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A Low Emission Coastal Cruise Vessel – MV Havila Capella

T.E. Berg[1], S.E. Moe[2], D. Leinebø[2] & Ø. Rabliås[1]
[1] *SINTEF Ocean, Trondheim, Norway*
[2] *HAVDesign AS, Fosnavaag, Norway*

ABSTRACT: Since January 2021, Havila Kystruten has been one of two companies sailing the coastal route between Bergen and Kirkenes. This paper contains information on the new shipping company Havila Kystruten and their 2019 bid for a 10-year operational license to sail the coastal route. The government's tender documents for the new license specified that the vessels operating the route had to be low-emission vessels. This requirement was in line with the government's white paper on the reduction of emissions for commercial and fishing vessels sailing in Norwegian waters. Thus, companies bidding for the new license had to offer new ships with low emission characteristics or rebuild existing vessels to obtain the low emission requirements. Based on the offers, the government decided to split the operational license between two companies. One part was given to the company previously operating the route (Hurtigruten) and the other to the new company Havila Kystruten. While Hurtigruten would rebuild the engine systems on some of their existing vessels, Havila Kystruten would operate the route using new vessels with low emission signature. The design requirements for these vessels were given by Havila Kystruten to the ship designer, Havyard Design and Solutions (now HAVDesign). Some of the requirements are listed in section 4 below. The latter part of this paper investigates the manoeuvring performance of the new Havila Kystruten vessels, containing a summary of a Research Council of Norway funded innovation project on harsh weather ship handling during port operations. The Port of Trondheim was selected as a case study.

1 INTRODUCTION

The coastal express route between Bergen and Kirkenes has been an important trade and passenger route since 1893 (https://snl.no/Hurtigruta, in Norwegian). In the beginning, several regional shipowners collaborated to build a regular service for coastal inhabitants and cargo. In recent years, the cargo part has become less important as larger cargo volumes have been shifted to dedicated coastal cargo vessels or transferred to the road. Transporting passengers is now the major source of income for the companies operating vessels on the coastal express route in addition to government funding.

The first part of the paper gives a description of past and present organisation of the coastal express route, followed by a brief description of the Havila Kystruten shipping company and their license to operate the Bergen – Kirkenes coastal route from January 2021. Havila Kystruten received their 10-year operational license in 2019 and needed new vessels to fulfil the license requirements. Design requirements for their vessels were given to the ship designer (Havyard Design and Solutions, now HAVDesign) as a baseline for the design of a new generation of passenger vessels for the Bergen - Kirkenes route. Some of the requirements are listed in sections 4 and 5 of the paper.

The last part of the paper describes a comparison of full-scale and simulation model outcomes for standard IMO manoeuvring tests and discusses the improvements and added functionality of SINTEF Ocean's vessel simulation tool VeSim for the investigation of port calls in adverse weather. The Port of Trondheim has been selected as a case study. This part, sections 6 – 9, also examines other applications of the simulation model.

2 THE COASTAL EXPRESS HISTORY

The coastal express route was established in 1893. From the start, it was based on a combination of local passenger traffic, cargo transport and national/international tourists. Gradually, the tourist traffic increased significantly. The income from this is now many times larger than that gained from local passenger traffic. Initially, different regional shipping companies operated the coastal express route. In 1947, the Department of Transport introduced a licensing scheme for four companies. From 1988, two regional shipping companies owned all vessels operating the coastal express route. In 2005, the companies started "Hurtigruten Group", which in 2007 was reorganised into the present company "Hurtigruten ASA". This company operated all vessels along the coastal express route until the end of 2020.

Following the Norwegian governments policy to allow more commercial companies to compete for governmental supported transportation contracts, they invited shipping companies to bid for a time limited license to operate. The change in income sources was to be built into the future license to operate contracts between the Norwegian government and shipping companies. An invitation to bid for a 10-year operational license (for the renamed coastal route) was published by the Ministry of Transport in 2018. The outcome of the call was that two companies received operational licenses: Hurtigruten would operate seven vessels, while the new company Havila Kystruten would operate four. The new licenses came into action on January 1st, 2021.

