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Highlights

Susanne Abrahamsson
President

High integrity

SSPA is growing, both in size and in adding new knowledge. Our main focus areas are:

• acting as a bridge between research and implementation in the maritime industry
• optimizing for energy efficiency while keeping environmental, financial, human and technological factors in mind and
• ensuring sustainable development through proper risk management.

Our vision remains unchanged as we strive to be recognised as your most rewarding partner for innovative and sustainable maritime development. To achieve this vision we have four core values that as a company we believe in and live by. One of them is high integrity, which is why our clients can confidently achieve their visions with us.

In this issue of Highlights you will find a selection of articles describing some of our ongoing projects that we can and want to share. Many of the projects that we are involved in cannot and won’t be shared, since we value high integrity and our clients’ and partners’ trust.

The trend of reduced sailing speed, or slow steaming, presents shippers with new, complex challenges. The Slow Steaming Logistics project aims to study how the industry has met and managed these new challenges, in order to create the knowledge base necessary for designing supply chains optimized for slow steaming.

About 90% of all goods travel on the sea for at least a part of their transport chain. The trend of reduced sailing speed, or slow steaming, presents shippers with new, complex challenges. The Slow Steaming Logistics project aims to study how the industry has met and managed these new challenges, in order to create the knowledge base necessary for designing supply chains optimized for slow steaming.

Slow Steaming Logistics
- the shippers’ challenges following slower sailing speeds

About 90% of all goods travel on the sea for at least a part of their transport chain. The trend of reduced sailing speed, or slow steaming, presents shippers with new, complex challenges. The Slow Steaming Logistics project aims to study how the industry has met and managed these new challenges, in order to create the knowledge base necessary for designing supply chains optimized for slow steaming. With the financial support of the Swedish Maritime Administration, the two prominent forwarders, DHL and Schenker, have teamed up with SSPA to address this topical and – for Swedish industry, commerce and the economy – critical issue.

Slow steaming in context

Of all the transport modes, shipping is the only one where the throttle is clearly used a mechanism for capacity control. This, combined with linear deep sea container shipping operators unilaterally optimizing fleet speeds, schedules and routes with regards to profits, have set the stage for slow steaming to regularly reoccur as a phenomenon in times of high bunker prices, low demand, abundant capacity and low freight rates.

The return of slower speeds in 2008/2009, after decades of increasing sailing speeds, was therefore hardly a surprise for anyone in this sector. At the same time, the speed/fuel consumption characteristics of the vessels make a reduction in speed a potent measure for reducing emissions from shipping and greater energy efficiency of the fleet; crucially an important attribute from a societal point of view, which also comes at a negative abatement cost.

The technical and maritime economic aspects of slow steaming are well researched, but the major issue that is historically under-

attended is how reducing speed impacts the customers of the service, i.e., the shippers, and how these effects can be managed effectively.

Welcomed initiative

The idea for the Slow Steaming Logistics project originated at SSPA and together with partners from academia, Chalmers and Gothenburg University, and partners from the industry e.g. DHL freight and Schenker Air and Ocean, the project was formed and received funding from the Swedish Maritime Administration.
After the start of the project, other key industry players from e.g. furniture manufacturing and distribution, steel production, industrial machinery, fashion etc., expressed an interest in allowing researchers from the project team to study their supply chains, how slow steaming has impacted them and how they managed these new circumstances.

The interest shown from the shippers emphasizes the notion that the questions this project seeks to answer are very topical and of critical importance for major players in trade and industry.

The two-year project is planned to be finalised by 2015 and the business partners and associates are eager to get the results as soon as possible.

Expected results

The analysis of the empirical data collected from the companies in the study, is expected to yield an evaluation of how different shippers value the trade-off between lead-time and through-put time on the one hand and reliability and frequency on the other. Additionally, descriptive and explanatory models of how different systems have managed the impact of slow steaming in their supply chains and how this has impacted their supply chain performance, are also being sought.

Finally, a model for designing a new or modifying an existing supply chain that is optimized for marginally longer lead-times and through-put times is to come out of this study. Given these elements, the questions surrouning how shippers can manage the impact of slow steaming effectively enough to cope with slower sailing speeds, without losing competitiveness, would be answered to a satisfactory degree.

Opportunities for expansion

Even though this specific project has not yet reached the finishing line, a number of intriguing opportunities for expansion have already been identified.

