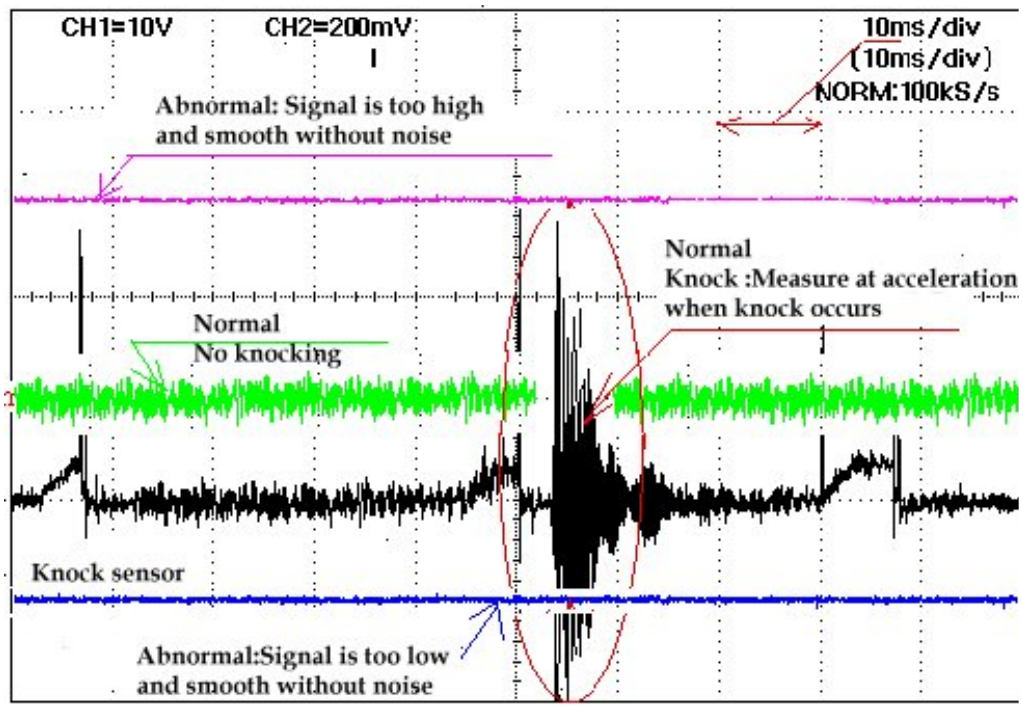
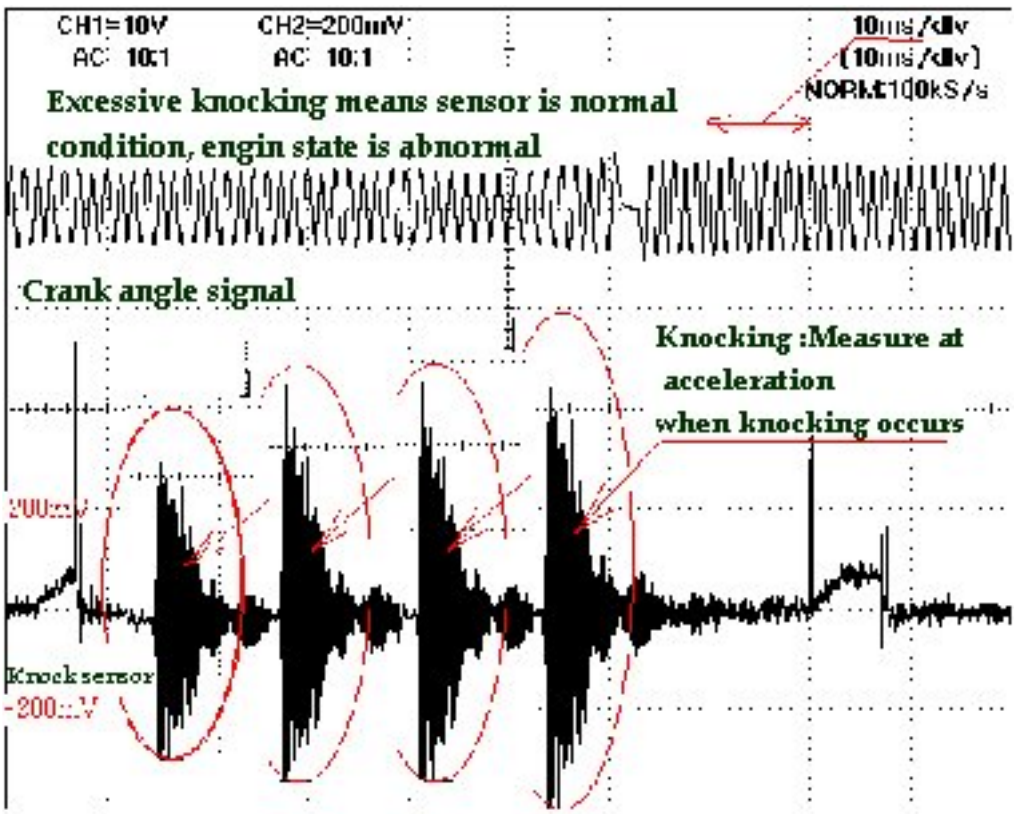
12. The signal check of Knock Sensor

1. Troubles

1. Malfunction of knock sensor	
Cause of trouble	Malfunction of knock sensor or wiring circuit failure (Signal, Ground line)
Counter action	1.1 Replace knock sensor 1.2 Bad connecting of knock sensor signal and ground line or short to battery or ground
Engine state	If ECU detect malfunction of knock sensor, ignition is always retarded about 8 ~ 12[°CRK]. It led to bad fuel economy and performance.
Signal measurement	

2. Communication malfunction between ECU and knock sensor signal	
Cause of trouble	Bad program or part in ECU
Counter action	Replace ECU
Engine state	If ECU detect communication malfunction, ignition is always retarded about 8 ~ 12[°CRK]. It led to bad fuel economy and performance.
Signal measurement	Knock signal is normal but communication is impossible in ECU. So, it should be checked with scanner.

