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(54) METHOD FOR CONTROLLING VESSEL RUDDERS

VERFAHREN ZUR STEUERUNG DER RUDER EINES SCHIFFS

MÉTHODE POUR L'ASSERVISSEMENT DES GOUVERNAILS D'UN NAVIRE.

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Description

Field of the invention

[0001] The present invention relates to an electronic control method of at least two rudders of a vessel, e.g. a sailboat with two rudders.

Background art

[0002] Vessels or boats, such as sailboats, are often provided with two rudders. This technical solution is mainly due to the need to comply with the construction constraints imposed by the market while ensuring good performance of the boat. Indeed, the rudder has a substantially flat, adjustable leg of the boat, named rudder blade, adapted to offer a given surface under the water level so as to steer the boat. The greater the rudder surface extension, in particular the depth under sea level, the greater will be the steering capacity of the boat when the rudder is directed. However, for marketing reasons, it is not always possible to build boats with the rudder protruding too far deep, because this would make it impossible for the boat to access shallow waters. Therefore, the solution with two rudders having the same shape and size allows to make boats in which the depth of each rudder is less than the depth which would be required for a single rudder while ensuring good steering performance of the boat. In such a solution, the rudders are directed by the user acting on a wheel, referred to as steering wheel. When the user acts on the steering wheel, the two rudders move at the same angular speed, thus being simultaneously directed so that they are always parallel to each other. Boats are often provided with two steering wheels. In this case, the user may act on either the first or the second steering wheel, and the two rudders are, as in the previous case, always directed so as to be parallel to each other. The mechanism which allows the rudders to be directed or rotated, typically requires that each rudder is provided with a respective gear, referred to as steering gear, or steering machine. These gears are electronically and/or mechanically in mutual communication so that the rudders are always parallel to each other. Typically, the rudder surfaces may be rotated with respect to the longitudinal symmetry plane of the hull by a given angle β either in one rotation direction or in the opposite direction. Although the solution of having two rudders which rotate simultaneously, i.e. synchronously at the same speed, and which are maintained always parallel to each other, is convenient from some points of view, it is not free from disadvantages. A disadvantage is that although the rudders directed transversely with respect to the longitudinal symmetry plane of the hull are used to steer the boat, the surface of both rudders thus directed offers a fluid-dynamic resistance which drastically reduces the cruising speed. In particular, the greater the amplitude of angle β , the higher will be the fluid-dynamic resistance offered by the rudders. However, it may

occur that in some situations it is actually necessary for both rudders to cooperate to steering the boat in the same manner, but in other situations it could be advantageous for one rudder to offer a smaller surface than the other, thus allowing a lower fluid-dynamic resistance and therefore a faster cruising speed. However, the known technique does not include such a possibility. Such a disadvantage is particularly emphasized for larger-size boats, e.g. sailboats of length equal to or greater than 20 m.

[0003] Control methods for controlling two rudders of a vessel are disclosed in GB1090110, US3101693, US2013160690, FR2873346 or WO2010112480. The need is thus felt to provide a rudder control method which allows to overcome at least the aforesaid drawback.

Summary of the invention

[0004] It is an object of the present invention to provide a method for controlling the rudders of a vessel, in particular a sailboat with two rudders, which allows to operate in a different manner on the rudders in order to steer the boat with better performance than that of the prior art. In particular, the method of the invention allows the boat to be steered in an optimized manner according to given situations which occur during navigation, e.g. during a regatta.

[0005] It is another object of the present invention to provide a method for controlling the rudders of a vessel, in particular of a two rudder sailboat, in which the fluid-dynamic resistance surface offered by the rudders is optimized to steer the boat conveniently while allowing the maximum possible navigation speed.

