

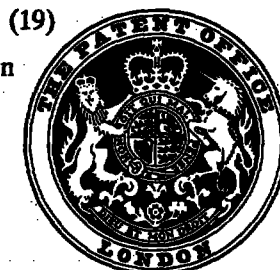
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(54) PROPULSION AND CONTROL SYSTEM FOR WATER CRAFT

(71) We, SCHOTTEL-WERFT JOSEF BECKER GmbH & CO. KG (FORMERLY SCHOTTEL-WERFT JOSEF BECKER KG), a German Kommanditgesellschaft, of 5401 Spay/Rhein, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a water craft having a propulsion and control system comprising at least one pair of thrust-generating rudders, e.g. rudder propellers, disposed one on each side of the longitudinal axis of the vessel and each pivotable about a vertical axis.

The prior art discloses ships with a plurality of rudder propellers which can be pivoted individually or optionally together by a common control element, for example a steering wheel. Nevertheless, the manoeuvrability of such ships does not satisfy all requirements, more particularly those made on tugs and other working vessels. What is required is a control system which enables the water craft to thrust into all directions without slewing, steering being achieved with a single control signal. Desirable slewing of the water craft should also be additionally possible.

The present invention provides a water craft having a propulsion and control system comprising a pair of thrust-generating rudders disposed one on each side of the longitudinal axis of the vessel, each rudder being adapted to pivot about its vertical axis, and a common control device having first means, controlled by a control element, for pivoting the rudders, the said first means - in response to operation of the control element - automatically pivoting the rudders unidirectionally (i.e. in the same direction of rotation) in synchronism relative to a reference position of the rudders in

which - given identical thrusts - equal and opposite torques are applied about the centre of gravity of the craft, the reference position being such that each thrust is directed at right-angles to a vertical plane containing the pivot axis of the rudder and the centre of gravity.

Preferably, second means are provided for superimposing limited synchronous counterdirectional pivoting on the synchronous unidirectional pivoting motion, so that a slewing about the vertical axis of the vessel can be superimposed upon the thrusting motion which is also known as traversing motion.

To permit optional selection between, for example, parallel alignment of the rudders for conventional travel and thrusting motion, where appropriate with additional slewing, third means are preferably provided for pivoting the rudders without the limitation of synchronous unidirectional pivoting from the reference position.

In one embodiment of the invention, a common control element (e.g. a lever) for controlling the first means and for controlling the second or third means facilitates manoeuvring. The ease of operation is improved still further if fourth means are provided for synchronously regulating the power rating of prime movers associated with the thrust-generating rudders, while the inclusion of fifth means for superimposing a synchronous regulation on the synchronous regulation improves manoeuvrability.

Preferably, electric, hydraulic, or pneumatic synchro systems, e.g. potentiometers, are provided for controlling the pivoting motion of the rudders, an element of such synchro systems (e.g. the wiper contact) being rotatable by the common control element via transmission elements. It is convenient for the common control element to be capable of superimposing

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appositely orientated supplementary rotation on the rotation of the said element of the synchro system. The second element of the synchro systems (e.g. the coil or casing) is preferable capable of performing a supplementary motion, being driven by a second control element.

Preferably, sixth means are provided for adjusting the blade of rudder propellers and seventh means are provided for superimposing and a synchronous adjustment on the synchronous adjustment, these means being controlled by a common lever.

There is thus provision for desired slewing motion and/or for desired thrusting motion, for example lateral offset motion, of the craft. The magnitude and direction of optimum thrust can be automatically predefined in dependence on the travelling direction for a desired slewing motion of the vessel. Regulation of thrust can be performed in proportion with the mean specified thrust, and this proportionality is retained if the thrust of variable-pitch propellers is extended through zero into the negative range. It is also possible to superimpose a slewing motion upon the thrust motion by altering only one of the thrust directions.

