INSTALLATION OF ENERGY SAVING DEVICES FOR THE IMPROVEMENT OF PROPELLER EFFICIENCY

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ABSTRACT

Ever since sail gave way to mechanical power as the prime method of propulsion, shipping has accounted for a substantial quantity of the world’s oil consumption which today amounts to about 4% but any increase in the efficiency of the propulsion system can lead to huge savings. The propeller of the ship provides the thrust required to move it and simultaneously has certain losses associated with it. A propeller in open water has a uniform inflow of water into it but the scenario is quite different when placed behind a ship. The flow field is changed by the ship’s hull. Due to viscosity the ship’s hull drags the water with it and this effect increases with distance to such an effect that water at the stern has a forward velocity. This phenomenon is called wake and it affects the inflow of water into the propeller.This paper discusses some arrangements to reduce these losses and improve the propulsion efficiency. Some of such devices are Mewis Duct, WED, Grim Vane Wheel, Pod Propulsion and Contrarotating Propellers. The above methods, through an improvement of efficiency lead to a lesser fuel consuming and a “greener” shipping world.

INTRODUCTION

When it comes to improving the fuel efficiency of a moving vessel, there are numerous areas where this can be done. The phenomenon of wake is primarily responsible for the losses in propeller action. This paper explores the phenomenon of wake, the factors affecting it, and why it leads to a reduction in efficiency. Moving further the descriptions of a few proven and potential devices that can increase the propulsion efficiency are also presented. Since efficiency is directly affecting the fuel consumption of the ship, the fitting of these devices can lead to major savings worldwide.

A ship moving in the water due to the action of the propeller is moving because the rotational energy given to the propeller is converted to thrust, thus giving the ship a translatory motion. Now, this conversion is not completely efficient, or simply the propulsive efficiency is not 100% and the reasons are many, the wake being the main cause. When the ship is moving, the friction on the hull creates a so-called boundary layer of water around it, wherein the velocity of the water on the surface of the hull is equal to that of the ship, but reduces with its distance from the surface of the hull,until zero velocity is reached at a finite distance.

The thickness of the friction belt too defines the movement of water around the hull. The friction belt is thickest at the aft end of the hull and this is nearly proportional to the length of the ship.

In addition to this the wake due to the interaction between hull and the propeller largely contribute to inefficient conversion of the rotation of the propeller to thrust. This phenomenon is explored to some extent in this paper.

Some methods and ways of recovering these losses are also discussed in the subsequent sections.

PROPELLER HULL INTERACTION

The propeller behind the hull behaves in a way different from how it would in open water. This is because of the interaction between the hull and the propeller.As the ship moves in the water it creates disturbances in the flow and these disturbances in turn affect the propeller in a negative manner referred to as wake. Wake is just not one effect; it’s a set of certain cause and effects of the hull on the propeller and vice a versa.

→ Wake due to slow down of water near the propeller

The ship is an obstruction to the usual flow of water past it, so the area available for flow of water reduces as the ship occupies it. Now, as we know, the less the area available for flow the more is the velocity, so the particles tend to accelerate as they move past the parallel middle body(maximum area occupied) but as they reach the stern, the area available for flow increases owing to the geometry of the ship and the velocity of the particles decreases. This leads to fairly sharp changes in the direction of flow, or a greater turbulence, making it difficult for the propeller to function efficiently and a incomplete conversion of rotational energy to thrust.

→Wake due to the boundary layer

As mentioned earlier, the ship drags along with it some water in its vicinity because of the viscous drag and this water moving along with the ship constitutes the boundary layer. According to the results from experiments the thickness of the boundary layer increases towards the aft. This implies that the water flowing into the propeller does so at generally reduced velocity, which is not equal at all places and this leads to a loss of thrust.

→Wake due to the effect of orbital velocity

The forward part of the ship experiences a positive pressure as it pushes the water out of the way. The ship is moving and so is this pressure point because of which waves are generated. Similarly at the aft of the hull, a lower pressure area is created and again waves are generated. The particles within a have an orbital motion about a horizontal axis parallel to the crests and troughs. Wave crests have a forward motion and wave troughs have an aft motion , depending upon the nature of waves near the propeller blades this orbital motion may add to or subtract from the flow velocity approaching the propeller.

