Figure 2

In his regular feature, this month MARCO VAN DAAL discusses how to determine power requirements for road transport

The need for speed

The need for speed is a bit of a strange title for an article related to heavy transport, as this industry generally maintains low speeds. In line with last month's article, however, in which the engine's power was translated into a tractive force and ultimately into a rim pull force, part of the engine's power is needed to speed up the transport combination.

The engine's power is first used to get a combination truck with counterweight plus transporter with cargo, from a stand still situation to a rolling situation. Once the combination is rolling, ideally you want to increase to a certain speed. Whether that speed is 5 km/hr (3.1 mph) or 50 km/hr (31 mph) it requires power to reach that speed. Similarly, besides getting the transport combination to roll, there may be an incline on the route. Negotiating an incline also requires power.

It is therefore clear that having sufficient power to get moving does not necessarily mean that there is sufficient power to complete the transport.

So how do we determine the real required power to complete a transport from start to finish? To answer this question we first have to answer two other questions as follows:

1. **What is the maximum incline during the route?**
2. **What is the maximum transport speed and how quickly do we want to reach that speed?**

The answer to question one is easily found, as this is the result of a route survey. A route survey is the foundation of every heavy transport. Not only for the maximum incline in the route, but also for turning radii, obstructions during the transport and traffic flow, to name just a few. In this case we assume a maximum incline of 3 %.

The second question is a bit trickier to answer. Given the existing transport combination, on a straight, flat and paved road, how fast would you want the transport to go? For the sake of this article we want the transport to travel at 15 km/h (9.3 mph). Also, we want to be able to reach this speed of 15 km/h in 30 seconds and maintain this speed until there is a need to decrease it. Last but not least, we want to be able to go from 0 to 15 km/h in 30 seconds even when travelling up the maximum incline of 3 %.

Below is a summary of the data from the truck that we analysed last month:

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.

Given is the following engine info:

- Mack prime mover (engine type E7-400)
- Energy output = 318 kW (426 hp)
- RPM at energy output = 1,800 per min
- Max torque = 1,560 N*m (1,149 lb*ft)
- RPM at max torque = 1,200 per min
- Max RPM = 2,100 per min
- Min RPM = 475 per min

The ratios of the first five gears (from the 18 total) of this truck's main gearbox are:

- 1st gear 16.42
- 2nd gear 8.78
- 3rd gear 6.28
- 4th gear 4.52
- 5th gear 3.22

The gear ratios of the transfer case are:

- 1st gear 2.37
- 2nd gear 1.24
- 3rd gear 1.00
- 4th gear 0.81

Differential gear ratio 8.27
Efficiency of all gears combined is 90 %

The truck has 12.00R24 tyres with a 24 inch (609.6 mm) radius:

- total axles = 3
- drive axles = 2
- truck weight = 10 tons (equally divided between front and rear axles)
- counterweight = 35 tons (on drive axles only)

Rim Pull min = (5 + 35) * 0.6 = 24 mTon or (Frp axle) 12 mTon per drive axle (26,432 LBS)

Rim Pull max = (5 + 35) * 0.8 = 32 mTon or (Frp axle) 16 mTon per drive axle (35,242 LBS)

We also know that when pulling a 12 axle hydraulic transporter (weight 40 tons) with a 200 ton load on it on a level road:

GVW = truck weight + transporter weight + load weight
= 10 + 35 + 40 + 200 = 285 mTon (627,753 LBS)

With a rolling resistance of 4% or 0.04 the required rim pull (Freq) is 285 ton * 0.04 = 11.4 mTon (25,110 LBS).

We determined that the first auxiliary gear resulted in wheel spin and that the second auxiliary gear, with a 1.24 gear ratio, resulted in a total tractive effort of:

39.5 mTon or 19.76 mTon per drive axle (43,538 LBS). This is the drive away gear.

Pulling force

In the new scenario, with 3 % incline and a speed of 15 km/h in 30 seconds, the original required pull force or rimpull of 11.4 mTon (25,110 LBS) is no longer sufficient.

Additional required pull force due to 3 % incline (Note that 3 % is 1.718 degrees):
Freq-incline = GVW * sin(incline) = 285 mTon * sin(1.718) = 8.54 mTon (18,820 LBS)
Additional required pull force due to acceleration (note that 15 km/hr is 4.167 m/s):

Freq-acceleration = GVW / g *(v / t) = 285 / 9.81 * (4.167 / 30) = 4.04 mTon (8,888 LBS) where g is the gravitation of 9.81 m/s^2 (32.19 ft/sec^2)

The new required pull force is now:
Freq + Freq-incline + Freq-acceleration = 11.4 + 8.54 + 4.04 = 23.98 mTon (52,819 LBS)

In the chosen gear combination the engine can deliver 39.5 mTon of pulling force, therefore the engine is strong enough in this new scenario and requires only 23.98 mTon. The required total rimpull of 23.98 mTon results in a rimpull of 11.99 mTon per axle. This is getting very close to the minimum rimpull of 12 mTon at which (in the worst case) the tyres will start spinning. An option could be to add counterweight to the prime mover just to make sure that even in the worst case the tyres will not spin. Adding 5 tons of counterweight results in a new minimum and maximum rimpull of:
Rim Pull min = (5 + 40) * 0.6 = 27 mTon or (Frp axle) 13.5 mTon per drive axle (29,735 LBS)

Rim Pull max = (5 + 40) * 0.8 = 36 mTon or (Frp axle) 18 mTon per drive axle (39,647 LBS)

Important calculations

The conclusion of this exercise is that the transport combination in question can be transported up a 3 % incline while still accelerating from 0 to 15 km/h in 30 seconds with just a bit of additional counterweight to avoid wheel spin.

Keep in mind that these numbers assume that the transport combination is on a straight road and that the prime mover is in line with the transporter. It becomes a different case when the combination is negotiating a turn and is no longer in line with the transporter.

As a rule of thumb, for every 10 degrees that the prime mover is out of line with the transporter it will lose 10 % of its effective pulling power. This means that if the transport combination in this example would have to make a 30 degree turn on a hilly road it would lose 30 % of its effective pulling power and would be able to transfer only 70 % of 39.5 mTon = 27.7 mTon to the transporter. This is getting close to the required 23.98 mTon that is required.

Such calculations are more important than one would think at first glance. Being on an incline and finding out that you do not have enough counter weight to reach the top puts you in a really serious situation, especially when traffic has accumulated behind you. It becomes even worse if the transport combination consists of a beam and dolly arrangement such as in Figure 1. ■


Figure 1