

BASIC TWO-STROKE TUNING

By Eric Gorr

Changing the power band of your dirt bike engine is simple when you know the basics. A myriad of different aftermarket accessories is available for you to custom tune your bike to better suit your needs. The most common mistake is to choose the wrong combination of engine components, making the engine run worse than stock. Use this as a guide to inform yourself on how changes in engine components can alter the powerband of bike's engine. Use the guide at the end of the chapter to map out your strategy for changing engine components to create the perfect power band.

TWO-STROKE PRINCIPLES

Although a two-stroke engine has less moving parts than a four-stroke engine, a two-stroke is a complex engine because it relies on gas dynamics. There are different phases taking place in the crankcase and in the cylinder bore at the same time. That is how a two-stroke engine completes a power cycle in only 360 degrees of crankshaft rotation compared to a four-stroke engine which requires 720 degrees of crankshaft rotation to complete one power cycle. These four drawings give an explanation of how a two-stroke engine works.

1) Starting with the piston at top dead center (TDC 0 degrees) ignition has occurred and the gasses in the combustion chamber are expanding and pushing down the piston. This pressurizes the crankcase causing the reed valve to close. At about 90 degrees after TDC the exhaust port opens ending the power stroke. A pressure wave of hot expanding gasses flows down the exhaust pipe. The blow-down phase has started and will end when the transfer ports open. The pressure in the cylinder must blow-down to below the pressure in the crankcase in order for the unburned mixture gasses to flow out the transfer ports during the scavenging phase.

2) Now the transfer ports are uncovered at about 120 degrees after TDC. The scavenging phase has begun. Meaning that the unburned mixture gasses are flowing out of the transfers and merging together to form a loop. The gasses travel up the back side of the cylinder and loops around in the cylinder head to scavenge out the burnt mixture gasses from the previous power stroke. It is critical that the burnt gasses are scavenged from the combustion chamber, in order to make room for as much unburned gasses as possible. That is the key to making more power in a two-stroke engine. The more unburned gasses you can squeeze into the combustion chamber, the more the engine will produce. Now the loop of unburned mixture gasses have traveled into the exhaust pipe's header section. The gasses aren't lost because a compression pressure wave has reflected from the end of the exhaust pipe, to pack the unburned gasses back into the cylinder before the piston closes off the port. This is the unique super-charging effect of two-stroke engines. The main advantage of two-stroke engines is that they can combust more volume of fuel/air mixture than the swept volume of the engine. Example: A 125cc four-stroke engine combusts about 110cc of F/A gasses but a 125cc two-stroke engine combusts about 180cc of F/A gasses.

3) Now the crankshaft has rotated past bottom dead center (BDC 180 degrees) and the piston is on the upstroke. The compression wave reflected from the exhaust pipe is packing the unburned gasses back in through the exhaust port as the piston closes off the port the start the compression phase. In the crankcase the pressure is below atmospheric producing a vacuum and a fresh charge of unburned mixture gasses is flowing through the reed valve into the crankcase.

4) The unburned mixture gasses are compresses and just before the piston reaches TDC, the ignition system discharges a spark causing the gasses to ignite and start the process all over again.

CYLINDER PORTING

The cylinder ports are designed to produce a certain power characteristic over a fairly narrow rpm band. Porting or tuning is a metal machining process performed to the cylinder ports (exhaust & transfers) that alters the timing, area size, and angles of the ports in order to adjust the power band to better suit the rider's demands. For example, a veteran trail rider riding an RM250 in the Rocky mountain region of the USA will need to adjust the power band for more low end power because of the steep hill climbs and the lower air density of higher altitudes. The only way to determine what changes will be needed to the engine is by measuring and calculating the stock engine's specifications. The most critical measurement is termed port-time-area. This term is a calculation of a port's size area and timing in relation to the displacement of the engine and the rpm. Experienced tuners know what the port-time-area values of the exhaust and transfer ports should be for an engine used for a particular purpose. In general, if a tuner wants to adjust the engine's power band for more low to mid range he would do the following things. Turn down the cylinder base on a lathe to increase the effective stroke (distance from TDC to exhaust port opening). This also retards the exhaust port timing and shortens the duration and increases the compression ratio. Next the transfer ports should be narrowed and re-angled with epoxy to reduce the port-time-area for an rpm peak of 7,000 rpm. The rear transfer ports need to be re-angled so they oppose each other rather than pointing forward to the exhaust port. This changes the loop scavenging flow pattern of the transfer ports to improve scavenging efficiency at low to mid rpm (2,000 to 5,000 rpm). An expert rider racing mx in England would want to adjust the power band of an RM250 for more mid to top end power. The cylinder would need to be tuned radically different than for trail riding.

