Course Name: Engine System and Performance
Professor Name: Pranab Kumar Mondal
Department Name: Mechanical engineering
Institute Name: Indian Institute of Technology, Guwahati
Week - 08
Lecture – 28

Lec 28: Introduction to Engine performance and its measurement

I welcome you all to the session of engine system and performance. And the topic of our today's discussion is engine performance and its measurement. In our last few classes, we have discussed about engine control system. Specifically, our discussion was on electronic control unit and its several components, several aspects. And we had seen that for all modern engines electronic control unit is essential and it is because of this unit only it is possible to run engine with maximum efficiency and that too emission level also can be reduced. But what we have understood is that the functionality of electronic control unit depends on, the input from several sensors and all these sensors are responsible to give some feedback to electronic control unit. Receiving feedback, electronic control unit or ECU directs several parts of engine to have adequate or stoichiometric air flow ratio to be discharge or to be drawn into the engine cylinder. Now, in line with this, today we shall try to discuss about engine performance because essentially at the end, we need to look at the performance of an engine and we need to certify the engine performance.

So, we need to measure engine efficiency and if we need to certify engine performance certainly. It depends on the measurement of a few quantities. So, let us discuss today what it is all about and then thereafter we shall discuss about measurement of a few important parameters. So, this engine performance is a relative term and it means how well an engine is doing its job with respect to input energy.

We all know by this time is that, an engine can operate only after receiving some input energy in the form of fuel. I mean, in the fuel itself, chemical energy is stored. At the cost of that input energy, the engine performs some work, and we get some energy output. Now, the question is, to have or to establish the performance of an engine, we need to measure the output. So, how well an engine is doing its job with respect to input energy is, essentially what engine performance is. Sometimes, we need to know what the best an engine can deliver in terms of energy or power output compared to other comparable engines.

So now the question is: whenever we talk about any particular engine or any engines, we see that a particular engine can operate within a range of speeds. At each and every speed within this range, the power output will vary. With a maximum power—that means an engine can operate within a range of speeds, and at each and every speed within this range, the power output from energy output—will vary, and there will be a maximum value of this power output. The question is, though the maximum power will have a unique value—that is, the maximum power.

But even though the power produced by the engine would be maximum, the power available at the shaft—that is, the usable power. So, the ratio of the power developed by the engine to the maximum usable power is known as load percent.

So, this is what we can tell, so this load percent will certainly, is not equal to the maximum power that would be developed by the engine. So usable power that is the power available at the shaft is not equal to the maximum power. So, what you can understand though a particular engine is operating within a range of speed and at each and every speed the power will vary, maximum power will be different, but the load percent will also be different.

So certainly, the performance of an engine, the performance of an engine is dependent on the relationship between the power or among the power developed specific fuel consumption within the useful range of speed and load. So, we are talking about engine performance, though engine can operate within a useful range of speed, but each speed there will be a maximum power and ratio of maximum power or ratio of power developed by the engine to the maximum usable power is the load percent.

So, certainly if we try to vary the speed that will change, if we vary the load that will change, if we even change this fuel supply or specific fuel consumption. So, speed specific fuel consumption, all these things are interrelated essentially for the performance of the engine. So, engine performance is very important term and if we need to predict the performance of an engine we need to know all these quantities. So, now, if we go to define engine performance parameter, typically what we have understood from our previous slide is that the engine performance depends on the speed, specific fuel consumption and the power developed.

So, even if we see that the power developed by an engine is high, we cannot say that at the cost of the same input energy, even if we keep the speed the same, the performance should be very high. So, we need to consider many things, such as speed, load, specific

fuel consumption, and power developed. Now, there are a few parameters used to measure engine performance, and those parameters are basically speed, load, air and fuel consumption, fuel consumption rate, and finally, the pollution level.

So, knowing all these quantities, we can tell something about engine performance. So, what we need to do is measure or know the measurement techniques of all these quantities to certify or annotate the performance of an engine. Now, the question is, in addition to these four quantities, another important quantity closely related to engine performance is the pressure variation in the cylinder.

