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Article title

Experimental dataset of a model-scale ship in calm water and waves

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Keywords

Model-scale Experiments; Ship Hydrodynamics; Ship Propulsion; Hull-propeller-rudder interaction; Calm Water; Regular Waves

Abstract

This article presents data derived from a series of experiments conducted on a scaled model ship, examining its performance in both calm water and regular waves. The acquisition of high-quality experimental data is essential for refining Computational Fluid Dynamics (CFD) simulations and modifying analytical methods to evaluate the powering performance of ships. Despite notable advancements in numerical models, there exists a corresponding imperative to elevate the precision of measurements and insights obtained from towing tank tests. Accordingly, a self-propelled model-scale of the KRISO Container Ship (KCS) hull is used to assess hydrodynamic performance of ships and investigate the interaction between the hull, propeller, and rudder. A set of captive model tests is carried out on the single-screw KCS model in the University of Southampton's Boldrewood towing tank. The model-scale experiments are conducted in an offloaded propeller condition at ship's design speed, which is characterised by a specific Froude number of 0.26. Various test configurations are explored, encompassing four rudder angles, five leeway angles, two wave conditions, and two propeller speeds. Throughout the experiments, multiple parameters were recorded, including the wave environment, ship motions, hull forces and moments, propeller thrust and torque, as well as rudder forces and moments. Initial analysis of the data involved comparing the calm water resistance results with previously published experimental data, revealing a favourable agreement. Additionally, video footage captured from two different angles during various runs serves as illustrative samples of the experimental procedures. This comprehensive series of experiments offers a benchmark for future research endeavours, providing a foundation for refining subsequent experiments, validating numerical methods, and enhancing mathematical models.

SPECIFICATIONS TABLE

Subject	Ocean and Maritime Engineering
Specific subject area	Powering performance investigation of a self-propelled scaled model container ship (KCS hull) in both calm water and waves.
Type of data	Table (.xlsx and .csv format), Videos. Raw
Data collection	All tests were conducted in the Boldrewood towing tank, which measures 138 m long, 6 m wide, and 3.5 m deep, with a maximum carriage speed of 10 m/s. A newly built scaled model of KCS hull with 3.773 m LBP was equipped with propeller thrust and torque load cells, a rpm encoder, a six-component rudder dynamometer, and a six degree of freedom inertial measurement unit [1,2]. Data acquisition with 250 Hz sampling rate was employed and propeller rpm and rudder heading control were achieved using two on-board GPD microPX PCs. This setting allows the model to be tested either attached to a carriage via a conventional post system or be operated in a free running mode either in towing tanks, model basins or lake environments.
Data source location	Institution: University of Southampton, Boldrewood Towing Tank City/Town/Region: Southampton Country: United Kingdom
Data accessibility	Repository name: University of Southampton Institutional Repository [2] Data identification number: *https://doi.org/10.5258/SOTON/D3076* Direct URL to data: https://eprints.soton.ac.uk/490226/
Related research article	*Turnock, S., Hosseinzadeh, S., Zhang, Y., Bowker, J., Buckland, D., Gregory, M., & Townsend, N. (2024). Hull-propeller-rudder interactions: Time-accurate data of a scaled model ship in waves. Ocean Engineering, 312, 119258. Doi: https://doi.org/10.1016/j.oceaneng.2024.119258*

VALUE OF THE DATA

- This comprehensive dataset provides naval architects, researchers, and engineers with valuable insights into hull-propeller-rudder interaction physics. It offers a deeper understanding of ship behaviour under various conditions, including different propeller speeds, drift angles, rudder angles, and wave conditions, which is crucial for improving ship design and performance optimization. The data enables in-depth investigation of propulsion system performance in both calm water and waves, allowing for more accurate modelling of real-world scenarios.
- The high-quality experimental data serves as a benchmark for verifying and validating CFD simulations. This enhances the reliability of numerical methods in ship design processes, potentially reducing the need for extensive physical testing and accelerating the design cycle. Researchers can use this data to refine existing CFD models, improving their accuracy in predicting ship performance across diverse operating conditions.
- The detailed measurements of hull, propeller, and rudder variables at model scale contribute significantly to the development and refinement of scaling processes. This aids in more accurate predictions of full-scale ship performance, connecting the gap between model tests and real-world applications. It enables naval architects to make more informed decisions during the early stages of ship design, potentially leading to more efficient and environmentally friendly vessels.
- The experimental methodology described serves as a guide for conducting self-propelled towing tank tests. This valuable resource can help standardize testing procedures across different facilities, improving the consistency and comparability of results in the field of ship hydrodynamics. It also provides a foundation for researchers to design more advanced experiments, pushing the boundaries of our understanding of ship behaviour in complex sea conditions.
- This dataset tackles challenges in the shipping industry by providing comprehensive performance data for a model ship tested across various drift and rudder angles, addressing critical issues such as energy efficiency improvement and greenhouse gas emission reduction. By offering detailed insights into ship behaviour under various conditions, it empowers engineers to develop more effective strategies for optimizing propulsion systems, minimizing fuel consumption, and enhancing manoeuvrability. This directly contributes to the industry's efforts to meet increasingly stringent environmental regulations and improve overall operational efficiency, potentially leading to more sustainable and cost-effective shipping practices.

