

The rigid bi-functional sail, new concept concerning the reduction of the drag of ships

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Abstract. The policy of the European Union in the energy field, for the period to follow until 2020, is based on three fundamental objectives: sustainability, competitiveness and safety in energy supply. The "Energy – Climate Changes" program sets out a number of objectives for the EU for the year 2020, known as the "20-20-20 objectives", namely: the reduction of greenhouse gas emissions by at least 20% from the level of those of 1990, a 20% increase in the share of renewable energy sources out of the total energy consumption as well as a target of 10% biofuels in the transports energy consumption. In this context, in order to produce or save a part of the propulsive power produced by the main propulsion machinery, by burning fossil fuels, we suggest the equipping of vessels designed for maritime transport with a bi-functional rigid sail. We consider that this device may have both the role of trapping wind energy and the role of acting as a deflector for reducing the resistance of the vessel's proceeding through the water by conveniently using the bow air current, as a result of the vessel's heading through the water with significant advantage in reducing the energy consumption for propulsion insurance.

1. Introduction

Starting from the idea that, before the advent of the industrial revolution, ships sailing on the ocean used to transport goods worldwide and reach speeds up to 16 knots, without polluting, in what follows we are going to resume the application of this type of energy which at that time it was used unrestrictedly and cost free. We also take into consideration the fact that the wind energy which seemed to be sufficient at that time can be also used to some extent nowadays for operating the power of the main propulsion machinery involving significant fossil fuel savings and gas combustion reductions.

Although over the years, transport vessels have strayed from the ecological path and begun to use air currents more and more rarely, until this method was used only in racing and by small pleasure yachts, we hold the idea that nowadays there is a need to modernize certain types of ships, so that the renewable energy be stored in the vessel's outer marine environment at a certain moment.

Before the advent of the industrial revolution, the most popular form of energy used for ship's propulsion was the wind. In this respect, nowadays ship builders have promoted creative solutions to trap the wind energy even when ships are equipped with modern internal combustion machinery. Thus, the present solutions mostly used are the following [1]:



Unfortunately for the fitting of merchant ships this solution has the disadvantage of being dependent on the type of vessel and the environmental factors, as well as the direction and force of wind.



Figure 1. Ship equipped with classic sails.



Figure 2. Ship equipped with rigid sails.

Hybrid propulsion is based on the opportunity of trapping wind energy of the certain moment replacing thus a part of the energy produced by conventional methods but it also presents the disadvantage that in normal conditions of underway the helical surface of the vessel grows and consequently the headway resistance increases as a result of air friction.



Figure 3. Ship equipped with 4 Flettner rotors.



Figure 4. Ship equipped with a kite type sail.

Although considered a constructive and cost efficient solution Flettner rotors propulsion involves the turning of propulsion cylinders which can pose difficult problems for the crew on deck and this in turn could enter into contact with these moving masses. Also the rotors lengths implies the rising of the ship's center of gravity with negative values upon the ship's stability or with the necessity of a supplementary ballast for lowering the center of gravity.

The use of the kite type sails represents an actual element of trapping wind energy, though this solution involves high installation costs which can be hardly supported during ship service and it can be used only with high wind speeds with important energy savings. It also presents the disadvantage of introducing great drifting forces which may lead to the ship's plying off course.

The new concept of bi-functional rigid sail which is the aim of our present paper developed as a result of our thesis entitled "Research on the use of alternative sources of energy to ship's propulsion" represents a new solution for conventional energy saving on board ships and by case for trapping wind energy with the purpose of using it as a means of propulsion energy.

2. Some considerations regarding the increase in transport speeds of present maritime vessels

The increase in the share of freight transport by sea, particularly of the specialized cargo transport has lately determined a growth in the ships service speed. Thus, current trends show that the service speed of ferryboats or container ships often exceeds 22 Kt, this trend also applying to tanker vessels with service speeds of 16 Kt. In this context, the velocity of air

coming from the fore part of the ship, that is the V_{sc} , grows high enough as a result of the vessel's heading through the water and in order to be possible to use the wind energy trapped from the environment at a given moment there must be a wind from the stern, V_{rv} , which is strong enough, so that the true wind velocity can be achieved, that is the V_{va} , from athwartships (see figure 5).