3. Heavy knocking occurrence

Cause of trouble	Internal combustion of engine is irregular 3.1 Overheating of engine or poor engine oil 3.2 A/F distribution is not matched with each cylinder 3.3 Low octane fuel, Increment of compression ratio 3.4 Overheated spark plug tip (low heat value: HOT type applied) 3.5 Knock sensor is not fixed on engine block 3.6 Shield line of knock sensor is not connected
Counter action	Remove the cause of trouble after connecting shield line of knock sensor and checking engine status.
Engine state	ECU doesn't recognize malfunction of knock sensor. And detect it as knocking and ignition is retarded too much. It led to bad fuel economy and performance.
Signal measurement	 Reference : When heavy knocking is occurred, check O2 sensor signal(Switching is fast or not). If signal is unstable, A/F is different between cylinders. If it is normal, check current of ignition coil with each cylinder. If current is different between cylinders, vibration by unstable combustion is detected as knocking.

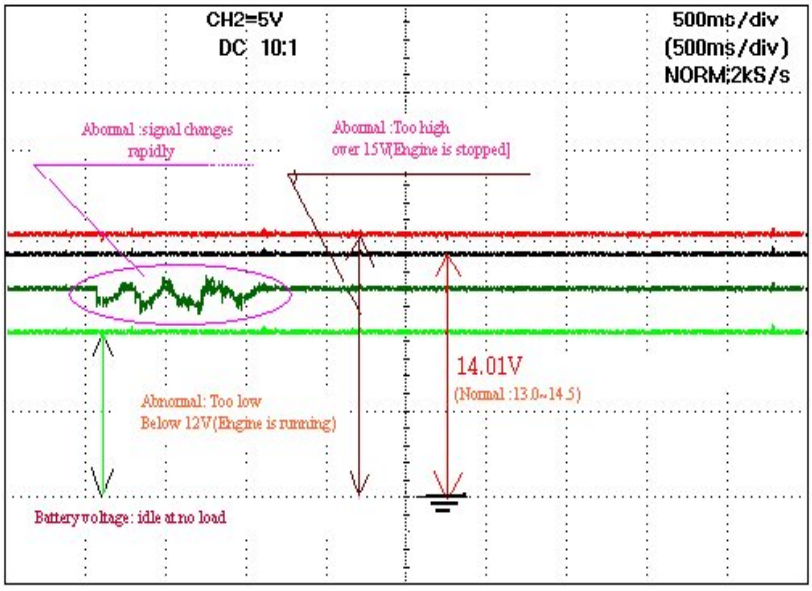
2. Field example

< Example 1 > Fast battery voltage change

Vehicle : Rio, Odometer : 2,400Km

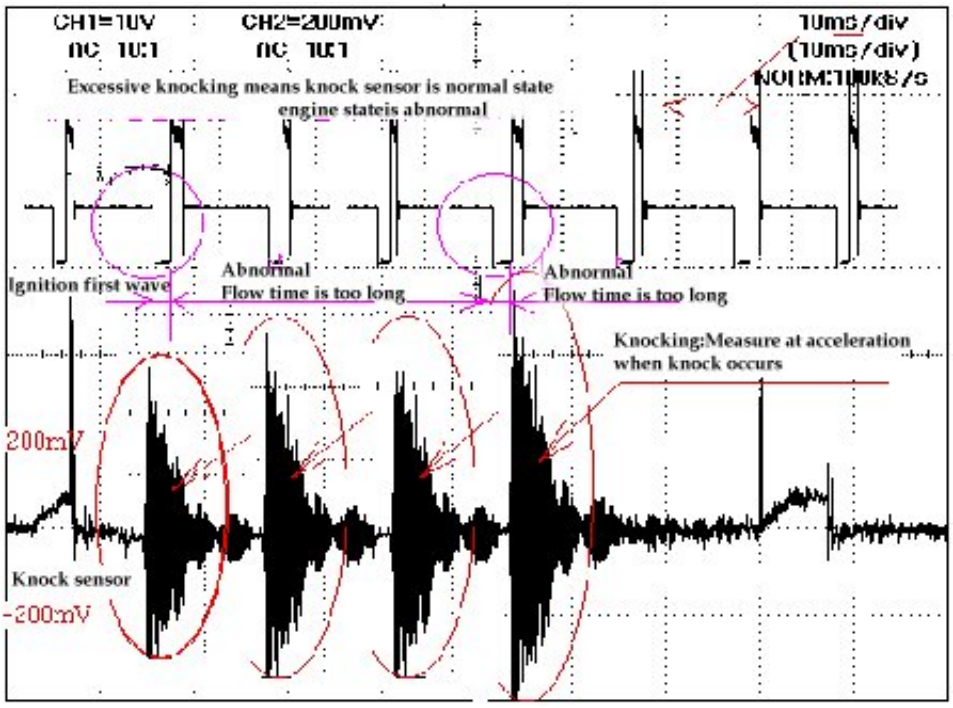
Problem description : Engine vibration is severe and knocking detection is frequent. Surging is occurred during driving.

Cause : Fast voltage variation is happened in line reading battery power in ECU. ECU calculates dwell time with this irregular voltage and it led to unstable combustion.

