UNDERSTANDING

HORSEPOWER VS TORQUE

By Bill Hancock

Anybody who has owned something with an engine has heard of horsepower, and many have heard of the term torque. What are these terms, what do they really mean and how do they interact? By learning what these values represent, you will have a better understanding of how an engine performs, and what is important.

Let's start with the basics of an engine. An internal combustion engine is a mechanical device capable of converting thermal energy into torque. Torque is quite simply a measure of the instantaneous force necessary to sustain the rotary motion of a shaft under a given load.

Work is defined as a force acting through a distance. Think of a weight lifter who lifts a set of weights off the ground. The work results from a force being applied through a distance. Horsepower is a measure of how many times he can lift those same weights, or how much work he can do in a given time interval.

Obviously, the person who can lift the same set of weights more times than his competitor, in the same length of time, has the higher horsepower. The person who can lift the heaviest weight produces the most torque. However, it is entirely possible for one weight lifter who lifts a lighter set of weights to have more horsepower, simply by lifting them many more times in a given interval. By using a formula we can compare the two weightlifters.

In 1780, James Watt is credited with defining the measurement of horsepower. Watt was trying to market his steam engine to replace the horse. In order to penetrate the market, Watt needed a way to let customers compare the steam engine to a horse in terms of power produced. James Watt carefully measured the sustained output of a draft horse walking in a circle while hitched to an arm connected to a water pump. The amount torque necessary to pump a given volume of water over a set period of time was measured for the horse and called a horsepower. When the steam engine was put to the test, it pumped more water in the same amount of time therefore it was deemed to produce more horsepower than the horse. It was determined that 33,000 lb-ft per minute would represent 1 horsepower. Another more graphic way of understanding this is shown in Fig 1.

The formula derived for horsepower became Torque x RPM divided by the constant 5252. So, let's apply this formula to one of our engines and see what happens. We will measure the output of the engine using an engine dynamometer.

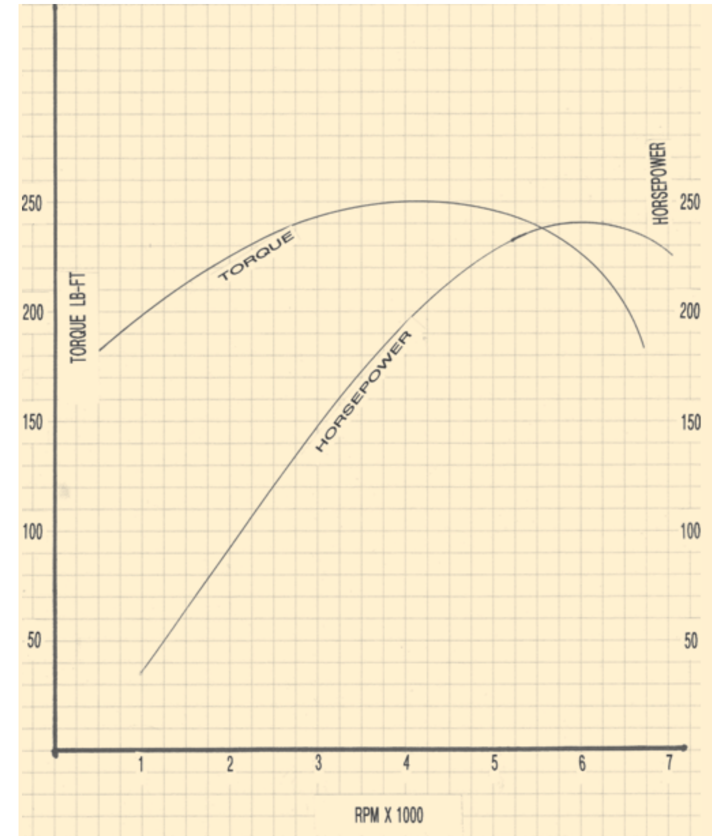


FIG -1 A theoretical Horsepower-Torque curve

The torque curve becomes the basis for an engine's performance signature and a way to compare the output of various engines. From the torque curve, we simply use our formula to calculate the horsepower at the various points and get the resultant horsepower curve. Looking at these two curves allows engineers and end users to choose an engine which will meet the needs of the device they have chosen to power. To better illustrate the differences, let's look at two very familiar vehicles. The first is a sports car which is light and capable of going 150 mph. The second is a Class A Motor Home with a diesel engine. For our example, let's assume that they both produce 500 horsepower. The sports car has an operating range of 1500-8000 RPM while the Motor Home engine has an operating range of 500-2300 RPM. The diesel engine produces in excess of 1000 lb-Ft of torque but will be limited to 80 mph because of the engine's RPM constraints. The sports car will not be able to pull a heavy trailer up a steep grade, but will easily run at 8000 RPM and produce

