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OPERATIONAL METHODS USED FOR IMPROVEMENT OF ENERGY EFFICIENCY OF A SHIP

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In this article there are covered several operational methods for improving energy efficiency of a ship using using the Fluid Flow Modeling (CFD) program, Ansys Fluent. The maritime transport sector is under considerable pressure to increase energy efficiency. While CO_2 emissions are decreasing in many other sectors, maritime transport emissions are expected to be increased in the future. Shipping Industry currently accounts for about 3% of global CO_2 emissions. As a result of increased transportation, and in combination with difficulties in implementing effective energy efficiency measures, its share is expected to grow. Fuel efficiency is linked to air emissions, measures and policies that successfully improve energy efficiency. Various researches have been carried out in the field of alternative power sources and into technical, operational and structural energy saving measures for shipping industry. In order to reduce fuel consumption and to increase energy efficiency we should take care about the position of the bow thruster, the location of the fins, the bilge keels, the form of the central skeg, the sea chest openings dimensions, the seemingly of the propellers, the rudders form, the hull openings position, the zinc anodes & lifting eyes position, the hull surface condition. The evaluated savings in resistance correspond to savings of the fuel that is consumed by the propulsion. Speed range of 18kn to 21kn is considered for the improvement percentages.

Keywords: energy efficiency, shipping industry, measures

ЭКСПЛУАТАЦИОННЫЕ МЕТОДЫ ПОВЫШЕНИЯ ЭНЕРГОЭФФЕКТИВНОСТИ СУДНА

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В этой статье рассматриваются несколько эксплуатационных методов повышения энергоэффективности судна с использованием программы Fluid Flow Modeling (CFD) Ansys Fluent. Сектор морского транспорта находится под значительным давлением в плане повышения энергоэффективности. В то время как выбросы CO_2 снижаются во многих других секторах, ожидается, что выбросы морского транспорта в будущем увеличатся. В настоящее время на судоходную отрасль приходится около 3% глобальных выбросов CO_2. Ожидается, что в результате увеличения транспорта и в сочетании с трудностями в реализации эффективных мер по повышению энергоэффективности его доля будет расти. Эффективность топливоиспользования связана с выбросами в атмосферу, мерами и политикой судовладельца, которые успешно повышают энергоэффективность. Были проведены различные исследования в области альтернативных источников энергии и технических, эксплуатационных и структурных мер по энергосбережению для судоходства. Для снижения расхода топлива и повышения энергоэффективности следует позаботиться о положении носового подруливающего устройства, расположении килей, скуловых килей, форме центрального скега, размерах отверстий в кингстонных ящиках, геометрии гребных винтов, формы рулей, положении проемов в корпусе, положении цинковых анодов и подъемных проушин, состоянии поверхности корпуса. Оцененная экономия сопротивления движению соответствует экономии топлива, потребляемого движителем. Диапазон скоростей от 18 узлов до 21 узла считается процентом улучшения.

Ключевые слова: энергоэффективность, судоходство, мероприятия.

1. Introduction

In order to improve energy efficiency and to reduce CO_2 emissions International Maritime Organization (IMO), has added a new chapter to MARPOL Annex VI on the prevention of CO_2 emissions, which entered into force on 1 January 2013. An energy efficiency design index (EEDI) value, which is related to the mass of CO_2 emissions per transport work to the ship size, must be produced for all new ships [1].

2. Formulation of the problem

Nowadays maritime transportation sector develops environmental pollution issues [2]. In order to reduce pollution we must reduce fossil fuels consumption. For this reason there have been developed several ways for improving energy efficiency. In this article the reader will discover some interesting methods and problems which should be taken in consideration, in the moment when we design and build a new ship.

3. Measures for improving energy efficiency

In order to reduce of fuel consumption, a big number of measures can be implemented to improve energy efficiency in shipping industry:

- Improvement of the position of the bow thruster;
- Location of the fins;
- Bilge keels position;
- The form of the central skeg;
- The sea chest openings dimensions;
- Seemingly the propellers;
- Rudders form;
- Hull openings position
- Zinc anodes & lifting eyes position;
- Hull surface condition.

3.1 Improvement of the position of the bow thruster

In Figure 1 we can see a ship which is equipped with an anti-suction tunnel (AST) in between the bow tunnels. In this position the AST is not very effective and could be removed. The correct location for the AST would be aft of the bow thruster tunnels.

The Bow thrusters are aligned on the same stream line and not on the same horizontal plane, which is the optimal arrangement. No grids or scallop fairings are applied on the bow thruster openings. In the Figure 2 you can see the CFD-simulation of the original arrangement of the typical influence of grids and AST on the local velocity field around the bow thrusters.

