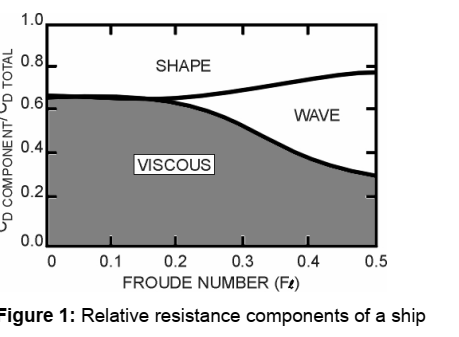
An investigation of air lubrication effect on ship resistance

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*ABSTRACT* **-** At low Froude numbers the study of ship resistance shows that the most important component of resistance for low and medium speed displacement ships is the frictional one. By reducing the frictional resistance (i.e.) by form optimization, air lubrication, air cavity etc. total resistance and fuel costs can be decreased. Now for existing ships, reduction of ship resistance by form optimization is difficult and not cost effective, but the application of air lubrication can be adapted to all ships easily. In this study, the air lubrication method is presented and the effect of air lubrication on resistance of vessels is studied. The analysis is performed by a commercial CFD code solving Navier-Stokes equations. For the air lubricated case, the coefficient of frictional resistance is calculated and the result from the current case is compared with those of ITTC’57 and the case without air lubrication.

For reduced fuel consumption and for low CO2 emissions on ships it is desired to reduce the ship drag. The drag force is divided into the form drag and the frictional drag. There are many possibilities to reduce the form drag by means of form optimization procedures. A reduction in the frictional drag depends on the wetted surface area of a ship and the fluid flow around it. Since it is difficult to change the wetted surface area, an application to vary the viscosity or the boundary layer around the ship has to be made. Recently, studies about air lubrication methods are carried out for reducing the drag forces on ships.

Injection of air into the turbulent boundary layer (between the stationary and moving water) can reduce the frictional resistance of the hull. A hull air lubrication system is a technique to reduce the frictional resistance between the ship’s hull and the water using a sheet of air or air bubbles. Reducing a ship’s resistances causes the need for the required driveline power to be decreased. This reduction on the power cuts down on the **fuel consumption** of the ship and therefore also decreases the **operational costs** of the vessel. In ideal situations, an air injection system can achieve up to 15% in the reduction of CO2 emissions together with significant fuel savings. This is not only a environmental step but also a cost effective side. It is a win-win situation for both the shipping industry and mother earth. A hull air lubrication system would reduce the emissions of Particulate Matter (PM), nitrogen oxides (NOX), sulphur oxides (SOX) and carbon dioxide (CO2).

. The amount of air generated by compressors, the ship’s geometry and the pressure needed are important factors that play a role on the cost of the hull air lubrication system. Ships with *flat bottoms have an advantage over V-shaped bottoms since the air on a V-shaped bottom will flow away much more easily than a flat bottom*. For a V-shaped bottom ship, it would require more air necessary to have the same effect as the flat bottom, increasing the demand for power. With higher draughts, higher pressure created by the compressor is necessary and therefore requiring more power of the air injection system. To make an air injection system profitable, it is to be considered that the power of the air injection system to be lower the savings in driveline power.

Projects such as Project Energy-saving air-Lubricated Ships (PELS) and the project Sustainable Methods for Optimal design and Operation of ships with air lubricated Hulls (SMOOTH) have researched the effects of air lubrication. Project PELS researched air lubrication on a model scale and achieved a 3-10% net effective power reduction in calm waters. Project SMOOTH targeted a 15% reduction of the consumed energy by drag reduction by means of air lubrication techniques.

There are three general approaches in this area:

• Injection of air bubbles (micro-bubbles) along the hull

• Air films under the hull

• Air cavities in the bottom of the hull

The **micro-bubble** method gives the possibility to reduce the friction without the need of a change in the present hull form of a ship. The application of the micro-bubble method reduces the surface friction by a variation of the viscosity of the fluid around the ship and makes a modification in the ship structure.

The **air layer** concept is a combination of air bubbles and air cavity concept. This forms a layer of air like a film reducing all frictional and viscous pressure related resistances that can affect the ship in calm water. The cons of this method arise when turbulences arise in the sailing of the ship. Like any other fluid air interface, the air seeks to escape the containment in the underside of the ship it is restricted to the basic idea of reducing the wetted surface are is lost if the wetted surface itself is constantly lost.

A distinct advantage in the **Air Cavity Ships (ACS)** is that the air can escape from the cavity only in case of extreme pitching and rolling. This is the best suitable for inland ships where emission control regulations are expected to be imposed in the near future. Another advantage is that the air cavities can also act as efficient stopping mechanisms by releasing the air in the cavities. The disadvantage in this system is that it requires extensive hull modification. This can be effectively implemented in twin hull ships.

The downside of all three techniques is that it is surprisingly easy to increase, rather than to decrease, the resistance and that many aspects of the behaviour of air in water are poorly understood. For example, the full-scale demonstrator vessel Seiun Maru showed a 2% decrease at only a limited speed range with an increase in required power over most over its speed range, notwithstanding huge resistance decreases tested at model scale.

The three approaches are the subject of two of MARIN’s research projects, PELS (Project Energy-saving air-Lubricated Ships) and SMOOTH (Sustainable Methods for Optimal design and Operation of ships with air lubricated Hulls). PELS is a Dutch research consortium and SMOOTH is an EU-funded consortium both consisting of ship owners, ship yards, paint manufacturers, model basins, and universities. The main goal is not only to perform model experiments, but also to demonstrate the effect on full-scale ships. Simultaneously, MARIN is a partner in a PhD research project focusing on understanding the fundamental mechanisms of air lubrication together with the Laboratory of Hydro and Aerodynamics at the University of Delft and the Physics of Fluids department at the University of Twente.

Drag reduction by air lubrication is a very active and actual research topic. It doesn’t apply as promisingly to sailing yachts and pleasure speed crafts the consideration of water repelling paints and bubble injection of a ship is a promising application. For larger ships unknowns remain on both ends of the scale ladder ranging from uncertainties in bubble boundary layer interaction to high Reynolds number.