Expansion of Operability Assessment Criteria in Bulk Carrier Transhipment Operations

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Summary
Moored vessel operability constraints are well defined for at berth applications. Criteria typically include assessment of mooring line loads, fender forces, peak-to-peak vessel motions and physical berth constraints for which guidelines and limits are readily available. In the context of transhipment operations these limiting factors remain relevant but not sufficient in defining the full system operational envelope due to the increased complexity of the multi-vessel floating system. In this study two additional factors, the relative motion of loading infrastructure and the requirements of tug stabilisation during operations, are considered to evaluate the extent to which annual transhipment operability is impacted in comparison to utilising more traditional in-port metrics.

Keywords: Transhipment, Operability, Tug Requirements, Boom Motions

Introduction

Bulk shipment operations are often limited by port channel and or berth pocket depth. To avoid costly dredging operations at these ports, operators are increasingly looking to avoid depth constraints via transhipment operations. While such operations can reduce the need for capital dredging costs they result in (un)loading operations occurring in more exposed and dynamic systems via ship-to-ship transfer. In such cases the prevailing metocean climate, ship to ship moorings and (un)loading procedures play a vital role in ensuring the overall economic viability and safety of the operation.

The economic sensitivity to the frequency of safe transhipment (un)loading windows at the selected site require a robust assessment of the criteria defining them. Traditional operability criteria, including mooring line and fender forces along with single vessel motions, remain relevant in transhipment contexts but are not sufficient in capturing the added complexity of these operations. In this study the following additional constraints have been added to the traditional conditions to assess the impacts on operability at a test transhipment site across a calendar year:

- Approximation of the required bollard pull and tug utilisation frequency to ensure stability during vessel-vessel (un)loading.
- Consideration of relative vessel-vessel motion at locations distant from the vessel centre lines such as during (un)loading operations via a boom.

Bollard Pull Approximation

In complex metocean climates it is anticipated that a single-point mooring transhipment operation will typically orient parallel to the prevailing current due to the combined draft of the system. This can prove problematic at some transhipment sites where inbound waves typically approach at some angle to the current, resulting in excessive vessel roll response. To prevent such conditions tugs are commonly employed during transhipment operation to ensure a favourable system heading relative to inbound waves.

For the purposes of the conducted feasibility study, a relative system-wave angle up to 30 degrees off the vessel bow was considered acceptable to minimise the impact of incident swell on operations. Thus, to assess the frequency with which tugs will be required at the considered site, along with the bollard pull needs of the tug, the following procedure was undertaken:

1. Discretisation of the full year of measured wind, wave, and current data at the site into 8760 numerical simulations each representing one hour of the assessed calendar year.
2. Determination of the natural equilibrium orientation of the combined vessel system in the prevailing wave, wind, and current conditions for each simulation.
3. If the system heading is naturally within 30 degrees of the swell direction, tugs are not required and the simulation commences unrestrained.
4. If the system requires tug restraint, the system is locked in yaw and executed. The mooring software MIKE 21 Mooring Analysis [1] then outputs the requisite forces required to maintain the locked vessel heading.
5. The output counter forces are then converted to the required bollard pull of the tug based on static equilibrium equations. This enables the flexible positioning of the tug tow line in post processing.

Active Boom Tracking

Timeseries depicting the motions of both the Ocean Going Vessel (OGV) and Transhipment Vessel (TSV) were derived using DHI's MIKE21 Mooring Analysis [1] software in all six degrees of motion for each hour of the assessed calendar year. The motions were then translated from the vessel midships to be relative to the centre of the nominated OGV hatch as depicted in Figure 1.

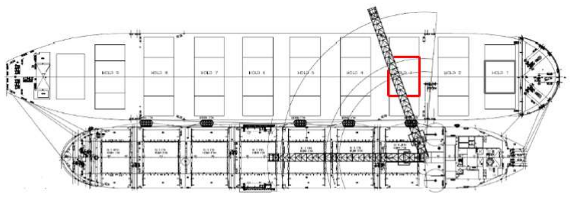

Figure 1 Transhipment system layout with assessed loading hatch indicated in red below the TSV boom. The hatch and boom locations are both distant from their respective vessel midships leading to increased relative motion.