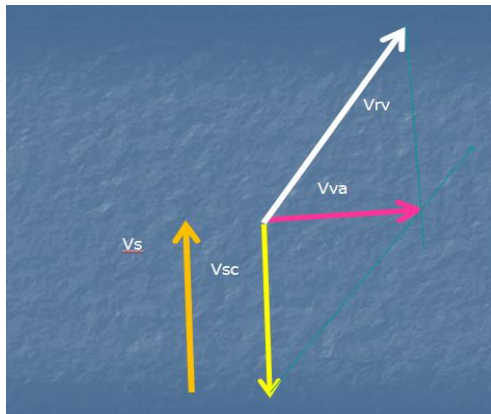


Figure 5. The true wind direction (V_{va})

V_s = Service ship velocity

V_{sc} = Water current velocity

V_{rv} = Real wind velocity

V_{va} = True wind velocity

Therefore, only under such circumstances it is possible to trap the wind energy when the true wind V_{va} can produce an active bearing stress in each trapping device. For example, the kite type sail under figure 4, which has recently appeared on “the unconventional energy market” gives excellent results on condition that the wind speed be 4-5 knots higher than the ship's speed that is, 25 Kt for a liner ship which would be regarded as a very high speed, would cause swells in the sea and the meteorological conditions would become unfavorable for trapping wind energy [2].

2.1. Equipping shipping vessels with bi-functional rigid sails

Given the abovementioned conditions of the increase in transport speed, we have developed an innovative device called bi-functional rigid sail (see figure 6), which has two important roles with the purpose to replace fossil fuel consumption, as demonstrated by experiments on models and by simulation. Thus, this device is installed in the bow and can have two functions: role of deflector when the velocity of air comes mostly from the bow and of rigid sail when the direction of the real wind is favorable.

The components of the bi-functional rigid sail are (figure 6): 1 – the rigid sail; 2 – the sail's axis; 3 – the symmetric profile of the sail; 4 – the sail joint which allows tilting as deflector; 5 – the sail chock for allowing the sail's orientation into the wind for trapping wind energy.

The bi-functional rigid sail has two degrees of freedom and allows two-plan rotation. According to the two declared roles, that is, of properly conducting the air current in conformity with the direction of the true wind and capturing the wind energy respectively when the sea wind speed (stern wind) is greater than the speed of the vessel underway.

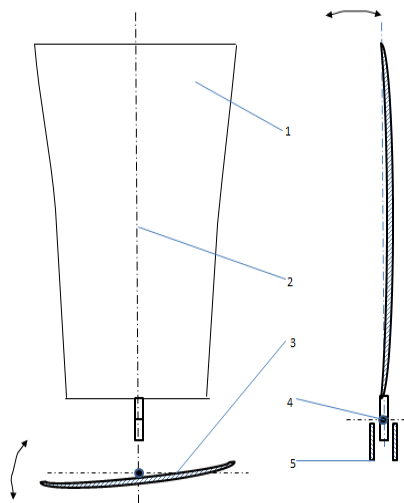


Figure 6. Bi-functional rigid sail.

2.2. Analysis of the Bi-functional rigid sail

To demonstrate the solution suggested, Ansys Workbench 14.0 software was used, in order to reveal the lowering of the ship's heading resistance by using the bi-functional rigid sail. In this regard, air flows, as compressible fluid, have been integrated around the ship's quickworks [3].

The simulated ship trials based on the use of finite element method [4], searched the optimal angle of inclination of the bi-functional rigid sail, and also its location in relation to the bow (see figure 7). In order to carry out these trials, a ship model has been produced at a scale of 1:10 where the sail had, in relation to the ship's bow, three successive locating aft points. The model under consideration was derived from a transport ship, performing handling operations and whose architecture fitted the installation of bi-functional rigid sail, and having the following characteristics: Width: 10.768 m; Length: 29.599 m; Height: 6.993 m, Total area: 552.911 m²; Volume: 2228.823 m³.

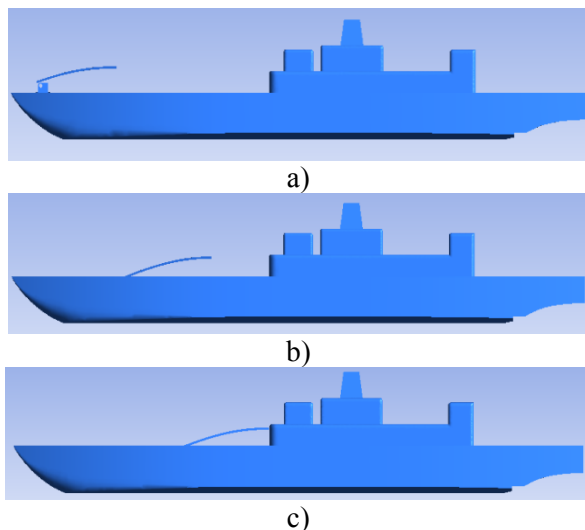


Figure 7. Placing the bi-functional sail type with deflective role

- a) placing the deflector in the fore part of the ship
- b) placing the deflector in the middle of the ship's fore part
- c) placing the deflector in front of the ship's superstructure

