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Towards Smart Green Blue Infrastructure

ANALYSING THE IMPACT OF VARIOUS GEOMETRIES ON THE OPERABILITY OF CREW TRANSFER VESSELS

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1. **ABSTRACT:** The rapid growth of the renewable energy sector, particularly offshore wind farms, has heightened the demand for Crew Transfer Vessels (CTVs). Ensuring the efficiency, safety, and comfort of these vessels is paramount, given their mission of transporting wind farm technicians and personnel to and from offshore sites. This research project explores the operability of eight different CTV geometries to identify the optimal design.

Utilising Maxsurf Modeller for geometry creation and ShipX for operability analysis through Strip Theory, comprehensive simulations were conducted to determine the ideal CTV configuration for optimal performance in the challenging conditions of the North Sea.

The study's findings explicitly reveal that a 20-metre CTV stands out as the optimal length choice for enhanced operability in North Sea operations. The implications of this research extend to the wider industry, offering a valuable framework for calculating the optimal geometry for CTVs with similar missions. This, in turn, has the potential to generate significant cost savings and streamline research efforts. By adopting more economical vessel designs, companies can maximise their profits and enhance the productivity of technicians, ensuring smoother and more efficient operations in the offshore wind energy sector. This research signifies a crucial step toward achieving greater efficiency and sustainability in the renewable energy industry.

2. INTRODUCTION

Most vessels are used to construct and maintain the operation of offshore sites. There is a variety of different markets covered by these vehicles. In this study, Crew transfer vessels (CTVs), which are now said to be in their own specialized area [1], will be the focus. CTVs are specialist vessels used to transfer wind farm technicians and other personnel to and from an offshore site and in particular, offshore wind farm sites. CTVs play a crucial role in the efficient and safe operation of offshore sites across various industries, including renewable energy, oil and gas, and marine research. These vessels are specifically designed to transport personnel and essential equipment between shore and offshore installations such as wind farms, oil rigs, and research platforms. Their significance lies in ensuring the continuous and smooth functioning of operations at remote offshore locations, where direct access may be challenging or impractical.

Data provided by VesselsValue to Offshore Engineer reveals that the UK leads in crew transfer vessel fleet value, with an estimated fleet value of $310 million. In terms of vessel count, Windcat Workboats emerges as the foremost player with a fleet of 50 vessels. Currently, global offshore wind farm capacity stands at 25GW, a figure projected to surge to approximately 235GW by 2030, 520GW by 2040, and potentially reaching 1000GW by 2050. As of the present date, the collective value of the global CTV fleet, consisting of 498 vessels, amounts to USD 824 million [2]. Advancements in technology and vessel design have led to improvements in the performance and capabilities of CTVs, including higher speeds, extended operational ranges, and enhanced safety features. These developments further reinforce the importance of crew transfer vessels as essential assets for the offshore industry, facilitating safe and efficient operations in remote marine environments.

The environment that these wind farms are situated in have to have average wind speeds strong enough to meet power generation requirements. This factor also tends to be mixed with an expense budget, where the offshore wind farms will favor shallow waters to save construction and maintenance costs. High winds and shallow waters together will result in higher and sharper waves, making these sites overall a rough environment [3]. A crew transfer vessel must withstand these rough conditions both for safety and comfort reasons. The vessel crew will require smoother sailings to carry out their tasks safely and efficiently. The technicians and other personnel on board will also require as smooth a sailing as possible to minimize stress, seasickness, and overall discomfort. With these factors minimized, the productivity of passengers will be optimized which increases the overall efficiency of the task in hand. The ability to carry out such measures will be challenged in adverse sea and weather conditions. How well a vessel securely copes with these conditions over a percentage of time is classed as the vessel's operability. However, there are many key parameters required to calculate and define a vessel's operability. The ship's mission is one of the main parameters along with the sea environment encountered during its mission, and the basic dynamic responses to regular waves [4].

Since vehicles were first invented different shapes and sizes have been tested to find the best performing geometries for its given mission and this same principle will be applied in this paper to investigate which geometry of CTV will provide best operability.

