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COMPARATIVE ANALYSIS OF THE MANEUVERABILITY PERFORMANCE OF A CHEMICAL TANKER WITH THE POWER OF THE PROPULSION INSTALLATION PB=6480kW

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ABSTRACT

This article investigates ship maneuverability by conducting and comparing calculations using two distinct computational platforms. The results obtained from these calculations are subsequently compared with real data from the sea trials. A detailed analysis of the discrepancies between theoretical and empirical results provides insights regarding the reliability and precision of each computational platform in assessing ship maneuverability in the naval domain. This research contributes to improving methods for evaluating ship performance and validating computational platforms used in the industry.

Keywords: manoeuvrability, turning circle, sea trials, preliminary

1. Introduction

The objective of the study case is the comparative analysis of the maneuverability performance of a chemical tanker with PB = 6480 kW. This analysis has been performed by comparing the maneuverability performance estimates with the help of the two specialized programs, namely: PHP and MPP with the results from the sea trials.

The purpose of the maneuverability tests is to verify the compliance of the technical and operational characteristics of the vessel with the parameters specified in the design documentation.

The main standard maneuvers recommended by ITTC and IMO organizations are: ship turning circle, yaw exit, zig-zag test, spiral maneuvers (direct and reverse), stop tests (inertia and crash-stop), man over board rescue maneuver, etc. Standard maneuvers provide essential information about the maneuverability performance of the vessels in calm water conditions and unlimited depth (greater than five drafts). If the maneuverability performance is acceptable under these assumptions, then the ship shall be considered to behave satisfactorily and correspond in accordance with its technical and operational characteristics.

The maneuverability of the vessel can be described by the following specific qualities [1]:

- the ability to initiate, as quickly as possible, a manoeuvre to avoid an obstacle (a yaw manoeuvre);
- ability to maintain a high speed in the yaw maneuver;
- the ability to exit the yaw movement;

- the ability to stop the vessel at short notice and for as short a distance as possible;

- ability to maintain the direction of navigation, in the absence of external disturbances (wind, waves, sea currents).[1]

2. Standard manoeuvres to identify maneuvering qualities

The main maneuvers performed at the sea trials are [1]:

- yaw test (actual manoeuvrability);
- spiral test (road stability);
- manoeuvre to exit the yaw (road stability);
- zigzag maneuver (counter-maneuvers);
- stop test;
- williamson maneuver (man over board rescue maneuver).

The paper presents the comparison between empirical methods and results from sea trials for one of the main maneuvers, namely the yaw test.

3. Ship turning circle

It is a manoeuvre used to determine the actual turning qualities. In the approach phase, the ship proceeds on its straight path at constant speed. In phase I, the rudder heel manoeuvre is performed starboard, with 35°. Due to the inertia of the ship, the angle of drift, β is null. Practically, it is considered that phase II begins with the appearance of the first non-zero values of the angle of drift β and of the trajectory tangent component of the velocity vector, v. At this stage, the vessel follows a time-varying response trajectory. The ship's head angle ψ, also changes over time. At the end of this phase, the radius of yaw stabilizes over time.

The geometric aspects that characterize phase II are:

- the advance, denoted by AD (distance measured in the direction of the initial course, between the point of zero position (ψ = 0) and the point corresponding to the rotation of the vessel by 90° (ψ = 90)),
- transfer (distance measured from the point corresponding to the rotation of the vessel by 90° (0 ψ = 90) to the right corresponding to the direction of initial course).
- In phase III, the radius of turn is practically constant in time, and the trajectory of the ship becomes an arc. The geometric sizes of phase III are:
- tactical diameter, denoted TD (distance measured from the point corresponding to the rotation of the vessel by 180° (ψ = 180°) to the right corresponding to the direction of initial course) [2];

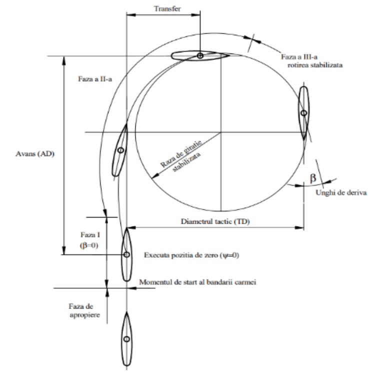

Figure 1 Trajectory of vessel in yaw manoeuvre

4 Description of the vessel

The ship studied in the article is a chemical/oil tanker, which was built in 2019 at Constanta Shipyard and is described by the following main dimensions:

Table 1 Main dimensions

Dimension	Value	U.M.
Length between perpendiculars	173.3	m
Maximum length	179.99	m
Depth	17.0	m
Breadth	32.26	m
Draught	10.6	m
Scantling draught	11.2	m
Deadweight	37000	tdw
Scantling deadweight	40050	tdw
Service speed	14.0	Kn

5 Manoeuvrability performance estimates

Estimates of the manoeuvrability performance of the oil-type vessel were made using the following:

- Maneuverability Performance module of the Preliminary Hydrodynamics Performance (PHP) software platform, implemented by the Research Center of the Faculty of Naval Architecture, "Dunarea de Jos" University Galati [3];
- According to the Multi-objective Project Planning (MPP) program conducted by Prof. M.G. Parsons from the University of Michigan, USA, the program can be easily used for preliminary forecasting of yaw performance and path stability of ships. The influence of limited depths on hydrodynamic derivatives may also be considered, see table 2, [4].

Table 2 Results of the estimated turning performance

Name	PHP results	MPP results	U.M.
Rudder heeling angle	35	35	°
Stabilised yaw diameter	475,31	458,98	m
Tactical diameter	596,025	578,12	m
Advance	539,826	526,01	m
Speed	6,53	6,01	Kn

6 Results from sea trials

The sea trials results were obtained from testing the vessel after completion of construction to verify the functionality of the vessel under normal operating conditions and the compliance of the technical and operational characteristics of the vessel with the parameters specified in the design documentation.

The results of the sea trials were obtained by means of GPS (Global Positioning System) equipment being recorded from second to second. In order to compare them with those estimated by preliminary design programs, we had to convert them from GPS coordinates into Cartesian numbers. This was achieved with the help of tabular spreadsheet.

The results from the sea trials to be studied have been obtained for 3 sister ships, one of them being the vessel studied in the paper, and the other two having the same main dimensions with it. The 3 ships were designated SHIP 1 (being the ship previously studied), SHIP 2 and SHIP 3.

Table 3 Main dimensions of surveyed ships

	SHIP 1	SHIP 2	SHIP 3	
Name	**Value**			**U.M.**
Length between perpendiculars	173.3	172	173	m
Maximum length	179.99	179.96	179.9	m
Depth	17	16.5	16.8	m
Breadth	32.26	32.2	32.2	m
Draught design	10.6	10.5	10.5	m
Scantling draught	11.2	11	11.1	m
Deadweight	37000	37500	37000	tdw
Scantling deadweight	40050	40000	40050	tdw
Service speed	14	14	14	Kn

Table 4 GPS coordinates for SHIP 1 (extract)

	STARBOARD				
Index	UTC	Lat	Lon	SoG	CoG
0	0:34:48	43.76	29.39	5.28	358.61
1	0:34:49	43.76	29.39	5.28	358.3
2	0:34:50	43.76	29.39	5.28	358.31
3	0:34:51	43.76	29.39	5.29	358.41
4	0:34:52	43.76	29.39	5.28	358.44
5	0:34:53	43.76	29.39	5.28	358.78

Table 5 GPS coordinates for SHIP 1 (extract)

	PORTSIDE				
Index	UTC	Lat	Lon	SoG	CoG
0	11:33.0	43.81	29.35	5.19	358.48
1	11:34.0	43.81	29.35	5.19	358.76
2	11:35.0	43.81	29.35	5.19	358.85
3	11:36.0	43.81	29.35	5.18	358.68
4	11:37.0	43.81	29.35	5.19	358.58
5	11:38.0	43.81	29.35	5.15	359.04

Table 6 GPS coordinates for SHIP 2 extract)

	STARBOARD				
Index	UTC	Lat	Lon	SoG	CoG
0	15:32:25	44.02	29.21	7.03	358.88
1	15:32:26	44.02	29.21	7.1	358.52
2	15:32:27	44.02	29.21	7.13	359.78
3	15:32:28	44.02	29.21	7.12	0.45
4	15:32:29	44.02	29.21	7.25	359.48
5	15:32:30	44.02	29.21	7.23	358.75