BACKGROUND

The shipping industry faces increasing pressure to improve energy efficiency and reduce greenhouse gas emissions [3]. Understanding ship performance in waves is essential to meet these demands. Hull-propeller-rudder interaction significantly affects a ship's overall performance, including fuel efficiency, manoeuvrability, and survivability [4,5]. Although numerical models are widely used in ship design, there is a lack of detailed experimental validation data for predicting the dynamic performance of ships in waves. Our research objectives are to generate a high-quality experimental dataset for a model-scale ship in calm water and waves, provide synchronized time-accurate data for wave height, ship motion, hull forces, propeller performance, and rudder forces, and investigate the effects of leeway and rudder angles on hull resistance and side forces. This dataset addresses the limitations of conventional tank testing, which typically uses towed models at zero drift [6-9]. By including various combinations of leeway and rudder angles, our data offers insights into hull-propeller-rudder interactions under more realistic conditions. This work contributes to improving ship design optimization, which has traditionally focused on calm water performance, and provides valuable experimental data for CFD validation [10-11]. Additionally, it aids in understanding the influence of leeway on hull-propeller-rudder interaction, crucial for the adoption of wind assist technologies.

DATA DESCRIPTION

The dataset presented in this article contains Excel files and videos of experiments conducted in Boldrewood towing tank. The data is stored in five folders named: Raw Data_IMU, Raw Data_Lasso, Raw Data_NI, Readme, and Videos. The specific test conditions are summarised in Table 1. This test matrix was designed to align with research objective outlined in the related research paper. During the experiments, the average water temperature was measured at 17.2°C, and Fresh Water Properties were calculated according to ITTC - Recommended Procedures [12] and used to analyse the data. The Model Fresh Water Density at tank temperature is 998.7 kg/m^3, and Model Fresh Water Kinematic Viscosity at tank temperature is 1.0766E-06 m^2/s.

The 'Readme' folder comprises three files. The 'README.txt' file presents a general introduction to the dataset. The file titled 'Towing Tank Raw Temperature Data 26-06-2023 08_00 - 28-06-2023 05_00.csv' provides details on the environmental conditions during the experiment, including Date/Time, Water temperature from six sensors, Air temperature from two sensors, Pressure, Air humidity from two sensors, and Water depth. The average values for each parameter can be found in the second row of the Excel sheet. Detailed experiment conditions are outlined in the Excel file 'KCS Test Plan June 2023.xlsx', which contains 13 columns representing differences for each run. It is worth noting that the first two runs (Run1 and Run2) were missed and later repeated in Run3 and Run4. The model speed was set at 1.581 m/s, equivalent to a full-scale speed of 24.0 knots. Two different propeller speeds were selected for the experiments, specifically at rotational speeds n=10.0 rps and n=18.3 rps, denoted as RPM$_1$ and RPM$_2$ in Table 1. The propeller speed was adjusted using a radio controller, with each speed calibrated using a pot number. The pot numbers for each run are provided in the 'KCS Test Plan June 2023.xlsx' file.

Table 1. Test plan of the experiments.

Model Speed (m/s)	Leeway angle (deg.)	Rudder angle (deg.)	Wave frequency (Hz)	Wave amplitude (m)	Propeller RPM
Vm =1.581 (Fn= 0.26)	-5	-10	0.798	0.019	RPM$_1$
	0	0			
	2.5	10	0.600	0.038	RPM$_2$
	5	20			
	7.5				
Total	5	4	2	2	2

The data for this series of experiments was collected using three different systems. A six-degree-of-freedom inertial measurement unit (IMU) was employed to gather information on model motion and accelerations. A data acquisition (DAQ) system, known as Lasso and developed by the Wolfson Unit for Marine Technology and Industrial Aerodynamics (WUMTIA), was utilized to record and collect data for each run. Additionally, a DAQ system designed specifically for Boldrewood towing tank carriage, employing NI LabVIEW software, was used to gather the necessary data. These systems were configured to capture various metrics simultaneously, facilitating a comprehensive analysis of the interactions between the hull, propeller, and rudder under different conditions. The implementation of these DAQ systems approach facilitated the collection of a broad spectrum of data points, thereby enhancing the depth and reliability of our findings.

