Highlights.

Stefan Eliasson
President & CEO

"The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking."

This quote is by the Nobel Prize winning physicist Albert Einstein, and has been a great inspiration for generations of scientists and researchers. Although this quote dates back many years, I think it still holds true for how we should turn our thinking and imagination into the driving force for developing the world.

I do not know if Albert Einstein had any specific interest in the maritime world or its research. Since he was born in central Europe, I would guess that he did not have much of an interest in the field. Regardless, his attitude to research has always been the inspiration for our thinking and research at SSPA.

Our ambition with SSPA Highlights is to bring you our latest thinking and research. Even if we have high ambitions, we do not believe that we will change the world in the same way as Albert Einstein did. Nevertheless, we do believe that some of our thoughts and research have the potential to change the world for you in your daily operations.

In one of our articles, about how mariner's health and performance are affected by the circadian rhythm, our research has been inspired by the 2017 Nobel Prize winner in physiology/medicine. In other articles, our research has been inspired by our own experience and thinking. We also describe what form we believe forthcoming research will take, e.g. in hydrodynamics.

We hope that you will be inspired to start thinking about how to change your world when you read this issue of SSPA Highlights. I can assure you that here at SSPA we are more than willing to help you develop that thinking.

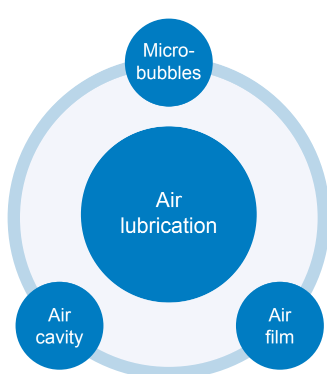
Enjoy your reading!

Hull air lubrication: future and challenges

The goal of reducing fuel consumption, enforced by international regulations and high fuel costs, is motivating ship designers to investigate revolutionary ideas or re-visit old techniques and apply them using new technologies. Hull line optimisation and propulsion system improvements are common practice for achieving this goal, but what if we can eliminate resistance (at least partially) at its source. Air lubrication reduces the drag force on the wetted surfaces of the hull due to the lower viscosity of air compared to water. Powerboats and navy vessels have been using this technique for decades to increase their cruising speed without much consideration to fuel economy. The shipping industry is now recognising the potential of employing this concept for its cargo ships and in the development of the future generation of green vessels. Unfortunately, there is no universal solution since the choice of the method for air lubrication depends on the vessel specification and operating conditions. SSPA has been involved in numerous projects to develop and test different systems of air lubrication for decades. In this article, we discuss some practical aspects of each method.

The resistance forces acting on the ship have two sources; the process of water displacement that results in creation of the wave system and skin friction caused by a moving surface in viscous fluid (water). To minimise the wave-making resistance, the shape of the hull is optimised according to the operational speed and main characteristics of the hull. It is common practice for designers to use computer simulations and model tests for reducing this type of resistance.

To decrease viscous friction, we need to reduce the area of the wetted surface of the hull, but since we cannot change the total displacement of the ship, the alternative is to replace water with air over some sections of the hull. The general term for this approach is "hull air lubrication" and is achieved in two ways; by completely removing water from the hull surface using pressurised air or by injecting bubbles into the water near the hull wall and thus decreasing the viscous friction.



Air lubrication reduces the drag force on the wetted surfaces of the hull due to the lower viscosity of air compared to water.

Air lubrication systems are divided into three categories: air film, microbubbles and air cavity. SSPA has carried out investigations on all these methods by performing tests, simulations and design consultation.

Air film

From an early stage of the air lubrication concept, this method has been the primary choice among designers. In 1882, Gustav de Laval successfully tested the idea of an air cushion, possibly for the first time, by releasing pressurised air through several slots on a boat's hull. Since the purpose of this method is to insert a thin layer of air between the hull surface and the water, a considerable amount of pressurised air is required to maintain the integrity of the air film over a rather limited area of wetted surface.

The air film system is highly effective in reducing viscous drag where the air layer is intact but the efficiency is reduced at higher cruising speeds if the airflow is low. Some hull designs maintain the integrity of the air layer by inserting guides, grooves and compartments to control the airflow. Adding appendages and chambers to the hull would result in higher drag, therefore air chambers are preferable here instead.

