Full-Scale Application of Hull Vane® on a 108m Holland-Class OPV of the Royal Netherlands Navy: Confirming Predictions and Tactical Benefits

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Figure 1 – HNLMS Groningen in dry dock with Hull Vane®

ABSTRACT

This paper presents the results of the full-scale application of the Hull Vane® on a 108m Offshore Patrol Vessel (OPV) of the Royal Netherlands Navy. The study builds upon previous research and Computational Fluid Dynamics (CFD) analyses published in FAST 2015[1] and MAST 2016[2], validating the anticipated improvements in fuel efficiency, operational range, and tactical performance. Full-scale measurements confirm an overall efficiency gain of 10% across the entire operational range, with a peak reduction in fuel consumption of 16% at 17.5 knots, and an increase in the vessel's top speed. The findings demonstrate that Hull Vane® enhances naval operability and reduces dependence on conventional energy sources, a critical factor for future maritime defence strategies.

1. INTRODUCTION

The Royal Netherlands Navy is dedicated to staying at the forefront of technological advancements to ensure its fleet remains highly efficient and operationally effective. Through continuous research, testing, and implementation of cutting-edge innovations, particularly in hydrodynamics and naval engineering, the navy enhances the performance, sustainability, and adaptability of its fleet. The Hull Vane®, a patented hydrofoil-type appendage, was selected for retrofitting on a Holland-class OPV following extensive CFD studies, model testing, and in-depth structural assessments and engineering analyses. Previous CFD simulations suggested significant fuel savings and seakeeping improvements[1], [2]. This paper validates those predictions with full-scale operational data, emphasizing the operational benefits for tactical deployment and sustainability. This initiative supports the navy's commitment to cost reduction, improved mission performance, and enhanced sustainability in modern naval operations.

2. BACKGROUND AND PREVIOUS RESEARCH

The Hull Vane® has been widely studied as a fuel-saving device for fast displacement vessels, reducing wave-making resistance and improving vessel efficiency[3]. Initial CFD studies on the Holland-Class OPV's predicted a 12.5% annual fuel reduction, will the optimization was focusing on the most fuel-intensive cruising speed of 17.5 knots, were

resistance reduction was calculated at 15.3%[1]. Despite the vessel operating at lower speeds most of the time, the Hull Vane® proved most beneficial during faster cruising, where the majority of fuel is consumed. Additionally, the study indicates an increase in top speed. A recommendation of the study was the removal of the trim wedge, as it hindered the Hull Vane®. This is also supported by Ferré's research, which concluded that the Hull Vane® outperformed the trim wedge across the entire speed range[4]. Further research showed positive effects on seakeeping, including a 13% reduction in vertical accelerations at the helicopter deck and a 17% improvement in range capability.
In 2016, cost savings of approximately €257,000 per ship per year were estimated based on the predicted fuel savings, leading the Royal Netherlands Navy to opt for a full-scale retrofit to validate these findings in real-world conditions[2].

The study "Application of Commercial Advances to Support the Naval Energy Transition" explores how commercial Energy Saving Technologies (ESTs) can enhance the sustainability of naval vessels[5]. It focuses on integrating ESTs like Hull Vanes, absorption chillers, and wind-assisted propulsion into the Venator-110 frigate, showing that these technologies can reduce energy demand by 13% and improve range by 21% at 15 knots when using traditional F-76 fuel. While transitioning to alternative fuels like methanol limits range, ESTs can help mitigate this impact. The study highlights the potential of ESTs to improve fuel efficiency and operational capabilities, laying the groundwork for future research on sustainable technologies in the naval and wider maritime sectors.

3. TEST VESSEL AND PERFORMANCE ASSESMENT

Figure 2 - HNLMS Holland (P843) in dock

3.1 Vessel Description

The 108-meter Holland-class Offshore Patrol Vessel (OPV) was developed by Command Material and IT (COMMIT), previously known as DMO, in collaboration with Damen Naval [6]. It is designed for maritime security, anti-piracy, and search-and-rescue operations. The vessel is equipped with hybrid propulsion and advanced seakeeping capabilities, making it an ideal candidate for Hull Vane® integration. The Hull Vane® was installed aft of the stern, replacing the existing trim wedge to optimise flow dynamics and enhance fuel efficiency.
The principal particulars of the vessel are given in Table 1.

