

WIND PROPULSION DEVICE FOR VESSELS

DESCRIPTION

5 Object of the invention

10 The present invention refers to a wind propulsion device for vessels, in particular, to a sail for vessels that comprises plasma jet actuators to actively control the airflow over the wind propulsion device, improving lift, reducing drag, preventing flow separation, and providing de-icing capability in freezing conditions.

Background of the invention

15 Wind propulsion systems are awakening renewed interest in marine vessels due to their potential to reduce fuel consumption.

20 However, these systems face aerodynamic limitations, such as flow separation at high angles of attack, which reduces efficiency. Flow separation alters lift, increases drag, and reduces propulsion effectiveness.

25 Plasma jet actuators, known for their active flow control capability, are widely studied in aeronautics, but have not been adapted to maritime wind propulsion to improve performance in variable wind conditions.

25 Description of the invention

30 Therefore, an objective of the present invention is to provide a wind propulsion device for vessels that allows for improved flow control, adaptation of the device's aerodynamic characteristics, and de-icing in adverse environmental conditions.

 With the wind propulsion device for vessels of the invention, the aforementioned drawbacks are resolved, presenting other advantages that will be described below.

 The wind propulsion device for vessels according to the present invention is described

in claim 1, and the dependent claims include additional features that are optional.

The wind propulsion device for vessels comprises a main body and one or more plasma jet actuators located in said main body.

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Furthermore, the wind propulsion device for vessels according to the present invention also preferably comprises one or more chambers oriented towards the one or more plasma jet actuators.

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According to a preferred embodiment, the one or more chambers are thermal chambers.

The wind propulsion device for vessels according to the present invention may also comprise sensors located in said main body, such as, for example, wind sensors.

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The wind propulsion device for vessels according to the present invention also preferably comprises a control unit connected to the one or more plasma jet actuators, which is also preferably connected to the sensors and/or the one or more chambers.

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According to a possible embodiment, the wind propulsion device for vessels according to the present invention also comprises a secondary body, which also comprises one or more plasma jet actuators, such as, for example, a flap.

This secondary body is preferably rotatable with respect to the main body.

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The plasma jet actuators can be located on two opposite sides of the main body, or displaced towards a leading edge and a curved area defined in the main body.

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The device according to the present invention utilizes plasma jet actuators to provide active flow control, thereby increasing lift, improving aerodynamic efficiency, and reducing flow separation.

The device according to the present invention also allows for configurations for the placement and control of the actuators, being located at key points for basic control of the flow and distributed for precise aerodynamic adjustments.

Furthermore, plasma jet actuators can serve as de-icing elements, focusing on specific areas prone to ice formation.

5 The device according to the present invention also allows for monitoring the operational status of the plasma jets. If a malfunction occurs, the absence of a thermal signature in the actuator indicates a failure, allowing for real-time detection and the adoption of corrective measures.

10 **Brief description of the drawings**

For a better understanding of what has been explained, drawings are attached in which, schematically and solely by way of non-limiting example, a practical case of embodiment is represented.

15 Figure 1 is a perspective view of a wind propulsion device for vessels according to the present invention;

20 Figures 2 and 3 are cross-sectional views of wind propulsion devices for vessels according to the present invention, according to two alternative embodiments;

Figure 4 is a block diagram showing the components of the wind propulsion device for vessels according to the present invention; and

25 Figures 5 and 6 are views of the aerodynamic profile of the wind propulsion device for vessels according to the present invention with a plasma actuator off and actuated, respectively.

30 **Description of a preferred embodiment**

As shown in the embodiment of Figure 1, the wind propulsion device for vessels according to the present invention comprises a main body (1) provided with one or more plasma jet actuators (2) and one or more chambers (3).

Preferably, the plasma jet actuators (2) are installed both to port and to wind propulsion device, which allows it to function independently of the wind direction. This configuration provides a high degree of guarantee that the system remains equally effective in conditions of wind from bow or stern, which makes it very versatile for maritime operations.

Furthermore, the plasma jet actuators (2) can be placed in two different configurations, depending on the desired aerodynamic control and the application.

The actuators (2) can be placed at strategic aerodynamic points, as shown in figures 2 and 3, such as near the leading edge or in high curvature areas prone to flow separation. Another key point is the position in which the flow passes from laminar to turbulent, which provides an increase in aerodynamic resistance.

Additionally, the wind propulsion device for vessels can include a secondary body (6), such as a flap, as shown in figures 2 and 3, and at least one actuator of the plasma jet (2) can also be placed in said secondary body (6), which can be rotatable with respect to the main body (1).

This configuration provides a direct control scheme in which the actuators (2) on the extrados side are activated in the direction of the wind. By activating these actuators (2), flow attachment is improved, preventing its separation and maintaining lift even at higher angles of attack.

Alternatively, a distributed placement of the plasma jet actuators (2) for adaptive aerodynamic control can be performed, in which the plasma jet actuators (2) are installed along a sectional or total length of the wind propulsion device.

