TRELLEBORG

The Effect of an Automated Mooring System (AutoMoor)

IN DECREASING THE WAVE EFFECTS ON A MOORED VESSEL

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WHITEPAPER

Abstract

Increasing operational efficiencies is a key goal of many ports and the shipping industry as a whole. External forces such as inclement weather, long period waves and the effects from passing ships can reduce berth efficiencies by increasing the motions of a vessel at berth.

A container vessel berthed in the outer harbor near a breakwater is analyzed for its motions at berth. In this location a breakwater provides good attenuation of the offshore wave energy (wind, sea and swell) at the berth but only has limited impact on long period (infragravity) wave energy. A comparison between the vessel subject to long period waves when moored with traditional lines and a number of Trelleborg AutoMoor units showed that the peak and average motions in surge and sway were reduced substantially. AutoMoor achieved 75% of motion off berth at a level less than the lowest 25% of that with mooring lines. The reduction in vessel motions indicates an increase in berth operability for product transfer from 65% to 95%.

Keywords: Infragravity Wave, Long-Period Wave, Vessel Motion, AutoMoor, Automated Mooring.

Contents

Introduction

The port industry continually faces the challenge of maximizing berth utilization to allow product or passenger transfers to occur as seamlessly as possible with minimal downtime. In general, this challenge arises from the need to:

- Prepare port infrastructure to cater for the ever-increasing vessel size.
- Discover innovative ways to reduce capital investment.
- Increase vessel traffic due to higher demand on ports and terminals.
- Find ways to lower operational costs and make the port more attractive.
- Reduce frequency of incidents that jeopardize port safety and cause downtime.
- Minimize the effects of adverse environmental and met-ocean conditions.
- Minimize the effects of passing vessels.

Focusing on factors that affect moored vessels at berth; in the simplest of terms, for a mooring system to be effective, it must counteract external forces acting on the vessel to restrain the motion sufficiently to allow efficient product transfer.

External forces can be grouped into two main categories:

i. Static – forces that for analysis can be considered not to change significantly over a short time including current, constant wind and short period waves.

ii. Dynamic – forces that change significantly over a short time including long-period waves, gusting winds or the effects of passing ships.

The efficiency of a mooring system of any kind is contingent on a number of factors:

- The 'human element' - lack of timely information to make informed decisions; inaction to changing conditions, or suboptimal practices.
- Ineffective facility designs or mooring pattern selection.
- The environment: met-ocean conditions or passing vessel.

One specific met-ocean condition is infragravity waves which are waves with periods greater than 30 seconds. The wave height is generally smaller than a regular wave when in deep water but can increase as water depth decreases. Due to having longer periods they are less affected by breakwaters, can travel uninhibited into harbors and as a result, can have significant impact on vessels moored within. There a significant risks associated with these waves including lines snapping and vessels drifting from berth. The downtime caused to operations can be significant, as the wave has a high level of energy transfer to the vessel and causes large vessel motions.

The use of automation in port operations is becoming more commonplace, with applications ranging from offshore autonomous ships to onshore fully automated container yards.

The Trelleborg AutoMoor system (Figure 1) is a passive automated vacuum mooring system that maintains a vessel mooring through the use of spring dampening. Each arm has a rated load of 20T with unit variants of T20 and T40 with one and two arms respectively. The passive system is engaged at the position of vessel berthing and extended/retracted if loads exceed rated limits.

Objective

The objective of this paper is to demonstrate the effectiveness of AutoMoor by expanding the window of operation for product transfer by reducing vessel motions. This is achieved by modelling the wave field in the harbor, applying the wave forces to a moored vessel, and benchmarking the AutoMoor solution against a conventional static mooring line arrangement.

Fig 1 – AutoMoor T40 unit

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AutoMoor achieved 75% of motion off berth at a level less than the lowest 25% achieved with mooring lines

Setup

A mooring analysis was performed for a vessel berthed at a container terminal located near a breakwater entrance where it is unprotected from the effects of infragravity waves (Figure 2).

