How to Choose a Powerband

by Eric Gorr

By making changes in engine components, nearly every Japanese dirt bike has the potential for two types of power. The engine can be tuned for midrange and high-rpm power or for low-end and midrange power. The midrange and high-rpm bike will have little or no low-end, hit explosively in the midrange, and have an abundance of top-end power that can be over-revved. This kind of power can put you out front in the straits, but it is harder to control and will tire out the rider more quickly. Expert outdoor riders tend to use engines tuned for high-rpm power.

An engine can also be tuned for low-end and midrange. Such an engine will have plenty of power down low, a beefy midrange, and a flat top-end. Supercross and enduro riders favor this kind of power. It is easy to use, and gives the rider confidence. Most riders can see faster times or just have more fun with more low-end and midrange.

With tuning, you can change your motorcycle's powerband to somewhere between one of these extremes. Only a few riders use the extremes. Professionals on outdoor tracks—especially 125cc European Grand Prix bikes—use engines that are almost all high-rpm power. These machines are extremely fast and require highly talented professionals to make the most of them. Enduro riders in extremely slippery, technical conditions use bikes tuned for lots of low-end. Trials riders use bikes that are tuned for nothing but low-end.

Generally speaking the higher the powerband peak (both in horsepower and rpm) the narrower the powerband. Conversely the lower the power peak the wider the powerband. Sometimes you can get the best of both worlds. Exhaust valves systems have made the biggest difference in widening the powerband. Innovations in exhaust pipe design and ignition systems have also contributed to making two-stroke engines as tractable as four-stroke engines.

Rider's should choose a powerband according to their skill level, terrain obstacles, and maintenance practices. Here are some tips on how to select the right powerband for you using these criteria.

Skill level

Generally speaking, beginning riders need low to midrange powerbands whiles expert riders can benefit from top-end powerbands. There are exceptions, though. Supercross bikes have low to midrange powerbands because the steep far-spaced jumps are positioned so close to the turns. Keep in mind that low-end to midrange powerbands are typically easier to use. In conditions where traction is minimal and the terrain is particularly technical, low-end power will allow you to keep the bike under control and ultimately go faster. Also, torquey bikes are more fun to ride casually. Expert and top-level riders need high-end power to be competitive, but the extra juice can easily slow down lesser riders even in good conditions, and is a handicap in slippery, difficult conditions.

Terrain obstacles

This term describes a wide variety of things ranging from the soil content to the elevation changes and the frequency of jumps and turns on a racetrack. Low to mid-range powerbands work well on soil like mud and sand. Tight tracks with lots of off-camber or difficult corners will favor low-end to midrange power. Smoother broader powerbands work well for enduro or trail riding over a wide variety of terrain and soil conditions. Midrange to top end powerbands work best on terrain with loamy soil, long fast uphills, and fast sweeping turns.

Maintenance practices

Generally speaking, powerbands designed for low to midrange require less engine maintenance than powerbands designed for high rpm. High-rpm powerbands usually require frequent use of the clutch in order to get the engine up into the rev range where the powerband is most effective. An engine that sustains high rpm requires more frequent replacement of parts such as; piston and rings, reeds, crankshaft bearings, and clutch plates. Also the carb jetting becomes more critical. If the main jet is one size too lean, the piston can seize. High-rpm powerbands have high compression ratios so fuel selection is critical. Most tuners recommend racing fuel because the specific gravity of fuels such as these doesn't vary with the season like super unleaded pump fuel.

Tuning for Specific Powerbands

I've designed the chart shown below, to give you some general guidelines on different powerbands and the changes required to the individual engine components. For specific recommendations on your model bike, refer to the chapters on tuning tips.

Component: Cylinder Head

Low To Midrange: 9.5:1 compression ratio, squish band 60% of bore area

Midrange and High-Rpm: 8:1 compression ratio, 40% squish

Component: Cylinder Ports

Low To Midrange: Exhaust port 90 ATDC, transfer ports 118 ATDC

Midrange and High-Rpm: Exhaust port 84 ATDC, transfer ports 116 ATDC

Component: Reeds

Low To Midrange: Dual-stage or .4mm fiberglass petals.

