NEW PERSPECTIVES FOR MARINE ENVIRONMENT PROTECTION THROUGH INNOVATIVE MARINE PROPULSION SYSTEMS

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Abstract: Nowadays, significant importance is awarded to the environment, especially the marine environment which could be considered responsible for our lives' normal cycle. By stating this we mean that oceans are the most important factor in the global environment equilibrium, as factors which dictate all climatic changes, and, in the end influence our personal, social and economic life.

Taking into account these reasons, it is in our power to protect as much as we can the environment. This is not just a theory or a story; we can really contribute to environment protection and preservation.

In the maritime field, during the last decades, there have been many changes in the environment protection area, starting with legislative changes and introduction of new rules, continuing with ship equipment improvements and, reaching, in the last years, the problem of changing the ship's propulsion systems concepts and configurations.

The solutions offered in this sense by the ship builders and ship owners vary and are based on the use of electrical power, fuels with low emission of pollutant elements, solar energy and wind energy in different ways. Some of these ideas are futuristic ones, but very good and important for the environment protection, yet they are impossible or difficult to be used in practice with consistent results.

Solutions like the use of electric powers, use of low emissions fuels and, why not, nuclear power are possible and effective in the propulsion of a medium size cargo ship, the last one even in case of large and very large cargo ships. Other solutions are not as sure as in how they will be able to generate enough power to move a fully loaded medium ship. There is a possibility to use them as an opportunity to reduce consumption of fossil fuels used nowadays, to compensate the loss of propulsion due to reduction of fuel consumption.

In this paper, we intend to present the advantages and, if there are, the disadvantages of these alternative propulsion systems, how they contribute to marine environment protection, and if it is possible to consider them as the future of marine transport propulsion systems.

Key words: perspective, marine environment, propulsion system, ship.

1. INTRODUCTION

This paper aims to bring to the fore once again the need to reduce air pollution, especially due to the marine propulsion engines.

The title of the paper "New perspectives for marine environment protection through innovative marine propulsion systems" shows the main direction that the paper was based on, promoting and using unconventional propulsion systems in combination with the ship's main engine.

The idea of using the combined system of sails - engine is quite old, but because of some constructive and conservative inconveniences, this system was not implemented.

In the circumstances in which - the price of oil is increasing, the atmosphere is degraded due to emissions of NO_x, SO_x, CO, and the degree of pollution of our planet rises every day, non-conventional energy solutions began to arouse the interest of stakeholders. Unconventional propulsion systems, such as wind power or electricity for propulsion, are now back into attention after having been ignored for a long period of time.

Nowadays there are considered to be five major sources of maritime environment pollution: pollution from land based industrial activity, underwater work, waste discarding in the maritime environment, ships and the atmosphere. (O'Rourke, 2006).

Therefore the primary methods of reducing NO_x are: reducing the lead on injection and analysing the constructive particularities of the combustion room. There are also secondary methods of reducing NO_x such as re-running the exhaust gasses, direct water injection, lowering the air preheating temperature before injecting the fuel, selective Catalytic Reduction (SCR), non-Selective Catalytic Reduction (SNCR). Reducing sulphurous oxide emissions (SO_x) is possible by using fuels which are low on sulphur and removing sulphur from exhaust gasses. When it comes to reducing carbon oxide emissions (CO) the quantity of carbon oxide CO cannot be reduced during the combustion process. For now, the most common solutions are reducing fuel consumption and using fuels with a low carbon/hydrogen ratio. (O'Rourke, 2006)

2. UNCONVENTIONAL SHIP PROPULSION MEANS

2.1 The main unconventional propulsion methods and systems

We call unconventional any other mean which differs from the classic propulsion of commercial vessels, which doesn't use internal combustion engines to produce the mechanical work needed to spin propeller shaft and therefore to move the ship. The main unconventional propulsion methods and systems are:

a) Vertical cylinders (The Flettner rotor).

b) The ship propelled by a sail lifted at a certain height – a "kite" – this propulsion mean leads to the reduction of fuel consumption and therefore to less polluting emissions.

c) Ship's propulsion using solar batteries and fixed or mobile sails: in this case the protection of the marine environment and of the atmosphere is almost total.

d) Electrical-powered ships: using electrical engines, together with the new hull shape, adopting the pod propellers, lead to both economic advantages and environment protection by lowering CO_2 emissions.