The coastal route from Bergen to Kirkenes services 34 ports along the western and northern coast of Norway, see Figure 1. In the summer season, some additional famous tourist sites are visited.

3 HAVILA KYSTRUTEN'S LICENSE TO OPERATE THE BERGEN – KIRKENES COASTAL ROUTE (2021 – 2030)

In their offer, Havila Kystruten specified that their ships would be newbuilt low-emission ships HAVDesign (then Havyard Design & Solutions) designed the new vessels (a HAV 923 design). Standard resistance and propulsion tests were run in SINTEF Ocean's laboratories, and building contracts were signed with two shipbuilding companies – Hijos de J. Barreras in Spain and Tersan in Turkey.

The Spanish contract was later cancelled due to significant delays in the yard's time schedule for building the hulls.

Figure 1. The Coastal Route from Bergen to Kirkenes (Courtesy: Havila Kystruten).

4 A BRIEF REVIEW OF THE HAV 923 DESIGN FOR HAVILA KYSTRUTEN

In 2019, the Norwegian Government published a white paper on emission reduction in Norwegian coastal and fishing vessels (Norwegian Government, 2019), stating a goal of a 50 % reduction of green-house gas (GHG) emissions by 2030. The new call for operators on the coastal route, published in 2018, included requirements for a significant reduction of GHG emissions compared to the ships in operation. To fulfil this requirement, the ship designer HAVDesign decided to focus on:

- The development of an energy efficient hull design;
- The world's largest energy pack (at the design date);
- A 4-hour, zero-emission sailing time using batteries;
- Port power loading from hydropower sources;
- Obtaining a 25% CO2 emission reduction; and
- Obtaining a 90% NOx reduction.

The vessel's main dimensions are L x B x T = 125 x 22 x 5.5 m. It has a passenger capacity of 640. The service speed is 15 knots.

5 MV HAVILA CAPELLA – THE FIRST HAVILA KYSTRUTEN VESSEL

MV Havila Capella was the first of four sister ships built for the new coastal route operator Havila

Kystruten. The vessel was built at Tersan Shipyard (Turkey). Planned delivery was set for the third quarter of 2020, but due to COVID-19 delivery was delayed. The yard's delivery tests took place in the Marmara Sea, north of Yalova, Turkey, in September 2021. Figure 2 shows the vessel during the yard's delivery tests.

In addition to the usual systems tests (engines, control system, hotel systems), the programme contained a set of manoeuvring tests, which included standard IMO manoeuvring tests (IMO Resolution MSC.137/76). These full-scale trail tests were recorded and post-processed by the Dutch research company Marin. Test outcomes were used to develop the vessel's Wheelhouse Poster, Pilot Card and Manoeuvring Booklet. Later, the yard test data were used in the validation of the SINTEF Ocean vessel simulation tool VeSim (VeSim, 2020).

The vessel left the yard in November 2021 with a full ship crew and used the transit to Norway partly for familiarisation training. After arriving in Bergen, MV Havila Capella started on her first Bergen – Kirkenes roundtrip on December 12th, 2021.

Figure 2. MV Havila Capella performing yard delivery tests for Tersan Shipyard.

6 INVESTIGATING THE MANOEUVRING PERFORMANCE OF MV HAVILA CAPELLA.

HAVDesign collaborated with the vessel owner Havila Kystruten, Norwegian Electric System (NES), Port of Trondheim and SINTEF Ocean to write a successful application to the Research Council of Norway (RCN) for an industry innovation type project. The project started in April 2019 and had a stipulated duration of 36 months. The goal of the project was to investigate operational challenges related to port calls in adverse weather. As a case, the project selected the Port of Trondheim for the study. This port was selected due to existing plans for the development of an advanced sensor system for vessel motions and metocean observations close to the port. This system was developed to be an important part of the infrastructure for a test bed for autonomous vessels. The area close to the Port of Trondheim would also be a central part of the larger Oceanlab infrastructure (shown in Figure 3). Oceanlab includes sites dedicated to a variety of scientific studies for marine and maritime stakeholders (https://www.sintef.no/en/latest-news/2021/norway-has-been-given-a-floating-ocean-laboratory/).