Dynamometer

An engine dynamometer is a mechanical device designed for testing and measuring engine output also called torque. It measures the output while the engine is running, much like a treadmill does for fitness enthusiasts. To get a better understanding of applying load to an engine, think of driving up a long grade where the grade gets steeper. In order to maintain your speed, you have to give the engine more and more throttle as the grade increases. An engine dynamometer allows you to simulate road load conditions for an infinite number of scenarios.

An electric dynamometer is essentially a generator which is driven by the test engine. To produce more load, the generator is required to produce more current. Hence the load at any given engine RPM can be infinitely varied. Another type of dynamometer is known as a water brake, and is essentially a water pump. To increase the load, the pump is forced to pump more water.

By being able to vary the amount of load, the engine can be tested at various points within its operating range. The torque values are taken are plotted at set RPM intervals. When enough of these points are measured and plotted, the points are joined by a line to form a graph, which is called the torque curve.

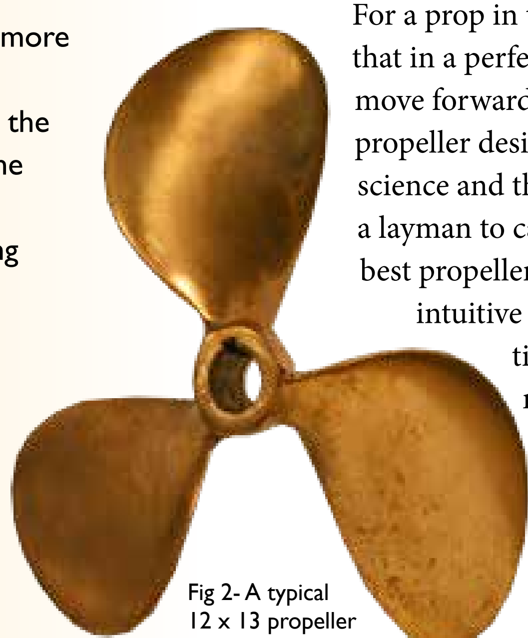


Fig 2- A typical 12 x 13 propeller found on a runabout

speeds of 150 mph. Both vehicles have the same peak horsepower but utilize it in different ways.

Engine performance advertising has always favored emphasizing the horsepower, but true end users, such as truckers or racers, are only interested in torque and what shape the torque curve looks like. The old adage horsepower sells cars but torque wins races illustrates the different viewpoints.

Suppose we take our boat engine to a test facility which has a dynamometer and the engine produces a steady value of 150 lb-ft of torque while running at 4000 RPM. Applying our formula Torque x RPM divided by 5252, we would multiply 150 times 4000 to get 600,000. We would divide that by 5252 which would yield 114.2 Horsepower.

Now given the torque curve, how do we use this information?

Since we are boat people, let's go through the exercise and try to choose an engine to power our 18 foot wooden runabout. First, we need to understand that we will be using a propeller which, unlike a tire on concrete pavement, has a fair amount of slippage. Our propeller, shown in Fig #2, has diameter constraints determined by the boat, pitch considerations and finally the number and shape of the blades. In our case, we will know that we have a relatively tight envelope for diameter on our 18 ft runabout, so our final choice will typically be somewhere between 12 and 14 inches in diameter. For a prop in that range, the pitch is typically 13, meaning that in a perfect world with no slippage the propeller would move forward 13 inches for every revolution. Because propeller design and application is a relatively inexact science and there are many variables, it is very difficult for a layman to calculate the best propeller using formulas. The best propeller engineers are usually the ones with the most intuitive field experience, and the best software. As time marches on however propeller design and manufacturing will progress very rapidly due to advanced engineering software and parts manufacturing capability.