→Wake due to the effect of propeller on the hull

The propeller is designed and constructed in a way so that it behaves as a screw when it turns through the water. Ideally it should move by one pitch in one revolution but it does not , that is because the water isn't stationary neither is it solid ,leading to a loss of thrust. The other effect is that the water behind the hull is drawn aft by the propeller

Hence , there is a suction created ahead of the propeller because of its rotation and thus resulting into a region of low pressure.

The forward of the ship is subjected to highest pressure, now because of the rotation of the propeller the aft is subjected to a lower pressure, the pressure difference increases , since the pressure forward is more there is an additional opposition. Further the water drawn aft by the propeller increases the speed at which the water flows past the hull, resulting in further increase in drag.

Over the years, a number of ingenious devices have been invented whose purpose is to modify the wake in such a manner as to improve the propulsive efficiency. Some of the more important ones are described hereafter.

MEWIS DUCT

One of the most effective methods of reducing fuel consumption in an existing ship is the installation of a Mewis Duct , which was invented fairly recently.

Construction:

It consists of a fixed duct of a diameter rather less than the propeller diameter installed ahead of the propeller , with the axis of the duct well above the axis of the propeller shaft. The duct cross section appears to be usually an aerofoil. Additionally the duct houses an integrated asymmetric fin arrangement. The fins may or may not have an aerofoil section. The duct is made smaller compared to the propeller and is installed above the propeller centre line so as to guide the turbulent water flow into its upper half in a comparatively smooth way. As we know that region about the propeller centerline is responsible for the generation of maximum amount of thrust because that is the region of highest wake. The duct tends to accelerate concentrate and channelize the flow in one direction in order to increase the total thrust produced , by reducing the variation in water velocities approaching the propeller. Also the aerofoil like cross section of the duct leads to generation of thrust.

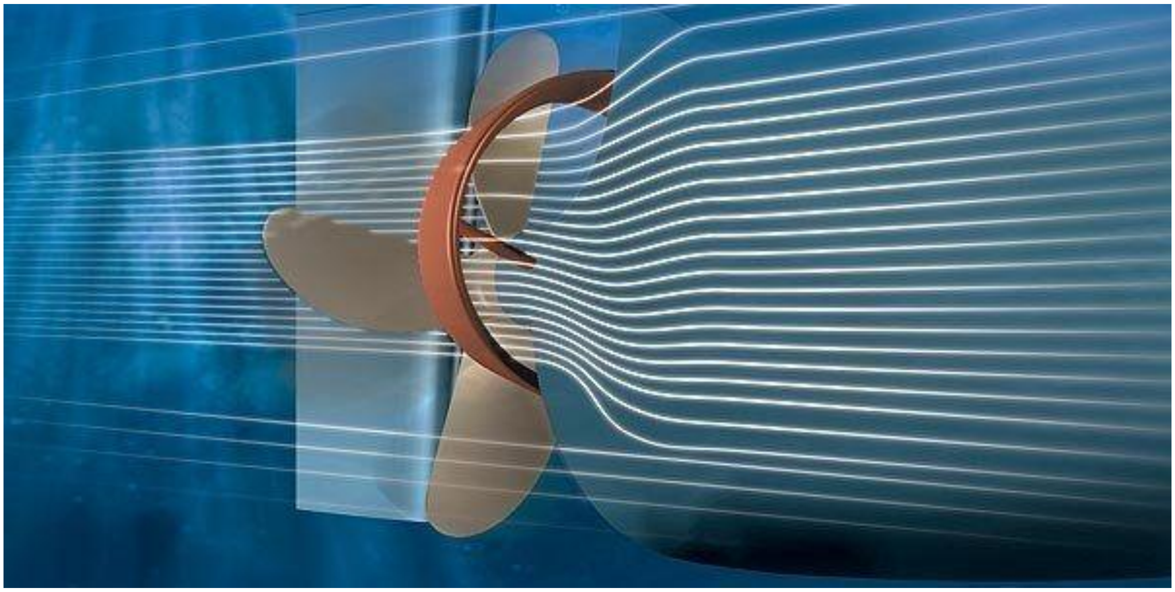
In addition to this, the fin system installed plays a very crucial role. It guides the water into the propeller and contributes to reduction of rotational losses by giving a pre-rotation to the water in the opposite direction imparted by the propeller. That may be achieved by having the fins angles in a particular fashion, which are established by testing.

