

Floating Structure For Transport Formed By A Train Arrangement Of Rotary Bodies Of Revolution Which Reduces The Drag Of Same During Sailing

DESCRIPTION

The present invention relates to a floating structure for transport formed by a tandem arrangement of rotating bodies of revolution, which reduces the resistance to advance thereof during its navigation.

By means of the present arrangement, the resistance to advance, constituted by the frictional or viscous resistance, and by the pressure resistance, also called residual resistance or resistance to wave formation, with respect to the known floating structures, is diminished, achieving either the decrease of the consumption, or the increase of the forward speed of said floating structure to a constant consumption. Furthermore, the possibility of loading inside said rotating bodies of revolution is foreseen.

PRIOR ART

Document US2009/0266288A1 discloses a method to reduce the frictional resistance between the body of a vessel and the water by emitting gases in the water, by supplying a plurality of gas outlets disposed at predetermined positions under water level in the front or bow of a ship's hull, pushing the hull upwards and thus decreasing the average density of water in surface contact with the hull.

Document JP2001-114185 discloses a method to reduce the pressure in the hull of a ship by very fine slits formed along the direction of seawater flow on the surface of the external plating of a ship, which was subjected to an anti-collision treatment, which reduces the resistance of the hull and prevents the adhesion of marine organisms.

Document JP4959667 discloses a device for reducing the frictional resistance in a ship's hull capable of emitting even air jets that generate bubbles from a plurality of holes formed in the lower part of the ship in which there is an air chamber.

Document EP0926060A3 discloses a method to reduce the frictional resistance of a ship with respect to water by generating bubbles by injecting gas into the water from selected locations that are spaced along the longitudinal direction by specific distances.

Document JP2009-248611 discloses a device for reducing the frictional resistance of a ship with respect to water capable of adequately changing the place of the production of bubbles and the number thereof according to the state of navigation of the ship or the state thereof, effectively reducing the frictional resistance by the precise blowing of bubbles even when turbulence occurs.

Document JP2010-280342 discloses a device for generating fine bubbles in a hull to reduce the frictional resistance of the fluid by forming thick layers of water that include fine bubbles on the submerged surface of the hull. It uses a pump capable of mixing a large amount of air in the suctioned water.

Document JP60-139586 discloses a bubble generator for reducing the frictional resistance, interconnected to a casing installed in the front hull of the lower plating of a ship.

Document JP62-268793 discloses a device for reducing the frictional resistance by the provision of air blowing means arranged in three layers respectively on both sides of the bow bulb where the dynamic pressure becomes negative.

Document US2764954 discloses an apparatus for the propulsion of ships by using an air jet stream interspersed with water to produce a reactive tensile force to propel the ship, substantially reducing the frictional resistance.

Document US5575232 discloses a method and a device for reducing the frictional resistance in a ship by generating micro bubbles.

Document US3875885 discloses a gas injection system for marine vehicles in which a primary gas injector creates an axial gas flow below the hull of the vessel, a primary aerator is provided below the hull of the vessel to generate an aerated flow of water and a second aerator, to further refine the aerated flow, which includes an inclined surface to give the main propulsive effect.

Document US6789491B2 discloses a method to reduce the frictional resistance of a ship between the external plating of the hull and the water by injecting air and thus generating microbubbles on the surface of said plating, below the waterline in the bow bulb.

Document US6186085B1 discloses a method to reduce the frictional resistance of a ship's hull by injecting microbubbles of predetermined diameter into the water from a position adjacent to

the starting point of the water stream line and from the position where the static pressure is low, and the microbubbles are distributed in at least part of the circumferential area of the submerged portion of the hull, thus reducing the frictional resistance thereof while sailing.

Finally, document EP0265382A1 of the same Applicant, discloses flotation wheels that allow the displacement of aquatic vehicles or the like, the wheels having a spherical conformation with multiple blades that are fixed with free rotation to a axis connected to the hull of a ship, thus facilitating the movement thereof.

All the objects of the prior art discussed above have many disadvantages, among which we can mention that they are not efficient and require a lot of energy to reduce the frictional resistance of a floating structure while sailing. Even in many cases, the decrease in the frictional resistance is minimal considering the energy consumed for this purpose, not to mention the complexity of the devices to cause this effect.