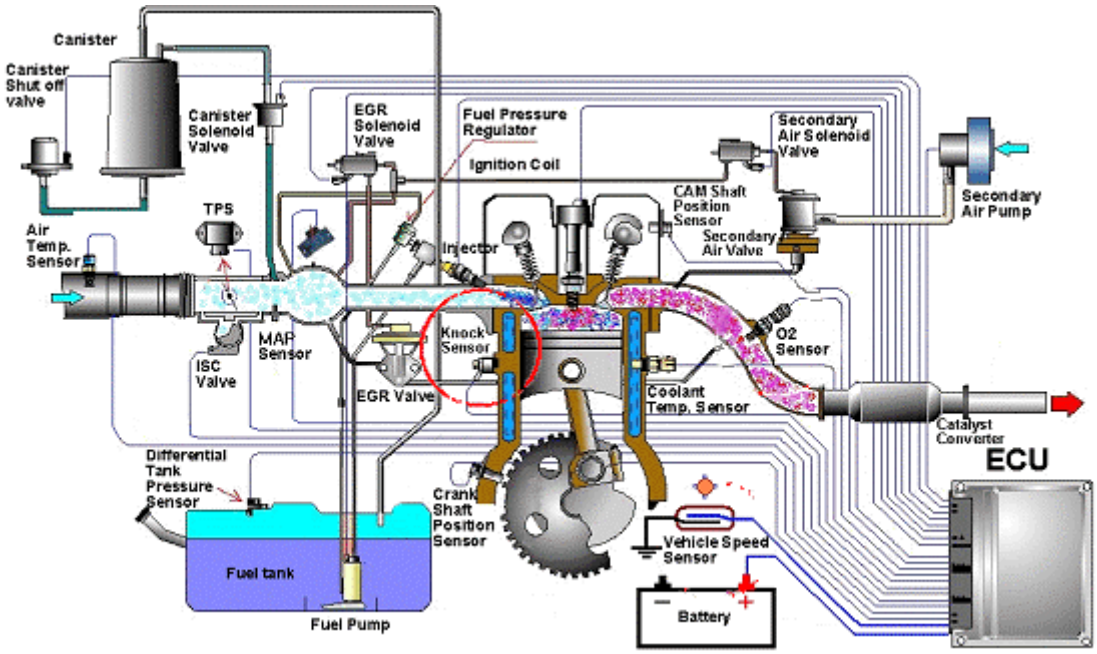


Explanation : In case of rapidly current increment by dwell time of ignition coil, combustion in each cylinder is unstable. The vibration that is occurred at this time is detected as knocking and it results in bad fuel economy and performance.

Enlargement of application : Unstable vehicle wiring prevent stable power supply and sensor signal.



3. Location of Knock sensor



< Picture of Knock sensor >

4. Check method

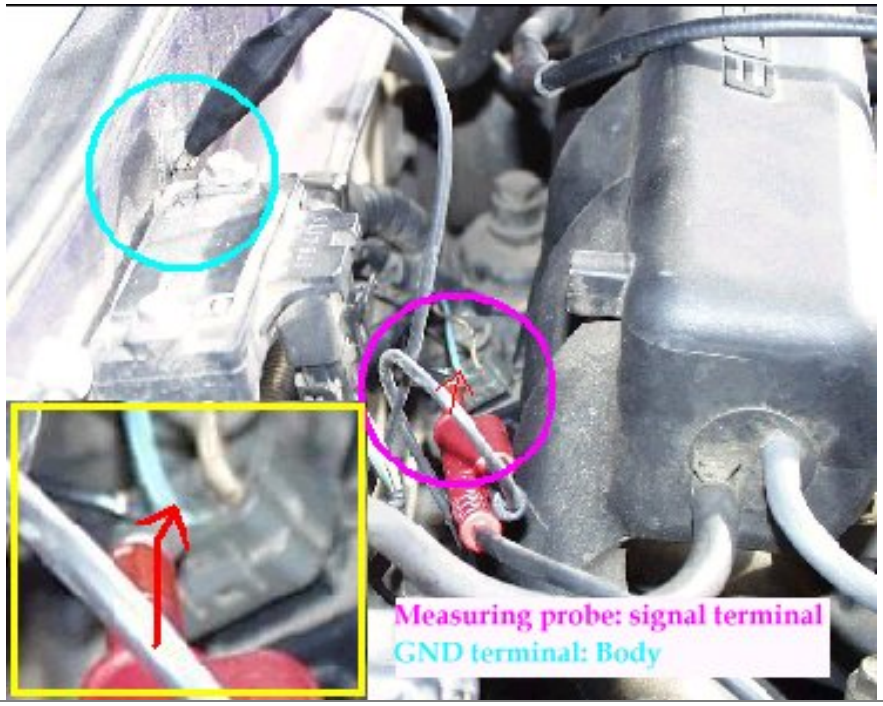
Explain the checking Method and Diagnosis of trouble.

Preparation

1.Oscilloscope (It prefers not to use Multimeter available)
2.Wiring Diagram for Knock sensor
3.Scanner

1.Find and connect the Signal and Ground line referencing the wiring diagram.
2.Connecting the Oscilloscope, check the Signal Voltage.
3.Measuring the Knock signal as making the rapid RPM change stepping on and out the Accelerator pedal
< Reference > Knock sensor signal is very fast (about 20KHz) and like Noise signal. Thus it prefers not to use Multimeter for checking the Signal status.
< Reference > In case of connecting the Auto-scanner, we can get the reference of the checking troubles because Auto-scanner is analyzing and diagnosing the some troubles automatically.
Connecting Method : To get more exact voltage, it must be measured on not battery side but closest position to ECU(within 30 mm).
Comparing Method :Compare the measured signal with Normal signal.
(1) After checking in IDLE state, Measuring the signal at WOT(Whole Open Throttle) as stepping on the accelerator pedal.
(2) With Connecting the Scanner, It prefers to check the ignition retard value by Knocking when Knock signal shows big variation(ECU detected knocking).
< Checking items >
(1) Is the Spark retard value through Scanner well displayed?
: Whether Ignition spark timing is retarded when real sound of Knocking is heard or Knock signal fluctuation is big (fluctuate between 1V and 5V).
(2) Whether the knock signal is lasted too low voltage (below 0.5 Volt) without big variation or is fluctuated severely.
(3)Whether the Knock signal line (or Ground line) is broken,
(4) Though knocking sound is still heard with normal condition or ignition retard is still “0” with big knock signal fluctuation, followings are assumed.
(a) Communication problem of the ECU internal: Knock signal is controlled by the ECU.
(b) Ignition angle is set to “0” by ECU arbitrary.

