Part5:

Spark Advance Tables:

In this session we are going to talk about "Ignition Timing and Spark Advance Tables in the ECU".

To better and complete understanding of this session, you should learn:

1- What is ignition system and how it works?
2- What is ignition timing?
3- What is spark advance and retard?
4- The effects of "Ignition Timing" on engine performance
5- Basic spark advance
6- Optimal spark advance
7- Spark advance tables in the WinOLS software

What is the "Ignition System" and how does it work?

In modern engines, ECU controls fuel delivery and ignition timing. Modern ECUs read the data from various sensors like the crankshaft position, intake manifold temperature, intake manifold pressure, throttle position, fuel mixture via the oxygen sensor, detonation via a knock sensor, and exhaust gas temperature sensors.

Then the ECU uses the collected data to precisely determine how much fuel to deliver and when and how far to advance the ignition timing. With electronic ignition systems, individual cylinders can have their own individual timing so that timing can be as aggressive as possible per cylinder without fuel detonation. As a result, sophisticated electronic ignition systems can be both more fuel-efficient, and produce better performance over their counterparts.

The electronic spark advance system calculates the duration for keeping the electric power on and the timing of ignition and outputs an ignition signal depending on the crank angle. This system detects the angular position of each cylinder based on the signal of the crank angle sensor. CU calculates the ition ti ing on the driving cond

ignal to the coil. The coil produces high-voltage elec

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ite the fuel at exactly the right time so that the expa

of work. If the ignition system ignites at the wrong ti

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l mixture in the cylinder burns, the temperature rises,

is transformation causes the pressure in the cylinder

rces the piston

In order to get the most torque and power from the engine, the target is to maximize the pressure in the cylinder during the power stroke. Maximizing pressure will also produce the best engine efficiency, which translates directly into better mileage. The timing of the spark is critical to success.

There is a small delay from the time of the spark to the time when the Air-Fuel mixture is all burning and the pressure in the cylinder reaches its maximum.

If the spark occurs right when the piston reaches the top of the compression stroke, the piston will have already moved down part of the way into its power stroke before the gases in the cylinder have reached their highest pressures.

To make the best use of the fuel, the spark should occur before the piston reaches the top of the compression stroke, so by the time the piston starts down into its power stroke the pressures are high enough to start producing useful work.

Work = Force * Distance

In a cylinder:

- **Force** = Pressure * Area of the piston
- **Distance** = Stroke length

So, when we're talking about a cylinder,

work = pressure * piston area * stroke length

And because the length of the stroke and the area of the piston are fixed, the only way to maximize work is by increasing pressure. To increase cylinder pressure, we can change the ignition timing

The timing of the spark is important, and the timing can either be “**Advanced”** or “**Retarded”** depending on conditions.

What is “Ignition Timing”? Advance and Retard:

So here we introduce 3 important things, ignition timing, spark advance and retard in a simple term:

1. **Ignition Timing:**

"Ignition Timing" refers to the number of degrees before the top dead center or BTDC that the spark will ignite the Air-Fuel mixture in the ignition chamber during the compression stroke.

2. **Advance Timing:**

Can be defined as changing the timing so the ignition happens “**sooner than**” the manufacturer's specified time.

3. **Retarded Timing:**

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...he timing specified by the manufacturer was set at 12...
...to 11 degrees BTDC, it would be referr...
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fuel takes to burn is roughly constant. But the speed of
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engine speed, the more advanc
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also eliminate knocking; some cars that have knoc
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Advanced timing is required because it takes time to burn the Air-Fuel mixture. Igniting the mixture before the piston reaches TDC will allow the mixture to fully burn soon after the piston reaches TDC. If the mixture is ignited at the correct time, the maximum pressure in the cylinder will occur sometime after the piston reaches TDC, allowing the ignited mixture to push the piston down the cylinder with the greatest force. This will maximize the engine's power-producing potential. If the ignition spark occurs at a position that is too advanced relative to piston position, the rapidly combusting mixture can actually push against the piston still moving up in its compression stroke, causing knocking and possible engine damage, this usually occurs at low rpm and is known as pre-ignition or in severe cases detonation. If the spark occurs too retarded relative to the piston position, maximum cylinder pressure will occur after the piston is already too far down in the cylinder on its power stroke. This results in lost power, overheating tendencies, high emissions, and unburned fuel.

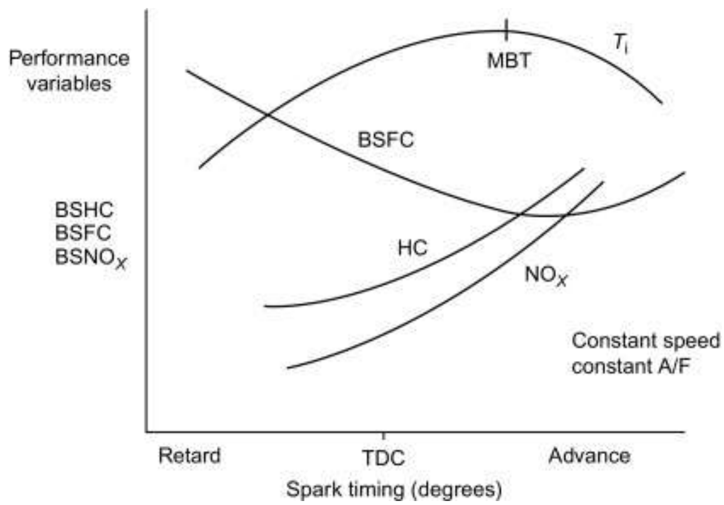
The ignition timing will need to become increasingly advanced relative to TDC as the engine speed increases so that the Air-Fuel mixture has the correct amount of time to fully burn. As the engine speed increases, the time available to burn the mixture decreases but the burning itself proceeds at the same speed, it needs to be started increasingly earlier to complete in time.