[0006] The present invention thus achieves the objects discussed above by providing an electronic control method for controlling at least two rudders of a vessel during navigation, in particular a sailboat with two rudders, which according to claim 1, comprises the following steps:

- selecting a first rudder as master rudder and at least a second rudder as slave rudder from said at least two rudders;
- as the master rudder rotates, if a first angle RA-MASTER defined between the master rudder and a longitudinal symmetry plane of the hull of the boat is either higher than or equal to a predetermined threshold angle RAS, a control system starts a synchronization procedure of the angular speed of the slave rudder with the angular speed of the master rudder, otherwise if said first angle RA-MASTER is smaller than said predetermined threshold angle RAS, the angular speed of the slave rudder is different from the angular speed of the master rudder.

[0007] The present invention is particularly adapted to control double rudder vessels allowing to operate in a different manner on the rudder angle, depending on an operative condition pre-selection, i.e. master/slave, of the rudders made manually by the commanding user.

[0008] The control method of the invention is particularly adapted to be implemented on boats the rudders of which are provided with independent, electrically-assisted hydraulic actuation systems, thus not connected by means of mechanical bar or other equivalent device.

[0009] The method of the invention may be implemented on sailboats of length equal to or greater than 20 m, e.g. 50 or 60 m.

[0010] This versatility has many advantages because in all conditions the rudders can be maneuvered in the best possible manner according to the condition itself.

[0011] The invention advantageously allows the two rudders to be directed, in given conditions, so that they are not parallel to each other. For example, the two rudders may have a mutual direction, or orientation, difference from 0 to 20°.

[0012] The invention includes selecting a first rudder as main rudder or master rudder. After having selected the master rudder, the second rudder is automatically set as secondary rudder or slave rudder. The invention further includes setting a threshold angle, preferably correlated to the master rudder, with respect to the longitudinal symmetry plane of the vessel. The threshold angle can be from 2° to 20°, preferably from 4° to 15° or from 5° to 12°, e.g. 10°.

[0013] In some cases, the master and slave rudders can advantageously rotate at the same angular speed, while in other cases they rotate at a mutually different angular speed. In particular, the angular speed of the master rudder can be higher than, equal to or lower than the angular speed of the slave rudder. The angular speed of each rudder is typically adjusted according to the method of the invention based on the rotation angle of the master rudder and on the threshold angle.

[0014] The dependent claims describe preferred embodiments of the invention.

Brief description of the drawings

[0015] Further features and advantages of the invention will become more apparent in the light of the detailed description of a preferred, but not exclusive, embodiment of a control method shown by way of non-limitative example, with the aid of the accompanying drawings, in which Fig. 1 is a flow chart of an embodiment of the method according to the invention.

Detailed description of a preferred embodiment of the invention

[0016] Referring to figure 1, an embodiment of a method for controlling at least two rudders of a vessel during navigation is shown.

[0017] In a preferred variant, the control method refers to a vessel, in particular to a sailboat, with only two rudders, for controlling the rudders during a regatta.

[0018] According to such an embodiment of the invention, the user selects a first rudder as main rudder or

master rudder and a predetermined threshold angle, referred to the master rudder. The second rudder is automatically set as secondary rudder or slave rudder by the control system. The downwind rudder is preferably chosen as master rudder.

[0019] The electronic control is performed by means of a control system provided, for example, with a programmable logic controller (PLC) with a cycle frequency higher than 1Hz. The programmable logic controller starts a check cycle as shown in Fig. 1 and described in detail below.

[0020] In general, after having selected the master rudder, such a check cycle includes that:

- as the master rudder rotates, if a first angle RA-MASTER (Master Rudder Angle), defined between the master rudder and the longitudinal symmetry plane of the hull of the vessel, is either higher than or equal to a predetermined threshold angle RAS (Rudder Angle Set-point), the control system starts a synchronization procedure of the angular speed of the slave rudder with the angular speed of the master rudder,
- otherwise if said first angle RA-MASTER is smaller than said predetermined threshold angle RAS, the angular speed of the slave rudder is different from the angular speed of the master rudder.

[0021] Said threshold angle is preferably chosen in the range $2^\circ \leq RAS \leq 20^\circ$, e.g. $4^\circ \leq RAS \leq 15^\circ$.