The folder named " Raw Data_IMU " contains data for 49 runs recorded by the IMU device. However, data for runs 1 and 9 are missing, resulting in a total of 47 .csv files. Each run file is named as " Run[run number]_IMU" and includes 11 columns with specific names: 'Time Stamp', 'Heave', 'Roll', 'Pitch', 'Yaw', 'Accelerometer X', 'Accelerometer Y', 'Accelerometer Z', 'Delta Angle X', 'Delta Angle Y', and 'Delta Angle Z'. The second row indicates the unit of measurement for each column. The " Raw Data_Lasso" folder contains data from 49 runs recorded by the Lasso DAQ. As previously mentioned, Run1 and Run2 are unavailable (repeated with the same conditions in Run3 and Run4), leaving a total of 47 runs. Each Run[run number].csv file includes 20 columns of data recorded by the Lasso software, featuring parameters such as 'Time', 'Thrust', 'Torque', 'Shaft RPM', 'Wave height', 'Carriage speed', 'SG0', 'SG1', 'SG2', 'SG3', 'SG4', 'SG5', 'SF AFT', 'Shaft power', 'Fx - rudder', 'Fy - rudder', 'Fz - rudder', 'Tx - rudder', 'Ty - rudder', and 'Tz - rudder'. The second row of each .csv file provides the measurement unit for each recorded channel. It should be noted that the data from SG0 to SG6 represents the rudder dynamometer readings in volts. This data has already been converted to rudder force and moment, and is presented as Fx – rudder, ... , Tz - rudder. Therefore, there is no need for further conversion of the rudder dynamometer data. The folder named “Raw Data_NI” stores data from a total of 49 runs, collected by NI LabVIEW installed on the carriage. The files are named as "Run[run number]_NI.csv" and consist of eight columns: 'Time', 'Carriage Position', 'Carriage Speed', 'Drag', 'SF FWD', 'Heave', 'Trim', and 'Waveprobes'. Data for each run begins from row 11 of the .csv files. Additionally, video footage captured from two different angles (bow and stern) during various runs serves as illustrative samples of the experimental procedures. The "Videos" folder contains six .MP4 files displaying footage from three different runs. Each filename is based on the run number and test condition. For instance, 'Run20_Calm Water_Bow.MP4' features a video showing the bow view of Run20 conducted in calm water, while 'Run30_Wave_Stern.MP4' presents the stern view of Run30 in wave.

It should be noted that a challenge of using complementary DAQ systems is the need to synchronize their acquisition. When the model is attached to the carriage, the onboard (Lasso) and carriage (NI) systems can be synchronized by splitting a cable and acquiring the same signal system on both. It is more difficult with the IMU; however, synchronization can be inferred from the x-axis acceleration and propeller measurements. When the rudder angle is not acquired, changes in angle when attached to the carriage can be observed as variations in side-force on both the rudder dynamometer and the hull side-force channels. Table 2 provides the channels name of collected data from each DAQ system.

Table 2. Channels of different DAQ systems.

DAQ sys.	LabVIEW	Lasso	IMU
Channels	Time	Time	Time Stamp
	Carriage Position	Thrust	Heave
	Carriage Speed	Torque	Roll
	Drag	Shaft RPM	Pitch
	SF FWD	Wave height	Yaw
	Heave	Carriage speed	Accelerometer X
	Trim	SG0	Accelerometer Y
	Waveprobes	SG1	Accelerometer Z
		SG2	Delta Angle X
		SG3	Delta Angle Y
		SG4	Delta Angle Z
		SG5	
		SF AFT	

As previously mentioned, the presented dataset contains raw experimental data, which requires a comprehensive understanding of each test case for effective utilization. The experiments were conducted under various conditions, including both calm water and wave scenarios, all of which are detailed in the 'KCS Test Plan June 2023.xlsx' file. To provide clarity, an initial analysis of one case in calm water and one case in waves are outlined here.

The test plan file indicates that Run3 took place in calm water with zero leeway angle, zero rudder angle, and no propeller attached to the hull. Run3 involves three different model speeds, which required to be separated from each other to provide the drag mean value corresponding to its respective speed. Figure 1 illustrates the trimming process employed during the post-processing stage. In this particular run (Run3_NI), three different model speeds were experimented with. Consequently, it becomes necessary to identify the points in time when the carriage speed undergoes changes. The process of dividing run segments should be carried out strategically, ensuring that the data is trimmed during stable system conditions and providing a minimum of 10 seconds of recorded data. In this specific run, three distinct segments were trimmed (V_{m-1}, V_{m-2}, V_{m-3}), aligning with the testing of three different model speeds. It is important to ensure that the selected segment points are applied consistently across all channels of the different DAQ systems. This run was specifically conducted for the purpose of comparing recorded data with previous experiments and TOKYO’15 data [13]. As such, no leeway angle, rudder angle, or propeller was involved. This represents the calm water data for the bare hull with rudder appendage. A similar process has been applied for Run4_NI, and the data are presented in Table 3.

