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THE MAGAZINE FOR EQUIPMENT USERS AND BUYERS

Design and application of

Spreader bars are a versatile below the hook rigging tool so widely used that often the concept is forgotten or neglected at the design stage.

MARCO VAN DAAL explains

Figure 2

A number of manufacturing companies offer commercial spreader bars for sale and, or, rent but many heavy lifting companies fabricate their own. As a spreader bar is not subjected to bending and shear, its design can be fairly light compared to a lift beam. In an ideal design a spreader bar is only subjected to compression forces and the slenderness of the tube or beam is the only consideration in the design stage.

This with the exception of extremely long spreader bars where the bar sags under its own weight. When sagging occurs, part of the compression force actually causes a bending moment in the spreader bar, therewith reducing its original capacity.

Figure 1

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.com/books/the-art-of-heavy-transport/

Van Daal has a real passion for sharing knowledge and experience – the primary reason for the seminars he holds around the world.

Spreader bars come in two main variations. One where the top slings are terminated at the spreader and one where the top slings continue down to connect to the load.

The first variant is the most common one. See Figure 1, showing a Modulift triple spreader bar arrangement.

Mostly this type of spreader consists of a central member, a hollow pipe or tube, connected a lifting arrangement. This arrangement can be welded to the pipe or it can be a separate end assembly that either bolts on, slips on or slips in or pins on. See Figure 2 for multiple arrangements.

Those spreaders with removable end assemblies are modular in nature and the pipe can be extended by means of inserts or struts.

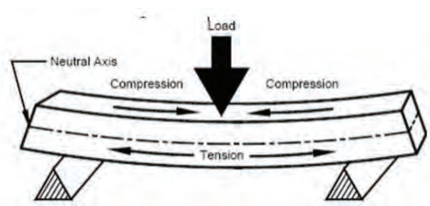
Due to the relatively lightweight construction it is important that the forces from the upper and lower sling intersect at the neutral axis to avoid bending forces in the pipe. Due to the simple construction, spreaders that are designed and fabricated in-house often lack this aspect of having these forces intersect at the neutral axis, this can have disastrous results.

Unstressed axis

The neutral axis is the axis in a beam or pipe along which there are no longitudinal stresses (Figure 3 illustrates this). It depicts a beam supported at the two extremes. When a load is applied the beam is subjected to flexing or bending. The upper part of the beam experiences a compressive force where it becomes slightly shorter. The lower part of the beam is subjected to tension where it actually stretches a bit).

If the upper part of the beam becomes a bit shorter and the lower part of the beam becomes a bit longer, there must be a part of the beam, between the upper and lower part, that remains of constant length. The line at which this occurs is called the neutral axis. For symmetrical constructions, for example, a spreader bar, the neutral axis is found at the geometric centroid. That suits us well because this has simplified the design of a correct spreader bar.

Figure 3



Why is it important that forces intersect at the neutral axis? Any force that is applied to the spreader at the neutral axis results in a purely compression force in the spreader bar or pipe. Any force that is applied to the spreader bar that is not lined up with the neutral axis will result in a bending force or bending moment. A spreader bar that is subject to bending forces and, or, bending moments is much more difficult to properly design and is no longer the simple and light weight construction we were aiming for.

Below are the most common spreader bar designs with an explanation of the forces applied to them.

Figure 4a shows the simplest design, basically a plate, with top and bottom holes, that is welded in a slotted pipe. No matter how this spreader is rigged, it is always subject to a bending moment due to its incorrect design.

The bending moment is equal to:

$M=F_{\text{bottom sling}} \times A$

As you can see, the bending moment increases as the angle α decreases.

Figure 4b shows already a large improvement; the top lug is slightly angled and if the top sling is rigged at the same angle, the top and bottom forces intersect at the neutral axis and no bending occurs. All you field riggers know, however, that it is not practical to rely on this. How often can the bottom sling not be rigged perfectly vertical, probably for most lifts there is a certain angle in this bottom sling. It may not be severe but any deviation from vertical introduces a bending moment.

Another field situation is where the

spreader bars

Figure 4A

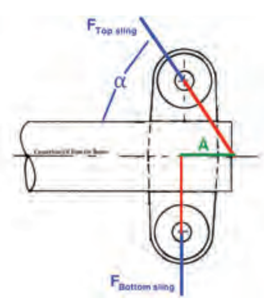


Figure 4B

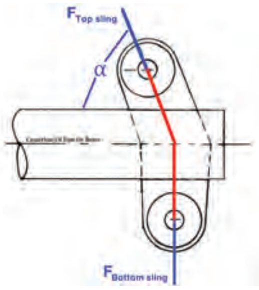
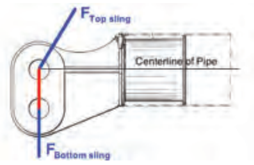


Figure 4C



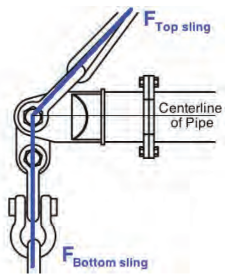


Figure 4D

spreader bar is used for multiple lifts of cargo of different sizes and weights. How often is a judgment call made in the field to not lengthen or shorten the spreader (take out or add an insert or strut) but use the spreader with angled bottom slings to save time.

