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Experimental Investigation of Hull Form for Electric Driven Ferry

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***Abstract*—**In this paper, the resistance and pitching values of the test of an electric ferry are presented. The research was carried out in the open flow channel of Klaipėda University with a multi-axis dynamometer. The received model resistance values were recalculated to the real vessel and the preliminary chosen propulsion unit power was compared. After analyzing the results of the pitching of the model, it was concluded that the shape of the hull needs to be further improved, taking into account the possible uneven weight distribution at the ends of the ferry. Further investigation of the hull of the electric ferry is recommended, including experiments with various water depths and activation of propulsion units.

***Keywords*—**Electrical ferry, model tests, open flow channel, pitching, resistance.

I. Introduction

In light of the apparent ecological problems, eco-friendly transport attracts increasing attention. This paper describes a research on electrically driven ferry project, which was implemented following main guidelines and aiming to fulfil the agreements of the Paris climate conference [1], where main contributors for emission reduction are the energy industries and transport sectors.

Electric ships of various forms have been in existence for around a decade. However, a wider usage of electric engines on ships is considered to be a relatively new development area. The most common benefit of such engines is the reduction of pollution, noise and vibrations. The financial aspect is another important criterion, although this aspect is not always positive. Electric or hybrid propulsive systems are rarely used for long distance passenger or freight transportation as it is difficult for them to compete with today's propulsion systems with internal combustion engines on a financial scale. Apart from the financial reasons including the cost of the batteries and other costly components of electric propulsion, traditional internal combustion engines have a great advantage in this rivalry due to a well-developed infrastructure, i.e., their ability to receive a big volume of energy reserve (liquid fuel) in an efficient and timely manner, as well as the ability to store significant amount of such energy on board (fuel tanks) in comparison with the electric energy tanks – batteries. Nevertheless, electric or hybrid systems can be very well suited for specific niches within the shipping industry.

Both electric propulsion and their separate components are currently in a development stage – the costly components such as batteries are still in the process of being improved with a view of increasing their power consumption capacity and reducing the net cost of production. However, the modern-day developments in this area create an astonishing scope for improvement of complex electric propulsion systems by combining various components and optimising the power management systems.

The choice of relevant components, identification of their parameters and optimisation of energy consumption control systems is a complex process, which requires as assessment of a great number of factors. In order to be able to design electric propulsion systems in ships effectively and in a timely manner, the new algorithms and test systems need to be created and the existing ones updated utilising the accumulated knowledge and experience [2]-[7].

Modern shipping is regulated via different forms of improving energy efficiency and reducing the environmental impact. Depending on various work regimes during the use and maintenance of ships, certain types of energy systems can be used inefficiently. Many kinds of research are being undertaken in search of the optimal distribution of elements of the electric propulsion system with an intension to deliver regulated parameters for secure ship operation [8]-[10].

The passenger ferry operating short distances is one of the vessel types that fit the above-described parameters of a specialized vessel. One of the project goals was to develop the hull form of the electric driven ferry to gain maximum effectiveness using electric energy as main driving power.

II. Experiment Setup

A. Vessel and Model Parameters

The operating speed of the ferry is 8 knots, which corresponds to the cruising speed of the vessel. Table I shows the model parameters in comparing to the original vessel dimensions. The size of model is chosen in accordance with the requirements of ITTC [11], [12], taking into account possible wave reflections from the walls of the flow channel. The scheme of the produced model and all its components are shown in Fig. 1.

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TABLE I
MODEL PARAMETERS IN COMPARISON TO THE ORIGINAL VESSEL DIMENSIONS

Model scale			1:20
Original vessel	Unit	Vessel	Model
Length	m	35.0	1.75
Breadth	m	11.9	0.60
Draft	m	1.7	0.085
Speed	kt	8	1.789
Speed	m/s	4.12	0.920
Water Depth	m	0.3	
Froude number		0.22	

The view of the ferry model equipped with the propulsion complex and installed dynamometer base is shown in Fig. 2.

