

# Hoist load loss of floating crane vessels

**ASSESSMENT** To date, many offshore wind farm installations have been completed using heavy lift jack-up vessels. Jack-ups are not subjected to heave, roll and pitch motions; surge, sway and yaw are limited so that the working platform can be considered as fixed, even in higher sea states. However, jacking operations require time, and footprints influence local soil conditions which have to be considered in project planning. Latest developments aim at conducting lift operations from heavy cargo vessels equipped with corresponding heavy-lift cranes for offshore installations, write Simon Dillenburg, from Hamburg-based engineering specialist thec offshore, and Björn Kramer from TÜV SÜD Industrie Service, Department Offshore Wind.

In the amendments to the International Code on Intact Stability (2008 IS Code) given in MSC.415(97), vessels using counter-ballasting during lifting operations need to withstand the case of a sudden loss of hook load. Intact stability is checked by means of the righting lever curve.

The area under the righting lever curve between the equilibrium condition after loss of the hook load and the downflooding angle (or the second interception of righting and heeling arm curve, whichever is less) needs to be greater than the area under the righting arm curve between the equilibrium condition during the lift and the equilibrium condition after loss of the hook load. However, even if stability criteria are fulfilled for the vessel, the situation may be critical for the crane when subjected to vessel motions.

The unintended loss of the hoist load due to the failure of non-redundant primary structural crane components, such as slings or hooks, is a rare event. It is typically covered by advanced crane standards, both in European and international waters. A comprehensive load case description is given in the standard EN 13001 Crane Safety – General design – Part 2: Load actions.

Once in force, it will be applied to all cranes in Europe, including offshore cranes, and

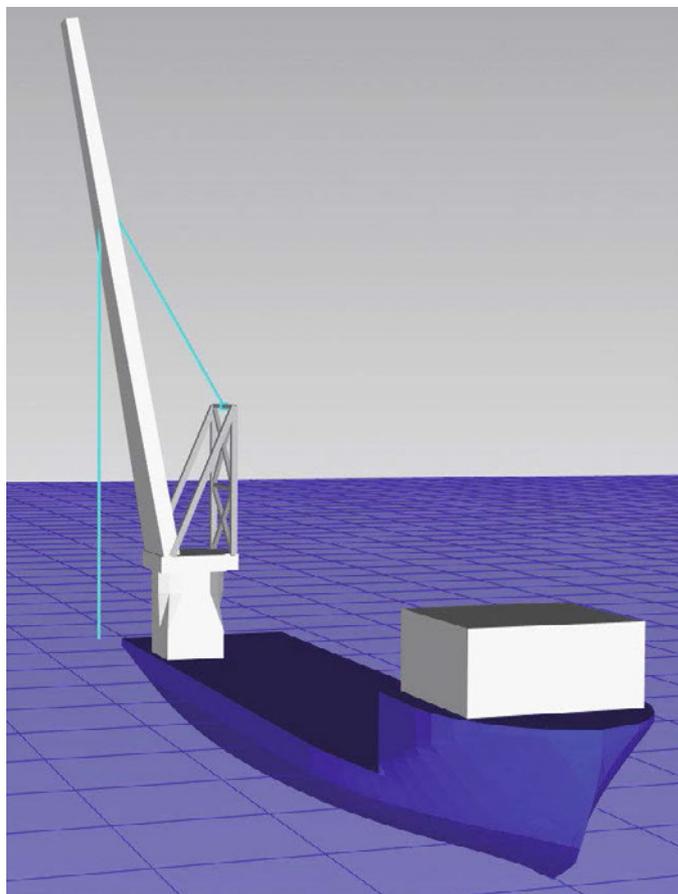


Figure 1: Vessel model

Source for all images: thec offshore

is therefore used as a basis in this article. The published draft (second delivery) is currently in the final voting process and describes the load case as follows: “The effects of unintentional loss of the hoist load shall be taken into account, especially on subsequent crane stability issues and strength issues such as jib or whole crane structure springing back, jib whipping

backwards and colliding with crane structure, jib falling back into normal position or reversal of loads in components designed as unidirectional (e.g., hydraulic cylinders, tension ties). In cases where dynamic analysis is not done, the effect of unintentional loss of hoist load may be calculated by applying a dynamic factor  $\phi = -0.3$  on the hoist load.”