Check method



5. Wave analysis

Signal characteristic of knock sensor is as followings :

A. Voltage characteristic of knock sensor :

26± 8 mV / g (5KHz base)

B. Voltage linearity of knock sensor :

3 - 12 KHz : ± 15% (5KHz base)

12 - 20 KHz : ± 25% (5KHz base)

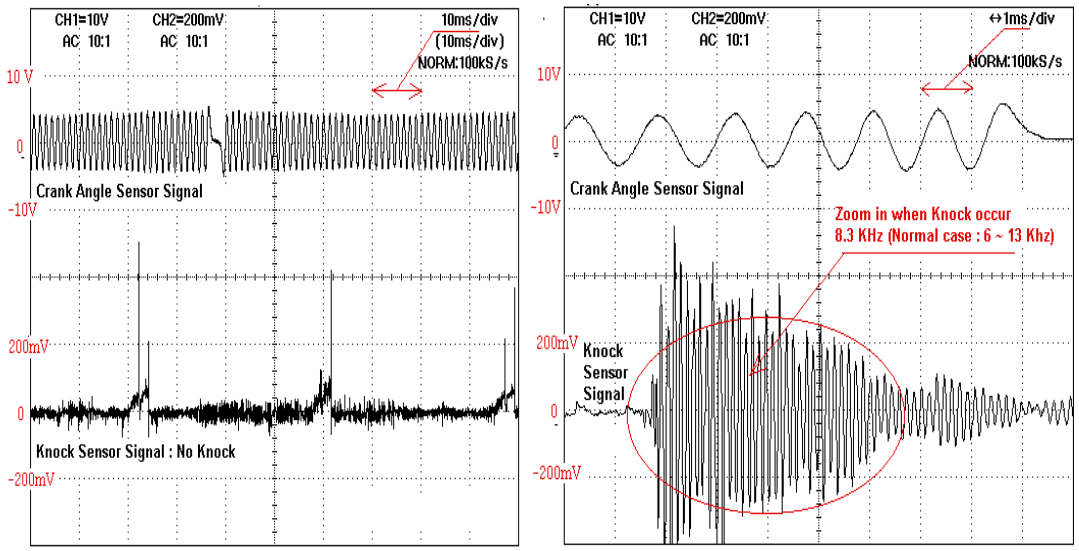
C. Electrical characteristic of knock sensor :

(1) CAPACITANCE : 0 - 1.4nF

(2) Frequency range : 3 - 20 KHz / Acceleration range : 100G

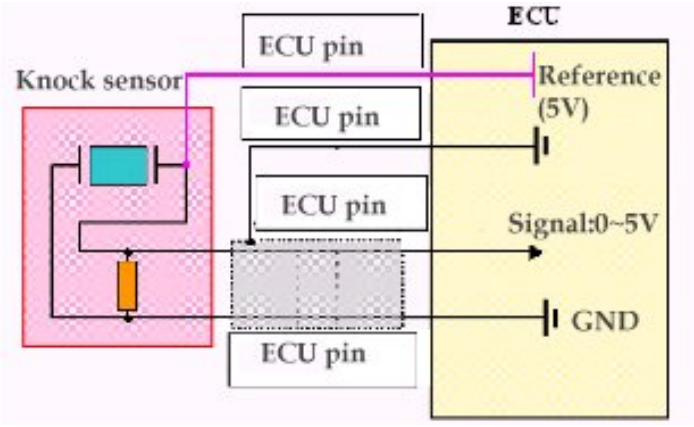
(3) Insulated resistance : Above 1MΩ with 750V

< Knocking signal : Without knocking(left) / With knocking (right) >

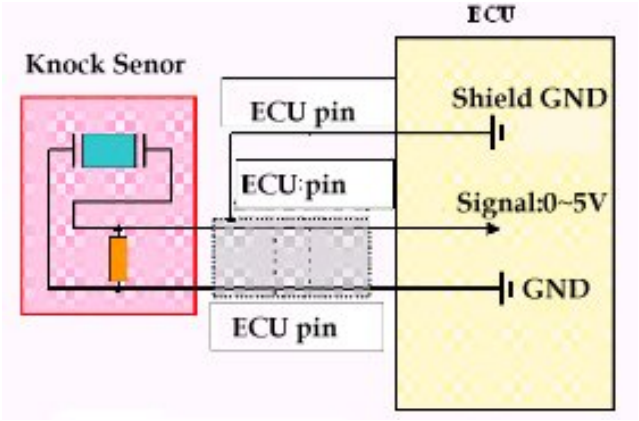


6. General

This knock sensor is using electric pressure caused by vibration (acceleration) by means of Piezo - ceramic. So, electric pressure is arisen when unstable explosion (Knocking : Detonation) is occurred within engine. One (I type engine) or two (V type engine) sensors are installed at sensitive position (center part of engine) at which vibration is detected more easily.



Knock Sensor wiring with 5V reference supply



Knock Sensor wiring without 5V reference supply

When knocking is occurred, knock existing cylinder is determined by crank angle signal (which tooth number) at which big knock signal is exist. To prevent misdetection caused by various kind of vibration, only special frequency (8~16KHz) is used. When knocking is not existed signal level is increased (low signal case) or decreased (high signal case) to maintain 1~2V knock signal level. Because knock sensor voltage is changed by engine vibration and engine vibration caused by knocking is too big and fast, real sensor voltage is changed very high and low. So, to sample signal data more quickly by ECU, this signal is quickly (10~40usec) sampled by hardware within ECU, and then the sampled signal is communicated with micro-processor by 1 msec. That is, special knock signal within the normal range (knocking signal) is received by microprocessor.

7. Principle (Algorithm) Introduction

Most of people know that knock sensor is used to retard ignition time with knocking. This is not wrong and there isn't many case of sensor error in the filed and even no strange behavior is shown with error. So, technicians may treat this nothing.

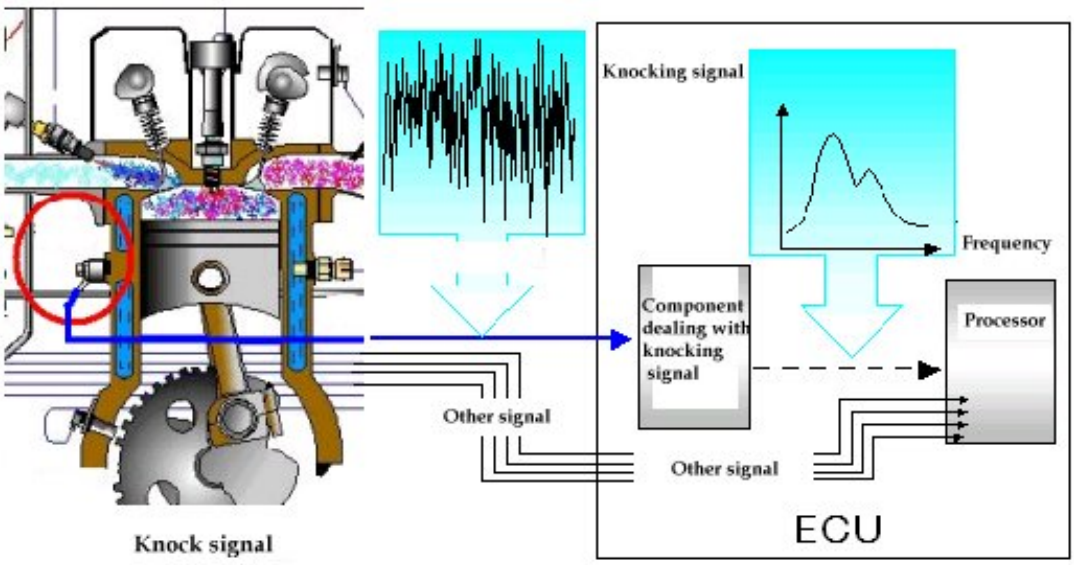
But, there are many behind story that you didn't know and there are also many cases that give a solution about the problem that you couldn't solve it before.