It is vital that CTVs are as comfortable and safe as possible, especially when the vessels will spend many hours at sea. During this time the vessel will encounter different dynamic loads, motions, and accelerations due to varied wave heights, periods, and headings, all of which can be unsettling for crew and passengers and therefore a limit has to be set on the quantity of these motions, this is known as a limiting criterion and will be covered in depth in the methodology section. An operability analysis to calculate and test a ships seakeeping ability following a set procedure will be covered in this study. The CTV must withstand these conditions during both the transit phase and the transfer phase. It is during these phases that the passengers are ferried from dock to offshore site, or from turbine to turbine, and transferred from vessel to wind turbine respectively. These are all factors considered when performing an operability assessment.

The study reported in this paper will also review the literature on a CTVs operability and seakeeping methods. Further to that, an overview of the operability assessment procedure is discussed. The report will then describe each stage of the methodology and its rationale. Eight different geometries of lengths 16m to 30m, will be taken through the same procedure to investigate which one of these geometries provides best operability. These analyses will be simulated in the North Sea, off the East Coast of England. The results of the analyses will be discussed and compared for each geometry to obtain the optimal geometry. A breakdown of results at different stages of the analysis will also be included to help explain the conclusions. Some recommendations as to who could use the results, and what they might be used for, will also be discussed. Finally, the concluding remarks suggest some potential further areas for research.

3. BACKGROUND

2.1 Crew Transfer Vessels

A Crew transfer vessel is typically between 12m and 24m in length, depending on where the mission is to be carried out. They can take 12 people on average each trip and have small cargo space for equipment needed for service repairs etc. A CTV typically has a catamaran hull form, but SWATH hull forms and a number of other hull forms are also used. In this report, the catamaran hull form will be investigated [1].

The CTV market has undergone significant expansion over the last 10 years, with designs evolving due to demands and competition. They have generally increased in size to accommodate more crew, thereby saving fuel costs, and in general larger vessels cope better in a variety of sea conditions. New vessels entering the market are setting a new standard and are leaving older vessels no longer fit for purpose [1]. 4C Offshore [1] also explains that the charterer pays for the fuel and lubricants out with the day rate, and therefore these new vessels are more fuel-efficient, using glass reinforced plastic to save weight and costs.

4C Offshore [1] explains that even though there is an increase in offshore wind farms, vessels such as Service Operational Vessels and even helicopters are joining the field. However, these other transfer methods are expensive, and with SOVs mainly being used for installation and construction of wind turbines, with helicopters having a limited passenger capacity and wind turbines also requiring extra platforms for helicopter transfers also carrying extra costs, CTVs still remain a popular option. They are relatively inexpensive to hire, with vessel coding and classification ensuring they meet the standard the charterer requires [1]. In addition, smaller start-up companies entering the market may be unable to afford helicopters and will look to the cheaper option of CTVs. With the competition between the options becoming tighter, it is vital that the optimal safety and comfort of a CTV is available for the vessel to remain a popular choice. A study to find the optimal geometry of a CTV, aimed at maximizing operator confidence that the vessel will perform seamlessly to the limiting criteria without fail, is therefore essential.

Some sites will lose days of work due to rough sea conditions, with some vessel sailings having to be cancelled for safety reasons. A possible solution would be to research the environment, including wave scatter diagrams etc. and investigate different geometries to suit the fixed offshore site. It is also important to have a flexible design that could be successfully used in other nearby sites operating under a different environment. This work will take these parameters into account and will investigate which geometry gives the highest operability and scientifically prove the best geometry for the proposed offshore site.

An alternative approach to operating and maintaining existing wind farms involves the use of helicopters. When weather conditions pose limitations on accessibility or when urgent crew transfers are necessary, helicopters become a viable option. Their distinct advantage lies in their reduced dependency on weather factors such as waves and currents, significantly enhancing access to wind farms. Moreover, maintenance trips using helicopters are notably shorter compared to traditional vessels. However, it's worth noting that helicopters come with a higher cost, totaling €6000 per day, while the cost for a CTV amounts to €1500 per day plus an additional €100 per trip [5].

3.2 Offshore Wind Farms

Renewable energy is generally accepted as being the future source of power generation. This will come with many benefits in terms of reduced air pollution through fossil fuels and greenhouse gasses. Wood [6] states that "switching to wind, water and solar energy could eliminate 4 to 7 million deaths from air pollution, annually" whilst "stabilizing the global energy factor" at the same time. The United Nations claimed in 2019 that there is only a decade left before the change to the climate is irreversible. Given the increasing contribution of offshore wind farms, there is an opportunity to contribute to this challenge.