Some results and conclusions are as follows.

−Power reductions of up to 8%, on average.

− A reduction of propeller induced pressure pulse and tip cavitation, which leads to less vibration in the aft ship

− The propeller rotation in heavy seas is more stable with the Mewis Duct installed.



WAKE EQUALISING DUCT

Construction:

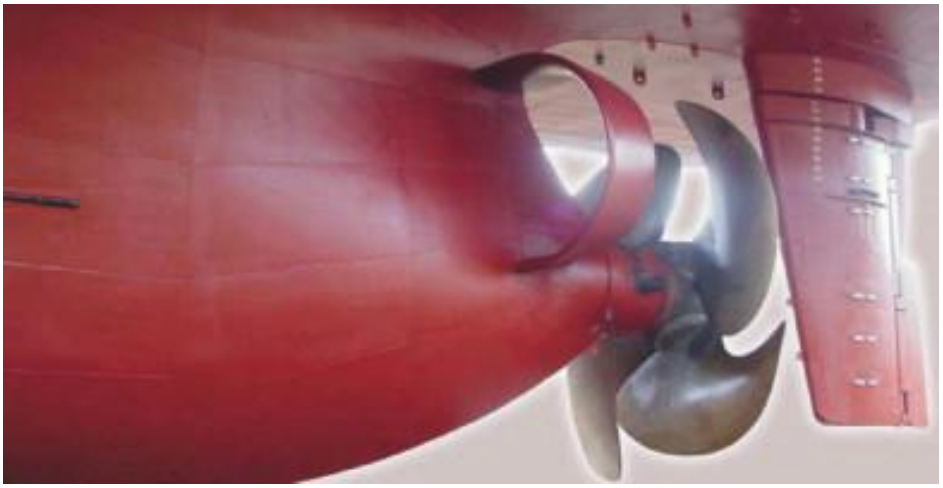
It consists of two aerofoil sectioned half ring ducts connected to the hull in front of the propeller, more specifically ahead and above the axis of the propeller. Some factors affecting the performance of the WED are:

1) Its longitudinal position with respect to the propeller
2) The inner diameter of the duct
3) The section shape,
4) Also, since the duct is constructed in two halves, the length of each half.
5) Angle of duct axis to the propeller axis

The intake velocity of water into the propeller is highly varying in direction and magnitude, especially in the region above the propeller. The WED reduces the loss by having a comparatively uniform wake field above the CL of the propellers that is the region subject to the most non-uniform and indefinite wake. The WED tries to combat slowdown of water ahead of propeller by having a converging duct, that is the velocity of water increases.

The sudden slowdown of water at the aft end of the hull leads to flow separation and to counteract this WED directs the flow towards the hull and separation is delayed, leading to a lesser drag.

The fact that this region above the centerline is subject to highest wake.



Some of the observed effects of the Wake Equalizing Duct are:

- Reduction of vibration levels due to a more even loading at the propeller tips.
- Reduced danger of cavitation erosion due to improved inflow into the propeller.
-Improved course stability and rudder action.
- Drag compensation. The W.E.D. develops thrust larger than its own drag.

CONTRAROTATING PROPELLERS

The contra rotating propeller too is another energy saving device whereby two propellers mounted on concentric shafts rotate in opposite direction so as to recover the rotational losses.

Construction:

Two propellers are mounted on concentric shafts so that they rotate in opposite direction. The prime mover is the same for both the fore and the rear propeller , with a gear box to reverse the direction of the drive for the rear one. To reduce shaft vibrations the number of blades of both the propellers is different so that not all blades pass each other simultaneously. Also the diameter of the fore propeller is slightly larger than the rear, to account for the contraction of the wake and to avoid the rear propeller to hit the tip vortex of the front propeller.

Working:

The propeller rotates the water along with it which is actually not desirable. If the water moves along with the propeller the thrust will be lost as some energy is given to the water. To recover these rotational losses contra rotating propellers were designed.

