FULL SCALE MEASUREMENT OF DYNAMIC SHIP MOTIONS AND SQUAT

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'Real time' information integrated with 'Dynamic Modelling' is challenging traditional methodology in many port operations scenarios. Technology can be put to work to develop efficiencies that result in commercial benefits; it can also be used to test developments, and to reinforce safety aspects.

The proposal to replace gross UKC allowance by ship dynamics modelling integrated with real time tide and wave data has required thorough testing to validate outcomes. This paper presents the methodology and findings of a series of measurements undertaken in an exercise specifically designed to check the predictions of the Dynamic Under Keel Clearance (DUKC) system, installed at the Port of Brisbane.

Results of the measurement program were used to validate the numerical modelling of dynamic motions and squat in the DUKC system. Excellent agreement was obtained between measured and computed bottom clearances along the channel, with the DUKC system at all times providing conservative allowances for dynamic motions and squat.

INTRODUCTION

Ports around the world are continually challenged to improve commercial performance. Navigable access channels can be the key to greater commercial viability of a competitive port by providing economical sea roads, for all types of vessels accessing the port.

The Port of Brisbane has been actively pursuing alternative means of draft determination and tidal window access for deep draft vessels transiting its 50 nautical miles of navigation channels. Recently, the Dynamic UKC® system, or DUKC®[1] System has been trialled in Brisbane as a more commercially efficient means of maximising vessel draft and tidal windows, challenging the inefficiencies of the static UKC system that has been in use in the port since its inception.

The dilemmas associated with optimising the use of expensive navigation channels have long been a concern for the Port of Brisbane Corporation. Having a navigable access transit of 88 kilometres from the entrance (Fairway buoy) to the port, at the mouth of the Brisbane River, see Figure 1, raises significant logistical problems in relation to vessel scheduling and draft/load determination. Depth restrictions at each end of the transit exacerbate these problems.

The Gross UKC system used by the Port requires vessels to retain a minimum of 1.9m UKC through the North West Channel, to accommodate the effect of wave conditions, tidal residual, and bed depth tolerance, based on worst case conditions.

Pressure from Oil Majors and from the commercial side of the industry have focussed on the fact that most of the vessel transits are in conditions that are very favorable, and therefore the vessel may be considered to be under loaded, or delayed unnecessarily in its transit entry window.

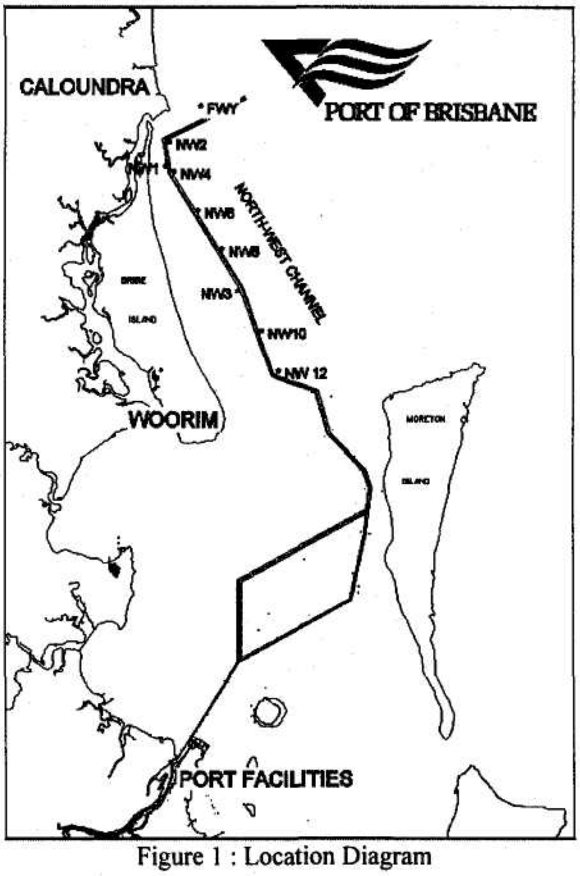

Figure 1 : Location Diagram

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The DUKC System, was designed to integrate wave and tide conditions with various relevant models, and the vessel's dynamic characteristics, to optimise both commercial and safety interests as explained by O'Brien (1).