Grids could be installed on the bow thruster openings.

CFD-simulations have shown significant reduction in resistance by applying grids and by removing the AST. The local flow field inside the thruster tunnels is illustrated in Figure 2, where by application of the grids, a reduction in flow velocities inside the tunnels can be observed Figure 3.

The potential reduction in resistance by adding the grids and by removing the AST is in the range of 1-3% throughout the speed range. On the other hand, the grids would reduce the side force of the bow thrusters by about 5%, which needs to be considered as well.

Figure 1 – Bow thrusters (starboard side view) and Anti-suction tunnel (AST)

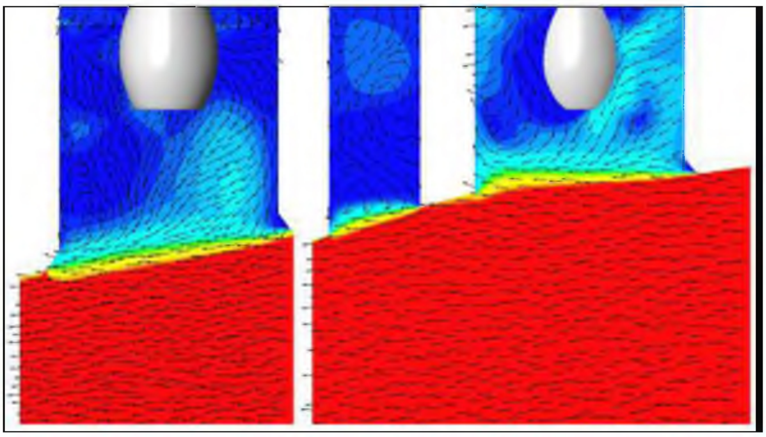

Figure 2 – Typical influence of grids and AST on the local velocity field around the bow thrusters- original arrangement

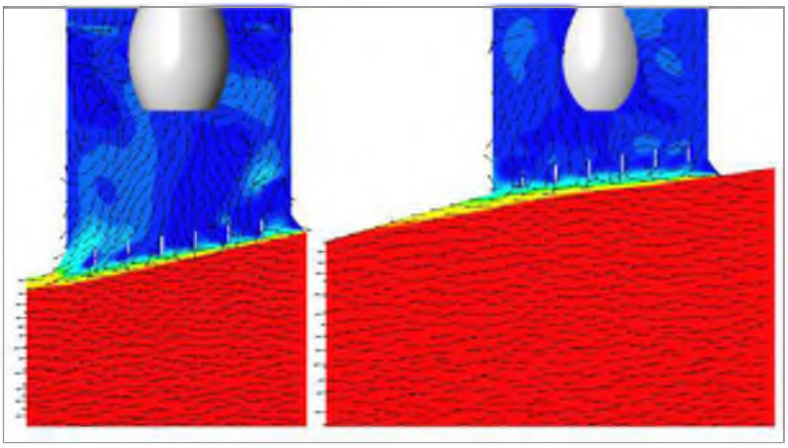

Figure 3: Typical influence of grids and AST on the local velocity field around the bow thrusters with the added grids and AST removed

3.2 Fin Stabilizers

We can studied the case for a ship equipped with fin stabilizers with backwards opening type located on aft of the largest frame [3]. When the fins are extracted, the arrangement is good from the fuel economy point of view. But when the fins are folded in, forward opening type of fins would be better from the fuel economy point of view.

The location of the fins aft of the largest frame is quite good from the fuel economy point of view, as opposed to being located forward of the largest frame (Figure 4). In this way the stabilizer recesses are more sheltered from the main flow around the hull. The opening in shell is quite large.

Figure 4 – Portside fin stabilizer recess

Adding a scallop fairing behind the fin stabilizer recesses could reduce resistance. The potential improvement in resistance could be in the range of 0.5-3%, and is dependent on speed, the individual hull shape and the geometry of the fin recesses. Estimation on improvement at 18 kn is around 1-3% while at 21 kn the improvement is estimated to be 0.5-1% Reduction in resistance can be determined by CFD-simulations. Figure 5 presents an optimized scallop fairing from a previous project and how it impacts the water flow over the recess.

