KNOWLEDGE = POWER !!

But, You've Gotta Admit...

Sometimes Imagination Can Be Even More Powerful Than Knowledge !!!

MotoMan

How Does a High Speed 4 Stroke Engine Really Work??

The purpose of this issue is two fold. First, to help you understand the workings of a modern four stroke engine. Even if you aren't an engineer or even planning to modify an engine, this will help you to avoid making some of the common (and usually expensive) mistakes that come from the "textbook" thinking of how engines work.

The second purpose of this newsletter, is to teach you the ideas behind making engines faster! Lot's of people have asked me how I learned to make engines so fast. After the 3rd grade, I basically daydreamed through 9 years of school. In fact, once I learned how to read and take multiple choice (guess) tests, school for me was mostly boring. I never realized what it was that was missing until years later when I got into bikes and engines. What was missing from my school experience ??

Creative Thinking !!

Now, of course, I'm not criticizing your school.... just mine :)

"1969"

Motorcycle engines have improved rapidly in the past 32 years. The problem is that the "state of the art" of engine building has stayed almost unchanged since the late sixties ! Millions of people can change parts on a motorcycle, but there are really only a small handful of people in the world who truly understand how to make a modern motorcycle faster. Most of the information available to the general public is still stuck in "**1969**". This may seem ridiculous to you now, but as you get more and more issues of Power News, you'll understand the **ideas** behind the modifications, not just the "how to" specifications.

As you learn the **ideas** regarding how motorcycles work, you'll begin to notice that you can apply the same kind of thinking to solve everyday problems that have nothing to do with motorcycles.

The "Textbook Explanation" of the 4 Stroke Engine:

Intake, Compression, Power, Exhaust. Except for "compression", the concept is quite easy to understand. Each cycle takes 4 strokes, and each "stroke' takes up 180 degrees of piston travel:

1) The intake valve opens as the piston goes down to suck in the fuel and air mixture.

2) The intake valve closes and the piston goes up to compress the mixture.

3) The spark plug ignites the mixture forcing the piston down.

4) The exhaust valve opens as the piston goes up to push out the burned gas.

The MotoMan's 8 Phase Engine !!

TORQUE

The word "torque" is often used incorrectly to describe low RPM horsepower. In the real world, horsepower is all that matters, because torque involves no motion whatsoever. Torque is simply the static measurement of twisting force. The ultimate goal is a linear rush of acceleration from 8,000 RPM to redline. The key to achieving that goal lies in understanding the way an engine produces horsepower.

When torque (static force) is combined with RPM (motion), the result is horsepower (Work / Acceleration). Of the three factors in the equation, the only fixed constant is RPM. In other words, RPM will always increase in a perfect numerical progression. (For example: there will always be 1,000 rpms between 5,000 and 6,000 rpm) Therefore, If the engine can be tuned to produce a constant torque output over a wide range of RPM, the horsepower will "automatically" multiply in the same perfect linear progression as the RPM !

A flat torque output ! This is the heart of the tuning challenge ! Because generally when an engine is tuned to make more torque in one RPM range, there is a similar loss at all other RPM's. To see why this happens, let's take a look at the tuning compromises at different RPM's. Since each step of the process will overlap the actual strokes of the piston, it's far more accurate to think of the cycle in terms of 8 phases rather than 4 180 degree strokes.

2 EXHAUST PHASES (Exhaust Blowdown / Exhaust Return)

Exhaust Blowdown:

The exhaust must be completely cleared from the cylinder. The only way to accomplish this, is to open the exhaust valves about 30-40 degrees before the bottom of the power stroke, so that the still burning charges pressure can begin to escape out of the cylinder. If the power phase were allowed to continue to the bottom of the piston stroke, the piston would have to work hard to push against the high pressure created by the still burning (and still expanding) gasses during the upward exhaust stroke. Instead, some of it's own pressure is used to blow itself out of the cylinder while the piston is still on the down stroke.

Exhaust Return:

By the time the piston reverses direction in the exhaust return phase, the excess pressure is gone. If the exhaust silencer is positioned as shown in the Dynamic Horsepower newsletter, there will be a slight vacuum which will actually pull the piston up !!

The "textbook 4 stroke" had positive pressure during the exhaust return phase, whereas I'm saying there is vacuum !! Which one makes more sense ??