For this project, the ship will be tested in an environment which would typically be found at the Hornsea One offshore wind farm, which is located in the southern North Sea, off the Yorkshire Coast (Power Technology). This will result in a similar simulation as if the vessels had been situated at Hornsea One. The wave scatter diagram of the proposed site will be taken from the MetoOceanView website to allow for the calculation of long-term statistics. Wave scatter diagrams and long-term statistics will be discussed later on in the paper.

According to the Orsted website, Hornsea One is the largest offshore wind farm in the world and is based in the North Sea, 120km off the coast of Yorkshire. With 174 turbines, spanning 407 square kilometers, it has a capacity of roughly 1200MW, which is enough to power over 1 million homes according to Orsted, almost double the next nearest, East Anglia One at 714MW [7].

With the proposed project due to undergo operability investigations in the North Sea, we should consider the annual environmental conditions typically found there. In winter months, gales and storms could be expected to result in aborted sailings, and without correct planning, this could result in lost operating days. Avoidance measures include the use of wave scatter diagrams which will be covered later in the report. This project could also be interchangeable, with the procedure being swapped in to suit another site with different conditions, in order to assess to the optimal geometry for best operability can be found for this site too.

3.3 Operability

During a CTV's mission, the vessel will experience two different phases where operability is key - the transit phase and the transfer phase. The transit phase is where the vessel is operating at cruising speed, which for this project this speed is 24 knots, during which technicians and other personnel will be ferried from the port to the offshore site. The transfer phase is where the technicians will transfer from the vessel onto the wind turbine as the vessel is pressed against the turbine base. Both these phases will require separate operability calculations.

During the transit process, it is vital that passengers and crew members remain safe and comfortable. Whilst the ship motions may not make the crew members sick, a smooth sailing is vital to enable them to carry out their operational tasks around the CTV. Technicians and other personnel tend to be more affected by motion sickness. They require a safe and comfortable transit in preparation for their scheduled tasks once they have arrived at the offshore site.

These requirements can be achieved in several different ways.

Tezdogan *et al.* [4] explains that there are 3 main parameters required to carry out an operability analysis: vessel geometry and loading condition, definition of the seaway and wave data, limiting criterion. Tezdogan et al. [4] provides an overview of the assessment process which could be used to determine a ship's operability, as shown in Figure 1.

During the transfer stage as mentioned before, the CTV will be stationary and therefore can be treated as a floating structure. According to Phillips *et al.* [8] there is far less experience and consensus on floating structures as regards the limiting criteria of vessel motion. However, there are methods which are used to analyze the behavior of floating structures. As previously mentioned, ShipX software using Strip Theory will be used for this study. This can be used for vessels in motion and for stationary vessels.

During the transfer stage, the crew and technicians are required to be able to move around safely before transferring over to the wind turbine. During this period, to minimize the danger, the limiting criteria will be smaller than during the transit period. Phillips *et al.* [8] believe that the limits of horizontal and vertical acceleration at the bow are 0.04g and 0.05g, respectively. These figures will also be used in the limiting criteria.

3.4 Wave Scatter Diagrams

A wave scatter diagram is essential in an operability assessment as it provides the climate of the area where the vessel's missions is to be carried out. A wave scatter diagram summarizes the wave climate and gives a joint probability of significant wave height, H_S (m) along with the wave zero crossing period, T_Z (s) or in the case given below, peak period T_S (s) [9].

Table 1 is a wave scatter diagram from the MetOceanView website of the annual wave count at different wave heights and periods. The information on the scatter diagram is taken from the Hornsea One offshore wind farm area based in the North Sea. The horizontal axis shows the peak period and the vertical axis shows the wave height. The table shows the wave heights range from 0 – 0.5m up to 7.5 – 8m and peak periods of 0-1s up to 19-20s and gives a significant wave height of 1 – 1.5m. The data provided in the scatter diagram is an annual average and is useful for calculating annual statistics. However, seasonal diagrams can also be used for calculating specific seasonal operability and are more useful for vessels only operating in certain seasons.

