

## **Hull and propeller development**

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### **Abstract:**

The reduction of resistance and the increase of propulsive efficiency are the major drivers for ship designer both for economic reasons and increasingly for reducing the ship's environmental footprint. Ship hull optimization has been utilized commonly to reduce the frictional resistance component of the ship. Reducing the frictional resistance by air injection below the ship in combination with special coatings is an active area of research. Air lubrication can be utilized by utilization of techniques such as air-cavity, microbubbles, and air film formation. Propeller is one of the key parameter for saving the ship energy loss. Propeller energy recovery devices to recover some of the rotational losses are co-axial contra rotating propeller, ducted propeller, integral propeller and rudder unit. This paper reviews about the hull modification and propeller development in the improvement of ship's energy utilization.

**Keywords:** frictional resistance, air lubrication, propeller energy recovery device.

### **Introduction:**

A ship is the most energy saving transporter among others. The steep rise in prices of raw materials such as crude oil is predicted to continue for the foreseeable future, in conjunction with the economic growth of developing countries. In the situation surrounding the marine transportation business, expectations for the development of energy-saving technologies for shipping are high, with the international need to address shipping costs and environmental issues such as CO<sub>2</sub> emissions. The air lubrication method is a technology to reduce skin friction resistance working on a hull by sending air to the bottom of the hull to create a layer of air bubbles between the hull and sea water. Three distinct approaches are identified: the injection of bubbles, air films, and air cavity ships. These three approaches are very useful in reducing the frictional resistance in hull. Since the proportion of skin friction resistance to total resistance is high, especially on large low-speed blunt ships, the air lubrication method has been focused on for quite some time as an effective measure to reduce skin friction resistance.

### **Air bubble lubrication:**

#### **Microbubbles using Hydrofoil air pump:**

A research area for drag reduction of ship with microbubbles has been active in recent years because of the energy saving potential and of the environmental safety for the marine pollution. The injection of air microbubbles into a turbulent boundary layer over the ship hull modifies the boundary layer and reduces its skin friction. Although recent applications of drag reduction technology with microbubbles to the ship reduce about 10-15% of the energy regarding the skin friction in the turbulent boundary layer, the energy necessary for the injection of air bubbles by using conventional bubble generators, which is about 5-10%, is generally ignored.

So a power-saving device which reduces the energy for the bubble injection has been produced. The new facility called WAIP (Winged Air Induction Pipe) which has an angled hydrofoil with an air introducer.

This device utilizes a low-pressure region produced above the hydrofoil as the ship moves forward, which drives the atmospheric air into the deep water.

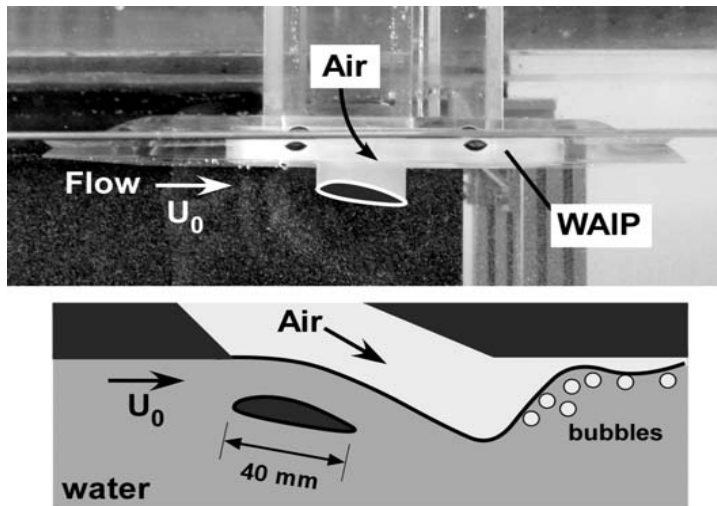


Fig: Side view of WAIP

WAIP (Winged Air Induction Pipe) technology:

WAIP technology is proven to be highly effective in reducing the frictional resistance caused by ship's propulsion. It was conceived for the purpose of lessening the amount of energy required for generating micro air-bubbles and also to reduce the size of generated micro-bubbles resulting in reduced buoyancy of the bubble. It turned out that the size of the ultra fine micro-bubbles generated by WAIP was in the vicinity of 10 microns which was 1/100 of the size of the air-bubbles generated by the conventional air compressor method.

