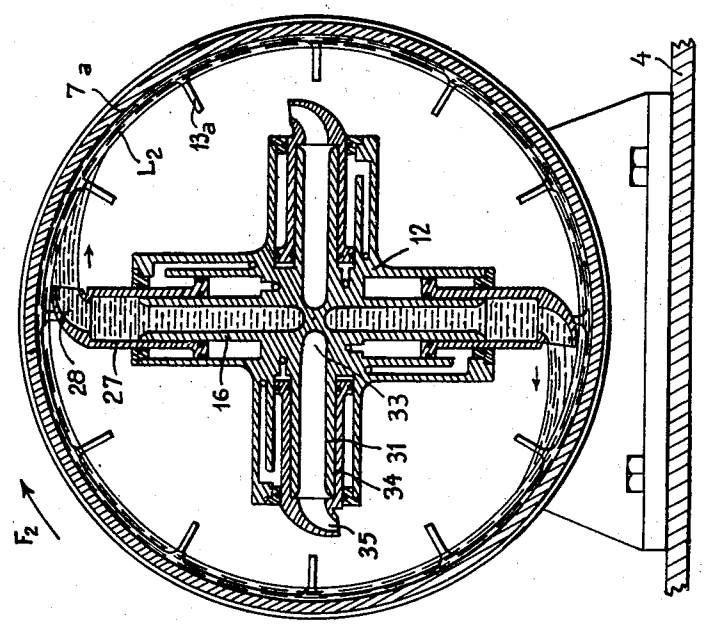


Fig. 3

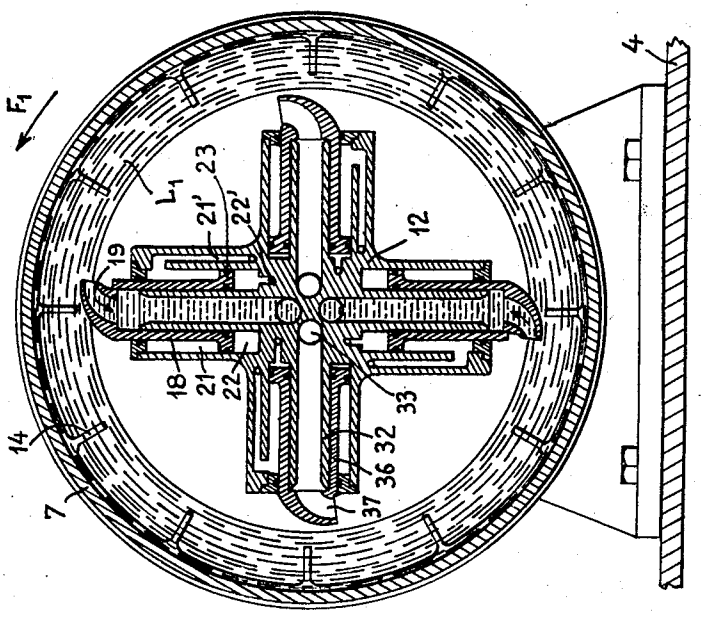


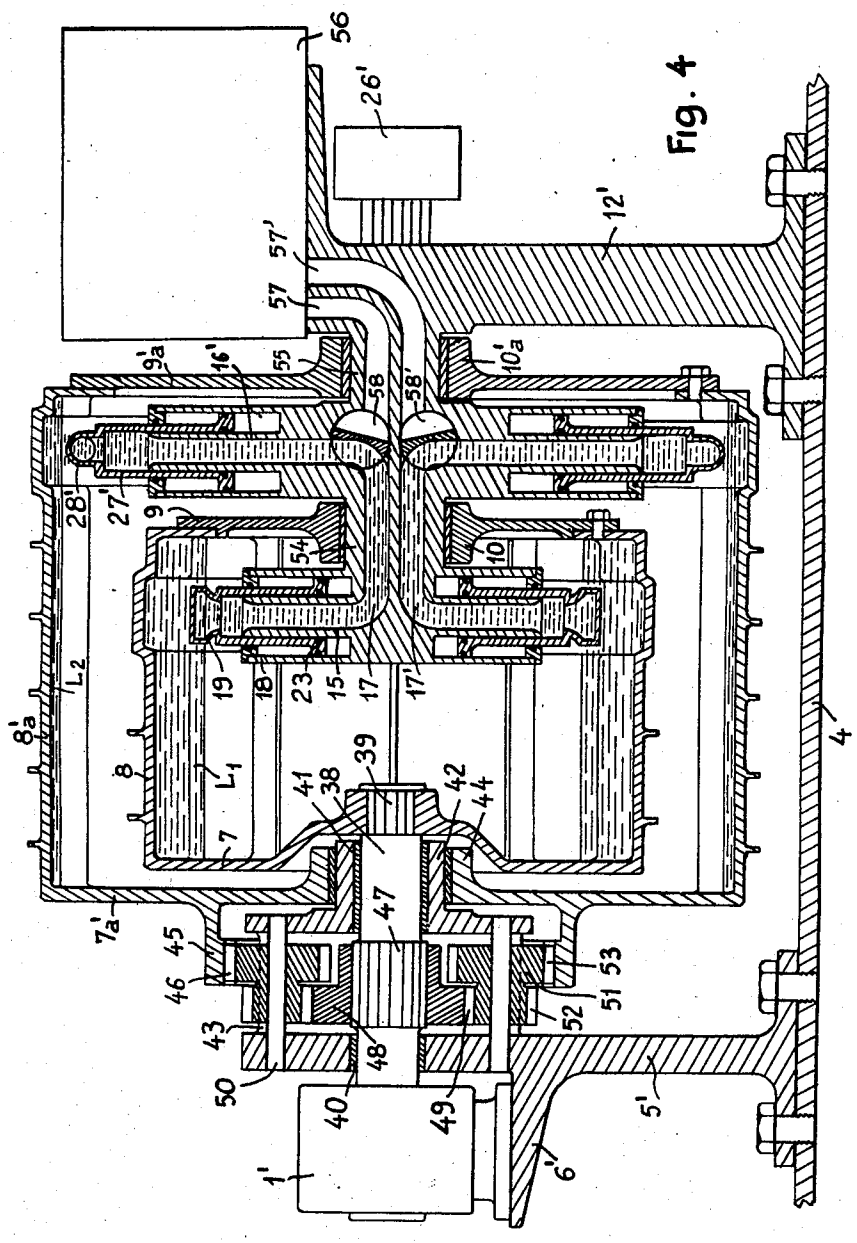
Fig. 2

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Fig. 4



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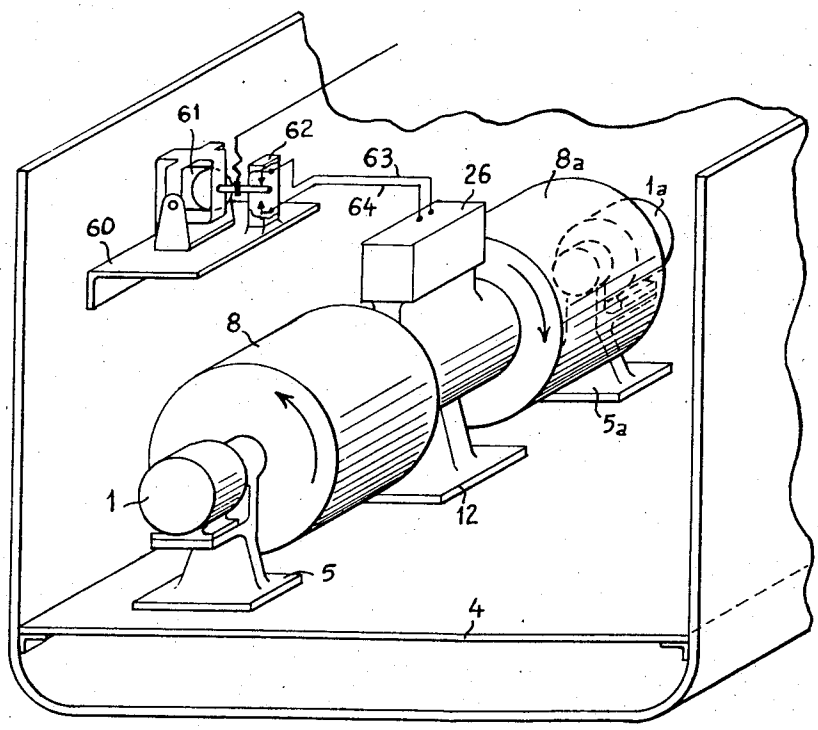


Fig. 5

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SHIP STABILIZING APPARATUS

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Claims priority, application France February 1, 1956

10 Claims. (Cl. 114—125)

The present invention relates to an apparatus intended to apply alternating mechanical impulses to a frame.

This apparatus is more particularly but not exclusively intended to prevent rolling of ships. It may also serve to prevent other kinds of oscillations than the rolling of ships.

The invention, in the case in which it is applied to reduce or to damp-out the rolling oscillation of a ship, relates especially to the utilization of the movements and of the changes in direction of a liquid mass working in a closed circuit under the following conditions:

(1) At least one driving mechanism maintains a continuous movement of a liquid mass and imparts thereto a generally rapid movement in a given direction, about an axis parallel to the axis of rolling of the ship;

(2) At chosen moments, and preferably under the action of controlling mechanisms, at least one part of this liquid mass is forced to pass through reaction members which are fixed with respect to the hull of the ship and are arranged so as to force the streams of liquid to change direction whilst maintaining substantially constant the vis viva of the liquid.

The streams of liquid during their passage through the said reaction members, apply to these members a couple which is transmitted to the hull and which represents the useful anti-rolling couple.

(3) The liquid continuing its movement, passes, without losing its vis viva (except for slight losses) into a second rotation maintaining member similar to the first and having its axis preferably parallel to that of the first maintaining member, and in which the linear speeds are substantially equal in absolute value to the speeds which it possessed in the first rotation maintaining member, but in the opposite direction.

(4) At chosen moments, and preferably under the action of servo-control mechanisms, the liquid is forced to pass into further reaction members which are rigidly fixed to the hull and which force the streams of liquid to change direction a second time, whilst maintaining substantially constant the vis viva of the liquid.

In this second change of direction, the streams of liquid apply to the reaction members a couple of opposite sense to that which was previously applied, and which is transmitted to the hull.

(5) The liquid immediately returns, without loss of vis viva (except for small losses) into the first driving member in which it again assumes, after the two changes in direction to which it has been subjected in the reaction members, the movement which it had previously.

The same cycle of operations take place, preferably under the action of servo-control members, under conditions which will be explained later.

