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Long vehicle loads

Problems with long loads are, thankfully, a rarity but they can and do occur. In his 36th article in this series MARCO VAN DAAL assesses the risk and explains ways to avoid trouble

While *en route* from origin to destination, heavy transports often encounter areas where manoeuvring is critical and demanding on both equipment and personnel. Notorious in many cases are port areas and sites that are still in the process of construction. Both are unpredictable in nature, even when a route survey has been conducted, it is difficult (if not impossible) to predict what will change between the time of the survey and the time of execution. In ports all over the world, cargo arrives on a continuous basis and is often stored temporarily in various areas inside the port vicinity. Sites that are still under construction are often subject to excavations, road diversions or partial new infrastructure. In particular, when transporting long cargo this can become a major challenge. Long cargo is here identified as cargo being transported on fixed transporters (no bolsters or turntables) of at least 18 to 24 axle lines.

The figures shown in this article are examples of such transports that have gone wrong for one reason or the other. These types of mishaps we do not see often, for two reasons:

1. only a small percentage of cargo is transported this way
2. if it does happen it is often in a secluded area (site or port) with little or no access for the general public

If there is a risk that such incidents can happen, one could ask the question why such long vehicles are used. As it turns out there is a multitude of reasons.

When transporting long vessels one can opt for a long vehicle or for a configuration with turntables. The decision process involves the following; availability of equipment, time (due to possible change of configuration), centre of gravity (which is higher when using turntables), infrastructure and many more.

For the transport of pipe racks, this decision process is often (not always) shorter as many pipe racks are not structurally strong enough to be supported in only two (turntable) locations.

In addition, in the case of pipe racks, there are often a large number of such units due to the modularisation concept and the time involved to load and unload becomes an important factor.

Considerations

Once it has been decided that a long vehicle will be used for the transport there are two important aspects that have to be taken into account. First, the engineering of such long vehicle loads is not straightforward. Second, the velocity parameters (read speed limitations) that are assumed at an engineering level are to be communicated to the operations level. A deviation from those assumed limits can have devastating results.

When performing transport calculations we normally assume that external forces, for example, acceleration, deceleration, road cambers and curve impact (or centripetal force) apply to the (combined) centre of gravity which, in turn, affects the load per axle. We then add up all those forces and ensure that

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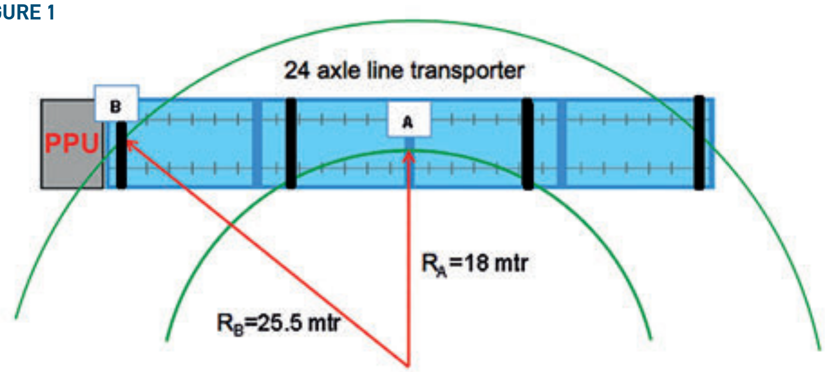
FIGURE 1



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-infostore.com/books Van Daal has a real passion for sharing knowledge and experience and holds training seminars around the world.

FIGURE 2

FIGURE 3

sufficient lashing is applied to the cargo to compensate for these forces. A perfectly correct approach.

It is the centripetal forces that can cause problems if not interpreted and determined correctly. Figure 1 shows a sketch of a 24 axle line self propelled transporter. This transporter carries a load supported by four transport saddles. These transport saddles are shown in black. The centre of gravity of the load is located in point "A" at the centreline of the transporter. Assuming that the transporter makes a turn of which the radius measured from point A is 18 metres (59 feet). In addition, we assume that the mass of the cargo is 360,000 kg (793,000 pounds) and the transporter velocity is 5 km/h or 1.38 m/sec (3.1 mph). The formula to determine the centripetal force is:

$$F = \frac{mV^2}{r}$$

Centripetal force is directed away from the centre and is perpendicular to the transport direction.