B. Testing Infrastructure

The experiment was carried out in the large open flow channel of Klaipeda University. The flow channel has the following geometrical characteristics of the test section: length – 10 meters, breadth – 1.2 meters, height – 0.8 meters, experiment water depth – 0.5 meters.

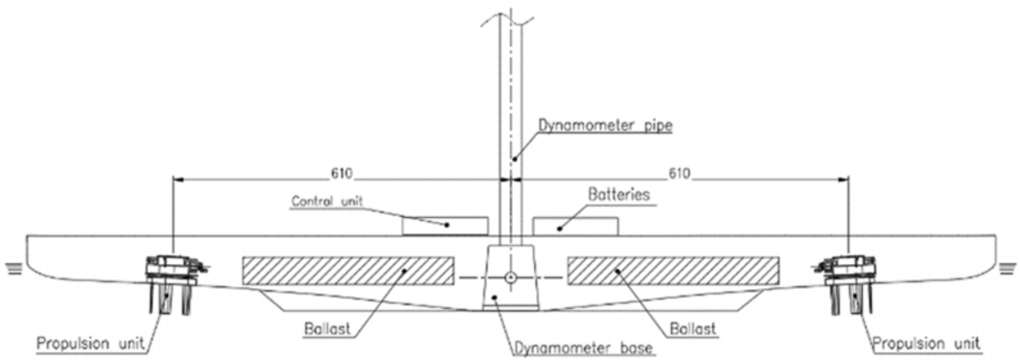

Fig. 1 The scheme of the model and all its components

Fig. 2 View on the ferry model

The flow channel is equipped with the multi-axis single post dynamometer from Wolfson Unit [13]. It was used to measure the resistance and the pitch angle of the model during the experiment. The dynamometer is capable to measure water resistance of the model up to 150 N with the accuracy of ± 0.05 N and pitch angles up to 10 degrees with the accuracy of ± 0.02 degrees. The view on open flow channel with multi-axis dynamometer is shown in Fig. 3, and the model connected to the dynamometer and prepared for experiment is shown in Fig. 4.

III. EXPERIMENT CONDITIONS

The experiment is based on the reverse principle when the vessel is fixed on the dynamometer axis and the water flow is created which flows around the model. The model has 2 degrees of freedom (heaving and pitching). The water flow corresponds to the speeds of the test model. The results of the experiment are written for the range of the vessel's speeds. The real vessel speeds are: 4, 6, 7, 7.5, 8 and 8.5 knots, what corresponds to the following model test speeds: 0.46, 0.69, 0.805, 0.863, 0.92, 1.04 m/s.

Fig. 3 View on open flow channel of Klaipeda University

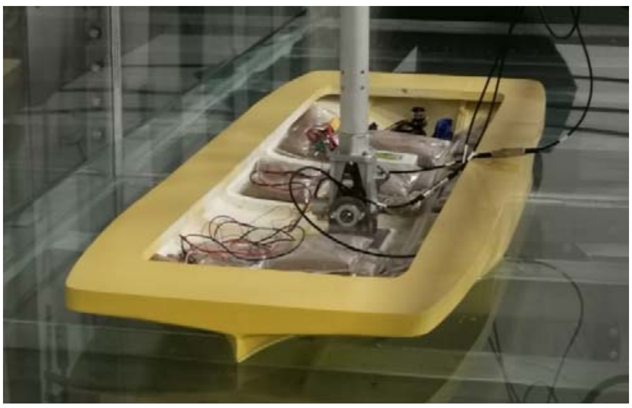

Fig. 4 Ferry model connected to the dynamometer

During the experiment, the following results are observed and analysed:

1. Visual observation of the flow around the hull. Attention is paid to the areas of stem and propulsion units.
2. The following hydrodynamic properties are measured: model resistance and pitch angles. The measured resistance values are recalculated to the real vessel and the chosen propulsion unit power is checked.