It is the same liquid mass which is concerned during the course of the successive cycles, and since the vis viva is maintained constant (except for very small losses), the power required for the movement of the maintaining members is reduced to a minimum. (The motors concerned with the maintenance of the movements compensate moreover for the small losses which are inevitable.

As will be explained in detail later, the movements of the liquid under the action of servo-control mechanisms which will be described below, are regulated in such manner as to obtain the following results:

The vector $\bar{M}$ representing the kinetic moment of the total mass of liquid with respect to an axis coupled to the ship and parallel to its rolling axis:

(*a*) At each instant *t*, the speed of the extremity of the vector $\bar{M}$ changed in direction is substantially equipollent to the couple which must be applied to the hull of the ship in order to oppose, at that instant, the rolling movement, in the best conditions.

(*b*) The vis viva of the liquid used—which operates in a closed circuit—remains at the same time preferably substantially constant, so that it may not be necessary (with the exception of small losses) continually to reconstitute this vis viva.

In certain forms of embodiment of the invention, the liquid is driven in the movement of rotation of a first casing which turns around an axis parallel to the rolling axis, and is drawn from this casing by extraction members.

The liquid then passes into piping systems which are rigidly fixed to the hull of the ship. These systems modify the direction of movement of the liquid and thus produce at every instant on the hull the useful couple which acts against rolling. By virtue of injection members, they lead the liquid to a second rotating casing in which it substantially retains its speed, and in which it continues to rotate with this casing until the couple which it is necessary to apply to the hull to counteract the rolling, has changed in direction. A second extraction (or drawing) system then takes the liquid from the second rotating casing and passes it into piping systems rigidly fixed to the hull, in which it applies a useful couple of opposite direction to the preceding couple and brings it back by means of injection members into the first rotating casing, again substantially maintaining its speed. (The maintenance of this speed is important from the point of view of economy of energy.)

A particularly interesting case is that in which the second casing rotates in the opposite direction to the first casing, about an axis parallel to that of the first or which may even be geometrically coincident with that of the first.

In the liquid circuit indicated above, the total vis viva of the liquid has remained substantially constant, with the exception of small losses (which are moreover compensated by the driving motors of the rotating casings), but its kinetic moment has varied and it is the variations of this kinetic moment which have applied to the ship, through the intermediary of the piping systems fixed to the hull, the useful couples which counteract rolling.

The movements and the discharges of the extraction members and the injection members are determined by a servo-control system which executes the orders transmitted to it by an automatic calculating apparatus, of known type.

This automatic calculating apparatus is coupled, in known manner, to various measuring or "detection" devices which measure the various factors concerned in the phenomenon of rolling. In order to measure these factors, use may be made in known manner of apparatus, which enable the various parameters to be determined which depend from the inclination of the ship, and especially the rolling angle, and the variations of these parameters, with time (differentials, integrals, etc.) for example small

pendulums, small gyroscopes (sometimes known as "gyro-pilots"), accelerometers, etc.

Devices may also be employed which are sensitive to the pressure of the sea on the ship, for example pressure gauges of various types, piezoelectric devices, etc.

Finally, with a view to counteracting rolling, the detectors are first of all concerned. Their indications are transmitted in known manner to a calculator which gives the necessary function or functions or the useful factors. The calculator controls the extraction devices and the injection devices of the liquid by means of servo-control mechanisms.

The equipments in accordance with the invention differ considerably from anti-rolling apparatus of known types, and have in particular the following advantages:

(1) The mass of liquid employed is small.

(2) The construction is simple and is particularly simpler than that of gyroscope damping devices, which have especially the serious drawback that they necessitate bearings which are subjected at the same time to high speeds of rotation and to enormous stresses. These drawbacks do not exist in the apparatus in accordance with the invention, in which in particular, the bearings of the rotating casings may be subjected to high speeds, but they are required to withstand much lower stresses and they are especially not subjected to the anti-rolling forces which are applied to the fixed piping systems which have been refererred to above.

(3) They are less bulky and lighter than the tank-type anti-rolling dampers, which require large masses of liquid and large tanks.

(4) They consume much less energy than anti-rolling devices which employ pumps.

(5) They do not necessitate considerable modifications to the hull which are inevitable with many other systems, especially with rolling dampers with paddles or rudder members.

(6) They are capable of obeying almost instantaneously.

(7) They can readily be made by mass-production methods.

A number of further special features of the invention will become apparent from the description which follows below with reference to the accompanying drawings, which are given in order to facilitate understanding of the invention and, by way of example, without implied limitation. The drawings relate by way of example to anti-rolling equipment for ships, but it is of course understood that very different forms may be employed without thereby departing from the spirit or from the scope of the invention.

In these drawings:

Fig. 1 is a cross-section through a vertical plane passing through the axis of rotation of an apparatus in which the two rotating casings are coaxial and end to end, rotating in opposite directions.

Fig. 2 is a cross-section taken through the plane A—A of Fig. 1.

Fig. 3 is a cross-section taken through the plane B—B of Fig. 1.

Fig. 4 relates to an apparatus similar to that of Fig. 1, but in which one of the rotating casings is mounted inside the other.

Fig. 5 is a fragmentary perspective view showing diagrammatically the apparatus of the present invention mounted in the hull of a ship.

In Fig. 1, a motor drives in rotation a shaft **2** carried by a bearing **3**. This bearing **3** is fixed to the deck **4** of the ship by the support **5**, and the motor **1** is fixed on a bracket **6** rigidly fixed to the support **5**.