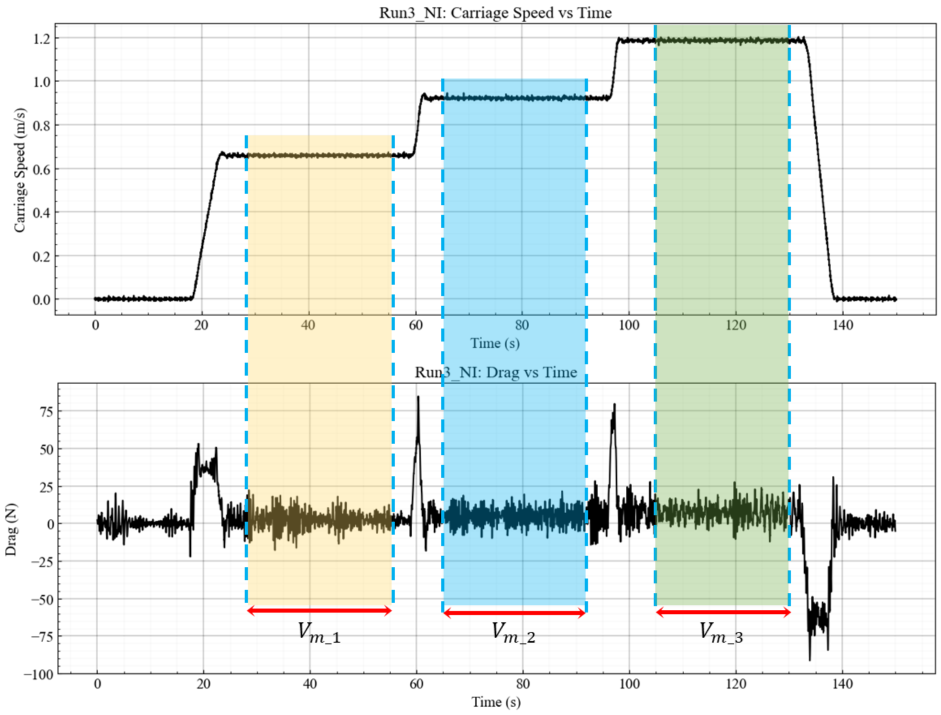

Figure 1. Trimming process of the calm water resistance at three different model speeds in Run3_NI.

The utilization of the KCS model in this experiment offers a valuable opportunity to cross-reference and compare the recorded data with the existing dataset from the Tokyo 2015 workshop [7]. The process commenced with a comprehensive examination of preliminary data derived from test runs employing the same model. These results were then compared to the scaled values obtained from the Tokyo 2015 tests on the KCS model, as well as to the historical test data from the University of Southampton (UoS) model [14]. The findings of these comparative analyses are presented in Figure 2, and further details are documented in Table 3. In this table, "V_S" denotes the speed of the full-scale ship, "V_m" represents the speed of the scaled model, "Fn" reflects the Froude number, and "R_{TM15}" corresponds to the model total resistance at 15°C. This multi-faceted approach not only enhances the credibility of the experimental data but also establishes a robust foundation for evaluating the performance and reliability of our results.

Table 3. Comparison of model total resistance to TOKYO'15 data at 15°C water temperature and in calm water condition (Run3_NI and Run4_NI).

			TOKYO 15 rescaled	**UoS Sept 22**	**UoS Nov22**	**Present Data**	**Comparison to Tokyo rescaled data (%)**		
V_S	**V_m**	**Fn**	**R_{TM15}**	**R_{TM15}**	**R_{TM15}**	**R_{TM15}**	**Sep 22 (ΔR_T)**	**Nov 22 (ΔR_T)**	**Present Data (ΔR_T)**
knots	**m/s**	**-**	**N**	**N**	**N**	**N**			
10.00	0.659	0.11	2.49	2.51	2.56	2.56	0.83	2.53	2.71
14.00	0.922	0.15	4.65	4.81	4.86	4.86	3.42	4.56	4.46
18.00	1.186	0.19	7.31	7.44	7.57	7.43	1.74	3.48	1.59
21.00	1.384	0.23	9.87	10.11	10.35	9.90	2.39	4.71	0.25
24.00	1.581	0.26	13.61	13.77	14.32	13.72	1.17	5.07	0.80
26.00	1.713	0.28	18.90	18.95	20.00	18.51	0.22	5.65	2.10

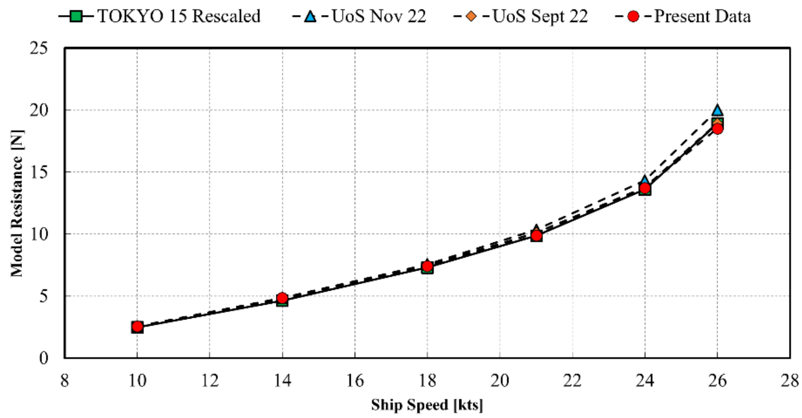

Figure 2. Calm water resistance at different ship speed scaled for 15°C water temperature [1].