To study the manoeuvring performance of MV Havila Capella (HAV 923 design) at an early design phase, it was decided to use SINTEF Ocean's vessel simulation tool VeSim, see Figure 4 (SINTEF, 2020). This figure illustrates topics covered by VeSim in studies of vessel behaviour in a seaway. This tool is used for combined seakeeping and manoeuvring studies in open deep water. To fulfil the project goal, VeSim had to be extended with restricted water hydrodynamics and position related external forces taking care of the influence of port-based infrastructures.

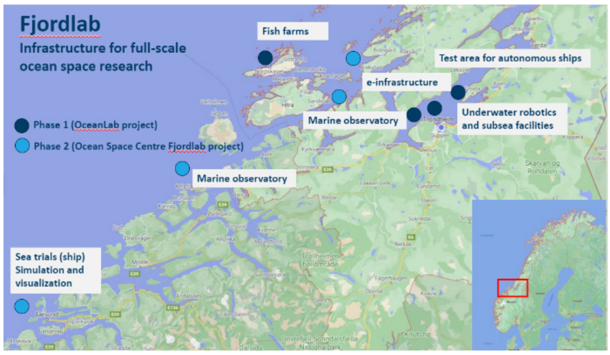

Figure 3. Locations included in the Oceanlab full-scale test bed for marine and maritime research.

In the first part of the project, SINTEF Ocean performed model tests with a 1:16.7 scale model of the azipulls (open water propulsion) and a naked hull model (resistance, oblique towing and PMM) in the Towing tank. The results were used to develop the first version of the VeSim deep water model. Due to delays in the building programme, it was not possible to compare model outcomes with the yard's delivery tests until late 2021. A comparison of calculated and measured IMO standard manoeuvres showed fairly good results for zig-zag tests. The turning circle tests showed significant differences, which were assumed to be a result of errors in the representation of the non-linear damping forces in the hull model and interaction between hull and azipull units. Even though there were uncertainties in the yard test, the simulation results were compared to these tests to assess the validity of the simulation model. Figure 5 shows a comparison of measured and calculated course and azipull angles for a 10°/10° zig-zag test. As can be seen from the figure, the turning speed of the azipulls is higher in the simulation than on the vessel. This could cause the smaller period predicted by VeSim. A comparison of the velocities for the same manoeuvre is shown in Figure 6. The simulation results and results from the yard tests are in reasonable agreement.

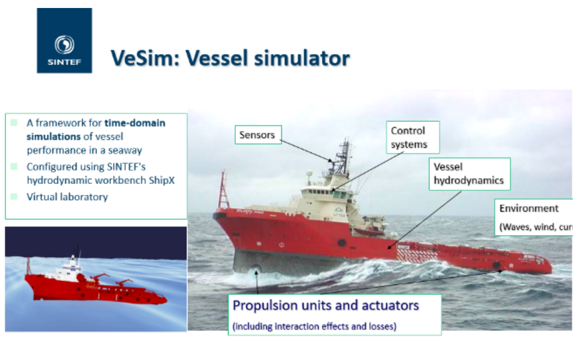

Figure 4. SINTEF Ocean's combined seakeeping and manoeuvring simulation tool VeSim.

The second part of the project studied and developed methods to include the effects of shallow and confined water influence on vessel hydrodynamics. Belgian expertise (Ghent University/Flanders Hydraulic Research) gave guidelines on how to include these effects on hydrodynamic coefficients in manoeuvring simulation models. Due to budget limitations, it was not possible to perform shallow water PMM tests (as such tests had to be performed at a foreign model tank). Instead, two numerical tools were used to calculate hydrodynamic forces for different water depths, SINTEF Ocean's HullVisc (SINTEF; 2018) and VERES-3D (Hoff, 2022). An example of water depth influence on the sway added mass calculated by VERES-3D is shown in Figure 7. The influence compares well with published data for shallow water influence (SIMMAN benchmark vessels, https://simman2014.dk). For sailing areas with varying water depths, a mean water depth over the ship's length was used as the parameter for estimating shallow water coefficients. This calculation takes place outside the VeSim and is given as input parameters to the motion solver in VeSim.