Poor volumetric efficiency at higher engine speeds also requires increased advancement of ignition timing. The correct timing advance for a given engine speed will allow for maximum cylinder pressure to be achieved at the correct crankshaft angular position. When setting the timing for an automobile engine, the factory timing setting can usually be found on a sticker in the engine bay.

The ignition timing is also depending on the load of the engine with more load, larger throttle opening, and therefore Air/Fuel Ratio, requiring less advance the mixture burns faster. Also, it is depending on the temperature of the engine with lower temperatures allowing for more advance. The speed with which the mixture burns depend on the type of fuel, the amount of turbulence in the airflow, which is tied to the design of the cylinder head and valve train system, and the Air/Fuel Ratio. It is a common myth that burns speed is linked with octane rating.

Effect of Spark Timing on Performance:

rk advance is the time before the top dead center or
ally expressed in a number of degrees of crankshaft r
ence of spark timing on engine brake specific fuel co
nstant speed and constant Air/Fuel Ratio for an engine.
crease with increased advance of spark timing. BSF
ed by timing. This picture shows that maximum torque
ming called advanced for mean best
e fuel consumption or BSFC is a measure of the fuel
burns fuel and produces rotational



Operation at or near MBT is desirable since this spark timing tends to optimize performance. This optimal spark timing varies with rpm. As will be explained, the engine control strategy involves regulating fuel delivery at a stoichiometric mixture and varying ignition timing for optimized performance. However, there is yet another variable to be controlled, which assists the engine control system in meeting exhaust gas emission regulations.

So, spark advances have effects on:

- Engine performance
- Engine pollution
- Fuel consumption
- Engine knocking
- And etc.

Engine revolution range and fuel burn characteristics affect ignition timing requirements. As an engine turns faster, spark plugs must fire at an earlier crank position to allow time for a given Air-Fuel mixture to ignite and achieve a high burn rate and maximum cylinder pressure by the time the piston is positioned to produce the best torque.

Spark advance is optimally timed to achieve the best torque by producing peak cylinder pressure.

Ignition timing is not only depending on engine revolution but also depend on engine load, mixture flame revolution, Air/Fuel Ratio, and other things…

Remember that a richer mixture burns more quickly, and a leaner mixture requires more time to burn and that is why sometimes exhaust manifold glows red.

Too little degree of spark advance will cause low power, bad gas mileage, backfiring, and poor performance. Too much advance will cause pre-ignition, hard starting, and knocking.

One of the essential destructive factors of the engine, which is also related to the spark advance, is the knock devastating phenomenon. Since this phenomenon is directly related to the spark advance, you must be fully acquainted with this phenomenon as a person who wants to learn the basics of the remap.

What is engine knocking?

In this section, you will see a complete and correct ignition cycle. And then you see the knock phenomenon in the engine due to the timing of the spark.

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and induced heat, spontaneous ignition of mixture oc
ignition inside the cylinder i
fronts hit, intense high-frequency pressure waves are pr
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n cause pre-ignition because of the high combustion
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Because you cannot see this phenomenon, we have provided an example of the engine's sound that has a knock here for you to get acquainted with this phenomenon properly.

Six reasons that cause engine knocking.

1. Low quality of fuel
2. Wrong engine Timing
3. Too lean Air/Fuel Mix
4. Bad Knock Sensor
5. High Compression Ratio
6. Improper spark plug

And how to stop engine knocking?

- Retard Ignition Timing.
- High Octane Fuel.
- Lower Compression Ratio
- Low Cylinder Temperature
- Optimize the Air/Fuel Ratio
- Use A Colder Spark Plug

Although the details of spark advance control are vehicle model and manufacturer-specific, there are generally two classes of correction that are used: fast correction and slow correction. In the fast correction scheme, the spark advance is decreased for the next engine cycle by a fixed amount (e.g., 5 degrees) whenever knock is detected. Then, the spark advance is incremented in one-degree increments every 5–20 crankshaft revolutions.

The fast correction ensures that minimum time is spent under heavy knocking conditions. Further, this scheme compensates for hysteresis (i.e., for one degree of spark advance to cause knocking, more than one degree must be removed to eliminate knocking).

In the slow correction scheme spark advance is decreased by one or more degrees each time knock is detected, until no knocking is detected. The spark advance proceeds in one-degree increments after many engine cycles.

The slow correction scheme is more of an adaptive closed-loop control than is the fast correction scheme. It primarily is employed to compensate for relatively slow changes in engine condition or fuel quality (i.e., octane rating).

Why is engine knock a ruinous phenomenon?

When detonation occurs, serious internal damage may happen, including melted spark plug electrodes, cracked piston rings, melted or cracked pistons, hammered rod bearings, and blown head gaskets. If you hear detonation, take your foot off the throttle immediately or pay the consequences!

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ve phenomenon, and if it increases more minor th
power and torque will not b

In ECU, the spark table controls the ignition in different working conditions. Depending on the technology of the engine and the ECU, the number of these tables can be from one to several tens of spark tables.

But in general, there are two types of spark tables in ECUs, such as Bosch, Siemens, etc. In the next part (part6), we will describe these two types of tables.