EXHAUST SYSTEMS AND EMISSIONS

EXHAUST SYSTEM OVERVIEW

The basic purpose of exhaust systems is to transport waste gasses out of the engine, away from the rider, and to the back of the bike. Exhaust systems also muffle the loud explosions in the combustion chamber – hence the term “muffler”. Due to stricter pollution regulations, exhaust systems have received the added duties of emissions control through the catalytic converter.

To create optimum engine performance, the exhaust system must completely evacuate combustion gasses from the combustion chamber. Any remaining gasses after the exhaust cycle is finished will dilute the incoming air-fuel mix which reduces volumetric efficiency.

Optimum performance is also achieved when the cylinder is filled as completely as possible with fresh air-fuel mix, with little or no air-fuel mix escaping out the exhaust valve during valve overlap.

In order to achieve optimum exhaust gas excavation and cylinder filling, the exhaust system must be properly fabricated in order to balance the pressures inside the cylinder between the exhaust stroke and the intake stroke. If properly fabricated, the exhaust system will create optimum airflow through the cylinder which will maximize horsepower and fuel economy.

The exhaust system is tuned by correct fabrication of the length and diameter of the exhaust tract which creates the proper free-flow of exhaust gasses. Correct fabrication will also create some backpressure that is needed to maximize cylinder infilling with fresh air-fuel mix, as well as enhance low to midrange rpm torque.

EXHAUST SCAVENGING - INERTIA

Scavenging is the process by which the speed of exhaust gasses travelling through the exhaust system help to pull combustion gasses out of the combustion chamber when the exhaust valve opens.

Scavenging is also the process by which “negative” sonic waves return to the exhaust valve during valve overlap, and push any fresh air-fuel mix back into the combustion chamber – air-fuel mix that may be drifting out the exhaust valve.

Inertia scavenging refers to the actual inertia or momentum possessed by the exhaust gasses and the incoming air-fuel mix. The faster the gasses travel, the more momentum they have.

When the exhaust valve closes, this does not mean that the flow of the exhaust gasses stop. Because of momentum, the exhaust gasses that have left the cylinder continue to travel through the exhaust system.

Even though the exhaust valve is closed, the previous exhaust cycle gasses - still travelling through the exhaust system - will have created a low pressure “vacuum” area at the closed exhaust valve. When the exhaust valve opens again, this vacuum helps to extract the exhaust gasses from the cylinder and this increases the scavenging effect in the combustion chamber.

The diameter of the header pipe is the main factor in controlling inertia. Optimum scavenging happens when the pipe is small enough to create a fast exhaust gas velocity without creating unwanted backpressure at high rpm.

A small diameter header will create the engine torque band in a lower rpm range. A larger diameter header will create the engine torque band in a higher rpm range.

EXHAUST SCAVENGING – SONIC WAVE

When the exhaust valve opens, the hot expanding combustion gasses - still inside the cylinder after the power stroke - rush past the now open exhaust valve and travel at high speed through the header.

When the exhaust gasses ram into the constricted end of the exhaust pipe, or when it slams into the atmosphere at the end of an open pipe, it creates a “negative” sonic pressure wave that bounces back through the exhaust system.

If the exhaust system is constructed with the correct length of header, the negative sonic pressure wave will “slam” into any air-fuel mix that is just beginning to escape out of the exhaust valve during valve overlap. At this point, the piston is near top dead center on the exhaust stroke and the exhaust valve is about to close.

The result is that the air-fuel mix is prevented from leaving through the exhaust valve, and it basically gets “packed” into the combustion chamber until the exhaust valve closes.

Preventing air-fuel mix from escaping improves engine power and volumetric efficiency. However, the exhaust wave timing will only be effective in a certain rpm range and the header length must be the correct length for that rpm range.

In lower rpm ranges the length of the header must be longer because there is more time between each overlap event. If the header is too short, the reverse “negative” sonic wave will arrive at the wrong time and the exhaust wave scavenging event will not be timed correctly. The longer header will maximize power in the lower rpm range.

In higher rpm ranges the header must be shorter because there is extremely little time between each firing of the cylinder and between each overlap event. The shorter header will maximize power in the higher rpm range.

Exhaust systems can be tuned to deliver proper arrival of the negative sonic pressure wave at precisely the time of valve overlap because the speed of the exhaust gasses and the speed of the negative sonic pressure wave is known.

The speed of the expanding hot exhaust gasses travelling through the header is a consistent speed of about 300 feet per second. The speed of the returning negative sonic pressure wave travels at about 1,700 feet per second, which is approximately the speed of sound.

Exhaust header length can therefore be tailored for a particular rpm range since it is known how fast the exhaust gasses and sonic pressure wave travel. Header length for street motorcycles will typically be tuned for low to midrange torque which will happen from zero to about 2,000 rpm. If headers are tuned to make top end power, then bottom end torque will suffer.

Sometimes bike owners put short, two inch diameter open pipes with no baffles on their cruiser to increase the exhaust note. Although the bike may sound better, horsepower and engine tuning is typically compromised.

In general, cruiser type street bikes need a header that is narrow in diameter, longer in length, and creates some backpressure. On the other extreme, a drag bike for example will have a larger diameter header, be shorter in length and have no baffles for backpressure.

MEAN FLOW VELOCITY

Mean flow velocity refers to the speed that exhaust gasses flow through the exhaust system. Mean flow is determined by the header diameter, rpm and cylinder displacement. Exhaust systems run most efficiently at a mean flow velocity of about 300 feet per second.

If exhaust gasses flow too fast, the combustion chamber can experience over-scavenging and run too lean. If the exhaust gasses flow too fast, the engine may also produce lower torque. This is why some backpressure is needed and some bikes use an exhaust pipe “power valve” to restrict exhaust flow at low and midrange rpm in order to produce peak torque during acceleration.

If exhaust gasses flow too slow, this can cause drivability problems at low speed. Power at the top end can also suffer from slower exhaust flow as the combustion chamber suffers from a lack of inertia scavenging.

Exhaust flow velocity increases in a linier fashion as rpm increases. A primary factor in mean flow velocity is header diameter. The smaller the header diameter, the quicker a certain flow velocity is reached. However, too small a diameter will cause flow that is too fast, and the friction between the exhaust gas and the header will begin to cause too much backpressure.

If the header is too large in diameter, this can cause a drop in power and it will become hard to tune the engine for proper low speed throttle response. The bigger the header diameter, the higher the rpm must be run in order to reach an optimum flow rate for scavenging.