Implementing the DUKC system and gaining support for its acceptance as a better system for Brisbane, in lieu of the Gross UKC system, has required substantial research and testing. In fact, the system has undergone continual testing, refinements and modifications since its establishment.

Import oil tankers are the majority of deep drafted vessels using the port of Brisbane, with export coal vessels the next deepest draft. A typical transit of the Channels from Caloundra to Fisherman Island subjects a vessel to the following effects:

- Roll, due to swell on or near the beam
- Heave
- Pitch
- Squat

Pilots and Masters have a natural suspicion about the accuracies of empirical tables defining the values associated with the above effects. Carte blanche acceptance of the DUKC, which has real time vessel dynamics embedded in the calculations, is sometimes too great an ask for the professional Pilot or Master, particularly when the DUKC system indicates transit strategies enabling greater draft and wider windows.

The Port of Brisbane Corporation has therefore embarked on a DUKC system validation testing program involving full-scale measurements of vessel motions.

FULL SCALE TESTING TECHNIQUE

Measuring the dynamics of vessels in transit requires the use of specialised Kinematic Differential GPS equipment. Three GPS receivers are positioned on the ship, one on each of the bridge wing extremities and one on the bow as per Figure 2.

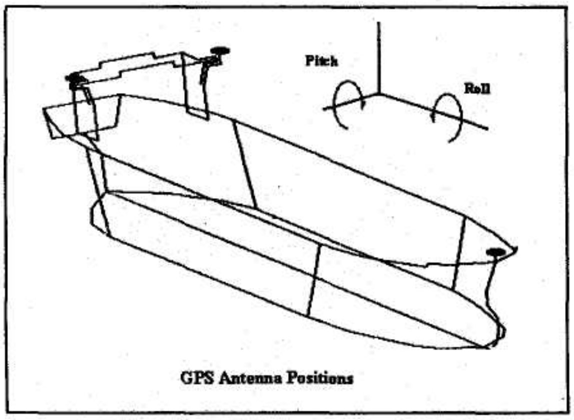


Figure 2: GPS Antenna locations.

To establish sufficient redundancies **and** for checks on the calculations, two base stations were used, one at Caloundra and one at Woorim. These are separated by a distance of twenty five kilometers.

Typically, this equipment is capable of accuracies of 50 millimetres both horizontally and vertically over the ranges involved.

All equipment and personnel board with the Pilot at the boarding ground. Set-up for all three onboard receivers takes approximately 15-20 minutes. Data was logged from the fairway buoy to the NW8 beacon - lack of memory prohibited the entire transit being logged. All the data was post-processed, thus no results were available at the time of the transit.

Two inbound ships have been tested at Brisbane, the Poul Stririt and Tohvuh Maru.

FULL SCALE TEST RESULTS: POUL SPIRIT

The Poul Spirit entered the port with the following characteristics:

LOA	244.8 m
Beam	41.3 m
DWT	98600 t
Draft	12.87 m
Entry date	20/12/97
Arrival at Fairway	11:00 hrs
Swell Height	0.31 m
Swell Period	10.45 sec

Transit Speed

The transit speed along the channel is far from constant; varying from about 10.2 knots, up to 14.0 knots, as can be seen in Figure 3 below.

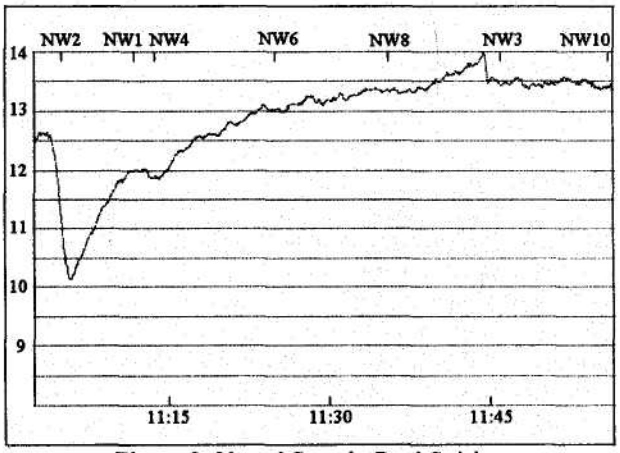


Figure 3: Vessel Speed : Poul Spirit

Figure 3 shows drastic reductions in speed occur at locations where the vessel turns, around NW2 beacon, with lesser reductions in speed at turns around NW4 and NW3.

