What is stability of the lifted load?

Richard Krabbendam investigates the possible cause of an unexplained accident in which a gas turbine rotor was dropped during a lift by a special spreader beam.

I recently investigated the reason a gas turbine rotor fell while it was being lifted by a special spreader beam, as shown in the picture (right). Fortunately nobody was hurt, but the damage done to the balanced rotor was significant.

So far, no one has really come up with an explanation as to why the accident happened. It would be nice to see the official investigation report on the cause of this accident so that we can all learn from the incident and avoid these mishaps in the future.

My first thought was that there had been an instability of the load and this must have been the cause of the incident,

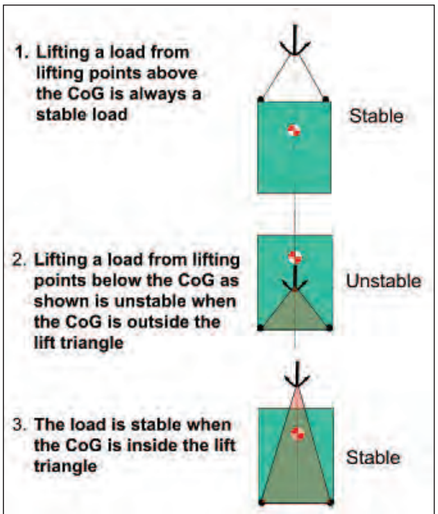

Figure 1: Stability of the l§oad.

The gas turbine rotor fell while it was being lifted by a special spreader beam.

in combination with some other external forces.

When lifting a load with slings from lift points that are above the centre of gravity (CoG), the load will always be a stable lift (Figure 1.1). This can change when raising a load from lift points that are below the CoG (Figure 1.2) and when the slings do not enclose the CoG. To make that load a stable lift again, one has to lengthen the slings so that they enclose the CoG, as shown in Figure 1.3.

When using a lifting beam outfitted with lifting trunnions D, A, B and E, it becomes even more complicated. The yellow lifting beam is supported by four grommets in hook block H (Figure 2 overleaf). The lifting trunnions on the green load are D' and E', with the load connected by grommets DD and EE. When the red triangle ABH is projected down through the liftpoints D' and E' and does not enclose the CoG of the load, the load will be unstable and tilt, as shown overleaf in Figure 3.

What it boils down to is that the lifting points, as well as the lifting trunnions on the lift beam, are hinge points around which the grommets are free to rotate and make the load unstable when the lift triangle ABH does not enclose the CoG. When we simplify this, it is clear that the whole system is stable when B>A, because in that case X is always bigger than Y and the load returns to its stable situation.

When B<A, then X is smaller than Y and the system becomes unstable and will tilt. In order to investigate whether a system is stable or not, one has to define the exact location of points H, A and B, as shown in Figure 2.

Accident

In the rotor accident shown in the opening picture, the lift beam used for this gas turbine rotor looks something like that shown in Figure 6. The green yokes are placed around the yellow lift beam, which is lifted by grommets or slings from the centre black pin H, just above the top flange of the lift beam. The green yokes are outfitted with pad-eyes D and E, which are below the bottom flange of the lift beam and are used to connect the grommets or shackles, which lead to the rotor shaft being lifted in a basket hitch around the shaft at points D' and E'.

What we have to look at now are the points of the lift triangle and the exact positions of the hinge points D, D' E and E', as those define whether the load is stable or not. In Figure 6 the height of the lift triangle h = H to the top of pad-eye D. If we look at the points D' and E', where the slings are laid around the shaft, it is a bit more complicated.

We have to look at a cross-section of the rotor shaft, with the sling(s) around it. (See Figure 8.) The orange sling around the rotor shaft gives a radial force P, which is equal to: P = F/(D*R).

We have to find the centre of mass of all these radial forces (P). This lies at 0.636 * R (= A in Figure 5) below the x-axle. If now the height h (= B in Figure 4) is smaller then 0.636*R, then the load becomes unstable and will tilt.

If the lift slings are fibre slings, friction between the rotor shaft and fibre slings is minimal and the tilting point will eventually shift to the bottom of the shaft. In that situation the distance will be equal to R = 0.5*D rotor (= A in Figure 5).

Conclusion

When we are using these types of lifting beams, where the lift is made from a single point in the centre of the lift beam, make

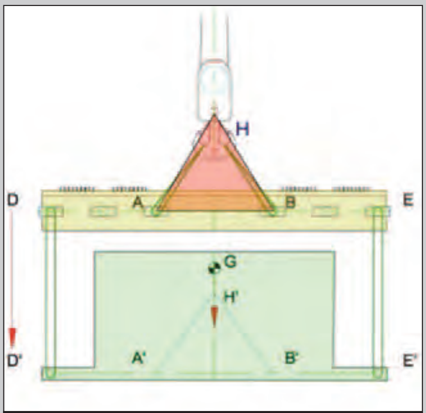

Figure 2: Stability spreader 1.

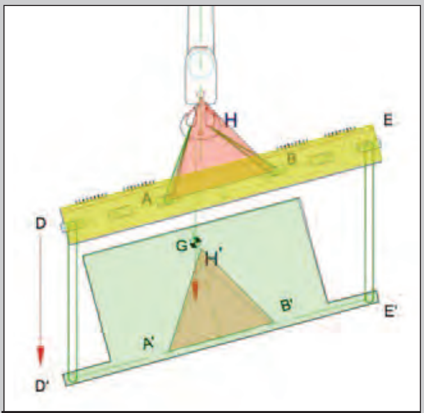

Figure 3: Stability spreader 2.