So, this is also a very important quantity to know. If we do not know the variation of pressure, it is very difficult to tell about the power developed. Though we can measure speed, load, air-fuel consumption rate, and to some extent, I will discuss the pollution level if time permits. But the question is, the pressure variation inside the engine cylinder is very important to know.

Probably if you try to recall we all have studied, the variation of pressure, temperature etc. inside the engine cylinder in the context of auto and diesel cycle. We had seen that pressure is continuously varying, temperature is continuously changing in the pressure temperature of the charge or combustion gases or the air fuel mixture. So, depending on the cycle, so if it is intake stroke certainly it is the pressure and temperature of the charge or air fuel mixture, if it is in the power stroke then certainly it is the pressure and temperature of the combustion gases.

Now, the question is we need to measure the variation of pressure, because pressure is directly related to the power that we could calculate. To establish thermal efficiency of auto and diesel cycles. Now, the pressure variation is important to know because it has some relation to know about the combustion processes. Knowing the variation of pressure, we also can measure the instantaneous rate of heat transfer. And also knowing the pressure histograms, we can tell about the knock characteristics of the engine.

So, that is why this quantity is very important to know. Because this quantity, pressure is important to know the combustion process. 2) is heat transfer rate and 3) is knock characteristic. So, all these three important quantities or aspects can be studied by knowing the pressure variation. So, in addition to these quantities we also should take into account the variation of pressure inside the cylinder and certainly if there is any specific technique or method available to know the variation of pressure inside the engine

cylinder. So, now question is if we go to the next slide what we can say in order to quantify the performance of engine.

So, in order to quantify the performance of an engine. All this speed, load, air and fuel consumption rate, pressure variation inside the cylinder, and pollution levels. All these important quantities, need to be measured. So, quantities such as speed, air fuel consumption rate, pressure variation inside the cylinder, and pollution levels need to be measured. So, let us first consider the measurement of speed.

We have to measure speed, load, air and fuel consumption rate, and then we also need to measure pressure variation and pollution level. So, first, let us discuss the measurement of engine speed. So, probably we know by this time, rpm is used to measure the speed of rotation of the shaft. We know that rpm is a measure of the frequency of rotation. It denotes full completion. It is the measure of the frequency of rotation because we need to know the speed.

So, the speed of the mechanical component, which is the output shaft of the engine. So, a reciprocating piston-type engine, the reciprocating motion of the piston is converted to rotational motion, which is available at the shaft of the engine—the external shaft or output shaft of the engine. So, if we need to know the RPM of the shaft, we can certainly quantify the speed of the engine. So, RPM is a measure of the frequency of rotation, and it denotes the number of full rotations completed in one minute around a fixed axis.

So, essentially, RPM is used as a measure of the rotational speed of a mechanical component, like the output shaft of an engine. So, if you go to the next slide, RPM is used as a measure of the rotational speed of a mechanical component, like the output shaft of an IC engine.

It is not necessarily that RPM would be used to measure rotational speed only of the output shaft of an IC engine, but rather any mechanical component that is turning or rotating. If we need to measure the rotational speed, RPM can be measured first, and RPM can be counted, and that RPM is used to measure the rotational speed. So, now the question is: We know by this time—in fact, we have studied from our previous classes—that nowadays, it is possible to have advanced sensors.

So, it is possible to have all these, high precision and low-cost sensor because of the advancement of digital technology. So, sensors are used to sense the speed. So, if we need to measure the RPM, we need to have a few sensors. So, devices which are used to

sense the speed or RPM of the mechanical component, typically devices used to measure rotational speed are: number one is encoders, number two is photoelectric sensor. That is optical type. Depends or works on receiving lights only. Number three is magnetic rotational speed sensor, this is proximity type. So, all these sensors or devices are used to sense the speed essentially to predict or quantify the rpm. So, all these devices are used to measure the speed or rotational speed of any mechanical component which is turning. So, if you go to the next slide what you can understand that measurement of rpm essentially depends on the sensors and all these sensors send data in the form of electric pulses mean the speed of rotation, which is mechanical motion. That mechanical motion should be converted to electrical pulses using these sensors. The sensors that we have discussed in the previous slide send data, which is essentially mechanical motion in the form of electrical pulses.