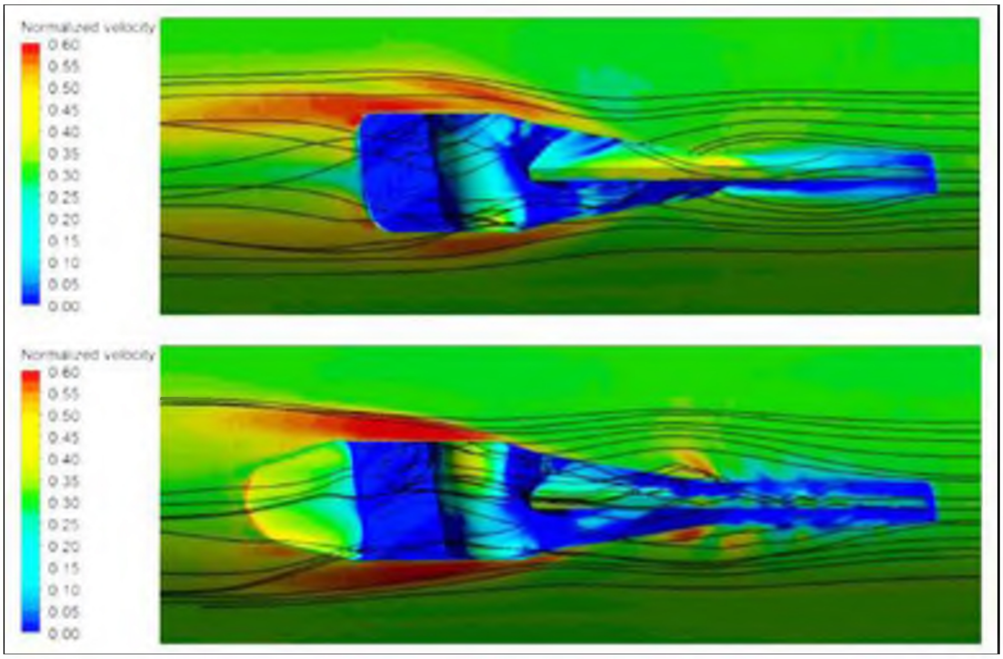

Figure 5 – Typical optimized scallop fairing behind the stabilizer recess and the influence of the scallop on the velocity distribution and local stream lines

As can be seen, the original opening works as a “water collecting bag” and the scallop fairing reduces this phenomenon clearly (less water flows into the recess). At higher speeds the water flows better over the recess and therefore the influence of the scallop reduces at higher speeds.

3.3 Bilge Keels

The study was made for a ship with the bilge keels with are quite long with a fairly high profile height (Figure 6). The alignment of the bilge keels seems to be along a streamline, though the actual loading condition (trim) and speed of the ship does affect the additional resistance due to bilge keels.

Reducing the length of the bilge keels could be considered, as bilge keels are dampening the roll motion by about 10% only, whereas the fin stabilizers are dampening about 80% for comparison. In practice the bilge keels are only effective when standing still at sea – at anchor. The size of bilge keels may also be affected by stability criterion (IMO WEATHER), which has to be taken into consideration before shortening.

The placement of zinc anodes along the bilge keels could be changed so that the anodes attach to the shell plating, rather than to the bilge keel itself. This way the anodes would be less exposed to the flow around the hull.

Figure 6 Portside bilge keel

3.4 Central Skeg

We consider a ship where the thickness of the central skeg is quite large and the trailing edge fairing on the skeg is rather short (Figure 7). However the trailing edge of the skeg is sharp, which is good from the resistance point of view.

A CFD-simulation on the effect of modifying the trailing edge shape of the central skeg could be performed, and the resulting improvement could be determined. The required steelwork on the skeg modification could be quite extensive.

Figure 7 – Central skeg

3.5 Sea Chests

We consider a ship with small sea chest openings. Figure 8 presents a sea chest on the starboard side aft ship.

On the figure the grids for the sea chest were not in place. In Figure 9 is illustrated a sea chest grid.

The grids on the sea chest should be installed in a way that no step is formed in the transition between shell plating surface and the grid surface. It is quite typical that the sea chest hatches are aligned a few cm inside the hull surface, which is not good from the fuel economy point of view.

3.6 Propellers

In Figure 10 you can see the seemingly the propellers with look quite modern. There is however some cavitation damage on the pressure side of the blades.

Figure 8 – Sea chest on the starboard side aft ship

Figure 9 – Sea chest grid

Figure 10 – Propeller blade. A streak of cavitation damage can be observed on the pressure side (near the lower edge in the photo)

The cavitation damage on the pressure side of the blades could be because of running in an off-design condition (lower than normal pitch or reverse) with high power. It could also be due to a design flaw in the blades or a mismatch in ship resistance vs. propeller design.

