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Wind Affecting Berthing Operations

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ABSTRACT: Almost every voyage culminates in a manoeuvre to berth the ship safely along a quay or wharf. During this phase a ship is affected by a number of factors, one of them being wind. This paper seeks to understand how wind affect a ship in regards of power consumption during berthing. A field study was conducted on a car passenger ferry, where every approach in one harbour was logged and analysed over a period of four months. The goal was to provide greater knowledge about energy usage and the study presents several interesting findings. It is estimated that power consumption is stable when the median wind speed is less than 4 m/s. Stronger winds have a significant effect on power consumption, e.g 17 m/s gives an 106,31% increase from calm conditions. Furthermore there is not discovered any correlation between consumption and wind direction in this study.

1 INTRODUCTION

Berthing of a ship is a critical phase of a journey that could lead to damages of own vessel as well as other structures [1, p. 2]. A navigator may experience avderse effects of wind while manoeuvring in harbors or restricted waterways [2]. This article will address this force in regards of power consumption, considering that external forces have implications for energy usage.

A detailed description of berthing operations will follow in the next section. It will also address some of the factors that affect ship handling and how to compensate for them. Section three will present the method used in this field study and important information about the ship and port. Section four presents the results of the study while section five discuss the results based on relevant literature. The last sections will present a conclusion and further research on the topic.

2 BACKGROUND

Ship handling is explained as close-quarter work were the navigator has to use forces under his control, direct or indirect, to cater for elements that are not under control [3, ch 1, p.1]. Elements under control would be propulsion or loading condition, while external factors such as current, wind or visibility are not under control [1, pp. 10-13]. A ship will be safely handled if elements are taken advantage of instead of disregarding them.

A ship handler needs to know how his ship responds to these factors and especially in port environments where there are several risks involved.

2.1 *Golden rules of berthing*

To safely berth a ship there are some universal guidelines that must be followed. One important rule is to have a controlled approach at slow speed [1, p. 4]. Slow speed is critically important when under keel clearance is low or when using a bow thruster. Depending on the hull design, a bow thruster will be ineffective between 2 and 5 knots [1, p. 12], [3, ch 1, p. 12]. At the same time, current and wind will have a greater effect on manoeuvrability at slow speed.

2.2 *Berthing in wind*

Wind is essentially air in motion that occurs due to pressure and temperature differences [3],[4]. The air is drawn from high pressure areas to low pressure areas to equalize the difference. Wind speed, also called velocity, increases with the pressure joint gradient. Near ground level, there are several factors that determine wind direction, such as terrain, topography and structures. Wind speed can also vary, creating gust winds that are remarkably dangerous [3, ch 3 p.94].

Strong winds could cause leeway and heading changes [1, p. 14]. Naturally the effect will vary depending on wind speed, direction and windage area of the ship [2]. Usually the ship will be most vulnerable when presenting its broadside, which has the largest windage area. The size of this area will also vary with loading condition [5, p. 41]. During strong winds a navigator must plan the manoeuvre according to the wind to minimise the potential danger and maximise the assistance.

The force of the wind can be understood as a point of influence on the above-water structure of a ship [1, p. 14]. This point will move depending on the ships heading and speed. The ship will usually settle in a position where the point of influence of the wind aligns with the pivot point. The pivot point is a theoretical point that indicates where the ship rotates along its length [1, p. 10], and the transverse ship speed equals 0.

If the ship has forward speed the pivot point (P) is forward [5, p. 36], [3, ch 1, p.11] and the point of influence of wind (W) will be astern. The result of this will be a force that turns the bow towards the wind. Note that this example uses a ship with large windage area aft.