Unlike the bubbles generated by compressed air, the micro air-bubble generated by WAIP tends to stay within the water flow around the hull and effectively covers a large area of the hull surface from bow to stern. Installation of WAIP units on the hull reduces the ship's frictional resistance by around 15 % to 20%, contributing to reduction of main engine power and fuel consumption. Interestingly, the size of microbubbles does not change once ejected into the water.

The WAIP unit is installed on the hull surface and consists of a wing-like blade attached to an air induction pipe connected to the atmospheric air intake. When underway, the vessel's forward movement through the water generates a suction force under the WAIP unit, thus the micro-bubbles are continuously pulled out of the WAIP unit. This air-bubble generating sequence occurs when the ship's draught is below a certain level and is sailing above a certain speed.



Fig: WAIP installation process in dry dock



Fig: Cast iron WAIP fitting

When the air and water boundary is located at the upper part of the air induction pipe, such as when the draught is high and the vessel's speed is below the critical level, the boundary level needs to be pushed down to just above the blade of the WAIP unit to be able to generate the microbubbles. To achieve this, a small-size air compressor will be used to lower the boundary to the level above the wing of the WAIP unit. This application of WAIP assisted by compressor is called WAIP air compressor and will enable any ship, whatever its draught or speed, to benefit from WAIP.

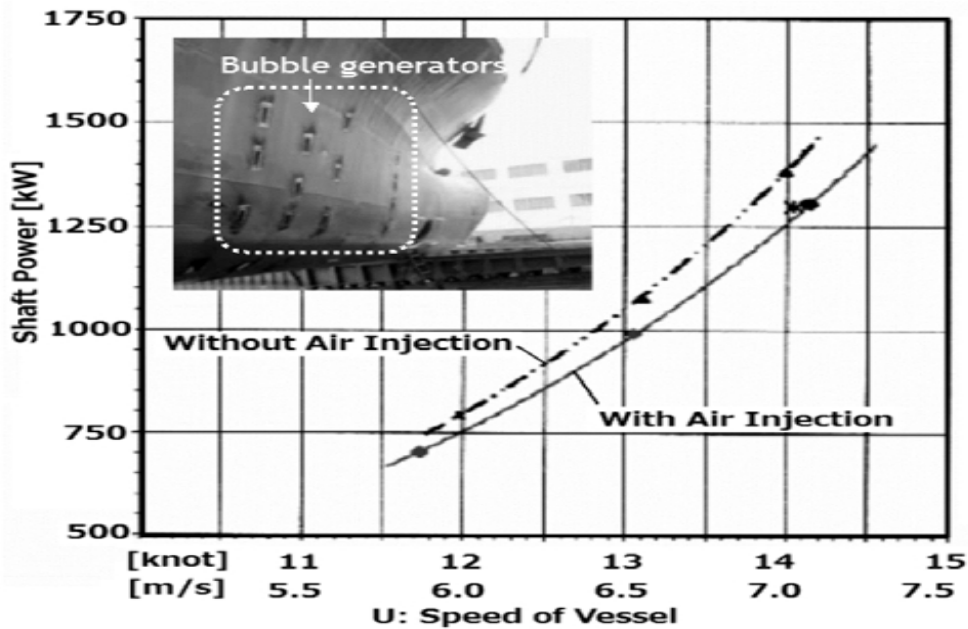


Fig shows Shaft power with and without air injection by WAIP

Air cavity system:

Air cavity system is an air lubrication technology for reducing the frictional resistance of the hull surface.

Figure 1 shows an image of an air lubrication method.



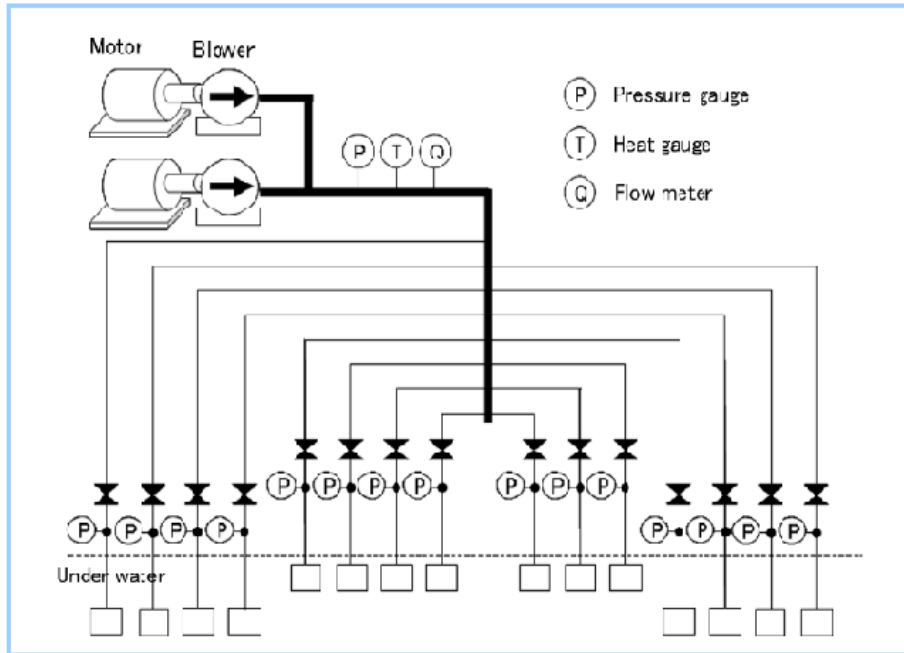
**Figure 1 An image of an air lubrication method**