The shaft **2**, which is parallel to the longitudinal axis of the ship rotatably drives a rotary casing **7** having an external rim **8**. This casing is closed by an end plate **9** which is rigidly fixed to a sleeve **10**. This sleeve **10** is supported on the counter-bearing **11** rigidly fixed to the frame **12**, and its axis is an extension of the axis of the shaft **2**. The frame **12** is fixed to the deck **4** of the ship.

The casing **7** is provided with paddles **13** and **14** and rotatably drives without sliding (or substantially without sliding) a certain portion L_1 of a liquid L. Under the action of centrifugal forces produced by the rotation of the casing **7**, the internal surface of the liquid takes the form of a cylinder of revolution having generators x_1y_1 and $x'_1y'_1$.

As shown on the right-hand side of Fig. 1, the apparatus comprises a further device entirely similar to that which has just been described.

A motor **1***a* rotatably drives a shaft **2***a* carried by a bearing **3***a*. The bearing **3***a* is fixed to the deck **4** by means of the support **5***a*, and the motor **1***a* is mounted on a bracket **6***a* integral with the support **5***a*.

The shaft **2***a* is also parallel to the longitudinal axis of the ship and, in the case shown in Fig. 1, its axis is an extension of the axis of the shaft **2**. It drives in rotation a rotary casing **7***a* having an external rim **8***a* and it is closed by an added end-plate **9***a* which is rigidly fixed to a sleeve **10***a*. The sleeve **10***a* is carried by the counter-bearing **11***a* rigidly fixed to the frame **12**, and its axis is the same as that of the sleeve **10** and of the shafts **2** and **2***a*.

The casing **7***a* carries paddles **13***a* and **14***a* and drives in rotation without sliding (or substantially without sliding) a further part L_2 of the liquid L, the internal surface of which is a cylinder of revolution having generating lines x_2y_2 *and* $x'_2y'_2$.

In the apparatus shown in Figs. 1, 2 and 3, the rotary casings **7** and **7***a* are driven in rotation in opposite directions to each other (in accordance with the arrows F_1 and F_2 drawn on Figs. 2 and 3) and preferably at equal speeds in absolute value and, consequently, the portions L_1 and L_2 of the liquid L rotate in opposite directions from each other, but preferably at equal linear speeds in absolute value.

There will now be described the reaction devices coupled to the frame of the apparatus (and consequently to the ship) and which force a part of the liquid to pass from the rotary casing **7** into the rotary casing **7***a* and vice-versa.

In Fig. 1, there can moreover be seen only the two devices which enable the liquid to be drawn from the rotary casing **7** in order to cause it to pass into the rotary casing **7***a* (and not those which pass the liquid from the casing **7***a* to the casing **7**).

These two devices are identical and can be deducted one from the other by a rotation of π about the general axis of rotation. One of these devices will now be described.

This comprises essentially a fixed piping system formed in the frame of the apparatus and having its two extremities arranged, one to draw-off the liquid (extraction device), the other to send it back (injection device). This piping system is formed by two tubes **15** and **16** rigidly fixed to the frame and coupled to each other by a channel **17** housed in the frame.

Over the tube **15** is adapted to slide a tube or draining member **18** which terminates in a curved-back and flattened portion **19** forming a scoop (Figs. 1 and 2) and which is intended to extract the liquid from the rotary casing **7**. Around the sliding tube **18** is provided a further tube **20** rigidly fixed to the frame so as to form between the tube **18** and the tube **20** chambers **21** and **22** which are further defined by the piston **23** fixed to the tube **18**, the cover **24** and the bottom **25**, and are intended to regulate the displacement of the tube **18** by hydraulic means.

To this end, the chambers **21** and **22** are connected by means of conduits **21'** and **22'** (shown in Fig. 2) housed in the frame, to a control box shown diagrammatically at **26** in Fig. 1. By means of this box **26** and the conduits **21'** and **22'**, it is possible to put under pressure, either the liquid contained in the chamber **21** or the liquid

contained in the chamber **22**, which enables the piston **23** and the tube **18** which is fixed to it to be moved in the desired direction.

On the tube **16** is arranged to slide a tube or conduit **27** which terminates in a curved-back portion **28** forming an injector (see Figs. 1 and 3) and which is intended to send the liquid into the rotary casing **7***a*. The tube or conduit **27** may be displaced laterally by hydraulic means similar to those which have just been described in respect to the movement of the tube or draining member **18**.

The scoops may be displaced between the two following extreme positions: complete immersion in the liquid and completely clear of the liquid. In order to permit complete penetration into the liquid so as to extract it completely, channels **29** and **29***a* are provided in the rims **8** and **8***a* so as to co-operate with the extremities of the scoops. On the other hand, ribs **30** and **30***a* are provided round the rims **8** and **8***a* in order to increase their strength.

As has already been previously stated above, there can be seen in Figs. 1, 2 and 3, a second device arranged at 180° to the first and intended also to extract the liquid from the casing **7** in order to send it into the casing **7***a*. This device is identical with that which has just been described.

The internal shape of the scoops is so arranged that the liquid passes into them tangentially or substantially tangentially in order to avoid losses of energy. The external shape of the scoop is arranged so as to avoid parasitic phenomena and turbulence.