Compromise: Thick carbon fiber petals

Midrange and High-Rpm: Large area 30-degree valve

Component: Carburetor

Low To Midrange: Smaller diameter or sleeved down carb (26mm for 80cc, 34mm for 125cc, 36mm 250cc)

Midrange and High-Rpm: Larger carb (28mm for 80cc, 38mm for 125cc, 39.5mm 250cc)

Component: Pipe

Low To Midrange: Fatty or Torque

Midrange and High-Rpm: Desert or Rpm

Component: Silencer or Spark arrestor

Low To Midrange: Short, small diameter

Midrange and High-Rpm: Long, large diameter

Component: Ignition Timing Advance timing

Low To Midrange: Stock timing

Midrange and High-Rpm: Retard timing

Component: Flywheel

Low To Midrange: Add weight

Compromise: Stock flywheel

Midrange and High-Rpm: PVL internal flywheel

Component: Fuel

Low To Midrange: Super unleaded 93 octane

Midrange and High-Rpm: Racing fuel 105 octane

Tuning Guide to Performance Modifications

When deciding what to do to your engine, you first need to decide what you want. What kind of riding do you do? What level of rider are you? How much money do you have to spend? Also, remember that you need to bring the bike to peak stock condition before you add aftermarket equipment. This section lists each performance mod and describes how to modify each system for the performance you want.

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 and transfers) that alters the timing, area size, and angles of the ports to adjust the powerband to better suit the rider's demands. For example, a veteran trail rider riding an RM250 in the Rocky Mountain region of the U.S. will need to adjust the powerband 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 the port's time-area. A port's time-area is a calculation of a port opening's area and timing in relation to the displacement of the engine and the rpm. Experienced tuners know what exhaust and transfer port time-area values work best for different purposes (motocross vs. enduro, for example). In general, if a tuner wants to adjust the engine's powerband for more low to midrange, he would do the following two things:

1. 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, shortens the exhaust-port duration, and increases the compression ratio.

2. Narrow the transfer ports and re-angle them with epoxy to reduce the port's time-area for an rpm peak of 7,000. 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 flow pattern of the transfer ports to improve scavenging efficiency at 2,000 to 5,000 rpm.

For both of these types of cylinder porting changes to be effective, other engine components would need to be changed as well.

Cylinder Head Modification

Cylinder-head shape also affects the powerband. Generally speaking, a cylinder head with a small-diameter, deep combustion chamber and a wide squish band combined with a high compression ratio is suited for low-end and midrange power. A cylinder head with a wide, shallow chamber and a narrow squish band and a lower compression ratio is suited for high-rpm power.

Cylinder heads with wide squish bands and high compression ratios will generate high turbulence in the combustion chamber. This turbulence is termed maximum squish velocity (MSV) and is rated in meters per second (m/s). A cylinder head designed for Supercross should have an MSV rating of 35m/s, whereas a head designed for motocross should have an MSV rating of 25m/s. The only way to accurately determine the MSV rating of a head is by measuring some basic engine dimensions and inputting the numbers into a TSR computer program called SQUISH.

In the model-tuning-tips sections of this book, the SQUISH program was used to calculate the modified head dimensions. Aftermarket companies like Cool Head also offer cylinder heads, which have different cartridges to give different cylinder head shapes. The various head cartridges have different combustion bowl shapes, compression ratios, and MSV ratings. The head cartridges are incrementally different, corresponding from powerbands ranging from extreme low-end to high rpm.

Crankshaft Modification

There are two popular mods hop-up companies are doing to crankshafts: stroking and turbo-vaning. Stroking increases the stroke of the crankshaft, which increases the displacement of the cylinder, boosts the midrange torque power but decreases the rpm peak. Two techniques are commonly used to stroke two-stroke crankshafts: welding closed the old big-end hole and re-drilling a new big-end hole or boring the pin hole larger and welding an eccentric flange to each crank half. Rick Petersen Motorsports in Covina California.