In design cases where experience of the crane dynamics and the foundation influence is available, a simplified quasi-static calculation with a dynamic factor of minus 0.3 (sufficient for the vast majority of cases) can be used. As an alternative, a more advanced dynamic and time-domain analysis provides more accurate results in cases beyond existing experience. Apart from critical situations on heavy cargo vessels, similar cases of failure may be expected on floating units used in oil production including floating production storage and offloading units and floating offshore wind turbine foundations.

The authors would like to contribute to the development of calculation methodologies for cranes in operation on different floating foundation types and sizes. It should be noted that different authorities (European or international) and varying standards may be involved, and even contradictory statements may be given. For example, permanently moored floating units fall under the legislation of the European machine directive 2006/42/EC, as the latest edition 2.2 (published October 2019) of the guide for application of the directive confirms.

Besides the basic issues – the crane structural integrity

and the stability of foundations in offshore applications, the vessel – additional risks include the safety of the crane operator usually assured by an extra risk factor for the structure that holds and shelters him. Typically, the failure load of the crane structure supporting his cabin is at least 25% higher than the failure loads of the main crane components above (e.g., jib, rope, hook). If the exceptional load case Loss of Hoist Load requires ongoing sheltering, the crane operator and principal components of crane and vessel (relevant also in a post-failure situation) may need extra safety. (Note: Failure load calculations are generally required for all offshore cranes where overload may occur due to entanglement of the hoisted load with an external supply vessel).

Additionally, horizontal accelerations, especially beyond 0.1 times earth gravity endanger personnel. This is relevant to all operations carried out at height as well as walking persons, but also to all others who may be exposed to danger at their workplaces (e.g., in the galley).

Therefore, the knowledge of the dynamic hook-loss reaction (accelerations, roll angle and stability of foundations) is beneficial not only for the

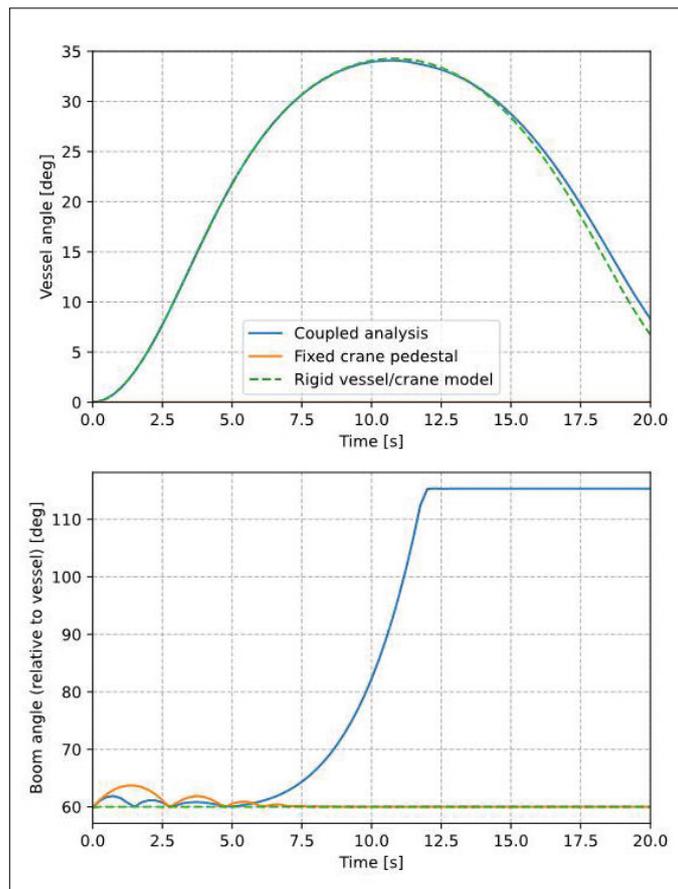


Figure 2: Trajectories of vessel and crane boom

crane manufacturer but also for the operating company during crane operations. Such data may improve decisions relating to major components with limited lifetime (e.g., the reduced lifetime of slewing bearings due to increased local contact pressure), the safety of other heavy cargo on deck and – last but not least – the

operational safety of personnel working on board.