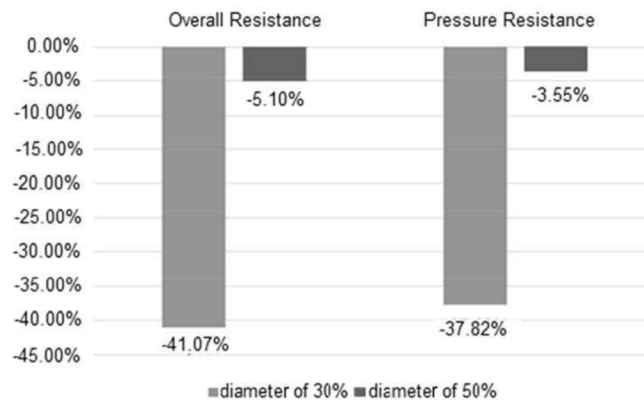
This has led the Applicant to develop a floating structure for transport formed by a tandem arrangement of rotating bodies of revolution that reduces the resistance to advance thereof during its navigation, said rotating bodies of revolution having a rotating speed synchronized with the forward speed of the assembly, and its longitudinal rotation axes being arranged perpendicular to the direction of advance of the floating structure. For the present application, said rotating bodies of revolution are preferably cylinders of identical geometry and dimensions. The longitudinal axes of rotation of said rotating cylinders are attached to support means such as forks, on which a platform is mounted, said platform being located above said cylinder tandem. Said cylinders are given a rotary impulse by driving means such as engines, for example, which are associated to said longitudinal axes of said rotating cylinders by transmission means such as belts, straps, chains or the like. In order to achieve an optimum effect in terms of reducing the resistance to advance during the advance of the floating structure, the Applicant has discovered that the draft of said cylinders must be of the order of 30% of its diameter. In order to achieve that said draft of the order of 30% of the diameter is maintained, the total load carried by the cylinders, both inside and outside thereof, must be evaluated.

DRAFT

During the research stage, after numerous tests simulated by the CFD system with OpenFoam, the Applicant has verified, as previously mentioned, that the ideal draft of a cylinder is of the order of 30% of its diameter, since said cylinder rotating at a speed synchronized with the forward speed of the assembly compared with the same body without rotation, with said draft, can get a reduction in the resistance to advance of up to 50% of the overall resistance, and this reduction being only 5% when the draft is 50% of the diameter.

Draft [% of diameter]	Forward Speed [m/sec]	Rotation Speed [m/sec]	Pressure Resistance [N]	Frictional Resistance [N]	Overall Resistance [N]	Rotation Torque [N.m]
30	1.0	0.0	20.297	13.593	21.656	0.4741
30	1.0	1.0	12.621	0.1405	12.762	-0.0513
50	1.0	0.0	46.123	0.6095	46.733	0.2600
50	1.0	1.0	44.486	-0.1380	44.348	-0.1970

Percentage of reduction of resistance
depending on the draft



SPACING BETWEEN TWO OR MORE CYLINDERS

As previously mentioned, the Applicant has verified that the optimum distance between two or more cylinders is obtained when the bodies approach approximately 5% or less of their diameter causing a very significant hydrodynamic effect of interaction, which disappears when the rotating bodies move away.

THRUST OF THE FRONT CYLINDER OF AN CYLINDER TANDEM ARRANGEMENT

With the optimum separation of around 5% or less and an optimum draft of the order of 30% of the diameter of the rotating cylinders, the Applicant has verified that the front cylinder in a cylinder tandem arrangement not only contributes to the decrease in the resistance to advance of a floating structure, but it also provides energy to the system, which is understood as thrust.

This phenomenon is achieved by the effect of an overpressure in said rotating cylinder and the increase in the speed of the water flow across the submerged profile of the cylinder. Since the cylinder is only partially submerged and already in roto-translatory movement, the submerged section gets a pressure offered by a medium approximately 1000 times denser than the air in contact with the section outside the water. Said pressure difference brings a thrust coincident with the direction of advance of the assembly to the roto-translatory movement.

According to the results obtained from testing, a cylinder of 6m diameter or length, with a draft of 2m depth and 12m length or beam, at the synchronized speed of 3.162 m/sec (both rotation and forward speed) provides a thrust equivalent to 73.14HP to the system.