Firstly, to expand the scope of the project to include other segments of shipping e.g. short sea shipping or ro-ro operations, are of greater interest especially with regards to sulphur emission regulations starting in 2015.

Secondly, a global consequence analysis of prolonged and widespread application of slow steaming is of interest for both the shipping industry and its customers; in particular, issues regarding capacity requirements for the shipping sector and the design of supply and distribution structures for the shippers.

Finally, concepts and solutions aimed at reducing the impact of slower sailing speeds on the lead-times for door-to-door transportation are where the greatest potential for expansion of this area of inquiry lies.

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Project Management Support to the Midway Alignment of the Bothnian Corridor

The Midway Alignment of the Bothnian Corridor is a vital, year-round maritime transport connection between Sweden and Finland. The project includes a complete transport system for both goods and passengers and was initiated by the city of Umeå in Sweden and the city of Vaasa in Finland. SSPA has been awarded the role of project management, functioning as the main support for the project coordinator, which means supporting and cooperating with running the project during 2014 and 2015. The link connects to three major roads classified by the UNECE as European roads of strategic importance – the E12, the E4 and the E8 – and to the recently built Bothnian Link main railway line. It also supports and complements the Priority Projects and the Core and Comprehensive Network of the European Union. The project is upgrading the transport route to fulfil national and international requirements for an environmentally and economically sustainable transport system with increased multi-modality and higher transport security.

Project objectives

- Improving the environmental and economic performance of port operations and the regional logistics system.
- Increasing market attractiveness.
- Securing long-term operational stability.
- Introducing innovative technologies and solutions, as well as disseminating best practices within the European Union.
- Designing and developing a new ferry for the Kvarken Strait.

SSPA taking a central role

SSPA has been awarded the role as Project Manager for implementing the project. This means that SSPA’s experts will closely follow, monitor and support the implementation of activities and supervise the work with the Project Management team during the first phase, until the end of 2015. Some of the activities that SSPA will be closely involved with are the project analyses, the concept development and the design of the ferry.

Project phases

The project is divided into two separate but linked phases:

**Phase 1 – 2012–2015:** Preparatory activities and feasibility studies, concept development for an improved transport link and land/port infrastructure, design of a new, preferably LNG-driven, eco-friendly ferry with sufficient icebreaking capacity, Budget EUR 20.7 million.

**Phase 2 – 2016-2018:** Construction of the ferry, land-based infrastructure construction including LNG transportation and storage, implementing the logistics system and operations, reporting of results and findings.

The Midway Alignment project is financed by municipal, regional and national financers from Finland and Sweden, private companies and the European Union TEN-T Call funds.

The maritime link Umeå – Vaasa provides an important connection in the EU from west to east. As a spin-off effect, it also facilitates trade with markets such as Norway, the Baltic countries, Eastern Europe and Russia. The strong historical and cultural bonds between the northern regions of Sweden, Norway and Finland go back centuries. The region has shared leadership, trade, communications and culture. Ferry traffic between the countries has existed uninterrupted for more than 50 years. The social exchange across Kvarken is of great importance, as individuals are given the possibility to live, work, study or travel freely across the borders. These parts of Sweden and Finland are areas with high growth rates, hosting several large, international companies. The regions of Umeå and Vaasa are among the most dynamic and rapidly expanding regions in their respective countries.

The proposed action will help to shift traffic from road to sea and rail by interconnecting two national rail networks and by bypassing more than 800 km of the existing road route. This also implies positive effects on service quality and safety. Operators, cargo owners and the general public all stand to gain. The time saved using the ferry instead of the road around the Gulf of Bothnia will increase the efficiency and competitiveness in the transport sector. It will also help to save the environment. Fuel consumption and emissions will be reduced considerably when trucks take the maritime route instead.

The ferry itself can be built for a practically emission-free operation. The goal is to design a modern vessel to meet the needs of both passengers and transport companies. Choosing liquefied natural gas (LNG) as the fuel and constructing the vessel using innovative material and technology means a lighter but
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A stronger vessel, which is less energy-intensive. This vessel will easily meet the IMO’s MARPOL Annex IV requirements on Sulphur Emission Control Areas (SECA) in the Baltic Sea. One of the purposes of the project will be to spread information effectively about technical, operational, safety-related, environmental solutions and financial aspects of implementing the Midway Alignment of the Bothnian Corridor. All things learned will be a valuable common asset for decision-makers in the future.