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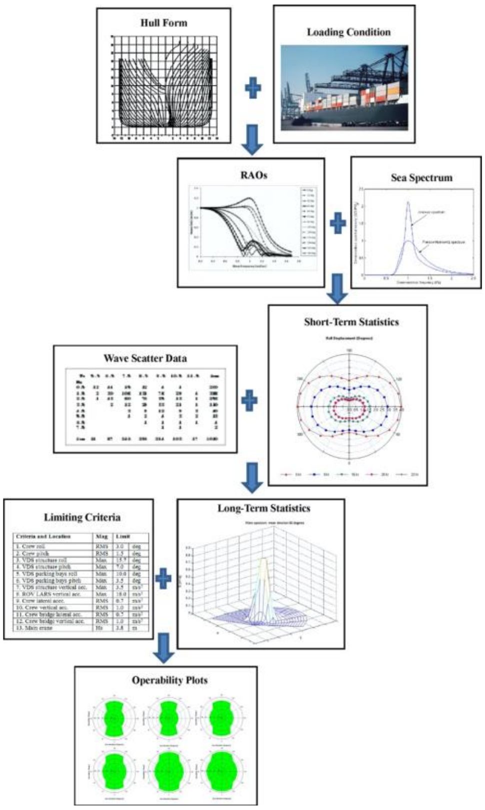

Figure 1: An overview of the operability procedure, taken from [4]

Table 1: Hornsea One Wave Scatter Diagram (MetOceanView)

m	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
0-0.5	331	3	103	1713	4038	1445	809	752	638	444	252	128	146	206	183	133	100	28	8	4
0.5-1	35	0	137	4165	7345	4438	2748	1387	1118	870	535	223	94	43	21	23	13	17	7	1
1-1.5	0	0	1	304	9696	5400	3406	2254	1053	1054	781	303	136	39	14	1	1	1	1	0
1.5-2	0	0	0	1	2472	8968	3287	1815	966	590	521	378	148	31	3	1	4	1	0	0
2-2.5	0	0	0	0	54	4472	3752	1570	722	404	267	264	144	44	4	1	3	0	0	0
2.5-3	0	0	0	0	1	903	3307	1650	567	328	155	128	75	42	4	2	0	0	0	0
3-3.5	0	0	0	0	0	22	1409	1617	513	294	105	56	42	13	3	2	0	0	0	0
3.5-4	0	0	0	0	0	0	241	999	525	297	107	31	22	2	1	1	0	0	0	0
4-4.5	0	0	0	0	0	0	9	396	350	227	82	36	9	8	3	0	0	0	0	0
4.5-5	0	0	0	0	0	0	0	100	157	145	90	43	10	2	1	0	0	0	0	0
5-5.5	0	0	0	0	0	0	0	34	36	83	63	52	4	3	0	0	0	0	0	0
5.5-6	0	0	0	0	0	0	0	2	13	26	50	26	8	7	0	0	0	0	0	0
6-6.5	0	0	0	0	0	0	0	0	5	5	7	16	2	2	0	0	0	0	0	0
6.5-7	0	0	0	0	0	0	0	0	1	0	0	11	4	1	0	0	0	0	0	0
7-7.5	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0
7.5-8	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0

3.5 Theory Background

Beck and Reed [10] posit that approximately 80% of forward speed seakeeping computations still rely on strip theory due to its expeditious and reliably accurate solutions, particularly suitable for engineering purposes and applicable to various conventional hull forms. Nevertheless, discrepancies between strip theory and experimental results for higher speed vessels or non-wall sided hull forms have driven research toward advanced theories like the 3-D Rankine panel method, unsteady Reynolds-Averaged Navier Stokes (RANS) methods, and Large Eddy Simulation (LES) methods [10].

As discussed by Newman [11], conventional strip theory exhibits deficiencies at low encounter frequencies and high speeds, attributed to assumptions inherent in the theory. At low encounter frequencies, issues arise from the evolution of forward speed effects and the complex nature of the diffraction problem in short incoming waves. Notably, the conventional strip theory becomes questionable at low encounter frequencies. As the frequency of encounter approaches zero, the added mass coefficients for vertical motions exponentially become infinite, classifying strip theory as a short-wavelength (high frequency) theory [10].

Another challenge strip theory faces relates to forward speed effects, where it simplistically models the interaction with forward speed and omits the effect of local steady flow around the vessel. Faltinsen and Zhao [12] note its robustness at moderate forward speeds but express skepticism about its suitability for high-speed applications. With increasing computational power, 3-D techniques, such as the Neumann-Kelvin theory and the Dawson (double-body) method, gain popularity for investigating seakeeping problems at forward speed [13-15]. Yasukawa [16] asserts that 3-D Rankine panel methods have been developed to address strip theory deficiencies, incorporating fully 3-D effects of flow and forward speed, unlike strip theory.