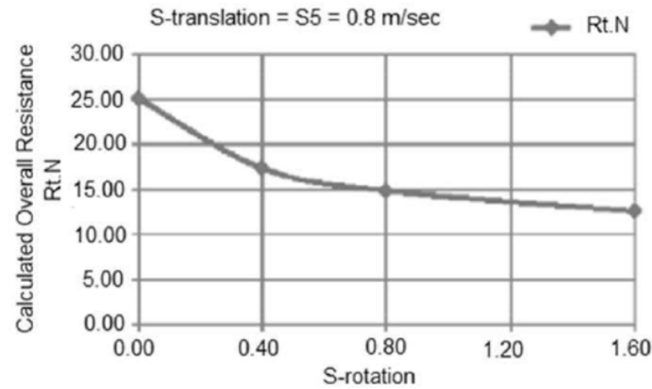
SYNCHRONIZED ROTATION OF THREE CYLINDERS, AND OVER-ROTATION FROM THE FRONT CYLINDER TO THE REAR CYLINDER IN A CYLINDER TANDEM ARRANGEMENT

The Applicant has evaluated different percentages of rotation speed in relation to the forward speed of the assembly, observing a continuous decrease in the resistance when generating an over-rotation in said cylinders, as can be seen in the figure below.

S-translation = $S_5 = 0.8$ m/sec

Variation of Overall Resistance

Calculated with the Rotation Speed



When analyzing an assembly of 3 rotating cylinders with synchronized rotation, the variation of the rotation speed or over-rotation was also discussed in an incremental way from the front cylinder to the rear cylinder, obtaining the following results:

- A) Three cylinders, synchronized rotation at the speed of 1m/sec, the reduction obtained was 43% of the overall resistance to advance of the assembly;
- B) Three cylinders, synchronized front cylinder, synchronized intermediate cylinder and rear cylinder rotating at twice the synchronized speed, the reduction obtained was 52% of the overall resistance to advance of the assembly;
- C) Three cylinders, synchronized front cylinder, intermediate cylinder rotating at 1.5 times the synchronized speed and rear cylinder rotating at twice the synchronized speed, the reduction obtained was 56% of the overall resistance to advance of the assembly.

Front Cylinder							
Front - Intermediate - Rear	Pressure Resistance [N]	Frictional Resistance [N]	Overall Resistance [N]	Rotation Torque [N.m]	EP [W]	RP [W]	Total Power [W]
V00-V00-V00	42.00	1.29	43.29	0.44	43.3	0.0	43.3
V10-V10-V10	-29.23	-0.10	-29.33	-0.21	-29.3	0.7	-28.7
V10-V10-V20	-29.90	-0.09	-29.98	-0.21	-30.0	0.7	-29.3
V10-V15-V20	-29.55	-0.08	-29.63	-0.21	-29.6	0.7	-29.0

Intermediate Cylinder							
Front -	Pressure	Frictional	Overall	Rotation	EP	RP	Total

Intermediate - Rear	Resistance [N]	Resistance [N]	Resistance [N]	Torque [N.m]	[W]	[W]	Power [W]
V00-V00-V00	13.04	0.90	13.94	0.22	13.9	0.0	13.9
V10-V10-V10	17.22	-0.59	16.63	-0.40	16.6	1.3	17.9
V10-V10-V20	13.05	-0.60	12.45	-0.42	12.4	1.3	13.8
V10-V15-V20	6.28	-1.37	4.91	-1.60	4.9	7.5	12.5

Rear Cylinder							
Front - Intermediate - Rear	Pressure Resistance [N]	Frictional Resistance [N]	Overall Resistance [N]	Rotation Torque [N.m]	EP [W]	RP [W]	Total Power [W]
V00-V00-V00	29.04	1.36	30.39	0.40	30.4	0.0	30.4
V10-V10-V10	62.91	-0.48	62.43	-0.32	62.4	1.0	63.4
V10-V10-V20	60.32	-1.39	58.94	-3.02	58.9	19.0	77.9
V10-V15-V20	64.38	-1.18	63.20	-2.93	63.2	18.4	81.6

V00 = no rotation

V10 = Synchronized Rotation Speed = 1 m/sec

V15 = 1.5 times the Synchronized Rotation Speed

V20 = twice the Synchronized Rotation Speed

TEP = Tow Effective Power = Overall Resistance x Forward Speed

RP = Rotation Power = Rotation Torque x Angular Rotation Speed

3-Cylinder Assembly							
Front - Intermediate - Rear	Pressure Resistance [N]	Frictional Resistance [N]	Overall Resistance [N]	Rotation Torque [N.m]	EP [W]	RP [W]	Total Power [W]
V00-V00-V00	84.07	3.54	87.61	1.06	87.61	0.00	87.61
V10-V10-V10	50.90	-1.17	49.73	-0.93	49.73	2.95	52.68
V10-V10-V20	43.47	-2.07	41.41	-3.65	41.41	20.96	62.37
V10-V15-V20	41.11	-2.63	38.49	-4.74	38.49	26.58	65.06

