BWS ONLINE – FORECASTING BERTH OPERATING SAFETY

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Abstract: BWS Online is a system designed to provide assistance to terminal operators in making decisions as to the operating safety of berthed vessels. A numerical vessel motion model is used to interpret the significance of forecast wave and wind conditions to berthed vessel operations. This provides a scientific tool for reducing the probability of an incident resulting from excessive motions of the moored vessel.

An introduction to the factors affecting berth operating conditions including swells, long waves and wind conditions, vessel size and load state and mooring configuration is provided.

This information is integrated by the BWS Online to provide assistance in planning vessel movements as well as monitoring the safe operation of berthed vessels. The System is Internet enabled to provide flexible access to all relevant parties. Details on the operation operation and functionality of the system are discussed. This is supported by a case study tracking the use of the BWS Online at the Port of Hay Point, Queensland.

Keywords: Berth Operating Safety, Berth Warning System, Ship Response modelling.

INTRODUCTION

For ports exposed to weather conditions that can induce significant motions on berthed vessels there is an ongoing risk to shipside and dockside personnel and equipment. Damage to ship, moorings and fenders is expensive to repair. Injury and death to personnel is tragic and intolerable.

Traditionally the vast majority of ports have relied upon vague weather forecasting, rules of thumb and the judgment of individuals to determine when operations surrounding a berthed vessel will become unsafe. Often the judgment is made commendably, but on a few tragic and expensive occasions the wrong decision is made.

As severe weather conditions close in on a port, operators find themselves drawn by conflicting responsibilities. The economic viability of the port could be threatened by regular premature closure of operations. On the other hand a safe environment for personnel and infrastructure must be provided.

Another scenario of concern to port operators is when a ship starts moving in its berth on an apparently calm day. This can be caused by the arrival of long waves of which there is often no warning.

In recent years there have been technological advancements which provide information to port operators to help them make decisions relating to port operating safety. These have included the installation of wave and wind measuring instruments with near real-time data feeds to computers where conditions can be monitored. The internet provides ready access to weather forecasts in the form of synoptic charts and weather warnings. Whilst this information is of significant benefit, there remains considerable interpretation required on the part of port operators.

Wind and wave data measurements give little accurate indication of conditions for the next 24 plus hours. Weather forecasts tend to be on a much larger scale than the immediate vicinity of a port, making specific interpretation of an event's impact on a port a challenge. Further, whilst the available information attempts to describe the conditions that drive the motions of a moored vessel, the impact those conditions will have on any given moored vessel remains unknown.

BWS Online integrates the available climate data including forecasts with vessel mooring configuration and load state and dimensions in modelling to determine what the resulting loads on moorings will be. This is correlated with peak mooring loads and calibrated against actual events to determine the level of berth operating safety.

MOORED VESSEL MOTIONS

The motion of a moored vessel can be described by six degrees of freedom (where the vessel is assumed to be a rigid body). That is there are six independent coordinates required to completely describe the position of a vessel at any point in time (Rao (1995)). These include Cartesian and rotational coordinates. They are illustrated in Figure 1. When determining loads on mooring lines, bollards and fenders the resultant motion of all six degrees of freedom must be considered.

The presence of moorings increases the complexity of modelling vessel motions as the moorings introduce non-linear responses. The equations of motion for each degree of freedom contain higher order powers of displacement and its derivatives.

In BWS Online the vessel motions and resulting loads on moorings are determined from a mathematical model. Sea state, wind, mooring characteristics, vessel load state and dimensions are inputs to a time domain simulation which outputs the resulting loads.

