Words: Stewart Sanderson

MAX POWER

Horsepower and torque: what are they exactly, and how do you calculate those all-important figures? Stu explains all.

Having worked as a tuner for 17 years, Stewart 'Stu' Sanderson is one of the most-respected names in the business.

A Level 5-trained fuel-injection technician, in the past Stu has worked for a Ford Rallye Sport dealer, a well-known fuel-injection specialist and various tuning companies.

Then seven years ago he joined forces with Kenny Walker and opened up Motorsport Developments near Blackpool (01253 508400, www.remapping.co.uk), specialising in engine management live remapping, as well as developing a range of Evolution chips which are now sold all over the world.

He's also jointly responsible with Webmaster, Petrucci for www.passionford.com. Started in 2003, it's grown rapidly from a few friends contributing, to one of the biggest Ford communities on the web.

Stu's enviable knowledge of the workings of modern-day Ford performance engines means that every month he's just the man to explain how and why things work, and most importantly how they can be improved.

I HOPE you enjoyed last month's article about rolling roads and weren't too upset by some of the things you read about why most of the figures they generate for flywheel power are wrong. But it did bring me neatly into a topic about the figures they generate, or, more accurately the units they use to clarify the graphs they generate.

These units of measurement are of course the horsepower and torque. It is quite surprising how many people don't know the difference between the two when they really should do, so I am going to dedicate this month to explaining precisely all you will ever need to know about power and torque, how it's derived and what the difference is between the two.

WHAT IS TORQUE?

Before you can fully understand horsepower, first you must understand torque, so this is where we will start. Torque is simply a twisting force used to rotate an object around an axis. The measurement used to express torque is most commonly 'foot pound' (expressed normally as ft.lb or lb.ft).

This measurement unit is actually very simple to visualise and express using common procedures. If we take a spanner that is 1 ft long and put it over a nut and then hang a 10 lb weight from the end of it, we would be exerting a rotational force of 10 ft.lb on the nut. If we hung a 30 lb weight off the end of the spanner it would then exert 30 ft.lb of rotational force on the nut.

Conversely, if we extended the spanner to 2 ft long, and used the same 30 lb weight on the end, we would then exert a force of 60 ft.lb. In a nutshell, the correct formula to use for calculation of torque output is force exerted x distance from the axis. If that doesn't make sense, please read it again until it does so that you can proceed further, as it's the most important part for you to grasp before moving on to tackle the rest.

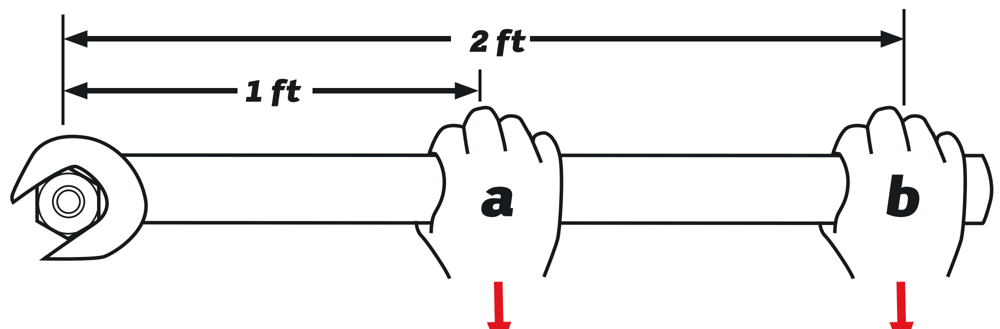
WHAT IS WORK DONE?

Work isn't often talked about when referring to cars, but it needs to be explained as it relates to power. As a simple definition, work is the transfer of energy from one thing to another. It is, however, often mistakenly believed to be the torque itself. This is a common mistake, and is because it uses the same units of measurement, such as ft.lb and Newton metres (Nm). Even so it is not the same at all, as we can often exert torque and actually achieve no work at all. A good example of this is when we apply our 30 ft.lb to a bolt already tightened to 60 ft.lb. We will be exerting the torque as expected, but it will not turn the nut and thus it will not result in any work done. The work done must be expressed as a movement. The correct formula to use for calculation of work done is force exerted x distance moved. No movement = no work done. Simple... and this brings us neatly to power.