### Calculation approach

For this article, hook load loss is assessed with a multi-body analysis approach comprising a heavy-cargo crane vessel with separate crane boom body and corresponding mass distribution. The vessel geometry is

based on a scaled model of the carrier vessel *Tai An Kou*, which is part of the MOSES software used for the analysis. MOSES is a marine simulation language widely used in the offshore industry.

Both the initial boom inclination and the hook load prior to loss are varied. After application of the hook load, the vessel is counter-ballasted until equilibrium is achieved. Then, the hook load is removed and the motion of vessel and crane boom is analysed in the time response domain. Effects of radiated waves are included and viscous drag is accounted for as considered in the original model. Although possible, the effects of waves and wind are not included in the analysis. Upon hook load loss, the stiffness of the system changes because only luffing gear remains tensioned. The stiffness is accounted for in the model. Figure 1 shows a graphical representation of the full calculation model.

To check the influence of the vessel size, the model is scaled as summarised in Table 1. Dimensions are scaled uniformly; the maximum hook load is correlated with the displacement.

Besides assessing the effect of load loss on coupled vessel and crane boom motion, additional cases with the boom



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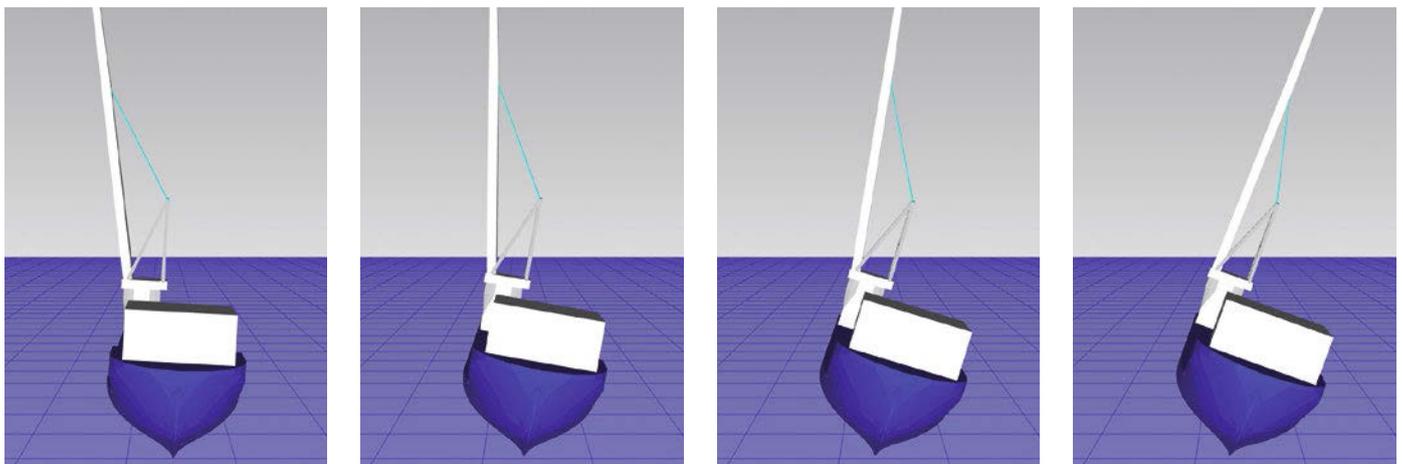


Figure 3: Vessel at t = 2 s, 4 s, 6 s and 8 s

Vessel no.	Length [m]	Beam [m]	Depth [m]	Draft [m]	Displacement [m <sup>3</sup> ]	Crane capacity [t]
1	116.0	25.5	7.5	4.6	10,160	1,000
2	158.0	34.7	10.3	6.3	25,673	2,500
3	200.0	43.9	13.0	8.0	52,072	5,000

Table 1: Vessel dimensions

rigidly connected to the vessel and a fixed crane pedestal are run for comparison purposes.