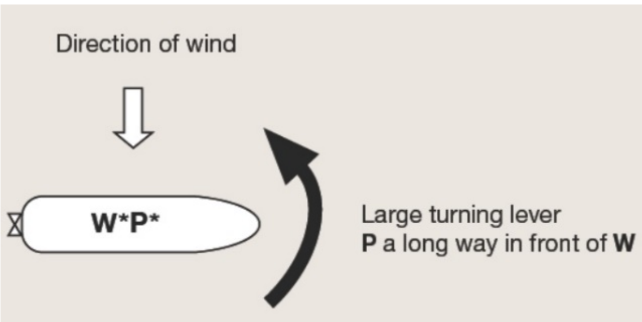

Figure 1. Alignment of W and P [1, p. 15]

The navigator must use available propulsion sufficiently to compensate for this resultant force. Wind force can be estimated using the following formulae [1, p. 16]:

$$Wind\ \ force = \frac{(Wind\ \ speed)^2 \times windagearea}{18000}$$

The ship in this field study has a windage area of approximately 1000m² on both sides, and 250m² in the front and stern.

Example:

$$F = \frac{4^2\ {}^{m}\!/\!{}_{s} \times 1000m^2}{18000} = 0,88\ {}^{t}\!/\!{}_{m^2}$$

$$F = \frac{8^2\ {}^{m}\!/\!{}_{s} \times 1000m^2}{18000} = 3,55\ {}^{t}\!/\!{}_{m^2}$$

$$F = \frac{8^2\ {}^{m}\!/\!{}_{s} \times 250m^2}{18000} = 0,88\ {}^{t}\!/\!{}_{m^2}$$

This example shows two important points. First, it shows that a doubling of wind speed gives approximately four times the force acting on the ship. Secondly, the force is vastly reduced when the direction switches from broadside to stern or front. If possible, the manoeuvre should therefor expose the smallest windage area to reduce the effect of strong winds [1, pp. 17-18].

In any situation, the navigator must use enough power on the thrusters to compensate for the force acting upon the ship.

3 FIELD STUDY

The goal of this study was to examine how wind affected the ships power consumption during berthing operations. The purpose is to present information that can be used in optimalization of operations, in regards of energy usage. To achieve this, the author logged every approach in one port, for four months.

3.1 *The ferry*

Every approach was made by MF Korsfjord, which is a ro-ro passenger ferry that runs on liquid natural gas (LNG). The ferry is a monohull, aft-bow symmetrical vessel as seen on figure 2. Korsfjord has 2 Schottel STP 1010, N=1000kW azimuth thrusters, one in each end [6]. Both have fixed pitch propellers and in general, thrust vectoring devices give enhanced manoeuvrability because the thrust is vectored [1, p. 10; 3, p. 50]. This design allows fully actuated berthing where surge, sway and yaw is controllable. Unfortunately the ship has a large windage area on both sides and a high B/D ratio. This indicates that the ship has a great potential for leeway in strong winds [1, p. 10].

Power is generated from two MITSUBISHI GS16R-MPTK (900 kw) gas engines and a MITSUBISHI S12R-MPTA (1000 kw) in standby. These engines provide the thrusters with power and consumption is logged using an energy monitoring system [7]. Consumption is directly affected by RPM on the thrusters. An increase in RPM gives an increase in consumption.

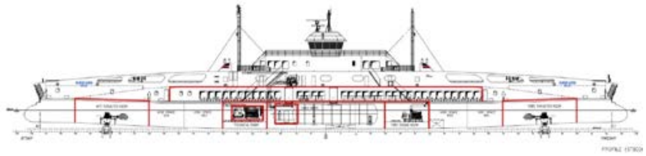

Figure 2. Starbord profile of M/F Korsfjord (courtesy of Fjord1)

Table 1. Main dimensions of M/F Korsfjord [6]

Length	122,75m
Beam	16,7 m
Draught	3,5 m
Height	20,5m
Maximum speed	17,5 knop
Gross registertonnage	2971

3.2 *The berth*

The port of Molde is an area with varying degrees of traffic. The quay is equipped with fenders. There is no noticable current in the area but sometimes there can be strong southern winds.

