How to calculate your pulling power

Safety expert Richard Krabbendam explains how to accurately assess the pulling power of heavy duty prime mover tractor units on a gradient.

The MAN TGA 41.660 prime mover tractor unit has 660 hp (485 kW).

Early in my career as a young engineer in the heavy transport and rigging industry, I asked my transport supervisor: "What force can this prime mover actually pull?" The experienced man could not give me an answer, so I asked him: "How do you select the type and number of prime mover tractor units needed for a particular heavy transport job then?" His answer was: "I use my experience from previous projects."

In fact his answer was quite right. In those days, that kind of knowledge was not readily available on the internet – we did not even have computers, internet, fax or e-mail. Communication was by regular mail and telex, and any offer was typed out by a secretary and sent to the client by regular post service.

Fortunately things have changed, but it took time to make this information available to the general public. It also meant that clients have become more demanding and want to know exactly how you, as a transport or lifting contractor, intend to execute a particular job.

Detailed Method Statements are required and reviewed over and over again and should be engineered in a correct way in order to avoid any unforeseen circumstances and reduce the risk of possible incidents or project delays.

To find out what actual pulling force in tonnes (to be correct we should use KiloNewtons (kN) as the unit of force) a certain tractor could develop in those days, we did a test in the yard.

Pulling test

The tractor unit's rear coupling was connected by a sling to an anchor point, which served as a hold-back system and was strong enough to withstand the force of the tractor unit. In between there was a measuring device. Then we told the driver to slowly build up tension on the sling and gradually increase the pulling force on the driven axles of the tractor unit, until the wheels started spinning on the road surface. The measured pulling force was the maximum tonnage that particular tractor unit could develop on that road surface.

That test simulated the actual working conditions, where a tractor is hooked up to a platform trailer with a heavy load on it. A heavy duty tractor can never develop more pulling force than approximately 50-80 percent of its driven axle weight. This is defined by the friction resistance of rubber tyres on the road surface.

When circumstances are ideal, and the road surface is either dry asphalt or concrete, the pulling force may reach 80 or 90 percent of the load on the propelled (driven) axles (assuming enough horsepower is available and the right gearing is used).
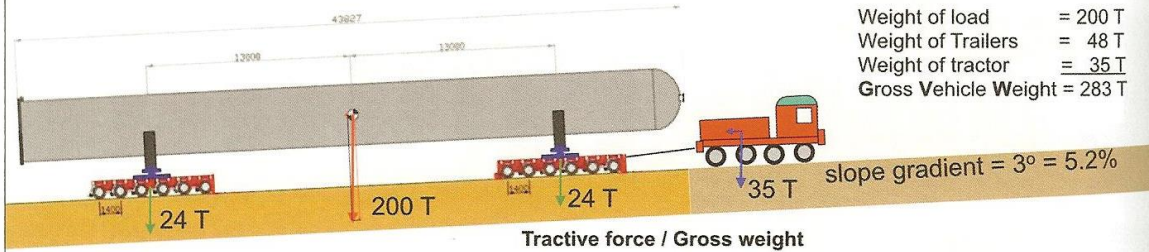
The lower number should be used when circumstances are far from ideal – that is on a gravel road or a wet, slippery deck surface. It is obvious that these numbers are just guidelines and should be applied correctly, depending on the local circumstances.

Maximum torque

Theoretically, one could calculate the pulling power of a tractor unit by starting with the maximum torque the engine can develop and converting this into the maximum available pulling force on the road surface, taking all gear ratios and efficiencies of the drive train into account.

However, the final contact is the rubber tyre on the concrete or asphalt road surface, which must transfer the available torque on the road surface. If the friction coefficient of the rubber tyre, the road surface and the load on the tyre is not sufficient, the tyre will skid. The easiest way to increase the pulling power of a tractor unit, and avoid skidding of the tyres, is to place more counterweight
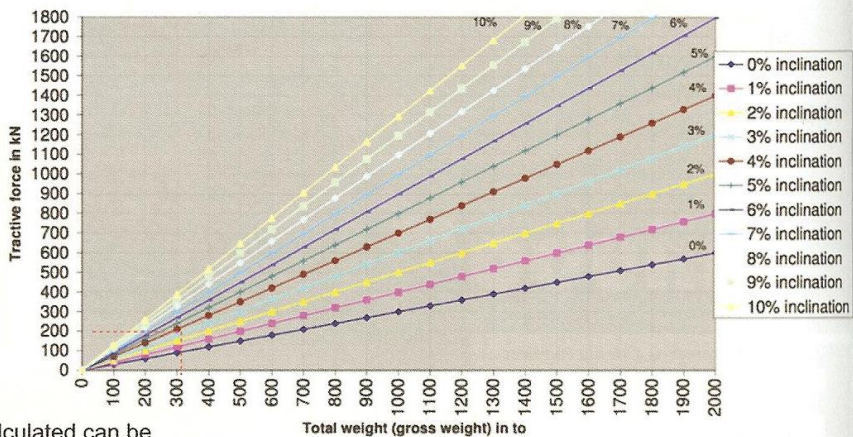
Calculating the required pulling force in Tons