As for the top slings, once the angle of the top lug is known, a fixed set of slings and shackles can be assigned to this spreader that are aligned with the offset lug. When running out of headroom, however, these top slings could be changed to shorter slings, therewith introducing a bending moment in the spreader bar.

Unwanted situations

How can we overcome these unwanted situations where the spreader bar is subject to bending moments (for which it was not designed) but not lose the flexibility of using the spreader in the field for cargo of varying size and weight?

Figure 4c is a step in the right direction. By positioning the hole for the top sling on the neutral axis, the angle of the top sling can no longer introduce a bending moment. In practice this means that any length sling can be used provided that common rigging sense is used i.e. maintain at least a 60 degree angle between the top sling and the spreader bar.

The bottom sling however can still introduce a bending moment in the spreader bar when not perfectly vertical.

Figure 4d shows a spreader that achieves what we are looking for, the flexibility of using it for cargo of different weight, but not overloading the spreader, and size, but without the risk of introducing bending moments.

This type of spreader, a Modulift design in this case, has similarities with the spreader in Figure 4c in the sense that it also has the hole for the top sling positioned on the neutral axis. In addition it is fitted with a so-called drop-link. The drop-link is a plate with two holes that fits in between the end cap flanges, the end cap is the female end, and the drop-link is the male end. The top hole of the drop-link is lined up with the holes of the end cap; the shackle pin holds it all in place and allows the drop link to rotate. The bottom hole of the drop-link connects to the rigging end ultimately to the bottom sling. The drop-link freely rotates about the shackle pin so the bottom sling and the top sling forces always intersect on the neutral axis. In other words, there is never a bending moment in the spreader pipe.

Figure 5 shows a detailed view of small capacity Modulift end caps with drop-link and shackle.

You may notice, in Figure 5, that the top shackle is a larger shackle than the bottom shackle. This is no coincidence or mistake in the rigging. Refer back to Figure 1, this is a 370 tonne transformer, the centre of gravity (CoG) is located central between the lifting trunnions. Each of the vertical slings carries 370 tonnes / 4 = 92.5 tonnes, a 100 tonne shackle would suffice at the bottom (drop link) of the two lower spreaders. The top slings are angled at 60 degrees from horizontal. Due to this angle the force in each of the top slings is 92.5 tonnes / sin 60 = 106 tonnes. A 100 tonne

Figure 5

shackle is not sufficient; it requires the next size up.

Down force

The second spreader type is where the slings are not terminated at the spreader but are guides around the end caps down to the load. As the angle of the slings above the spreader create a down force onto the spreader, assist slings are rigged to the spreader to avoid this. See Figure 6.

This type of spreader has its advantages as well as its disadvantages. Advantage is that no shackles at the spreader level are required for the main slings, just some smaller type shackles for the assist slings. Also, only two main slings are required as opposed to four main slings with the earlier described spreader.

A disadvantage is that this spreader is always subject to some degree of bending due to the location of the assist sling lugs. The closer these lugs are to the extremes of the spreader, the smaller the bending moment in the spreader bar but, the higher the tension in the assist slings. A slight bending is also introduced by the two main slings as the approach angles (from the crane hook to the spreader) and the depart angles (from the spreader to the load) are not the same.

The compression force likely applies

FIgure 6

slightly above the neutral axis. This makes this type of spreader less suitable for slip-in, slip-on and pinned inserts. Bolted inserts would be best as the bolts take the eccentricity of the compression forces.

Last but not least, analysis of these types of spreader is more complicated than with the previously described spreaders.

The down force caused by the 60 degree angle is now taken by the assist slings. Figure 6 shows the lift of an HRSG unit with a weight of 200 tonnes. The two main slings each take 100 tonnes, this sling's tension is equal below as well as above the spreader as it is an continuous sling. As there was no head room limitation, the angle between the main sling and the horizontal measures 75 degrees.

If the top and bottom sling would terminate at the shackle the top sling tension would be:
100 tonnes / sin 75 = 103.5 tonnes.

This is not the case as it is a continuous sling but when we draw a force diagram, we are 3.5 tonnes short that needs to be accounted for. This 3.5 tonnes is taken by the assist slings to resist the down force onto the spreader caused by the two main slings. These assist slings, however, would have to be at the extremes of the spreader bar to take this 3.5 tonnes of tension. In Figure 6 you can see that the assist slings are nowhere near the extremes. The angle of the assist slings with the horizontal is 85 degrees. The tension in the assist slings is therefore:

EQUATION 1

$$F_{assist} = \frac{\sin 75}{\sin 85} * 3.5 = 3.4 \ ton$$

The difference is small due to the large top angles; if the top angles were smaller the difference in tension in the assist slings would be significant depending on the termination location. ■