Turbo-vaning a crankshaft is an old, discredited technique that allegedly improves the volumetric efficiency of the engine by fastening scoops to the crank. Every decade some hop-up shop revives this old idea and gives it a trendy name. These crank modifications cause oil to be directed away from the connecting rod, and often the vanes will detach from the crank at high rpm, causing catastrophic engine damage. My advice: Don't waste the $750! The concept of aspirating a two-stroke is common in diesel engines, with components like belt-driven superchargers, exhaust gas driven turbo-chargers, or even a combination of each. Those components are designed for engines that don't use expansion chambers.

Carburetor Modification

In general, a small-diameter carburetor will provide high air-mass velocity and good flow characteristics for a low- to mid-rpm powerband. A large diameter carburetor works better for high-rpm powerbands. For 125cc engines, a 34mm carburetor works well for Supercross and enduro and a 36- or 38mm carburetor works best for fast motocross tracks. For 250cc engines, a 36mm carburetor works best for low- to mid-rpm powerbands, and a 39.5mm carburetor works best for high-rpm powerbands. Recently, there has been a trend in the use of airfoils and rifle boring for carbs. These innovations are designed to improve airflow at low throttle openings. Some companies like Performance Engineering in Florida offer a service to over-bore the carb and they include inserts to reduce the diameter of the carb. For example, a 38mm carb for a 250cc bike will be bored to 39.5mms and two inserts will be supplied. The carb can then be restricted to a diameter of 36 or 38mm. Not every carb can be over-bored. The maximum diameter of the carb cannot exceed the width of the slide. Otherwise air will by-pass the venturi and the engine will run too lean. There are two ways to over-bore a carb, by stripping it down and turning it on a lathe (Kehin PWK and Mikuni round slide), or by milling it on a vertical mill using a rotary-table. The rotary-table method is necessary for carbs where the needle jet cannot be removed (Kehin PJ and Mikuni TMX). Whenever a carb is over-bored the jetting must be richened to compensate for the loss of intake velocity.

Aftermarket Reed Valves

Like large-bore carburetors, bigger reed valves with large flow area work best for high-rpm powerbands. 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 midrange power. Three other factors must be considered 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. The 30-degree valve is designed for low-end to midrange power and the 45-degree valve is designed for high-rpm power. Two types of reed-petal materials are commonly used, carbon fiber and fiberglass. Carbon fiber reeds are lightweight but relatively stiff (spring tension) and are designed to resist fluttering at high rpm. Fiberglass reeds have relatively low spring tension so they instantly respond to pressure 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-end to midrange powerbands, and carbon fiber reeds are better for high-rpm engines. Regarding longevity, the fiberglass reeds tend to split whereas the carbon fiber reeds tend to chip.

Some aftermarket reeds, such as the 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. The Boyesen RAD valve is different than a traditional reed valve. Bikes with single rear shocks have offset carbs. The RAD valve is designed to evenly redistribute the gas flow from the offset carb to the crankcases. A RAD valve will give an overall improvement to the powerband. Polini of Italy makes a reed valve called the Supervalve. It features several mini sets of reeds positioned vertically, instead of horizontally (as on conventional reed valves). These valves are excellent for enduro riding because they improve throttle response. In addition, 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.

Aftermarket Exhaust Pipes

The exhaust pipes of high-performance two-stroke engines are designed to harness the energy of the pressure waves from combustion. The diameter and length of the five main sections of the pipe—head pipe, diffuser cone, dwell, baffle cone, and stinger—are critical to producing the desired powerband. In general, aftermarket exhaust pipes shift the powerband up the rpm scale. Most pipes are designed for original cylinders not tuned cylinders.