[0022] If the first angle RA-MASTER is smaller than the threshold angle RAS, the control system controls the setting of the angular speed of the slave rudder to zero.

[0023] With reference to the rudders, "center" is defined as the position of the rudder parallel to the longitudinal symmetry plane of the hull, i.e. the position in which the angle defined between the rudder, in particular the blade of the rudder, and the longitudinal symmetry plane of the hull is 0°.

[0024] More in detail, the cycle includes that if the master rudder is rotated far, or away, from the center and if the first angle RA-MASTER is either higher than or equal to the predetermined threshold angle RAS, the control system controls a first setting of the angular speed of the slave rudder to a value higher than the angular speed value of the master rudder until the RA-SLAVE=RA-MASTER condition is satisfied, where RA-SLAVE (Slave Rudder Angle) is a second angle defined between the slave rudder and said longitudinal symmetry plane of the hull.

[0025] Thereby, the slave rudder advantageously cooperates, as the rudder master rotates, to steering the boat in an increasing manner. In essence, the slave rudder follows the rudder master. Having satisfied the RA-SLAVE=RA-MASTER condition, the control system controls a second setting of the angular speed of the slave rudder to a value equal to the angular speed value of the master rudder, thus achieving the synchronization of the speed of the two rudders. Continuing the rotation in the

same rotation direction, the master rudder, together with the slave rudder, reaches its travel stop angle, e.g. equal to $\pm 35^\circ$ with respect to the longitudinal symmetry plane of the hull. Having reached this travel stop angle, the control system locks the rudders in this position until the user decides to rotate the master rudder towards the center. The check cycle is continuously repeated until the travel stop angle is reached. If, although the angular speed of the slave rudder is set to a value higher than the angular speed value of the master rudder, the RA-SLAVE=RA-MASTER is not satisfied, the rudders continue to rotate at a different angular speed until the master rudder reaches its travel stop angle, e.g. equal to $\pm 35^\circ$. This travel stop angle having been reached by the master rudder only, the control system locks the rudders until the user decides to rotate the master rudder towards the center. The check cycle is continuously repeated until the travel stop angle is reached by the master rudder.

[0026] Instead, if the master rudder is rotated away from the center and if the first angle RA-MASTER is smaller than the predetermined threshold angle RAS, the control system directly sets the angular speed of the slave rudder to zero. Continuing the rotation of the master rudder in the same rotation direction, i.e. away from the center, the control system performs the operations described in the preceding paragraph as soon as the first angle RA-MASTER reaches the value of the threshold angle RAS.

[0027] The check cycle also includes that, if the master rudder is rotated towards the center and the first angle RA-MASTER is smaller than the predetermined threshold angle RAS, the control system controls a first setting of the angular speed of the slave rudder to a value higher than the angular speed value of the master rudder until the RA-SLAVE=0° condition is satisfied, i.e. the slave rudder reaches the center, i.e. its position parallel to the longitudinal symmetry plane of the hull. Having satisfied the RA-SLAVE=0° condition, the control system controls a second setting of the angular speed of the slave rudder to a value equal to zero.

[0028] Continuing to rotate in the same rotation direction, i.e. towards the center, the master rudder reaches the position parallel to the longitudinal symmetry plane of the hull, i.e. the 0° position. Having reached this 0° position, the control system locks the rudders until the user decides to rotate the master rudder away from the center. The check cycle is continuously repeated until the master rudder reaches the 0° position. If, although the angular speed of the slave rudder is set to a value higher than the angular speed value of the master rudder, the RA-SLAVE=0° is not satisfied, the rudders continue to rotate at a different angular speed until the master rudder reaches the position parallel to the longitudinal symmetry plane, i.e. the 0° position. Once this 0° position has been reached by the master rudder, the control system locks the rudders until the user decides to rotate the master rudder away from the center. The check cycle is continuously repeated until the master rudder reaches the 0° position.