Checking by simulation, the values of the ship's heading resistance due to air currents, significant variations thereof were observed, determined for the ship equipped with bi-functional rigid sail as compared to the conventional ship type [5]. Thus, it was found that the highest heading resistance occurred in b) at a 30° angle of loll, when the heading resistance, decreased by 35 % (figure 8).

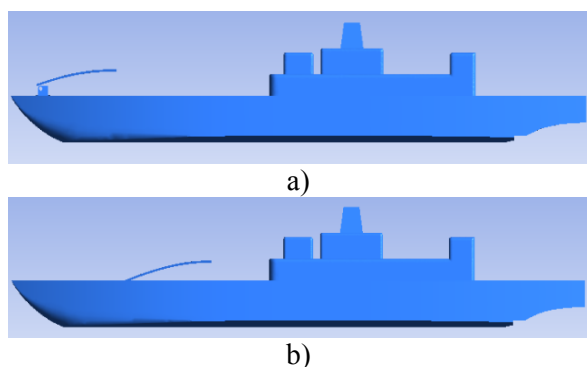


Figure 8. Specific variations of speeds
a) distribution of speeds
b) deflector placed near the superstructure, tilted at an angle of 30°

3. Results

The results of the comparative study connected to the two scenarios considered to equipping the ship, with and without bi-functional rigid sail highlight major variations in thrust (see figure 9). It appears that these increases are not linear, maximum values being recorded for cases where the wind speeds 10 to 17.5 m/s when the heading resistance increases for the unequipped ship with 332% and 330% respectively (see figure 10).

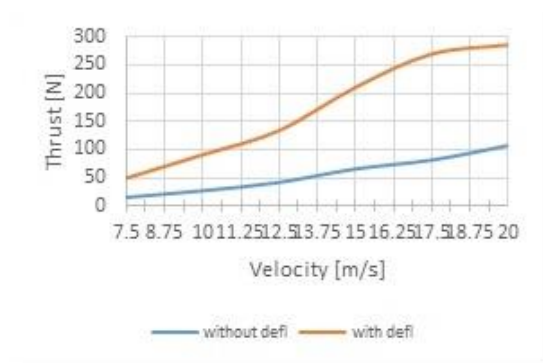


Figure 9. Thrust variations for the two cases considered.

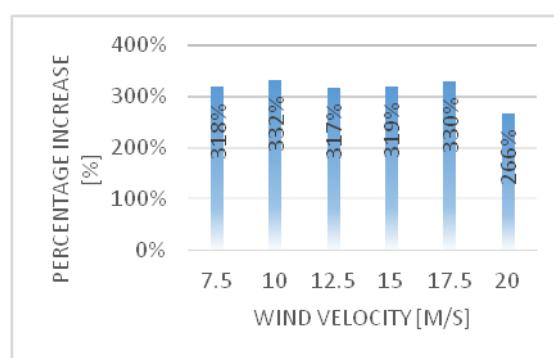


Figure 10. Comparison of thrust values set for the ship equipped with/without deflector.

4. Conclusions

Where the configuration of the ship allows the placement on board of such a bi-functional rigid sail and technical difficulties represented by its development and placement can be overcome so that using this solution would not affect the safe operation of the ship, this innovative technique could be a viable alternative to increase the energy efficiency of the entire energy complex represented by the ship and implicitly of the effective trapping wind energy from the marine environment.

Therefore the analysis of the doctoral thesis "Research on the use of alternative sources of energy to ship's propulsion" [5] leads to the following advantages concerning the equipment of vessels with this type of sail, as follows:

- diminishing the headway resistance as a result of the convenient swing of the air current produced by the vessel's headway;
- trapping the stern wind for the active propulsion and discharge of vessel's reactive propulsion with important savings of fossil fuels;
- increasing the crew's working on deck level of comfort by a convenient deviation of the air current produced by the vessel's underway speed;

- constructive simplification and increased fiability without involving important technological solutions;
- reduced maintenace and simple usage;
- the posibility of working optimization regarding the direction and force of wind at a certain moment;
- a low price for equipping a vessel with such a type of sail.

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