Here is an example. The exhaust port would have to be raised and widened to change the port-time-area peak for a higher rpm (9,000 rpm). For either of these cylinder modifications to be effective, other engine components would also need to be changed to get the desired tuning effect.

CYLINDER HEAD

Cylinder heads can be reshaped to change the power band. Generally speaking, a cylinder head with a small diameter and deep combustion chamber, and a wide squish band (60% of the bore area). Combined with a compression ratio of 9 to 1 is ideally suited for low to mid range power. A cylinder head with a wide shallow chamber and a narrow squish band (35-45% of bore area) and a compression ratio of 8 to 1, is ideally suited for high rpm power.

There are many reasons why a particular head design works for certain types of racing. For example; a head with a wide squish band and a high compression ratio will generate high turbulence in the combustion chamber. This turbulence is termed Maximum Squish Velocity, MSV is rated in meters per second (m/s). A cylinder head designed for supercross should have an MSV rating of 28m/s. Computer design software is used to calculate the MSV for head designs. In the model tuning tips chapters of this book, all the head specs quoted have MSV ratings designed for the intended power band changes.

CRANKSHAFT

There are two popular mods hop-up companies are doing to crankshafts; stroking and turbo-vaning. Stroking means to increase the distance from the crank center to the big end pin center. There are two techniques for stroking crankshafts; weld old hole and re-drill a new big end pin hole, or by installing an off-set big end pin. The method of weld and re-drilling is labor intensive. The off-set pin system is cheap, non-permanent, and can be changed quickly. In general, increasing the stroke of a crankshaft boosts the mid range power but decreases the engine's rpm peak.

The term "Turbo-Crank" refers to a modification to the crankshaft of a two-stroke engine, whereby scoops are fastened to the crank in order to improve the volumetric efficiency of the engine. Every decade some hop-up shop revives this old idea and gives it a trendy name with product promises that it can't live up to. These crank modifications cause oil to be directed away from the connecting rod and often times the vanes will detach from the crank at high rpm, causing catastrophic engine damage. My advice, don't waste the \$750!

CARBURETOR

In general a small diameter carburetor will have high velocity and a good flow characteristic for a low to mid rpm power band. A large diameter carburetor works better for high rpm power bands. For 125 cc engines a 34mm carburetor works well for supercross and enduro and a 36 or 38 mm carburetor works best for fast mx tracks. For 250 cc engines a 36 mm carburetor works best for low to mid power bands and a 39.5 mm carburetor works best for top end power bands. Recently there has been a trend in the use of air-foils and rifle-boring for carbs. These innovations are designed to improve air flow at low throttle openings. Some companies sell carb inserts, to change the diameter of a carb. Typically a set of inserts is sold with a service of over boring the carb. For example; a carb for a 250cc bike (38mm) will be bored to 39.5mm and two inserts will be supplied. The carb can then be restricted to a diameter of 36 or 38mm.