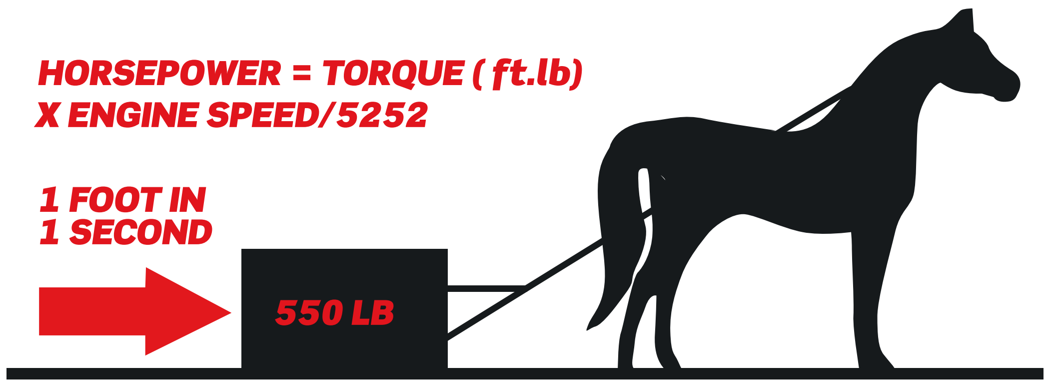
WHAT IS POWER?

Power is the amount of work done in a period of time, so

TORQUE = FORCE X DISTANCE



Both these pulling forces (a and b) will result in the same rotational torque at the nut



the more power an engine develops, the more work it can get done in any given time span.

Power can be best described by comparing two different humans. If we take a strong human and a weak human and ask them to move 500 lb of sandbags from the ground, and put them on a shelf 1 ft above the ground, the big strong man may be able to lift all of the sandbags up onto the shelf in one go, but the weaker man may have to move a few at a time, and take 10 goes. Both men will have done 500 ft.lb of work, but the stronger man did it much faster, thus he would be deemed more powerful as he is now proven to be able to do the same amount of work, but in less time than the less powerful man When related to a car, the more power an engine has the more work it can get done in less time. This work may be perceived as powering a car up a large hill, or maybe accelerating the car hard on a long straight road.

WHAT IS HORSEPOWER?

So what is horsepower, then? Well, James Watt came up with the measurement of horsepower for us when he came to market his steam engine. In those days, the accepted power source was horses, and Watt needed to find a way to compare the capabilities of his new steam engine to the horse. He spent a long time comparing and measuring a horse's ability to do work in a given time span, and he eventually decided upon a formula that gave a good indication of an average horse's work ability.

Watt measured a horse's ability to lift coal up a mineshaft using a rope and a pulley. After much calculation, he settled on the definition of one horsepower being 33,000 lb.ft per minute... This basically means he decided that a horse was capable of moving 33,000 lb of weight, 1 ft in 1 minute. How he came up with this figure is actually quite interesting so I will tell you about it...

He studied an average horse attached to a typical mill (say grinding corn) walking around a 24 ft diameter circle. He calculated that the horse pulled with a force of 180 lb, although to my knowledge nobody has ever detailed how he came up with that figure in the first place, but it is known that he did. He noted that a horse normally made 144 trips around the circle in an hour which, when calculated out to revolutions per minute meant that the horse travelled at a speed of 180.96 ft per minute. Watt simply rounded off the speed to 181 ft per minute and multiplied that by the 180 lb of force the horse pulled (181x180) and came up with 32,580 ft.lb per minute. That figure was rounded off to 33,000 ft.lb per minute, the very same figure we still use today.

So, what's the relationship between power and torque?

This is quite simple to work out by using this equation: torque (ft.lb) x engine speed/5252 = horsepower.

