

CREW TRANSFER VESSEL PERFORMANCE EVALUATION

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SUMMARY

This paper summarises the experience gained by Seaspeed Marine Consulting Ltd in evaluating the operational performance of crew transfer vessels (CTV) from theoretical performance predictions, model tests and sea trials. In particular, experience of the typical limiting conditions which apply to these craft is discussed along with methods of presenting their performance characteristics in an appropriate format for verifying predictions with sea trials results and for input into techno-economic models.

1. INTRODUCTION

Crew Transfer Vessels (CTV), as applicable to the offshore wind farm industry, are an interesting class of ship, not least because of the diversity of craft types employed. They are also of a size (generally between 12 and 24 metres) for which performance prediction and evaluation is less well established, particularly for their mode of operation involving the transfer of personnel from the vessel to a fixed structure at sea.

Since their primary role is to transfer technicians (generally up to 12) and a limited payload of tools and spares (generally up to a few tonnes) between a local port and offshore wind turbines, their size is largely determined by the weather conditions in which they are required to operate – the smaller vessels operating up to about one metre significant wave height in largely protected areas, and the larger vessels operating up to about two metres significant wave height in more exposed areas.

Clearly it would not be cost efficient to operate craft that are larger and hence more costly in an environment that could be adequately serviced by smaller, less costly, vessels. However it is also important to have a vessel, or fleet of vessels, that has the flexibility to work successfully within a range of wind farms and their associated operational environments. Thus, it is important to the economics of offshore wind power that the performance, particularly the limiting performance, of different CTV's is not only well understood but also that the commercial value of that performance is properly appreciated.

This paper presents methods recently employed within the industry that go some way to addressing these issues.

2. LIMITING PERFORMANCE PARAMETERS

The performance parameters of particular importance to the operation of CTV's are many and their significance can vary depending on the operational environment of

interest. However, once the vessel's fuel consumption, range, payload capacity and associated calm water speeds and handling have been determined by the design specification (also largely determining cost), and accepting that the structural design, general arrangement, outfit and overall reliability are acceptable, then the main parameters of interest are those associated with the vessels ability to handle deteriorating sea conditions. From operational experience, the parameters which have been found to limit the ability of the CTV's to perform satisfactorily in this respect include the following:

Vessel motion during transit – it has been found that the vertical and horizontal accelerations experienced on board CTVs, due to the affect on human comfort and performance, are generally the limiting motion parameters in the transit mode. For the ship's crew it is the effect on their ability to perform the necessary operational tasks around the vessel that is of interest whereas for the technicians the main issue is comfort and safety. Motion sickness is not usually an issue for the crew although for the technicians this, and their general well being in preparation for the work required of them once on the turbines, is of primary importance, as is the ability to have (limited) freedom to move safely around the passenger saloon.

It is generally accepted from experience that rms values of vertical acceleration of about 0.15g and horizontal acceleration (that is the combination of both the longitudinal and lateral components of acceleration, in the ship axis) of about 0.12g are associated with the limits of acceptable conditions. Whilst rms vertical acceleration is also important with regard to sea-sickness, so is the length of exposure and the frequency of the motion. Again from experience, it appears that values of motion sickness incidence of about 20% to 25% (calculated using ISO 2631-1:1997 with a Km of 1/3) are associated with the limits of acceptable conditions.

Whilst angular motions are also of interest with regards to vessel limiting performance, it is more their influence

on ship axis accelerations that is of interest. However, typical rms limits of 4 degrees for pitch and 6 degrees for roll are often applied.

Shock acceleration due to slamming is also of importance, although it is a normal principle of ‘good seamanship’ to attempt to avoid slamming as far as is practicable, by changes in speed and heading. There are no specific limits involved, but attention is drawn to the requirements of ISO 2631-1:1997 and EU Directive 2002/44/EC with respect to limits of whole body vibration and also to other generally accepted threshold limitations. Whole body vibration limits are not normally an issue for the larger CTV although monitoring (health surveillance) is almost certainly required. Slamming levels (depending on their severity) of say up to 5 to 10 per hour may be deemed to be acceptable.