NOTE: The explanation of centripetal vs. cetrifugal force is outside the scope of this article.

$$F_A = \frac{mV^2}{r} = \frac{360,000 * (1.38)^2}{18} = 38kN$$

This is the cetripetal force on the cargo in point "A" and roughly equals 3.8 tonnes.

This is, however, not the centripetal force that the cargo applies to the transporter. Review again Figure 1 and note that there is a transport saddle at one of the extremes of the transporter, in point "B". Also note that the radius to that point "B" measures 25.5 m (as opposed to the 18 m to point "A"). When the transporter makes a full circle, point "B" has travelled a longer distance (the circumference of the circle) than point "A".

- Point "A" has travelled:
  2*18 m * Pi equals
  (18*2) * 3.14 = 113 m (370 feet)
- Point "B" has travelled:
  2*25.5 m * Pi equals
  (25.5*2) * 3.15 = 160 m (525 feet)

If point "B" has travelled a longer distance than point "A" in the same time, it can only mean that Point "B" is travelling at a higher speed. Indeed, if point "A is travelling at 1.38 m/s, than point "B" is travelling at 1.955 m/s and this results in an increased centripetal force at these extremes of the transporter.

This can be experienced when riding a bus as a passenger. When seated towards the centre of the bus one experienced a much lower centripetal force than when seated at the front or rear of the bus.

$$F_B = \frac{mV^2}{r} = \frac{360,000 * (1.955)^2}{25.5} = 54kN$$

NOTE: Any cargo supported in more than two locations represents a so-called "statically undetermined" situation where it is not possible to calculate how much each support point carries. In this example it is assumed that the entire weight of the cargo was carried by the support point at the extremes of the transporter as this results in the worst case scenario against which lashing is to be applied.

As we are all human, we all have human shortcomings. As mentioned before, pipe racks come in multiple units. Human nature is the behaviour that after having transported a number of these pipe racks the operator becomes (over) confident and increases his velocity. Let's assume that he increases his velocity to 10 km/h or 2.77 m/s (up from 5 km/h or 6.2 mph).

As an immediate result the centripetal force in point "A" increases accordingly.

$$F_A = \frac{mV^2}{r} = \frac{360,000 * (2.77)^2}{18} = 153kN$$

Once again, the centripetal force against which lashing is to be applied is much higher as these occur in point "B" as a result of a much higher velocity (3.92 m/s compared to 2.77 m/s).

$$F_A = \frac{mV^2}{r} = \frac{360,000 * (3.92)^2}{25.5} = 217kN$$

In summary

Figure 4 shows an overview of the applicable centripetal forces in each of the four scenarios. As one can see, these have increased from 38 kN to 217 kN, an increase of more than 500 %.

A higher centripetal force means that certain axles and axle groups are now exposed to a higher load as the cargo is "pushed" toward that side of the transporter. Likewise, certain axles and axle groups, on the other side of the transporter, now experience a lower load. This in itself is not necessarily a problem as long as these higher loads are still within the hydraulic and structural limits of the transporter, as long as the lower loads do not create an uplift and as long as the applied lashing can cope with the centripetal forces in question.

In addition, when centripetal forces increase, the higher forces onto the axles and axle groups cause more deflection of the tyres. Together with lesser tyre deflection on the other side of the transporter, it can be stated that the transporter deck will tilt under the influence of the centripetal forces. When underestimated this can result in an unrecoverable situation.

This example has demonstrated that it is of great importance that the velocity parameters or speed limitations are communicated to the operating crew and that these speed limitations (5 km/h or 3.1 mph) are not to be exceeded.

The figures is this article clearly show that the transport ran into some sort of problem. The theory as outlined above could be one explanation but it does not have to be the only one. This article highlights just one of the possible problems that one can run into when centripetal forces are underestimated. ■

FIGURE 4

V_A = 5 km/h = 1.38 m/s	V_A = 10 km/h = 2.77 m/s
F_A = 38 kN = 3.8 ton	F_A = 153 kN = 15.3 ton
F_B = 54 kN = 5.4 ton	F_B = 218 kN = 21.8 ton
An increase of 42 %	An increase of 574 %