The invention will be described further, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows in diagrammatic form a ship with a pair of rudder propellers, situated near the bows and aligned for conventional travelling;

Figure 2 shows the ship according to Figure 1, in which the rudder propellers are aligned in the position for pure thrusting motion (traversing motion);

Figure 3 shows the same ship with rudder propellers in a position for a lateral forward thrusting motion (traversing);

Figure 4 shows the rudder propellers set for accurate side thrust;

Figure 5 shows slewing plus cross-traversing;

Figure 6 shows the only possibility for pure slewing with two rudder propellers;

Figure 7 shows in diagrammatic form a complete propulsion and control system for the ship;

Figure 8 shows in vertical cross-section, on line VIII-VIII in Figure 9, a single-lever control system for thrusting and slewing;

Figure 9 is a section on line A-B in Figure 8 and illustrates a combined transmission;

Figure 10 shows in diagrammatic form a general view of another embodiment of the complete system;

Figure 11 shows in vertical cross-section, on line XI-XI in Figure 12, a control system (control signal delivery) relating to Figure 10;

Figure 12 is a section on line A'-B' in Figure 11 and illustrates the corresponding

combined transmission; and

Figure 13 is a section on line C-D on Figure 11.

The motion of a ship 1 can be divided into two parts, a thrusting motion (traversing) and a slewing motion. The slewing point of the ship 1 is the centre of gravity 2. Efforts are made to arrange the towing hook of tugs above the centre of gravity 2. Efforts are made to maintain the slewing point with and without the applied load. The mass centre of gravity also plays a part during acceleration but it will always be situated close to the centre of gravity so that this can be regarded with sufficient accuracy as the centre of rotation.

If a ship is to be moved without rotation (to traverse) it is necessary for the thrust forces to act without moments on the centre of gravity, i.e. the moments of the individual forces must cancel each other. Forces act without moments only in ahead and astern travel with rudder propellers in a normal arrangement ahead or behind the centre of gravity and in alignment parallel with the longitudinal axis of the ship. Appropriate rudder angles must be found for all transverse motions. By departing in accordance with the invention from the parallel alignment of the rudder propellers it is possible to produce forces which are free of moments and act in any desired direction by means of single-lever operation. Figure 1 to 6 explain these relationships.

Figure 1 shows in diagrammatic form a ship 1 with its centre of gravity 2 and the points 3 and 4 on which the thrust forces act. The thrust forces 5 and 6 act symmetrically with respect to the centre of gravity and parallel with the longitudinal axis so that their resultant is free of moments in ahead and astern travel. Torques having the lever arms a and b , and tending to slew the ship, will result if the two rudder propellers are rotated in synchronism through the control angle.

Figure 2 shows a reference position of the rudder propellers 3,4 whose availability is essential to the invention. Two lines 7,8 (which include an acute angle) extend through the centre of gravity 2 and through the points 3 and 4 on which the thrust of the rudder propellers act. The rudder propellers are turned so that in ahead travel the thrust forces are situated at right angles to these lines. The moments associated with the thrust forces of the rudder propellers will then cancel each other. A reduced resultant thrust will then be applied in the direction of ahead travel. This thrust is the maximum possible traversing force. It can act in any direction and is obtained when the rudder propellers are pivoted in synchronism. In no position will there be any torque about the centre of gravity 2. In every

position the angle between the thrust forces is the same and is supplementary to the angle between the lines 7 and 8.

Figure 3 shows the manner in which a resultant thrust 9 is obtained due to synchronous pivoting of the rudder propellers from the position illustrated in Figure 2, which thrust acts on the centre of gravity without torque and at the steering angle ϕ to the longitudinal axis of the ship.

Figure 4 shows a resultant steering angle ϕ of 90° , causing the ship to traverse to the right. It is a prerequisite for the above-described relationships that the intensity of the thrust of both rudder propellers is of equal magnitude. The prime movers of the propellers must therefore be driven in synchronism.

