Possibility of placing a retractable sail system for an oil tanker to optimize its efficiency

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**Abstract.** Nowadays, self-propelled maritime transport increasingly depends on the use of new technologies and energy from renewable sources.The Action Plan clearly shows that the vision of building a ship that does not release emissions is realistic. As far as manufacturing time is concerned, it is not only a question of technology development but also of the advancement of economy, infrastructure, laws, the freight market, etc. This paper aims to analyze a VLCC ship in terms of energy efficiency by introducing innovative systems on board and correlating with the classical systems of the ship. Also, the paper present theoretical and practical considerations for optimizing the operation of energy systems at a VLCC of 305000 dwt. The paper introduces an innovative VLCC concept where, through onboard innovative power systems, bring major improvements to this type of ship.

**Keywords.** VLCC, sail, wind resistance

# Introduction

There are currently various emerging technologies that allow the use of renewable energy by small vessels or boats. These solutions may become applicable to larger ships in the future. Renewable energy sources have the potential to provide abundant energy supply with minimal environmental impact and relatively low costs. It should be stressed that it is quite possible to build a ship that operates without emissions today with existing technology, although it would not be economically convenient considering the today's maritime transport market.

Using sails can reduce fuel consumption and also reduce emissions, but it also has potential disadvantages such as:

* Vessels occupy a lot of space and therefore access is restricted during loading and unloading and therefore the cranes have to work around them
* Booms can generate unfavorable wind resistance. There is also a risk for crew with regard to changing wind conditions. Particularly on storms, masts and sails can cause dangerous ship shifts
* In sailing, the ship tends to tilt. This may be impossible for container vessels and cargo ships, to operate under sailboat conditions. To avoid situations of this kind, an excessive ballast is needed, which is not economical

# ****Sail system configuration****

At the 305,000 dwt oil tank I will design five sail systems for better fuel economy. Of the five shipboard systems, we have four identical systems and one different system in the bow of the ship. Depending on the body of the ship we will place the five systems according to figure 1, as follows:

* the four same type systems placed in the curbs, two systems of the same type placed on the starboard and two systems of the same type on the port placed symmetrically as follows: two systems placed in the bow of the cargo tank no. 2 at a distance of 71.25 m from the bow of the ship and 261.75 m from the aft of the ship, and two systems placed in the aft of the cargo tank no. 5 at a distance of 109.25 m from the aft of the ship and at a distance of 223.75 m from the ship's bow
* one system located on the bow of the ship at a distance of 12 m



**Figure 1.** **Sail system configuration**

As can be seen in Figure 1, the systems are tiltable depending on the navigation and cargo requirements as follows:

* The four identical systems are tiltable at 90º from the vertical position in the horizontal position
* The ship's flap system at 180º from the middle of the mast



**Figure 2.** **Sail system configuration**

As can be seen in Figure 2, the system consists of the main mast and three side arms that can be opened at an angle of 90 ° to the main mast. On the three arms are placed the floats that are in the same three identicals. The veels open from top to bottom as needed depending on the navigation conditions.

At the same time, they can be folded into the fan system as can be seen in Figure 3 rotation can be done at a 360° angle only for identical masts because it is possible to increase the large surface working in the wind. For identical masts, each mast has a height of 38 m and consists of three identical sails having a length of 18 m and a height of 12 m each. For the forward mast, it has a height of 38 m and consists of two identical sails having a length of 18 m and a height of 18 m each. The forward mast is formed of only two arms rotating at 90° to the mast and symmetrical to it. The sail system also works on the fan opening system.



**Figure 3.** **Sail system configuration**

# ****Calculation of sail system****

At For the sail system described in the previous section, I will calculate the sail drag at different wind speeds.

 [kN] (1)

- sail force

 - air density (at 20ºC)



- the coefficient of sail force

 

- sail area

 (2)

- the speed of apparent wind

I have to calculate the apparent wind speed. For this I take into account the following:



Nd

Nd





 (3)

 (4)

 (5)

- has negative value, so it has no practical significance.

## Calculation of apparent wind speed

**Table 1.** Calculation of apparent wind speed (VR = 30 Nd)

|  |  |  |
| --- | --- | --- |
|  |  |  |
| **1** | 42.42641 | 30 |
| **2** | 42.37924 | 28.55243 |
| **3** | 42.23742 | 27.03794 |
| **4** | 42 | 25.45584 |
| **5** | 41.66533 | 23.80499 |
| **6** | 41.46082 | 22.95327 |
| **7** | 41.23106 | 22.08369 |
| **8** | 40.69398 | 20.28971 |
| **9** | 40.38564 | 19.36457 |
| **10** | 40.04997 | 18.42011 |
| **11** | 39.68627 | 17.45583 |
| **12** | 40.69398 | 20.28971 |
| **13** | 40.38564 | 19.36457 |