REED VALVE

Think of a reed valve like a carburetor, bigger valves with large flow-areas work best for high rpm power bands. In general, reed valves with six or more petals are used for high rpm engines. Reed valves with four petals are used for dirt bikes that need strong low end and mid range power. There are three other factors to consider when choosing a reed valve. The angle of the reed valve, the type of reed material, and the petal thickness. The two common reed valve angles are 30 and 45 degrees. A 30-degree valve is designed for low to mid rpm and a 45 degree valve is designed for high rpm. There are two types of reed petal materials commonly used, carbon fiber and fiberglass. Carbon fiber reeds are lightweight but relatively stiff (spring tension) and designed to resist fluttering at high rpm. Fiberglass reeds have relatively low spring tension so they instantly respond to pressure that changes in the crankcase, however the low spring tension makes them flutter at high rpm thereby limiting the amount of power. Fiberglass reed petals are good for low to mid power bands and carbon fiber reeds are better for high rpm engines.

Boyesen Dual Stage reeds have a large thick base reed with a smaller thinner reed mounted on top. This setup widens the rpm range where the reed valve flows best. The thin reeds respond to low rpm and low frequency pressure pulses. The thick reeds respond to higher-pressure pulses and resist fluttering at high rpm. A Boyesen RAD valve is different than a traditional reed valve. Bikes with single rear shocks have off-set carbs. The RAD valve is designed to redistribute the gas flow to the crankcases evenly. A RAD valve will give an overall improvement to the power band. Polini of Italy makes a reed valve called the Supervalve. It features several mini sets of reeds positioned vertically instead of horizontally like conventional reed valves. These valves are excellent for enduro riding because of improved throttle response. In tests on an inertia chassis dyno show the Supervalve to be superior when power shifting. However these valves don't generate greater peak power than conventional reed valves. Supervalves are imported to America and sold by Moto Italia in Maine.

EXHAUST PIPE

The exhaust pipe of a two-stroke engine attempts to harness the energy of the pressure waves from combustion. The diameter and length of the five main sections of a pipe, are critical to producing the desired power band. The five sections of the pipe are the head pipe, diffuser cone, dwell, baffle cone, and the stinger. In general, after market exhaust pipes shift the power band up the rpm scale. Most pipes are designed for original cylinders not tuned cylinders. Companies like MOTOWERKS custom computer design and fabricate pipes based on the cylinder specifications and the type of power band targeted.

SILENCER

Silencers come in all sorts of shapes and sizes. A long silencer with a small diameter enhance the low to mid power because it increases the bleed-down pressure in the pipe. A silencer with a short length and a large core diameter provides the best bleed-down pressure for a high rpm engine. Too much pressure in the pipe at high rpm will radically increase the temperature of the piston crown and could cause the piston to seize in the cylinder.

FLYWHEEL WEIGHTS

The flywheel is weighted to improve the engine's tractability at low to mid rpms. There are two different types of flywheel weights, weld-on and thread-on. A-Loop performs the weld-on flywheel weight service. Steahly makes thread-on flywheel weights. This product threads onto the fine left-hand threads that are on the center hub of most Japanese magneto rotors. normally the threads are used for the flywheel remover tool. Thread-on flywheel weights can only be used if the threads on the flywheel are in perfect condition. The advantage to weld-on weights is they can't possibly come off.

External rotor flywheels have a larger diameter than internal rotor flywheels so they have greater flywheel inertia. Internal rotor flywheels give quicker throttle response.

AFFECTS OF THE IGNITION TIMING

Here is how changes in the static ignition timing affects the power band of a Japanese dirt bike. Advancing the timing will make the power band hit harder in the mid range but fall flat on top end. Advancing the timing gives the flame front in the combustion chamber, adequate time to travel across the chamber to form a great pressure rise. The rapid pressure rise contributes to a power band's "Hit". In some cases the pressure rise can be so great that it causes an audible pinging noise from the engine. As the engine rpm increases, the pressure in the cylinder becomes so great that pumping losses occur to the piston. That is why engines with too much spark advance or too high of a compression ratio, run flat at high rpm.

Retarding the timing will make the power band smoother in the mid-range and give more top end over rev. When the spark fires closer to TDC, the pressure rise in the cylinder isn't as great. The emphasis is on gaining more degrees of retard at high rpm. This causes a shift of the heat from the cylinder to the pipe. This can prevent the piston from melting at high rpm, but the biggest benefit is how the heat affects the tuning in the pipe. When the temperature rises, the velocity of the waves in the pipe increases. At high rpm this can cause a closer synchronization between the returning compression wave and the piston speed. This effectively extends the rpm peak of the pipe.