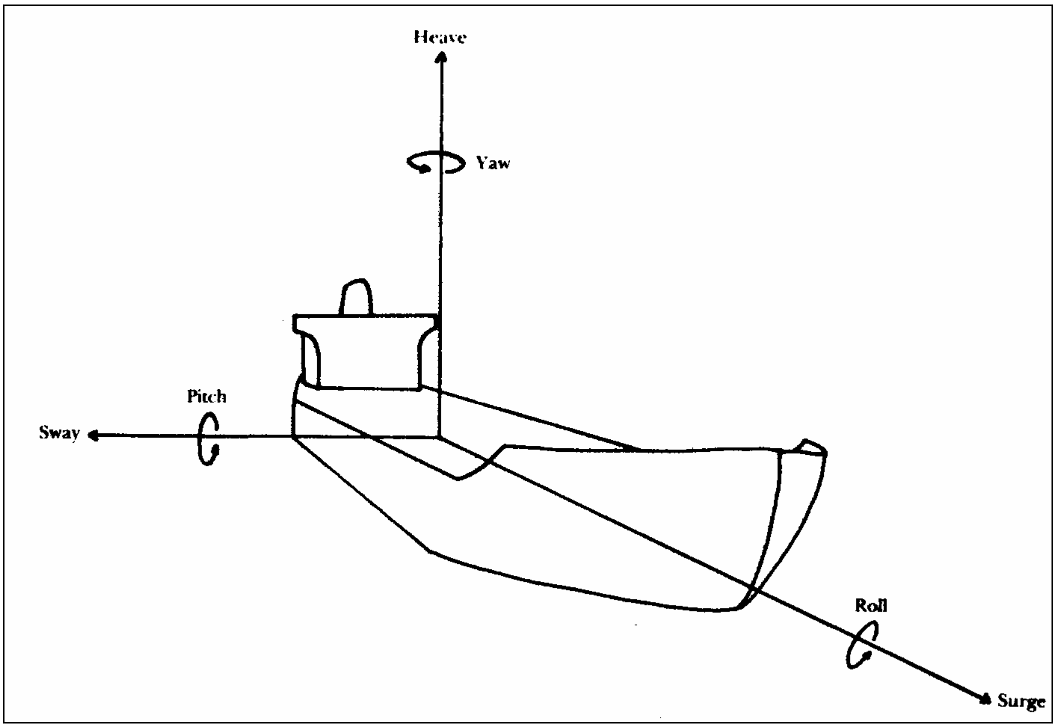

Figure 1. Six degrees of freedom of a vessel (George (1983)).

FACTORS AFFECTING VESSEL MOTIONS

The primary factors influencing the motion of moored vessels include:

- Sea state
- Wind condition
- Vessel dimensions and load state
- Mooring configuration

Sea State

Sea state is usually described as a frequency spectrum. That is wave energy with respect to various frequencies. For large vessels, motions that can be significant to berth operating safety can be induced by wave energy at periods (1/frequency(Hz)) from 4 to 300 seconds. The spectra provided should cover frequencies in this range.

For the purpose of comprehension of the mechanism involved in wave induced vessel motions, the frequency spectrum can be divided into three parts:

1. *Sea waves* – Periods shorter than approximately 7 seconds. These are generated by winds in the local area. They generally contain relatively small amounts of energy and tend not to induce significant motions in large vessels. The occurrence of large sea waves will usually be associated with strong winds. In this instance it is usually the winds causing vessel motions.

2. *Swell* – Periods from 7 to 30 seconds. Swells can be generated by systems far away from the local area. As sea waves move away from their generation area they lengthen, their height is reduced and their speed increased (Goda (1985)). They become swell. Swell

induced significant vessel motions particularly in the vertical modes (heave, pitch and roll).

3. *Long Waves* – Periods longer than 30 seconds. These too are generated far away from the local area. They can travel attached to swell or detach and travel separately. Typically long wave heights are very small, making them almost impossible to detect with the naked eye. Long waves are most significant to moored vessels inducing slow drift oscillations in the horizontal modes (surge, sway and yaw). Significant vessel motions in apparently calm wind and wave conditions are usually an indication of the presence of long waves.

Wave incident angle on a berthed vessel is critical in determining wave response. The wave response model must include the correct vessel orientation to incident waves. Accurate transformations for wave energy and direction from measuring and forecast locations to the berth are required.

Wind Condition
Winds can induce vessel motions in the horizontal modes (surge, sway and yaw). Key parameters in describing the affect of wind on vessel motions include incident direction of wind on vessel, wind speed and area of vessel facing the wind. Wind speeds sustained for 20 seconds or longer can induce motions on large moored vessels.