In the eastern end of the quay there is an automated loading ramp for veichles. This ramp will automatically position itself during berthing operations. When the ships is in the right position the ramp will lower itself to a shelf underneath the trapdoor in the bow. This ramp will keep the bow secured during loading and unloading, while the aft thruster pushes the stern towards the quay.

Table 2. Main dimensions of berth

Length	85 m
Minimal depth	4,7 m
True course	065°
Weight	85 t

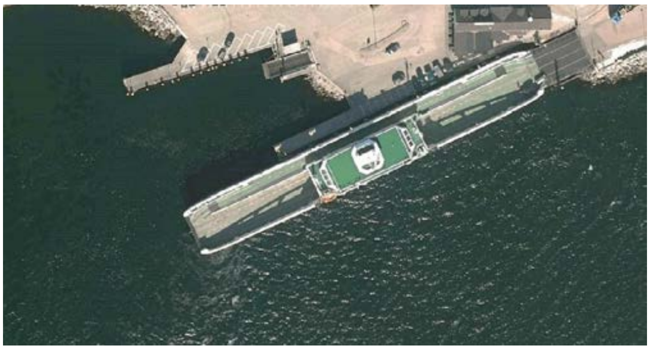

Figure 3. Satelite photo of M/F Korsfjord before loading in Molde [8].

3.3 *Data collection*

This article is written as a result of a quantitative field study. Data was collected between 07.10.19 and 31.01.20 on board MF Korsfjord that navigates between Molde and Vestnes in coastal Norway. The ships own equipment was used to log every bit of information. The ship is equipped with an Høglund IAS [7] that shows transit time, speed, course, position and usage of KW for each journey. Wind is measured by an external unit on the bridge roof [9], approximately 20 metres above sea level.

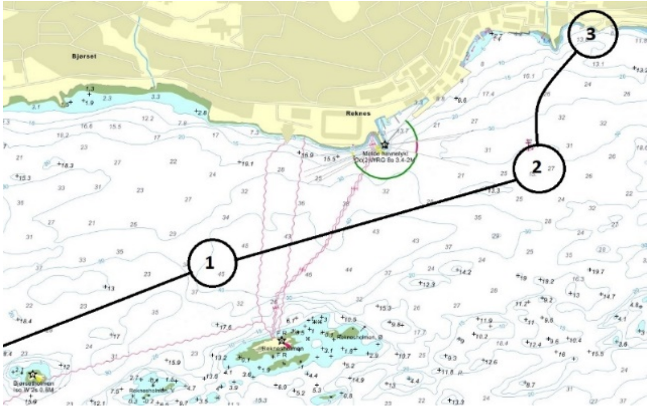

Figure 4. Port of Molde [10].

Figure 5. Wheelhouse of M/F Korsfjord.

Berthing the ferry is split into different phases, as shown in figure 4. During transit the ship sails at around 11,5 knots towards Molde with both thruster at around 220 RPM. Step 1 is a point at 0,9 nautical miles from the quay where the course is adjusted to approximately 070^0. Here the forward thruster RPM is reduced to 0. Aft thruster RPM is reduced to 160 RPM. The ship still sails on autopilot. At step 2 an audio message plays on the bridge to inform the navigator to commence manoeuvre procedure for arrival. Here the ship is 0,4 nautical miles from the quay. The ships speed is logged, then the navigator turns off the autopilot and steers the ships towards the quay. When the manoeuver is finished, the navigator logs wind, consumption, notices and time in the table at step 3. Every approach had to be performed in 8 minutes or less, to be valid for this study. Consumption and time spent manoeuvring is logged between step 2 and 3. The track was created in ECDIS and followed on each approach. Wind speed and direction is logged visually as median wind over a period of 30 seconds after arrival.

The ship is equipped with a surveillance system [11] that give audio warnings when the speed limit i broken. To complete a successful berthing the navigator must keep a speed lower than what is shown on table 3 at all times.

The figure above shows the wheelhouse of the ferry used in this study. Wind is registered using the display in the ceiling. On the right side is a display of

ECDIS-chart, used for marking the points in points in figure 5.