Since the KCS model is equipped with a radio controller capable of remotely controlling the rudder angle and propeller speed, the rudder angle was adjusted during each run to enhance the efficiency of the experiment. The rudder angle was varied across a range of 4 angles, from -10 to 20 degrees. Figure 6 provides a visual depiction of the operational procedure, indicating that the carriage begins with a -10-degree angle and, after traveling 25 meters, the rudder angle is adjusted in accordance with the test plan. Unlike the appended hull resistance test in different speeds, when examining tests involving different rudder angles, the plots of drag and carriage speed can be insufficient for accurately determining the trimming part of the recorded data. In this scenario, a more effective approach is to use the time history of rudder forces. Figure 3 provides an illustrative example of a sample run featuring various rudder angles in wave.

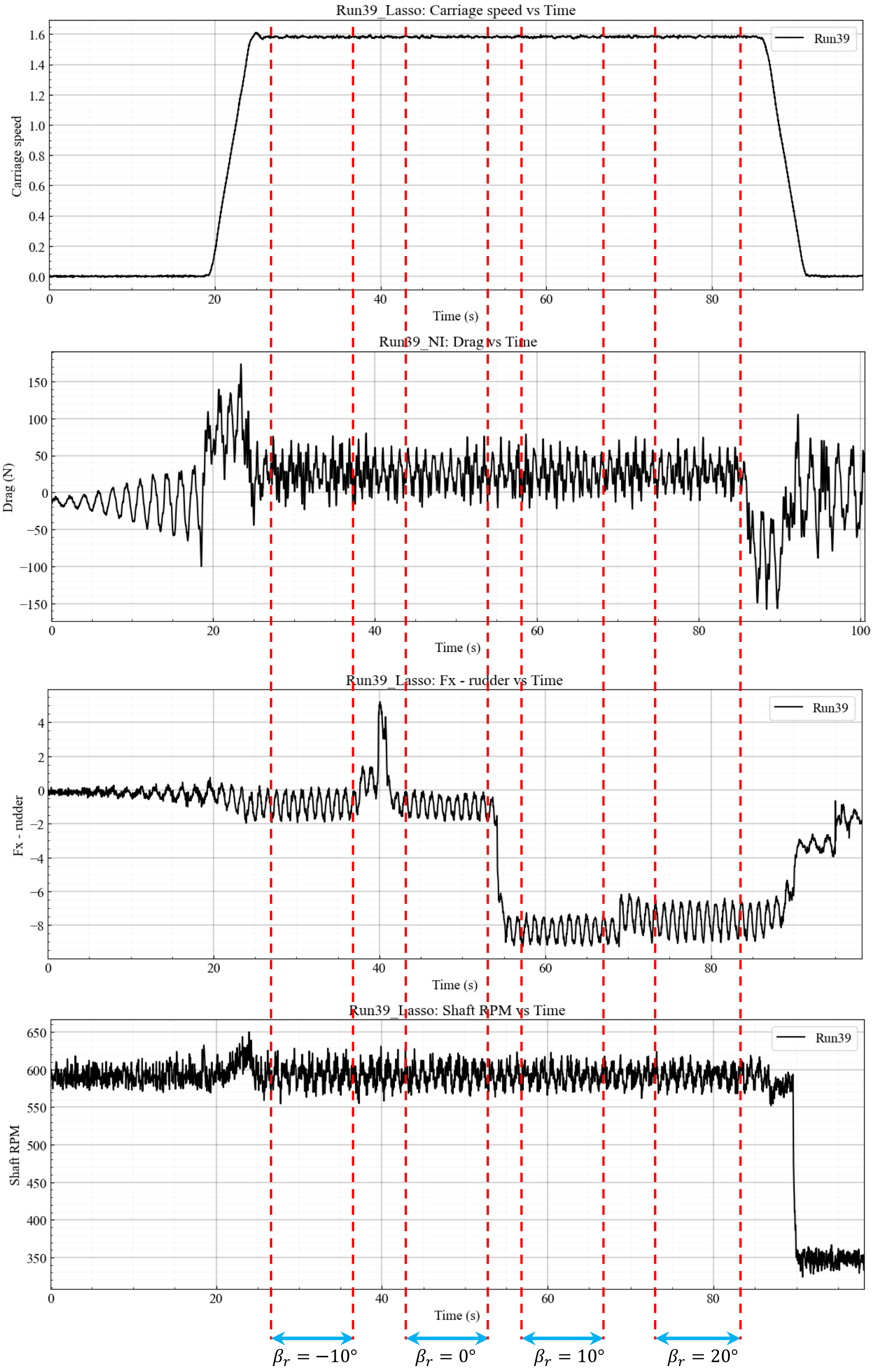

Figure 3. Trimming process of Run39 in wave at different rudder angles with -5 leeway angle and 0.6 Hz wave frequency.