It is important to note that whilst vessel acceleration motions can be reduced (and hence comfort levels increased) by a reduction in vessel speed, there is a lower threshold of speed below which it would not be commercially viable to operate the craft. This issue is discussed later in this section.

Vessel motion during step-across-fender transfer – there is far less experience and consensus with respect to the limits of vessel motion for the transfer mode. However, since this mode requires the crew and technicians to move around the vessel safely and to prepare for and undertake the transfer operation, the vertical and horizontal acceleration limits of the vessel are clearly less than those for transit. It has been found that rms acceleration limits in the technician saloon of about 0.05g for vertical acceleration and about 0.04g for horizontal acceleration are generally associated with limiting conditions for this mode. For the actual step-across transfer point the relative motion between that point on the vessel and the turbine tower docking poles should be essentially zero. It has been suggested that since safe transfers can be made if the frequency of slip at the transfer point is low enough then it should be possible to define such a threshold. A value of one slip in every ten minutes has been suggested as a limit, and on the basis that a slip occurs due to a larger than normal wave passing under the vessel, then this could be interpreted as a no-slip confidence level of about 99% (assuming an average zero crossing wave period of about 6 seconds). From experience of current industry practice, it has been estimated that equivalent confidence limits (on the basis of slips per unit time) far lower than this are sometimes employed – possibly as low as 70% - although this is mitigated in practice by good seamanship

(largely by undertaking the actual transfer during visually observed quiescent periods). It is proposed here that the industry aim should be to significantly increase the actual confidence limits for no-slip conditions currently deemed to be acceptable, possibly to as high as 95% to 98%, along with specific transfer task training at sea.

Angular motions tend to be more important than for the transit mode, and a typical rms limit for transfer of 3 degrees for roll is often applied.

Whilst all of the above may be applicable for conventional step across fender transfers, when specific access systems are employed then the motion limits may be different.

Handling limitations – there are a number of other limiting performance parameters that are relevant to CTV operations and can include:

- **Wetness:** this is sometimes a limiting factor in head sea transit operations where the relative bow motion is so great that green water washes over the foredeck. This is not normally sustainable for any length of time and is generally avoided operationally by reducing speed and/or changing heading. Higher (bow) freeboard vessels tend to suffer less from this particular problem.
- **Slamming:** as noted previously, slamming can induce very high vertical accelerations and should be avoided as far as possible. Operationally, reduced speed and a change in heading can reduce the slamming frequency. In practice, vessels with higher wet-deck clearance (for multihulls) and deeper forefoot submergence suffer less from this problem. A related issue for transfer operations is the rapid increase in buoyancy force that occurs when the amplitude of a passing wave is great enough to reach the wet-deck, This is one of the mechanisms that induce fender slippage – and clearly vessels with higher wet-deck clearance suffer less from this problem.
- **Deck-diving and broaching:** these often related phenomena can be limiting factors when operating at speed in stern quartering and following seas where the vessel can accelerate down a wave front and end up burying its bow into the back of the wave in front, sometimes inducing a directional instability which can lead to broaching. Operationally, these can be avoided by a reduction in speed and possibly a

change in heading. Again, higher freeboard vessels and those with particularly high directional stability suffer less from these issues.

