IGNITION CURVES

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What is the benefit of an ignition system with variable ignition timing? The short answer is: a fuller power power curve. If you don't change anything else on the engine, the peak power remains as it was, but at over-revs, the power drops less with the ignition timing, and most importantly, you can almost fill up the torque hole that every high-performance two-stroke engine shows at two-thirds torque speed.

Now comes the long answer. I would like to explain not only which advantages such an ignition system brings in, but also to clarify the reasons, so that the reader with this knowledge can do further research on his own. But first I will not talk about the ignition; that will come later. First I would like to clarify what is going on during purging.

Everything must fit

What makes a two-stroke engine a high-performance engine? The exhaust.
It first sucks the cylinder empty when the exhaust port opens. When the exhaust gases are out, the scavenge ports open and fresh gas flows out of the crankcase through the scavenging ports into the cylinder. The exhaust then still sucks and a part of this fresh gas is sucked across the cylinder into the exhaust manifold.
If the RPM (rotational speed), exhaust length and sound velocity all match, the scavenge ports are now closed by the piston again and at the same time the flow in the exhaust manifold changes its direction and the escaped fresh gas is pushed back into the cylinder. Finally, the piston then also closes the exhaust port again, so that the fresh gas that has been pushed back into the cylinder is trapped.

There are two cases where RPM, exhaust length and sound velocity do not all match:

If the RPM is too high (or the exhaust is too long, or the sound velocity is too low), fresh gas is still sucked into the manifold, but the backflow starts too late for this RPM:
the exhaust port closes again before all this fresh gas has been pushed back. That is why power drops at overspeed.

Hole

On the other hand, if the RPM is too low (or the exhaust is too short, or the speed of sound is too high), the engine behaves even more grumpily. Although the cylinder is sucked empty and purged, and there is enough fresh gas in the manifold to charge the cylinder afterwards, but the backflow starts much too early for this speed, when the scavenge ports are still open. The overpressure generated by the backflow in the cylinder, immediately escapes again via the scavenge ports into the crankcase.
When the scavengers finally close, there is no overpressure in the cylinder. The overpressure exists in the crankcase, which is not exactly necessary for the next intake process.
And the reverse flow has not only started too early, but also comes to a stop much too early and then changes the direction of flow again (Helmholtz-here-and-there). The little bit of fresh gas that remained in the cylinder is sucked out again afterwards. And then finally, but too late, the piston closes the exhaust. No wonder that there is a huge torque hole.

In addition, the engine now drinks a lot of fuel: per horsepower it consumes much more gasoline and a considerable part of it disappears unburned through the tail pipe.

Burning rate and expansion

There are two ways to adapt the exhaust to too high or too low revs:
Change the exhaust length or change the speed of sound.
Exhausts with sliding manifolds like a trombone have already existed, and also exhausts where the end cone was slidable. This can work, but it requires a lot of effort.
Influencing the speed of sound is easier; it works via the exhaust gas temperature.

The maximum temperature in the combustion chamber can be up to 2400°C. But because of the expansion of the downward moving piston the exhaust gas cools down again before the exhaust opens. And this expansion can be varied.
It starts when the combustion is just completed and the cylinder pressure is maximum, and it lasts until exhaust opens. The earlier after TDC (top death center) the combustion is finished, the greater is the subsequent expansion and the cooler is the exhaust gas when it enters the exhaust.

When combustion is complete depends on two factors: the ignition timing and the burning rate. The latter depends on the quantity (much or little fresh gas), the quality (clean fresh gas or much mixing with exhaust gas), the mixing ratio air / gasoline (rich, lean or just right), and the turbulence caused by the squish band.

If you want to have hot exhaust gas, set the ignition timing to late so that the combustion starts late, install a small main jet because lean mixture burns slower and therefore longer, and install a handful of head gaskets so that the squish edge hardly squeezes.
You might have experienced the opposite: early ignition, rich mixture and high compression take away the engine's revving ability.
But you should not play with all the above factors. To get power and a healthy engine it is

important that the combustion is as fast as possible. So use the right main jet, a compact combustion chamber and squeeze effectively. To influence the exhaust gas temperature we have the ignition timing.
Now we are at the heart of the matter: at low engine speeds either the exhaust is too short or the sound velocity is too high. Variable exhaust lengths require too much effort, so the speed of sound and thus the exhaust gas temperature must be lowered. We achieve this with early ignition. And for high speeds, the exhaust is actually too long, so we compensate with late ignition.

Intersections

Any engine that is even approximately healthy can handle 16° of pre-ignition. With this fixed value we make a dyno measurement and the result is some kind of power curve. Then we set the ignition to 12° fixed and measure again. Let's assume that the 16° power curve is the best up to 10,000 rpm, and the 12° curve from 10,000 rpm. At 10,000 rpm the both curves intersect, so they have the same power there. One could then say: at 10,000 rpm, the 16° curve is just as much too early as the 12° is too late. 14° could therefore be the optimum value for 10,000 rpm. Then we set the ignition to 14° fixed and make a power curve again. For example, this 14° curve intersects the 16° curve at 8000 rpm and the 12° curve at 11000 rpm.
Then we can conclude that 15° is optimal at 8000 rpm, 14° at 10,000 rpm, and 13° at 11000 rpm.