To provide a more in-depth understanding of the trimmed data, Figure 4 showcases the trimmed data specifically for a -10-degree rudder angle (first segment in Figure 3), including carriage speed, shaft RPM, drag, , Fx-rudder, wave height, and heave. The same method can be applied to all remaining channels. It worth noticing that the data located in the repository and plots provided in this article are unfiltered data. It is recommended to utilize zero-phase digital filtering to reduce noise and smooth out fluctuations in a signal while preserving essential features such as peaks, valleys, and trends. These descriptions provide a more detailed insight into the trimmed data. Following data trimming, the mean values for each segment can be calculated. Subsequently, various parameters can be derived from the experimental data, enabling an in-depth analysis of the impact of different leeway angles and rudder angles on the hydrodynamics performance of the vessel.

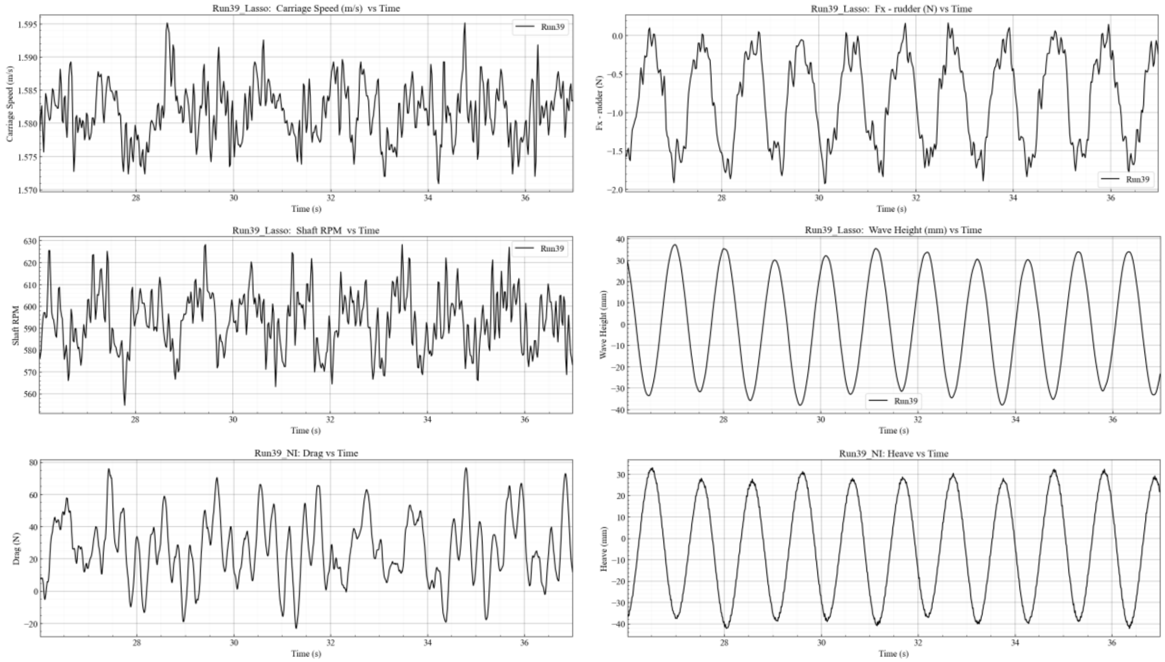

Figure 4. Trimmed data of different channels for the case with -10-degree rudder angle and -5-degree leeway angle (first segment of Figure 3).

EXPERIMENTAL DESIGN, MATERIALS AND METHODS

In this series of experiments, a scaled geosim model of the KRISO Container Ship (KCS) hull form with a scale ratio of λ=1/60.96 was manufactured from laser cut plywood frames with strip planks and given a hydrodynamically smooth paint finish. Table 4 presents the main specifications of the University of Southampton (UoS) KCS model. The model has standard trip studs mounted at 5% of length from bow. To provide valuable insights into the interaction between the hull, propeller, and rudder, both rudder and propeller were used in this experiment. This allows a thorough series of tests to be carried out across various conditions, encompassing RPM settings, rudder angles, and drift angles, in both calm water and wave scenarios. The model was constructed with a detachable bow section, facilitating the attachment and testing of various bow types. Standard trip studs were mounted at 5% of the length from the bow to trigger turbulence in the boundary layer. This technique ensures simulation of full-scale flow physics on the model, minimizing scale effects and improving the accuracy of the experiments. Figure 5 illustrates the test setup and the installed model. As depicted, the model is attached at two points to the towing tank carriage to measure side forces and conduct the experiment at various drift angles. The main post and second post were 2.5 m and 1.5 m away from the stern, respectively, and the yaw pivot point that creates the drift angle was 2.0 m from the stern and was in the centre of the main post and second post. The rudder dynamometer was positioned 98.43 mm from the stern and 261.08 mm from the bottom of the model. The model appendages, including the rudder and propeller, are depicted in Figure 5c and d, respectively.

Table 4. Main particulars of KCS hull.