Yasukawa [16] applies the theory of Bertram and Yasukawa [17] in the time domain to container ships with strong flare, demonstrating improved predictions of hydrodynamic forces, ship motions, and local pressures compared to strip theory. However, lateral hydrodynamic forces exhibit unsatisfactory results, attributed to viscous flow effects, with the author suggesting potential mitigation through empirical corrections akin to those employed in strip theory. This theory background has been summarized from Tezdogan [18].

4. METHODOLOGY

The following sections will briefly explain the necessary stages in predicting a vessel's operability.

4.1 CTV Design using MAXSURF

MAXSURF is a software package designed for use by naval architects and provides integrated tools for hull modelling as well as being able to predict motions and resistance, stability and structural analysis and many more. For this particular project, MAXSURF Modeller is used to generate the CTV geometries. A basic catamaran model is provided by the software, and this will be used as a basis ship for each of the geometries to be scaled from. Each vessel will be run through identical simulations to provide a consistent comparison. The basic characteristics of each vessel are given in Table 2.

Table 2: Basic geometries of each CTV investigated in this study

	Catamaran Lengths							
	16m	18m	20m	22m	24m	26m	28m	30m
Length (L_{BP}) (m)	15.23	17.60	19.03	20.94	22.84	24.75	26.65	28.55
Overall beam (B_{OA}) (m)	4.605	5.180	5.755	6.326	6.911	7.482	8.061	8.635
Beam of demi-hull (B_{DH}) (m)	0.46	0.52	0.58	0.63	0.69	0.75	0.81	0.86
Draught (T) (m)	0.46	0.52	0.578	0.635	0.69	0.751	0.81	0.87
Displacement (Δ) m^3	3.940	5.640	7.751	10.253	13.504	16.996	23.266	26.238
Long. Center of gravity (LCG) aft of amidships (m)	6.08	6.94	7.71	8.51	9.32	10.08	10.95	11.62
Vertical center of gravity (VCG) (m)	1.49	1.68	1.87	2.05	2.24	2.43	2.61	2.8
Roll radius of gyration (r_{44}) (m)	0.54	0.61	0.68	0.75	0.82	0.89	0.95	1.02
Pitch radius of gyration (r_{55}) (m)	3.94	4.4	4.93	5.38	5.73	6.40	6.84	7.39

Eight catamaran geometries in total were created ranging from 16m to 30m in 2m increments. Each vessel was scaled from the basis catamaran provided by Maxsurf to the length required. Each file was exported as a DXF file for ShipX to read the sections correctly.

4.2 Operability Index

Knowledge of a vessel's motion characteristics, environmental conditions, and limiting criteria are all essential to be able to compute the operability index as a percentage of time a vessel will not breach the given criteria. These vessel motions are evaluated against the limiting criteria for all the sea states in a wave scatter diagram to compute the operability index [19].

With the set mission of a CTV, the limiting criteria will be set around passenger comfort and safety. The main factor affecting seakeeping performance is vertical accelerations but also partly lateral accelerations [4].

The main cause of sea sickness is the effect of the vertical acceleration on human metabolism. The International Standard determines the regions of discomfort as a function of acceleration speeds, frequencies and exposure times. The influence of accelerations on human performance on-board can be quantified using a number of parameters. They can be used as a benchmark for comparing human performance between ship designs [18].

The International Standard ISO 2631/1 [20] defines a method for assessing whole-body vibration in relation to human health and comfort, linking this to the likelihood of vibration and motion sickness.

The percentage operability bar charts show the percentage of time the vessel can carry out its mission without exceeding the limiting criteria. The bar charts include the percentage of a successful voyage for each part of the criteria as well as a mean percentage of all the criteria. Both probabilities are calculated through different equations. For a certain seakeeping criterion, ship speed, and wave heading, the percentage operability is calculated as follows:

$$P_{\mathrm{Op}}^{\beta} = \sum_{j=1}^{N_{H_s}} \sum_{k=1}^{N_{T_p}} p_{jk} \left(H_{sj} < H_{s_{cr}}, T_k \right) \quad (1)$$

P_{Op}^{β}: percentage operability for a certain heading β, ship speed and seakeeping criterion. H_{scr} is the limiting significant wave height and T is the wave period.