There are two reasons for buying an aftermarket pipe; to replace a damaged pipe or to gain performance. The stock exhaust pipes of most late model Japanese dirt bikes offer excellent performance. In fact, many aftermarket pipes are just copies of OEM pipes. The reason nobody buys OEM pipes is because they are way too expensive. There are several different manufacturers of pipes in the world. Generally speaking, the pipes manufactured in Europe (SPES, DEP Sport, MESSICO, HGS) offer greater high-rpm performance at a much higher price ($350) than the American pipes (FMF, PC, Dyno-Port, Bill's, R&D). The European pipes are designed to work in conjunction with ported cylinders whereas the American pipes are designed to work with stock cylinders.

Pipes are available in two types of material, steel and aluminum. The steel pipes are made in bare and plated finishes. Plated pipes require no maintenance whereas bare metal pipes require constant maintenance to prevent corrosion. FMF's new Burly pipe is made of thicker steel and resists rock dents. There is no performance difference between the two finishes. The energy of the finite amplitude waves reflecting through the pipe is not affected by surface finish. However, sharp edges and abrupt transitions between sections of the pipe affect the fuel/air particles carried by the waves.

It is possible to determine how the shape of the pipe will affect the performance of your bike. The pipe manufacturers label their pipes with terms that describe the pipe's affect on the powerband. Terms like "Fatty, Supercross, and Torque" are associated with enhancements in the low to midrange of the powerband. Terms like "Desert, motocross, or RPM" are associated with enhancements in the upper midrange and top end of the powerband. Generally speaking, pipes with designations such as this work well with cylinders and heads tuned for the same type of powerband. It is unusual for a "RPM" pipe to work well with a "torque" cylinder.

Aftermarket Silencers

Silencers come in all sorts of shapes and sizes. The idea is to use the silencer to maximize the pressure and velocity in the pipe. That profile will be different for powerbands and riders' demands. 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. Designing the silencer is the final step when developing a pipe package. Silencers are designed on the dyno and verified on the racetrack. Generally speaking if you buy an aftermarket pipe, buy the silencer to go along with it. Some popular silencers have optional end caps that have spark arrestors built into them.

Flywheel Weights

A heavier flywheel will smooth out power delivery. The flywheel is weighted to improve the engine's tractability at low to mid-rpm. Flywheel weights are best for powerful bikes with decent low-end and an explosive hit. The weight will smooth out the hit and reduce wheelspin, which will improve your drive out of corners. One popular myth associated with flywheel weights is that they increase low-end power. If an engine doesn't have enough low-end torque in the first place it will be worse with the extra flywheel weight.

Two different types of flywheel weights are available: weld-on and thread-on. A-Loop performs the weld-on flywheel weight service. Steahly is a company that 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. 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. Modern bikes use external rotor flywheels. They have a larger diameter than internal rotor flywheels so they have greater flywheel inertia. PVL makes an internal rotor flywheel that gives quicker throttle response.

Ignition Timing

The ignition timing has a minimal affect on the powerband. Retarding the timing has the affect of reducing the hit of the powerband in the midrange and extending the top end overrev. Overrev is a slang term that describes the useable length of the powerband at high rpm.

The scientific reason for the shift of the powerband to extremely high rpm is because the temperature in the pipe increases with the retarded timing. That is because the burn cycle takes about 55 degrees of crankshaft rotation. When the timing is retarded the burn cycle starts later and continues into the pipe. Raising the exhaust gas temperature raises the velocity of the waves to be more synchronous with the piston speed and port timing of the cylinder.

Advancing the timing has the affect of increasing the midrange hit of the powerband, but makes the power flatten-out at high rpm. The reason is that the relatively long spark lead time enables for a greater pressure rise in the cylinder before the piston reaches TDC. This produces more torque in the midrange but the high pressure contributes to pumping losses at extremely high rpm.

Aftermarket Ignitions

The latest innovation in ignition systems is the 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. Firepower of Holland makes igniter boxes for most 125s. These aftermarket ignition systems are strictly for top end power. Chapparel in California sells an igniter box for YZ125s, their product is designed for stadium racing, providing a strong mid-range hit in the powerband.