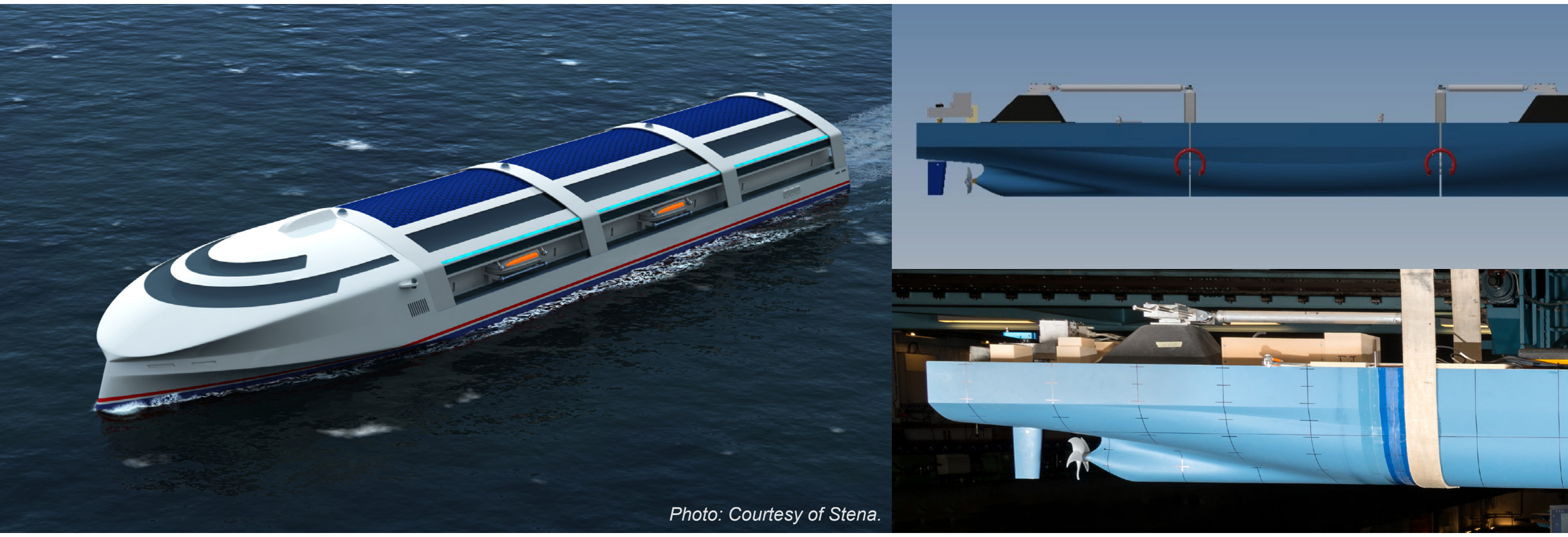


An artist's rendering of the future Stena Elektra together with a rendering of the CAD drawing of the scale model and a picture of the structural dynamic model as-built by SSPA.

Tailored model tests for hull structural dynamics

In the trend towards more efficient transport, energy-efficient operation and reduced environmental impact at sea, ship hulls tend to increase in size (OECD 2015*). With the increase in ship size there is also an increased risk of hull structural resonance being excited by waves and for instance slamming loads, as well as significant hull bending in large and long waves. This also holds for ships that utilise novel hull design principles, such as lightweight designs, novel hull forms, hulls with alternative weight distribution etc. SSPA has developed techniques for analysis of ship hull structural dynamics over several years, i.e. analysis of the structural response due to wind and wave loads. We decided to share this information and join forces with several partners to develop knowledge, and a new research project was formed and led by SSPA. This resulted in an accurate model testing technique, know-how to carry out this kind of model testing and insights into possibilities to develop further important techniques to support this important area of technology.

SSPA's commitment started as internal development with internal funding. In this initial stage, much valuable knowledge and many valuable techniques were developed, while it was also recognised that an effort was needed on a larger scale to drive and support the development of efficient sea transport in terms of energy consumption, economics and alternative propulsion.