Traversing alone in any desired direction is not sufficient for all manoeuvres since external forces, wind, currents, and drive forces which do not act accurately on the lateral centre of gravity or a shift of the centre of gravity due to different loading and trim may result in slewing which must be compensated. In general it must therefore be possible for a slewing motion to be superimposed on the traversing motion. A torque which is to be superimposed on the thrust (transversing force) can be produced by limited rotation of the thrust forces against each other from their traversing direction (detuning). This alters the available traversing force. Right-hand traversing plus counterdirectional rotation of the rudder propellers, i.e. of the thrust forces, to the right produces increased right-hand thrust of the ship accompanied by clockwise slewing (Figure 5). Right-hand traversing plus counterdirectional left-hand rotation of the rudder propellers results in reduced right-hand thrust of the ship plus anticlockwise slewing. In fact traversing can be reduced to such an extent as to result in on-the-spot slewing, the only possible pure slewing motion which can be obtained with two rudder propellers (Figure 6).

A torque can also be produced, for example with the rudder propellers in the position shown in Figure 2, by individual variation of the thrust forces of the rudder propellers or by detuning the pitch of the propellers relative to each other.

The following operations can thus be performed by the propulsion and control system of the ship in accordance with the invention:

1. Infinite synchronous steering of the parallel aligned rudder propellers through 360° (Figure 1).

2. Changeover from parallel alignment of the rudder propellers to the above-described initial traversing position (Figure 2).

3. Infinite synchronous steering of the

rudder propellers through 360° from the initial period, for traversing.

4. Superimposition of slewing motion on the traversing motion by counterdirectional detuning of the rudder positions.

5. Superimposition of slewing motion on the traversing motion by counterdirectional detuning of the thrust.

6. Superimposition of slewing motion on the traversing motion by detuning of the propeller pitches.

Figure 7 shows in diagrammatic form a general arrangement of a propulsion and control system according to the invention. The thrust direction of two rudder propellers 103, 104, which can be driven by respective engines 101, 102, is controlled by a lever 10, namely by rotating it about the axis 11. The lever has two ratchet positions 12 and 13: in position 12 the rudder propellers are aligned in parallel (as in Figure 1), they are controlled in synchronism and unidirectionally, and the ship therefore travels in a conventional manner; in position 13 the rudder propellers are arranged at a given angle to one another corresponding to the initial traversing position (Figure 2). Rotation about the axis 11 defines the traversing direction. The lever 10 can also be rotated about its own axis 14. This rotation causes oppositely orientated detuning of the thrust directions and therefore results in traversing being accompanied by a slewing motion. The direction of rotation of the lever 10 about the axis 14 corresponds to the slewing direction of the ship. The intensity of thrust is set by a lever 15. Movement in the direction 16 causes the engine speeds or propeller pitches of both systems to be adjusted in synchronism. Rotation of the lever about its axis 17 results in the magnitude of the thrusts being detuned relative to each other, a procedure which also results in slewing of the ship. The indicated transmission diagram relating to the lever 15 indicates the manner in which this problem can be solved by simple mechanical means if potentiometers 18, 19 are used for control purposes. Follow-up control systems with potentiometers as synchro systems are known and will not be described in this context. The same problem can also be solved by hydraulic or pneumatic means, also known.

Figures 8 and 9 show the compound transmission which is operated by the lever 10. Synchro systems 20, 21, 22 are used to control the rudder propellers and can be potentiometers in an electrical solution to the problem. Capacitative or inductive control means can be used in place of synchro systems based on resistors, and hydraulic or pneumatic means or a combined control system can of course be employed. The lever 10 drives the synchro