The motions of the TSV loading boom relative to the centre of the OGV hatch are tracked via a positional timeseries plot (an example of which is presented in Figure 2). For the purposes of assessing the operability of a given scenario, the boom was required to remain within 5 meters of its initial starting location (depicted by the blue circle in Figure 2). The central origin for the operability circle was updated at 10-minute intervals throughout the simulation to reflect the ability of operators to account for long term drift during (un)loading. Updated operability limit radii 10 and 20 minutes after commencement of the simulation are represented by the orange and green circles respectively.

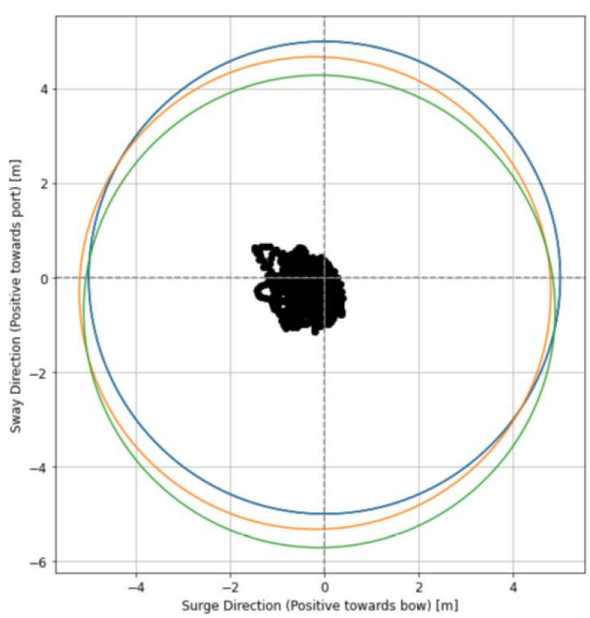

Figure 2 Sample boom motion plot tracking motion of the TSV boom head above the nominated OGV hatch. In the presented example the loading boom remains within the operable envelope for the entirety of the simulation.

Results

At the assessed transhipment site tugs were deemed to be necessary to maintain vessel headings less than 30 degrees from the incident wave direction in 88% of the assessed hours due to the dominant local currents typically acting perpendicular to the local swell conditions. This high utilisation requirement has the capacity to heavily impact the economic modelling of the operation, and thus highlights the importance of considering tug requirements as an operational metric.

Of the 8760 assessed characteristic hours at the transhipment site excessive movement of the TSV loading boom relative to the OGV hatch was modelled in 3.27% of cases. This value is compared to the prevalence of more traditional operability metrics in Table 1.

Table 1 Comparison of the prevalence of operability exceedance modes across the assessed scenarios. Boom motion exceedances can be seen to represent a comparable portion of observed failures to traditional in-port metrics.

Failure Mechanism	Percentage of Exceedances
Fender Exceedance	3.60%
Mooring Line Forces	1.52%
Boom Motion Exceedances	3.27%

While all operability metrics in the observed case study represent only a small downtime estimate at the site the relative scale of boom failure to the traditional in-port metrics highlight the importance of its consideration in wider transhipment operability assessments.

Conclusion

Extension of the operability criteria associated with transhipment operations to explicitly consider the relative motion of active vessel components has been shown to have a comparable influence on overall system operability to fender and line force considerations. Likewise, the inclusion of bollard pull and tug requirements in a full calendar year analysis enables a more wholistic representation of expected annual operability and fiscal viability of transhipment operations.

The assessment of these driving economic and operational factors has the potential~~ly~~ to heavily influence the business case for transhipment operations in comparison to assessing traditional operational criteria alone. These concepts can be further expanded to encompass additional operational design considerations pertaining to fender contact, personnel transfer and ship to shore offloading operations that require a degree of accuracy beyond those assessed using peak to peak vessel motion requirements alone.

References

[1] DHI (2021). MIKE21 Maritime, Frequency Response Calculator and Mooring Analysis Scientific Documentation.