This device allows for more precise aerodynamic control and permits selective activation of all or part of the actuators based on the needs of the situation.

The number and position of the actuators (2) allow for different aerodynamic characteristics:

- Maximum elevation angle: When high lift is required, all actuators (2) along the extrados can be activated.

5 - Optimal Efficiency Mode: In this mode, only the actuators that provide the greatest aerodynamic efficiency, i.e., lift/drag ratio, are activated. This selective control minimizes energy consumption and improves performance by reducing drag and maximizing lift when necessary.

10 Additionally, it can be dynamically adjusted by a control unit (4) which actuators (2) are activated based on information received from onboard sensors (5), such as wind speed, wind angle, or vessel speed, optimizing aerodynamic performance in real-time.

15 The plasma jet actuators (2) can also have an additional function as de-icing elements in cold environments. Ice accumulation can have a critical impact on aerodynamic efficiency, especially on vessels operating in cold waters. In the propulsion device according to the present invention, the plasma jet actuators (2) are placed in critical areas to prevent or eliminate ice accumulation.

20 For example, these key regions for de-icing can be:

- Stagnation point: The area of the leading edge where the airflow first comes into contact with the main body (1), prone to initial ice formation.

25 - Suction peak: The point of greatest suction on the extrados side, where ice can alter the aerodynamic profile and cause flow instability.

- Laminar-turbulent transition zone: Accumulation in this zone can induce premature turbulence, reducing overall efficiency.

30 - Suction grid for suction wings: In configurations with suction-based lift enhancement, plasma jets can de-ice the suction grid to maintain optimal airflow through the suction ports.

- Control: The de-icing mode activates the plasma jets at low power or in pulsed mode,

depending on the severity of ice formation. This mode can be controlled manually or automatically based on temperature sensor information to ensure continuous operation in icy environments.

5 The cameras (3) can be thermal cameras to monitor the operational status of the plasma jet actuators (2). The thermal cameras (3) capture real-time thermal signatures of each plasma jet. An active actuator emits a detectable thermal signature, while a non-functional actuator does not. This thermal feedback mechanism provides real-time monitoring, allowing operators to quickly identify and resolve actuator failures.

10 The control unit (4) integrates feedback from the sensors (5), thermal images captured by the cameras (3), and adaptive algorithms to ensure optimal performance and adjustment of the actuators based on wind and operating conditions.

15 The sensors (5), for example, measure wind speed and direction to guide the activation and distribution of the plasma jets based on real-time environmental conditions.

For their part, the thermal cameras (3) detect the functionality of the plasma jet actuators (2) and possible malfunctions, while the adaptive control algorithm dynamically adjusts actuator activation, optimizing lift, efficiency, or de-icing, depending on the vessel's operational requirements.

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Figures 5 and 6 show the wind propulsion device for vessels according to the present invention with a plasma jet actuator (2) off and activated, respectively, allowing observation of the effect achieved by said plasma jet.

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Although a specific embodiment of the invention has been referred to, it is evident to a person skilled in the art that the described wind propulsion device for vessels is susceptible to numerous variations and modifications, and that all the mentioned details can be replaced by other technically equivalent ones, without departing from the scope of protection defined by the appended claims.

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CLAIMS

- 5 1. Wind propulsion device for vessels, comprising a main body (1), characterized in that it also comprises one or more plasma jet actuators (2) located in said main body (1).
2. Wind propulsion device for vessels according to claim 1, further comprising one or more cameras (3) oriented towards the one or more plasma jet actuators (2).
- 10 3. Wind propulsion device for vessels according to claim 2, wherein the one or more cameras (3) are thermal cameras.
4. Wind propulsion device for vessels according to any of the preceding claims, further comprising sensors (5) located in said main body (1).
- 15 5. Wind propulsion device for vessels according to claim 4, wherein the sensors (5) are wind sensors.
6. Wind propulsion device for vessels according to any of the preceding claims, further comprising a control unit (4) connected to the one or more plasma jet actuators (2).
- 20 7. Wind propulsion device for vessels according to claim 6, wherein the control unit (4) is also connected to the sensors (5) and/or to the one or more cameras (3).
8. Wind propulsion device for vessels according to any of the preceding claims, further comprising a secondary body (6), which also comprises one or more plasma jet actuators (2).
- 25 9. Wind propulsion device for vessels according to claim 8, wherein the secondary body (6) is a flap.
- 30 10. Wind propulsion device for vessels according to claim 8 or 9, wherein the secondary body (6) is rotatable with respect to the main body (1).
11. Wind propulsion device for vessels according to claim 1, wherein the plasma jet

actuators (2) are located on two opposite sides of the main body (1).

12. Wind propulsion device for vessels according to claim 1, wherein the main body (1) has a shape that defines a leading edge and a curved area, with the plasma jet actuators (2) being located displaced towards the leading edge and the curved area.

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