Table 1 - Main dimensions of Holland-Class OPV

Length-over-all	108.4 m
Waterline length	102.8 m
Design displacement	3.750 ton
Beam-over-all	16m
Design draught	4.55 m
Propulsion power	2 x 5460 kW
Range at 15 knots	5.000 nm
Max. Service speed	21.5 knots

3.2 Measurement Methodology

Post-installation trials were conducted over multiple operational profiles to measure fuel consumption, vessel speed, and seakeeping behaviour. A combination of on-board sensors and external validation through towing tank benchmarks was used to assess performance improvements.

Figure 3 - Tank test model Holland-Class © Dutch Ministry of Defence

During sea trials, fuel consumption was measured using flow meters installed in both the fuel supply and return lines, ensuring accurate measuring of fuel consumption. Additionally, strain gauges on the propeller shaft measured torque, which was used to calculate power output, providing direct insight into propulsion efficiency.

4. INTEGRATION OF THE HULL VANE®

The integration of the Hull Vane® on the Holland-class OPV was a unique process that differed significantly from conventional refits. Unlike standard installations where the Hull Vane® is simply mounted onto the existing structure, this retrofit required the removal of the ship's trim wedge. This modification was essential to ensure optimal flow conditions and maximize efficiency gains[1]. To maintain the launch and recovery ramp, an additional hull fairing was incorporated at the centerline, seamlessly integrating the trim wedge into the hull. Outside the ramp area, the trim wedge was completely removed, see Figure 4.


Figure 4 - Removal of the trim wedge

This required an extensive reinforcement and reattachment process, involving reshaping and welding the ship's hull to ensure structural integrity. The precision demanded by this operation made it a complex but essential adaptation. Initially, a three-strut configuration was simulated, however, to maintain full functionality of the launch and recovery ramp, a four-strut configuration was implemented, with two struts positioned alongside the ramp.

The success of this integration was largely due to the collaboration between key stakeholders, including COMMIT and Damen Naval. Their combined expertise ensured that structural modifications were executed with precision while maintaining the vessel's operational readiness. This partnership exemplifies the importance of industry collaboration in implementing cutting-edge naval technologies.

Figure 5 - Hull Vane® installed

5. RESULTS & VALIDATION

5.1 Resistance Reduction & Efficiency Gains

Full-scale trials confirmed a 10% efficiency gain across the entire operational range, as demonstrated by sea trial measurements and towing tank tests. At a cruising speed of 17.5 knots, resistance was reduced by 16%, surpassing initial CFD estimates[1]. Additionally, the vessel's top speed increased, highlighting the significant performance benefits of the Hull Vane®. All the sea trial measurements where performed by Marin Research Institute Netherlands (MARIN)

5.2 Tactical & Operational Benefits

The implementation of the Hull Vane® significantly increased the vessel's operational range, as estimated by CFD. At 15 knots, the predicted range improved from 5,000 to 5,850 nautical miles, correlating with the fuel-saving potential of the Hull Vane®. Since sea trials confirmed CFD predictions at 17.5 knots, a similar order of magnitude is expected for overall range improvement.

CFD analysis also indicated enhanced seakeeping, with reduced vertical accelerations at the helicopter deck, improving stability and operational readiness. Although challenging to quantify during sea trials, a noticeable reduction in heel during high-speed turns was observed, supporting the predicted hydrodynamic benefits.

The operational range to the Caribbean is approximately 5000 nautical miles. With the implementation of the Hull Vane®, the vessel achieves a 16% improvement in efficiency at a cruising speed of 17.5 knots, assuming a third-order effect on fuel consumption. This results in an increase in the vessel's cruising speed for the same fuel consumption, from 17.5 knots to 18.55 knots, which can be calculated using the following formula:

$$V_{S;Cruise\ with\ Hv} = \frac{V_{S;Cruise\ without\ Hv}}{\sqrt[3]{(1 - Fuel\ saving)}} = \frac{17.5}{\sqrt[3]{1 - 0.16}} = 18.55\ knot \tag{1}$$

This indicates that the time required to complete the 5000 nm journey is reduced from 285 hours (without the Hull Vane®) to approximately 270 hours (with the Hull Vane®), saving nearly a full day. Furthermore, if the vessel operates at lower speeds, the time savings would be even greater, demonstrating enhanced operational efficiency with the Hull Vane® under various cruising conditions.

