Course Name: Engine System and Performance
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Week - 06
Lecture – 17

Lec 17: Manifold Absolute Pressure sensor (MAP) and Throttle Position Sensor (TPS)

I welcome you all to the session on engine system and performance. Today, we shall discuss two different types of sensors. If we try to recall, in the previous class, we discussed the need for a sensor in the engine management system. We also talked about the input to the sensors and the output from a sensor. We also discussed two important sensors in the previous class. In line with our discussion from the previous class, today we shall focus on this sensor: the manifold absolute pressure sensor.

This sensor is a key sensor for the engine, particularly for modern engines, because it senses load. You all know that the load of an engine is very vital because the power produced by an engine must be capable of meeting the demand or load of the engine. So, if we need an engine that can meet variable demand—whether it is a stationary engine or part of a locomotive system— the engine must have the capability to produce or meet variable load. We all know that if the load increases, the engine must produce more power to maintain constant speed.

We can discuss this with an example. In one of the previous classes, we saw that if an engine runs at 50 kilometers per hour on a straight road, then suddenly encounters an uphill, the speed will reduce. However, this should not be the desirable feature of an engine. When the engine experiences more load, it needs to adjust speed because the speed will decrease. But, as I mentioned, this is not desirable. So, the engine must produce more power to meet that additional load.

How come an engine can have more power output? Certainly, we need to ensure that the rate of combustion will be higher. If we need to have a higher rate of combustion, we need to ensure that the air-fuel mixture—whether it is an SI engine or even a CI engine or a modern SI engine—the amount of air and fuel introduced into the engine cylinder should be increased. So, that information should be communicated. to the engine, and that information should be sensed by the electronic control unit or engine management system. Then, the electronic control unit or engine management system will provide feedback to specific parts of the engine block so that the engine can run at a designed speed when the situation demands it.

For the air—whether it is a CI engine, a modern SI engine, or an old SI engine—the air-fuel mixture supplied to the engine should be increased. So, now let us examine that particular case. This particular sensor, the manifold absolute pressure sensor—commonly called the MAP sensor— So, what will happen?

Essentially, if we need to supply more air, only then can we supply more fuel by adjusting the fuel timing, valve timing, or by controlling the fuel injector valve. Now, the question is: we first need to ensure that an adequate amount of air is present in the engine cylinder to meet the additional load. Air should come through the intake manifold, meaning if we have a sensor that can detect the vacuum inside the intake manifold—as you may recall from your basic undergraduate internal combustion engine course, even with a simple venturi—when there is a suction stroke, the piston moves from top dead center to bottom dead center, creating a vacuum inside the engine cylinder. The outside ambient pressure causes a pressure difference, which drives airflow into the intake manifold. This means a sensor should detect the vacuum inside the intake manifold and relay that information to the electronic control unit. If there is more vacuum, we need to supply more air.

So, that information will be received by the ECU through the use of a manifold absolute pressure sensor. Then, the electronic control unit or ECU will give some input or information to the fuel injection system to supply an additional amount of fuel so as to maintain a proper balance between air and fuel—the air-fuel ratio. So, let us now look into this particular schematic depiction, and then we shall discuss the operational procedure. Now, the question is: we all know that when the engine is working hard, what does it mean? So, when the engine is working hard, that means we need to supply a greater amount of air.

That is, the engine working hard means the engine is producing more load. The engine is experiencing more load; the engine is developing more power. If we need to supply a greater amount of air, that means that information should be sensed by this manifold air pressure sensor. So, there will be a greater amount of air, which means there will be a greater pressure difference for a given throttle position. So, if we need to have a greater pressure difference, the vacuum will be greater because atmospheric pressure is constant.

So, that sensed information should be detected by the sensor for a given throttle position, and it will go to the ECU. The ECU will now give some input to the fuel injection system to supply an additional amount of fuel. Typically, that means sensing the vacuum in the intake manifold, the ECU will give some feedback to the fuel injection system to supply an additional amount of fuel—that means fuel enrichment is needed. And always, the manifold air pressure sensor, tries to provide fuel enrichment because that will somehow help the engine to produce more power. Now, the question is: In such a case, when the engine is working hard, a greater amount of air should be introduced into the engine cylinder, and that information will be sensed by this manifold air pressure sensor.

The ECU will sense that and will give feedback to the fuel injection system to supply an additional amount of fuel. There should be a question. The moment when the engine is getting more fuel, that is fuel enrichment. Another problem is the detrimental effect, which is the knock or detonation. So, then simultaneously, the ECU has to give some input to the ignition system to back off or to retard the ignition timing.

