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Around in the ground

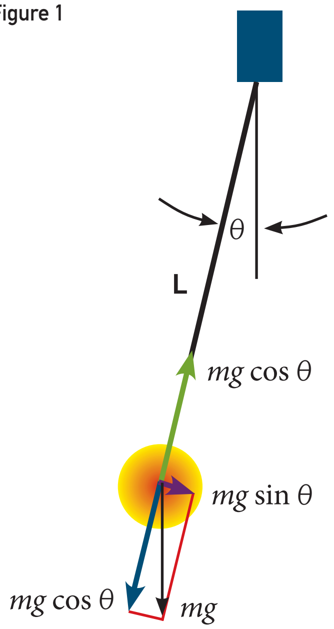
MARCO VAN DAAL takes a closer look at what goes on around and underneath a crane when lifting wind turbine components

It is worth mentioning that the wind industry has been subject to a higher percentage of crane accidents than other industries. In the January issue of *IC*, Søren Jansen and Klaus Meissner wrote an excellent article on the safe use of mobile cranes. They highlight that (almost) all crane accident cases are caused by behavioural issues as opposed to technical issues. Behavioural issues cover everything from the way the operator handles the crane to how and where the crane is set up, engineering issues and incorrect assumptions. Not all behavioural issues are the result of wilful wrongdoing but could be the result of simply not knowing. The laws of nature, however, always apply and are unforgiving.

The FEM *5.016* guidance paper that Jansen and Meissner refer to is a paper that every director, sales manager, supervisor and crane operator should read to understand how wind can affect a crane while erecting wind turbines and that underestimating or neglecting wind is no laughing matter.

In this article the intention is to give some more background information to aid in the understanding why lifting wind turbine components is different from performing other lifts.

Figure 1



$$T=2\pi\sqrt{(l/g)}$$

The formula above was presented in the previous article. It calculates the period (T) of a free hanging load such as a nacelle. The period is defined as one full swing, i.e. the time it takes for the load to swing from the far left to the far right and back. Let's assume that we are lifting a nacelle to a 100 metre elevation. According to the formula the period (T) of the nacelle while at ground level (it has just been lifted off the transporter) is 20 seconds.

Once again, the formula does not take into account the weight (mass) of the nacelle nor does it take into account the (initial) amplitude angle. Amplitude angle being the angle the nacelle swings away from its vertical neutral position. Both amplitude angle and mass have no influence on the period (T).

Figure 1 shows the forces that play on a freely suspended load. This Figure is applicable for all suspended loads, irrespective of mass, length of rope and amplitude angle. The (near) horizontal component (mg sinθ) is the force that is responsible for decelerating the load and bringing it back to its neutral position which is vertical. For small angles of θ (Theta) this horizontal component is also the side force that the crane boom is subjected to. This force does not just stay at the boom; it transfers all the way down to ground level and can result in an increase in ground pressure underneath the crane.

Figure 2 shows the different stages of a freely swaying suspended load: point A being the neutral vertical point, and points B and C being the extremes of the period (T) (with B being the left extreme and C being the right extreme). In each of these points the load possesses a certain amount of both potential energy and kinetic energy. Kinetic energy (K.E.) is the energy that the load possesses due to its motion, it is expressed as:

K.E.=½mv²

m = mass of the load

V = velocity of the load

Potential energy (P.E.) is the energy that the load possesses due to its location, it is expressed as:

P.E.=m g h

m = mass of the load

g = gravity

h = height compared to its initial position

The sum of potential energy and kinetic energy is called mechanical energy (M.E.) Mechanical energy remains constant as long as we do not add or take away energy.

K.E. + P.E. = M.E. = constant

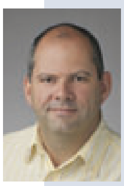
Back to Figure 2, if the load was hanging still and perfectly vertical it would be in point A. We therefore call point A the initial point or starting point.

Let us assume, however, that the load has just been lifted off a transporter and it is slightly swaying from left to right.