Overdimensioned or undersized vessels

Experience from ship operations with large vessels shows that today's regulations, methods and tools are not fully able to take into account the structural characteristics of a number of today's more optimised types of vessels. These vessels differ from previous designs in that structural dynamics account for a large proportion of the total load on the vessel. Structural dynamics is also often identified as the most significant weakness of today's methods, tools and regulations for hull scantling.

This means that an increasing proportion of vessels are not optimally dimensioned for their transport task. Of these, many become overdimensioned and have increased energy consumption and life cycle costs as a result. Others become undersized with insufficient safety margins, which also leads to increased need for maintenance and high costs but has also in some cases resulted in breakdowns even with relatively new vessels. As a result, classification rules based on quasi-static hull loads have been updated in recent years to reduce the risk of accidents.

Vessels optimised for alternative propulsions

In addition to increasing ship size, the demand for hulls suitable for alternative means of propulsion is increasing. To strengthen the development of ships propelled partly or entirely by alternatives such as batteries and wind, it is important to improve tools for structural design to provide possibilities to implement hulls optimised

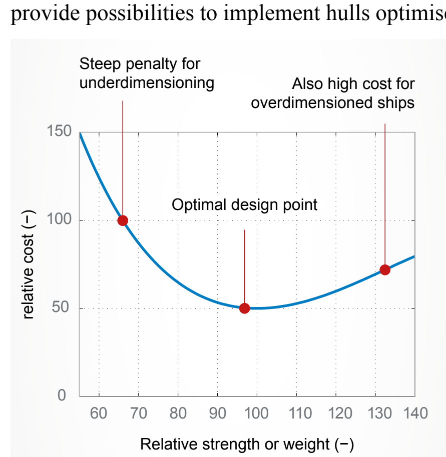
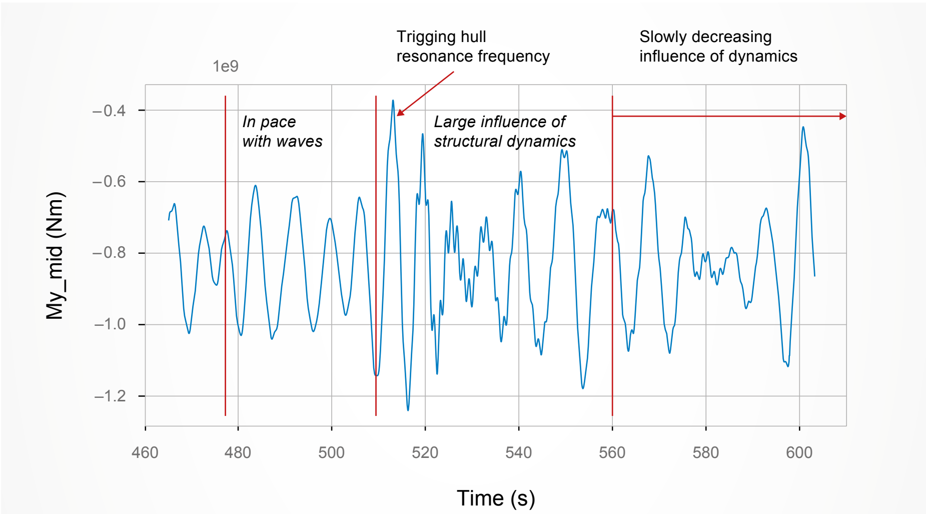


Illustration of influence of optimal hull structural design on costs.

**OECD-Report - Merk, O. (2015) "The impact of Mega-Ships".*



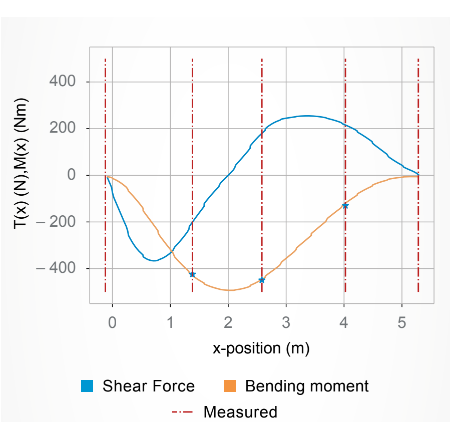
Time history of midship bending moment from a test run with the Stena Elektra model.

by such means of propulsion. For example, a hull that is to host a large and heavy battery pack will need a novel hull and structural design to carry loads from batteries, provide the right stability and right roll periods for good comfort. It also provides the option to distribute weight to cancel out still water bending moments in order to decrease loads and enable a lighter more optimised hull.