Before explain it, it is need to understand how ECU detect knocking and treat it?.

Knocking sensor is applied after about 6 – 8 weeks of engine dynamometer test. In case of no knock sensor engine dynamometer test takes about 12weeks then you can imagine how many tests are done for knock test.

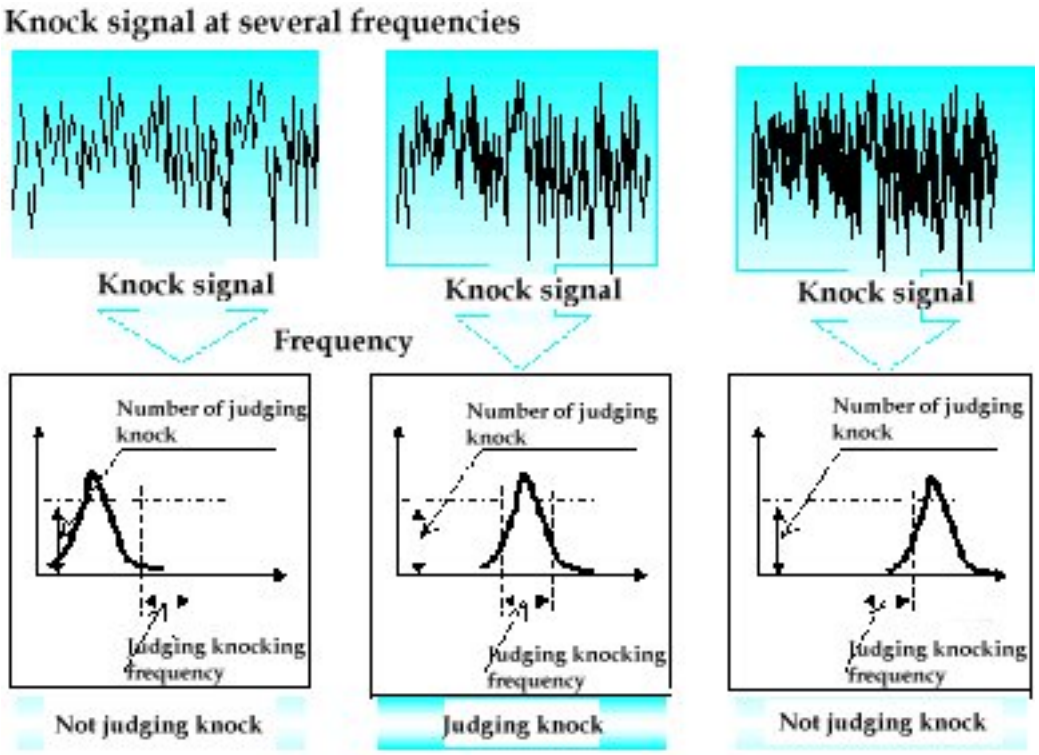
7.1 Principal of knock sensor operation.

1) Knock sensor signal is using the voltage that is generated when pressure is applied to piezoceramic or crystal . In case of knocking, about 8 – 16KHz of vibration is occurred. Then, there is something unclear point. How can ECU process 8 – 16 of frequency within 1msec? Because the fastest ECU can process only 1000 data within 1sec. Of cause it is impossible. Thus, ECU uses hardware to handle knocking signals and transfer it the processor.