[0029] If, instead, the master rudder is rotated towards the center and the first angle RA-MASTER is either higher than or equal to the threshold angle RAS, the control system directly controls a setting of the angular speed of the slave rudder to a value equal to the value of the angular speed of the master rudder thus achieving the synchronization of the speeds of the two rudders. Continuing the rotation of the master rudder in the same rotation direction, i.e. towards the center, as soon as the first angle RA-MASTER becomes smaller than the threshold angle RAS, the control system performs the operations described in the preceding paragraph.

[0030] Equivalently, in an alternative check cycle with respect to that described above, the condition concerning the first angle RA-MASTER may consider the following two cases: 1) RA-MASTER higher than the threshold angle RAS, or 2) RA-MASTER either smaller than or equal to the threshold angle RAS. The travel stop angle of the rudders may vary as a function of the type of vessel.

[0031] The control method of the present invention is implemented by means of a control system which interacts with the components of the steering gears, there being a steering gear provided for each rudder. Each steering gear comprises an electrically-assisted, hydraulic actuation system. The rotation of the rudders typically occurs as a consequence of the rotation of the steering wheel. In an exemplary variant, an encoder adapted to detect the angular position of the rudders with respect to the longitudinal symmetry plane of the hull is provided. Such an encoder sends a signal to the programmable logic controller (PLC) which, in turn, executes the instructions described above and shown in the flow chart in Fig. 1.

[0032] According to the conditions which occur during the control, the programmable logic controller (PLC) controls the angular speed of the two rudders by adjusting the hydraulic fluid flow in each hydraulic actuation system.

[0033] In particular, a variant includes

- two through-rod, dual-acting cylinders for each rudder, with a pair of cylinders for each rudder and two chambers for each cylinder, and with the through rod connected to an end to the rudder,
 - and four proportional valves, each valve managing opposite chambers of a respective pair of cylinders in parallel;
- the PLC sends an analog signal to said four proportional valves so as to adjust the flow of hydraulic fluid (oil) in the corresponding hydraulic system, i.e. in the chambers of the two pairs of cylinders, and thus the angular speed of each rudder. Optionally, at each rotation of a steering wheel, the control system reads the load on said at least two rudders and controls the application of a feedback force, which is proportional to said load, on the steering wheel. According to a variant, when the user acts on the steering wheel, e.g. by rotating it in a first rotation direction,

a force is automatically applied on the rudder wheel in a second rotation direction opposite to the first direction. The modulus of such a force is proportional to the hydro-dynamic force on the rudder blades. The hydro-dynamic force on the rudders may be detected by means of specific load cells, preferably arranged on a pin integral with the respective rods.

Claims

1. An electronic control method for controlling at least two rudders of a vessel during navigation, the vessel having a hull provided with a longitudinal symmetry plane, the method using a control system and comprising the following steps:

- selecting a first rudder as master rudder and at least a second rudder as slave rudder from said at least two rudders;

characterized in that

- as the master rudder rotates, if a first angle (RA-MASTER) defined between the master rudder and said longitudinal symmetry plane is either higher than or equal to a predetermined threshold angle (RAS), the control system starts a synchronization procedure of the angular speed of the slave rudder with the angular speed of the master rudder, otherwise if said first angle (RA-MASTER) is smaller than said predetermined threshold angle (RAS), the angular speed of the slave rudder is different from the angular speed of the master rudder.
2. A method according to claim 1, wherein the value of said predetermined threshold angle (RAS) is $10^\circ \leq \text{RAS} \leq 20^\circ$, preferably $10^\circ \leq \text{RAS} \leq 15^\circ$.
 3. A method according to claim 1 or 2, wherein, if said first angle (RA-MASTER) is smaller than said predetermined threshold angle (RAS) the control system controls the setting of the angular speed of the slave rudder to zero.
 4. A method according to claim 1 or 2, wherein, if the master rudder is rotated far from a position thereof parallel to said longitudinal symmetry plane and if the first angle (RA-MASTER) is either higher than or equal to the predetermined threshold angle (RAS), the control system controls a first setting of the angular speed of the slave rudder to a value higher than the angular speed value of the master rudder until the RA-SLAVE=RA-MASTER condition is satisfied, wherein RA-SLAVE is a second angle defined between the slave rudder and said longitudinal symmetry plane; having satisfied the RA-SLAVE=RA-

MASTER condition, the control system controls a second setting of the angular speed of the slave rudder to a value equal to the angular speed value of the master rudder, thus achieving said synchronization.

