Lift Study Modelling

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Abstract

Mobile cranes are widely used in the engineering industry for the construction and assembly of heavy machinery, infrastructure and other large payloads. During both the design and manufacturing phases of a project, it is important to consider the method used to position large components. Should this positioning involve the use of mobile cranes, the ability to rapidly evaluate the suitability of a variety of cranes can inform design decisions and simplify initial lift studies. To achieve this, ASPEC has developed 3D modelling and calculation tools capable of assessing suitability with minimal user input. This does not forego the need for an approved lift study, but rather simplifies early selection of potential cranes.

1. Crane Types

ASPEC has focused on two main crane types: all-terrain cranes and crawler cranes. All-terrain cranes (demonstrated in Figure 1 below) can be driven on roads and are supported by outriggers when lifting. Conversely, crawler cranes (Figure 2) require transport to lift sites and are supported by a set of tracks.

Figure 1 - All Terrain Crane

Figure 2 - Crawler Crane

2. 3D Modelling

In order to determine the placement of cranes, 3D models have been developed in Autodesk Inventor. These feature all key dimensions, including:

- Body length and width;
- Outrigger width (for all-terrain cranes);
- Track width, length and spacing (for crawler cranes);
- Counterweight swing radius;
- Slew point.

The assembly of the crane allows full range of motion in slewing and lifting for all boom lengths. Key geometry such as the lifting axis, ground and boom pivot point are represented by included work features. These allow for the positioning of the crane and simple measurement of the lift radius. The lift radius and boom length can then be used to determine the crane's lifting capacity for the given scenario. Figure 3 (below) demonstrates the crane 3D model showing two capacities and radii for a proposed lift.

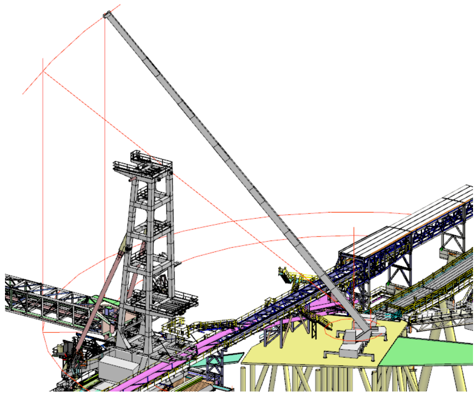

Figure 3 - Crane Positioned in Construction Location

In addition to determining the lift radius, the availability of a parametric 3D model allows engineers to assess the suitability of pick points and component placement. Furthermore, the lift sequence can be animated using CAD software to accurately track the lift path.

3. Lifting Capacity

To assess a crane's suitability for the specified lift, its chart capacity must be calculated. This is achieved by using Microsoft Excel, where the user enters the crane type, crane model, counterweight mass, boom length and lift radius. Lift charts for all cranes are stored within the sheet, and the lifting capacity is calculated by linearly interpolating between chart capacities at specified lift radii.

The spreadsheet also has the capability of determining gross lifting loads. The net load, deductions and rigging can be entered, with typical items including the hook, rope, slings, shackles and any other auxiliary tools. A contingency is added to the net load, and the utilization is calculated as the quotient of the de-rated chart capacity and gross load. Provided that the utilization is below the specified target and all values have been correctly assumed, the crane has sufficient capacity to perform the lift.

4. Ground Bearing Capacity – All Terrain Cranes

While load charts specify the maximum load that can be lifted without crane overturn or structural failure, the operating surface must also be able to support the crane and its load. Ground bearing capacity is the surface's resistance to shear forces caused by the applied ground bearing pressure of the crane. Should this capacity be less than the applied pressure, the resultant instability may cause overturn.

For all terrain cranes, pressure is applied by the outrigger feet. This pressure can be calculated by finding the vertical reactions forces at each of the feet, however Queensland regulations [1] specify that this value should be calculated as 65% of the total load divided by outrigger foot area:

$$Ground\ Bearing\ Pressure = \frac{0.65(Total\ Crane\ Mass + Gross\ Load)}{Individual\ Outrigger\ Foot\ Area}$$

If this value exceeds the ground bearing capacity of the surface, mats must be used to increase the foot area.

In the spreadsheet, capacities are listed for varying soils, while the pressure calculation is automatically performed based on entered loads and crane selection. This allows the user to easily assess the requirement of matting.