*Co-financed by the European Union*  
Trans-European Transport Network (TEN-T)

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Close collaboration in hull development of an innovative chemical tanker

Marinform AS introduced the idea of a 25,000 DWT chemical tanker designed for operating at lower design speed, with a lower block coefficient and halved ballast requirement. To convince their customers of the benefit of such a vessel, they needed a partner who could first validate their concept and later optimize the hull design. SSPA was chosen and could provide independent expertise at each step of the hull development: early power estimation, hull form optimization and finally, tank testing.

Design concept
Marinform AS in Norway and StoGda in Poland have developed a new type of 25,000 DWT chemical tanker. Marinform AS, the originator of the design concept, introduced the idea of a hull designed for operating at a lower design speed, with a lower block coefficient and halved ballast requirement. Together with StoGda, lead designer for the construction work, they decided to thoroughly investigate the potential of their concept, first with an early evaluation of the design, then through a complete optimization, with freedom to modify the main dimensions of the hull. The complete operational profile was to be considered during the whole study.

Early evaluation of concept
SSPA, as one of the major players in tank testing over the past 75 years, was first commissioned to provide an independent estimation of the power demand of such a vessel, thus achieving confidence in the project among the different players and financers. This laid the ground for a sensitivity analysis which indicated that despite the promising conclusions of the study, further power saving could be achieved by refining the main dimensions.

Going for major gains through a statistical approach
During this phase of the project, the full operative profile was in focus. Alternative designs were compared using empirical formulae based on statistics from SSPA's large test database. A complete route over the Atlantic
was considered, using realistic weather and loading conditions. The hull presenting the lower fuel consumption over the complete voyage was selected. This method allowed studying, very cost-effectively, a large variation of parameters and propulsion configuration, thus acting at an early stage on the parameters that most influence oil consumption.

**A finer image: Hull form optimization supported by CFD**

To further refine the power predictions while evaluating up to hundreds of hull variants, a hull development based on CFD (Computational Fluid Dynamics) computations using SHIPFLOW® was undertaken. Experience from tank measurements combined with expertise in computational hydrodynamics is the key to a broad approach during the hull optimization process.

**Visualization of the flow predicted by CFD around the aft body of the optimized 25,000 DWT chemical tanker.**

**Validation of the whole study via model testing and final power prediction**

The resulting design was thereafter subjected to thorough model testing at various loading conditions. Model testing is part of an array of tools that are all necessary for understanding the design as a whole, and at the same time it is the foundation on which statistics and CFD can rely to constantly improve their accuracy.

**Achieved reduction of the index, EEDI**

Following the tests, the chemical tanker developed for Marinform AS was evaluated against vessels tested at SSPA. Four models corresponding to vessels ranging from 24,000 DWT to 25,500 DWT were identified in the database as the most suitable for this comparison. The performance of the vessels can be illustrated by their EEDI (Energy Efficiency Design Index) achieved respectively. Data at the required EEDI draught (often scantling) is unfortunately not always available. It was therefore decided to compute all indices at design draught for each of the vessels. It is reasonable to assume that the conclusions taken from this comparison are valid at scantling draught as well.

The figure below shows the relative position of each vessel to the different EEDI reference lines. The achieved index for the hull developed in collaboration with Marinform/StoGda lies in the vicinity of the EEDI value that will come into force in 2020. Of course, this is to be considered with some reservation, as the index is evaluated for design loading conditions, disregarding other systems on board.

However, the trends are very promising, and the study confirmed the positive effect of the optimization on the power demand. This in turn, and together with a design speed lower than average, allowed for a lower installed power on-board, reducing the EEDI index drastically.

**Further gains at Ballast**

The EEDI index does not reflect the full performance of the vessel, as it focuses on a single loading condition and a single speed. Other speeds may of course be of interest and for a tanker, ballast draft should also be considered. The current vessel presents a very light ballast displacement, estimated to be 10% lower than the average in the world fleet. Consequently the hull presents an extremely low wetted surface at this draft. This, together with the very good characteristics already described for design draft, led to a power demand exceeding expectations.

**A high-level partner**

The combination of expertise in various domains of hydrodynamics such as model testing, CFD, and sea-keeping, together with a rich history of model testing and thus a large database of hull forms, make SSPA a unique partner in the hull development process. Customers have already acknowledged this high-level expertise and the project described above illustrates how, through close collaboration, the new challenges of the industry can be met.
SSPA, together with Swedish, Norwegian and Danish partners, is in the process of completing a project called NÖKS (Närsjöfart i Öresund, Kattegatt och Skagerrak – Short Sea Shipping in the Sound, Kattegat and Skagerrak) that is looking at the issue of transferring transportation from land to sea in the region.

