# D3.14 Demonstration aft-ship replacement: "Ernst Kramer" (DEM)

Synergetics | Synergies for Green Transformation of Inland and Coastal Shipping

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| **GRANT AGREEMENT NO.** | 101096809 |
| **DURATION OF THE PROJECT** | 42 months |
| **DELIVERABLE NUMBER** | D3.14 |
| **DISSEMINATION LEVEL** | Public |
| **DELIVERABLE LEADER** | DST |
| **STATUS** | FINAL |
| **SUBMISSION DATE** | 20.12.2024 |
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Funded by the Horizon Europe Programme of the European Union under grant agreement No 101096809
Funded by the Horizon Europe guarantee of the United Kingdom, under project No 10068310
Funded by the Swiss State Secretariat for Education, Research and Innovation

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Deliverable D3.14 is a deliverable of type "demonstrator, pilot, prototype" (DEM). This document provides additional information on the background, status and plans. A detailed report will be submitted in June 2025 with the deliverable D3.15 Evaluation report aft-ship replacement: "Ernst Kramer".

The demonstration of the hydrodynamic improvement potential of the use case Ernst Kramer reached the next milestone. After the baseline tests at DST - Development Centre for Ship Technology and Transport Systems had been completed in April, the multi-objective optimisation and experimental verification were conducted.

The baseline tests, covered representative combinations of water depths and loading conditions/draughts, selected based on real operational data (see Figure 1). Monitoring data of Ernst Kramer collected over several months was used to develop an operational profile of the vessel. Based on that, the relevant conditions for both the test campaign and optimisation are selected.

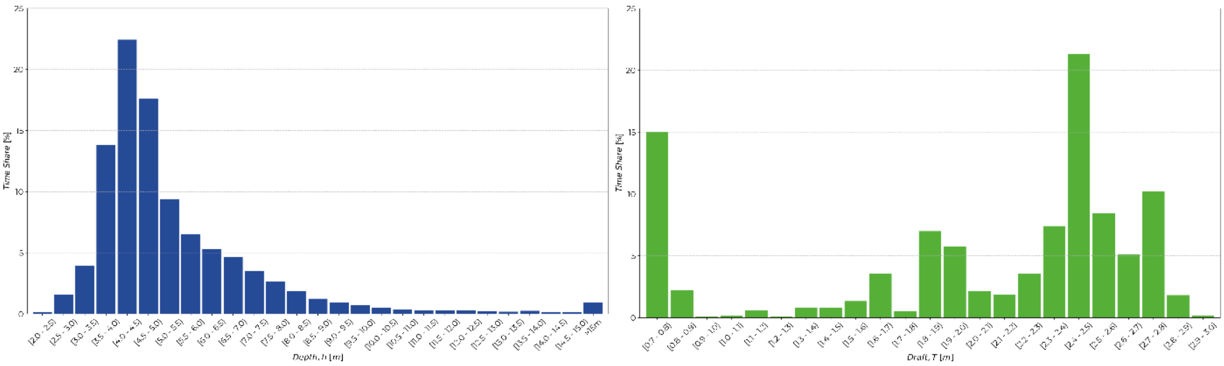


*Figure 1: Distribution of water depths (left) and vessel's mean draught (right) based on onboard long-term monitoring data. The water depth distribution highlights predominant operational ranges.*

The test campaign, shown in Table 1, included model resistance and propulsion tests across speeds ranging from $10$ and $18\ km/h$, depending on the condition, i.e., under keel clearance and depth Froude number. The draught conditions tested ranged from partial load ($T = 1.9\ m$) to a representative high utilisation ($T = 2.8\ m$) to a load case representing the empty vessel with a trim by stern ($T_A = 1.3\ m, T_F = 0.75\ m$). Water depths included deep, shallow, and intermediate levels – specifically $h = 7.5\ , 5\ m$ and $3.5\ m$ – reflecting the vessel's typical operating areas across the Rhine, tributaries, and certain canals.

Table 1: Test matrix for baseline tests.

| ↓ T [m] / h [m] → | 7.5 | 5 | 3.5 |
|---|---|---|---|
| **LC1** $T_A = 2.8\ m\ ; T_F = 2.8\ m$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 18\ km/h$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 17\ km/h$ | $v_1 = 10\ km/h$<br>$v_2 = 12\ km/h$ |
| **LC2** $T_A = 1.9\ m\ ; T_F = 1.9\ m$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 18\ km/h$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 17\ km/h$ | $v_1 = 10\ km/h$<br>$v_2 = 12\ km/h$ |
| **LC3** $T_A = 1.35\ m\ ; T_F = 0.75\ m$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 18\ km/h$ | $v_1 = 12\ km/h$<br>$v_2 = 16\ km/h$<br>$v_3 = 17\ km/h$ | $v_1 = 10\ km/h$<br>$v_2 = 12\ km/h$ |

LC - Loading Condition; $T_A$ - draught at aft perpendicular; $T_F$ - draught at forward perpendicular; $v$ - speed



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High-fidelity RANSE CFD simulations were coupled with the parametric geometry in an automated optimisation environment, focusing on the aft-ship due to its influence on power demand, particularly in shallow water. More or less identical displacement, same propeller diameter and similar minimum draught to ensure the resilience against low-water periods were used as design constraints. The design space exploration was followed by a response surface optimisation to determine the best combination of the selected design variables. Depending on the conditions the best design showed power demands between 15% and 35% lower than the original ship.