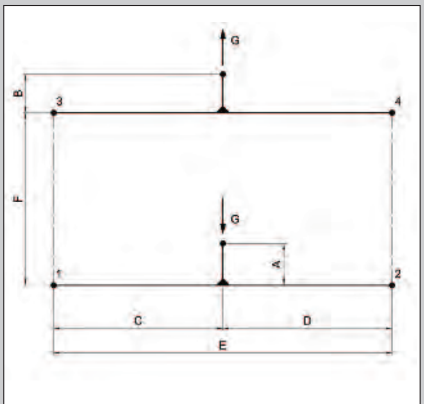

Figure 4: Stability 1.

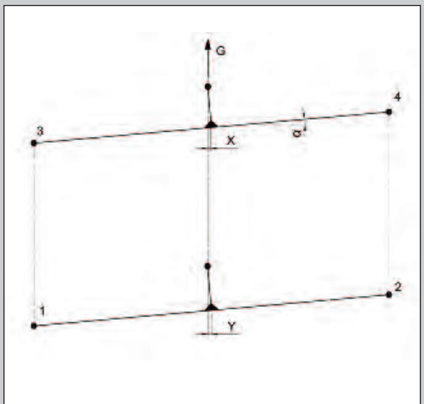

Figure 5: Stability 2.

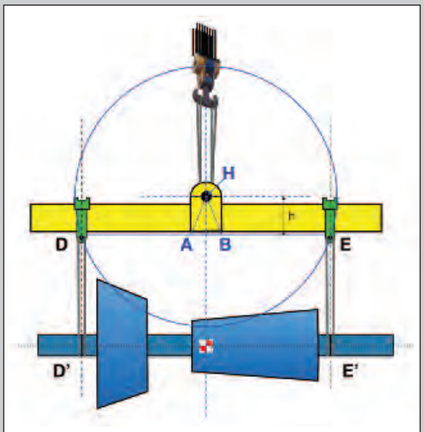

Figure 6: Stability rotor 1.

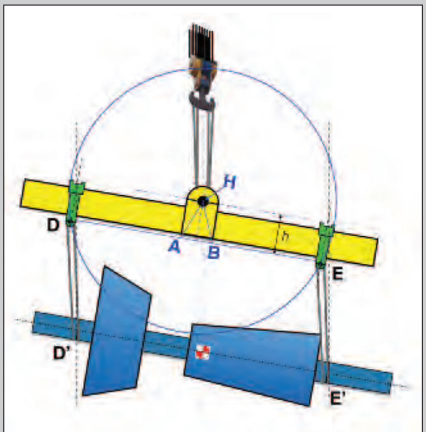

Figure 7: Stability rotor 2.

What it boils down to is that the lifting points, as well as the lifting trunnions on the lift beam, are hinge points around which the grommets are free to rotate and make the load unstable when the lift triangle ABH does not enclose the CoG.

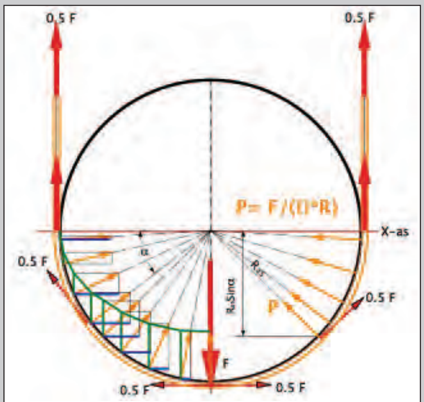

Figure 8: Load around the shaft.

A sequence of shots showing a mobile port crane being lifted from the outriggers of the crane using a lift beam with insufficiently long slings.

sure the distance h (= distance from hinge point of lift pin H to the top of pad-eye pins D) is always significantly bigger than half the rotor shaft diameter.

As I do not know the dimensions of the lift beam used in the rotor lift, I cannot make a judgement on this case, but it seems that stability of the load was very small and just a small external force (which could have been the force from a steering line) could have caused the tilting of the rotor, with the lift sling sliding off and the rotor shaft falling.

If we do not understand all the implications of load stability clearly, we could be in for a nasty surprise – as pictured above, where a mobile port crane was lifted from the outriggers of the crane using a lift beam with insufficiently long slings.

Apparently, the CoG of the crane was only barely enclosed by the lift triangle, projected down to the lift points at the outriggers. Although ostensibly a stable lift, in fact it had very little stability.

During the lift, a sudden external force on the crane made it unstable, causing it to tip and land on the quayside and the heavy lift vessel.

HLPFI

Please note, this article is intended for guidance only. While every care has been taken to ensure the accuracy of the contents, no responsibility will be accepted by the publishers for any errors.

Richard Krabbendam was a heavy lift specialist during his whole working career, after which he formed Krabbendam Advisory Service. A Master of Mechanical Engineering from Delft University of Technology, he has worked with BigLift and Mammoet, and was a co-founder of ITREC. He helped to set up Jumbo Offshore and was involved in the development of its super heavy lift carrier fleet, the J-Class, which uses two 900-tonne mast cranes for subsea installation works. Since his retirement from Jumbo he has been working as a freelance trainer/engineering consultant.

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