Table 7 GPS coordinates for SHIP 2 (extract)

	PORTSIDE				
Index	UTC	Lat	Lon	SoG	CoG
0	05:31.0	43.98	29.23	7.21	358.32
1	05:32.0	43.98	29.23	7.3	358.15
2	05:33.0	43.98	29.23	7.22	358.16
3	05:34.0	43.98	29.23	7.33	358.91
4	05:35.0	43.98	29.23	7.09	359.75
5	05:36.0	43.98	29.23	7.11	359.79

Table 8 GPS coordinates for SHIP 3 (extract)

	STARBOARD				
Index	UTC	Lat	Lon	SoG	CoG
0	07:19.0	43.85	29.31	5.92	357.22
1	07:20.0	43.85	29.31	5.94	357.23
2	07:21.0	43.85	29.31	5.92	357.16
3	07:22.0	43.85	29.31	5.94	357.12
4	07:23.0	43.85	29.31	5.93	357.01
5	07:24.0	43.85	29.31	5.95	357.15

Table 9 GPS coordinates for SHIP 3 (extract)

	PORTSIDE				
Index	UTC	Lat	Lon	SoG	CoG
0	8:42:54	43.82	29.32	6.33	358.41
1	8:42:55	43.82	29.32	6.34	358.35
2	8:42:56	43.82	29.32	6.32	358.32
3	8:42:57	43.82	29.32	6.33	358.27
4	8:42:58	43.82	29.32	6.32	358.26
5	8:42:59	43.82	29.32	6.33	358.28

Following the transformation of GPS co-ordinates into Cartesian numbers, graphs were generated corresponding to the trajectories of the 3 ships for the yaw maneuvers for both port and starboard.