So, these things are done by the ECU or EMS (Engine Management System) simultaneously. Before discussing the operational procedure and using this schematic definition, what is the operational procedure? This sensor generates or produces a signal. Any sensor that we have discussed in the previous class—any sensor output—is an electrical signal, a voltage signal. So, like other sensors, this sensor will generate a signal that is proportional to the amount of vacuum in the intake manifold.

That is proportional to the amount of vacuum in the intake manifold. So, this is the basically important aspect. Based on this, this particular type of sensor works. Now I have given you an example. If we now focus our attention on this particular schematic deflection, just to illustrate the operational procedure of this, what we can see from this type of sensor—as I said—is that this sensor works purely on the amount of vacuum produced inside the intake manifold. So, if we look at the left-hand side of this schematic deflection, we can see that there are two different chambers. If we look at the top chamber, this chamber is basically known as the vacuum chamber.

So, this is a vacuum chamber, and this part is connected to the intake manifold. While the lower one is known as the reference air chamber. That chamber is either sealed or vented. Even if it is sealed, it contains atmospheric pressure.

If it is vented, there is no point in discussing this because it would be open to the atmosphere. Now, these two chambers are separated by a diaphragm.

So, this is a movable diaphragm. Now, you can see that this diaphragm can move depending on the pressure difference. The bottom chamber is the reference air chamber, which always has some absolute barometric pressure. That is set before this sensor starts working. On the top, the sensor is basically a vacuum chamber, and this part is connected to the intake manifold to measure the extent of vacuum in the intake manifold. So, when there is a vacuum, you can certainly understand there will be a pressure difference because this is atmospheric pressure. That movement is recorded by this pressure-sensitive electronic circuit. So, if I now again mark it, this part is pressure-sensitive. The electronic circuit is basically called pressure-sensitive because the movement of this diaphragm is solely due to the change in pressure. The sensor's electronic circuit will monitor the movement of this diaphragm and produce a signal. The rate of voltage that will develop will depend on the change in pressure. Let me repeat it once again. There is a pressure-sensitive electronic circuit. This circuit is responsible for monitoring the movement of this diaphragm.

This diaphragm separates these two chambers. The upper one is connected to the intake manifold to measure the extent of vacuum in the intake manifold, while the lower one has vacuum. Atmospheric pressure. So, this lower chamber is known as the reference air chamber. Filled with air, it may either be sealed or have a vent to ensure it is open to the atmosphere.

Now, by monitoring the movement of this diaphragm, this circuit will produce a voltage signal proportional to the change in pressure. This signal will be sensed by the sensor and will be sent to the ECU, or electronic control unit, which will then provide information to the fuel injection system to supply additional fuel to maintain balance or a stoichiometric air-fuel ratio as much as possible. The vacuum chamber is connected to the intake manifold through a rubber hose and this chamber will somehow indicate the extent of vacuum in the intake manifold—number one—and the movement of the diaphragm. So, this MAP sensor monitors the movement of the diaphragm and generates a voltage signal proportional to the change in pressure. The voltage signal generated by this sensor is an analog signal. So, if I go to the next slide. The voltage signal is an analog voltage signal (typically 1 to 5 volts).

So, if we go back to this schematic depiction, this pressure sensitive electronic circuit will monitor the movement of the diaphragm Since the movement of the diaphragm is proportional to the change in pressure, in a way, that sensor is sensing a change in pressure between these two chambers. And that information, that sensor will produce a voltage signal that is essentially an analog signal, which is proportional to the change in pressure. And its value is typically 1 to 5 volts.

That information will go to the ECU and then ECU will give some feedback to the fuel injection system to supply additional amount of fuel depending on the requirement. The idea is that if more amount of air is coming because of more vacuum inside the intake manifold then to burn that amount of air we need to supply additional amount of fuel because essentially if the engine load becomes more so speed has to be more and then will be more vacuum created inside the intake manifold that means maybe will be the engine will be receiving more amount of air but to burn to have efficient combustion with the presence of that additional amount of air additional amount of fuel should be supplied and that is what is done by the sensor. Now, this sensor is known as reference air chamber. So, this MAP, that is manifold air pressure sensor, first registered barometric absolute pressure, which is known as BAP, to set the reference point.

Because if we do not ensure that MAP will register barometric absolute pressure as a reference point, then the movement of this diaphragm will be erroneous. And hence, the signal that would be generated by this circuit would be erroneous. So basically, if we need to calculate the load properly, always we need to ensure that this particular sensor, that is MAP, will register barometric absolute pressure as the reference point, and that is why it is known as reference air chamber. So, this is all about manifold absolute pressure sensor.