HOW TO ADJUST THE TIMING

Rotating the stator plate relative to the crankcases changes the timing. Most manufacturers stamp the stator plate with three marks, near the plate's mounting holes. The center mark is the standard timing. If you loosen the plate mounting bolts and rotate the stator plate clockwise to the flywheel's rotation, that will advance the ignition timing. If you rotate the stator plate counterclockwise to the flywheel's rotation, that will retard the ignition timing. Never rotate the stator plate more than .028in/.7mm past the original standard timing mark. Kawasaki and Yamaha stator plates are marked. Honda stators have a sheet metal plate riveted to one of the mount holes. This plate insures that the stator can only be installed in one position. If you want to adjust the ignition timing on a Honda CR, you'll have to file the sheet metal plate, with a 1/4in rat-tail file.

AFTERMARKET IGNITIONS

The latest innovation in ignition systems is an internal rotor with bolt-on discs that function as flywheel weights. PVL of Germany makes these ignitions for modern Japanese dirt bikes. Another advantage to the PVL ignition is that they make a variety of disc weights so you can tune the flywheel inertia to suit racetrack conditions.

MSD is an aftermarket ignition component manufacturer. They are making ignition systems for CR and RM 125 and 250. MSD's ignition system features the ability to control the number of degrees of advance and retard. These aftermarket ignition systems sell for less than the OEM equivalent.

TIPS FOR BIG BORING CYLINDERS

In the mid nineties, European electro-plating companies started service centers in America. This made it possible to over bore cylinders and electro-plate them to precise tolerances. This process is used by tuners to push an engine's displacement to the limit of the racing class rules, or make the engine legal for a different class.

When you change the displacement of the cylinder, there are so many factors to consider. Factors like; port-time-area, compression ratio, exhaust valves, carb jetting, silencer, and ignition timing. Here is an explanation of what you need to do when planning to over bore a cylinder.

Port-Time-Area - This is the size and opening timing of the exhaust and intake ports, versus the size of the cylinder and the rpm. When increasing the displacement of the cylinder, the cylinder has to be bored to a larger diameter. The ports enter the cylinder at angles of approximately 15 degrees. When the cylinder bore is made larger, the transfer ports drop in height and retard the timing and duration of those ports. The exhaust port gets narrower. If you just over bored and plated a cylinder, it would have much more low end power than stock. Normally tuners have to adjust the ports to suit the demands of the larger engine displacement. Those exact dimension changes can be determined with TSR's Time-Area computer program.

Cylinder Head - The head's dimensions must be changed to suit the larger piston. The bore must be enlarged to the finished bore size. Then the squish band deck height must be set to the proper installed squish clearance. The larger bore size will increase the squish turbulence so the head's squish band may have to be narrowed. The volume of the head must be increased to suit the change in cylinder displacement. Otherwise the engine will run flat at high rpm or ping in the mid range from detonation.

Exhaust Valves - When the bore size is increased, the exhaust valve to piston clearance must be checked and adjusted. This pertains to the types of exhaust valves that operate within close proximity of the piston. If the exhaust valves aren't modified, the piston could strike the valves and cause serious engine damage.

Carb - The piston diameter and carb bore diameter are closely related. The larger the ratio between the piston size and the carb size, the higher the intake velocity. That makes the jetting richer. Figure on leaning the jetting after an engine is over bored.

Ignition Timing - The timing can be retarded to improve the over rev. Normally over bored engines tend to run flat on top end.

Pipe and Silencer - Because only the bore size is changed, you won't need a longer pipe only one with a larger center section. FMF's line of Fatty pipes work great on engines with larger displacement. Some riders use silencers that are shorter with larger outlets to adjust the back-pressure in the pipe for the larger engine displacement.