The penetration of a scoop into the liquid is effected very gradually as and when the quantity of liquid in the casing diminishes, and generally in such manner that the mouth of the scoop may be almost wholly plunged into the liquid, but with the lower edge of the mouth tangential or almost tangential to the internal surface of the liquid.

The two scoops which are located in the same rotary casing, for example the two scoops shown in Figs. 1 and 2 in the casing **7**, have in general symmetrical displacements in order to maintain a perfect balance.

The internal shape of the injection nozzles is determined in such manner that the liquid is discharged therefrom as tangentially as possible to the internal surface of the liquid which already exists inside the casing, and that the streams of liquid may be free from turbulence.

The displacement of the injection nozzle is effected gradually from the periphery and in accordance with the passage of the liquid into the casing.

All the surfaces of the piping systems, the scoops and the injectors which are in contact with the liquid are made as smooth as possible.

There will now be described the two devices which enable the liquid to be extracted from the casing **7***a* so as to return it to the casing **7**.

These are only shown in Figs. 2 and 3. They are identical with each other and, like those previously described, may be deduced one from the other by a rotation of π about the general axis of rotation. They are furthermore identical to the devices described above with the exception that the scoop-carrier tubes are now in the casing **7***a* (that is to say shown in Fig. 3, which is the cross-section of the casing **7***a*) whilst the injector-carrier tubes are in the casing **7** and are shown in Fig. 2 which is the cross-section of the casing **7**.

Each of these devices comprises a tube **31** (see Fig. 3) rigidly fixed to the frame, and a tube **32** (see Fig. 2) also fixed to the frame, these two tubes being coupled together by a piping system **33** (see Figs. 2 and 3) also housed in the frame and identical with the piping system **17** of Fig. 1.

On the tube **31** (Fig. 3) is arranged to slide a tube **34** which terminates in a curved-back and flattened portion **35** forming a scoop, intended to extract the liquid from the rotary casing **7***a*. On the tube **32** (Fig. 2) is adapted to slide a tube **36** which terminates in a curved-back portion **37** forming an injector intended to send back the liquid into the casing **7**.

The displacements of the tubes **34** and **36** are effected hydraulically in the same manner as the displacements of the tubes **18** and **27**, and this under conditions which will be explained later.

In a very general way, the control of the extraction and injection devices may be effected by very varied kinds of hydraulic means, or also by mechanical or electrical or pneumatic means, or by various combinations of these means.

In the positions shown in Figs. 1, 2 and 3, the two scoops **19** (see particularly Fig. 2) are plunged into the ring of liquid driven in rotation by the casing **7**.

On the other hand, the injectors **37** (see Fig. 2) are in the withdrawn position. The result is that the positions shown correspond to an instant when the liquid driven by the casing **7** in the direction of the arrow F_1 is extracted from this casing.

At the same time, the injectors **28** (see Figs. 1 and 3) are in a tangential position to the liquid ring of the casing **7***a* and inject the liquid into this casing in the direction of rotation of the casing (arrow F_2). As regards the scoops **35**, these are then in the withdrawn position in the casing **7***a*.

The operation takes place as follows:

At every instant t, the liquid ring whch is driven in rotation at an angular speed u_1 by the casing **7** possesses, with relation to the axis of rotation, a kinetic moment $\bar{M}_1$, represented by a vector parallel to the axis of rotation, which axis is in addition parallel to the rolling axis of the ship.

Moreover, the value of this kinetic moment (or moment of the momentum of the liquid) is:

$$\bar{M}_1 = m_1 R_1^2 u_1$$

in which m_1 is the mass of this liquid ring in the casing **7**, R_1 is its radius of gyration, and u_1 its angular speed.

At the same instant, the liquid ring inside the casing **7***a* is driven by this casing at an angular speed of $-u_1$, and its kinetic moment relative to the axis of rotation is similarly:

$$\bar{M}_2 = -m_2 R_2^2 u_1$$

in which m_2 is the mass of this liquid ring and R_2 is its radius of gyration.

The total kinetic couple $\bar{M}$ is given by the albebraic equation:

$$\bar{M} = \bar{M}_1 + \bar{M}_2 = u_1(m_1 R_1^2 - m_2 R_2^2)$$

the couple applied at each instant on the hull is equal to the differential:

$$\frac{d\bar{M}}{dt} = \frac{d}{dt}[u_1(m_1 R_1^2 - m_2 R_2^2)]$$

In order to vary the factor $m_1 R_1^2 - m_2 R_2^2$, it is only necessary to send liquid from the casing **7** to the casing **7***a* or vice versa. In other words, it is necessary to transfer the liquid from the casing **7** to the casing **7***a*, or vice-versa, depending on the instants.

In addition, this transfer should be made more or less quickly, depending on the cases and the instants, in order to give the differential expressed above the appropriate value at each instant t. During the course of this transfer, the liquid applies to the "reaction members" formed by the conduits, the useful anti-rolling couples.

As has been previously stated, the transfer members are controlled at every instant by a control box **26**, which, in the case of Figs. 1, 2 and 3, acts by hydraulic means on the scoop-carrier tubes and on the injection tubes in order to extract at each instant in the desired direction (that is to say from left to right or from right to left, depending on the instants) and with a desired rate of flow.

The box 26 comprises for example an assembly of servo-motors (not shown) which are generally electric motors driving pumps. It is these pumps which control hydraulically the pistons such as the pistons 23 of the extraction devices (see Fig. 1) and also the corresponding pistons of the injection devices.