2.2 Propelling the ship using rotating vertical cylinders (The Flettner rotor)

The system is based on the Magnus effect, applied to a vertical cylinder sitting in an air current.

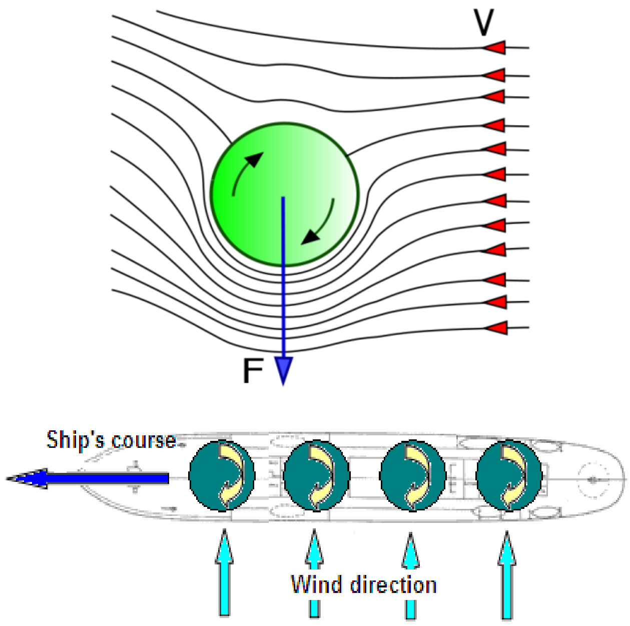

Fig. 1. Magnus Effect

2.3 The propulsion of ships using fixed/mobile sails covered with solar panels

- *Solar energy*: use of photo voltaic cells panels mounted on fixed/mobile sail, fitted on the main deck.
- *Wind energy*: used directly for propulsion by using sails mounted on the main deck, sails made from a composite material.
- *Wave energy*: this type of energy can be transformed into several kinds of energy by combining relative movements of the ship, of fins and of the waves.
- *Energy from combustion batteries*: almost 50% of the energy used for propulsion is generated by combustion batteries, based on the principle of the chemical reaction between oxygen and hydrogen, which generated energy in the propulsion systems and fins, and also for other consumers: drinking water generator and heating system.

2.3 Using aeolian energy through the kite

Using the kite, which is fitted in the fore part of the ship, does not affect the operational possibilities for the ship's holds because the kite is hoisted on a special fore mast (there aren't any classical masts on deck). (Barsan E, Grosan N. V., 2011)

2.4 Using the kite for propulsion

The kite, which is considered to be an aerodynamic surface found in an air current, is under the action of three main forces: the weight force ($\overline{W}$), the total aerodynamic force ($\overline{T_{af}}$) and the cable tension $\overline{C_t}$.

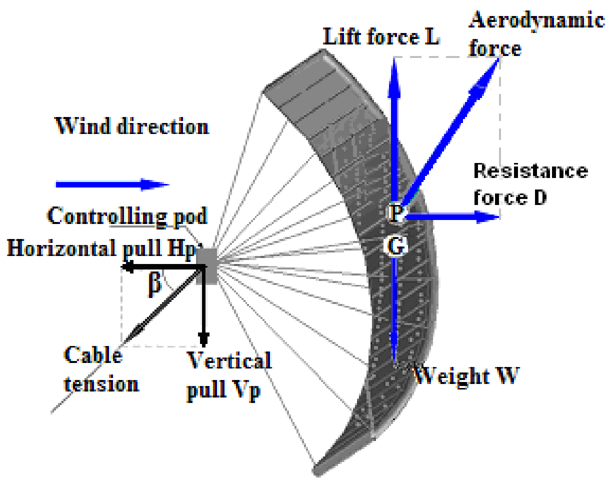

Fig. 2 Forces on a kite

As shown in Fig. 2 the forces which act upon hydrodynamic or aerodynamic profiles give a resultant force $\overline{T_{af}}$ (aerodynamic force) which decomposes by the direction of velocity in infinite and by a direction which is perpendicular on it.