What are the reasons behind the aim of moving freight from road and rail to the sea in the region?

The arguments are:

- Greater capacity deficiencies in road-based infrastructure.
- Greater demands for eco-efficient transport.
- Maritime transport can provide a minimum environmental impact.
- Making rail capacity available for passenger traffic.
- Infrastructures at sea and ship capacity are available.
- Low cost of using ship infrastructures
- Possibilities of transporting large volumes at sea.
- Lower costs for goods transport.
- Fewer accidents.
- Less congestion.
- Less need for maintenance of road/rail.

The different transport modes operate in parallel along the coasts in the Skagerrak and Kattegat.

Electrified railways have been set up as a future green freight transport solution but have developed very slowly in Norway. Freight transport by road creates challenges in the most densely populated areas where the road network is not developed to cope with the growing workload. Capacity constraints and the substantial cost of developing additional rail and road capacity are other material reasons that favour a modal shift to seaborne transportation.

Furthermore, even if increased capacity would alleviate issues regarding congestion and the quality of service on road and rail, it does little to address other human health and environmental concerns such as hazardous emissions and emissions of greenhouse gases, noise and vibration pollution in densely populated areas, accidents resulting in serious injuries or death, and so on.

From challenges to solutions

Today, maritime transport has challenges in terms of quality of service e.g. frequency and flexibility compared to other modes of transport. Although the environmental impact per goods unit is very low for shipping, emissions of particulate matter (PM), Sulphur oxides (SO\(_x\)) and nitrogen oxides (NO\(_x\)) are troubling. However, short sea shipping has a large capacity and can handle significant increases in volume.

Additionally, the environmental performance of short sea shipping will be significantly increased following more stringent environmental regulations such as the reduction of maximum allowable sulphur content of the fuel used for shipping in the Sulphur Emission Control Area (SECA) that comes into effect on 1 January 2015 and the introduction of Nitrogen Emission Control Area (NECA) in the 2020s. These regulations, though ostensibly put in place to increase the health and environmental performance of the shipping sector, could potentially lead to the reverse effect. The costs of these improvements are non-negligible and if left unattended in the short term, could potentially result in a “modal backshift”
i.e. reallocation of transported volumes from sea to less environmentally sustainable and more congested land-based modes. This paradox i.e. reducing the health and environmental performance of the transport system by improving the performance of its best performing mode presents significant challenges for achieving the purpose of the NÖKS project.

Project results and contribution
The purpose of the project was to create a platform for collaboration and knowledge transfer between industry, government and academia in the Sound/Kattegat/Skagerrak region. The basis for the work was in several projects carried out by the project partners and other stakeholders in the region.

The project aimed to link all the experiences and take them on in creating holistic, sustainable and efficient transport solutions, environmentally-driven maritime growth and development by taking advantage of the regional differences – specializations – in a maritime company structure/expertise, and research to propose further development.

The project’s overall objective was to shift freight from road to maritime transport. The primary goal was freight transport but combinations with passenger transport are considered as an option. To enable this, there was a need for analysing existing knowledge and develop joint strategies for the three countries, which satisfy the demand patterns and are feasible in long-term applications. The project therefore intended to link organizations between countries to identify and develop the necessary spatial planning, transport and infrastructure. The transport solutions must be economically sustainable and provide reduced environmental impact, including reducing greenhouse gas emissions, as well as being safe and energy-efficient.

During the course of the project freight flows in the region were studied and the relevant technology development and suitable ship types were mapped. The industry requirements for an accelerated modal shift as well as planned, recent and required investments in vessels and infrastructure have been identified primarily through interviews, workshops and previous studies.

Based on the results of this exploratory study, the typical conditions for short sea shipping in the region including barriers and opportunities for increasing the share of maritime transport have been evaluated. An important factor in the development of maritime transport is the regional development of the infrastructure. Furthermore the need for concepts that would enable a small-scale, fine grid distribution along the coastline of the countries in this region has been identified.

Examples of such concepts are the “Godsfergen” concept or push barges. The results of this project, identifying the needs, opportunities and obstacles, will create the basis for future efforts for securing funding to pursue sustainable and profitable solutions for increasing the share of maritime transport in the ÖKS region.