Finally, the Hull Vane® reduces fuel dependency, an increasingly critical factor given rising costs and sustainability objectives within defense operations offering both economic and strategic advantages.

In addition to fuel savings, the Hull Vane® has a notable impact on the vessel's stern wave. During tank testing, it was observed that the stern wave was significantly reduced, which was visually confirmed during subsequent sea trials. This reduction in wave generation is illustrated in Figure 6, showing a comparison between the vessel with and without the Hull Vane® (left without, right with Hull Vane®). This reduction in wave resistance is not only beneficial for fuel efficiency but also has tactical advantages. A reduced stern wave translates into a reduced wake signature to drones, satellites and aircrafts.

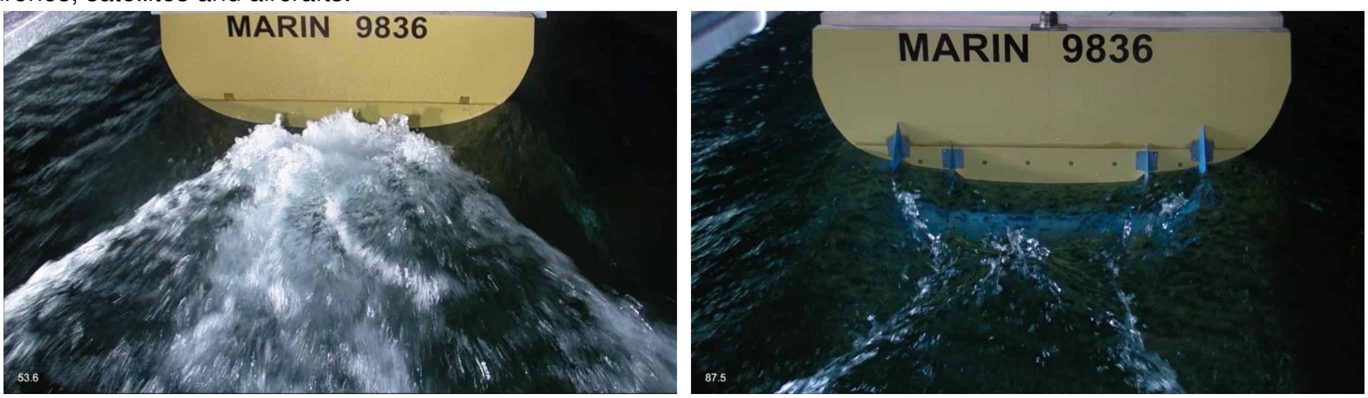

Figure 6 - Suppressed stern wave comparison, left w/o Hull Vane®, right w Hull Vane® © Marin

With a Hull Vane®, the launch and recovery of the FRISC via the slipway in the stern was tested during sea trials and is now more gradual, due to less turbulence in the water. The crew no longer has to ‘surf’ their way in which improves both safety and efficiency.

6. RETURN ON INVESTMENT (ROI) ANALYSIS

A return on investment (ROI) analysis was conducted using operational data from FAST 2015 and current fuel prices. The operational profile indicates that the vessel operates at varying speeds throughout the year, with the highest fuel consumption occurring at higher speeds.

6.1 Operational Profile and Fuel Consumption

The operational profile from FAST 2015 provides an estimate of the vessel’s annual usage at different speeds:

Table 2 - Operational profile and estimated fuel consumption

Vs (knots)	Operational Time (%)	Fuel Consumption approx. (tons/day)
5	43%	2
7.5	24%	5
12.5	19%	12
17.5	13%	30
22.5	1%	70

As stated in the research by BMT, naval vessels typically operate on F-76 fuel [5]. Given the current fuel price of $1,070 per ton, the annual fuel expenditure without the Hull Vane® is significant [7].