V00 = no rotation

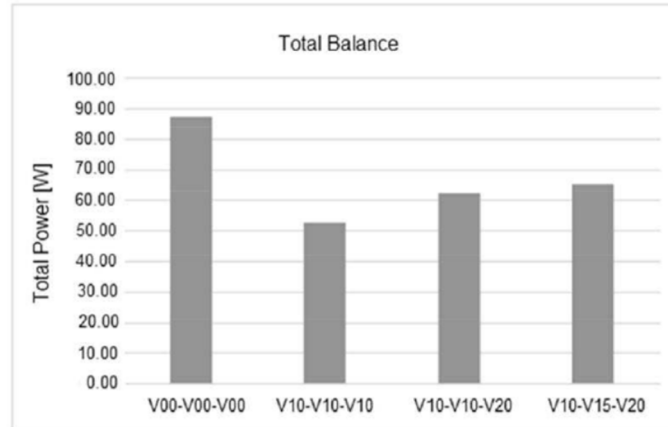
V10 = Synchronized Rotation Speed = 1 m/sec

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V20 = twice the Synchronized Rotation Speed

TEP = Tow Effective Power = Overall Resistance x Forward Speed

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As can be noted, the over-rotation has a significant impact in the overall resistance. Although from the point of view of the energy balance, the optimal choice is that of synchronized rotation at the same forward speed of the floating structure, from the point of view of the need to achieve an increase in speed thereof, the other options are very valid.

Different configurations were tested:

- A) All cylinders rotating synchronously;
- B) Only the front cylinder rotating synchronously;
- C) Only the rear cylinder rotating synchronously; and
- D) All cylinders without rotation.

It has been observed that the greatest decrease, and even the thrust in all cases, is always provided by the front cylinder.

However, when the rear cylinder was analyzed while rotating only, and even in the case of over-rotation, said rear cylinder brings a reduction of the overall resistance of the assembly of the order of 5%.

As expected, the benefit of the rotation is progressively related to the scale used. That is why each floating structure that applies this method of energy reduction in its bow and/or the stern, should test the best scale option for each configuration.

A further feature of the invention is that each of the rotating cylinders can carry load inside, and can also include inside a static and concentric cylinder of smaller diameter to transport said load, thus harnessing the volume and improving the cost per transported ton ratio.

The rotating cylinders do not have any type of wings or blades, their surface being as smooth as possible.

The effect of decreasing the resistance to advance is much greater than the resistance generated by the cylinders in the water, since the pressure resistance is modified, also called residual resistance or resistance to wave formation. The pressure resistance is the cause of about 90% of the overall resistance of a floating structure and increases exponentially depending on the speed.

Furthermore, fluvial and maritime transportation costs include both fuel consumption and all costs related to transport time, such as daily rental and crew hiring; that is why with this arrangement, either the reduction of consumption or the increase in the forward speed of the floating structure at a constant consumption is sought. This results in less polluting and more economic floating structures, or with shorter cycle times with their respective savings as long as logistics is concerned.

This generates a highly efficient ratio of energy consumed per ton of load transported and, in addition, a highly stable design.

Then, an object of the present invention is a floating structure for transport formed by a tandem arrangement of rotating bodies of revolution that decreases the resistance to advance thereof during its navigation, characterized in that said tandem arrangement of rotating bodies of revolution is formed by a front body of revolution, intermediate bodies of revolution and a rear

body of revolution which have a rotation synchronized with the forward speed of said structure, said intermediate bodies of revolution being related to each other by their longitudinal rotation axes by attachment means fixed to an upper platform, and at the same time the longitudinal rotation axes of said front and rear bodies of revolution are associated to the rotation axes of the bodies of revolution adjacent to them by hinge means, said hinge means pivotally joined to one end of the draft control means, which are joined by the other end thereof pivotally to said upper platform, said longitudinal rotation axes arranged perpendicular to the direction of advance of said structure and associated to driving means; and said rotating bodies of revolution being spaced apart from each other by a distance of approximately 5% or less of their maximum diameters.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 illustrates a side view of a tandem of rotating cylinders with a rotation synchronized with the forward speed of a floating structure, submerged by 30% of their diameter.