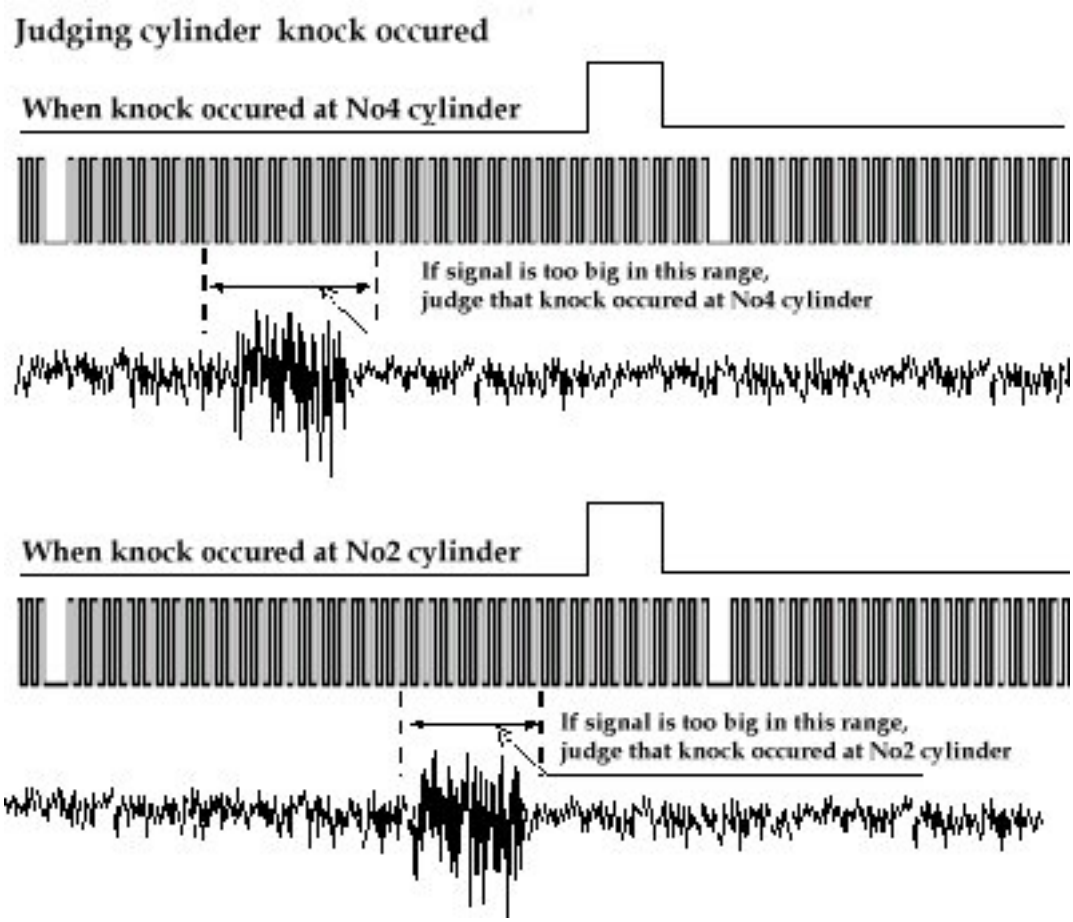
<Reference>

If this component(component that handle knocking signal and transfer it to processor) in the ECU is impossible then ECU detect "Knock sensor communication error"



2) ECU detects knocking when knocking frequency (8 – 16KHz) is bigger than the threshold. Most of technicians understand that knocking is detected when knock sensor signal is getting bigger. This is not wrong but if I say exactly, knocking is detected when big knocking signal is located within the frequency window of knocking.

Then, is knocking detection impossible when frequency is not within the window even with very big knocking ? I can say yes. But it is very difficult to generate the vibration with the frequency that can not detect as knocking.

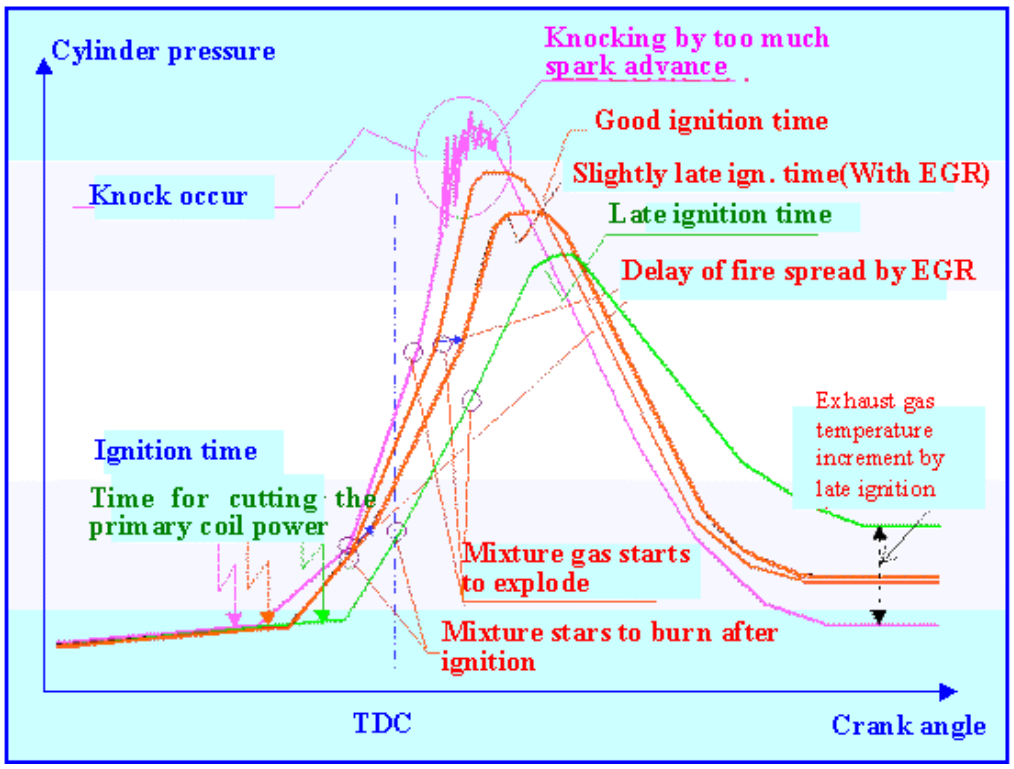


3) Knocking sensor uses crank angle sensor and cam signal to define each cylinder number. We call it as knocking window. This knocking window is decided after test that checks where knock signal is located from long tooth. And more wide range is set as a window. Cam signal is used to detect cylinder number.

For example, with knocking at cylinder no. 1, if knocking signal is big between 10 – 20teeth after long tooth after cam signal, then input this area as knock window into the ECU. After that, if big knocking signal is occurred in this window then knocking is detected. Therefore the vehicle with knock sensor controls individual ignition for each cylinder.

Referenced : some vehicles retard spark for all cylinder regardless cylinder number and this is a old program. And V engine has 2 knocking sensor at each block because engine knocking noise is not well transferred to the other block.