Vessel Dimensions and Load State
Vessel dimensions and load state will influence the motions induced by sea state and wind. Dimensions and load state influence the resonance frequencies for each mode of oscillation as well as the damping affects of the water. As a vessel load state changes its wind area and height of centre of gravity also change.

Mooring Configuration
The vessel motions are affected by the number and location of mooring lines, fenders and bollards as well as the length and angle of mooring lines. Motions will also be affected by the elastic properties of the moorings.

BWS ONLINE

BWS Online gives consideration to each factor affecting vessel motions to the extent made possible by the availability of data at a given location. Forecast wind and wave conditions are input to give the system predictive capability. The forecasting models used depend on availability and applicability at each site.

The forecast and measured climate data is input to the wave response model along with the vessel dimensions. Mooring loads are determined for the vessel in various states of loading. These are correlated to levels of operating safety ranging from Normal to Alert. The number of warning level increments is customised to meet the requirements of the individual port.

Warning levels are presented graphically as shown in Figure 2. Time series for berth operating safety based on both measured and forecast data are presented. This provides the facility for operators to consider the quality of recent forecasts in decision making.

Time series of berth operating safety are provided for three vessel load states (ballast, 50% and 100%). The load state can have a significant influence on the movement of the vessel in the berth. Changes in load state with time should be considered when making decisions to berth a vessel or to remove it from berth.

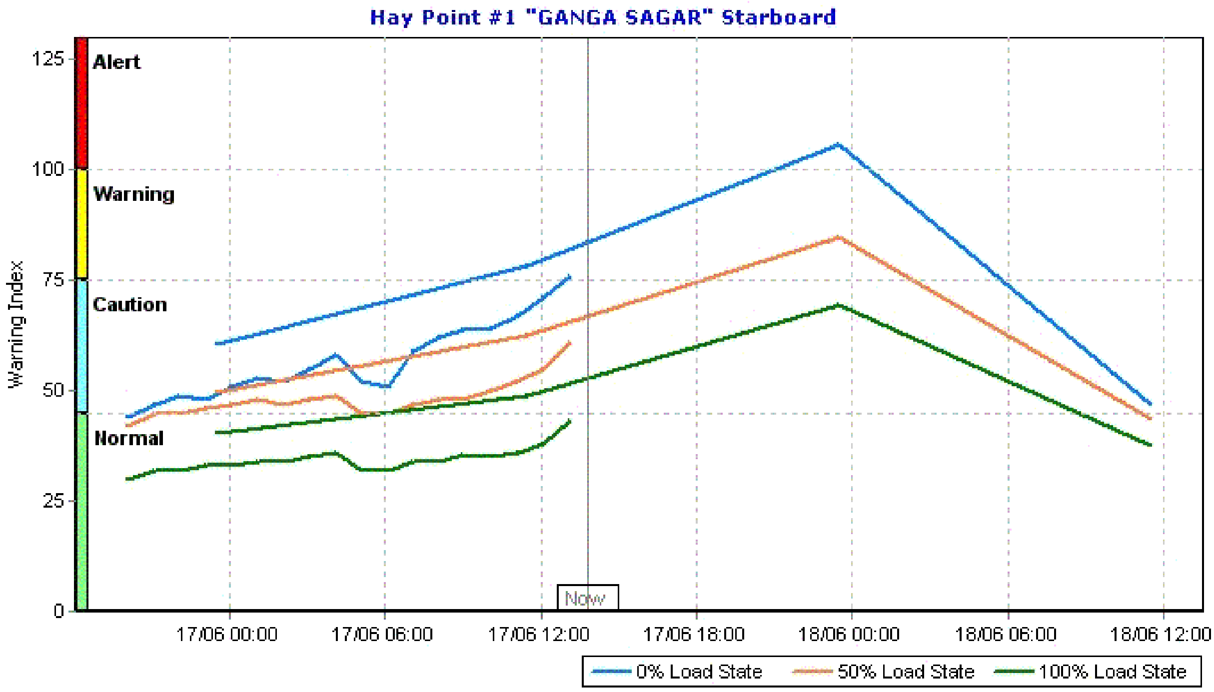

Figure 2. BWS Online graphical display of berth operating safety levels.