Now let's say we need to choose a propeller which typically will produce the speeds and performance we need for our hull type, shape and weight. The next thing to do is compare the propeller curve to the engine output or torque curve. Our goal is to have the two curves match.

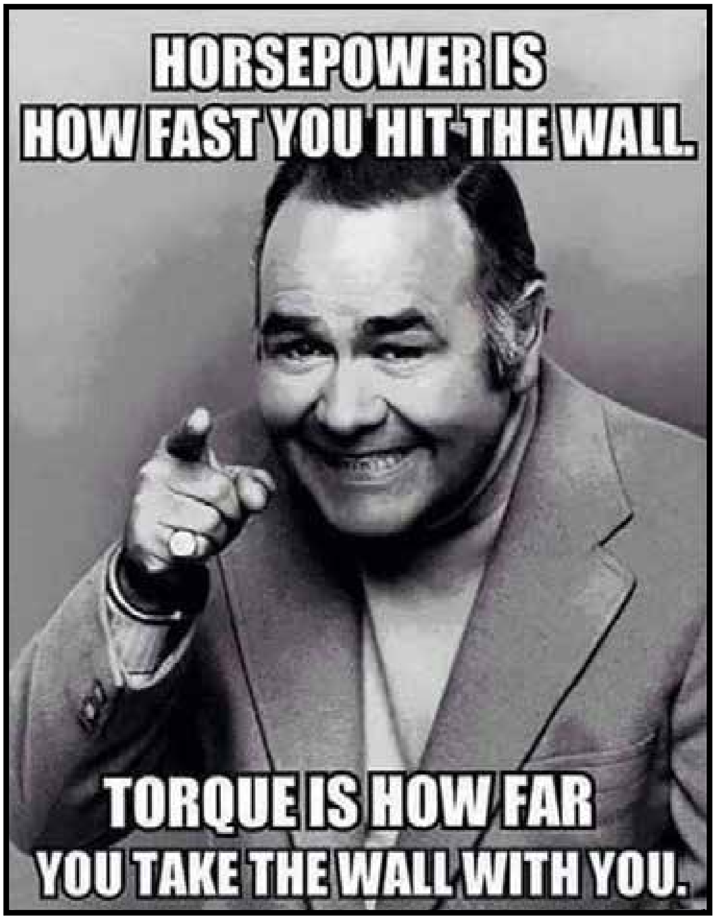
We can change the output of the engine by various tuning methods. Using displacement, RPM capability, compression ratio, cam grinds, spark timing, we can tailor an engine package to match the requirements of the hull and propeller.

While this exercise is somewhat complicated it is not impossible to achieve. What we are trying to illustrate here is that matching an engine with a particular boat, and selecting the correct propeller is more than just finding an engine which will fit between the stringers and under the engine hatch.

So, that leaves us with the final question.

Let's say you are re-powering a boat and want to increase the performance. How do you do it? First, look around at similar boats that have been re-powered and see what they have used for engines. Talk to the engine manufacturers and get performance data, specifically the torque and horsepower curve. Make friends with a propeller manufacturer and try their suggestion. If you have friends who have spare propellers, go to the lake and try swapping props until you achieve the results you need. Once you narrow your selection, try variations, such as 3 blades vs four blades, within that range. Keep detailed notes of speed versus RPM, all run at Wide Open Throttle or WOT as we call it. Use a GPS to measure your speed. (Note-if there is water current or wind, be sure to run your test in both directions on your test course).

FIG 3- A three arm Prop Puller



Once you have chosen a prop, then run some tests to determine the best cruising speed. The optimum cruising speed is the point where you get the maximum miles per gallon. If the top speed is not satisfactory, you may want to change props again and get a better match. For example, you may find that increasing the pitch will reduce your overall top speed but allow you to pick up valuable fuel mileage. You may want to get up on plane faster for example. Often a four blade prop works best in this application. In the end, the prop manufacturers are usually very knowledgeable. If you provide them with good data such as the weight, size, torque and horsepower , they can usually come very close on the first try.

The upside of this is that you will get very good at changing props in the parking lot at the boat ramp. To save valuable time at the ramp, try all of the props in your shop first, to ensure they fit and you have the necessary tools for installation and removal.

Happy Boating!