Ignition curves

What is the benefit of an ignition system with variable ignition timing?

The short answer is a fuller power curve.

If you do not change anything on the engine, the peak performance stays as it was, but during overrev (There is less of a performance drop) and above all the torque hole at two-thirds peak torque speed can be reasonably managed.

Now comes the long answer.

I do not just want to explain the benefits of such ignition, but also clarify the reasons, so that the reader can continue to research with this knowledge. At first I will not talk about the ignition; it will come later. First I would like to make clear what is going on during cylinder scavenging.

Everything has to fit

What makes a two-stroke engine a high-performance engine? The exhaust.

The vacuum from Exh Opening first empties the cylinder. When the exhaust gases are out, the transfers open and fresh gas flows out of the crankcase via the scavenging channels in the cylinder.

The exhaust continues to suck, and part of that fresh gas passes through the cylinder to the exhaust manifold.

If speed, exhaust length and speed of sound all match, then before the port closes again and at the same time changes the flow in the exhaust manifold, the direction of flow and the escaped fresh gas is pushed back in the cylinder.

Finally the piston closes the exhaust port again, so that the pushed back fresh gas in the cylinder is trapped.

There are two cases where speed, exhaust length and sound velocity do not all fit together: If the engine speed is too high (or the exhaust is too long, or the sound speed too low).   Although still fresh gas sucked in the manifold, the return flow begins too late for this speed: the outlet slot closes again before all this fresh gas is pushed back.

That's what causes overrev performance to fall.

On the other hand, if the engine speed is too low (or the exhaust too short, or the speed of sound too high), the engine behaves even grumpier.

Although the cylinder is sucked empty and rinsed, and sufficient fresh gas comes in the manifold to be able to charge the cylinder afterwards, the return flow starts much too early for this speed, if the transfers are still open.

The overpressure which is generated by the return flow into the cylinder (via the exhaust port), escapes immediately through the scavenging channels back into the crankcase. When the exhaust port finally closes, there is no overpressure ("supercharging") in the cylinder. There is overpressure in the crankcase, which is not helpful for the next intake cycle.

And the backflow not only starts too early, but comes to a standstill too early and then changes the flow direction again (Helmholtz). The little fresh gas that still remained in the cylinder is subsequently sucked out again. And then finally, but far too late, the piston closes the exhaust port.

No wonder that there is then a huge torque hole. In addition, the engine is now drinking extra fuel: per horsepower, it consumes a lot more gasoline and a significant part of it disappears unburned through the tailpipe.

Burning speed and expansion
There are two ways to adjust the exhaust to high or low speeds: change the exhaust length or change the speed of sound. Exhausts with sliding manifolds like a trombone have been used, and also exhausts where the end cone was able to slide. That may work, but it requires a lot expenditure.

The speed of sound is easier; this works over the exhaust gas temperature. The maximum temperature in the combustion chamber can be up to 2300 ° C. But due to the expansion on the downstroke, this cools the exhaust largely again before the outlet opens.

And this Expansion can vary. It starts namely, when the combustion is just completed and the cylinder pressure is maximum, and it lasts until Eo. The sooner after TDC the combustion is finished, the greater is the subsequent expansion and the cooler the exhaust gas when it flows into the exhaust pipe.

When combustion is completed depends on two factors: the ignition timing and the combustion speed.

The latter in turn 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 from the turbulence that is caused by the pinch edge.

If you really want to have hot exhaust gas, so set the ignition timing to late so that the combustion starts late, use a small main jet because lean mixture burns slower and therefore longer, and install a handful of head gaskets so that the there is very low compression.

You may have already experienced the reverse: pre-ignition, rich mixture and high compression prevent the engine fmor revving.

But you should not play with all the above factors. For power and a healthy engine too it is important that the combustion takes place as quickly as possible. So really, one uses a compact combustion chamber and squeezes the mixture effectively.

To influence the exhaust gas temperature, this leaves us with ignition timing. Now we are at the heart of the matter: at low speeds either the exhaust is too short or the speed of sound too high. Variable exhaust pipe lengths require too much effort, so we want to reduce the exhaust gas temperature and thus the speed of sound.

We achieve this with advanced ignition timing.
And for high speeds, the exhaust is actually too long, so we compensate for that with late ignition timing.

Intersections
Any engine that is even close to healthy can withstand 16 ° of ignition advance. With this fixed value we do a baseline test and thereby comes out a performance curve.

Then we set the ignition to 12 ° and measure again. When we compare that to the 16 ° power curve , the 16 degree is best is up to 10,000 rpm, and the 12 ° in turn is better after 10,000 rpm.

At 10,000 rpm, both curves intersect; so they have the same performance at that point.

You could say: at 10,000 rpm 16 ° is just as early as the 12 ° is too late.   14 ° could be the optimal value for 10,000 rpm.

Then we set the ignition to 14 ° fix and make again a power curve. For example, this 14 ° curve crosses 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.

To dispose
At the top RPM you can experiment without worries. After the peak power speed there is very little detonation risk, and it makes no sense anyway to give it a lot of ignition advance.   On the other hand, you have to be careful about the peak torque RPM; there, too much ignition timing can be expensive.