The weight force $\overline{W}$ always acts in the kite's centre of gravity, "G", and it's oriented towards the centre of the earth.

The third force, the cable tension $\overline{C_t}$ is applied in the connexion point of the link cable with the kite's stays, "C".

3. SHIP PROPULSION USING THE KITE

3.1 Wind effect on sails

Given that the propulsion using the kite is strongly related to the one using classical sails, and that often the two sails are compared, we considered that some general considerations on sail propulsion are necessary.

The resultant of the pressure forces $\overline{D}$ (Fig. 3a) acts in the centre of pressure of the surface, which can be considered most of the time its geometrical centre, and is oriented in the direction of the air flow and its size depends on the total surface of the sail, it's form and the speed of the air current.

In order to do an exact calculation of the values of the forces $\overline{L}$ and $\overline{D}$, respectively $\overline{T_{af}}$, then, when the sail is oriented in different directions from the wind we use the diagram called *"The sail's polar"*.

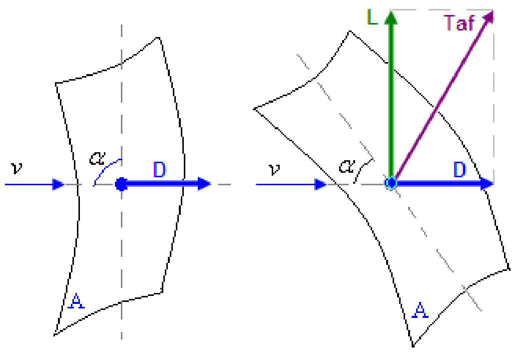

Fig. 3a. Cross wind

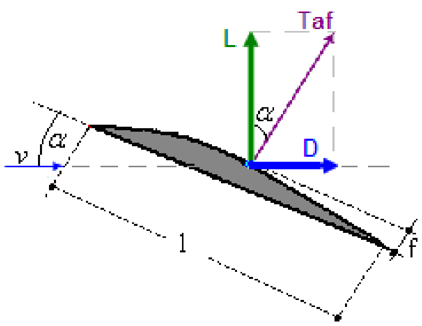

Fig. 3b. Transverse wind

Using the principle of sails propulsion as a starting point, principle which is used in sports as well (kite-surfing), it was managed to propel a ship by using a kite with a certain surface and lifted at a height where the winds have almost constant speed and direction. (Brabeck Stephan, 2011)

The most notable accomplishments in the propulsion domain using the kite belong to the companies SkySails GmbH & Co. KG from Germany and KiteShip from the United States. Although they differ in size and shape of the kite, in the positioning of the "pod" and in the number of "pod"-kite connexion strings, the principle is the same. (Fagiano L, M. Milanese, V. Razza, I. Gerlero, 2010).

3.2. The kite's forces and moments

There are several forces acting upon the kite: lift force ($\overline{L}$), drag force ($\overline{D}$), weight force ($\overline{W}$), cable tension ($\overline{T_c}$).

The total aerodynamic force, $\overline{T_{af}}$, is decomposed on the direction of the speed tending to infinity $\overline{D}$ (drag force), and on a direction perpendicular on it $\overline{L}$ (lift force). The two forces are calculated using the formulas:

$$D = C_D \rho \frac{v_\infty^2}{2} S \quad (1)$$

$$L = C_L \rho \frac{v_\infty^2}{2} S \quad (2)$$

where: C_D: drag coefficient, C_L: lift coefficient, ρ: air gravity, S: the total surface of the kite.