Wind-assisted propulsion also offers challenges and possibilities that require improved knowledge on hull scantling and hull structural dynamics.

Collaboration to develop knowledge

Stena has been involved in the development of techniques to evaluate hull structural dynamics in a collaboration between SSPA, Chalmers University of Technology and the Royal Institute of Technology (KTH). Stena plans to have scaled up operation of electrically propelled vessels by 2030. A research project with the partners above was formed and led by SSPA. This project was granted funding from the research portfolio of the Swedish Transport Administration.



Accurate test setup verified against calculated still water bending moment.

Tests with Stena Elektra

SSPA has tested a hull of Stena Elektra with the correct model scale stiffness for a hull with room for a flexible layout and a lightweight hull with energy-efficient hull lines to make battery propulsion feasible.

This joint effort was carried out in a project where a model testing technique was developed together with computations by state-of-the-art hydrodynamic simulations, FE-tools and analytical calculations.

There were several technical challenges to overcome to be able to build a scale model with the right properties in terms of structural dynamics. To provide room for correct mass distribution and stiffness, the model was, to a large extent, built in carbon fibre and aluminium. The model was designed to capture the most important modes of hull vibration.
A design divided into four sections was developed and prepared with adjustable stiffness, the appropriate amount of structural damping and thin membranes of latex. The section cuts required a completely dry environment to be able to have very accurate high resolution transducers. The model design and construction are shown on page 8. Measurement accuracy was verified by, for example, a comparison between calculated and measured bending moment in still water as shown in the illustration below.

A few of the principles of ship structural dynamics are shown above which display a time series of the measurements of midship hull bending moment on the Stena Elektra hull. In this figure, an initial period of bending moment response entirely in pace with the wave encounter frequency can be seen.

A second phase with a lot of hull resonance triggered by somewhat larger waves can also be noted. After that a period of slow decay in the resonant bending moment is displayed. A ship hull normally has a very low structural damping, which results in slowly decaying hull girder vibrations once started.

Results of high value

In addition to the model tests, simulations were performed which showed that simulations can be useful for understanding principles and studying the influence of different design parameters. It was also apparent that simulation techniques need further refinement to give high quality results. This study also showed that model tests with high quality measurements are a very powerful tool in combination with simulations to generate high value results for the development of new ships, also in the area of hull scantling and hull structural dynamics.

Building up of knowledge to support

SSPA aims to continue joint research efforts and knowledge-sharing to continue to be a driving part of the build-up of knowledge to support commercial partners, regulatory bodies and the transportation business as a whole.

Illustrations by SSPA.

Olov Lundbäck

Specialist, Simulations & Algorithms.

Since joining SSPA in 2016, Olov has been involved in projects in the areas of ship motion simulations, battery hybrid propulsion, seabed erosion and marine operations. Prior to joining SSPA, he has worked with solid mechanics and hydrodynamics within subsea infrastructure for the oil and gas industry, engine development at Scania and at Westcon Group. He has a PhD in ship dynamics from Chalmers University of Technology and an MSc in Naval Architecture from the Royal Institute of Technology.

Contact information
E-mail: olov.lundback@sspa.se

Jonny Nisbet

Senior Specialist, Submersibles.

Jonny received his MSc in Naval Architecture from the Chalmers University of Technology in 1989 and his PhD in Thermo-Fluid Dynamics from Chalmers in 1994. He has worked for SSPA since 2009, except for one year spent on research and consultancy projects related to manoeuvring and seakeeping. He specialises in submarine hydrodynamics, model testing and the simulation of manoeuvring performance.

Contact information
E-mail: jonny.nisbet@sspa.se