CREW CHIEF NOTES: The Torque to Power Conversion

Introduction

Engines are characterized by their torque and power, each of which changes depending on the speed at which the engine is running. Power is the rate at which work is used or generated. Torque is a measure of twisting force. Torque is the quantity measured by an instrument like a dynamometer, and power is calculated from the measured torque.

The Relationship between Power and Torque

Power is the rate at which work is done.

$$P = \frac{W}{t}$$

Work is force times distance, so

$$P = \frac{F\,d}{t}$$

Or, writing it slightly differently

$$P = F\left(\frac{d}{t}\right)$$

$$P = F\,v \qquad (1)$$

Power is also force times speed.

We can also write the power in terms of the rotational parameters of the engine. Assuming that the force is always applied at right angles to the radius of the shaft that is turning, we can use $\tau = Fr$ and $v = r\omega$ to write

$$\begin{aligned} P &= F\,v \\ &= \left(\frac{\tau}{r}\right)(r\omega) \\ P &= \tau\omega \end{aligned} \qquad (2)$$

Calculating Power from Torque

The tricky thing about rotational motion is that it involves radians and revolutions, units which tend to appear and disappear mysteriously. In the British system, horsepower is a derived unit without a clear link to fundamental units.

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Conversions and Units

$$1\text{ hp} = 745.7\text{ W} = 550\frac{\text{ft lb}}{\text{s}}$$

Starting with Equation (2), in British units, torque is in foot pounds and ω is in revolutions per minute (rpm).

$$P = \tau\,\omega$$
$$P = \left[\frac{\text{ft lb}}{1}\right]\left[\frac{\text{rev}}{\text{min}}\right]$$

We want power in hp. Use the conversion factor between hp and ft lb/s

$$[P] = \left[\frac{\text{ft lb}}{1}\right]\left[\frac{\text{rev}}{\text{min}}\right]\left[\frac{1\text{ hp}}{550\,\frac{\text{ft lb}}{s}}\right]$$
$$= \left[\frac{\cancel{\text{ft}}\ \cancel{\text{lb}}}{1}\right]\left[\frac{\text{rev}}{\text{min}}\right]\left[\frac{1\text{ hp s}}{550\ \cancel{\text{ft}}\ \cancel{\text{lb}}}\right]$$
$$= \frac{1}{550}\frac{\text{rev s hp}}{\text{min}}$$

Now convert between s and min

$$[P] = \frac{1}{550}\frac{\text{rev s hp}}{\text{min}}\left[\frac{1\text{ min}}{60\text{ s}}\right]$$
$$= \frac{1}{550(60)}\text{hp rev}$$
$$= \frac{1}{3.3\times10^{4}}\text{hp rev}$$

Finally, we have to account for the revolutions. There are 2π radians in one revolution.

$$[P] = \frac{1}{3.3\times10^{4}}\frac{\text{hp}}{}\ \frac{\text{rev}}{1}\left[\frac{2\pi\text{ radians}}{1\text{ rev}}\right]$$
$$= \frac{1}{5252.1131}\text{hp}$$

The radians magically go away – as radians are wont to do. Power and the torque curves are related to each other, as shown in Figure 1. Calculating power from torque in British units is done via:

$$P(\text{in hp}) = \frac{\tau(\text{in ft-lb})\,\omega(\text{in rev per min})}{5252} \qquad (3)\text{a}$$

You can go through a similar exercise in metric units, where the conversion factor is 9549.

$$P(\text{in kW}) = \frac{\tau(\text{in N-m})\,\omega(\text{in rev per min})}{9549} \qquad (3)\text{b}$$

Figure 1 (which is for a race engine) shows that torque and horsepower curves plotted as a function of engine speed have similar shapes. The similarity is because they are so closely related to each other. Torque and horsepower curves always cross at 5252 rpm. If you insert ω = 5252 rpm in Equation (3)a, you find that this rotational speed is where power and torque are equal. The torque curve will always peak at a smaller rpm value than the horsepower curve.

Figure 1 shows that an engine produces its maximum torque and horsepower over a narrow band. The range of speeds over which the horsepower is maximum is called the *power band*. The engine is most efficient in this range, but since you have to change speed, you can't drive in this range of engine speeds all the time. That's where the transmission comes in.

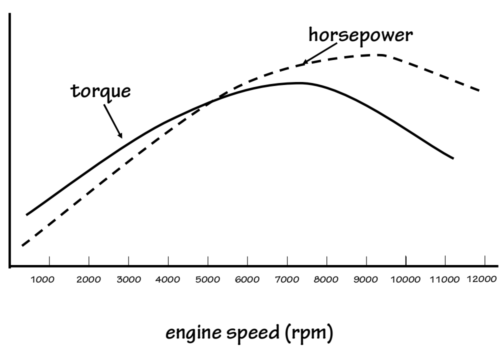

Figure 1: Power and torque curves

Table 1 compares the output of a NASCAR engine and its commercial counterpart. The maximum values of torque and horsepower occur at higher rpm on the race engine than they do for the passenger car engine. The race engine produces a lot more torque and horsepower, which is why they are able to accelerate more quickly and attain a higher ultimate speed.

As you start your car from a stop, you have low speed and high acceleration. As you reach cruising speed, you have less need for acceleration. Torque is proportional to acceleration and power is proportional to speed.

As Dr. Andy Randolph, engine technical director for Earnhardt Childress Racing Engines put it, "Horsepower makes you fast. Torque makes you feel good." Accelerating from 0 to 60 mph in four seconds is a result of torque. Engines are tuned by adjusting the shapes of the torque and horsepower curves .

	2006 Toyota Camry LE V6	**NASCAR Engine**
Number of cylinders	6	8
Bore × stroke (in)	3.70 × 3.27	4.185 × 3.25
Camshaft Type	Dual Overhead	Pushrod
Displacement per cylinder (in^3)	35.2	44.98
Total displacement (in^3/L)	211/3.46	358/5.867
Compression ratio	10.8:1	12:1
Number of valves per cylinder	4	2
Torque (ft-lbs@rpm)	268@6200	550@7500
Horsepower (hp@rpm)	248@4700	850@9200

Table 1: Engine parameters compared for a NASCAR engine and its commercial counterpart.

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