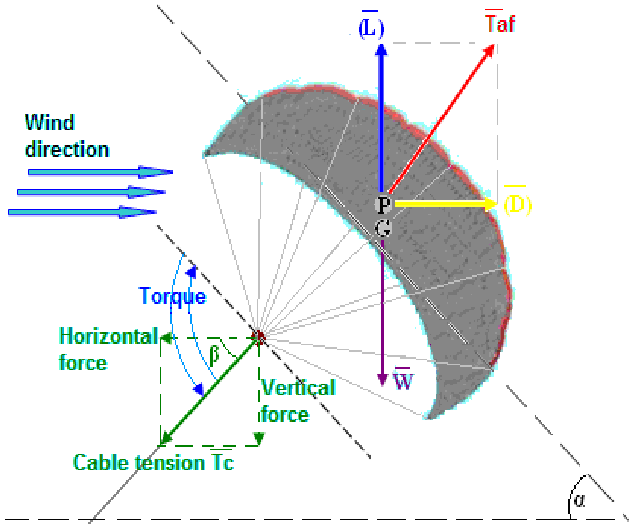

Fig. 4. Kite's forces and moments

By calculating the values of $\overline{D}$ and L from Eq. 1 and Eq. 2 we can determine the value of the total aerodynamic force using the formula:

$$T_{af} = \sqrt{L^2 + D^2} \quad (3)$$

4. THE INFLUENCE OF THE KITE ON COURSE STABILITY AND SHIP MANOEUVRABILITY

4.1 Simulation of ship's movement due to the kite's action

In order to study the kite's influence on the movement stability and ship's maneuverability we used the navigation simulator TRANSAS NAVI-TRAINER 5000.

The basis for the mathematical model is represented by a set of non-linear equations allowing us to define the evolutionary parameters of the ship. For this purpose two coordinate systems will be used: one fixed axis system $X_G O\ Y_G ZG$ and a mobile system, fixed on the ship XOYZ.

4.2 The surface wind's influence on the ship

The air flow around the ship's hull is considered to be uniform and constant in speed and direction. The real wind's speed is expressed according to Beaufort scale resulting as a mean value of the wind at 6 meters height above the sea surface. Wind's relative speed (V_A) is defined as the sum between the wind's speed and the ship's speed.

4.3 The kite's influence on the ship's maneuverability and movement stability

Choosing the kite's model for the supplementary propulsion of the ship, moreover choosing the aerodynamic profile, is a complex process because:

- the kite works permanently in a dynamic process, moving all the time, mostly in an approximate eight-shaped way under the air current influence,
- when reported to the ship's position it is not stationary,
- it works under different angles on the water's plan and on the direction of the ship's movement.

4.4 The simulation of the kite's action over the ship

To analyse the extra power given by the kite and the way this influences the manoeuvre capacity and course stability, we used the navigation simulator.

For this we chose a commercial maritime ship, of medium size and capacity. The forces developed by the kite were projected on the water surface and applied to a maritime tug.

The simulations were executed in conditions in which the wind from the sea surface has no influence on the ship and in conditions in which the wind from the sea surface has influence.

After the simulations made in different wind conditions and speed regimes, both of the ship and the tug to which kite's traction force was applied, simulations presented in annexes I, II and III, a series of conclusions can be drawn on the behaviour of a ship powered by the mixed engine-kite system, conclusions which can be used as a starting point for research on unconventional propulsion using the kite.

The initial conditions were also altered on the way to give a more complete picture on the ship's manoeuvrability for different wind and speed regimes.

5. CONCLUSIONS

The possibility of towing the ship using a kite by calculating the forces developed by a kite of certain dimensions and aerodynamic shape and the total aerodynamic force which can move a freighter can be determined. Of course, it was taken into consideration the ship's size. The way in which the traction force developed by the kite influences the ship's course stability, its trim and list is a very important aspect. One of the ship's main nautical characteristics is course stability; this is defined by the way in which the ship is resistant to the exterior forces applied and maintains its pre-set course. It can be observed from the simulations the great influence created by the kite on course stability.

Research can also continue in the matter of producing electrical energy using the kite. In the ground based studies, on fixed platforms, it was demonstrated that it is possible to produce electrical energy using a kite moving up or down, or using a series of kites. Research can be extended, and these kites can be mounted on board ships, experimenting in a primary phase the way the ship moves at slow speed or is adrift and the energy produced by the auxiliary engines (current generators) is replaced by the energy supplied by the kites.

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Received: July 10, 2015 / Accepted: December 10, 2015 / Paper available online: December 20, 2015 © International Journal of Modern Manufacturing Technologies.