### Analysis results

Investigations reveal that coupled analyses may show critical boom rebound behaviour, whereas the same case with either a fixed crane foundation or a rigid crane/vessel does not yield a critical outcome.

Figure 2 and Figure 3 show the results of a sample simulation. Although not shown in the images, the luffing ropes become slack. It can be seen that the crane boom makes contact with the A-frame (close to 115°) after approximately nine seconds. In the analysis, the crane boom is kept in the same position after initial contact.

As mentioned before, when this load loss scenario is assessed for a fixed crane, the boom rebound is not critical. Results also show that the vessel motion influences the crane boom trajectory, but the model of the crane (multi-body model or crane and vessel modelled rigidly connected to each other)

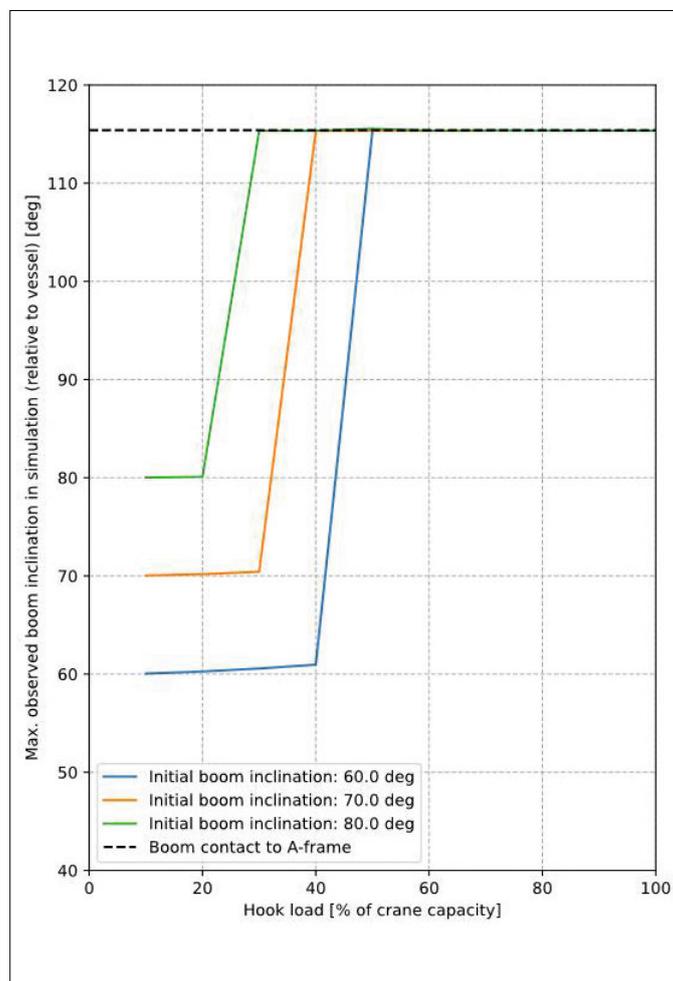


Figure 4: Maximum boom inclination for various cases

hardly influences the vessel motion.

For the assessed vessels, boom rebound reaches critical levels for loads exceeding 20% to 40% of the crane capacity, depending on the initial boom inclination. This is shown in Figure 4 for the 2,500-tonne vessel. The curves are comparable for all vessel sizes assessed herein.

The authors would like to emphasise that the values stated here are valid only for the assessed configuration. Different vessel geometries, crane sizes, vertical centres of gravity, countermeasures (such as additional external buoyancy), would yield different results. The focus of this article is to point out that coupled analyses may be required in the design process to consider the interaction between vessel and crane with utmost diligence.

Further investigations are planned.

### Conclusion

Existing codes and standards cover the event of unintended sudden hook load loss with respect to vessel stability and crane integrity for fixed cranes. Based on the outcome of investigations conducted in the course of the present article, a coupled analysis approach is viewed as essential for floating heavy cargo crane vessels.