system 22 via a hollow shaft 23 and gear wheels 24, 25. The synchro system 22 defines the direction of thrust when the rudder propellers are in parallel alignment (Figure 1). The synchro systems 20 and 21, which define the direction of thrust when the lever is set to the "traversing" position 13, are driven via gear wheels 26 and 27 (Figures 2 to 6). Both transmitters are set in accordance with the geometrical conditions of the ship. If the lever 10 is moved from position 12 to position 13, the slide 28 will depress the switch 29 to change over, via relays not shown, from the synchro system 25 to the synchro system 26 and 27. The gear wheel 24 is disposed on the hollow shaft 23 so as to be transversely slidable thereon. To this end the gear wheel is provided with a slot 105. If the lever 10 is rotated about the axis 14, the lug 106 will be rotated out of the plane of Figure 8 and the gear wheel 24 will be transversely displaced as already described. This transverse sliding motion results in counter-rotation of the gear wheels 26 and 27 and therefore also of the synchro systems 20 and 21. This produces the above-mentioned detuning of the thrust in opposite directions which results in slewing of the ship if cross-traversing predominates. The gear wheels 25, 26, 27 are retained in rockers 30, 31 and 32 so as to maintain constant mesh between the gear wheels, more particularly when the gear wheel 24 is transversely displaced. The rockers are urged by springs 33, 34, 35 towards the middle gear wheel 24.

Supplementary rotation of the synchro systems 20, 21 can also be obtained by the use of gear wheels with helical teeth and by displacing the central gear wheel 24 in the direction of its axis.

Torque can be applied to the ship also by rotating the lever 15 about the axis 17. This results in detuning of the thrust forces and causes slewing of the ship, for example in the position illustrated in Figure 2.

Another advantageous embodiment of the compound transmission is shown in Figures 10 to 13. A lever 36 defines the direction of motion of the ship by being rotated about a vertical axis 37. A switch 38 can select normal travel with parallel aligned rudder propellers or traversing travel with detuned rudder propellers. Rotation of the lever 36 about a horizontal axis 39 sets the intensity of thrust either by altering the engine speeds or the pitch of the propellers. If the pitch of the propellers is altered the lever can be moved beyond zero, i.e. the vertical position, into the other direction so that the direction of motion of the ship is reversed. To obtain additional rotation of the ship during traversing it is necessary to rotate a handwheel 40. Depending on the traversing direction the

handwheel 40 results in detuning of thrust or thrust direction or both, for as long as the handwheel is rotated out of its zero position.

Figures 11 to 13 show details of the compound transmission. If the lever 36 is rotated about the vertical axis 37, synchro systems 45, 46, 47 will be driven via gearwheels 41, 42, 43. The synchro system 45 controls the rudder propellers (Figure 1) which are aligned parallel with each other. The synchro systems 46 and 47 define the direction of thrust of the rudder propellers for traversing. The switch 38 changes over from the synchro system 45 to the synchro systems 46, 47. The casing of the synchro systems 46 and 47 are mounted on gearwheels 48 and 49 and can be adjusted through a limited angle. They are adjusted by the handwheel 40 via a shaft 50 and a gearwheel 51. A stop abutment 52 is mounted on the shaft 50 in order to restrict the angle. Rotation of the handwheel 40 therefore results in oppositely orientated alteration of the thrust directions.

If the lever 36 is moved about the horizontal axis 39 in the direction 39', either the engine speed or the pitch of the propellers will be adjusted via the gear rack 53 as the result of a rocker 54 adjusting switches 55 and 56 and therefore sliding potentiometers 57 and 58 or equivalent control means. The potentiometers define the pitch of the propellers or the engine speeds and their casings are also mounted on a gearwheel 59 which can be adjusted through a limited angle. If the said gearwheel is rotated, the switches 55 and 56 bearing on a plate 60 will move up or down so that the thrust is detuned in opposite senses.

The magnitude of detuning depends on the angle of position of the rocker 54 and therefore on the mean specified thrust. The rocker 54 will be in the horizontal position if no thrust is specified and the lever 36 is therefore in the vertical zero position. If the lever 36 is moved beyond the said zero position the detuning of the thrust is reversed to cause slewing in the opposite direction. These counteracting characteristics are also produced by the synchro systems 46 and 47 if the thrust becomes negative beyond zero, a feature which is normally possible only with variable-pitch propellers.