The blades are of stainless steel, which requires less polishing to remain in good condition. In case of bronze blades, regular polishing is important or otherwise about 1% per year will be lost due to fouled propellers. The blades were not yet cleaned at the time of inspection, so minor fouling on the surface could be seen. Also the cavitation damage should be repaired as it will decrease the efficiency of the propellers.

3.7 Rudders

As can be seen from Figure 11 we consider a ship with has the gap between the rudder and head box minimal, which is good. The shape of the head box could be improved on, as it is quite blunt. Also the alignment of the head box with the flow could be checked.

Improvement due to modified head boxes is estimated at 0.5-1% throughout the speed range. Improvement due to this modification can be studied with CFD-simulations. Additionally an extension to the head boxes would improve on course stability, but could have a minor negative effect on harbour manoeuvring.

Figure 11 – Portside rudder and head box

3.8 Hull Openings

As can be seen from the Figure 12 we have chosen the case of a vessel with is using two types of hull penetrations. We consider that the majority of the openings are of the type that is shown on the left in Figure 12. The end of the pipe penetrating the hull is not protruding beyond the shell plating but there is a sharp collar-like recess around the opening.

The penetrations should be done as shown in Figure 12 on the right, so that there is no protrusion or additional recess. The fuel saving potential of these shell penetrations is small, but some protrusions may cavitate causing coating damages behind the openings.

Figure 12 – Hull openings at starboard side midship

3.9 Zinc Anodes & Lifting Eyes

We consider a vessel with has no impressed current cathodic protection system, so there is a number of zinc anodes installed all over the hull. Relocating or rearranging some of the anodes is proposed below.

In Figure 13 we can see a ship with was the zinc anodes on the portside bilge keel.

The zinc anodes are proposed to be moved from the bilge keels onto the adjacent shell plating. This way the anodes would be better protected from the flow.

Figure 14 presents the zinc anodes on the shaft brackets.

Zinc anodes on the shaft brackets are proposed to be aligned with the flow as now they installed are perpendicular to the direction of flow. As a result to our study we can install smaller anodes here.

The anode on the central skeg as seen in Figure 15 could be relocated to the adjacent shell plating to be better protected from the flow.

Figure 13 – Zinc anodes on the portside bilge keel

Figure 14 – Zinc anodes on the shaft brackets

Figure 15 – Zinc anode on the central skeg starboard side

It is not known how many permanent lifting eyes are attached below the bottom, but all the lifting eyes are either new ones or replaced by new ones. It is quite common to have permanent lifting eyes on the shell plating, but usually those lifting eyes get damaged before the next dry dock and must be replaced by new ones before using them. Therefore, it is recommended to remove all of the lifting eyes after finishing the propeller and rudder works.

3.10 Hull Surface Condition

The difference between a ship with a good condition region on the blasted area and a ship with a poor condition region in an untreated region can be seen in Figure 16.

Figure 16 – Comparison of surface quality in regions where abrasive blasting has been applied (on the right) and where no abrasive blasting has been applied (on the left)

As can be seen there are some 2-3mm high blisters in parts of the untreated areas, whereas the surface smoothness in the blasted area is generally in the range of less than 1mm.

It is recommended that the surface of the whole hull would always be totally stripped before applying a new coating. An uneven surface quality can lead to additional resistance of a few percent.

If partial blasting is considered, the blasting effort should be focused on getting as much square meters as possible to an even surface quality. The priority on blasting could be on the high flow velocity areas such as the bow, the rudder, bilge keels and other appendages, but keeping in mind that most of the square metres come from flat areas such as the flat bottom.

4. Conclusion

We can improve energy efficiency of a ship by improving and optimizing different parts of the ship.

There are various possibilities for improving energy efficiency covered in this article that can be implemented on a ship.

By improving energy efficiency we can reduce the fuel consumption, save money for the owners and reduce air pollution.

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УПРАВЛЕНИЕ ВИНТОВОЙ ХАРАКТЕРИСТИКОЙ ГЛАВНОГО ДВИГАТЕЛЯ ПУТЕМ СТРУЙНОЙ ПОДАЧИ ДОПОЛНИТЕЛЬНОЙ ВОДЫ НА ПЕРО РУЛЯ ПРИ МАНЕВРИРОВАНИИ СУДНА

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Наиболее распространенная компоновка винто-рулевого комплекса, состоящего из винта фиксированного шага и пера руля, существенно ограничивает возможности управления судном при малой скорости набегающего потока и требует применения дополнительных средств управления. Необходимость обес-