Gearing Explained

Introduction to TORQUE, WORK and POWER

Torque is the twisting force about a point, sometimes called a 'moment'. The torque is defined as the force multiplied by the distance from the pivot perpendicular to the force.
Torque = Force x Distance Perp. to Pivot

For example: One foot pound of torque is the twisting force necessary to support a one pound weight on a weightless horizontal bar, one foot from the pivot. You might directly measure torque when tightening a nut to a specified torque using a torque wrench. Here, a twisting force is applied to the nut, until the resistance to rotation of the nut is equal to the torque required.

Work is the the transfer of energy. The work done is equal to the force applied multiplied by the distance travelled in the direction of that force.

Work = Force x Distance Travelled
Power is the rate of doing work, the amount of work done in a unit of time. The power produced is the work done divided by the time taken.

$$\text{Power} = \frac{\text{Force x Distance Travelled}}{\text{Time}}$$

For example: If a weight is fixed solidly to the floor and you try to lift it, you are applying force. However the weight cannot move, so no work is done on the weight. Although force is exerted by your arms, no energy is transferred to the weight. If you lift a one pound weight one foot, then by definition one foot pound of work has been done. If you take one minute to do this then you will be producing power at one foot pound per minute.

One horsepower is 33,000 foot pounds per minute. To find the horsepower of an engine, the torque produced by the engine is measured and the horsepower calculated. This is done using a dynamometer which is essentially a brake with a measuring device - hence the term brake horse power (bhp) which is often used. A torque curve is produced by plotting the torque measured against the engine speed.
With torque in foot pounds:

$$\text{Horsepower} = \frac{\text{Torque x RPM}}{5252}$$

Using this equation a power curve can be produced from the torque curve.

How does this apply to a motorcycle?

For the rider, torque is the all-important factor. A bike will accelerate at a rate that matches its torque curve (ignoring rolling / air resistance). The torque peak is the point at which the bike has maximum acceleration, either side of this peak it is less. For a given torque at the rear wheel, the acceleration of the bike is the same, irrespective of the engine speed. Horsepower increases with the engine speed until well after the torque peak, and only peaks when the decreasing torque compensates for the increasing rpm. (look at the equation.) The acceleration at the torque peak is greater than that at the power peak.
So why do we talk about horsepower so much? Consider a large waterwheel. While it's obvious that the water wheel generate a large torque, its rotational speed is very slow and hence its power (the ability to do work over time) is low. A waterwheel is therefore not generally very powerful. A powerful engine with lots of horsepower is one which produces high torque at high rpm.

Theoretically, producing torque at high rpm is better than producing torque low rpm, as at high rpm you can use gearing. A powerful engine is useful because it can then be geared down - you don't want the rear wheel of your bike doing 8000rpm anyway! Gearing down reduces the speed at the rear wheel with a corresponding increase in torque. This does not affect the power of the engine apart from frictional losses. Incidentally a properly lubricated chain drive is 98.5% efficient, significantly better than a geared drive. For road racing, this theory closely matches reality, but for offroad the above is not the only consideration. (still awake?!...)

But what does that mean about gearing...

The stock gearing of your bike is likely to have been determined by choosing a compromise ratio based on what worked best for test riders in "average" conditions. As soon as the bike is taken out of average conditions - by engine tune, terrain, track design or rider style the stock gearing might no longer be the optimum solution - a different setup might get you round the track faster.

Maximum speed occurs when the driving force is exactly counterbalanced by the air and rolling resistances. At this point the acceleration has fallen to zero.
Setting up the gearing of any vehicle is a trade-off between acceleration and top speed.
Gearing a bike up to produce higher top speed with less acceleration is done using a larger countershaft (gearbox) sprocket or a smaller rear sprocket.
Gearing a bike down giving it more acceleration with lower top speed is done using a smaller countershaft (gearbox) sprocket or a larger rear sprocket.
The ratio chart shows the gearing ratios for different numbers of teeth on the gearbox and rear sprockets. The numbers given are the number of revolutions of the gearbox sprocket required to cause one complete revolution of the back wheel. These figures are calculated by dividing the number of teeth on the rear chainwheel by the number of teeth on the gearbox sprocket.

From the table it is clear that changing one tooth on the gearbox sprocket has a significantly larger effect on the gearing than changing one tooth on the rear sprocket. To make a small change in gearing it is therefore necessary to change the rear chainwheel size by one tooth, as changing the gearbox sprocket makes a far larger difference in gearing.