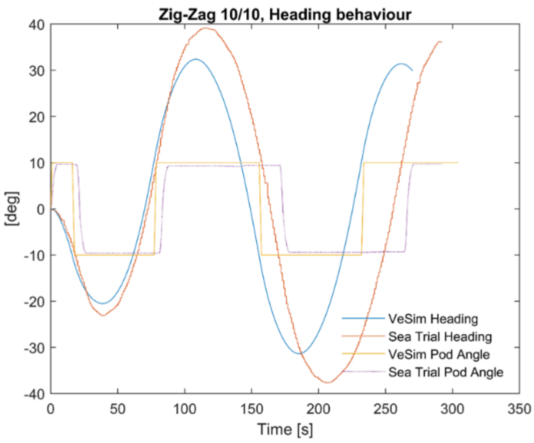

Figure 5. Comparison of sea trial results and VeSim calculation for the IMO 10°/10° zig-zag test - heading and azipull angle.

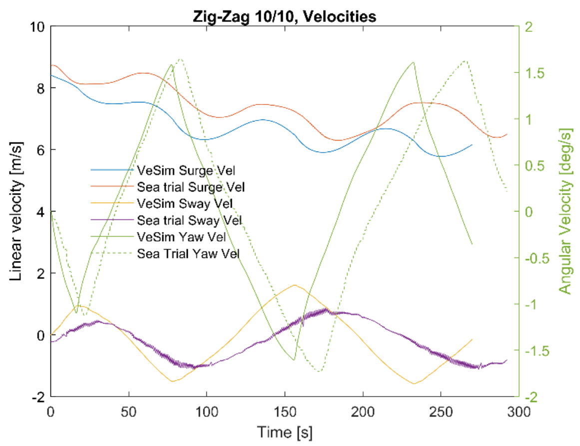

Figure 6. Comparison of sea trial results and VeSIM calculation for the IMO 10/10 zig-zag test - velocities.

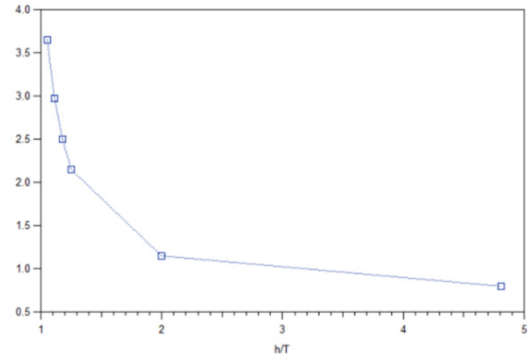

Figure 7. Example of calculated shallow water sway added mass for the KVLCC2 benchmark vessel. Curve shows non-dimensional values (sway added mass divided by ship mass) based on Veres-3D calculations.

Effects of lateral restriction are important in some critical parts of the sailing route such as Trollfjorden, see Figure 8, as well as manoeuvring in ports. An initial study of the effect of a long vertical wall was made as a part of the manoeuvring model tests in SINTEF Ocean's model tank.

7 FINAL PASSAGE TO PORT OF TRONDHEIM

Under normal weather conditions, coastal route vessels berth at quay 1 and 2 at Pir 1, see Figure 9. For strong westerly and north westerly winds, an alternative berth is located at quay 51 at Ila (see Figure 9). Normal tracks for the final part of the passage are shown in Figure 10. In some situations, the master will test out the actual weather conditions before deciding to use the priority quays or the alternative one. In a normal case, the vessel slows down outside of Pier 1 and backs into the quay. This manoeuvre has its drawbacks in harsh weather.