Vessel Draft and Bathymetry

The deepest point on the hull during the transit, and the relevant surveyed depth actually below the ship is shown in Figure 4. The deepest point of the hull was computed by generating a three dimensional model of the ship's hull using information from the general arrangement plans. The model was then rotated and shifted according to the computed roll, pitch and heave values.

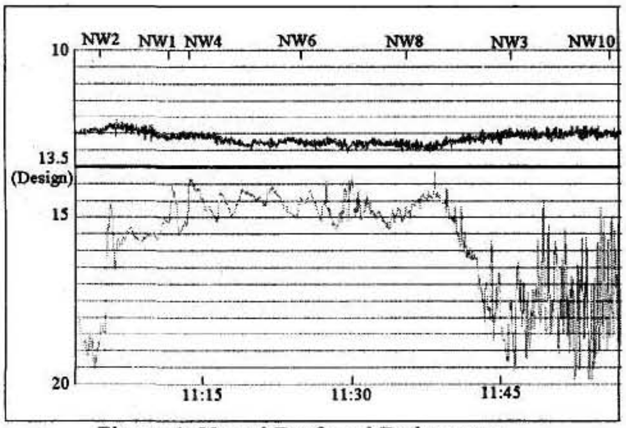


Figure 4: Vessel Draft and Bathymetry

This shows that the minimum clearance achieved during the transit was 0.6 metres, at a point between NW6 and NW8, around the 'coffee rock' area.

Bow and Bridge Squat

The different squat characteristics applicable to the bow and bridge sections of the vessel are shown below in Figure 5. Pitch has been left in the graph, and a smooth curve superimposed for easy interpretation.

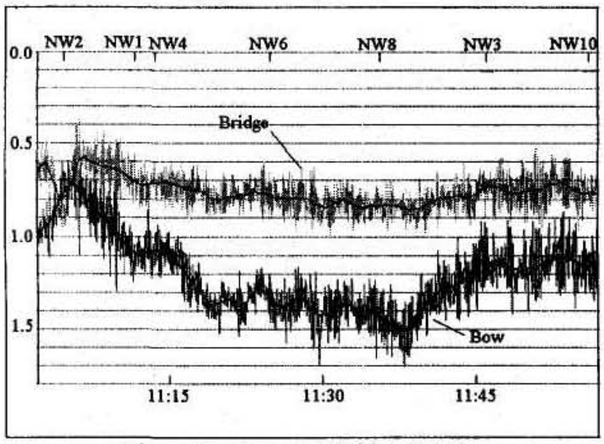


Figure 5 : Bow and Bridge Squat

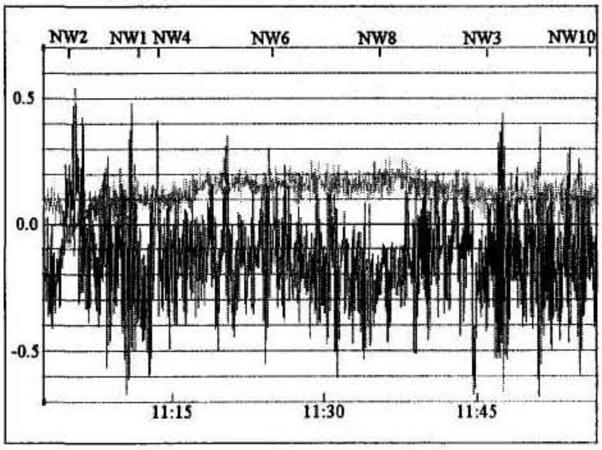
A clear increase in vessel squat can be seen between NW6 and NW8 caused by the shallower 'coffee rock' area. The vessel squat is increased by approximately 0.3 metres due to the reduced channel depth over this area and to slightly increased vessel speed.

It has been shown by Hatch (2) that vessel acceleration and undulations in the sea floor, such as occur over this area, can have a large effect on vessel squat. Full-scale measurement of squat assists in ensuring that pilots and masters exercise caution over areas of concern and helps to establish where added safety factors are required in squat prediction.