Project Partners
• Vestfold University College - Project Leader (Norway)
• SSPA Sweden AB - Lead Partner (Sweden)
• SMTF, Swedish Maritime Technology Forum (Sweden)
• Innovatum (Sweden)
• EMUC, Maritime Development Center of Europe (Denmark)

Financiers
The European Regional Development Fund
Main drivers for fuel choice

When assessing alternative fuels for shipping, many factors need to be considered, including:

- market factors such as cost and availability
- technical and operational factors including necessary onboard installations, safety, maturity of technology, and availability of equipment
- environmental factors including emissions, fuel production and transport impacts ("well to tank"), and impacts from accidental spills.

New regulations have driven shipowners to find ways of reducing emissions of sulphur and nitrogen oxides. Over the longer term, it is expected that there will also be targets for reduced particulate matter and CO₂. Switching from heavy fuel oil to a cleaner alternative fuel is a good solution from many perspectives.

Why methanol?

One of the objectives of the recently completed EffShip (Efficient Shipping with Low Emissions) project was to identify possible alternatives to existing marine fuels that could result in lower emissions and be implemented within the next five years. It was concluded that methanol is a competitive alternative for meeting emissions guidelines, and based on this the SPIRETH (Alcohol (Spirits) and Ethers as Marine Fuel) project was formed to investigate this alternative more thoroughly. SPIRETH focused on an investigation of technical, operational, safety, and emission factors of methanol-based fuels through on-board demonstration and full scale laboratory testing.

Wide availability and many feedstocks

Methanol, also known as methyl alcohol or wood alcohol, is the simplest alcohol and widely used in the chemical industry. It is also used as an energy source, and this application is growing. The majority of methanol produced today is from natural gas, the same feedstock used for LNG. Although it takes more energy to produce methanol, there are many advantages due to the simplified distribution and use. It is a liquid transported in chemical product tankers at atmospheric temperature and pressure, and stored in tanks similar to those used for gasoline. Thus distribution, handling, and bunkering systems for methanol would be very similar to those used today for traditional marine fuels.

Methanol can be produced from a wide range of feedstocks – any carbon source can be used. Natural gas and coal are the most common, but the most exciting for the future are the renewables. Some examples of renewable

Methanol – an alternative fuel for greener shipping

Methanol is a promising alternative fuel for reducing emissions and improving the environmental performance of shipping. It contains no sulphur and because it is a clean burning alcohol, emissions of NOx and particulate matter from combustion are low. It is widely available and storage and distribution are similar to conventional fuels. Interest in this fuel is growing, and SSPA was co-coordinator of an important pilot project to demonstrate the use of methanol fuel on-board a ship and in adapted marine engines.

The Stena Scanrail with methanol tank installed on the weather deck.
feedstock used in current production are forest biomass, municipal waste, and black liquor from pulp mills. On Iceland, methanol is produced using CO₂ emissions and energy from a geothermal plant, and has been certified as a renewable fuel of non-biological origin. Ships converted to operate on methanol can simply begin blending in renewable methanol in the future to reduce their operational carbon footprint.

Although methanol has many characteristics making it suitable for a marine fuel, prior to the SPIRETH project it had not been tested in marine diesel engines.

**Demonstrating methanol on a ship**

The SPIRETH project objective was to test the fuels methanol and di-methyl ether (DME) in marine engines in a full-scale pilot project. Two project testing and development streams were defined as follows:

- **DME**: An OBATE™ (On Board Alcohol to Ether) process unit for dehydrating methanol to a fuel mix of DME, water, and methanol was designed, installed, and operated on-board the Stena Scanrail, a ro-pax ferry operating between Gothenburg, Sweden, and Frederikshavn, Denmark. An auxiliary engine was modified to run on the OBATE™ fuel mix and installed on board the ship.
- **Methanol**: Conversion of a full-scale marine diesel engine in a laboratory installation to run efficiently on methanol with pilot fuel ignition.

**Methanol shown to be a viable alternative**

SPIRETH has shown that it is feasible to convert ships to operate on methanol and DME-based fuels, and these fuels are viable alternatives to reduce emissions. On-board arrangements for methanol storage, distribution, and handling were designed and installed on the Stena Scanrail. A retrofit solution was developed for conversion of a ship’s main diesel engine to methanol operation, for testing in a laboratory. Low emissions, high efficiency, robust solution and cost-effective conversion were key factors considered when evaluating the different combustion concepts and design solutions. Diesel combustion of methanol with pilot fuel ignition was determined to be the preferred combustion retrofit concept.