Parameters	Full-Scale	UoS Model
Scale (λ)	1	60.96
Displacement (tonne)	52030	0.23
Depth (m)	19.0	0.312
Breadth (m)	32.2	0.528
LBP (m)	230	3.773
LWL (m)	232.5	3.814
Draft Amidships (m)	10.8	0.177
KCS Rudder	NACA 0018	
Wetted Area Rudder (m^2)	115	0.031
Wetted Surface Area (hull+rudder) (m^2)	9539	2.567
Propeller	KP505 (NACA 66) 5 blade	
Propeller Diameter (m)	7.9	0.13
A_e/A_o	0.8	0.8
Propeller rotation direction (from stern)	Clockwise	clockwise

The model was towed using a twin post system that used a manufactured plate fitted in the model. This plate allows a range of drift angles to be set between +/- 8 deg. in 0.5 deg. intervals. For the drift tests the twin posts are mounted on the towing tank centreline. As a result, the motion of the model is constrained to heave and pitch about the tank centreline rather than the ship axis system. The locations of the posts are given in Figure 5a. The model was equipped with the necessary devices that need to be installed on it. Since the KCS model was originally designed for free-running tests, the DAQ box designed by the Wolfson Unit is consistently installed to the model. Additionally, the batteries (two) and two on-board GPD microPX PCs were attached to the model. A high-quality finished titanium alloy KP505 propeller was manufactured and used in the self-propelled tests (see Table 4 and Figure 5d). In addition, for these experiments a single piece all-movable rudder with the same planform as the original semi balanced skeg rudder was used (Table 4).

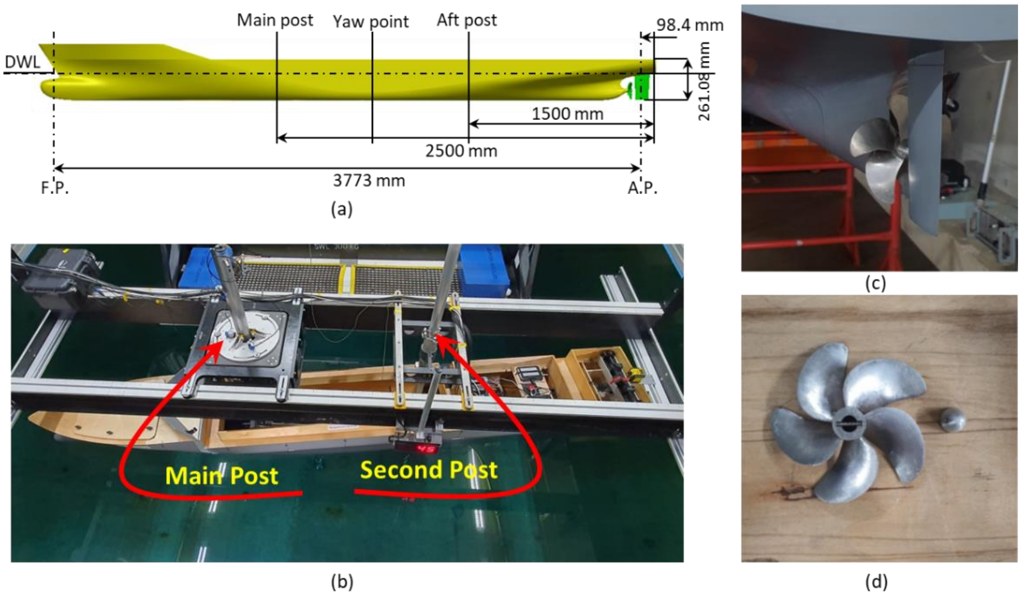

Figure 5. a) a side view of KCS model; b) test setup with the location of measurement points; c) KCS rudder view from the stern of the model; d) KP505 propeller model [14].

Typically, the weight of the bare hull and all instrumentation should be measured separately to precisely align with the designed loading condition and draft. To reach the intended loading condition, the model was ballasted below the designated waterline, and the desired draft was accomplished by adding supplementary weights to the model. During the experiments, data was collected from different channels, as detailed in Table 2. Following each run, different DAQ software was used to assess the data for consistency before proceeding to the next run. A sampling rate of 250 Hz was maintained for all collected data. It is worth noticing that the main data recorded in the tank axis followed the right-hand rule (positive to port) both for the model and rudder and the rudder dynamometer recorded the data in ship axis system.

All tests were conducted in the Boldrewood towing tank [15], which measures 138 m long, 6 m wide, and 3.5 m deep, with a maximum carriage speed of 10 m/s. The tank is equipped with 12 independent 0.5 m HR Wallingford wave makers at its western end, complemented by a static beach on the eastern side and a deployable full-length side beach along the southern wall [15]. The carriage drive facilitates testing of up to four tow speeds per run, with a fixed rpm controller enabling the use of preset rpm values. Similarly, predefined rudder angles optimize the efficiency of each test. Table 5 presents two specific head sea regular waves employed in the experiments. The selection of these particular wave frequencies is intended to offer a thorough exploration of the impact of various sea states on hydrodynamic interactions. These wave conditions, coupled with adjustments in rudder and drift angles, constitute a robust experimental framework for examining a range of real-world ocean scenarios.