When it reaches point B, its velocity (v) decreases to zero (0) as it is about to reverse its direction. When the velocity (v) is zero (0) it means that its kinetic energy is also zero (0). It can, therefore, be stated that in point B the load only possesses potential energy. This potential energy is transformed from the kinetic energy and is equal to "m g h". Since the mass and the gravity are constant, we can say that the potential energy (transformed from the kinetic energy) determines the difference in height (h) compared to its initial point. This makes sense as a faster swaying load will reach (obviously) higher. The same applies for point C.

In point A, where the load possesses no potential energy but only kinetic energy, the velocity of the load is at its highest. On either side of point A the velocity of the load decreases until it reaches zero (0) >

ABOUT THE AUTHOR



Marco van Daal has been in the heavy lift and transport industry since 1993. He started at Mammoet Transport from the Netherlands and later with Fagioli PSC from Italy, both leading companies in the industry. His 20-year plus experience extends to five continents and more than 55 countries. It resulted in a book *The Art of Heavy Transport*, available at: www.khl-infostore.com/books Van Daal has a real passion for sharing knowledge and experience and holds seminars around the world.

Figure 2

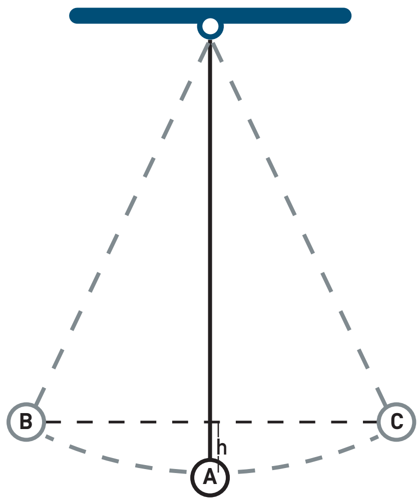


Figure 3

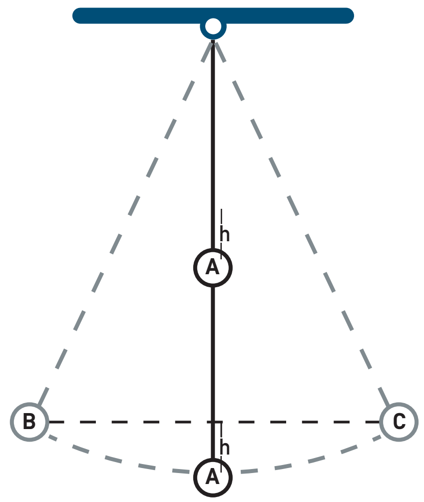
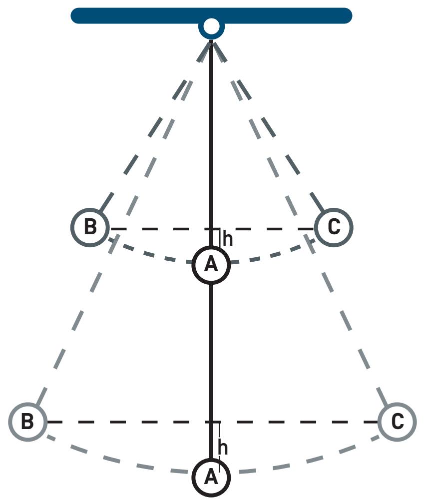


Figure 4



in point B and C. The load is now lifted to half its elevation, let us say to a 50 m elevation; the hoist wire above the load is also 50 m, as we started with a 100 m initial length (see Figure 3).

The period of the load has now been reduced to 14 seconds. The kinetic energy in point A did not change as we have not added or taken away any energy. Since the mass has not changed, the velocity in point A cannot have changed either.

As the load approaches point B, all of the kinetic energy is transformed into potential energy equal to "m g h". As stated before, the mass (m) and the gravity (g) did not change. Therefore, the height (h) did not change either. However, as the length of the hoist wire has been shortened from 100 m to 50 m the swaying load makes a partial circle with a smaller radius (see Figure 4). According to the formula, the load will reach to height (h) but in order to reach that height it will sway to a larger amplitude angle θ (Theta).