The risk and safety analysis in SPIRETH contributed to the development of ship classification society rules for methanol as a ship fuel. The work also contributed to the International Maritime Organization’s draft IGF code (International Code of Safety for Ships using Gases or Other Low-Flashpoint Fuels).

**Future projects and directions**

Interest in methanol as a marine fuel continues to grow. The SPIRETH project has contributed to Stena Rederi’s initiation of a project to convert the Stena Germanica, the world’s third largest ro-pax ferry, to methanol operation. There has been significant international interest in project findings and methanol is now firmly on the list of viable solutions for improving the environmental performance of shipping.
Vulnerability reduction technologies for large maritime composite structures

The use of composite material to reduce the structural weight has earned an increase of importance to the maritime sector. A reduction in weight can lead to several synergy effects such as lower operational costs, improved stability properties and greater cargo capacity. On the other hand, composites are vulnerable to fire. The material is combustible and will lose its load-carrying capacity at the early stage of a fire compared with steel. To cope with this, technical solutions for reducing this vulnerability are imperative. This is one of the objectives in a recent research project, Convince, in which SSPA has been a partner.

The Convince project is a military research project, financed by the European Defence Agency, EDA. It started in 2007 and is still running. The project involves several companies and research institutes from six countries with the aim of finding vulnerability reduction technologies for large maritime composite structures. The participants have done a lot of work and this article does not intend to reflect the whole project, only highlight some of the areas where SSPA was involved.

The participating countries have different focuses. Sweden and Norway are looking at vulnerability reduction technology for a fully composite naval ship, whereas some of the others are focusing on a composite superstructure on a hull made of steel. The general approach is divided into two work packages after the primary and secondary weapon effects: blast and fire. Although this is a military project, several of the outcomes are also valid for non-military applications.

Normally, large naval ships are made of steel. Some of the benefits with steel are the fact that it is not combustible and that it is weldable. The advantage with non-combustible materials when it comes to limiting a fire is obvious and a well-crafted weld between, for example, a bulkhead and a deck, can be as strong as the base material. A fully composite ship must have sufficient overall fire safety, even if the material it’s made from is combustible. To cope with this, an overall risk based assessment must be done to show equivalent safety.

To limit damage longitudinally in a ship in the event of an internal blast, the bulkheads must be strong. Of course the joint between the bulkhead and the deck also needs to resist the forces involved. In a steel ship this joint is simply welded with sufficient strength. In a composite ship however, a traditional composite joint between a bulkhead and a deck is relatively weak and another solution for the joint is needed if the bulkhead is to be blast resistant.

Residual strength after fire
In the case of a fire in a compartment of a composite ship there is a major risk that the bulkhead loses its load-carrying capacity due to the high temperature. Therefore these bulkheads are usually fitted with special reinforcements. The reinforcements have usually been composite beams glued or laminated on to the bulkhead, known as fire-stiffeners. Using these reinforcements the time before collapse is increased. However, in the Convince project some of the bulkheads need to be blast resistant as well. To withstand the load from a blast, the bulkhead is designed to allow very large deformation to carry the blast pressure load as a membrane. It is probably more complicated to design reinforcements that will allow this large deformation and still remain attached to the bulkhead after an internal blast. Therefore another approach to achieve the required fire protection is suggested by SSPA.

Do not look at the damaged bulkhead alone. Develop a global ship FEM model to show what happens with both global and local strength in the case of damage due to a fire in one or more compartments. If necessary, use interior structural members near the damaged bulkhead to prevent the deck collapsing.

Use of internal structure instead of fire-stiffeners.

The suggested approach can be summarized in nine steps:
1. Determine speed requirements after the damage has occurred e.g. five knots in a rough sea.
2. Make a strip-calculation to get the global bending moment and the global shear force for the reduced speed.
3. Determine the deck loads, either actual or from the classification society.
4. Decide the extent of the damage caused by the fire and which bulkheads and decks that don’t carry load anymore.
5. Apply global bending, global shearing and deck loads to the damaged ship model.
6. Evaluate both the global ship strength and behaviour of the decks in adjacent compartments near the damage.
7. If necessary use interior structures e.g. interior bulkheads, or pillars, to allow the deck to still carry its deck load.
8. Extend or move the damage in the ship and repeat pt. 5 to 7 until requirements are met.
9. Let the above analysis serve as input when designing the ship’s general arrangement.
The described method can also be used for other types of damage. It takes time to create a global ship FEM-model and therefore it is wise to use it for other structural members as well, e.g. a box girder.