- **Propulsor ventilation:** whilst this is not normally an issue during transit in a well designed vessel, it can be a limitation in transfer operations which rely on high thrust levels being maintained. During a step-across-fender transfer the bow of the vessel remains largely stationary and pitches about that point. In relatively short steep waves, the vessel can pitch stern-up when the wave crest is near amidships and thus the propulsor at the stern can be lifted nearer to, or clear of, the water where ventilation is more likely to occur. This would reduce thrust, and consequently fender friction force, thus rendering a fender slip more likely. This problem is more prevalent on vessels with low propulsor submergence and with high length to displacement ratio hull forms.
- **Stern swamping:** this only appears to be a problem during transfer operations in a stern sea orientation but can occur without much warning. It can be more of an issue on Swath craft, particularly since they suffer less from other transfer limitations. Higher stern freeboard is clearly an advantage in such conditions.
- **Manoeuvrability:** this is of particular importance during approach to the turbine tower in preparation for transfer. The identification of the most important parameters with regards to manoeuvrability in the approach mode is particularly difficult since so much depends on the skill and experience of the ship's Master, and their familiarity with the vessel. However, there is little doubt that the ability to vector propulsive thrust and to rapidly change thrust from ahead to astern (and vice versa), are of significant benefit. Likewise, the absence of high lateral windage and/or underwater lateral forces and moments make the approach easier to undertake particularly in cross wind or tide conditions. Another parameter found to have been limiting during the approach mode on some vessels is excessive pitch since it increases the difficulty in making controlled contact with the turbine docking poles. The maximum allowable docking impact load for turbine towers is generally about 200 kN with a vertical force limit of about 400 kN.

- **Speed loss during transit** – speed loss in a seaway may be voluntary (in order to reduce motions or to avoid other unwanted vessel behaviour) or involuntary (speed loss primarily due to added drag and reduced propulsive efficiency of the vessel from wind and waves). Speed loss of whichever sort is unwelcome from an operational efficiency perspective and as noted previously, there is likely to be a threshold average speed below which operations are no longer commercially viable. For the purposes of CTV performance evaluation, average speeds below 15 knots are generally thought to be unacceptably low.

3. PREDICTIONS vs SEA TRIALS RESULTS

Ship motion performance at sea can be theoretically predicted reasonably well, particularly in terms of vertical motions. However handling issues, primarily those associated with limiting conditions, are far more difficult to predict and it is normal to use physical scale model testing to assist in this regard.

Computer simulation of vessel behaviour during the transfer mode has developed over the past few years and can provide realistic estimates of vertical forces and motions although it is less clear whether lateral forces and motions or longitudinal forces are satisfactorily predicted. Again, physical scale model testing is used to provide a more comprehensive understanding of the likely performance of the vessel during approach to the turbine docking area and subsequent transfer.

All these predictions are undertaken using idealised or historical sea state spectra, in order to provide guidance as to how the vessel will behave in practice. Whilst sea conditions rarely, if ever, match exactly those used for performance predictions, the results from full scale sea trials do in general appear to support the results from professionally undertaken performance predictions.

The main parameters used to define sea conditions are significant wave height, modal period, spectral shape (that is the distribution of wave frequencies within the sea spectrum, generally assuming an ITTC or JONSWAP spectrum for predictions in UK sea areas) and an energy spreading function (generally using a +/- 90 degree Cosine squared function for prediction work).

Based on the above, and the afore- mentioned motion and handling limitations, a typical performance prediction for an 20 metre CTV during transit is provided

in Figure 1. For the calculation of the average speed it has been assumed that the vessel will spend an equal amount of time at the five main headings (head, bow, beam, stern and following). The seastates are defined with a single average period.

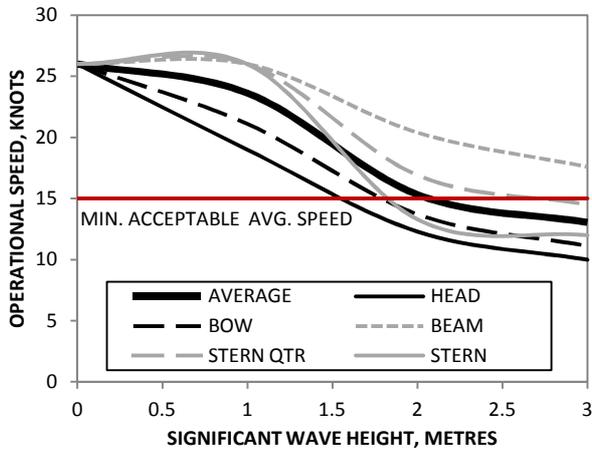


Figure 1: Speed vs Hsig for limiting conditions

However, for small fast craft, the spectral modal period and frequency distribution are known to be particularly influential with regards to accelerations experienced on board when operating at speed and a more comprehensive performance prediction presentation (Performance plot or P-Plot) is provided in Figure 2 (this time for a 16 metre CTV) where the effect of wave period is clearly shown. The power limit for the vessel is also indicated, based on theoretical calculations of added drag at sea.