Knocking is occurred after 6° - 14° after TDC

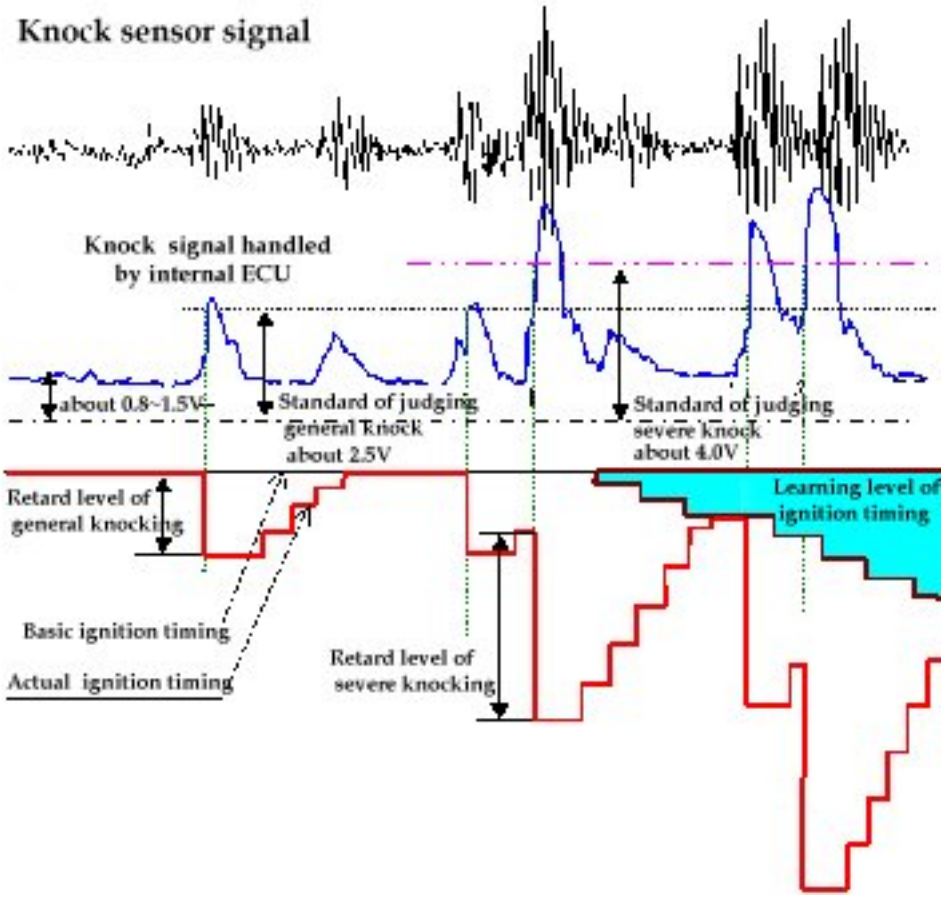


4) Amplify or reduce knocking signal.

This means, knocking signal is big or small depending on each case, ECU control knock sensor signal without knocking to 1V by amplifying or reducing it. For example, knock sensor signal in idle without knocking is very low (0.5V). But if engine speed is over 4000rpm then signal voltage is high (3 – 4V). Therefore keep constant voltage(about 1.0 –1.5V) without knocking and if signal is over certain threshold (3.5 – 4.0V) then it is considered as knocking.. You may think that knocking threshold setting depending on engine condition instead of increasing or decreasing of knock sensor signal. But we have to detect line break error that generates very small value with normal working engine without knocking. And if knocking signal is over 4V due to vibration at high engine speed, then how can we decide the threshold for real knocking detection? Therefore ECU adjust knock sensor signal to 1V without knocking and set different detection threshold depending on engine conditions.

Reference: In some case 2.5V is generated with line break error while other case use raw signal with line break.

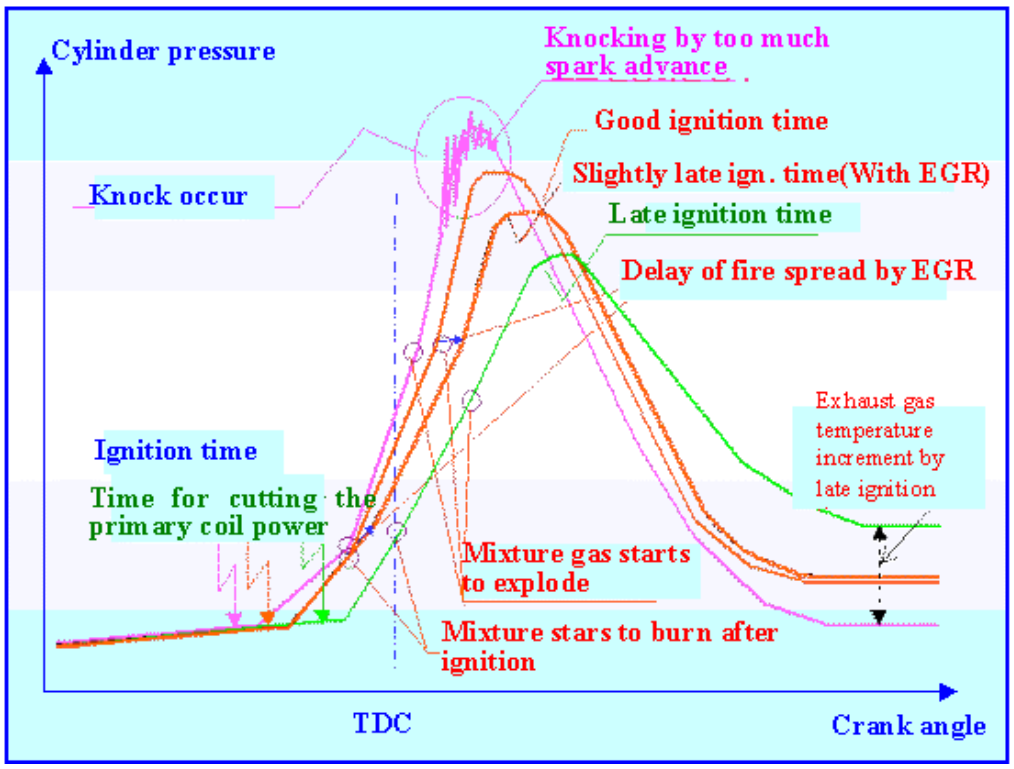
5) After knocking detection, cylinder with knocking is retarded by 2 type. It is light or middle knocking and severe knocking. Detection threshold is voltage level of knocking signal.



6) If spark retard by knocking is over 4deg, then adaptation is start. That means, if spark retard over 4° is continued for more than 10 – 20 cycles (input data), then a certain value (0.2 - 1°) is retarded as a basic value. The maximum retard value is approximately 6° or 12° and it depends on engine rpm and air flow.

And then if knocking is not occurred for more than 40～100 cycles(input data) then spark time is advanced by step of a certain value.(generally 0.1～0.3°)

For example, knocking will happen with using of low octane number. Then ECU retard the spark angle at every knocking events and learn adaptation not to get knocking with basic ignition angle. And if we use fuel with high octane number, then knocking will disappear and spark time will advanced.



7) If spark retard by knocking is over 4°, then provide additional fuel.

Exhaust gas temperature is rising with spark retard. In order to prevent the damage of oxygen sensor and catalyst by high exhaust temperature, additional fuel is provided to reduce the temperature.

8) Spark time is always retard about 8° ~12° with knock sensor error. In this case, not only the power but also fuel economy is getting worse.