P_{jk} (H_{sj}<H_{scr}, T_k): probability of occurrence of a significant wave height in interval *j* below the limiting significant wave height with a wave period n interval *k* [21].

It is important to identify limiting seakeeping requirements in order to determine a craft's operational envelope. The limiting criteria relate to the passengers' and crew's safety and comfort, the vessel's safety and capacity, or operational considerations. National and international rules and standards provide these certain limiting requirements. The limiting criteria chosen are based on the comfort and safety of passengers suitable for both the transit phase and the transfer phase shown in Table 3 and Table 4, respectively. The variables such as ship stability, loading conditions, power requirements, operational considerations, speed capabilities, and steering systems with maneuvering facilities are also important factors to consider, however within the scope of the research reported in this paper only seakeeping related criteria have been considered.

Table 3: Limiting criterion for transit phase

Criteria	Value	Location	Reference
Vertical acceleration, Root Mean Square (RMS)	0.15g	Fore Peak (FP)	[8]
Roll, RMS	6.0deg	Center of gravity	[22]
Pitch, RMS	4.0deg	Center of gravity	[22]
Motion Sickness Incidence (MSI)	20% in 2 hours	Accommodation	[8]
Motion Induced Interruptions (MII)	1 per minute	Accommodation	[18]
Slamming	10 per hour	FP	[8]

Table 4: Limiting criterion for transfer phase

Criteria	Value	Location	Reference
Vertical acceleration, RMS	0.05g	FP	[8]
Horizontal acceleration, RMS	0.04g	FP	[22]
Roll, RMS	2.5deg	FP	[21]
Pitch, RMS	2.0deg	FP	[21]

5. RESULTS

In this report, 8 different geometries of CTV's ranging from 16m to 30m were taken through an operability analysis to investigate which one of these geometries provides best operability. Table 5 shows the percentage operability of each geometry which has been calculated through a combination of long-term statistics and a limiting criterion as explained earlier in the paper. The operability calculations have been performed for each geometry separately and the results have been grouped into each individual length of CTV with both transit and transfer speed included. The table represents the percentage of time that a vessel can carry out its mission without exceeding the limiting criteria. The charts show the percentage operability of the lowest percentage operability index for that given wave heading.

Table 5: Operability indices (%) for independent wave headings at both phases for each CTV geometry

	Ship speed													
	0 knots							24 knots						
	Wave headings													
	0°	30°	60°	90°	120°	150°	180°	0°	30°	60°	90°	120°	150°	180°
16m	97	99	46	20	55	100	98	100	100	97	48	100	99	100
18m	98	100	50	18	65	100	99	99	100	99	47	100	100	100
20m	98	100	47	18	63	100	99	100	100	100	74	100	100	100
22m	99	100	46	16	66	100	99	100	100	100	54	100	100	100
24m	99	100	42	15	57	100	99	100	100	100	60	100	100	100
26m	99	100	42	15	58	100	99	100	100	100	67	100	100	100

28m	99	100	35	14	43	100	99	100	100	100	73	100	100	100
30m	99	100	39	15	56	100	99	100	100	100	53	100	100	100

A pattern occurs throughout all the results in that the percentage operability at 60°, 90° and 120° wave headings is lower and particularly lower at a 90° heading. The catamaran design used from this report has particularly narrow demihulls and a large separation between the hulls and due to these particular wave headings causing more wave induced motions, this is likely to be an impacting factor. In Tezdogan *et al.* [4], the catamaran used has demihulls with a width of approximately 30% of the total breadth, whereas the demihulls used in this study have a width of only approximately 10% of the total breadth, proving they are quite significantly thinner than another CTVs.

Figure 2 provides a summary for the average percentage operability of each length and speed with the assumption that each wave heading has an equal probability of occurrence.

Figure 2 also provides the average annual statistics for each length based at the Hornsea One site in the southern North Sea. The average percentage operability is given for both the transit and transfer phase. As can be seen from the table, results can be read for a given length, for example the 24m CTV provides an average percentage operability of 73.69% and 94.30% for the transfer and transit phases respectively. This results in a total annual average percentage operability of 84.00%. This means that the 20m CTV on average is operational and satisfying the limiting criteria during 96.4% of the year for the transit phase, 75.2% for the transfer phase, and 85.8% of the annual season.