Prior to initiating the test matrix, it is essential to calibrate all equipment for precise and reliable outcomes. This involves setting baseline measurements for all sensors, adjusting the data acquisition system, and validating the alignment and settings of both the rudder and propeller. The calibration procedure plays a crucial role in mitigating errors and discrepancies, laying a robust foundation for the successive stages of the study. A Mini40 IP68 model was employed to measure the force acting on the rudder. The rudder dynamometer was calibrated using a calibration matrix for the force-torque sensor from ATI Industrial Automation, the product's manufacturer. To calibrate the forward side force, we used weights and hangers, recording the measurements with the DAQ software (Lasso). The calibration method is important as it determines the convention for measuring data, such as using the right-hand or left-hand rule. After installing the hanger on the test setup and selecting the correct channel, we added weights (e.g. 0-40 N) incrementally and saved the data. We repeated this process for drag calibration, using a different installation approach (as the direction is different). In our experiment, we followed the right-hand rule, positioning the side force towards the starboard (right side) of the model. It's essential to maintain complete stillness of the carriage during calibration to ensure accurate results. The aft side force data was measured using an LVDT (Linear Variable Differential Transformer) power supply. To calibrate the aft side force block, we first securely clamp it to a desk. We then apply a range of weights, hanging them from the block. This process provides calibration points across a full range, ensuring accurate force measurements throughout the experiment. To calibrate the heave sensor, a dedicated device was attached to the main post. A wire connected to this post allowed various distances to be measured, enabling sensor calibration. For this experiment, the heave range was set from 0 mm (low value) to 250 mm (high value). The pitch sensor calibration involved setting a range of ±45 degrees. Both calibration data sets were saved in the DAQ software to ensure accurate measurements during the experiment.

Table 5. Details of regular wave properties [14].

	Wave-1	Wave-2
λ/LBP	0.651	1.150
Wavelength (m)	2.455	4.338
Wave frequency (Hz)	0.798	0.600
Wave period (s)	1.254	1.667
Wave speed (m/s)	1.958	2.602
Wave amplitude (m)	0.019	0.038

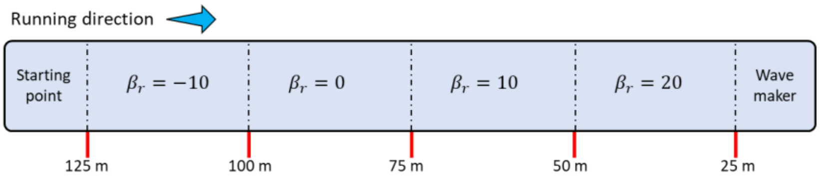

Figure 6. Schematic view of running method for each test in the tank

As already stated, during each run four rudder angles were configured to change after travelling 25 meters of the tank. This approach allows testing all 4 rudder angles in one run with the same RPM and leeway angle and wave condition (if applicable). Figure 6 visually outlines the running process, illustrating that the carriage initiates with a -10-degree rudder angle and, after covering

25 meters, the rudder angle adjusted according to the test plan. This sequence continues until all positive/negative rudder angles are tested. It is essential to make gentle adjustments to the rudder angle, and a minimum of 10 seconds of data should be recorded for each set of rudder angles. This series of experiments was conducted based on the recommendations presented by the International Towing Tank Conference (ITTC) [16-18] and the guidelines for self-propulsion tests outlined by [19].

The following steps were considered for each test runs:

1. Adjust the desired leeway angle.
2. Confirm the proper functioning of all sensors.
3. Set the DAQ system to zero.
4. Start the wave maker with appropriate wave amplitude and frequency (skip this step for calm water)
5. Initiate the DAQ system to begin recording data.
6. Set the propulsion RPM to the desired pot number if it is not zero.
7. Start the carriage with a zero-rudder angle.
8. Change the rudder angle after covering 25 meters.
9. Stop the DAQ system upon reaching the end of the tank.
10. Set both the rudder and propeller to zero and preparing for the next run.

It is noteworthy that a minimum waiting time of 5–10 minutes was applied between two runs (calm water) and 10-20 minutes (wave condition) to ensure the water surface had calmed down.

LIMITATIONS

Not applicable

ETHICS STATEMENT

The authors have read and follow the ethical requirements for publication in Data in Brief and confirming that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

CRediT AUTHOR STATEMENT

Saeed Hosseinzadeh: Validation, Formal analysis, Investigation, Visualization, Writing - Original Draft, Writing - Review & Editing; **Stephen Turnock:** Conceptualization, Software, Methodology, Writing - Review & Editing, Supervision, Project administration, Funding acquisition; **Haesol Lee:** Conceptualization, Methodology, Data curation, Validation, Formal analysis, **Rodolfo Olvera:** Resources.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the first-year cohort of students of SESS6077 for their participation in testing a new approach to ship power laboratories. Additionally, special thanks are extended to James Bowker, Magnus Gregory, and Sam MacPherson for their assistance. Funding for the development of the KCS hull was supplied by the School of Engineering and the instrumentation fitout was part of the Clean Maritime Demonstration project AMPS-USV as well as Winds of Change project of Innovate UK. The expertise of Boldrewood towing tank staff Bertrand Malas and David Turner was vital.

DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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