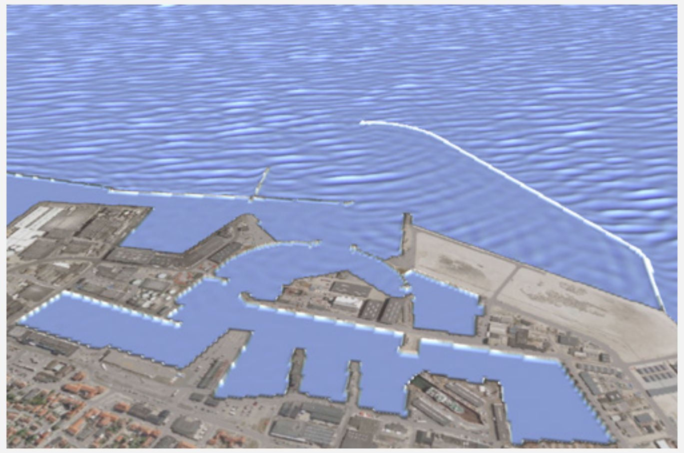

Fig 2. Wave propagation within harbor example

Using the newly developed AutoMoor supported module in DHI's truly dynamic mooring analysis software, MIKE 21 MA [1], which is capable of extremely fast and high precision hydrodynamic simulations, a study was conducted comparing motions of a vessel when moored with mooring lines and AutoMoor T40 units. The combined sea, swell and infragravity wave forcing was created using the industry standard wave agitation software MIKE 21 BW model of the entire port domain. The vessel considered was a 10,000 TEU container vessel.

The analysis was performed on the vessel when moored in an 'optimal' conventional mooring (Figure 3) arrangement of 14 lines; 5 lines at bow and stern, 2 spring lines at bow and stern, all at 10T pretension. These lines were modeled as broken-in polyester polypropylene with MBL 110T. The results from this analysis were used as a baseline to compare to the Trelleborg AutoMoor system.

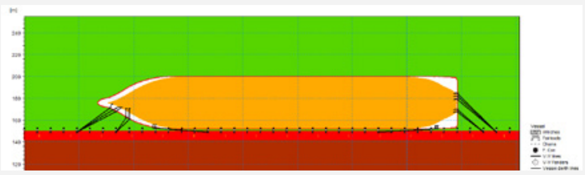

Fig 3. Vessel mooring line arrangement

Several cases were conducted where the number of units and locations along the berth were varied.

The results in the plot shown on page 8 compare motions of the vessel when moored with mooring lines to that with 6 x T40 AutoMoor units and 12 x T40 AutoMoor units. Using an AutoMoor arrangement, the vessel is berthed with 5T pretension and a maximum rated load of 20T per arm (two arms per T40 unit). The AutoMoor arm will pay-out when the rated load of 20T is reached, maintaining this loading toward the berth until the vessel has returned to the fender-line.

The AutoMoor units apply force directly in the surge and sway motions of the vessel, compared to a mooring line that applies force in the vector from bollard to fairlead, equating to a low translation of line tension to restoring force. The arrangement of the AutoMoor units along the berth has impacts on the vessel's yaw, as clustering towards the bow and stern would have positive effects but be traded off against universality across vessel sizes.