Advantages of this method:

- Possibility of retrofitting to existing hulls
- Very efficient in reducing drag
- Minimum effect on manoeuvring

Disadvantages of this method:

- High airflow rate is required to maintain the air layer
- Works best on flat and horizontal sections of hull
- Effective only in short range

Air cavity

If we consider using a confined section to control the air film, the design becomes an air cavity (chamber). Depending on the size of chamber and cruising speed, air cavity systems (ACS) are divided into single wave, multi-wave and multi-chamber designs.

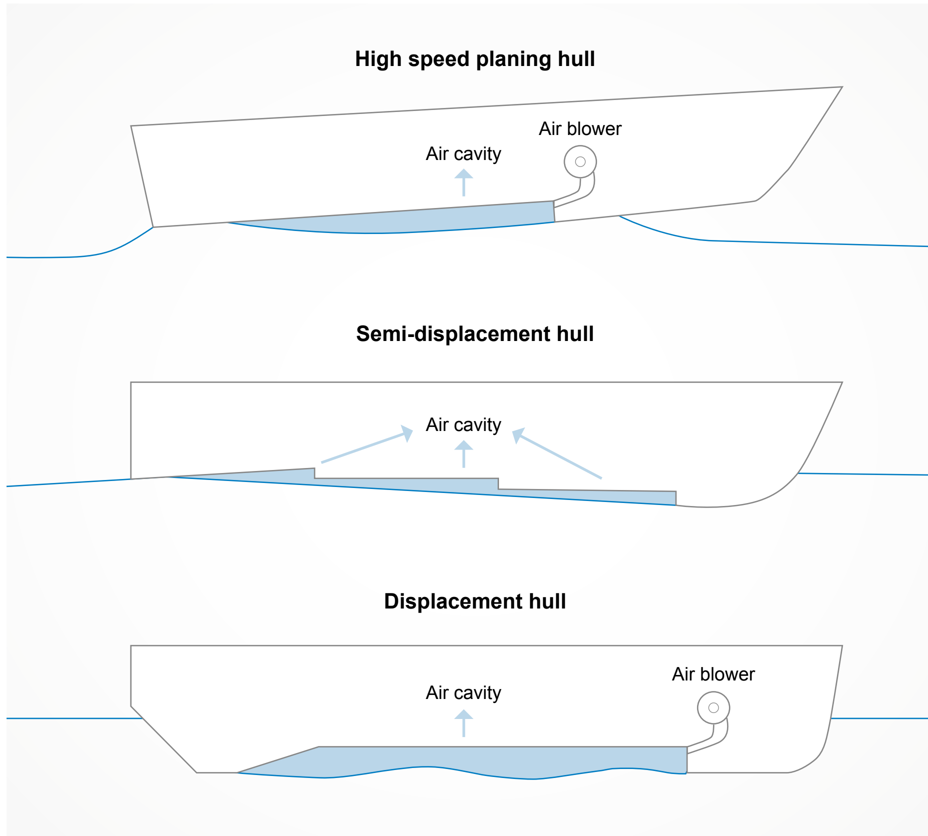
SSPA has been involved in different projects using all three design concepts for the air cavity system. For the single wave system in the EU project, BB GREEN, the air supported vessel (ASV) designed by SES Europe AS achieved up to 40% drag reduction at a speed of 30 knots compared to similar hulls.

A similar concept was used in the EFFISES project (Energy efficient safe innovative fast ships and vessels) in which the air chambers were placed inside the hull bottom of two catamarans, sized 40 m and 125 m.

Maintaining the air inside the chamber is a challenge for long hulls with slower speeds as the free surface inside the chamber can form a wave system with several wavelengths inside the chamber. The wavelength directly correlates to the square of the speed $=2\pi V^2/g$.

SSPA investigated different designs for the project AirMAX (shipowner STENA) to minimise the resistance of the P-MAX tanker model. The extensive study was performed by designing the optimum hull shape to accommodate the largest flat bottom for air chambers as well as the geometry of the chambers.

