and nitrogen are exposed to high temperatures together. By diluting the intake charge with burnt exhaust gas, the peak temperature in the combustion chamber is reduced. This method of reducing harmful emissions has been used for years on automobiles as EGR (exhaust gas recycling) valves and may become standard equipment on motorcycles as the emissions noose is tightened.

The process of combustion starts when a spark is ignited in the combustion chamber. A flame develops around the spark plug then travels across the combustion chamber until it is quenched along the walls. As the flame front nears the outside of the cylinder, the head and piston are close together. The exposed metal surface area is increased and the volume of burning mixture is reduced. This causes the amount of heat energy transferred out of the gas to exceed the energy created and the flame goes out.

Because everything happens very quickly in a modern engine, the spark must occur before the piston has reached top dead center on the compression stroke. The goal is to have the spark early enough to provide the peak cylinder pressure at the optimal point in the piston stroke.

If the spark is too early, the flame front will consume enough of the mixture to cause the pressure to rise too soon, possibly before the piston has completed the compression stroke. At best this will reduce power as extra work must be taken from the engine to compress the burning gas. At worst it could lead to the engine damaging abnormal combustion. If the spark is delayed some of the mixture will not burn until too late in the piston's travel to be effective. There is an optimal time for the ignition to occur for peak efficiency which varies with engine design, speed, throttle setting and fuel — any earlier or later produces less power.

As we discussed last month, sometimes the combustion process does not work correctly. When everything goes as planned, the flame front advances across the combustion chamber at a subsonic speed. The problem occurs because the burnt gases heat and compress the unburned portion of the mixture. Heat and pressure cause chemical reactions to increase in speed. If the energy release becomes too rapid, a high-pressure spike is created that may be as much as 25 times the normal pressure levels in the cylinder. This pressure causes the cylinder to ring audibly, giving rise to the knock phenomenon (commonly called detonation).

Knock can be very damaging. The pressure wave and resultant heat can deform and/or melt pistons, valves and heads as well as hammer the lower end bearings. Any modification that increases the cylinder pressure will increase the engine's octane requirement. As the OEMs build some safety margin into their engine designs, small modifications usually do not cause problems.

Another abnormal combustion event is surface ignition. Surface ignition is when a hot portion of the combustion chamber, such as a carbon deposit, glowing spark plug electrode or exhaust valve lights the mixture. This can be either before the spark (pre-ignition) or after the spark (post-ignition). Of the two, pre-ignition is the most dangerous as it advances the spark timing resulting in greater heat and pressure in the combustion chamber. As the temperature and pressure rise, the possibility of knock increases. Further, the increased temperature promotes even earlier pre-ignition. This condition can rapidly spiral and destroy an engine. Post-ignition is not much better as the ignition system is no longer in control of the combustion sequence and peak pressure will occur sooner in the cycle than desired.

The combustion process is an extremely complex and dynamic event for which this article is only a very basic overview. Any modification that allows the air/fuel ratio and timing to be altered can be tuned to produce power increases. It has been my experience with roadracing that considerable testing must be conducted to realize these gains, and it is very easy to go backwards. A shop with a dyno and exhaust gas analyzer has a great advantage when selling hop-up parts. Any modification that increases cylinder pressure will likely increase the minimum octane needed. This may or may not be a problem given the aforementioned safety margin built into production bikes.

The limiting factor in engine power is the ability to get the maximum mass of fresh mixture and minimize the amount of unburned gas trapped in the cylinder each cycle. Any part that allows for greater cylinder filling will increase power, but beware and test as the factories have done a very good job on the stock machines. An interesting point is the most effective modification we have found on our roadracer is to use and tune for highly oxygenated race gas formulated specifically for modern sportbikes. This fuel is available from a major fuel suppler, but is expensive at $9 per gallon. As they say, speed costs ... How fast can your customers afford to go? ●

Ray Engelhardt is president of Engineered Racing Product (800) 542-9762, an engineering consulting firm and suspensio component manufacturer. E-mail your comments and engineerin questions to ray@engineeredracingproducts.com.

shop talk
Engelhardt on engineering