The servo-motors are controlled in dependence on an automatic calculating apparatus which produces the necessary function or functions of the parameters which are transmitted to it by the various detection devices.

These detection devices themselves measure, at each instant, the various factors which are involved in the phenomenon of rolling. These are in particular the various parameters which are in relation with the inclination of the ship and especially the angle of roll, and their variations with time (differentials, integrals, etc.). They are also the various parameters which are associated with the pressure applied by the sea to the hull.

As regards the measuring or detection devices, there may be employed in particular, small pendulums, small gyroscopes (gyro-pilots) accelerometers, pressure gauges of various types and especially piezo-electric devices.

One of the advantages of the invention is the possibility of varying certain characteristics of the apparatus in accordance with the circumstances and the times. Depending on the amount of swell, it is possible, in particular, to vary the speeds of the casings 7 and 7*a*, by acting on the speeds of the motors 1 and 1*a*, which could especially be electric motors with collectors (for direct current or alternating current).

It is also possible to vary the total quantity of liquid employed by limiting the travel of the scoops, while maintaining the same total mass of liquid. This total mass may, however, also be varied.

To this end, auxiliary fixed reservoirs may be employed which are not shown in Figs. 1, 2 and 3. One of these is shown in Fig. 4. The liquid is passed by means of suitable pumps from this fixed reservoir to one of the rotary casings 7 and 7*a* when it is desired to increase the mass of the liquid.

On the other hand, if it is desired to reduce this mass, it is only necessary to set-up a derivation on the channels 17 and 17′ so as to return the desired quantity of liquid into the fixed reservoir.

It should also be noted that in Fig. 1 no valve has been shown on the piping systems such as 17, whereas it is of course generally an advantage to provide such valves, since they give a supplementary means of regulation.

A further means of regulation (not shown) which may in some cases be very important, may be constituted by needles similar to those which are used for the regulation of hydraulic turbines and especially of Pelton wheels. These needles or spindles may be placed in particular inside the nozzles of the injectors.

The apparatus shown in Fig. 4 shows a device similar to that of Fig. 1 which has the special advantage of taking up less space in the longitudinal direction.

The casing 7*a* is in this case arranged around the casing 7, and in the example shown in Fig. 4 it is driven in rotation in the opposite direction to that of the casing 7. The casing 7 is rotatably driven by the driving shaft 38 by means of grooves 39. The shaft 38 passes through bearings 40 and 41 carried respectively by the support 5′ and by the barrel 42 coupled to the support 5′ by the arms 43. The support 5′ is rigidly fixed to the deck 4 of the ship.

The shaft 38 is directly driven in rotation by the motor 1′ which is mounted on the bracket 6′ fixed to the support 5′. A sleeve 44 (on the left-hand side of Fig. 4) is rigidly fixed to the casing 7′*a* and enables it to be centered on the barrel 42 which serves as its bearing. The casing 7′*a* carries in addition a ring 45 which is provided with internal teeth 46.

On the driving shaft 38, there is mounted besides on grooves 47, a pinion 48 provided with teeth 49. On shafts 50 which are carried on the support 5′, are freely mounted wheels 51 provided with teeth 52 and 53 of different diameters. The teeth 52 of smaller diameter engage with the teeth 49 of the driving pinion 48. The teeth 53 engage with the internal teeth 47 which are rigidly fixed to the casing 7′*a*.

By this means, the casing 7′*a* is driven in rotation by the motor 1′ in the opposite direction to the casing 7, and the desired ratio of the angular speeds of the two casings is obtained by a suitable choice of the diameters of the four sets of teeth 49, 52, 53 and 46. In general, it is preferable in this way to make the linear speeds of the liquid rings in the casings 7 and 7′*a* equal or substantially equal in absolute value, but of opposite directions.

On the other hand, the casings 7 and 7′*a* are supported by means of the sleeves 10 and 10′*a* on the bearing surfaces 54 and 55 rigidly fixed to the frame 12′.

The liquid-transfer devices are similar to those which have already been described with reference to Fig. 1 and operate in the same manner.

In Fig. 4, however, there has been shown in addition an auxiliary tank 56 which is not rotating but fixed. This tank rests on the frame 12′. From this tank, four conduits pass out and rejoin the four transfer conduits formed in the frame. Two of these conduits, the conduits 57 and 57′ only, are shown in Fig. 4. They are connected to the conduits 17 and 17′ which serve to transfer the liquid from the casing 7 to the casing 7′*a*. A valve 58 enables the conduit 17 to be put into communication with the conduit 57 and interrupts the communication between the conduit 17 and the conduit 16′. A valve 58′ carries out the same function for the conduits 17′ and 57′.

If, for a certain period of time, the conduits 17 and 57 on the one hand and 17′ and 57′ on the other are put into communication, the liquid which is present in the casing 7 is sent during this period into the fixed tank 56 instead of being transferred to the casing 7′*a*. This enables the total quantity of liquid working in the apparatus to be reduced, if this is possible, that is to say if the condition of the sea can only give rise to a small or fairly small rolling motion.

If, on the contrary, it is desired to increase the quantity of liquid working (when it is necessary to counteract a greater degree of rolling) the two other conduits coming from the tank 56 (not shown in Fig. 4) are put into communication at the suitable moment with the injection conduits located in the casing 7 and, by virtue of suitable pumps (not shown in Fig. 4) the desired quantity of liquid passes from the tank 56 into the casing 7.