As seen from, the percentage operability for the transfer phase is considerably less than for the transit phase. The limiting criteria for the transfer phase are stricter to ensure a safer transfer of technicians to the wind turbine. Also, when a ship is stationary it is more susceptible to wave induced motions. Both of these factors will result in a higher likelihood of the transfer criteria being breached. The wave scatter diagram used for this report is an annual scatter diagram and will provide the average probability of different waves from throughout the year. This will result in an average annual percentage operability for each CTV. More accurate results could be obtained by using seasonal scatter diagrams.

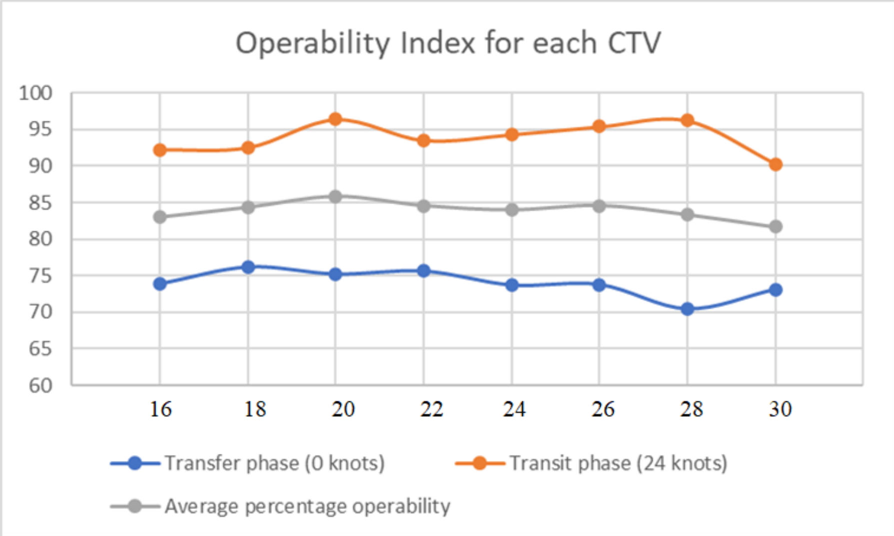

Figure 2: Average percentage operability indices (%) for each CTV against the vessel length (m.)

When taking the average annual percentage operability, we can see from

Figure 2 that the 20m CTV provides the best operability of 85.80% closely followed by the 26m CTV. The 30m CTV provided the worst results with an average annual percentage operability of 81.68%. However, the results were very tight with only a difference of 4.12% between the highest and lowest percentage operability indices. It is interesting to see there is no trend between average percentage operability and length of CTV.

It should also be kept in mind that the percentage operability is fully dependent on the preset criteria. If a criterion was to be altered, the results would vary accordingly. For example, a tighter limiting criterion would result in a lower percentage operability.

6. CONCLUSIONS

Due to the prolific growth in offshore wind farms and the consequential increase in usage of CTVs for transportation, this emphasizes the need to understand the factors that can influence the wellbeing and therefore efficiency of such offshore operations.

This study has been carried out to investigate different geometries on operability analysis of CTVs operating in a specific sea area. This was accomplished by modelling eight different geometries of lengths 16m to 30m on MAXSURF Modeller and taking each geometry through an operability analysis on VERES ShipX. The operability analysis was carried out by applying a wave scatter diagram and limiting criteria to the short and long-term statistics respectively and calculated by using the strip theory method. The key results are summarized below:

(1) The 20m CTV operating at Hornsea One offshore site was identified as the optimal geometry based on average annual percentage operability indices, considering factors like vertical and horizontal acceleration, roll and pitch motions, motion-induced interruptions, motion sickness incidence, and slamming.

(2) Despite no correlation found between different geometries and operability, it was observed that all vessels performed poorly at 90-degree wave headings, possibly linked to the narrow demihulls. The suggestion to widen demihulls for potential improvements was made.

(3) The study's significance lies in providing a useful approach for calculating vessel operability, enhancing understanding of passenger comfort, safety, and overall performance in the context of the increasing adoption of CTVs in offshore wind farms.

In essence, this study offers a valuable methodology for assessing vessel operability, thereby advancing our comprehension of passenger comfort, safety, and overall performance in light of the growing adoption of CTVs in offshore wind farms.

7. ACKNOWLEDGMENTS

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