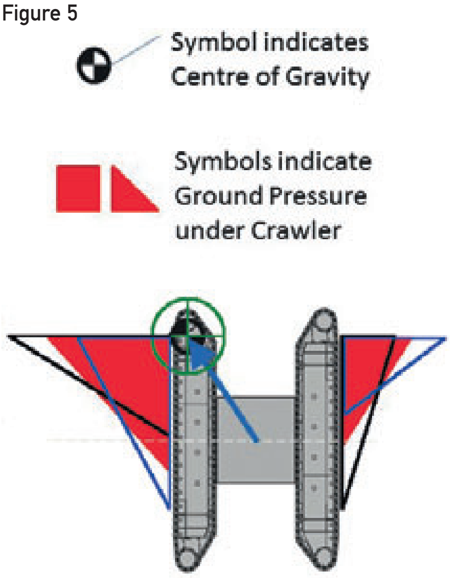
Going back to Figure 1, we can easily see that a larger angle θ (Theta) results in larger (near) horizontal components "mg sinθ". This larger force, as explained earlier, transfers all the way down to ground level and can result in an increase in ground pressure. And it gets worse. As we have seen, the velocity in point A has not changed between the initial lift with 100 m and 50 m hoist wire. The period of time (T) however has decreased from 20 seconds to 14 seconds. This means that the velocity (v) is now decreasing from maximum value (in point A) to zero value (in point B and C) in a shorter time (20 sec vs 14 seconds for the full period). Lifting the load another 25 m will reduce the period (T) to 10 seconds. The load sways increasingly more violent. This can only be achieved with an increased deceleration force. Any increase in any of the forces on the load automatically transfer to a force onto the boom as well, and any force on the boom transfers to ground level and can mean an increase in ground pressure.

In summary, when we lift a load from ground level to a certain elevation it can result in an increase in ground pressure. This increase can have devastating results if not understood or accounted for.

Two questions should come to mind now: 1.) Why is this only applicable for wind turbine components? 2.) Why do I keep reading "can increase ground pressure" instead of "will increase ground pressure"?

1.) This theory is not only applicable to wind turbine components; accidents just happen more frequently while erecting turbines more than in any other industry. Why is that? Ask yourself, how often is an average crane taken to the limit in terms of boom length and, or, elevation and capacity combined? While you may not be able to answer that question, I can inform you that while erecting wind turbines it is almost 100 % of the time.

Figure 5



2.) A swaying load can make a variety of movements. It can sway from left to right, depending on the angle of the crane's superstructure and boom compared to the carrier; however, this does not necessarily have to result in an increase in ground pressure. The load can also sway away from the crane and towards the crane; this motion does have an impact on the ground pressure. How much impact, however, again depends on the angle of the crane and the amplitude of the load. The load, for example, can sway in a circular motion; this can have an impact in one direction (left and right) and does have an impact in the other direction (to and from). Last but not least, as we know, where there are wind turbines there is wind. The load can sway in an ellipse-shaped motion. The constant wind coming from one side of the load may push the load away from its centreline, but may not allow the load to fully sway back. This is kind of unpredictable in terms of ground pressure.

Figure 5 is taken from the article of Søren Jansen and Klaus Meissner. It shows only the last distribution case, the non-symmetrical loading. The ground pressure under the tracks is shown in red and can be calculated for a stable environment. When the load sways, however, (as is shown by the circle around the original Centre of Gravity) the ground pressure changes. The black outline represents the load swinging to the left; the blue outline represents the load swinging to the right. A significant increase in ground pressure is caused by a seemingly harmless motion. Without going into calculations, the FEM 5.016 document advises a rule of thumb on ground pressure increases. It recommends taking into account 20 to 35 % ground pressure increase compared to ground pressure given by the manufacturer. ■