Use may also be made of the auxiliary fixed tank 56 if it is considered necessary to empty the two rotary casings 7 and 7′*a*, either before the apparatus is put into operation, or before it is stopped, with the object on the one hand of avoiding out-of-balance effects at the moment of starting or of stopping, and on the other hand of reducing the inertia of the driven portions at these times.

In order to empty the liquid before stopping, use may be made of the scoops by proceeding as explained above for the case of a partial emptying. If emptying has not been effected before stopping and it is desired to empty before starting-up again, use will be made of pumps (not shown on the drawing).

The fluid employed under the conditions given above will in general be a liquid, its characteristics being varied according to the particular case of application. In particular, use can be made of liquids having very different densities and viscosities (for example oils, water, silicones, etc.). Use could also be made if so desired of liquids of high density (for example mercury) or even of powders (for example graphite powders, powdered bi-sulphide of molybdenum). In very many cases, it would appear desirable to give preference to a liquid of high fluidity.

Fig. 5 shows an apparatus embodying features of the present invention mounted in the hull of a ship to counter-

act oscillations of the hull caused by the sea surrounding the hull. The general geometrical axis of the apparatus is parallel to the longitudinal axis of the hull. As seen in Fig. 5, the supports **5**, **5***a* and **12** are connected to the deck **4** of the ship. Upon these supports are mounted, as previously described, the apparatus assembly which includes the motors **1** and **1***a*, the rotary casings having the rims **8** and **8***a*, and the control box **26**. In addition, a gyroscopic device **61** of known construction is mounted on a platform **60** which is secured to the hull. The gyropilot apparatus **61** acts upon, in known manner, the electrical contacts of the housing **62**. These electrical contacts are connected to electrical conductors **63** and **64** which lead to the control box **26**. In the box **26**, these conductors are suitably connected to electric servo-motors which control pumps or distribution vanes. The conductors can also be connected to electro-magnets which suitably control distribution valves.

As has been already stated above, the invention is not limited to anti-rolling devices. It may in particular be applied to counteract oscillations in various branches of industry, whether in the case of vehicles, of ships, of aircraft, or of fixed machines.

As far as the pitching of ships is concerned (in the cases in which it would be possible to consider reducing them without disadvantage) the devices to be employed in accordance with the present invention would be exactly similar to those which have been described for counteracting rolling. The axes of rotation of the casings, instead of being parallel to the rolling axis of the ship, would however be perpendicular to the longitudinal central plane.

The number and the arrangement of the apparatus such as those which have been described may be widely varied. For example, the rotary casings such as **7** and **7***a* may be arranged otherwise than in the manner indicated; in particular they may be arranged side by side.

As regards the maintenance of the movement of the rotary casings, this may, as has been seen above, be effected by means of a single motor, with the interposition of gears as in the case of Fig. 4. This maintenance may also be obtained by independent motors, as in the case of Fig. 1. In this case, there may be an advantage in coupling together these two motors, electrically if they are electric motors.

It is very important to note that, broadly speaking, the assembly of nozzles formed by the piping systems such as **19** and **35** of Figs. 1, 2 and 3, forms the analogue of a turbine rotor especially of a hydraulic turbine—which is assumed to be rigidly locked to the hull of the ship.

The apparatus according to the present invention essentially differs from the known devices, in which solid flywheels are used, with hydraulic means to periodically retard and accelerate the rotation velocity of the flywheels. In the present invention the liquid mass forms by itself the efficient mass against the perturbing torque; moreover, the rotation velocity of the rotation maintaining member is substantially constant, for a given perturbing torque.

What I claim is:

1. In a structure exposed to oscillation forces, in combination, a frame rigid with said structure, an apparatus adapted to apply alternating mechanical impulses to said frame to counteract oscillations of said structure and comprising a liquid mass forming essentially an inertia mass, bearings connected to said frame, a first rotation maintaining member carried by said bearings and having a geometrical axis parallel to the axis of the oscillation to be counteracted and adapted to drive in rotation in a first direction at least a portion of said liquid mass at a substantially constant speed, second bearings connected to said frame, a second rotation-maintaining member carried by said second bearings and having a geometrical axis adapted to drive in rotation the other portion of said liquid mass at a substantially constant speed, but in a direction of rotation opposite to said first direction, at least one motor fixed on said frame and coupled with said rotation-maintaining members for driving them in rotation, reaction members connected to the frame and adapted to pass the liquid mass at appropriately selected instants from one of the rotation-maintaining members into the other rotation-maintaining member, and said reaction members being adapted to change the direction of flow of the liquid mass therein while substantially preserving the speed of said liquid mass at its absolute value.