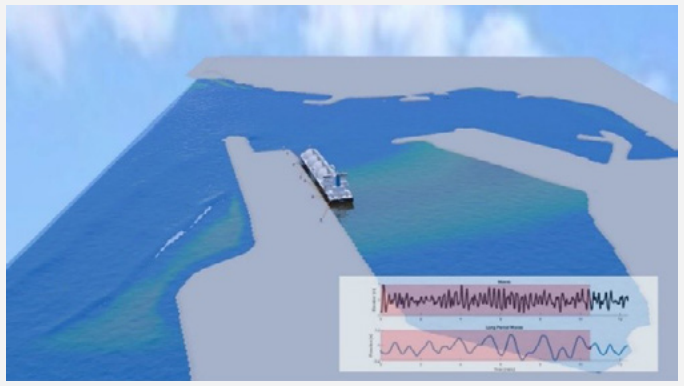

Fig 4. DHI Mike 21 vessel at berth example

Figure 4 shows an example of vessel (LNG carrier) motion calculation using DHI's MIKE 21 MA at berth caused by offshore waves (sea and swell, the white foam indicates wave breaking at the coast) and infragravity waves (long waves, colored) simulated by MIKE 21 BW software.

Results

The minimum number of AutoMoor units required to safely moor the vessel in this scenario is 6 x T40 units, to achieve lower motions than with mooring lines. By increasing the number of AutoMoor units, vessel motions are further reduced. The peak motion of the vessel in surge and sway are shown in Figure 5 with a short time series example of sway motion shown in Figure 6.

The range of the vessel motion in surge and sway when using mooring lines is 1.1m and 0.77m respectively. The range when using 6 x T40's and 12 x T40's in surge are 0.64m and 0.29m respectively and 0.7m and 0.44m in sway respectively (Figure 7 and Figure 8).

When the vessel is moored with AutoMoor, up to 75% of sway motions are maintained at levels less than the lowest 25% of motion achieved when it was moored with conventional mooring lines. This translates to an increase of berth operability from 65% to 95%.

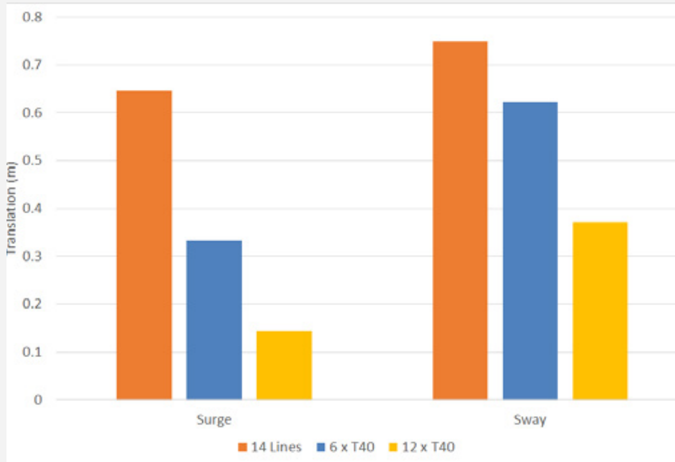

Fig 5. Peak vessel motions

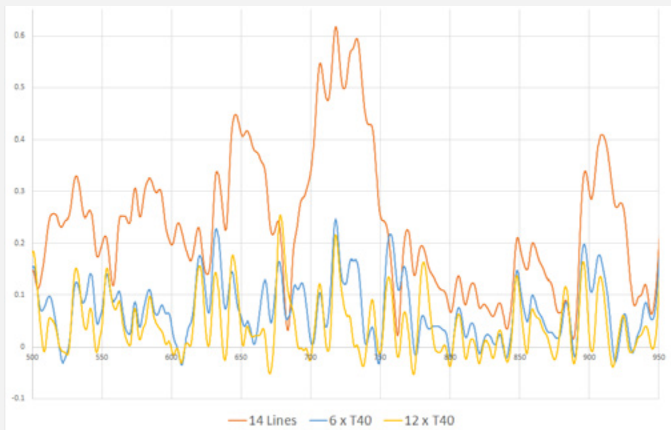

Fig 6. Example time-series vessel sway motions

The reduction in vessel motions indicates an increase in berth operability for product transfer from 65% to 95%