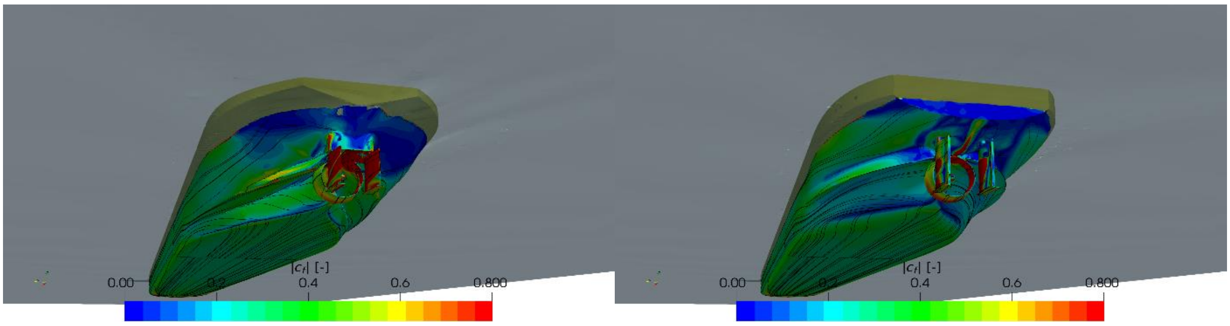


Figure 2: Streaklines and flow separation zones on original (left) and optimised (right) aft-ships

Following the multi-objective optimization, the redesigned aft-ship was physically produced, replacing the aft-ship of model M2202 with the optimized version, designated as M2211. The tests were performed using the same test campaign presented in Table 1.

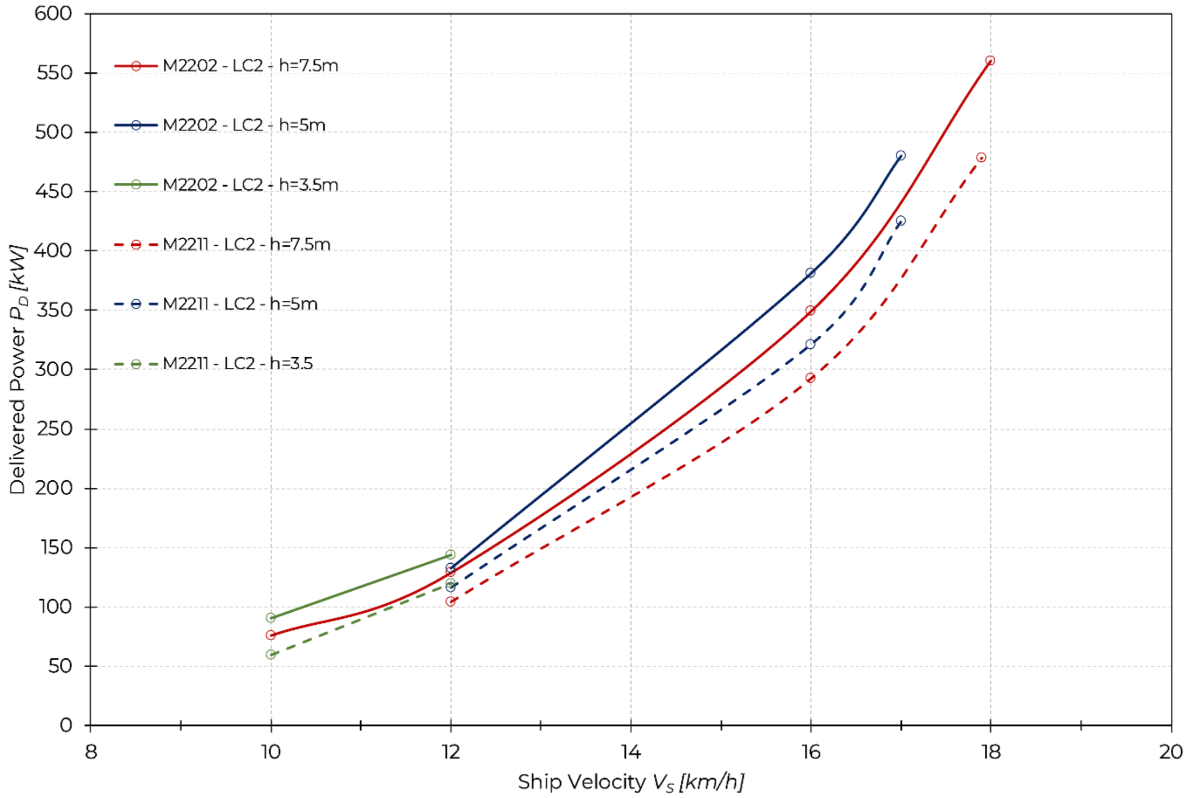


*Figure 3: Predicted power demand comparison between the original aft-ship design (M2202) and the optimized design (M2211) for Loading Condition 2 (LC2), based on results from model tests.*



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Figure 3, presenting the predicted power demand, confirms the hydrodynamic improvements achieved through the optimization process (see also Figure 4). The optimized aft-ship design consistently shows lower power demand across all water depths and speeds under partial loading conditions compared to the original design. A detailed comparison and analysis will be provided in Deliverable D.3.15 – *Evolution Report on Aft-Ship Replacement: "Ernst Kramer"*.

*Figure 4: Experimental verification of the optimisation results in DST's large shallow water basin. The smooth ship wake for the new design on the right can be noticed.*



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