The experiment water depth is established at 0.3 m that corresponds to the projected minimum operation draft for this ferry. The tests are made with the propulsion complex installed, but not activated.

IV. Experiment Results and Discussion

The flow around the stem at the maximum test speed is shown in Fig. 5.

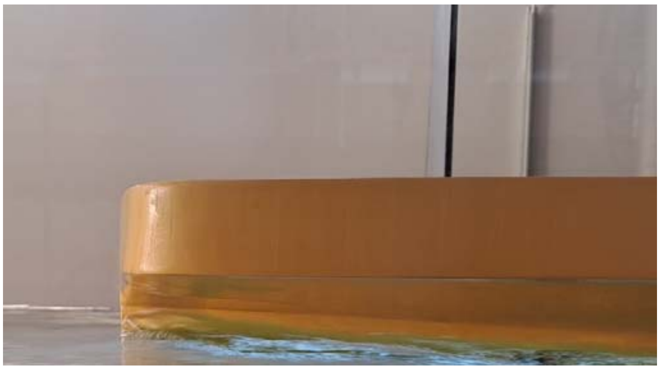

Fig. 5 Water flow at stem of the model at maximum test speed of 1.04 m/s

It can be seen that the wave is significantly rising and almost reaching the horizontal part of the vessels form. Although it is not critical, but in combination with uneven vessel balancing (heavier cargo in forepart) it can cause a significant increase in resistance of the vessel. Taking into account that the form of the vessel was developed for the electric driven ferry and it has low body volumes in fore and aft of the vessel (see also Fig. 4), it becomes less resistive to the uneven distributed weights.

The resistance of the model is shown in Fig. 6.

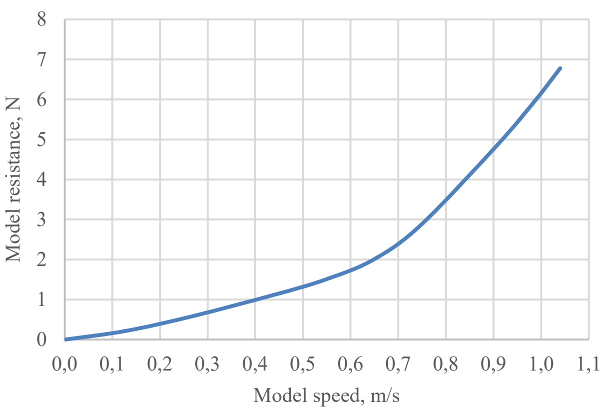

Fig. 6 The resistance of the model for different speeds

The model test results have been recalculated using ITTC method and the results of the calculation are provided in Fig. 7.

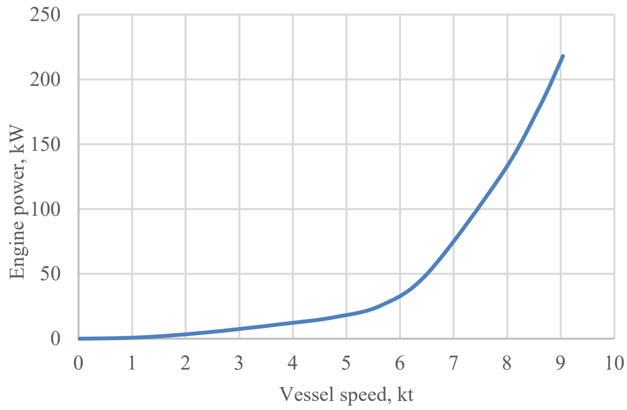

Fig. 7 The resistance values recalculated to the real vessel

The propulsion units chosen for the vessel are Voith-Schneider type eVSP9 [14] with 200 kW power. The results are in accordance with the preliminary design figures. The declared efficiency of the propulsion unit is 65%, therefore with the required engine power of 135 kW to reach 8 knots operating speed, it will be enough power to operate the ferry with operating speed using only one propulsion unit. The average pitching angles recorded during experiment for different speeds are around 1.5 degrees. The results of the model tests are showing that the hull with the fore and aft part formed for the electric driven vessel and having sharp waterline entrance angles is very sensitive to the influence of the water flow at maximum speeds. Although the resistance values received show the positive influence of such hull form, the operation parameters seem to suffer.