OPERATION OF BWS ONLINE

BWS Online is used to assist in planning vessel berthings and to monitor the operating safety of berthed vessels.

At ports where multiple vessels can be waiting to berth, the ***BWS Online Planner*** allows operators to try a range of vessels in a berth to compare predictions of operating safety. Vessels of different sizes can experience significantly different motions in the same wave and wind conditions.

The *BWS Online Monitor* displays the operating safety of currently berthed vessels. It automatically updates as new measured or forecast climate data becomes available. Port operators specify the actions that should be taken when each operating safety level is reached. Factors to consider when setting these limits include:

1. Time required to ready a vessel for sailing (complete loading/unloading, survey)
2. Time required for pilot to be available
3. Availability of tugs
4. Opening and closing of sailing windows
5. Other sailings planned for the tide

As suggested by its name, BWS Online can be made available via a secure internet site to all interested parties (Port Authority, pilots, agents, shipping line). The functionality exists to specify the level of access available to each user.

Other functions available with BWS Online include:

- Searchable Ship database
- Measured and forecast climate data (waves, wind and tides)
- Searchable history of berth operating safety levels

CASE STUDY: BWS ONLINE AT HAY POINT (QLD)

Background

The port of Hay Point is a major coal exporting port on the central Queensland coast south of Mackay. There are five berths with facilities capable of loading 20,000 to 250,000 DWT bulk carriers. In the summer the port is exposed to cyclonic swells and strong winds predominantly from the north east. In the winter, the predominant long period swells are generated by storms in the Southern Ocean (O'Brien (2000)).

In June 2002 a significant swell event rolled into Hay Point from the South East. The available measured wave and wind information gave insufficient warning of the event. Two of the berthed vessels experienced extreme motions causing significant damage to berth and ship.

OMC was able to demonstrate that the capability existed to forecast this event at least 24 hours before it arrived at Hay Point. This would have provided sufficient warning to vacate berths as required to prevent damage. The decision was made to install BWS Online at Hay Point. The installation was completed in January 2003.

Tropical Cyclone "Beni"

On 1 February 2003 a low pressure system formed approximately 1500km due east from Brisbane, Queensland. Over the next few days the system intensified and moved north west towards the central Queensland coast. By mid-afternoon 4 February 2003 the system was sitting off the coast north east of Hay Point.

Late on 2 February swell began to arrive at Hay Point. This was detected by BWS Online forecasts. Swells remained high for the following 60 hours with some tidal variation. The forecast provided a good indication of the basic shape of swell growth during this period, though its resolution was insufficient to predict the exact time of peak swell conditions or the tidal variation.

Figure 3 shows the operating safety determined by the BWS Online based upon measured and forecast conditions for a vessel at ballast in one berth at Hay Point during TC "Beni". The system provided sufficient warning to assist terminal operators in decision making.

The Planner and the Monitor were used in making the decision to move certain vessels to the safety of open water. The most exposed berths remained closed for the duration of the forecast severe conditions. Damage to berth facilities, the ship and personnel were prevented with minimal port downtime. Operators closely monitored conditions and felt BWS Online accurately forecast the operating conditions that eventuated.