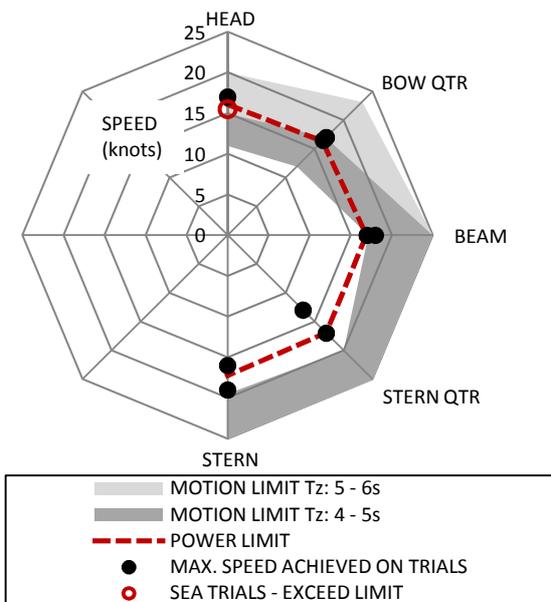
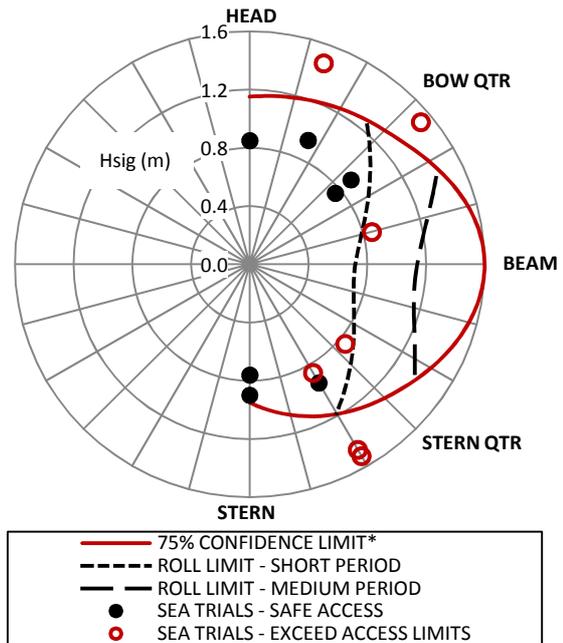


Figure 2: Limiting speeds P-Plot for Hsig of 1.0 metres

Data from the results of sea trials are also provided on this figure and it can be seen that, with the development

of a number of such figures covering say three or four significant wave heights, a comprehensive assessment of the performance of CTV at sea can be developed and verified by sea trials.

A similar presentation, this time for the transfer mode on the same 16 metre CTV has been developed (Figure 3) although the effect of wave period on transfer limits had not, at the time of writing, been researched sufficiently to provide comprehensive data in this regard.



* For no-slip transfer using step across rubber fender

Figure 3: Transfer limits P-Plot

4. CTV OPERATIONAL AVAILABILITY

Understanding and defining the performance of CTV at sea during their various modes of operation is clearly of significant benefit but really only a stepping stone to making commercial use of this information.

In the RINA conference of the same name in 2014, Seaspeed presented a methodology for the assessment of CTV availability on a wind-farm on the basis of vessel size and cost. This method involved the comprehensive assessment of the performance limitations of a number of such craft using data for a specific wind farm (i.e. specific environmental conditions, transit routes and turbine docking arrangements). Such an assessment has been undertaken using that methodology where both the transit and transfer limits were determined for a range of CTV between 15 and 28 metres in overall length.