V. Conclusions

The comparison of the model resistance recalculated to real vessel required engine power of 135 kW and the preliminary chosen propulsion unit from Voith-Schneider type eVSP9 with 200 kW power shows that the power of the propulsion units is chosen correctly.

The pitching of the model was evaluated and the average pitch angles of 1.5 degrees showed the necessity to search for a better hull form solution considering possible uneven weight distribution at the ends of the ferry. The following tests should focus on increasing of longitudinal stability of the vessel with keeping the resistance values within acceptable limits for the electric driven vessel.

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REFERENCES

[1] Paris climate conference COP21. Accesses on 31.10.2022: https://www.parismou.org/.

[2] Vershinin V., Makhonin S., Parshikov V., Khomyak V. Development of electric propulsion systems for ships of various types. Transactions of the Krylov State Research Centre. 2019; 1(387): 107–122 (in Russian).

[3] N. Bennabi and H. Menana, "Improving Efficiency and Emissions of Small Ships by the Use of Hybrid Electrical Propulsion," no. January, 2017, doi: 10.13234/j.issn.2095-2805.2017.2.001.

[4] N. Bennabi, J. F. Charpentier, H. Menana, J. Y. Billard, and P. Genet, "Hybrid propulsion systems for small ships: Context and challenges," in Proceedings - 2016 22nd International Conference on Electrical Machines, ICEM 2016, 2016, doi: 10.1109/ICELMACH.2016.7732943.

[5] S. Jafarzadeh and I. Schjølberg, "Operational profiles of ships in Norwegian waters: An activity-based approach to assess the benefits of hybrid and electric propulsion," Transp. Res. Part D Transp. Environ., vol. 65, no. October, pp. 500–523, 2018, doi: 10.1016/j.trd.2018.09.021.

[6] A. G. Koumentakos. "Developments in Electric and Green Marine Ships," Appl. Syst. Innov., vol. 2, no. 4, p. 34, 2019, doi: 10.3390/asi2040034.

[7] M. Jaurola, A. Hedin, S. Tikkanen, and K. Huhtala, "Optimising design and power management in energy-efficient marine vessel power systems: a literature review," J. Mar. Eng. Technol., vol. 18, no. 2, pp. 92–101, 2019, doi: 10.1080/20464177.2018.1505584.

[8] D. K. Lee, Y. K. Jeong, J. G. Shin, and D. K. Oh, "Optimized design of electric propulsion system for small crafts using the differential evolution algorithm," Int. J. Precis. Eng. Manuf. - Green Technol., vol. 1, no. 3, pp. 229–240, 2014, doi: 10.1007/s40684-014-0029-9.

[9] J. Zhu, L. Chen, X. Wang, and L. Yu, "Bi-level optimal sizing and energy management of hybrid electric propulsion systems," Appl. Energy, vol. 260, no. December 2019, p. 114134, 2020, doi: 10.1016/j.apenergy.2019.114134.

[10] C. Bordin and O. Mo, "Including power management strategies and load profiles in the mathematical optimization of energy storage sizing for fuel consumption reduction in maritime vessels," J. Energy Storage, vol. 23, no. October 2018, pp. 425–441, 2019, doi: 10.1016/j.est.2019.03.021.

[11] ITTC – Recommended Procedures and Guidelines. (2017). Ship Models.

[12] ITTC – Recommended Procedures and Guidelines. (2021). Resistance Test.

[13] Wolfson Unit official web page. Accessed on 31.10.2022: https://www.wumtia.soton.ac.uk/products/dynamometry

[14] Voith GmbH & Co. official web page. Accessed on 31.10.2022: https://voith.com/corp-en/drives-transmissions/voith-schneider-propeller-vsp.html