So if you have an engine that generates 200 ft.lb of torque at 3000 rpm you multiply the two together and then divide it by 5252 and you find that you have an engine that develops 114.24 bhp @ 3000 rpm: (200x3000/5252 = 114.24 bhp)

5252? WHY?

Your next question is I expect going to be what's the 5252 figure used for? Where did that come from? Well, remember that 33,000 ft.lb per minute? Well, if we break that down into seconds (divide it by 60) we get 550 ft.lb per second. So we know that one unit of bhp = 550 ft.lb per second.

The units of torque are in lb.ft of course, so to get from torque to horsepower we need to find out what the 'per second' unit is going to be for the torque, and we get this by multiplying the torque by engine speed. Of course, engine speed is normally referred to in revolutions per minute (rpm) and since we want a 'per second' unit we need to convert revolutions per minute into revolutions per second which as it happens is quite easy. We just divide the revs per minute number by 60, of course because we have 60 seconds in a minute.

Now, what we need next is a dimensionless unit for revolutions. This unit already exists and is in fact called a radian. A radian is a ratio of the length of an arc divided by the length of a radius, so the units of length cancel out and you're left with a dimensionless measure. You can think of a revolution as a measurement of an angle. One revolution is 360 degrees of a circle. Since the circumference of a circle is (2 x pi x radius), there are 2-pi radians in a revolution. To convert revolutions per minute to radians per second, you multiply rpm by (2-pi/60), which equals 0.10472 radians per second. This finally gives us the 'per second' unit we need to calculate horsepower. So let's see how this works out all together shall we? We need to get to horsepower, which is 550 ft.lb per second, using torque measured in lb.ft and engine speed measured in rpm, so if we divide the 550 ft.lb by the 0.10472 radians per second (engine speed), we get 550/0.10472, which equals 5252.

So, if you multiply torque by engine speed and divide the product by 5252, rpm is converted to radians per second and you can get from torque to horsepower. Simple eh? No, I agree it's not, but at least somebody else did it all for us and we just need to remember the result of it all which was 5252.

HORSEPOWER CAN BE CONVERTED INTO OTHER UNITS AS WELL

1 HORSEPOWER = 746 WATTS

So if you took a 1 horsepower horse and put it on a treadmill, it could operate a generator producing a continuous 746 watts.

1 HORSEPOWER FOR AN HOUR = 2545 BTU

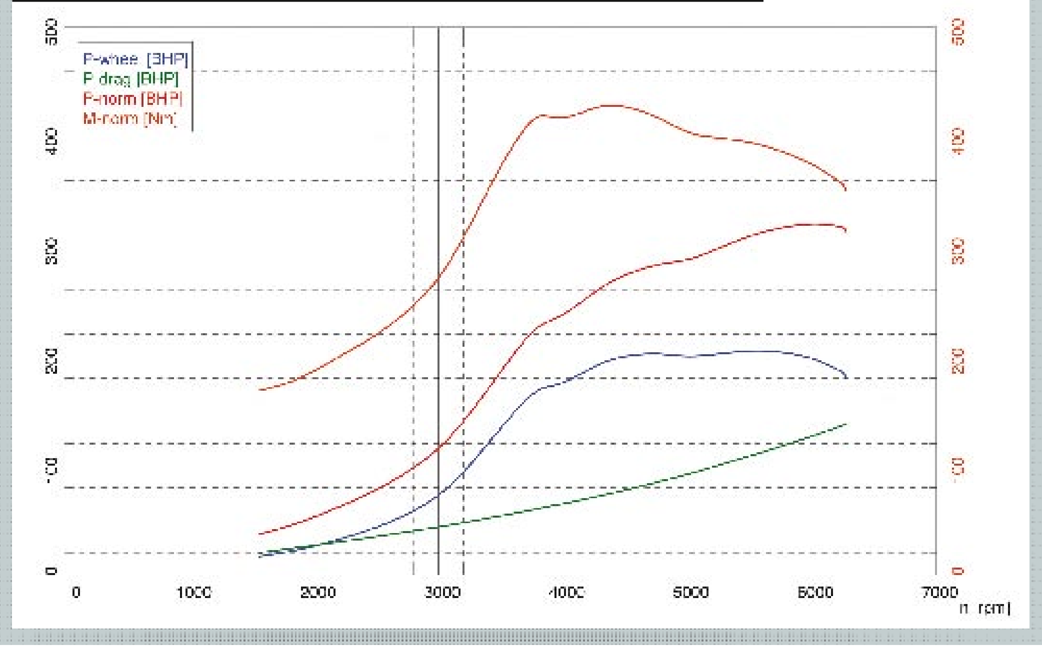
If you took that 746 watts and ran it through an electric heater for an hour, it would produce 2545 BTU (where a BTU is the amount of energy needed to raise the temperature of 1 lb of water 1 degree F).