The performance limitations applied were those noted in section 2 of this paper. The primary limitations during transit were found to be vertical and horizontal

accelerations (limiting the vessel before slamming, wetness or excessive pitch or roll became a problem). Speed in a stern sea was also limited to avoid deck diving and in this regard, use was made of the UK MCA's research project 502 and MGN 328(M). In the transfer mode, an assessment of the vessels ability to perform a step-across fender transfer was made using physical model test data based on a no-slip confidence level of 80% - although slightly higher limits were used for stern and following sea orientations to obviate the need for considerations of propulsor ventilation and stern swamping which would have been analytically more difficult to accommodate. It was found that for these vessels, pitch, roll and acceleration motion did not restrict their operation during transfer: the limitation was found to be solely due to the ability of the vessel to maintain sufficient bollard thrust, and hence bow fender friction, to prevent bow slip. With regards to the approach to the turbine tower, which is a difficult mode of operation to analyse, it was assumed that if transfer was deemed to be possible once docked, then the approach would also have been possible to undertake.

The resulting information is provided in Figures 4 and 5 on the basis of CTV availability (for operation on the wind farm) against vessel size and cost respectively. Availability is defined here as the percentage time in one year (i.e. in terms of 365 twelve hour days) the CTV is able to be on the wind farm, loitering or transferring personnel. Should the weather conditions be such that it cannot transit or transfer then the vessel is considered not to be available. Availability also accounts for the lost time in transit when operating in rough weather. The cost is the daily charter rate in 2013/2014.

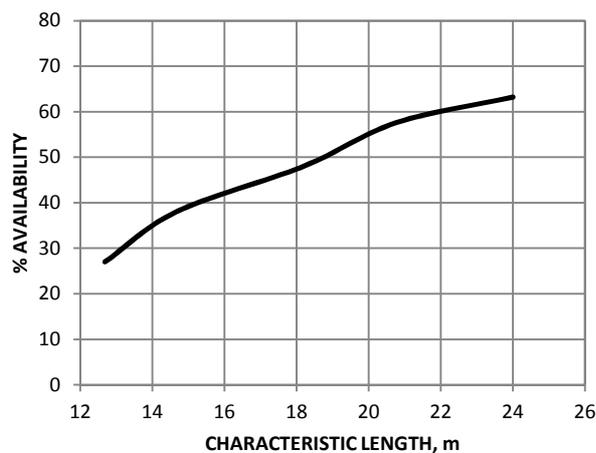


Figure 4: Availability vs vessel size

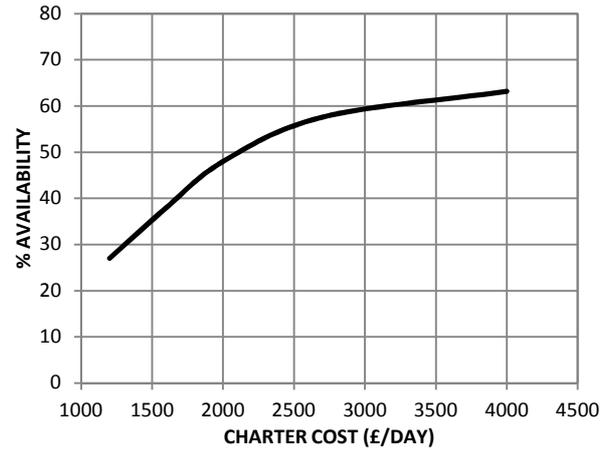


Figure 5: Availability vs vessel charter cost

5. CONCLUSIONS

It can be seen that there are a number of ways of evaluating the performance of CTVs, depending on the type of information required. The assessment of the limiting performance is essential to the determination of the likely availability of these craft for efficient commercial operation in what are by their nature, windy and hence rough sea environments. At this stage in the development of the CTV industry, the ability to verify performance predictions by sea trial results is important to those contracting these vessels due to the wide variety of vessels on offer and their associated variations in performance. The use of such P-Plots in contracting these craft (where performance predictions made prior to the contract can be verified by sea trials during the contract) could reduce the commercial risk to those wishing to make use of new CTV design developments – and at the same time put pressure on the designers to ensure that their predictions are reliable.

6. AUTHORS BIOGRAPHY

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