Box girders

When a ship is operated at sea it is exposed to wave loads. These wave loads create global bending moments in hogging and sagging. The size of these moments depends, among other things, on the sea-state and ship speed. The purpose of the box girder is to maintain enough global hull strength after an internal explosion or similar damage so that the ship can safely return to port in a damaged condition, at a reduced speed. The concept with box girders is not new. Box girders were investigated in a Swedish project in 2004 and have also been studied and implemented on steel ships by other navies.

Usually global bending moments are taken from classification society rules that in some cases are independent of the ship’s speed. Thus it can also be larger than the real global hull moments for the reduced speed. To enable a less conservative design, a prediction of the real moments for the reduced speed has been made based on strip-theory. This method takes speed and motion into account and results in a more realistic input for dimensioning the box girder. In this particular case, the box girder should be designed for five knots in sea state 7, corresponding to the conditions in the North Atlantic.

The result of the strip calculations showed global bending moments which was in the magnitude of half the moments stated by the classification rules. It is therefore well worth implementing the strip-theory to find more realistic dimensions of the box girders and avoid over-dimensioning.

The global bending moment causes alternate tensile and compressive stresses at the deck level where the box girders are placed. In this particular case, it was the buckling behaviour of the box girder when it was exposed to the compressive stress that was the dimensioning factor. Two-compartment damage with a buckling length of 17.6 m was assumed for our reference ship.

**This method on how to design a box girder can be summarized as follows:**

1. Determine the speed requirements after the damage occurs.
2. Do a strip-calculation to find out the global bending moment for the reduced speed.
3. Design your midsection for full speed according to the classification society for an undamaged ship, including a first assumption of the box girder’s dimensions.
4. Decide the extension of the damage in the cross-section/transverse direction of the ship.
5. Calculate the cross section properties for the damaged cross section and use it to determine the longitudinal load impacting the box girder.
6. Define the extension of the damage in the longitudinal direction of the ship. Use this length as the buckling length for the box girder.
7. Check the buckling behaviour of the box girder with the above longitudinal load and buckling length.
8. If necessary go back to step 3 for another iteration using new dimensions for the box girder.

**Note:** Alternatively, if you have a global ship FEM-model, the box girder can be designed using a similar method described above under the heading “Residual strength after fire”.

**Conclusions**

When designing ships in non-conventional material, special focus must be on the added risks. The total risk profile is usually complicated and must be balanced with the ship’s properties (e.g. a lighter ship) and costs. In this article two fairly straightforward methods to cope with residual strength after damage are shown. By combining modern tools such as FEM and Linear strip theory it is possible to suggest technical solutions that are sufficiently safe without being over-dimensioned. The methods can also be applied to a passenger or container ship.

At SSPA we have the knowledge and tools to guide you from risk to blueprint.
How to sail an **Olympic Laser** class dinghy - towing tank tests

The Laser dinghy is a strict one-design Olympic class and very few, if any, alterations are allowed. So what can be done in a towing tank to provide new insights for sailors? There is no meaning in just measuring the resistance since nothing can be done to the hull to minimize it. So what’s left? The way people sail the boat! Where the crew is positioned in different speed ranges and how much to heel the boat in different conditions could be a new contribution, or could confirm the way the best sailors sail the dinghy based on experience. In addition, a small thing like how much drag the self-bailer is generating when open is a typical question asked by keen sailors that we have now verified. Another question is how big an influence does my weight have on the performance?

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**Collaboration with Chalmers**

SSPA has joined a project with Chalmers University of Technology in Gothenburg focusing on sports and technology. Education and research at Chalmers is well known and aims to contribute to a sustainable future for our society. For the past few years, the Area of Advance Materials Science has supported the project. The initiative has generated external funding and been welcomed at Chalmers, among staff, students, the sports movement in Sweden, and large and small companies.

The action of a small group of researchers and students, most working on an interdisciplin ary and voluntary basis beside their normal work, has created a surprising impact. One noticeable thing is in recruiting new students, who have been attracted by the activities in five sports: Swimming, Equestrian, Sailing, Athletics and Floor ball. The exhibitions, informal lectures and presentations that the research group have held have attracted students, who previously would not have considered engineering as an option.

For research, the distance between research projects and ideas can be reduced compared with research projects involving industrial partners. For instance, new materials and usable products can be tested by interested and inquisitive users. The driving force is that individual athletes are eager and willing to test new ideas that promise to provide the slightest advantage.