Figure 4 - Outrigger Matting

5. Ground Bearing Pressure – Crawler Cranes

When considering crawler cranes, calculating ground bearing pressure is much more complicated. Rather than featuring four discrete reactions applied at each outrigger, crawler cranes will apply a continuous support that varies along the length of each track. This pressure distribution can be either trapezoidal or triangular depending on the load magnitude and position.

An estimate of the applied pressure can be calculated from pressures caused by the load, V, the moment about the transverse axis, f_t, and the moment about the longitudinal axis, f_l. With a gross load of F at a lift radius of r, these values are given by:

$$V = \frac{W_{ns} + W_s + F}{2wL}$$

$$f_t = \frac{3\big((W_s d_s + Fr)\cos\alpha + W_{ns} d_{ns}\big)}{w(L)^2}$$

$$f_l = \frac{(W_s d_s + Fr)\sin\alpha}{wLx}$$

This gives resultant ground bearing pressures at each corner of:

$$GBP = V \pm f_t \pm f_l$$

The pressure distribution becomes triangular when any of the bearing pressures become negative. This reduces the effective support length of the tracks from L to L_{tri}. This new length is given by:

$$L_{tri} = 1.5L - \frac{3((W_s d_s + Fr)\cos\alpha + W_{ns} d_{ns})}{W_s + W_{ns} + F}$$

If the distribution is triangular towards the front, the front left and right bearing pressures are given by:

$$GBP_{Front} = \frac{(W_s + W_{ns} + F)x \pm 2(W_s d_s + Fr)\sin\alpha}{wL_{tri}x}$$

In these calculations W_s and W_{ns} denote the weights (in Newtons) of the crane's slewing (boom, counterweight, cab, etc.) and non-slewing (tracks, carbody, etc) masses, while d_s and d_{ns} denote respective centroid positions relative to the slew axis. α is the slew angle of the crane (positive anti-clockwise from travel direction), L is the track length, w is track width and x is the distance between track centerlines. These dimensions are demonstrated in the figure below:

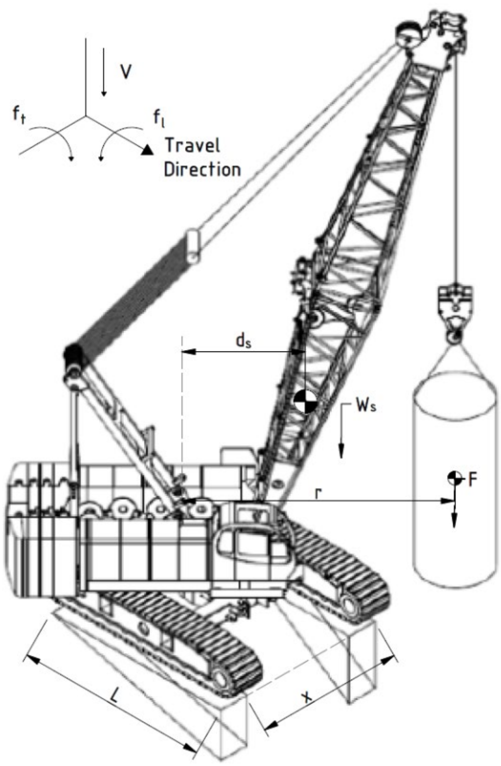

Figure 5 - Crane Loads and Dimensions

Values of centroid locations and masses for each crane are stored within the spreadsheet to automate this calculation based on the selected crane and inputted load. Available cranes have been tested against each company's ground bearing calculation software to ensure that the entered data is correct, allowing the user to be confident in the generated results. Typically, the results from the spreadsheet were found to be conservative, however the maximum underestimate of ground bearing pressure was within 11% of the value obtained from manufacturer software. To account for this, a 10% contingency is added to the maximum bearing pressure.

All calculations by the spreadsheet should be checked against manufacturer software for any published lift study. However, automatic calculations allow for rapid initial crane selection and negates the requirement for all users to have every manufacturer's software installed.

6. Lift Study Report

Using the 3D modelling tools and spreadsheet calculation, a user can easily generate the core of a lift study report. The Inventor files allow simple placement in lift scenarios, which can be used to create lift diagrams and determine lift radius. The spreadsheet then outputs all results in a report template that can be printed to a PDF. While this does not replace a lift study conducted by an authorized person, simple crane selection early in the design process can improve design and manufacturing decisions.

7. Works Cited

[1] Workplace Health and Safety Queensland, "Mobile Crane Code of Practice 2006," 1 January 2012. [Online]. Available: https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0019/17128/mobile-crane-cop-2006.pdf.