## Calculation of sail drag

**Table 2.** Sail drag calculation (VR = 30 knots)

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | [kN] | [kN] |
| 1 | 30 | 2038.284 | 10191.42 |
| 2 | 28.55243 | 1846.326 | 9231.632 |
| 3 | 27.03794 | 1655.653 | 8278.267 |
| 4 | 25.45584 | 1467.564 | 7337.822 |
| 5 | 23.80499 | 1283.388 | 6416.941 |
| 6 | 22.95327 | 1193.195 | 5965.973 |
| 7 | 22.08369 | 1104.5 | 5522.498 |
| 8 | 20.28971 | 932.3388 | 4661.694 |
| 9 | 19.36457 | 849.2548 | 4246.274 |
| 10 | 18.42011 | 768.4341 | 3842.17 |
| 11 | 17.45583 | 690.0859 | 3450.429 |
| 12 | 20.28971 | 932.3388 | 4661.694 |
| 13 | 19.36457 | 849.2548 | 4246.274 |
| 14 | 18.42011 | 768.4341 | 3842.17 |
| 15 | 17.45583 | 690.0859 | 3450.429 |

# The technical and economic efficiency of the sailing system

I will calculate for wind speed values of 30 knots and the maximum sails surface area of 3240 m². The results obtained by the wind speed and the ship can be tracked below.

**Table 3.** Calculation of apparent wind speed

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Ship speed [knots] | Engine power-P [Kw] | Effective consumption –C [t/h] | Drag sails force-Fd [kN] | Sails power-Ps[Kw] | Ship required power-Preq [Kw] | Total fuel consumption [t/h]-Ct | Fuel saving- ΔC [t/h] |
| 0 | 0 | 0 | 10191 | 0 | 0 | 0 | 0 |
| 2 | 85.81 | 0.01493 | 9231.6 | 18463 | -18377 | -3.1976 | 3.2126 |
| 4 | 581 | 0.10126 | 827.26 | 33113 | -32531 | -5.6604 | 5.7616 |
| 6 | 1660 | 0.28832 | 7337.8 | 44026 | -42366 | -7.37175 | 7.6606 |
| 8 | 3300 | 0.57437 | 6416.9 | 51335 | -48034 | -8.3580 | 8.9323 |
| 9 | 4295 | 0.74753 | 5965.9 | 53693 | -49398 | -8.5953 | 9.3427 |
| 10 | 5388 | 0.93556 | 5522.4 | 55224 | -49836 | -8.6715 | 9.6091 |
| 12 | 9903 | 1.72322 | 4661.6 | 55940 | -46036 | -8.010 | 9.7336 |
| 13 | 13350 | 2.3231 | 4246.2 | 55201 | -41850 | -7.2820 | 9.6050 |
| 14 | 17864 | 3.10889 | 3842.1 | 53790 | -35925 | -6.2510 | 9.3595 |
| 15 | 23777 | 4.13769 | 3450. | 5156 | -27979 | -4.8683 | 9.0056 |
| 16 | 31518 | 5.48467 | 3072.1 | 49154 | -17636 | -3.0686 | 8.5528 |

We note that at the wind speed of 30 knots and a surface area of 3240 m² sails the ship no longer requires the force of the engines to reach the speed of 16 knots. So we have 100% fuel savings. Since the total sail area is no longer efficient above the wind speed of 30 knots, we will analyze the economic efficiency by reducing the very large area by using a limited number of sails.

# Calculation of sail efficiency at different degrees of sea

In the initial design phase, drag resistance generated by sea waves can be determined by:

$R\_{VM}=C\_{VM}\frac{ρ∙v}{2}S$[kN] (6)

The value of the CVM is selected from the tables according to the degree of the sea and is:

**Table 4.** The value of the CVM

|  |  |
| --- | --- |
| Beaufort value | CVM |
| 1 … 2 | (0,1 … 0,2)∙10-3 |
| 3 … 4 | (0,3 … 0,4)∙10-3 |
| 5 … 6 | (0,5 … 0,6)∙10-3 |

The ship's overall propulsion resistance is determined on the basis that:

$R\_{T}=R+R\_{S}$ [kN] (7)

where: R is the main forward resistance and RS is the additional forward resistance. The vessel's displacement by water at a certain constant speed is achieved by means of the propulsion system which, by its developing force, has to overcome the total resistance. Towing power is produced by the propeller and has the definition relation:

 [kW] (8)

 [CP] (9)

where: RT is the total drag resistance in kN and v the speed of the ship in m / s.

**Figure 4.** Calculation of ship resistance according to sea level

# Calculation of sail efficiency at different degrees of sea

It is estimated that using sails the cost of fuel can fall between 10-35% depending on the wind conditions. It is concluded that the benefits of both the environment and the financial can be convincing. Sail vendors indicate that using this system, ship operation will become more profitable, secure and independent of the decline in fuel reserves.The idea of using a combined sail-engine system is not a new generation idea, but because of constructive and conservative inconveniences, this system has not been implemented on a large scale. Nowadays, five elements are considered to be major sources of pollution of the marine environment: industrial activity on land, underwater, waste discharged into the marine environment, ships and the atmosphere. Unfortunately, as I have shown earlier, the measures were taken and which are still being considered are not a true reflection of the workload effort.

Good results have indeed been achieved in certain areas of the world, such as the limitation of SOx production in northern Europe and the North American coast, but are still areas in the world where no precautionary measures have been taken into account.

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