Table 3. Speed limit during berthing.

Distance to pier	Maximum speed over ground
277,8 nm	7
245,5 m	6
122,75 m	5
61,375 m	3

4 RESULTS

There were conducted 140 approaches in Molde port, during this trial. Of those 140, 15 approaches were not included in the analysis because the speed limit was exceeded or the approach lasted for more than 8 minutes, resulting in corruption of data. The study gave the following results based on n=125 approaches.

4.1 *The Effect of Wind speed*

First off is a comparison of average time spent manouevring and average consumption needed for approaches in different wind conditions. Note that table 4 only presents wind speed, regardless of direction. The table also depicts the change in percentage for each variable, using 0 m/s as a starting point. Time spent on the approach shows a slight increase in time, even though the goal was to use the same amount of time on each approach.

During the trial there were a lot of approaches in calm weather, while only a few approaches were made during strong winds. No wind speed were registered on 13 m/s or 16 m/s, and therefore the values were removed from table 4. The average consumption seems to be quite stable between 0 m/s and 4 m/s. At 5 m/s and beyond the consumption gradually increases with stronger winds, if we disregard the result from 6 m/s. Figure 6 shows a graphic representation of table 4.

Table 4. Overview of results from field study.

Wind speed (m/s)	Average time (seconds)	%	Average consumption (kw)	%
0 (n=4)	360	1	23,75	1
1 (n=29)	369,55	2,65	25,20	6,10
2 (n=30)	368,16	2,26	25,16	5,93
3 (n=15)	371,13	3,09	25,26	6,35
4 (n=17)	365,29	1,46	24,95	5,05
5 (n=3)	361,33	0,36	28,33	19,28
6 (n=1)	364	1,11	24	1,05
7 (n=4)	374,75	4,09	27,75	16,84
8 (n=6)	383	6,38	30,16	26,98
9 (n=1)	387	7,5	31	30,52
10 (n=1)	357	-0,83	30	26,31
11 (n=2)	381	5,83	32,5	36,84
12 (n=2)	382,5	6,25	37,5	57,89
14 (n=3)	373,66	3,79	39	64,21
15 (n=6)	395,66	9,90	42,5	78,94
17 (n=1)	382	6,11	49	106,31

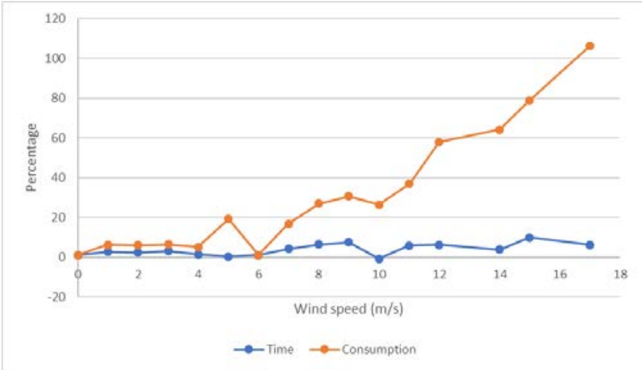

Figure 6. Illustration of results from table 4.

4.2 *Consumption and wind direction*

Figure 7 shows a graph for consumption in relation to wind direction. During this trial there were no wind above 4 m/s, registered from north or east. The result shows that consumption gradually increases, but there are few to no differences in consumption when divided by direction. Unfortunately the result is dominated by western winds, which makes it difficult to accurately measure differences in consumption.

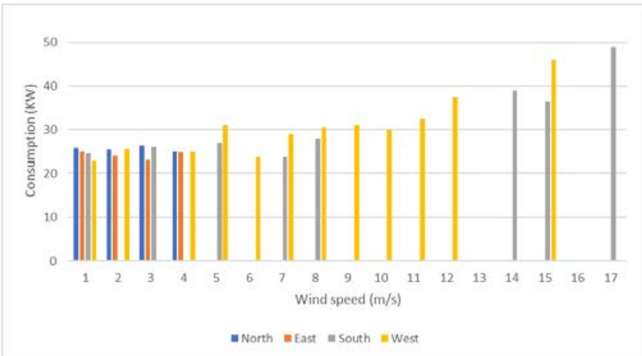

Figure 7. Wind speed compared to consumption for different directions.