If the ship is slewed by detuning of the thrust the traversing direction will change. It is therefore convenient to allow thrust detuning to act only close to the ahead and astern direction. To achieve this effect, the system is constructed so that the rotation of the gearwheel 59 first be released by a cam 61. The said cam is connected via the hollow shaft 62 to the travelling direction lever 36. It is traced by rollers 63 and 64, connected to the gearwheel 59, and is so shaped that

rotation of the gearwheel 59 is possible only in ahead and astern travel.

The gearwheel 59 is driven by the hand-wheel 40 via the shaft 50 and a driver 65. The driver is fixedly connected with the shaft 50 and engages between the members of a prestressed hairpin spring 66. The members bear upon a pin 67 which is mounted axially parallel on a gearwheel 68. If the shaft 60 is rotated the driver will entrain one member of the hairpin spring and stress the latter. The second member of the spring will bear upon the spring 67 and entrain the gearwheel 68 if rotation is released by the cam 61.

The advantage of the compound transmission illustrated in Figure 12, 13 is that the correct control variables are automatically adjusted for any desired slewing of the ship and corresponding tendencies are retained beyond zero thrust for variable-pitch propellers.

Slewing can be achieved if only one of the two thrust direction is altered for each traversing direction, including ahead and astern.

The invention is not confined to a pair of rudder propellers but can also be embodied if more than two propellers are provided. If only one pair of rudder propellers is provided such propellers can be mounted on the stern of the ship, by contrast to the example according to Figure 1. The invention relates also to all propulsion systems which are equivalent to rudder propellers in the sense of the invention, i.e. to all propulsion systems which exert thrust which can be slewed about the point of action 3, 4.

WHAT WE CLAIM IS:-

1. A water craft having a propulsion and control system comprising a pair of thrust-generating rudders disposed one on each side of the longitudinal axis of the vessel, each rudder being adapted to pivot about its vertical axis, and a common control device having first means, controlled by a control element, for pivoting the rudders, the said first means - in response to operation of the control element - automatically pivoting the rudders unidirectionally (i.e. in the same direction of rotation) in synchronism relative to a reference position of the rudders in which - given identical thrusts - equal and opposite torques are applied about the centre of gravity of the craft, the reference position being such that each thrust is directed at right-angles to a vertical plane containing the pivot axis of the rudder and the centre of gravity.

2. A craft as claimed in claim 1, in which the vertical planes containing the centre of gravity and the respective pivot axes include an acute angle.

3. A craft as claimed in claim 1 or 2, in which the control device includes second

means, controlled by a control element, for pivoting the rudders, the said second means - in response to operation of the control element - automatically superimposing limited synchronous counterdirectional pivoting motion of the rudders on the synchronous unidirectional pivoting motion caused by the said first means.

4. A craft as claimed in any of claims 1 to 3, in which the common control device includes third means, controlled by a control element, for pivoting the rudders, the said third means - in response to operation of the control element - automatically pivoting the rudders without the limitation of synchronous unidirectional pivoting from the reference position.

5. A craft as claimed in claim 3 or 4, in which the first means and the second or third means are controlled by a common control element.

6. A craft as claimed in any of claims 1 to 5, in which each rudder is operatively connected to a prime mover in order to provide thrust, the control device comprising fourth means for regulating the power rating of the prime movers in synchronism.

7. A craft as claimed in claim 6, in which the control device includes fifth means for superimposing asynchronous regulation on the synchronous regulation.

8. A craft as claimed in any of claims 1 to 7, in which the control device includes electric, hydraulic, or pneumatic synchro systems for controlling the pivoting motion of the rudders, one element of such synchro systems being rotatable by a or the common control element via transmission elements.

9. A craft as claimed in claim 8, in which an oppositely orientated supplementary rotation can be superimposed on the rotation of the said element of the synchro system via transmission elements by the said common control element.

10. A craft as claimed in claim 8, in which the second element of the synchro systems is able to perform a supplementary motion which is driven by a second control element.