Now we shall discuss another important type of sensor in today's class, that is the throttle position sensor. So, this sensor, which is also known as TPS, is very common. In fact, almost all engines have this sensor. From the name itself, you can understand its sole purpose is to control the throttle position opening area using this sensor. So, in a way, that until now, we have discussed the manifold air pressure sensor. For a given throttle position, if there is more vacuum inside the intake manifold, more air will be introduced. To have efficient combustion, we need to supply additional fuel to justify the additional air supply.

Now, this sensor is basically used when there is a need to control the throttle position opening. TPS, throttle position sensor—is used to inform the engine control module or ECU about the accelerator pedal and throttle plate position. So, if we look at this particular part, that there is a pedal. As the accelerator pedal—we all know in a vehicle—is pushed, the throttle plate opens, thus rotating the sensor's internal variable resistor.

Basically, when the accelerator pedal is pushed, it opens the throttle plate more, which in turn rotates the sensor's internal variable resistor. As the internal variable resistor changes due to the change in throttle plate opening area, that will be sensed by the sensor.

Now, as the throttle opens, the voltage—if we go back to the previous slide, what we can see— as the pedal is pushed it will open the throttle plate and which in turn will try to rotate the internal variable register of the sensors which in turn will produce a signal so that means as the throttle opens a signal will develop a signal will be produced and that signal as the throttle opens voltage signal will be produced which in turn will provide a signal about the rate of throttle opening as well as throttle position. So, this is very important. So, basically what we can see that a voltage will be produced if we go to the previous slide. What we can see as the accelerator pedal is pushed that will open the throttle plate that will change the throttle plate position which in turn will create to rotate the sensor's internal variable resistor. Essentially, we will be having a voltage output.

So, if you go to the next slide, already I have written. So, that means as the throttle open, voltage signal will be produced, which in turn will give some signal about the amount of or the rate of throttle opening or degree of throttle opening as well as throttle position. Now, this signal will be sensed or this signal will be sent to the ECU or electronic control unit. Then, electronic control unit will try to adjust again the valve timing, which is there in the fuel injection system. So, essentially, the moment we are trying to have a control over the throttle position, we are trying to have the control over the mass of air to be drawn into the engine cylinder.

So, when there is a change in mass of air to be drawn into the engine cylinder, to utilize that additional amount of air, we need to supply additional amount of fuel. Otherwise, the introduction of additional amount of air into the engine cylinder will not be justified. So that is what about this particular sensor's operational procedure. Now question is, what about the voltage?

The output voltage is 0.45 volts for fully closed throttle and 4.5 volts for wide open throttle wide open throttle. So, now question is, this is the range. So, if the sensor receives a voltage signal around, say, having magnitude 4 volt, that means it is close to the wide-open throttle. So that means that information will receive by this TPS, go to the ECU.

ECU will try to have a control over the valve timing, valve of the fuel injection system, so that fuel enrichment can be done, additional amount of fuel can be supplied, so as to maintain a balance between air-fuel ratio. Now, question is the signal that will be produced by this sensor is to be converted to the digital one. So, there must be a low-pass in filter essentially to, filter out any noise that is very likely to be there. And if the noise is there, then output voltage will be a radius. And essentially, information that will receive by the ECU will be erroneous. ECU will try to give again some wrong information to the valve of the, fuel injection system. So, see this low-pass filter, TPS voltage is to be converted to a digital value and to do this we need a low pass filter essentially to remove any noise. That will otherwise prevent.

The Analog to Digital Converter for obtaining an accurate result. So, essentially, TPS voltage, which is again an analog voltage, should be converted to a digital value. For that, we need this low-pass filter to remove any noise that would otherwise prevent the conversion, and we would not be able to get correct or accurate results. So, if we now go back to the schematic depiction of the circuit, what we can see is that there is, throttle position sensor, so essentially, that using the sensor, the engine tries to measure the throttle position. That information or that signal goes to this electronic computer, the ECU and accordingly, the ECU will set up some correction so as to ensure a little more or a little less. The valve opening of the fuel injection system, that information will go to the fuel injection system so that the valve timing or valve opening area can be controlled.

Now, to summarize today's discussion, we have discussed two different types of sensors: the manifold absolute pressure sensor (MAP), which is a key sensor for any engine—or, for any modern engine. Because it senses the load, and we have also discussed the throttle position sensor (TPS), which is present in almost every engine. Starting from their necessity in modern engine systems or electronic control units to their operational procedures, we have tried to cover them in today's class. So, with this, I will stop here today, and we shall continue our discussion in the next class.