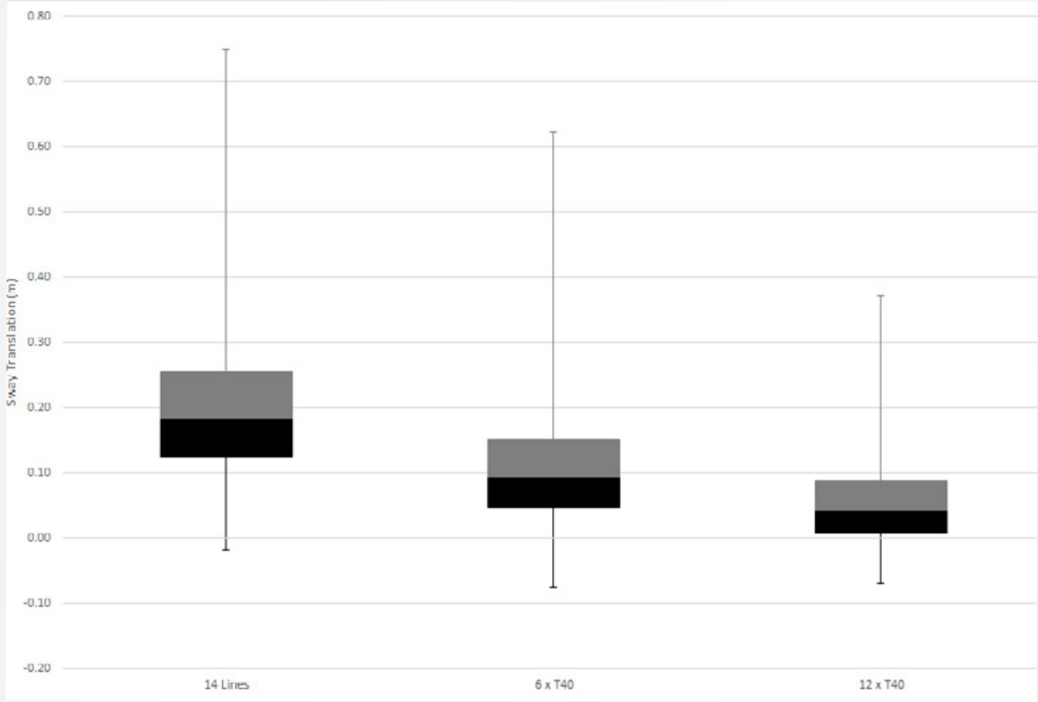

Fig 7. Vessel sway distribution

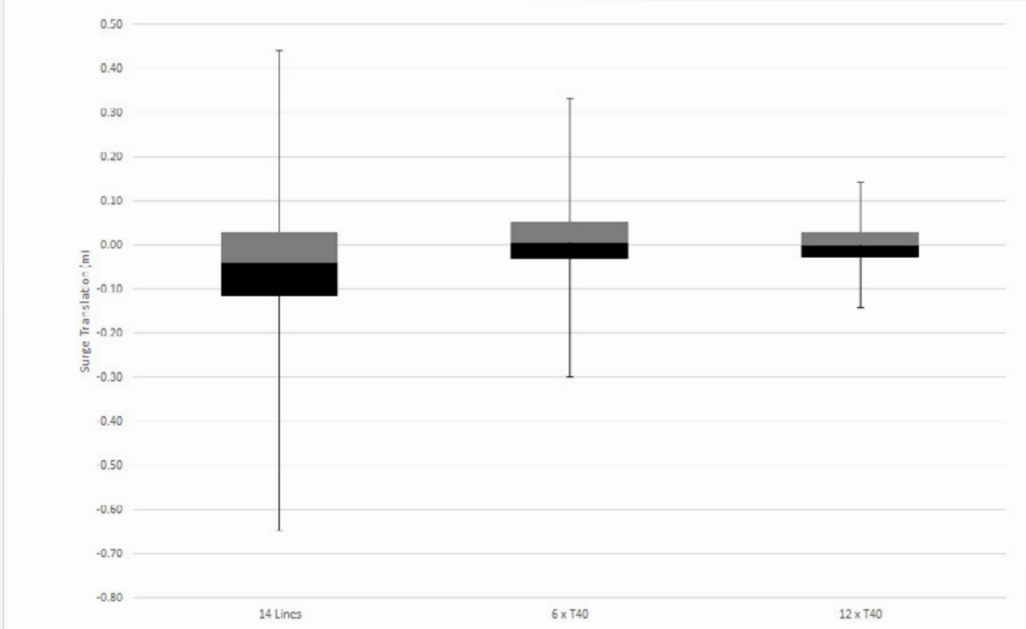

Fig 8. Vessel surge distribution

Discussion

The use of AutoMoor in this scenario adds a level of motion dampening that cannot be achieved through mooring lines. The response from the AutoMoor passive system far exceeds that of the mooring lines within a small vessel displacement.

Vessel movement exceeding the passive system is allowed while maintaining the force towards the berth position. The effect is to limit the peak motions and remove inertia from the vessel. The consideration for the arrangement of AutoMoor units along the berth-line is dependent on the berth utilization by vessel lengths and the vessel motion to be reduced. Catering for a range of vessel types can lead to compromises in performances or higher equipment requirements.

The intended limit of vessel motions for a specific wave or across many waves can lead to varying requirements on the number of units. The plot displayed in Figure 5 shows the reduction of peak loads through the addition of further units. The sway plot (Figure 6) further shows the vessel motion with AutoMoor has a lower amplitude than for mooring lines. This is confirmed in Figure 7 showing the vessel is held within a smaller area of movement for a larger proportion of the time. Another consideration is that the mooring lines have a maximum peak loading of 40% MBL followed by a minimum peak with slack-lines; the range from maximum to minimum peaks would lead to fatigue in the lines and eventual line failure. The mooring line setup and arrangement is considered in the analysis to be in optimal condition. In practice, lines are frequently left untended, causing them to go slack, or substandard line arrangements are used.

The AutoMoor units all operated within their performance ratings for the duration of the vessel motion and consistently limited vessel motions without reaching mechanical limits. The motion off the fenders is shown to occur at a lower occurrence rate (Figure 7) when moored with AutoMoor and to be focused within a smaller distance. The surge and sway of the vessel are contained within smaller ranges with AutoMoor, due to the mooring forces acting directly in-line with vessel motions; surge and sway.