2. In a structure exposed to oscillation forces, in combination, a frame rigid with said structure, an apparatus adapted to apply alternating mechanical impulses to said frame to counteract oscillations of said structure and comprising a liquid mass forming essentially an inertia mass, bearings connected to said frame, a first rotation-maintaining member carried by said bearings and having a geometrical axis parallel to the axis of the oscillation to be counteracted and adapted to drive in rotation in a first direction at least a portion of said liquid mass at a substantially constant speed, second bearings connected to said frame, a second rotation-maintaining member carried by said second bearings and having a geometrical axis parallel to the geometrical axis of the first rotation-maintaining member and adapted to drive in rotation the other portion of said liquid mass at a substantially constant speed but in a direction of rotation opposite to said first direction, at least one motor fixed on said frame and coupled with said rotation-maintaining members for driving them in rotation, a first group of reaction devices connected to said frame and comprising (*a*) extraction devices adapted to extract the liquid at appropriately selected instants from the first rotation-maintaining member, (*b*) injection devices adapted to return the liquid into the second rotation-maintaining member and (*c*) reaction conduits serving to connect together said extraction devices and said injection devices and constructed to force the streams of liquid to change direction before the liquid is returned to the second rotation-maintaining member, a second group of reaction devices connected to said frame and comprising (*a*) extraction devices adapted to draw the liquid at appropriately selected instants from the second rotation-maintaining member, (*b*) injection devices adapted to re-inject the liquid into the first rotation-maintaining member and (*c*) reaction conduits serving to connect together said extraction devices and said injection devices and constructed to force the streams of liquid again to change direction before the liquid is re-injected into the first rotation-maintaining member.

3. An apparatus as defined in claim 1, in which said rotation-maintaining members are rotating casings.

4. In a ship exposed to rolling oscillations, in combination, a hull and a deck rigid with said hull, an apparatus adapted to apply alternating mechanical impulses to said deck to counteract rolling oscillations of said ship forming and comprising a liquid mass, essentially an inertia mass, bearings connected to the deck, a first rotation-maintaining member carried by said bearings and having a geometrical axis parallel to the rolling axis of the ship and adapted to drive in rotation in a first direction at least a portion of said liquid mass at a substantially constant speed, second bearings connected to said deck, a second rotation-maintaining member carried by said second bearings adapted to drive in rotation the other portion of said liquid mass at a substantially constant speed but in a direction of rotation opposite to said first direction, at least one motor fixed on said deck and coupled with said rotation-maintaining members for driving them in rotation, a first group of reaction devices connected to the deck and comprising (*a*) extraction devices adapted to extract the liquid at appropriately selected instants from the first rotation-maintaining member, (*b*) injection devices adapted to return the liquid into the second rotation maintaining member, and (*c*) reaction conduits serving to connect together said extraction devices and said injec-

tion devices and constructed to force the streams of liquid to change direction before the liquid is returned to the second rotation-maintaining member, a second group of reaction devices connected to said deck and comprising (*a*) extraction devices adapted to draw the liquid at appropriately selected instants from the second rotation-maintaining member, (*b*) injection devices adapted to re-inject the liquid into the first rotation-maintaining member, and (*c*) reaction conduits serving to connect together said extraction devices and said injection devices and constructed to force the streams of liquid again to change direction before the liquid is re-injected into the first rotation-maintaining member.

5. An apparatus as defined in claim 2, wherein the extraction devices adapted to extract the liquid at appropriately selected instants from the rotation-maintaining members comprise draining members secured against rotation but movable radially, and scoops fixed at the ends of said draining members.

6. An apparatus as defined in claim 2, wherein the injection devices comprise conduits secured against rotation but movable radially, and injectors fixed at the ends of said conduits.

7. In a ship exposed to oscillation forces, in combination, a hull and a deck rigid with said hull, an apparatus adapted to apply alternating mechanical impulses to said deck to counteract oscillations of said ship and comprising a liquid mass forming essentially an inertia mass, bearings connected to the deck, a first rotation-maintaining member carried by said bearings and having a geometrical axis parallel to the axis of the oscillation to be counteracted and adapted to drive in rotation in a first direction at least a portion of said liquid mass at a substantially constant speed, second bearings connected to said deck, a second rotation-maintaining member carried by said second bearings adapted to drive in rotation the other portion of said liquid mass at a substantially constant speed, but in a direction of rotation opposite to said first direction, at least one motor fixed on said deck and coupled with said rotation-maintaining members for driving them in rotation, reaction members connected to the deck and adapted to pass the liquid mass at appropriately selected instants from one of the rotation-maintaining members into the other rotation-maintaining member, said reaction members being adapted to change the direction of flow of the liquid mass therein while substantially preserving the speed of said liquid mass at its absolute value.

8. In a ship exposed to rolling oscillations, in combination, a hull and a deck rigid with said hull, an apparatus adapted to apply alternating mechanical impulses to said deck to counteract rolling oscillations of said ship and comprising a liquid mass forming essentially an inertia mass, bearings connected to the deck, a first rotation-maintaining member carried by said bearings and having a geometrical axis parallel to the rolling axis of the ship and adapted to drive in rotation in a first direction at least a portion of said liquid mass at a substantially constant speed, second bearings connected to said deck, a second rotation-maintaining member carried by said second bearings and having a geometrical axis parallel to the geometrical axis of the first rotation-maintaining member and adapted to drive in rotation the other portion of said liquid mass at a substantially constant speed but in a direction of rotation opposite to said first direction, at least one motor fixed on said deck and coupled with said rotation-maintaining members for driving them in rotation, reaction members connected to the deck and adapted to pass the liquid mass at appropriately selected instants from one of the rotation-maintaining members into the other rotation-maintaining member, said reaction members being adapted to change the direction of flow of the liquid mass therein while substantially preserving the speed of said liquid mass at its absolute value.

9. An apparatus as defined in claim 5, further comprising hydraulic means for controlling the movable parts of the extraction devices.

10. An apparatus as defined in claim 6, further comprising hydraulic means for controlling the movable parts of the injection devices.

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