Figure 8. A narrow passage – Trollfjorden – sailed by coastal route vessel MV Havila Capella. Photo: Marius Beck Dahle

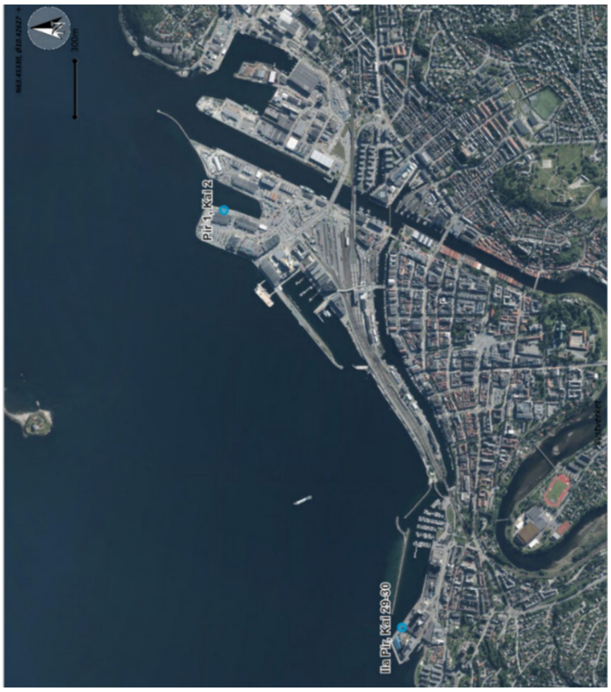

Figure 9. Quay layout in Port of Trondheim. Primary quay for coastal route vessels is at Pir 1, quay 2 (upper left). Alternative quay is at Ila Pir, quays 28-39 (lower right).

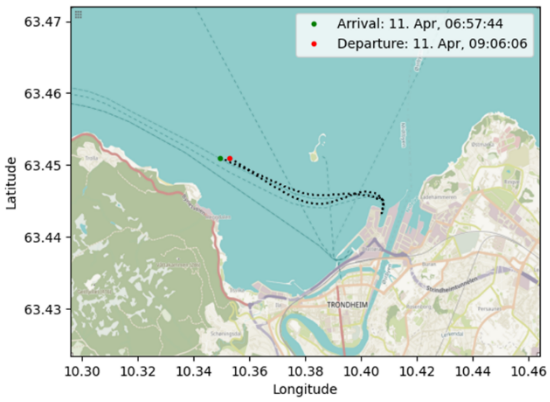

Figure 10. Example of tracks for coastal route vessels calling Port of Trondheim.

8 EXTENDING THE VESIM TOOL

The project made a major improvement on the standard way of adding external forces in VeSim. Based on a 3D model of the Port of Trondheim, a project specific CFD model was developed to investigate the wind field behind buildings along the final approach to the normal quay for the coastal route vessels, illustrated in Figure 11. Using the calculated wind field on a strip theory representation of the vessel (normally 21 sections), position-based wind forces/moments are calculated.

The same method is used when local currents are included in the VeSim model. The project started to develop a high-resolution grid for current distribution based on a metocean current model. This model will be validated using some of the sensors available through the Oceanlab infrastructure shown in Figure 3.

Based on input from Havila Kystruten's masters, it was decided to neglect further development of the VeSim's wave force model (based on open water standard wave spectra) as wave forces are much smaller than wind forces under harsh weather conditions in the Port of Trondheim. The existing wave force model includes first-order excitation forces, slowly varying wave drift forces and a nonlinear modification of the restoring and incident wave forces due to vessel geometry.

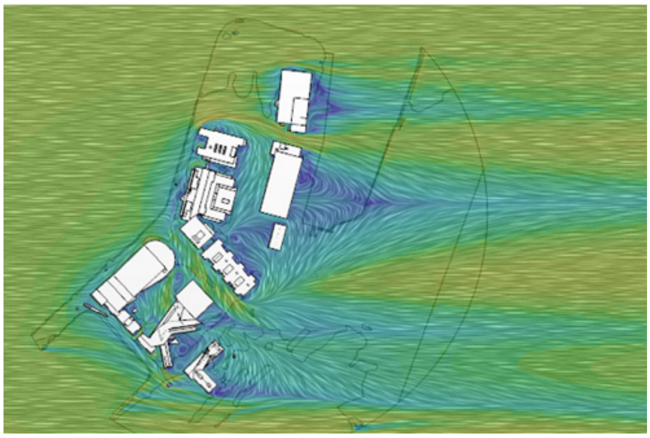

Figure 11. Wind field for the final approach phase to normal coastal route quay.