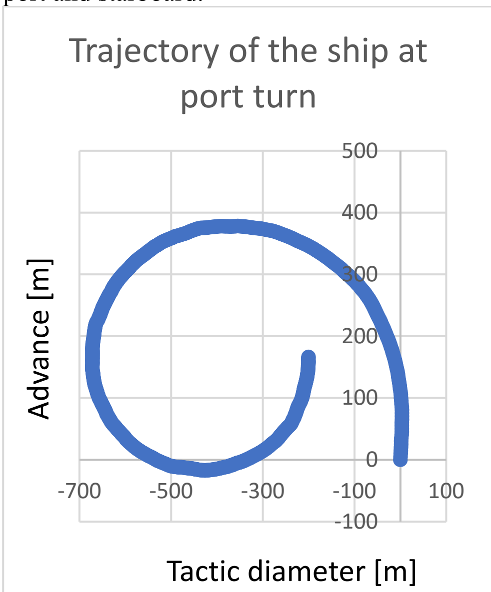

Figure 2 Trajectory of vessel at yaw manoeuvre for SHIP 1, turning to portside

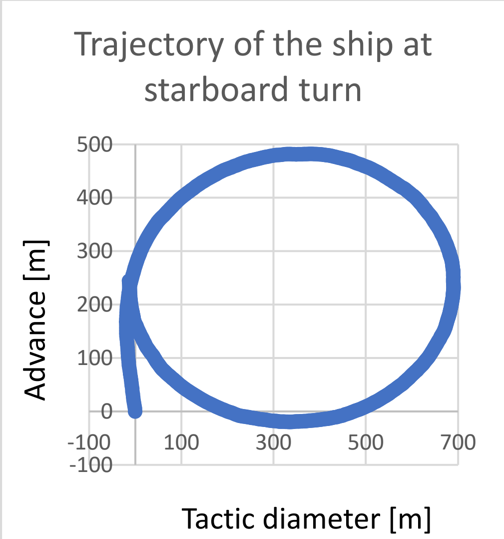

Figure 3 Trajectory of vessel at yaw manoeuvre for SHIP 1, turning to starboard

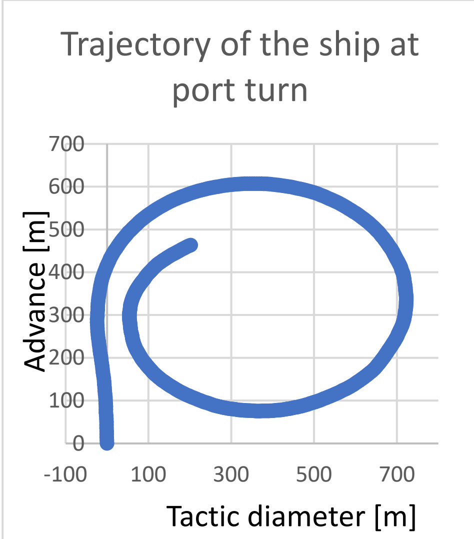

Figure 5 Trajectory of vessel at yaw manoeuvre for SHIP 2, turning to portside

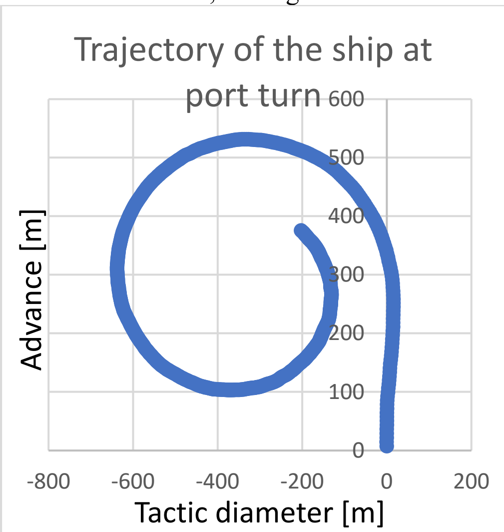

Figure 4 Trajectory of vessel at yaw manoeuvre for SHIP 2, turning to starboard

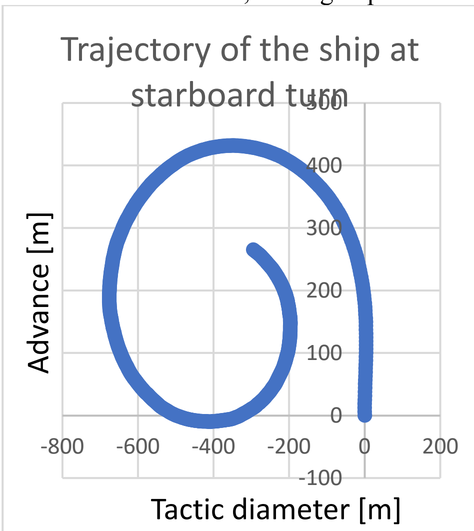

Figure 6 Trajectory of vessel at yaw manoeuvre for SHIP 3, turning to starboard

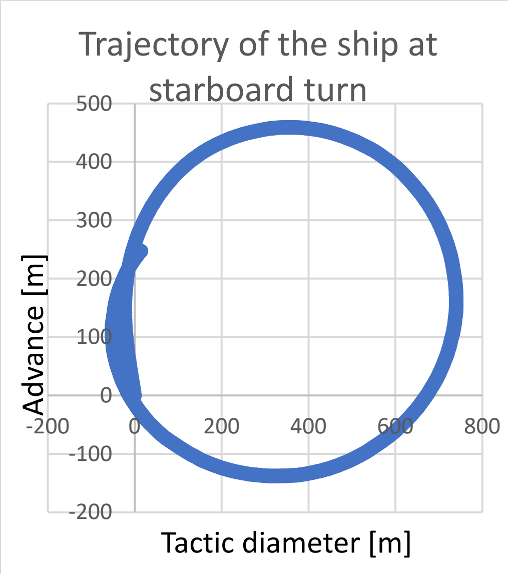

Figure 7 Trajectory of vessel at yaw manoeuvre for SHIP 3, turning to portside

Graphical representation of trajectories at port yaw maneuver of the 3 ships:

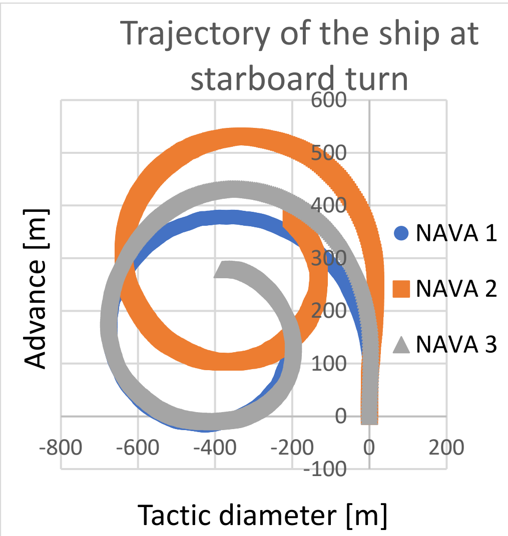

Figure 8 Trajectory of study vessels at port yaw manoeuvre, turning to starboard

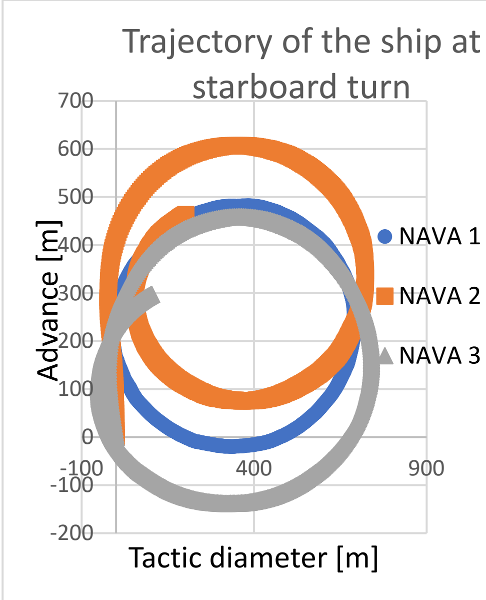

Figure 9 Trajectory of study vessels at port yaw manoeuvre, turning to portside

From **Figure 8,** it can be seen that SHIP 2, unlike the other two ships, has a larger advance, but smaller tactical diameter.

From **Figure 9,** it can be seen that SHIP 2, unlike the other two ships has a larger advance but a tactical diameter similar to that of SHIP 3, while the tactical diameter of SHIP 1 is smaller than theirs.

Table 10 Results obtained for yaw manoeuvre

	STARBOARD		
	SHIP 1	SHIP 2	SHIP 3
Rudder heeling angle [°]	35	35	35
Stabilised yaw diameter [m]	690	700	710
Tactical diameter [m]	690	700	710
Advance [m]	500	600	490
Speed [Kn]	10,5	14,3	12

Table 11 Results obtained for yaw manoeuvre

	PORT		
	SHIP 1	SHIP 2	SHIP 3
Rudder heeling angle [°]	35	35	35
Stabilised yaw diameter [m]	480	510	490
Tactical diameter [m]	680	640	690
Advance [m]	380	520	430
Speed [Kn]	9,8	14,1	12,1

Table 12 Comparative analysis of empirical vs. nature results for port yaw manoeuvre

Name	SHIP 1	SHIP 2	SHIP 3	PHP results	MPP results
Rudder heeling angle [°]	35	35	35	35	35
Stabilised yaw diameter [m]	480	510	490	475,31	458,98
Tactical diameter [m]	680	640	690	596,025	578,12
Advance [m]	380	520	440	539,826	526,01
Speed [Kn]	9,8	14,1	12,1	6,53	6,01

7 Conclusions

The work was carried out using maneuverability performance estimation programs called PHP and MPP, and then the results of mathematical estimates were compared with the results obtained in the sea trials.

The diagrams for the yaw maneuver on both port and starboard for the 3 sister ships were made in order to be able to visualize the differences in maneuverability performance for 3 vessels with almost identical main dimensions.

In Figure 8, entitled 'Trajectory of study vessels at port yaw manoeuvre, turning to starboard, it can be seen that SHIP 2 has a different trajectory than SHIP 1 and SHIP 3.

Also, from Figure 8, it can be seen that the trajectory of SHIP 1 and SHIP 3 are almost identical, which means that the presence of disturbances did not significantly influence the maneuverability tests.

Following the analyses, it can be seen that the results of the maneuverability performance estimates are satisfactory as they are close to those of sea samples, which means that the two programs used,

PHP and MPP, to estimate numerical methods can be used at the preliminary design stage of shipbuilding.

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