5. A method according to claim 1 or 2 or 3, wherein, if the master rudder is rotated far away from a position thereof parallel to said longitudinal symmetry plane and if said first angle (RA-MASTER) is smaller than the predetermined threshold angle (RAS), the control system directly sets the angular speed of the slave rudder to zero.
6. A method according to claim 1 or 2, wherein if said master rudder is rotated towards a position thereof parallel to said longitudinal symmetry plane and if the first angle (RA-MASTER) is either higher than or equal to the predetermined threshold angle (RAS), the control system directly sets the angular speed of the slave rudder to a value equal to the value of the angular speed of the master rudder, thus achieving said synchronization.
7. A method according to claim 1 or 2 or 3, wherein, if the master rudder is rotated towards a position thereof parallel to said longitudinal symmetry plane and if the first angle (RA-MASTER) is smaller than the predetermined threshold angle (RAS), the control system controls a first setting of the angular speed of the slave rudder to a value higher than the angular speed value of the master rudder until the RA-SLAVE=0° condition is satisfied, wherein RA-SLAVE is a second angle defined between the slave rudder and said longitudinal symmetry plane; having satisfied the RA-SLAVE=0° condition, the control system controls a second setting of the angular speed of the slave rudder to a value equal to zero.
8. A method according to any one of the preceding claims, wherein at each rotation of a steering wheel, the control system reads the load on said at least two rudders and controls the application of a feedback force, proportional to said load, on the steering wheel.
9. A method according to any one of the preceding claims, wherein the electronic control is carried out by means of a programmable logic controller (PLC) at a cycle frequency higher than 1 Hz.

Patentansprüche

1. Elektronisches Steuerungsverfahren zur Steuerung von mindestens zwei Rudern eines Schiffes während der Navigation, wobei das Schiff einen Schiffsrumpf mit einer Längs-Symmetrieebene aufweist,

das Verfahren ein Steuerungssystem verwendet und die folgenden Schritte aufweist:

- Auswählen aus den zumindest zwei Ruder eines ersten Ruders als Hauptrudder und zumindest eines zweiten Ruders als Nebenrudder;

dadurch gekennzeichnet, dass

wenn sich das Hauptrudder dreht und ein erster Winkel (RA-MASTER), der zwischen dem Hauptrudder und der Längs-Symmetrieebene definiert ist, größer oder gleich einem vorbestimmten Grenzwinkel (RAS) ist, beginnt das Steuerungssystem mit der Synchronisation der Drehgeschwindigkeit von Hauptrudder und Nebenrudder, anderenfalls, wenn der erste Winkel (RA-MASTER) kleiner ist als der vorbestimmte Grenzwinkel (RAS), weicht die Drehgeschwindigkeit des Nebenruders von der Drehgeschwindigkeit des Hauptruders ab.