In displacement hulls with high block coefficients, such as tankers, the flat bottom area is 30–40% of the total wetted surface. Since the friction resistance of a hull is proportional to the wetted surface as $R = C_f \times 1/2\, \rho\, V^2\, S$, using an air cavity has a big impact on drag reduction. On the other hand, because of the deep draft and larger volume of the chambers in a tanker, the cost of pressurised air is higher



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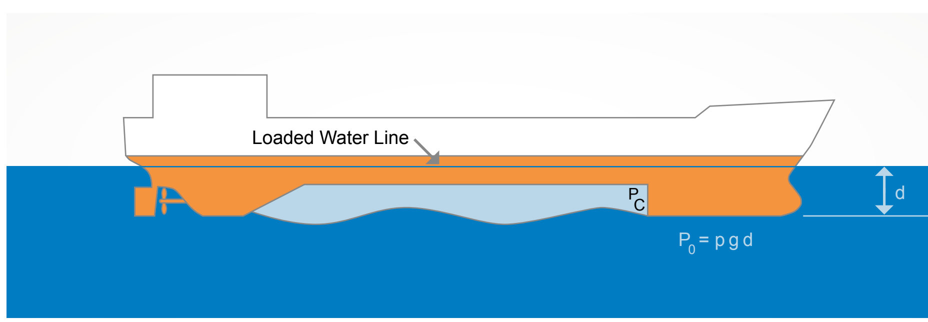
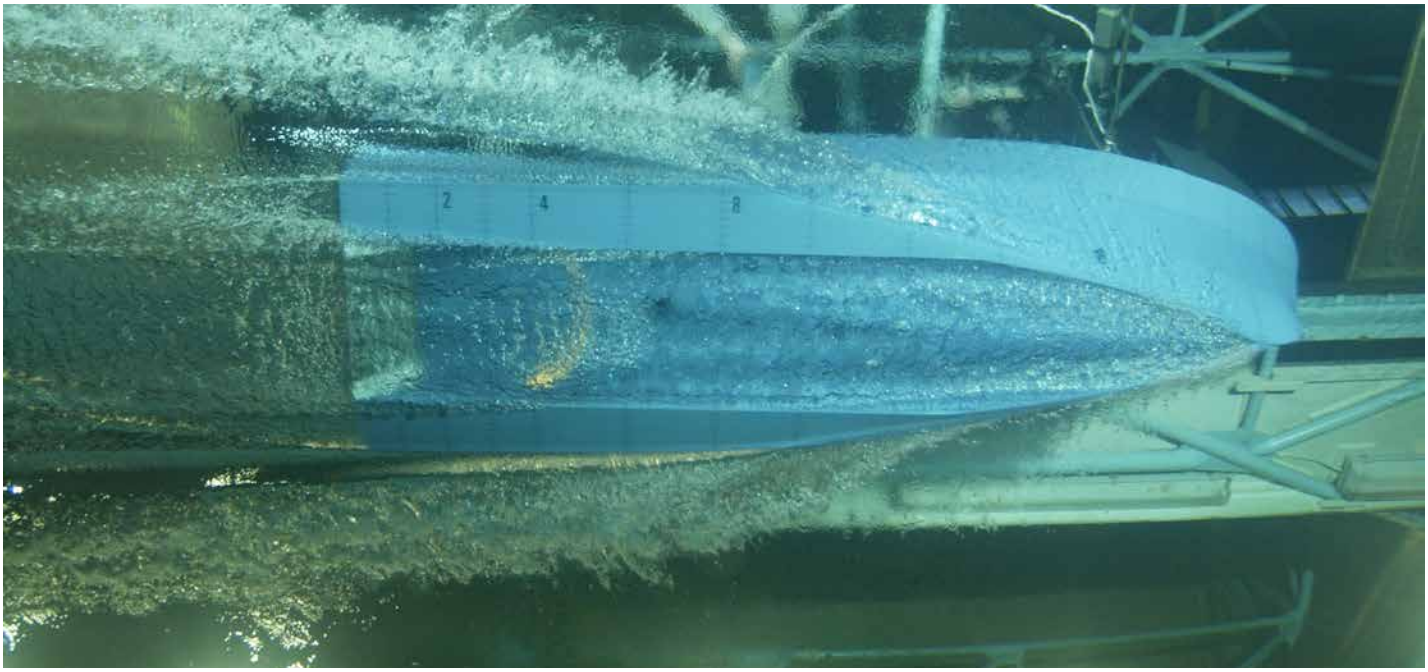