7.2 Reason to use knocking sensor.

1) No need to change spark time by different fuel (Octane number)

One of reason to use knock sensor in the vehicle is to increase power and protect the engine form the knocking. But big advance for developer is that they can use any octane number of fuel. Without knock sensor, spark time have to be adjusted depending on each market's octane number. But no need to do it with knocking sensor.

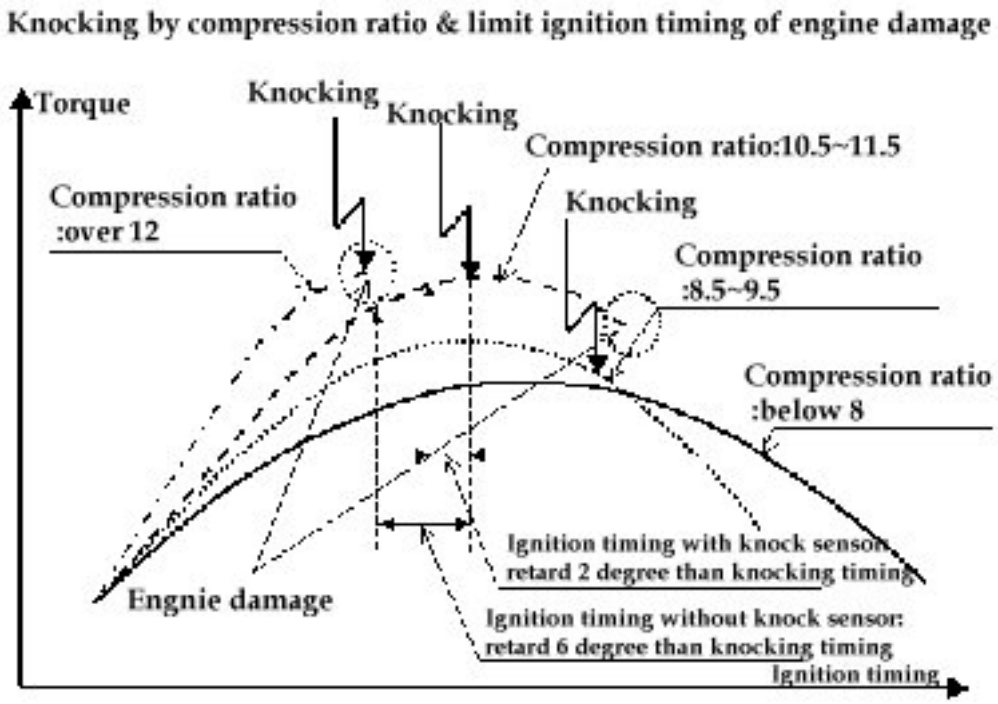
Reference: Octane number is the number that indicates suppression of knocking. And if this value is big then less knocking is occurred.

The knocking level is 100 when we use octane (C8H18) fuel. So, below 100 means more knocking and over 100means less knocking.

Domestic fuel's octane number is 92~93.

In case of diesel fuel, cetane number is used to indicate knocking level. 100 is when we use cetane (C11H24) as fuel. Domestic diesel fuel is about 52~54.

2) Increase engine endurance.



Current compression ratio is mostly over 10. And there is a case that increase compression ratio up to 13. But in the past, even 9 was very high with carburetor engine. The reason of high rate is that first this is not ignition control type and second, knock sensor is used.

With low compression ratio, knocking has not so much severe on engine. That means, even with pre-ignition before TDC, cylinder pressure is not increasing so much. But with high compression ratio, engine will be damaged. In worse case, it makes hole in the cylinder head or piston. If ignition angle is adjustable and if spark is advance by mistake then engine can get big damage. Therefore, ignition time is set by ECU and not adjustable.

3) Increasing engine torque : But the engineer who know knocking control by electric control unit will say “if engine is normal” for this point. Because spark can be retarded with knocking detection. Then how can knocking sensor increase torque instead of to decrease.

7.3 Engine torque reduction by knocking sensor

ECU algorithm was made to accept knock signal when knock is occurred and it is defined by frequency. If natural vibration of engine is identical to frequency range of knocking, we can not distinguish it. Therefore, Knocking is detected when engine vibration is severe with bad oil before engine running in. And spark time is retarded and additional fuel is provided to prevent exhaust gas temperature increasing by retard.

And finally engine torque will decrease due to spark retard and fuel economy will getting worse due to additional fuel to improve engine torque.

The reasons of this problem are as followings.

1) Engine vibration before first engine run in is detected as knocking.

2) Engine vibration by bad cylinder distribution is detected as knocking. If engine oil gas into the engine is not distributed equally to each cylinders, engine vibration is generated due to different combustion power of among each cylinders that have different air fuel ratio at each cylinders. If the vehicle has cylinder distribution problem from the factory, then this vehicle will detect always knocking due to different air fuel ratio of each cylinder.

3) The ignition energy is not enough and Engine vibration due to different combustion power is detected as knocking..

4) Engine is aged and engine vibration due to different compression ratio among the each cylinders is detected as knocking.

Most of time, it is difficult to define the spark retard by knocking detection due to engine vibration. Because it is not well coming to the surface and driver or even technician treat the vibration as normal condition. And as we don't know how much is normal power, we don't know how much engine power is decreased.

Therefore, if engine sound and vibration is rough then you can suspect that spark is retarded too much by knocking detection

As a reference, spark retard by knocking detection and by adaptation is decided by engine speed and air quantity at the point of knocking. It is calculated by ECU but is not shown by scanner.

In my case, the reason is to avoid the trouble with customer. If customer or technician asked to me that "There are so much spark retard by knocking. Why knocking is occurred so much?" then it is very difficult to explain the above 4 reason of engine vibration and even we know the reasons, we can not fix it. So, it is better not to show it.

Then what technical can do to for this problem? This is same question as "How can we improve that engine is revolving well.?" and the countermeasure is also same. To fix engine balances and to improve engine conditions to get good combustion is the direction of maintenance.

It is difficult to get countermeasure about the problem that is not showing any abnormal conditions externally.

As remarked, knocking sensor seems to be not a interesting one to driver or technician, but if engine condition is not good then it is possible to suspect that power and fuel economy reduction by spark retard with knocking detection.