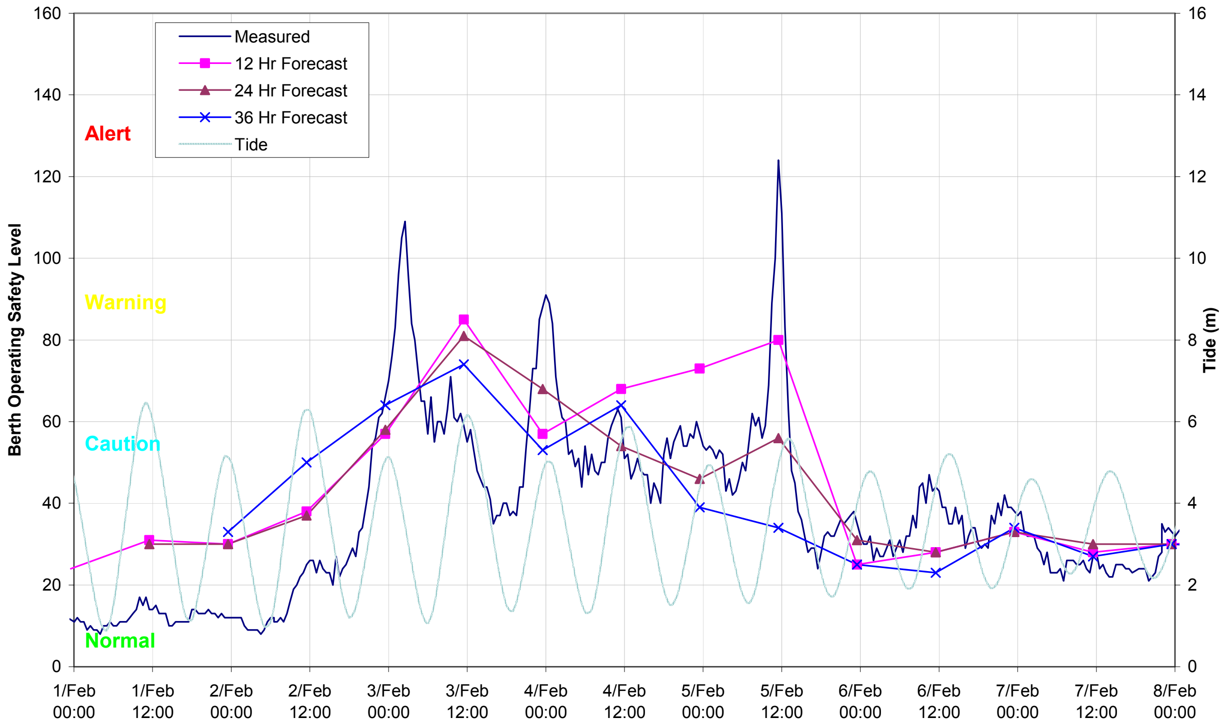

Figure 3. Berth operating safety at Hay Point during TC "Beni".

Economic Benefits of BWS Online

In addition to preventing damage to ships, berth infrastructure or injury to personnel, BWS Online has provided economic benefit at Hay Point by assisting in planning vessel loading.

Cape size vessels at Hay Point take approximately 20+ hours to load. The tide cycle at Hay Point is semi-diurnal. There is an intervening high water between berthing time and planned sailing time on which, if wave and wind conditions deteriorate, the vessel may need to sail. On occasions when the intervening high water is the lower high water, the vessel is restricted to loading to the maximum draft of the intervening low water in the first 12 hours of loading. This can leave insufficient time for the vessel to load to its desired sailing draft by the planned sailing time.

The Hay Point Regional Harbour Master noted that BWS Online was providing a reliable prediction of the likelihood of conditions deteriorating to an extent that a vessel would be required to sail on the intervening high water. The rule for loading was changed such that on occasions when BWS Online was predicting conditions less than 50% of the CAUTION stage, loading would not be restricted by the intervening high water. This significantly simplifies the planning of ship loading and provides vessels with the greatest opportunity to load to their desired draft.

CONCLUSIONS

- BWS combines available wind and wave measurements with forecast data and the vessel load state, dimensions and mooring configuration to provide a forecast of berth operating safety.

- BWS Online represents a significant advancement over existing tools to assist with decision making relating to vessel berthings and departures for the following reasons:
  - It has forecasting capability.
  - It interprets raw wind and wave data to provide a clear assessment on the affect the conditions described by that data will have to the actual berthed ship.
  - In is internet enabled allowing easy access by all interested parties.

- BWS Online can improve the operating safety of ports exposed to swell or wind events that can induce significant motions in berthed vessels which pose a threat to ship, berth infrastructure and personnel.

- BWS Online can be used to economic advantage by preventing expensive damage to infrastructure. The information it provides can also be used to refine port operating procedures and improve efficiency.

ACKNOWLEDGEMENTS

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