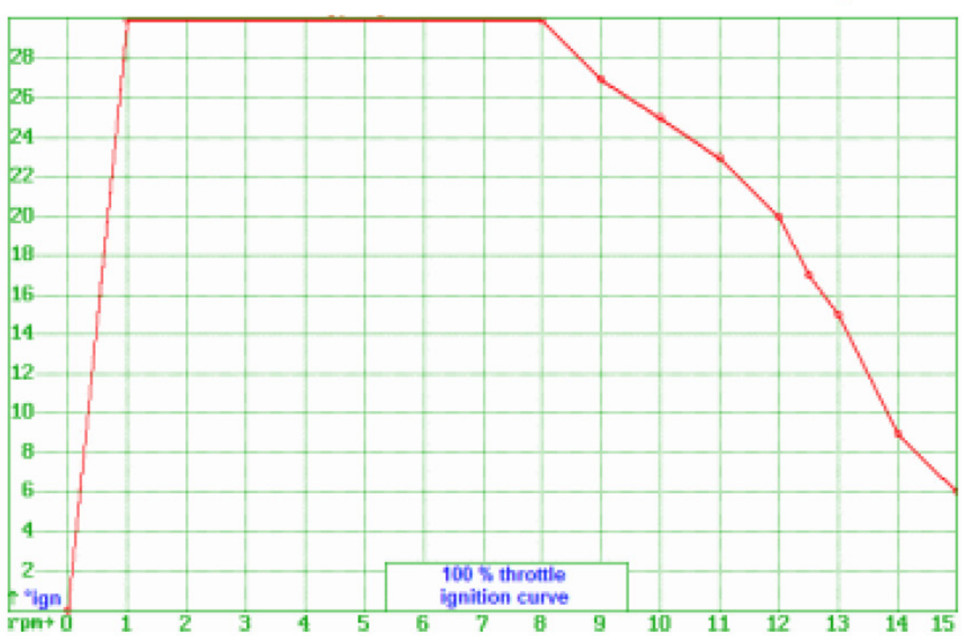
Even further down, where the engine has little torque, and thus poor cylinder filling, the danger is smaller again.

Below the torque peak, even GP engines can easily handle 30 ° ignition advance, and that works even up to 8000 rpm. But someone who tries a 30 ° flat advance for a complete power curve up to the maximum RPM, can actually avoid the effort and just dispose of the engine immediately.   With so much ignition advance, you can only test this where the engine has poor cylinder filling. So stop before the torque rises steeply.

From then on to the peak power speed you have to be very careful and After each partial measurement, spark plug and piston must be checked for signs of detonation. A warning: do not look at four-stroke advance values; they operate with much more ignition timing. Formula 1 engines eg : With their huge bore and ultra short stroke, have a combustion chamber like a pancake. There is little squish area, because valves are everywhere. The things are therefore even at full throttle operating with more than 50 ° ignition advance because otherwise the flame does not reach all corners in time.

GP-curve For example, I show the full-throttle ignition curve of a 125cc GP engine at 12750 rpm maximum torque and at 13000 rpm has its peak performance:

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 story is a temperature game. It only serves to lower the exhaust gas temperature to optimize for each situation.

It is important that the circumstances at the test bench are exactly the same as on the race track. The acceleration time, ie the time in which the exhaust is heated, must be practical. That's why you can only determine these ignition curves on a dynamic test bench; in a static power measurement, the exhaust is much too hot.

Incidentally, this also applies to the design of exhaust systems: Pipes developed on a static test bench are far too long. Then you turn the engine up on the track you either have to retard the timing (costs performance) or too meager (cost piston, Cylinder and possibly driver).

Another advantage of a dynamic test bench: because the engine only measures about ten seconds during a measurement instead of five minutes, in this case it can also survive a bit too much ignition advance, which at one static measurement would end in tears.

Incidentally, even with an optimal exhaust and a matching ignition curve of the engine will not over-rev unrestricted, because the time cross sections (blowdown time-area, I am guessing- RN) get too small at overrev. Because of the insufficient blowdown time-area after peak, the cylinder pressure is still above the case pressure and exhaust gas will back-flow into the transfer ducts.

When the cylinder scavenging finally starts, you will first be flushed with exhaust gas. (because exhaust gas has been pushed down into the transfers) Next comes partially-contaminated charge up from the transfers and finally clean purge gas enters the cylinder. That's why overrev performance drops so steeply .

Balance and residual energy
Dips in the power curve, I already explained: the resonances are no longer fit for speed and disturb the scavenging instead of promoting it.

Fortunately, with low cylinder filling, the combustion temperature and thus also the exhaust gas temperature are low, so that the speed of sound drops. At the next working stroke, there is somewhat less scavenging and a little more filling. This is how a balance is established.

That works too without ignition adjustment. Automatic ignition advance is still a positive effect. With more advance, the expansion due to burning before Eö is greater. This reduces not only the exhaust gas temperature but also the residual energy that is available for exhaust resonance.

At very low speeds then come the resonances totally in the wrong moment, but at least they are not so strong and have less effect.

Last note
Finally, a practical note: if you are dealing with an unknown engine, you should always first start with a much larger main jet than ideal, and then reduce until the mixture is right.   The danger lies in installing a slightly larger main jet, especially if the engine was originally too much was lean.   *Much too lean means: totally no performance and therefore no heat development*. But if you give this very lean engine a slightly larger jet, it becomes only just a little too lean; then the power comes, and thus the heat, which can then be terminal.   By the way, here too the difference between dynamic and static testing can decide how to measure life or death for the engine.