Air bubbles are discharged from the air blow-off portion mounted on the bottom of the hull and the air bubble flow covers the bottom of the hull.

Air discharged from the air blow-off portion mounted on the bottom of the hull turns into air bubbles because of the tearing-off forces of the surrounding flows and then runs to the direction of the stern with air bubbles covering the bottom of the hull. In approaches toward putting the air lubrication method into practical use, researchers have recently measured total resistance and local skin-friction resistance working on a model hull i.e. a flat plate hull having a total length of fifty meters and have confirmed that these resistances decrease. Among the several actual hull experiments on the air lubrication method that have so far been carried out, the roughly five-percent energy-saving documented by researchers on an actual hull experiment using a cement carrier has attracted interest in the effectiveness of actual hull experiments on an air lubrication method.

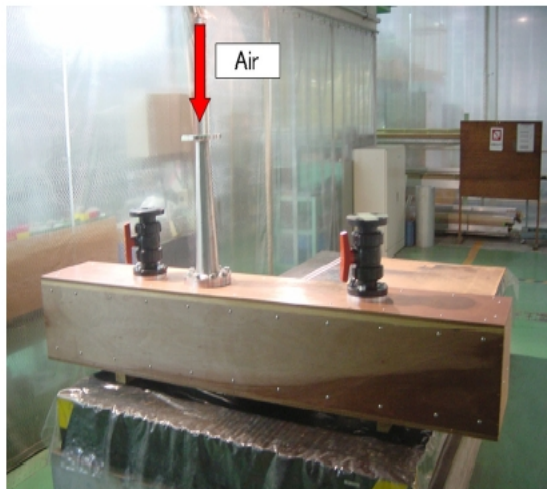
#### **Mock-up model:**

Figure 2 shows the piping diagram. Air discharged from blowers is temporarily stored in a head tank and fifteen air supply branch pipes connected to the head tank are piped to the air supply portion mounted on the bottom of the hull. One air supply branch pipe is connected to one chamber (air chamber). All of the chambers are housed in a recess. In the test, the recess and chambers of the mock-up model were fabricated and the air blow-off conditions were observed. The test was conducted in a sea keeping tank at MHI's Nagasaki Research & Development Center.

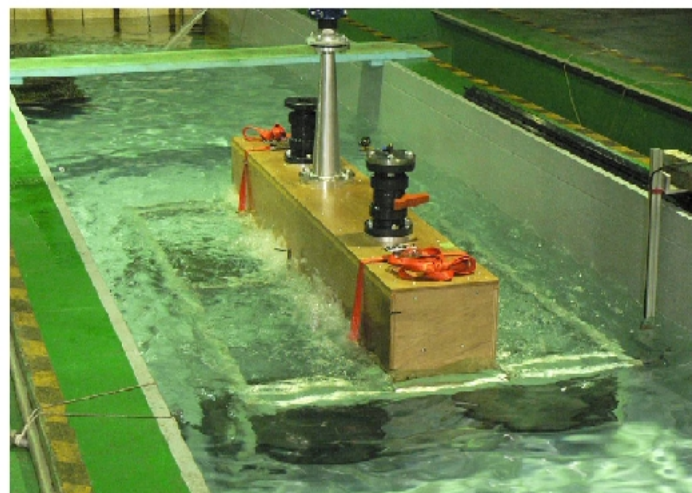


**Fig 2**

Figure 3 shows an overview photograph of the chamber. A communicating pipe connected to the air supply pipe is attached to the top portion of the chamber, where its attached point is offset by 200 mm away from the center of the chamber. On the bottom portion of the chamber are installed sixteen small apertures from which air is blown off.