Figure 2 illustrates a perspective view of said tandem of rotating cylinders associated to individual driving means, inside which concentric and static cylinders for transporting load are provided.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a floating structure 1 for transport formed by a tandem arrangement of rotating cylinders 2 formed by a front cylinder 6, intermediate cylinders 7 and a rear cylinder 8, which have a rotation synchronized with the advance speed of the floating structure assembly. Said intermediate cylinders 7 are interconnected by their longitudinal rotation axes 4 by attachment means 5, such as, for example, bars, fixed to an upper platform 12, at the same time as the longitudinal rotation axes of said front cylinder 6 and rear cylinder 8 are associated to the rotation axes of the cylinders adjacent thereto by hinge means 10, such as, for example, pivoting arms. Said hinge means 10 are pivotally joined to one of the ends of draft control means 9, which are pivotally joined at the other end to said upper platform 12.

Said longitudinal rotation axes 4 are arranged perpendicular to the direction of advance of said structure and associated with driving means (not shown). Also said rotating cylinders are separated from each other by a distance of about 5% of the diameter.

The draft control means 9 keep said front and rear rotating cylinders 6, 8 submerged in the order of 30% of their diameter during navigation and they are, for example, pistons.

On the other hand, said driving means (not shown) rotationally drive said rotating cylinders 2 and they are, for example, engines, said driving means (not shown) being associated to said longitudinal rotation axes 4 of said front, intermediate and rear rotating cylinders 6, 7, 8 by transmission means (not shown) which can be belts, straps, chains, gears or the like.

It should be noted that the surface of said rotating cylinders 2 is smooth.

Figure 2 illustrates said rotating cylinders 2 associated through said transmission means 14 to individual driving means 11, wherein the inside of said rotating cylinders 2 is hollow and it can carry load therein, or it can accommodate concentric and static cylinders 13 of smaller diameter to carry said load.

Finally, said rotating cylinders 2 have over-rotation capacity supplied by said driving means 11.

CLAIMS

1. A floating structure for transport (1) formed by a tandem arrangement of rotating bodies of revolution (2) that reduces the resistance to advance thereof during its navigation, comprising:

- a front body of revolution (6), intermediate bodies of revolution (7) and a rear body of revolution (8),

- longitudinal rotation axes (4) arranged perpendicular to the direction of advance of said structure,
characterized in that:

said rotating bodies of revolution (2) have a rotation synchronized with the forward speed of said structure;

said intermediate bodies of revolution (7) are related to each other by their longitudinal rotation axes (4) by attachment means (5) fixed to an upper platform (12);

said longitudinal rotation axes of said front (6) and rear (8) bodies of revolution are associated to the rotation axes of the bodies of revolution adjacent thereto by hinge means (10), said hinge means (10) pivotally joined to one of the ends of the draft control means (9), which keep said front and rear rotating bodies of revolution (6,8) submerged in the order of 30% its maximum diameter during navigation and are pivotally joined by the other end thereof to said upper platform (12);

said rotating bodies of revolution (2) being separated from each other by a distance of approximately 5% or less of their maximum diameter; and

said longitudinal rotation axes (4) are associated with driving means (11) which supply over-rotation capacity to said rotating bodies of revolution (2).

2. The structure according to claim 1, **characterized in that** said draft control means (9) are pistons.

3. The structure according to claim 1, **characterized in that** said driving means (11) rotatably drive said rotating bodies of revolution (2), said driving means (11) being engines and associated to said longitudinal rotation axes (4) of said front, intermediate and rear rotating bodies of revolution (6, 7, 8) by transmission means (14).

4. The structure according to claim 3, **characterized in that** said transmission means (14) are belts, straps, chains, gears or the like.
5. The structure according to claim 1, **characterized in that** said attachment means (5) are bars.
6. The structure according to claim 1, **characterized in that** said hinge means (10) are pivoting arms.
7. The structure according to claim 1, **characterized in that** the surfaces of said rotating bodies of revolution (2) are smooth and their interiors are hollow in order to have the capacity to carry load.
8. The structure according to claim 1, **characterized in that** each of said rotating bodies of revolution can include in its interior, in turn, static and concentric bodies of revolution (13) of smaller diameter to carry load.
9. The structure according to claim 1, **characterized in that** said bodies of revolution are cylinders.
10. A method for reducing resistance to advance of a floating structure according to claim 1, characterized in that it comprises the following steps:
 - arranging said longitudinal rotation axes (4) of said tandem arrangement of rotating bodies of revolution (2) perpendicularly to the direction of advance of the floating structure (1);
 - rotating said tandem arrangement of rotating bodies of revolution (2) in a synchronized way with the forward speed of said floating structure for transport (1);
 - submerging and maintaining the depth of said tandem arrangement of rotating bodies of revolution (2) in the order of 30% of its maximum diameter during navigation; and
 - maintaining said tandem arrangement of rotating bodies of revolution (2) separated from each other by a distance of about 5% or less of their maximum diameter.