11. A craft as claimed in any of claims 1 to 10, in which the thrust-generating rudders are rudder propellers whose blades are adjustable, the control device including sixth means for adjusting the blades in synchronism.

12. A craft as claimed in claim 11, in which the control device includes seventh means for superimposing asynchronous adjustment on the synchronous adjustment.



rotation of the gearwheel 59 is possible only in ahead and astern travel.

The gearwheel 59 is driven by the hand-wheel 40 via the shaft 50 and a driver 65.

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The advantage of the compound transmission illustrated in Figure 12, 13 is that the correct control variables are automatically adjusted for any desired slewing of the ship and corresponding tendencies are retained beyond zero thrust for variable-pitch propellers.

Slewing can be achieved if only one of the two thrust direction is altered for each traversing direction, including ahead and astern.

The invention is not confined to a pair of rudder propellers but can also be embodied if more than two propellers are provided. If only one pair of rudder propellers is provided such propellers can be mounted on the stern of the ship, by contrast to the example according to Figure 1. The invention relates also to all propulsion systems which are equivalent to rudder propellers in the sense of the invention, i.e. to all propulsion systems which exert thrust which can be slewed about the point of action 3, 4.

WHAT WE CLAIM IS:-

1. A water craft having a propulsion and control system comprising a pair of thrust-generating rudders disposed one on each side of the longitudinal axis of the vessel, each rudder being adapted to pivot about its vertical axis, and a common control device having first means, controlled by a control element, for pivoting the rudders, the said first means - in response to operation of the control element - automatically pivoting the rudders unidirectionally (i.e. in the same direction of rotation) in synchronism relative to a reference position of the rudders in which - given identical thrusts - equal and opposite torques are applied about the centre of gravity of the craft, the reference position being such that each thrust is directed at right-angles to a vertical plane containing the pivot axis of the rudder and the centre of gravity.

2. A craft as claimed in claim 1, in which the vertical planes containing the centre of gravity and the respective pivot axes include an acute angle.

3. A craft as claimed in claim 1 or 2, in which the control device includes second

means, controlled by a control element, for pivoting the rudders, the said second means - in response to operation of the control element - automatically superimposing limited synchronous counterdirectional pivoting motion of the rudders on the synchronous unidirectional pivoting motion caused by the said first means.

4. A craft as claimed in any of claims 1 to 3, in which the common control device includes third means, controlled by a control element, for pivoting the rudders, the said third means - in response to operation of the control element - automatically pivoting the rudders without the limitation of synchronous unidirectional pivoting from the reference position.

5. A craft as claimed in claim 3 or 4, in which the first means and the second or third means are controlled by a common control element.

6. A craft as claimed in any of claims 1 to 5, in which each rudder is operatively connected to a prime mover in order to provide thrust, the control device comprising fourth means for regulating the power rating of the prime movers in synchronism.

7. A craft as claimed in claim 6, in which the control device includes fifth means for superimposing asynchronous regulation on the synchronous regulation.

8. A craft as claimed in any of claims 1 to 7, in which the control device includes electric, hydraulic, or pneumatic synchro systems for controlling the pivoting motion of the rudders, one element of such synchro systems being rotatable by a or the common control element *via* transmission elements.

9. A craft as claimed in claim 8, in which an oppositely orientated supplementary rotation can be superimposed on the rotation of the said element of the synchro system *via* transmission elements by the said common control element.

10. A craft as claimed in claim 8, in which the second element of the synchro systems is able to perform a supplementary motion which is driven by a second control element.

11. A craft as claimed in any of claims 1 to 10, in which the thrust-generating rudders are rudder propellers whose blades are adjustable, the control device including sixth means for adjusting the blades in synchronism.

12. A craft as claimed in claim 11, in which the control device includes seventh means for superimposing asynchronous adjustment on the synchronous adjustment.



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13. A water craft having a propulsion and control system substantially as described herein with reference to, and as shown in, Figures 1 to 6 and either Figures 7 to 9 or Figures 10 to 13 of the accompanying drawings.

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