5 DISCUSSION

There are several interesting findings that were revealed during this study. As mentioned above, wind affect the ferry by causing leeway or heading changes. It is therefore necessary to counter this force using the ships propulsion system. However, an increased usage of RPM on thrusters leads to increased power consumption.

The results from table 4 indicates that wind effect is absent in winds with speed of 4 m/s or less. In these conditions there is no need for increased RPM, above minimum steering RPM, to counter the force of wind during berthing. As a result, the average consumption lies between 23,75 kw and 25,26 kw, which is a relatively marginal difference.

Figure 6 shows a trend that indicates an increased consumption when wind speed is 5 m/s or greater. Increase in consumption could be explained as an effect of more force acting upon the ships windage area. A necessary increase in RPM would therefore cause a higher consumption during berthing.

On the other hand, the increase in consumption is not that high considering the vast increase in wind force. As mentioned earlier, doubling the wind speed gives four times the force acting upon the ship [1]. It would be logical that consumption rose proportional with wind force. However, this is not the case. Consumption seems to follow an almost linear growth. For example, doubling the wind speed from 7m/s to 14m/s only gives an increase in consumption of approximately 40,54%.

This phenomenon could be explained by the guidelines for berthing provided in section 2.2. It stated that ship handler should plan a manouvre to maximise the assistance. In calm conditions the propulsion system need a minimum amount of power to steer the ship or maintain speed. This amount of power is measured to be around 25 kw in this study. When the wind force increases, the consumption also increases but on a much smaller scale. The reason for this could be that the wind force is used as assistance when berthing. For example southern winds push the ship towards the loading ramp, meaning that the navigator has to use propulsion to maintain the heading and slowly reduce speed. On the other hand, no power is required to maintain speed during the manouvre or push the ship forward. These advantages propably reduce the overall power consumption.

Figure 7 shows consumption categorized by wind direction and wind speed. One of the goals of this study was to examine possible differences in consumption based on wind direction. Unfortunately there were no winds above 4 m/s registered from north or east during this trial. Strong winds were also mainly registered from the south. This makes it hard to compare differences in consumption by wind direction. More data is needed to properly examine this factor. Although there were insufficient data gathered, it is possible to see a marginal difference in consumption between southern and western winds.

Even though there are some differences, the study has a great limitation in regards of measuring the effect of wind direction. During berthing the ferry changes course several times. This could reduce the impact of wind direction. It would therefor be reasonable to pinpoint that wind direction propably have an effect on consumption but it did not appear in this study.

It is possible to calculate the effect of wind in great detail, using the results from this study. However, there are several weaknesses to this method that drastically reduces the validity of data. As mentioned in chapter 2, the ships is affected by a number of factors during berthing. In this trial these effects have been neglected, simply because there were no equipment available to accurately measure them. It is highly likely that current, trim or waves have an impact on consumption as well as wind.

The result is also based on trials conducted manually by a human. To fully recreate an approach, even in the same conditions, is not always possible. The data gathered during this trial shows several approaches in similar conditions where power consumption and time spent manouevring varies. The numbers presented in this study must therefore be seen as estimates or trends.

6 CONCLUSION

Wind has been described as a factor affecting ships during berthing operations. In this field study, the effect of wind is not present at 4 m/s or lower in regards of power consumption. Stronger winds require more power on the propulsion machinery but the increase is not proportional. Finally, no correlation between consumption and wind direction were discoveres during this field study.

7 FURTHER RESEARCH

It could be interesting to measure the effect of wind during transit or recreating the same trial with equipment to measure more variables such as trim, draught and wave height. This research could be relevant for optimalization of operations.

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