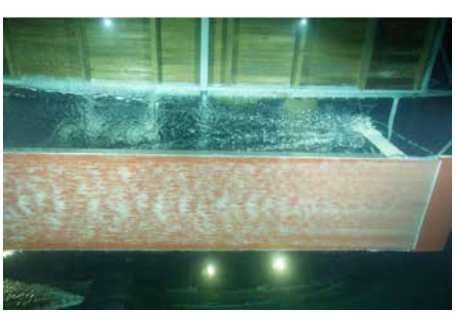
Schematic of a large displacement hull with multi-wave air cavity system.

SSPA investigated different designs for the project P-MAX air to minimise the resistance of the 182 m tanker. Photo: Courtesy of STENA AB. Read more at www.sspa.se



ASV hull designed by Effect Ships International AS (SES Europe AS) and tested in SSPA's facility. Read more about the BB GREEN project at www.bbgreen.info. Photo: Anders Mikaelsson, SSPA.

A major focus was on the re-attachment process at the end of the chamber to prevent extra force acting on the hull.



Through the EU project SMOOTH, SSPA has tested a concept on flat plates and measured the effect of different parameters on minimising the friction. Read more at www.smooth-ships.eu

compared to smaller hulls. Therefore, it is important to maintain the air inside the chamber as much as possible. A major focus here was the re-attachment at the end of the chamber to prevent extra force acting on the hull.

Advantages of this method:
- Lower airflow rate is required to maintain the air inside the cavity in calm water
- No limit in the length of the cavity

Disadvantages of the method:
- No possibility of retrofitting the chambers on existing hulls
- Loses effectiveness in high waves and rough seas

Microbubbles

This method is gaining popularity since it can be used on existing hulls. An example of this system is the Mitsubishi Air Lubrication System (MALS) concept. Small bubbles are injected into the water near the ship's hull through several nozzles, which reduces the resistance. The exact process in which friction decreases in the mixture of air and water is dependent on many factors such as size of the bubbles and where they are injected. However, it is obvious that we need the bubbles to be as close as possible to the solid surface of the hull. The biggest challenge here is to keep the bubbles inside the so-called boundary layer. Through the EU project SMOOTH (Sustainable Methods For Optimal Design And Operation Of Ships With Air-Lubricated Hulls), SSPA has tested this concept on flat plates and measured the effect of different parameters on minimising friction.

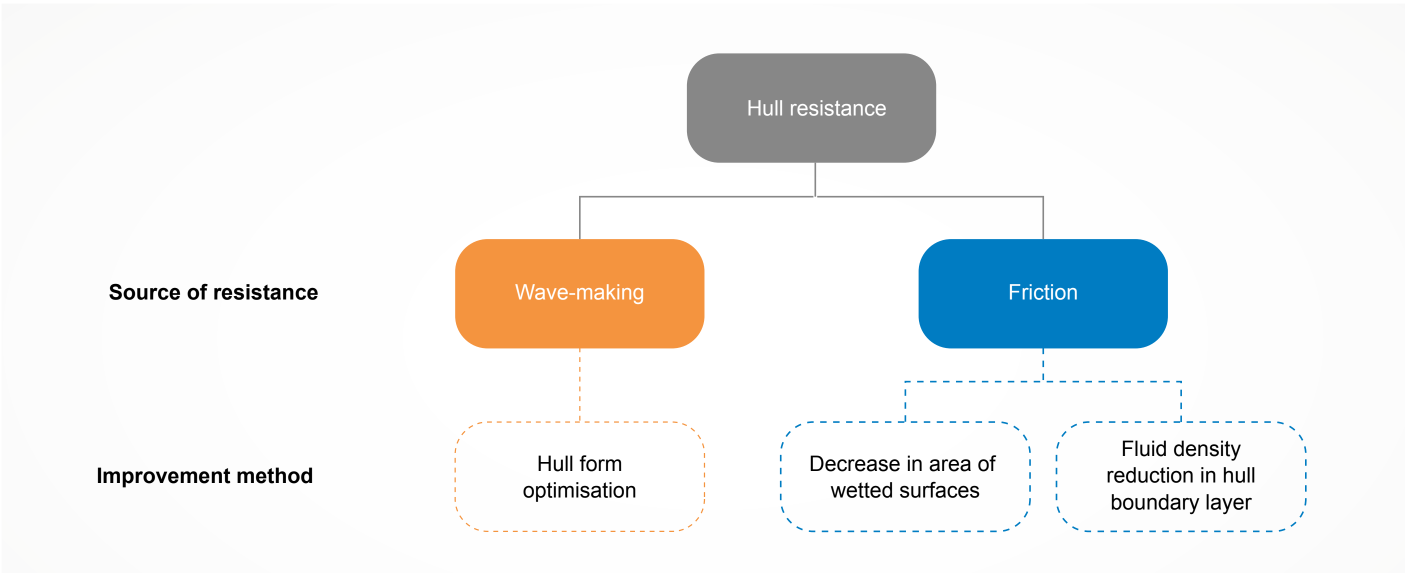
The bubbles that washed away from the area near the hull-wall lose their effect. Therefore, drag reduction only works in a section close to the air outlet. Several air injectors could be placed separately to continuously reduce the drag along the hull wall. The size of the micro-bubbles is also important since big bubbles cannot move inside the boundary layer and the buoyancy force influences their motion.