2. Verfahren gemäß Anspruch 1, wobei der Wert des vorbestimmten Grenzwinkels (RAS) im Bereich $10^\circ \leq \text{RAS} \leq 20^\circ$, vorzugsweise $10^\circ \leq \text{RAS} \leq 15^\circ$ liegt.
3. Verfahren gemäß Anspruch 1 oder 2, wobei im Fall, dass der erste Winkel (RA-MASTER) kleiner ist als der vorbestimmte Grenzwinkel (RAS), das Steuerungssystem das Setting für die Drehgeschwindigkeit des Nebenruders auf Null regelt.
4. Verfahren gemäß Anspruch 1 oder 2, wobei im Fall, dass das Hauptrudder weit aus seiner Position parallel zur Längs-Symmetrieebene heraus gedreht ist und der erste Winkel (RA-MASTER) größer oder gleich dem vorbestimmten Grenzwinkel (RAS) ist, regelt das Steuerungssystem eine erste Einstellung der Drehgeschwindigkeit des Nebenruders auf einen Wert größer als der Drehgeschwindigkeits-Wert des Hauptruders, bis die Bedingung RA-SLAVE = RA-MASTER erfüllt ist, wobei RA-SLAVE ein zweiter Winkel ist, der zwischen dem Nebenrudder und der Längs-Symmetrieebene definiert ist; wenn die Bedingung RA-SLAVE = RA-MASTER erfüllt ist, regelt das Steuerungssystem eine zweite Einstellung der Drehgeschwindigkeit des Nebenruders auf einen Wert, der gleich der Drehgeschwindigkeit des Hauptruders ist, wodurch die Synchronisation erreicht wird.
5. Verfahren gemäß Anspruch 1, 2 oder 3, wobei im Fall, dass das Hauptrudder weit aus seiner Position parallel zur Längs-Symmetrieebene heraus gedreht ist und der erste Winkel (RA-MASTER) kleiner als der vorbestimmte Grenzwinkel (RAS) ist, das Steuerungssystem die Drehgeschwindigkeit des Nebenruders auf Null setzt.
6. Verfahren gemäß Anspruch 1 oder 2, wobei im Fall,

dass das Hauptrudder in Richtung seiner Position parallel zur Längs-Symmetrieebene gedreht wird und der erste Winkel (RA-MASTER) größer oder gleich dem vorbestimmten Grenzwinkel (RAS) ist, das Steuerungssystem die Drehgeschwindigkeit des Nebenruders direkt auf einen Wert setzt, der gleich dem Wert der Drehgeschwindigkeit des Hauptruders ist, wodurch die Synchronisation erreicht wird.

7. Verfahren gemäß Anspruch 1, 2 oder 3, wobei im Fall, dass das Hauptrudder in Richtung seiner Position parallel zur Längs-Symmetrieebene gedreht wird und der erste Winkel (RA-MASTER) kleiner als der vorbestimmte Grenzwinkel (RAS) ist, das Steuerungssystem eine erste Einstellung der Drehgeschwindigkeit des Nebenruders solange auf einen Wert regelt, der größer ist als die Drehgeschwindigkeit des Hauptruders, bis die Bedingung RA-SLAVE = 0° erfüllt ist, wobei RA-SLAVE ein zweiter Winkel ist, der zwischen dem Nebenrudder und der Längs-Symmetrieebene definiert ist; wenn RA-Slave = 0° erfüllt ist, regelt das Steuerungssystem eine zweite Einstellung der Drehgeschwindigkeit des Nebenruders auf den Wert Null.
8. Verfahren gemäß einem der vorigen Ansprüche, wobei das Steuerungssystem bei jeder Drehung des Steuerrades die Last auf die zumindest zwei Ruder ausliest und proportional zu der Last das Aufbringen einer Feedback-Kraft auf das Steuerrad steuert.
9. Verfahren gemäß einem der vorigen Ansprüche, wobei die elektronische Steuerung mittels einer programmierbaren Logik-Steuerung (PLC) mit einer Taktfrequenz von mehr als 1 Hz durchgeführt wird.

Revendications

1. Procédé de commande électronique pour commander au moins deux gouvernails d'un navire pendant la navigation, le navire ayant une coque pourvue d'un plan de symétrie longitudinal, le procédé utilisant un système de commande et comprenant les étapes suivantes :