6.2 Fuel Savings and ROI Calculation

The Hull Vane® has been demonstrated to reduce fuel consumption by:

- 1.3% at 5 knots
- 5.4% at 7.5 knots
- 13.7% at 12.5 knots
- 16.0% at 17.5 knots
- 11.1% at 22.5 knots

Applying these savings to the operational profile and fuel costs, the annual fuel cost savings due to the Hull Vane® amount to approximately $425,715.

6.3 Payback Period and Investment Viability

Given the initial investment required for the Hull Vane®, the estimated payback period is approximately 2 years on the Hull Vane purchase. The Hull Vane® on the HNLMS Groningen has been operating since early 2023. At that time, the vessel had been in service for 10 years since its launch in 2013 [6]. So the Hull Vane could be seen as a midlife upgrade for the Holland-class OPV. Given the estimated payback period of 2.5 years, the investment will be recovered by 2026. Most likely, HNLMS Groningen will remain in service until 2036, when it is expected to be replaced by a new class of OPV. This means the investment will continue to generate savings for at least 10 years [8]. Based on current fuel prices, the annual savings amount to $425,715, resulting in a total savings of at least $4.25 million per vessel over the remaining operational period. This makes the Hull Vane® a financially viable and strategically valuable upgrade for naval operations, offering long-term operational cost reductions and improved sustainability.

7. STRUCTURAL CONSIDERATIONS

The design and integration of the Hull Vane® on the 108m OPV required specific structural reinforcements due to the unique load conditions encountered. One of the key challenges was the increased fatigue loading caused by the significant distance between the inner struts. To mitigate this, extensive finite element analysis (FEA) was conducted to evaluate stress distribution and fatigue resistance over the vessel's operational lifespan.

To address these concerns, a custom-engineered cast steel T-joint was developed to provide additional structural rigidity. This T-joint serves as the primary connection between the Hull Vane® and the vertical strut, ensuring that cyclic stresses are adequately managed while maintaining the structural integrity of the Hull Vane. The use of a cast steel component allowed for an optimized shape that minimizes stress concentrations and enhances the durability of the attachment points. The stress levels were reduced to such a low level that the material could be changed from S460 to S355 steel, simplifying the construction process and reducing costs.

Figure 7 - T-connection inner struts

The implementation of this solution required close collaboration between Damen Naval, COMMIT, and structural specialists. Material validation ensured that the design met naval safety standards and fatigue life expectations. The integration of this structural reinforcement highlights the importance of tailored engineering solutions in adapting advanced hydrodynamic appendages for military applications

8. CONCLUSIONS

The full-scale implementation of the Hull Vane® on a Holland-class OPV has validated the predictions made in prior CFD studies through extensive sea trials. The measured improvements in efficiency, speed, and seakeeping confirm Hull Vane® as a valuable enhancement for naval operations. Specifically, fuel savings of up to 16% at 17.5 knots and an overall annual reduction of 10% have resulted in increased operational range and improved tactical deployment capabilities.

Furthermore, the structural challenges encountered during installation, particularly the increased fatigue loading due to the distance between the inner struts, necessitated innovative engineering solutions. The development of a custom-engineered cast steel T-joint highlights the importance of structural optimization in ensuring durability and longevity. The successful implementation of these structural reinforcements demonstrates that advanced hydrodynamic appendages can be integrated into military vessels while maintaining compliance with stringent naval safety standards.

From an economic perspective, the Hull Vane® proves to be a financially viable investment with a payback period of approximately 2.5 years. Given the estimated service life of the HNLMS Groningen until 2036, the investment will generate at least 10 years of cost savings, amounting to approximately $4.25 million per vessel.

This case study showcases how interdisciplinary collaboration between hydrodynamicists, structural engineers, and naval stakeholders can result in ground-breaking advancements in ship efficiency. The Hull Vane® has proven to be not only an effective performance enhancer but also a long-term investment in sustainability and operational effectiveness for modern naval fleets.

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