Offshore Lifting Analysis

Oderinde Faith & Jim-George Tekena

Successful offshore operations require loads to be lifted and lowered at some point. The installation of topsides, jackets, piles, subsea modules etc., and the transfer of cargo at sea involves lifting and lowering delicate and usually heavy objects. As a result, careful analyses of the magnitude of the loads and the carrying capacity of the lifting gears and cranes has to be carried out to ensure safety to life and security of multimillion dollar investments.

Lifting Operation

A lifting operation is typically concerned with the lifting and lowering of loads. A load is the item that is to be lifted which could include workers and cargo. At a basic level, lifting can be performed manually or using lifting equipment. In manual lifting, no lifting equipment are necessary, only the brute strength of the 'lifter' is required. Marine lifting operation requires complex engineering and planning and the complexity of operation increases further with the size and weight of the load.

Examples of Offshore Lifting

Lifting is a common operation in offshore construction and installation projects at sea. Some examples of offshore lifting include:

i. Lifting of subsea equipment e.g. jumpers, production trees etc.
ii. Offshore jacket installation on site
iii. Installation of Helideck
iv. Lifting and removal of offshore assets in de-commissioning phase
v. Transfer of cargo/passenger between vessels

The mass and geometry of the lifted load varies depending on the operation however, the fundamental principles of lifting remains the same.

Lifting Equipment and Accessories

Lifting equipment includes any equipment or machinery used at work for lifting or lowering loads. **Cranes** are generally used for lifting various types of loads. Cranes have **hoists**, a device used for lifting and lowering by means of a drum or wheel around which a chain or rope wraps
Lifting accessories or lifting gears are used together with cranes and they include slings, padeyes, spreader beams, shackles etc. Note that all the lifting gears must be able to withstand the loads imposed during the lifting operation

Lifting cranes along with lifting gears (shackles, slings)

Lift Classification

Marine lifting operations are typically divided into two categories depending on the weight.

1. **Light Lifts (< 1000 tons):** In this classification, the weight of the lifted object is less than 1-2% of the displacement (weight) of the vessel. In this case, the load is light enough for coupled dynamics to be ignored. Examples includes spools, piles, small module lift

2. **Heavy Lifts (> 1000 tons):** The weight of the load is typically more than 2% of the vessel displacement. Here, the weight of the load becomes comparable to the vessel displacement hence, coupled dynamics of the load and the vessel must be taken into account

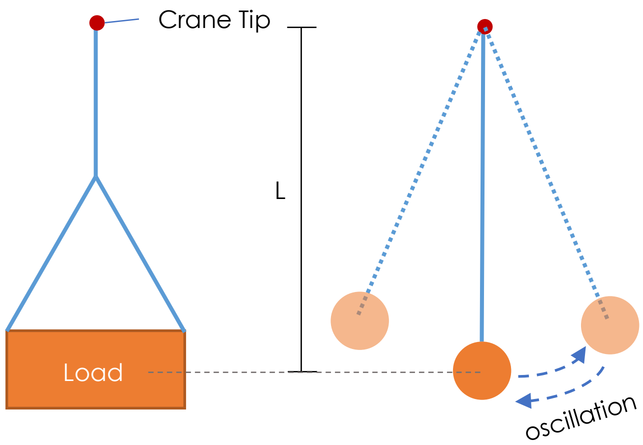
Considerations for Lift Analysis

1. Resonance

During a lifting operation, the hanging load oscillates back and forth just like a pendulum or a swing. Resonance (large amplitude oscillations) may occur if the natural frequency of the system is sufficiently close to the oscillation frequency.

$$f = \frac{1}{2\pi}\cdot\sqrt{\frac{g}{L}}$$

f = Natural Frequency
L = Length of the sling from the load's centroid to the crane tip

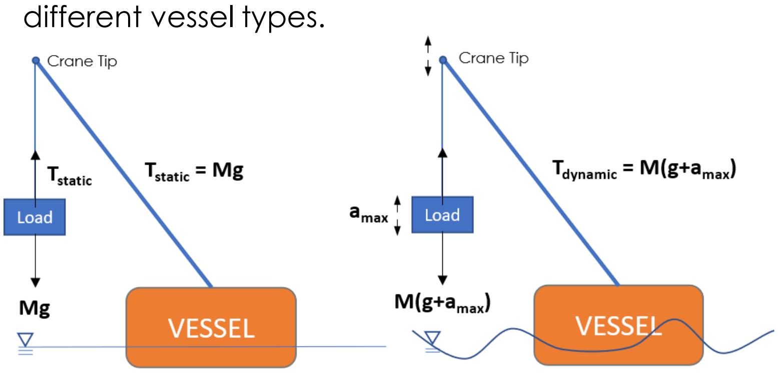


Offshore lift comparison to a pendulum

It is crucial to analyze a marine lift operation for a range of wave periods (inverse of wave frequency) to ensure that the natural frequency of the pendulum doesn't coincide with wave frequencies. When designing, the range of wave periods represents different operational stages. Maximum wave motions that represents resonant motions are captured at these operational stages.