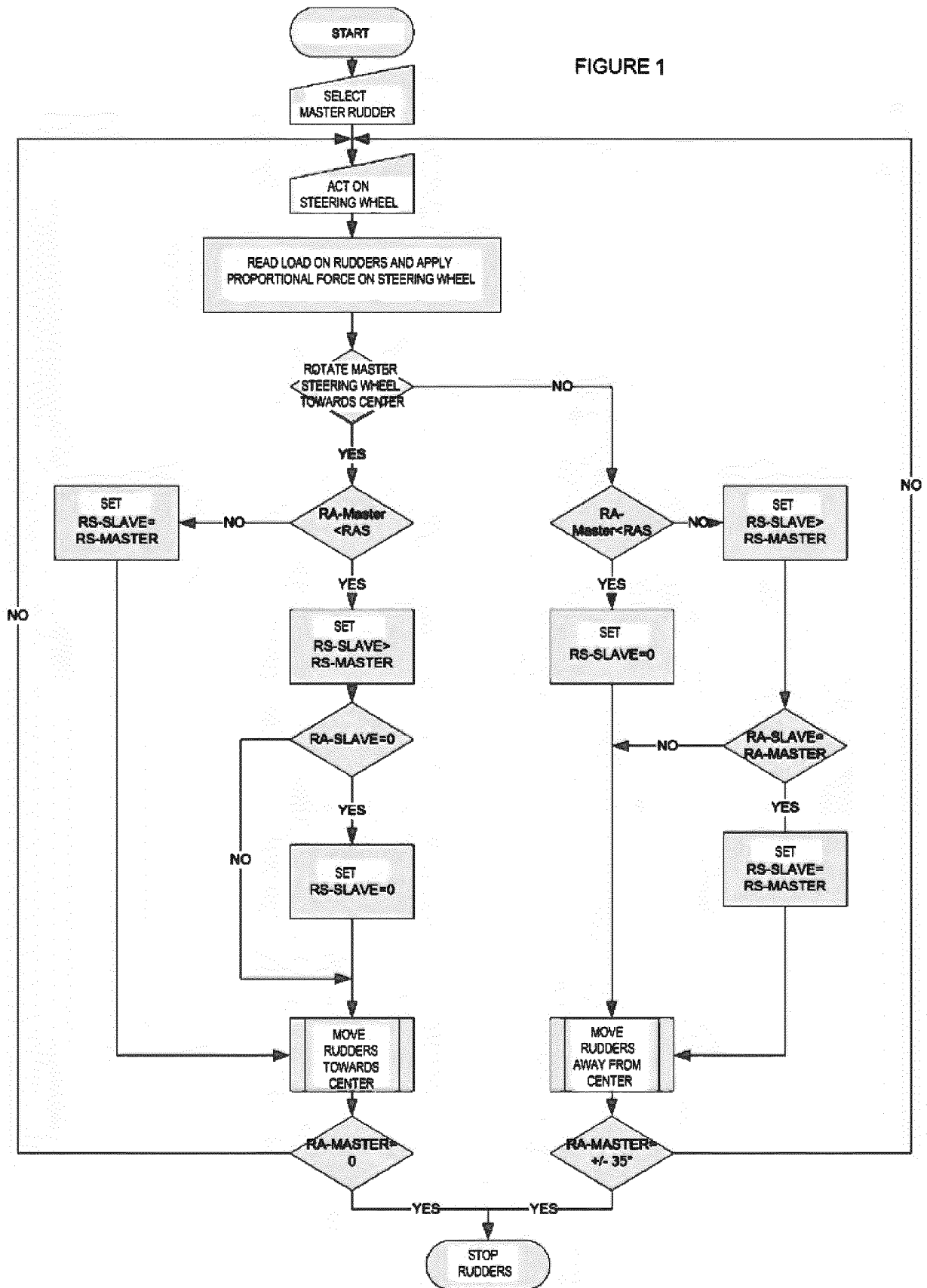
- la sélection d'un premier gouvernail en tant que gouvernail maître et d'au moins un second gouvernail en tant que gouvernail esclave parmi les dits au moins deux gouvernails ;

caractérisé en ce que

- lorsque le gouvernail maître tourne, si un premier angle (RA-MAÎTRE) défini entre le gouvernail maître et ledit plan de symétrie longitudinal est supérieur ou égal à un angle seuil prédéterminé (RAS), le système de commande démarre