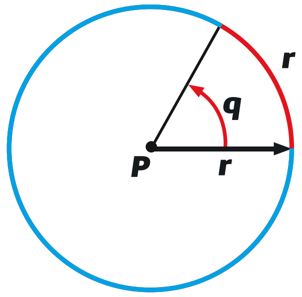
1 BTU = 1055 JOULES (OR 252 GRAM-CALORIES OR 0.252 FOOD CALORIES)

Presumably, a horse producing 1 horsepower would burn 641 calories in one hour if it were 100 per cent efficient.

'Torque wins races', so the saying goes. If only it was as easy as that!

Some rolling road operators provide torque figures from dyno runs in Nm making the 5252 rpm crossover rule redundant (see '5252? Why?')





Above: a Radian is a dimensionless unit for revolutions

IN A NUTSHELL

Hopefully after reading this article you will now understand the following:

1. The turning power generated by an engine is actually the torque.
2. The horsepower figures quoted about engines simply relate to how much work can be done by that torque in a given time.

You may also have heard the statement, usually in the pub, that sounds something like: "Horsepower sells cars, but torque wins races". Is that true? Well, yes and no. I feel that the person who first quoted that doesn't actually understand what he is talking about as without torque you have no horsepower to start with, so his horsepower would be pretty damn useless at winning any races without any torque wouldn't they? So, it's kind of a meaningless quote. However, it does have a ring of truth if broadened somewhat and related to a road car.

Looking at a road engine — as most of us are — we want as much turning force across as much of our engine's operating range as possible because for one, it makes it easier to drive, and two, it does make it accelerate better at any given engine speed. Now nearly all road engines I can think of are designed to have a peak volumetric efficiency (VE) somewhere between 2000 and 4000 rpm.

The torque figure will pretty much always peak at the engine's peak VE range, so wherever you feel that big shove in the back as you accelerate your engine, that's the peak torque and peak VE point of the engine that you are feeling.

The engine tends to lose torque as it moves further away from this peak efficiency area it was designed to operate in, be that slower or faster.

But as the engine is going faster and faster it will still do more work in any given time frame due to it processing more air/fuel, and so the horsepower figure should continue to climb as the engine is revved faster whilst the torque falls off as we go further away from the peak torque and VE.

So, the key to making good horsepower is to keep the torque figure high for as long as possible. That way, our horsepower graph will be climbing steeply.

Just remember: the torque is the actual turning force generated by your engine, and the horsepower is the amount of work that torque can do for you at that particular engine speed.

OTHER MEASUREMENTS USED

It's worth noting here that all these figures are related to the units we use here in the UK and US, namely bhp and ft.lb of torque. But there are others in use.

On the continent you tend to see PS — this stands for PferdeStarke, the German equivalent of horsepower. In some other European countries you will often hear the term CV, which stands for Cheval Vapeur. These measures were chosen in Europe because they were a little easier to express in nice, round metric numbers but it's worth knowing that one PS or CV is actually only 0.986 bhp.

Most manufacturers now quote PS instead of bhp. Hence the Fiesta ST is 150 PS (148 bhp)