The sports and technology group has come up with a number of research proposals and applications, ideas for master thesis work, bachelor thesis work, an international summer course for engineers, and developed a new master’s course starting in 2014. Networks with local, national and international players in the sports industry have been created, making the results of the research known to various new sectors.

The main objective for 2014 is creating a Sports technology centre. This includes five professorships and the following areas, of which several are close to SSPA’s competence: sailing dynamics, materials science in sport, measurements and modelling in sport, biomechanics in sport, and mathematics.

The centre will contribute to a more sustainable society through excellence in research, education, outreach and recruitment. The knowledge generated by the centre will improve the performance aspect in sports and to health and wellbeing for the public.

**Tow tank testing**

In the sailing sector, SSPA has carried out tow tank testing on a Laser class dinghy, showing very interesting results about how to sail a dinghy.
A dinghy was provided by one of Sweden’s top sailors. A towing rig was constructed so the hull could be towed without making holes in the boat. The dinghy was towed with a rod connected to a dynamometer close to the mast position about 20 cm above the deck. The actual towing point in this study was not important since we aimed for the actual sailing conditions regardless of how the trim and heel was achieved. In a small boat like this the person sailing it will be able to adjust position by moving forward, aft or sideways to heel or trim the dinghy to the desired condition.

The set up to the carriage allowed the hull to move freely in heave, pitch and roll but was restricted in surge, sway and yaw. Our attempt was to restrict the tests to downwind at a limited number of speeds. If upwind conditions were included in the test matrix, this first attempt would have been too extensive. Parameters such as leeway, load distribution between rudder and centreboard, righting moment etc., would have been included in that case. The rudder and centreboard were also excluded and we left these for two students doing their Masters’ at Chalmers to add afterwards using Computational Fluid Dynamics (CFD).

The weight tests were carried out using an 80 kg manikin as norm. Tests were repeated with ±10 kg. The relative change in resistance is shown in the diagram. The initial results indicate that the weight has the biggest influence in the middle speed range (around 6 knots) but for both higher and lower speeds the influence is less. Would the curves coincide for 13 knots? The next test session in the tow tank might possibly provide an answer.

Tests followed with a variation of trim versus speed. As expected the lowest resistance was found with the most possible forward trim for very low speed. For speeds below 3 knots the sailor should preferably sit forward of the mast. However this is prohibited by class rules (no part of the body in front of the mast). At higher speeds, 4 knots and upwards, the weight should be moved more and more aft as the speed increases. This is nothing new for an experienced sailor, but interesting to validate and obtain data about.

The explanation is that for low speeds, minimizing the wetted surface is the most important factor but for higher speeds, when wave resistance starts to be a dominating factor, long waterline is what gives speed (and lower resistance).

Heel is also an important factor and it was seen at all speeds heel all the way up to where the shear line with the curled deck edge was touching the water was favourable. It should be remembered that this was downwind and no aspects were considered regarding the effectiveness of the sailplan. Again the effect from minimizing the wetted area was the explanation and at heel the long waterline could be kept for all speeds.
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Best sailing condition below 3 knots.

The self-bailer
An attempt to detect the resistance from the self-bailer was carried out at 4, 6 and 8 knots. Even though it was small, the influence was detectable. And how to handle the resulting insight is the secret of the ordering customer, Chalmers University of Technology.

SSPA’s vision is to be recognised as the most rewarding partner for innovative and sustainable maritime development. To always offer the latest knowledge and best practices, about 20 per cent of the company’s resources are engaged in research and development. The Swedish government founded SSPA in 1940 and in 1984 it was established as the limited company SSPA Sweden AB. The company has been owned by the Foundation Chalmers University of Technology since 1994.

SSPA offers a wide range of maritime services, including ship design, energy optimisation, finding the most effective ways to interact with other types of transportation, and conducting maritime infrastructure studies together with safety and environmental risk assessments. Our customers include shipowners, ports, shipyards, manufacturers and maritime authorities worldwide.

Our three focus areas are:
• SSPA acts as a bridge between theory and practice, research and implementation, the present and the future. The foundation is the ability to provide unbiased expertise, advice, and services to our customers and other stakeholders.
• SSPA ensures sustainable development through proper risk management in close cooperation with the customer.
• SSPA has the financial, environmental, human and technological factors in mind for optimal energy efficiency.

Our head office is located in Gothenburg and we have a branch office in Stockholm.