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Weight of load = 200 T
Weight of Trailers = 48 T
Weight of tractor = 35 T
Gross Vehicle Weight = 283 T

slope gradient = 3° = 5.2%

Calculation of required pulling force:

3% friction+5.2% slope =

8.2% of 283 = **23.2 Ton**

Max. pulling power of one tractor unit on **2 rear driven axles** each with a load of 12 ton is:
24x0.8 = **19.2 Ton (not enough)**

In case **3 rear axles were driven** then it would be 3x12x0.8= **28.8 T, which would do the job!**

Tractive force / Gross weight

Tractive force in kN

- 0% inclination
- 1% inclination
- 2% inclination
- 3% inclination
- 4% inclination
- 5% inclination
- 6% inclination
- 7% inclination
- 8% inclination
- 9% inclination
- 10% inclination

Total weight (gross weight) in to

What has been calculated can be represented in the **diagram** above

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on the rear of the tractor unit, resulting in more load on the driven axles and consequently more grip.

Required pulling force

The required pulling force depends on the friction resistance forces of the transport combination on the road, which are:

- Rolling friction.
- Slope gradient.
- Friction in curves.
- Wind resistance.

The main ones to be considered are rolling friction and resistance due to a certain gradient. The rolling friction of a combination is approximately 1.5-3 percent of the gross combination weight (GCW), or more for different road surfaces.

Wind resistance can be ignored and friction in curves greatly depends on the radius of the curve, the angle at which the tractor unit is pulling it, and of course the condition of the road surface.

To make a simple calculation, let us consider a standard type of MAN TGA 41.660 8 x 4 tractor unit. When we talk

about a slope gradient of 4 percent, it means the road will climb 4 m in height over a distance of 100 m, measured along the slope. For relatively small slopes, we can just add the slope gradient percentage to the friction percentage.

Developed pulling force

The MAN TGA 41.660 prime mover tractor unit has 660 hp (485 KW) and is equipped with a torque converter – maximum torque 2,700 Nm (Newton metre) – and only the two rear axles are driven (8 x 4). It can accept a load on the fifth wheel coupling of approximately 27.5 tonnes and the gross vehicle weight (GVW) of this unit (own weight 12.5 tonnes) is rated at 41 tonnes. But, depending on the local authorities, the allowable GVW could be less.

The technical rated loads on each axle (with the front steering axle being No1 and the last axle being No 4) are:
No 1 = 7,500-8,000 kg,
No 2 = 7,500-8,000 kg,
No 3 = 13,000 kg,
No 4 = 13,000 kg.

They total 41,000 kg.

A maximum load of 26 tonnes is allowed on the two rear driven axles, giving this maximum-ballasted MAN tractor a maximum pulling force of 26 x 0.8 (= 80 percent) = 20.8 tonnes, though under ideal circumstances it could achieve 26 x 0.9 (= 90 percent) = 23.4 tonnes.

Normally these units are not loaded up to their maximum capacity and, for calculation purposes, it is recommended to use a maximum of 12 tonnes per rear driven axle, giving this unit a maximum pulling capacity of 24 x 0.8 = 19.2 tonnes.

In extreme conditions, some additional counterweight can be added in order to retain the tractive power on the road and avoid skidding (spinning) of the wheels. Again, this presupposes that the engine power and drive train have enough power to create the required torque.

If you are interested in learning how to calculate pulling power, using the engine torque and drive train specification, I suggest you download Bechtel's Trailer, Trucks and Tractors PDF File Part 6.

The DAF XF truck is just one of a number of powerful prime mover tractor units available globally.

Typical examples

So how would we tackle a 230-tonne generator needing to be rolled-off from a flat top barge against the 5 percent slope of the ro-ro ramp?

First we need to calculate the GCW of the planned transport. In this case we used a 12-axle line Goldhofer THP/SL hydraulic platform trailer with an approximate payload of 300 tonnes.

To estimate the GCW, we add all the weights together: generator (230 tonnes) + load spreading beams (3 tonnes) + trailer weight (12 x 4 = 48 tonnes) + estimated 1 HD tractor unit (35 tonnes) = 316 tonnes

GCW. Rolling resistance is 3 percent + 5 percent slope gradient = 8 percent total resistance. Required pulling force: 8 percent of 316 tonnes is 316 x 0.08 = 25.28-tonne force.

Now we need to find out whether this tractor unit can indeed develop the required pulling force of 25.28 tonnes. The DAF HD Tractor was an 8 x 4 unit and it was ballasted up to a GCW of 35 tonnes. The maximum load on the two rear-propelled axles was 2 x 12 = 24 tonnes, so the absolute maximum pulling force this tractor could develop was 24 x 0.9 = 21.6 tonnes. So when we executed this project we did not have

enough pulling power and needed the help of an extra tractor unit.

The relationship between required pulling force, slope gradients and the GCW is shown in the graphic illustration on page 120.

There are a number of tractor manufacturers and in Europe brands like Volvo, Scania, MAN, DAF, Iveco and Mercedes all make standard tractor units. The more tailor-made units are built by Titan-Mercedes, Tractomas-Nicolas and, in the USA, MACK, Peterbilt, Kenworth, Oshkosh and others. ⟋ 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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