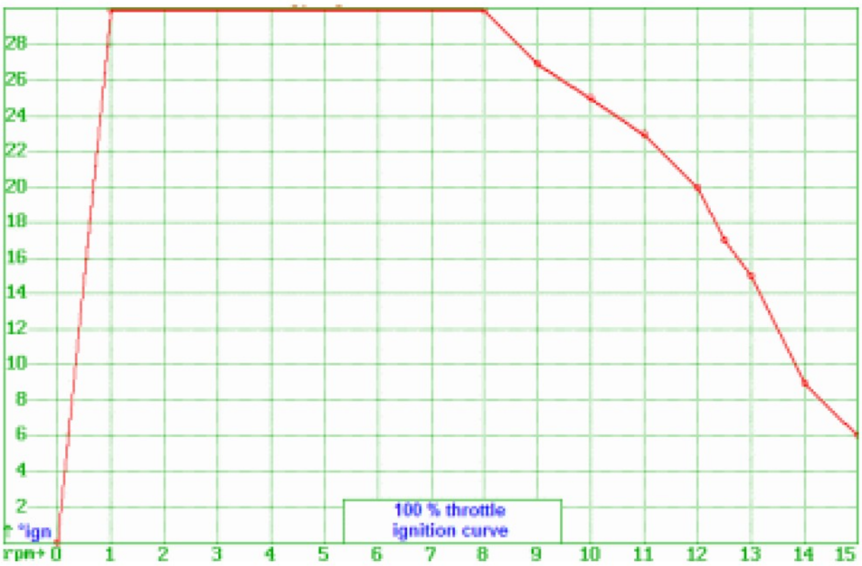
Dispose

At the top, we can experiment without worrying. Past the power speed, there is hardly any risk of detonation and it makes no sense to give extremely much pre-ignition there anyway. But near the torque speed you have to be careful; too much pre-ignition can be expensive. Even further down, where the engine has little torque, that means little fill, the danger is smaller again.
Even GP engines can easily handle 30° of pre-ignition there, and that still works well up to 8000 rpm. But if you try to measure a complete power curve up to the maximum speed with this 30° pre-ignition, you can actually save the trouble and dispose the engine directly. With so much pre-ignition you may only measure where the engine has little filling. So stop before the torque rises steeply. From then on up to the power speed one must proceed very carefully and after each partial measurement, check spark plug and piston for signs of detonation.
One caveat: don't look at four-stroke readings; the wrong-stroke ones run with a lot more pre-ignition. Formula 1-engines, for example, with their giant bore and ultra-short stroke, have a combustion chamber like a pancake.
There are hardly any squish bands, because there are valves everywhere. Therefore, even at full throttle, they still run with more than over 50° pre-ignition because otherwise the flame does not reach all corners in time.

GP curve

I show here for example the full throttle ignition curve of a 125cc GP engine which reaches at 12750 rpm its maximum torque and at 13000 rpm its maximum power:

U/min	°Vorzündung
0	0
1000	30
8000	30
9000	27
10000	25
11000	23
12000	20
12500	17
13000	15
14000	9
15000	6



Dynamic

The whole ignition thing is a temperature game. It only serves to optimize the exhaust gas temperature for each situation. The important thing is that the circumstances on the test bench are exactly the same as on the race track. The acceleration time, i.e. the time during which the exhaust is heated up, must be in line with practice. That is why these ignition curves can only be determined on a dynamic test bench; with a static power measurement, the exhaust gets much too hot.
By the way, this also applies to the design of exhaust systems: if you develop them on a static test bench, they turn out much too long. To get the engine to rev up on the track, you either have to ignite too late (costs power) or nozzle too lean (costs pistons, cylinders and possibly also the driver),

Another advantage of a dynamic test bench: because the engine is only fully loaded for about ten seconds instead of five minutes, it can survive a little too much pre-ignition, which in a static test would end in tears.

By the way, even with an optimal exhaust and a matching ignition curve, the engine will not rev up indefinitely, because the time cross sections are too small at overspeed. Because of the too small pre-exhaust time cross sections when scavenging ports are opening the cylinder pressure is still higher than the scavenging pressure and exhaust gas flows into the scavenging port. When purging then starts, exhaust gas is used first.
Then dirty fresh gas comes up, and when clean purge gas finally makes its way to the cylinder, the scavenge ports close again. This is why the power output drops so steeply at overspeed.

Equilibrium and residual energy

I have already explained that the power drops sharply 'at the bottom': the resonances no longer match the speed and disturb the scavenging instead of promoting it.
Fortunately, at low cylinder charge, the combustion temperature and thus the exhaust gas temperature is low, so that the speed of sound decreases. On the next power stroke, there is then a little less scavenging disturbance and a little more filling. So an equilibrium is established. This also works without ignition adjustment.
With ignition timing, there is another positive effect. With early ignition, the expansion from end of combustion to exhaust opens is greater. This not only reduces the exhaust gas temperature, but also the residual energy available to the exhaust resonance. At very low engine speeds the resonances come at the wrong moment, but at least they are not so strong and can be less messed up.

Terminal

Finally a practical remark: if you are dealing with an unknown engine, you should always install a **much** larger main jet first, and then reduce it until the mixture is right. Merely a **slightly** larger main jet can be dangerous, namely if the engine was originally too lean.
Much too lean means: totally no power and therefore no heat development.
But if you give this engine a slightly larger nozzle, it is only a little bit too lean;
then the power already comes, and with it the heat, which can then be terminal.
By the way, the difference between dynamic and static measurement can make the difference between life and death for the engine.