The tuning tradeoff: The best time to open the exhaust valves is a compromise between extracting the most power from the power phase at low RPM, and losing the least power from the exhaust phase at high RPM.

3 INTAKE PHASES

There are 3 distinctly different ways the intake charge enters the engine.

Intake Overlap:

The intake phase actually begins during the end of the exhaust return phase. About 15 degrees before the top of the piston stroke, the intake valves open. This is also called the camshaft overlap period because the intake and exhaust valves are both open a small amount at the same time. (the exhaust valves are closing and the intake valves are opening.)

The low pressure from the exiting exhaust creates a flow pattern across the top of the cylinder that draws fresh intake mixture into the cylinder to displace the last remaining spent gases. The truly ingenious part of this design, is that the flow of intake mixture into the cylinder has been started while the piston is still going up... against the direction of the flow it's pumping !!!

Intake Suction:

Now the piston has passed the top and now accelerating down it's stroke. At the same time, the valves are opening rapidly to allow the intake charge to enter the cylinder with minimal resistance. Since the fuel/air mixture has a certain amount of mass, it tends to lag behind the piston, and this lag time becomes more pronounced as the RPM's increase. As a result, the piston first creates a low pressure condition in the cylinder, and the mixture rushes in to fill it.

Intake Charging:

This is the time when the piston has passed the bottom of it's stroke, and begun to move up. Because of the charge momentum created by the intake suction phase, lots of fuel and air mixture is still rushing down the intake tract to fill the cylinder. This phenomenon increases with the engine speed, to the point that a progressively higher percentage of the cylinder filling occurs after the piston is no longer physically "sucking" the charge in. Because of this, it's necessary to extend the intake phase way past the physical 180 degree intake stroke. On average, the valves don’t completely close until the piston has moved up about 55 degrees past the bottom of it's 180 degree stroke !!

The tuning tradeoff: As you can see, the length of these phases has to do with the speed of the engine ! This is another compromise, because while the delayed valve closing improves high RPM cylinder filling, the charge velocity isn't high enough at lower RPM, and the piston will push some of the fuel/air mixture back into the port. This is one of the most important things to understand about the intake process !!

Also, in order to extract the most power from the intake phase, the inducted charge must burn completely. If the carburetors are jetted right, the average fuel/air mixture will be right. But, since fuel is heavier than air, it's possible for some of the fuel to separate from the mixture as it moves through the ports and into the cylinder. This causes distinct lean and rich pockets in the cylinder, which will result in poor combustion efficiency.

The fuel/air charge should remain turbulent in the cylinder to maintain a uniform mixture throughout. One popular way to do this in a two valve engine is to curve the intake port to "swirl" the mixture into the cylinder. This doesn't work with a four or five valve head though, because too much turbulence is created in the port, which disrupts the volume of flow into the cylinder.

Compression Phase

The moment the intake valves are closed during the upward compression stroke marks the end of the intake phase, and the beginning of the compression phase. Since it's the expansion of the burning charge that pushes the piston down, the more the fuel/air charge can be initially compressed, the greater the total expansion will be once it's burned.

The limit to the maximum possible compression ratio is detonation. The one factor that has the greatest effect on limiting the detonation is the combustion efficiency.

2 Burning Phases

Pre Power Burning Phase

The spark will use some time to spread into a flame all the way through the fuel. If this time is used when the piston is going down, then some of the fuel's potential power will be lost. So, the best moment to ignite the spark will be before the piston has reached the top of it's compression stroke, usually around 35-40 degrees before top dead center.

Power Production Stroke

The piston reaches the top, reverses direction, and only now is the engine finally making power! The piston is then forced down to the point of the exhaust blowdown phase, about 140 degrees down from top, and the cycle starts over.

Conclusion

As well as the four stroke engine works, it's far from perfect. In addition to the basic tuning problems, a lot of energy is used up to recharge the cylinder for the power stroke. In fact, out of the 720 degrees in a complete cycle, on average, the power phase lasts less than 140 degrees! Many improvements can be made to the remaining 580 degrees that will maximize the power phase, and just as importantly, minimize recharging losses.

The secret to producing a constant output of torque is to consistently fill the cylinders better at all RPM’s.