Roll and Pitch

Vessel pitch and roll were measured and are shown below in Figure 6. Pitch is shown as the faint oscillating line, while Roll is the darker oscillating line. The trim and list components have not been removed from the data.

Figure 6: Roll and Pitch



As can be seen from Figure 6, the pitch during this transit was fairly small while the roll varies from 0.5 to -0.7 degrees (port to stbd). The roll graph is below the zero axis, indicating that the vessel had an inherent list.

FULL SCALE TEST RESULTS: TOHYUH MARU

The Tohyuh Maru was the second ship tested and entered the port with the following characteristics:

LOA	242 m
Beam	42 m
DWT	95843 t
Draft	12.1 m
Entry date	23/01/98
Arrival at Fairway	11:00 hrs
Swell Height	1.42 m
Swell Period	9.66 sec

The following results have been graphed for this transit:

- Vessel transit speed
- Vessel draft and bathymetry
- Bow and bridge squat
- Roll and pitch/trim

Transit Speed

The transit speed again varied greatly along the channel; from about 7.0 knots up to 14.0 knots, however lower speeds were maintained over the critical area between NW6 and NW8, as can be seen in Figure 7 below.

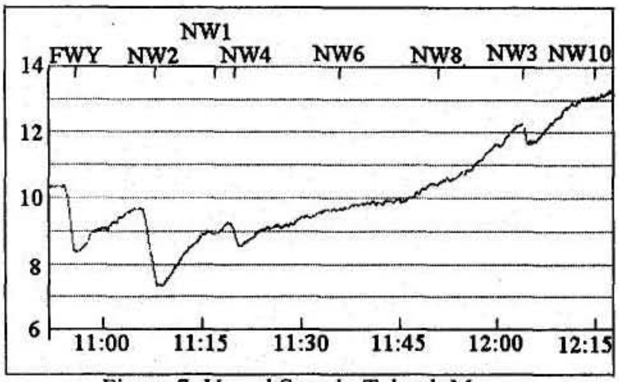


Figure 7: Vessel Speed : Tohyuh Maru

Vessel Draft and Bathymetry

The deepest point on the hull during the transit, and the relevant surveyed depth actually below the ship is shown below in Figure 8.

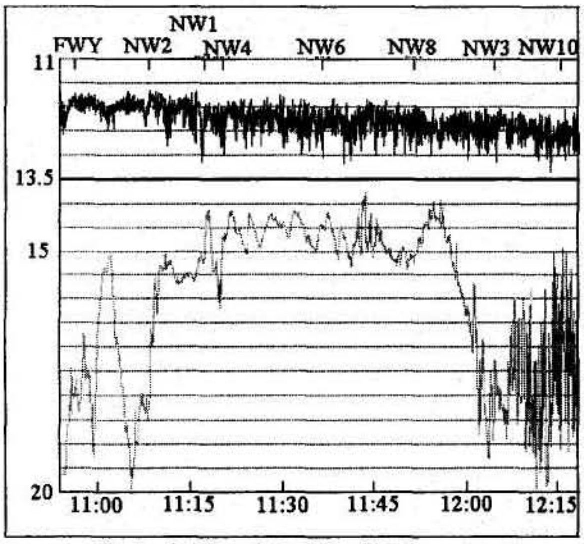


Figure 8: Vessel Draft and Bathymetry

Figure 8 shows that the minimum clearance achieved during the transit was 0.5 metres, again at a point around the 'coffee rock' area. The swell was much larger for this ship which is reflected in the greater variation in draft.

Bow and Bridge Squat

The different squat characteristics applicable to the bow and bridge sections of the vessel are shown below in Figure 9. Pitch has been left in the graph, and a smooth curve superimposed for easy interpretation.