- une procédure de synchronisation de la vitesse angulaire du gouvernail esclave avec la vitesse angulaire du gouvernail maître, sinon si ledit premier angle (RA-MAÎTRE) est inférieur audit angle seuil prédéterminé (RAS), la vitesse angulaire du gouvernail esclave est différente de la vitesse angulaire du gouvernail maître. 5
2. Procédé selon la revendication 1, dans lequel la valeur dudit angle seuil prédéterminé (RAS) est de $10^{\circ} \leq \text{RAS} \leq 20^{\circ}$, de préférence de $10^{\circ} \leq \text{RAS} \leq 15^{\circ}$. 10
 3. Procédé selon la revendication 1 ou 2, dans lequel, si ledit premier angle (RA-MAÎTRE) est inférieur audit angle seuil prédéterminé (RAS), le système de commande commande le réglage de la vitesse angulaire du gouvernail esclave à zéro. 15
 4. Procédé selon la revendication 1 ou 2, dans lequel, si le gouvernail maître est tourné loin depuis une position de celui-ci parallèle audit plan de symétrie longitudinal et si le premier angle (RA-MAÎTRE) est supérieur ou égal à l'angle seuil prédéterminé (RAS), le système de commande commande un premier réglage de la vitesse angulaire du gouvernail esclave à une valeur supérieure à la valeur de vitesse angulaire du gouvernail maître jusqu'à ce que la condition RA-ESCLAVE = RA-MAÎTRE soit satisfaite, dans lequel RA-ESCLAVE est un second angle défini entre le gouvernail esclave et ledit plan de symétrie longitudinal ; ayant satisfait la condition RA-ESCLAVE = RA-MAÎTRE, le système de commande commande un second réglage de la vitesse angulaire du gouvernail esclave à une valeur égale à la valeur de vitesse angulaire du gouvernail maître, parvenant ainsi à ladite synchronisation. 20 25 30 35
 5. Procédé selon la revendication 1 ou 2 ou 3, dans lequel, si le gouvernail maître est tourné loin en éloignement d'une position de celui-ci parallèle audit plan de symétrie longitudinal et si le premier angle (RA-MAÎTRE) est inférieur à l'angle seuil prédéterminé (RAS), le système de commande règle directement la vitesse angulaire du gouvernail esclave à zéro. 40 45
 6. Procédé selon la revendication 1 ou 2, dans lequel, si ledit gouvernail maître est tourné vers une position de celui-ci parallèle audit plan de symétrie longitudinal et si le premier angle (RA-MAÎTRE) est supérieur ou égal à l'angle seuil prédéterminé (RAS), le système de commande règle directement la vitesse angulaire du gouvernail esclave à une valeur égale à la valeur de la vitesse angulaire du gouvernail maître, parvenant ainsi à ladite synchronisation. 50 55
 7. Procédé selon la revendication 1 ou 2 ou 3, dans lequel, si le gouvernail maître est tourné vers une position de celui-ci parallèle audit plan de symétrie longitudinal et si le premier angle (RA-MAÎTRE) est inférieur à l'angle seuil prédéterminé (RAS), le système de commande commande un premier réglage de la vitesse angulaire du gouvernail esclave à une valeur supérieure à la valeur de vitesse angulaire du gouvernail maître jusqu'à ce que la condition RA-ESCLAVE = 0° soit satisfaite, dans lequel RA-ESCLAVE est un second angle défini entre le gouvernail esclave et ledit plan de symétrie longitudinal ; ayant satisfait la condition RA-ESCLAVE = 0° , le système de commande commande un second réglage de la vitesse angulaire du gouvernail esclave à une valeur égale à zéro. 8.
 8. Procédé selon l'une quelconque des revendications précédentes, dans lequel, à chaque rotation d'une roue de gouvernail, le système de commande lit la charge sur lesdits au moins deux gouvernails et commande l'application d'une force de rétroaction, proportionnelle à ladite charge, sur la roue de gouvernail. 9.
 9. Procédé selon l'une quelconque des revendications précédentes, dans lequel la commande électronique est réalisée au moyen d'un automate programmable (PLC) à une fréquence de cycle supérieure à 1 Hz.

FIGURE 1



REFERENCES CITED IN THE DESCRIPTION

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