2. Dynamic Amplification Factor (DAF)

During a lift, the lifted mass is exposed to dynamic loads due to waves. To account for this, in the absence of a dynamic response analysis, a dynamic amplification factor (DAF) is used. The DAF is the ratio of Dynamic Hook load ($T_{dynamic}$) to Static Hook Load (T_{static}). LOC (London offshore Consultants) guidelines contains DAF values for different vessel types.



Calm Sea, No wave motion

Motion due to waves

Dynamic Hook Load = Weight + Max. Acceleration Force

$$T_{dynamic} = mg + ma = m(g + a)$$

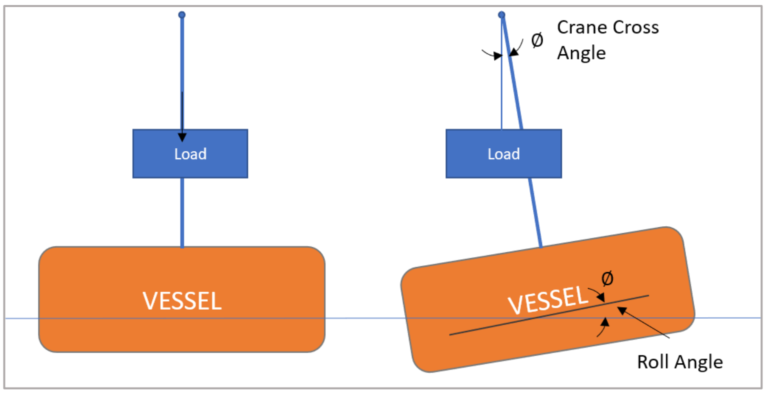
Here, $T_{dynamic}$ = Dynamic hook load
m = mass of the lifted object
g = gravitational acceleration
a = maximum acceleration experienced by the lifted object

$$\text{DAF} = \frac{\text{Dynamic Hook Load}}{\text{Static Hook Load (Gross Weight + Rigging)}}$$

3. Crane Cross Angles

The crane cross angle is the angle between the hook load line and the vertical plane of the boom. For a stern lift, the crane cross angle is caused by vessel roll motions.

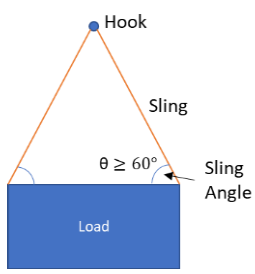
For lifts over the sides (port or starboard) of a vessel, the crane cross angles results from vessel pitch motions.

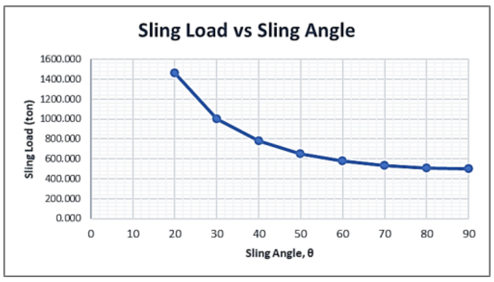


Cross angles reduce the carrying capacity of the crane for the same load. It also increases the probability of a collision between the lifted load and nearby structures. For these reasons crane cross angles are typically limited to 1.0 degree for a stern lift and 3.0 degrees for lifts over the side of the vessel.

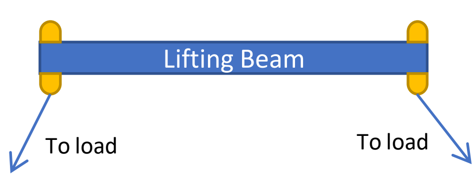
Other Analysis Considerations

1. Determine the weight and center of gravity of the module to be lifted. SACS software can help with this.
2. Determine the sling angle. For practical purposes the sling angle cannot be less than 60°. Sling angle varies with load in sling as this graph shows.

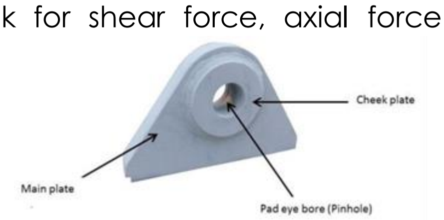




3. Carry out Lifting beam analysis: Lifting beams help to increase the sling angle without increasing the sling's length. Bending and Buckling strength of the beam has to be assessed to check that they are within requirement



4. Padeye Stress Analysis: Padeyes have to be check for shear force, axial force and Normal force



5. Crane tip motions: determine the relative motion between the crane tip and the waves. Formulas exist for this calculation

References: www.marineinsight.com, www.thenavalarch.com

For more information, contact info@feddogroup.com