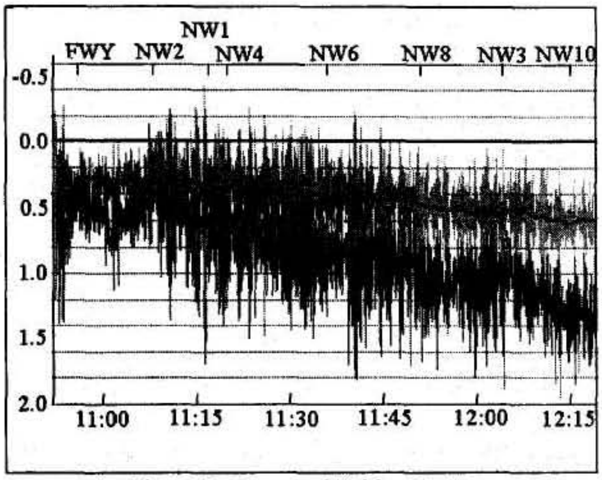


Figure 9 : Bow and Bridge Squat

As part of the Quality Assurance (QA) the squat was computed for the 10 minute period while the vessel was stationary at the pilot boarding grounds. Squat measured 0.05m.

Roll and Pitch

Vessel pitch and roll are shown below in Figure 10. Again, pitch is shown as the faint oscillating line, while roll is the darker oscillating line.

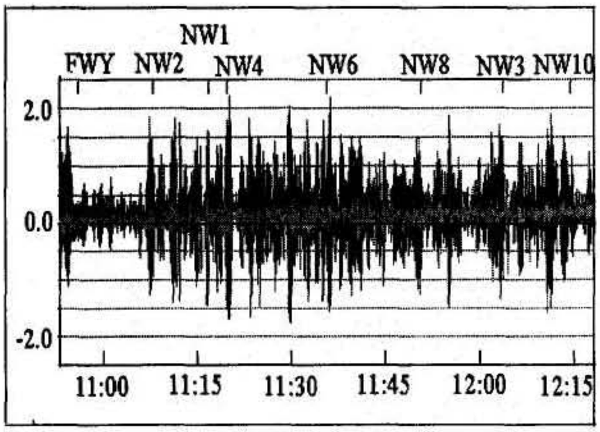


Figure 10: Roll and Pitch

As can be seen from Figure 10, the roll and pitch for the Tohyuh Maru was much larger overall due to the swell conditions. The transit between the Fairway beacon and NW2 shows little roll because of the swell direction, however after rounding NW2 roll becomes a significant component of the draft equation. Roll ranged from -1.7 to +2.2 degrees, indicating an inherent list, which was confirmed by static draft measurements.

COMPARISON OF FULL SCALE RESULTS TO DUKC

The purpose of measuring the actual under keel clearance is to compare results with the Dynamic Under Keel Clearance software, thereby gaining a level of confidence with the system.

Results for the Poul Spirit show that actual minimum UKC was 0.6 above channel design depth, while the DUKC system output was 0m (a safety margin of 0.6m). An almost identical result was obtained for the Tohyuh Maru (0.5m above channel design depth, compared to 0m minimum bottom clearance by DUKC system).

The individual components of dynamic motions and squat were also analysed for both transits and compared with the DUKC modelling results. All dynamic motions were found to be within the allowances computed by the DUKC system.

Valuable data was provided on the effects of vessel acceleration and undulating sea floor on squat (so-called "dynamic squat" effects) and minor modifications were made to the DUKC squat model to allow for these effects in the Brisbane system.

CONCLUSIONS

The full-scale tests have clearly identified that a transit to the port has great variations in speed, squat and dynamic motions and that a simplified Gross UKC approach is not economically efficient. Instead, deep draft vessels need to adhere to a predetermined transit strategy that integrates speed and vessel dynamics with the varying channel dimensions.

The test program has provided valuable full-scale data on dynamic ship motions and squat. These data have confirmed that the DUKC system provides a tool that the Port can use to optimise economic efficiency, without compromising safety standards.

The project, aimed at optimising port entries and departures, emphasises the Corporation's stance on Customer Service and Market position improvement through the achievement of high standards of efficiency and subsequent effectiveness. It is one of the several initiatives that will see the development of the port from the present form to its projected 2005 plan.

REFERENCES

1. O'Brien, W. T., Experience Using an Innovative Under Keel Clearance Prediction System in Australian Ports. Port Technology International, Sixth Edition, ICG Publishing Ltd., 1997, pp. 165-169.

2. Hatch, T. L., Experience Measuring Full Scale Squat of Full Form Vessels at Australian Ports. Paper to be presented at Coasts & Port Conference, Perth, Australia, April, 1999.