Conclusion

This study showed that AutoMoor T40 units successfully moored the vessel with a significant decrease in vessel surge and sway when compared to mooring with lines. The reduction in vessel motions indicates an increase in berth operability for product transfer from 65% to 95%.

Infragravity waves can have large effects on the motions of the vessel at berth due to their interaction, leading to higher vessel excitation than from a regular sea-state.

Vessels in these conditions will typically have motions that cannot be restrained by mooring lines effectively to maintain cargo operations or a safe mooring. From the two AutoMoor cases considered, AutoMoor achieved 75% of motion off berth at a level less than the lowest 25% of that with mooring lines.

There are opportunities where addressing a particular magnitude of infragravity waves can lead to increasing the duration of the cargo transfer window. There may be occurrences of higher magnitude waves that remain outside this window, but the reduction in operational downtime can significantly improve port efficiency and vessel turn-around time. In a container terminal, the transfer rate of containers will be increased as the vessel motions are reduced.

Related applications

Wave effects on vessels are specific to the local conditions and are therefore common through all port and vessel types. The findings in this paper are an indication of the improvements possible when automated moorings are used in complex wave action that traditional mooring lines fail to capture.

[1] MIKE Powered by DHI software technology, https://www.mikepoweredbydhi.com/

Trelleborg is a world leader in engineered polymer solutions that seal, damp and protect critical applications in demanding environments. Its innovative solutions accelerate performance for customers in a sustainable way.

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