Advantages of this method:
- Possibility of retrofitting to existing hulls
- Minimum effect on manoeuvring

Disadvantages of this method:
- Effective only in short range
- Bubbles grow and don't stay in boundary layer

Commercially viable and a stepping stone to the zero carbon emission vessel?

Are there enough benefits from hull air lubrication solutions to take them into serious consideration when looking into building new vessels or major conversions? The straight answer is; it depends! For naval vessels and racing power boats the business case is



The goal of reducing fuel consumption, enforced by international regulations and high fuel costs, is motivating ship designers to investigate revolutionary ideas or re-visit old techniques and apply them using new technologies. Hull line optimisation and propulsion system improvements are common practice for achieving this goal, but what if we can eliminate resistance (at least partially) at its source.

There is no universal solution since the choice of the method for air lubrication depends on the vessel specification and operating conditions.

somewhat different. Merchant shipping has to take many aspects into account before introducing new technologies such as hull air-lubrication. The bottom line is safety, the International Maritime Organization (IMO) demands, class rules and national requirements. Air-film and microbubble techniques have been tried and tested onboard existing merchant vessels, both in new vessels and in retrofits. Safety has also been handled. Air cavity systems are still untested for full size merchant cargo vessels.

The business case needs to be investigated for all techniques. Even though the resistance benefits could be of interest, the net energy consumption – saving in main engine power – should be greater than the additional energy consumption from the air lubrication system. At the same time the energy saving needs to give a larger cost saving than the capital and operational costs the air lubrication system is adding to the balance sheet.

Traditionally, ideas like hull air-lubrication evolve with high fuel oil prices. Today the oil price is much lower than some years ago, but other interesting factors to add to the equation are lurking around the corner. CO^2 emission tax! How will it be implemented? The answer will provide a response to what reducing emissions is actually worth.

The other upcoming piece in this puzzle is electrification. How can the use of stored electrical energy change the above calculation? We know that batteries charged with onshore energy only will be a solution for vessels with shorter routes within the foreseeable future. However, what if capacity was sufficient for powering the fans for the air lubrication system? It is all about the business case calculation. Even the smallest gain is positive. Flettner rotors and solar panels are planned on some new vessels as a way to reduce fossil fuel consumption. A combination of increasingly efficient electrical systems and new carbon emission free ways to capture energy at sea might be a step towards making air lubrication systems commercially viable. Then, if the savings in fuel consumptions are invested in more environmentally friendly solutions, like fuels cells, carbon emission free vessels would be the next evolutionary step.

If not mentioned, photos and illustrations by SSPA.

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Magnus graduated with an MSc in Naval Architecture from Chalmers University of Technology in 2004. Prior to joining SSPA, he held various positions within commercial ship design consultancy and shipyard business, with focus on energy efficiency, newbuilding and conversions. Magnus experience spreads over a wide range, from Naval applications, Luxury yachts to Research vessel and Merchant ships like LNGC. Magnus joined SSPA in 2013 as Marketing & Sales Manager, Ship Design. Since 2018 he holds the position as Senior Naval Architect.

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