The water around the fore propeller gives a swirling motion , this leads to a loss of thrust, and the aft propeller since it rotates in the opposite direction tends to cancel the rotation of water around the propeller and thus minimizes these losses to a great extent

Advantages:

In single propellers of controllable pitch type , the increase in pitch of the propeller leads to an increase in rotational losses, but in this case the rotational losses are anyways recovered by the other propeller. The reduction in propeller diameter as compared to a single propeller reduces frictional losses too. Eventually, the propeller efficiency is usually increased.

Disadvantages:

The mechanical installation of coaxial contra-rotating shafts is complicated, expensive and requires more maintenance. This involves gearing to split the power between the shafts and give opposite rotation. Further complication is caused by the need for bearings and stern seals in between the two shafts, so as to support the inner shaft and prevent water entering the space in between.

GRIM VANE WHEEL

The vane wheel is a second propeller downstream of the main propeller, which runs freely without torque on the shaft.

Construction:

A vane wheel is composed of a set of equally-spaced narrow blades mounted on a hub which freely rotate around the propeller shaft which is extended abaft the propeller.

Working:

A vane wheel basically increases the propeller diameter. Since the vane wheel reduces the axial and tangential velocity in the wake of the main propeller, the optimum pitch of the propeller may be increased and rate decreased, similar to a contra-rotating propeller. That increases efficiency. The inner part of the vane wheel, the turbine part, has a pitch such that it is driven, by the wake of the main propeller. The outer part of the blades of the vane wheel, the propeller part, has a different pitch, which causes it to generate thrust. Vane wheels are subjected to strong fluctuations in loading. Problems with the strength of the blades have been encountered frequently and this has led to its limited application.

Advantages:

- -Substantial recovery of rotational energy
- -Greater possible jet cross-section of vane wheel, since the low rpm rate and large number of blades enable smaller vertical clearances to be accepted.
- -Less resistance from rudder behind the vane wheel. This is reflected in the relative rotative efficiency.
- -Better stopping ability
- -Reduces cavitation.

POD PROPULSION

Pod propulsion is one of the widely used energy saving methods of propulsion employed on ships replacing the traditional propellers.

Construction:

A pod is an assembly of all those devices which transfer the torque to the propeller mounted on it, could be one or two at either end, rotating in opposite directions. These propellers are rotated by a motor that is placed inside the pod. The motor is not always but most of the times driven by a diesel generator installed inside the ship and the power produced is transmitted to the motor in the pod using cables. Alternative design is to have the main engine just above the pod and drive being transmitted using a bewel gear arrangement. This construction is known as an azimuthing thruster. Both the above mentioned propulsion devices are free to revolve 360^0 about a pivot point which now eliminates the need of a separate rudder.

Working:

Pods are installed below the stern of the ship. The cable arrangement that transmits the power is covered inside a pod. The motor may have two parts rotating in opposite directions thus we may have two contrarotating propellers thus recovering rotational losses. Podded propellers have an improved inflow velocity field since they do not have shafting and A bracket system ahead of them to cause a disturbance to the inflow. So the wake field is improved. Additionally, the pods can be placed wherever most feasible and efficient because there is no restriction imposed by the location of engine and shafting .This system posses a very exclusive maneuverability advantage awing to the flexibility of the pod angle.

Advantages:

1) Pods are dual purpose i.e. steering and propulsion both

2) The cargo carrying capacity can be increased.
3) No restriction on the location of the prime mover, usually a diesel engine.
4) Flexibility of having the propeller wherever desired taking into consideration wake field etc.

Disadvantages:

1)The pods are subject to a high fluctuating set of forces below the stern.

2) The cabling and the wiring driving the motor may fail and repairing may be difficult.

3). The motor must have a very strict ingress protection , the gland packing etc should provide a perfect sealing to ensure longer and efficient operation of the motor.

CONCLUSION

We have thus discussed the performance including the advantages and the disadvantages of various propulsion improvement devices. The fitting of these devices does not require considerable structural changes but it depends on economic capability of different ship-owners and to what extent they can make it profitable for themselves. The fitting of the above .mentioned devices does not improve the efficiency drastically. But consider a ship using 500 tonnes of oil per day, a mere minimum saving of 1% amounts to 5 tonnes per day. When this is summed up over a year of service it leads to saving of about 1800 tonnes. And when adopted on multitude of ships it results in lesser fuel being burnt every year.

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