Due to the short period of operation, neither of the two Havila Kystruten vessels (MV Havila Capella and MV Havila Castor) met adverse weather conditions during their visits to the Port of Trondheim. It has thus not been possible to test the extended VeSim model for such conditions.

9 OPERATIONAL EXPERIENCE

The first sistership, MV Havila Castor, joined MV Havila Capella on the coastal route on 10 May 2022. The last two vessels (MV Havila Polaris and MV Havila Pollux are expected to start their service in late 2022 and the first quarter of 2023).

Most of the time, the vessels sail close to the coastline where engine blackouts or other control system failures will be critical due to the short distance to reefs and islets. As the most common wind direction during the winter season is westerly, the vessels' large wind area will result in forces driving the vessel towards the coastline, see Figure 12. A situation like this happened with the cruise vessel "MV Viking Sky" in March 2019 when passing the exposed Hustadvika area under adverse weather conditions. The vessel lost most of its propulsion power due to a technical failure and started drifting toward shoals and the coastline. A maritime emergency operation was declared, and rescue helicopters scrambled to lift passengers from the vessel (in total 456 passengers were flown to a shore-based rescue centre). During this operation, the ship's anchors were dragging on the sea bottom and thus reducing the drifting motion until the engineers were able to restart the engines and turn the vessel towards deeper waters. This incident is still (November 2022) under investigation by the Norwegian Safety

Investigation Authority (https://havarikommisjonen.no/Sjofart/Pagaende-undersokelser).

Figure 12. MV Havila Capella sailing the Bergen – Kirkenes coastal route outside Flø, Ulstein. Photo: Per Eide

Based on feedback from the masters of these vessels, it is concluded that they generally are very pleased with the vessel's operational performance. All the masters had experience with similar vessels having twin Azipull units and bow thrusters. The manoeuvring performance in calm water was excellent. They expressed a need for tuning the response time for the bow thrusters and more information on the reduction of the thruster performance with forward speed. The tuning has been performed and more information on bow thruster performance at low speeds (forward and backward) has been provided.

The masters expressed concerns about the reliability of the onboard wind sensors for some wind directions. For low- and zero-speed operations, wind sensor data is important for controlling azipull and bow thruster responses, especially for beam winds.

A collection of senior officers' experiences of operational challenges, along with an analysis of these and feedback on the outcomes of the analysis, will be an efficient way to build operational knowledge for the officers who take leading positions on the last two sister vessels.

10 CONCLUSIONS AND FUTURE APPLICATION OF THE PROJECT'S RESULTS

The HAV 923 design is a highly successful design for operation along the coastal route from Bergen to Kirkenes. Compared to the previous vessels operating the route, the new vessel represents a 25% cut in green-house gas emissions. The fuel reduction goal for the new Havila Kystruten's vessels has been fulfilled. Additional reduction in green-house gas emissions will, in the future, be increased when shore-based power loading systems are installed in more of the ports called by the vessels. Changing from fossil fuel to biofuel is another way to reduce the carbon footprint. The vessels are prepared for this when biofuel is commercially available.

The vessel's manoeuvring and steering performance under normal operational conditions are evaluated as satisfactory by masters on the vessels.

Further use of the vessel's VeSim model could be accomplished via a transfer of the model to a full mission training simulator. Such a simulator would be very beneficial for new nautical officers without previous experience on vessels with twin azipull propulsion systems.

ACKNOWLEDGEMENT

The authors recognise the important input given by the masters of the first two Havila Kystruten vessels. Their input on operational experience has been (and will continue to be) of great value to designers, system developers and researchers.
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