**Fig 3**



**Fig 4**

**Fig 4: Air blow-off conditions(underwater)**

A picture of the air blow-off conditions, with the chamber placed underwater.

**Air layers:**

The air layer concept can be seen as a combination of micro bubbles technique and air cavity ships. An air stream is injected into the bottom region of a ship and an air film forms. This air layer is subjected to influences as turbulence and the natural instabilities that occur on any fluid-liquid interface. With an air film of half a millimeter thick, a drag reduction of 90% was obtained although no Reynolds effects were taken into account. Researchers carried out experiments with air film lubrication on a flat plate and for model ships, all without a water-repellent coating. They managed to obtain drag reduction, but had difficulties in obtaining a stable air film, especially at higher flow Reynolds numbers. They noted that the air layer can increase the frictional drag when the liquid-gas interface become instable, resulting in breaking up the layer in larger sized bubbles that also may reduce frictional drag.

### **Propeller development:**

#### **Propeller Boss Cap Fins (PBCF):**

Propeller Boss Cap Fins are small fins fitted to a propeller's boss cap and are made of the same material as the Boss Cap. They can be easily installed in the same way as the Boss Cap. The PBCF was developed jointly by Mitsui OSK Lines, West Japan Fluid Engineering Laboratory Co. Ltd. and Mikado Propeller Co.Ltd .They have been fitted on Mitsui OSK Lines vessels. Actual measurements on over 60 ships have shown benefits of 4-5% in fuel saving and an increase in speed of about 2% .The fins are intended to reduce the energy lost into the hub vortex. Without the fins, the flow of water around the propeller generates a hub vortex that wastes almost 10% of the engines energy and thus the fins help to reduce this effect. Other benefits include a reduction in stern vibrations, reduction of propeller noise and acoustic equipment. The latter makes them particularly suitable for oceanic research vessels. The fins can also be installed on Controllable pitch propellers are used on fast ferries and RoRos which benefit from the reduction in fuel consumption and increase in ship's speed. More than 1,500 ships have been fitted with Propeller Boss Cap Fins up to 2008.



#### **Contra Rotating Propeller (CRP):**

This kind of propeller has two coaxial propellers sited one behind the other and rotating in opposite directions. It has the hydrodynamic advantage of recovering part of the slip stream rotational energy which would otherwise be lost to a conventional single screw system which leads to an energy saving about 15% in power. Contra Rotating Propellers are becoming accepted as the propulsion device capable of giving the highest efficiency in several fields of the marine industry and are being fitted in various system configurations to such vessels as Large Container Ships, LNG Carriers, Large RO/Ro Ferries.



fig shows the contrarotating propeller

**Efficiency propeller:**

Optimum performance is achieved if propeller and rudder are integrated called as efficiency rudder. The Efficiency Rudder is in successful operation on many vessels, safely maneuvering the ships with minimum need for fuel at maximum comfort level and improved propulsive performance

The streamlined torpedo in the propeller has the following effects: By reduction of the propeller inflow velocity, especially close to the hub, the propeller can work more efficiently. A more uniform and less contracted slipstream behind the propeller reduces losses in kinetic energy application of the Efficiency Rudder is particularly beneficial with high-powered ships such as Ro-Ro vessels, RoPax ferries, container / multipurpose vessels and ice-classed cargo vessels and tankers.



Fig: Efficiency Rudder layout of twin-screw vessel.

**Contracted and loaded tip propellers:**

The Contracted and Loaded Tip (CLT) propeller is offered by the Spanish designer, SISTEMAR. These propellers are designed with an end plate which reduces the tip vortices, thereby enabling the radial load distribution to be more heavily loaded at the tip than with conventional propellers. In turn, this means that the optimum propeller diameter is smaller, and there is the possibility of reducing cavitations.



SISTEMAR (2005) refers to comparative trials on two sister ships (164,000 dwt bulk carriers) where the ship fitted with the CLT propeller required 12% less power for the same speed.

#### **Conclusion:**

There are many technical levers to save fuel and thus emissions for ships. The best option for improving the power consumption on ships is to evaluate and optimize the design systematically with regards to the underwater and propulsive efficiency in calm water and in a seaway. Various concepts for propeller race energy recovery and hull flow smoothing may give valuable improvement in individual cases but requires systematic evaluation in each case.

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