So, that means these RPM sensors convert mechanical motion into electrical pulses with or without contact even. That means it is not necessary that the sensor has to attach or should be attached to the shaft. When the sensors are brought near a turning shaft, then only that sensor can sense the speed and measure RPM. So, if we can measure RPM, then we can certainly measure the speed of the shaft. So, RPM sensors convert mechanical motion into electrical pulses with or without contact. It is not necessary that the sensor should be in touch with the mechanical component or mechanical parts that are rotating.

Now, the question is, so the sensor will receive some signal, mechanical motion, then we will convert it to electrical pulses. Finally, these resultant output signals are then fed to a digital counter, totalizer, tachometer, or other controlling stroke monitoring device. So, essentially, you can understand that mechanical motion should be converted into electrical pulses by the sensors or RPM sensors, and the resultant output signal will then be fed to the digital counter, then totalizer, tachometer, etc., for final monitoring, controlling, or counting.

So, to this end, let us first discuss the tachometer, which is used to measure RPM. So, if we go to the next slide, we can see the measurement of engine speed using a photoelectric tachometer. So, if I tell you something about this particular device, it is not that we always need to use a photoelectric tachometer; we can also use a mechanical tachometer. So, perhaps by now that tachometers are used to measure rotation speed of any mechanically moving component that is turning or rotating.

Now, the question is: this tachometer can be a photoelectric type. And it can also be a mechanical type. So, mechanical tachometers—perhaps you have studied—are used in several other cases, perhaps when you have tested. An internal combustion engine, perhaps you all had to measure the speed of the engine by varying load.

So, essentially, what you had to do was vary the load and measure the speed to obtain some performance curves of the internal combustion engine. So, during this test, we all had to use a tachometer to measure the rotational speed of the shaft, and mechanical-type tachometers utilize the fact that. The centrifugal force on the rotating mass depends on the speed of rotation. So, that is what it is.

Now, the question is: we will be discussing the photoelectric-type tachometer in today's class, and this particular type of tachometer depends on light. So that is what we will discuss today. Receiving light (works using light). So, if we look at now the schematic depiction of this particular device, which is used to measure the speed of internal combustion engine, rather shaft of the output shaft or external shaft of the engine.

Let us now discuss about the procedure of measuring RPM using this device. So, what you can see from the schematic depiction is that, so this is essentially engine block and you can see that the shaft of this engine is now connected to this disk. This disk is not an ordinary disk rather this disk is opaque. So, disk is mounted on the shaft of the engine. So, when shaft is rotating disc also will rotate but the special feature of this disc is opaque and has a few holes and holes are equidistant around the periphery. And construction is such that in one side of the disk, we can see there is a light source. This particular type works on using light or if we need to use this particular type of tachometer to measure RPM, certainly we need a light source because this particular sensor, RPM sensor needs light to generate electric or electrical pulses. So, this opaque disk is rotating continuously because disk is connected to the shaft.

The disk has a few holes around the periphery, and the holes are equidistant. On one side of the disk, there is a light source, and on the other side, there is a light sensor. This light source and light sensor, along with the disc arrangement, are such that the light source, the center of the hole, and the light sensor are aligned with each other. Construction-wise, the disc is fabricated with all the equidistant holes in such a way that the light source, the center of the hole, and the light sensor are aligned. The light source, the center of the hole, and the light sensor are all aligned with each other. So, when the disc is rotating, the

hole and the opaque part will appear alternately between the light source and the light sensor.

Now, when the hole appears, and the hole center, light source, and light sensor are aligned. Light will pass through the holes onto the sensor, and when the sensor receives light, it will generate electrical pulses. Now, the frequency—since we know the number of holes— and if we need to measure the speed of the shaft, there is a relation. This is the operational principle or procedure for measuring RPM using this particular type of tachometer.

So, what is the situation? Only when a hole appears between the light source and the light sensor, will light pass through the holes onto the sensor. But when the opaque part appears in between—because it is continuously rotating—no light will pass, and the sensor will not generate any electrical pulse. If we measure the frequency, so when light passes onto the sensor, through the hole, an electrical pulse is generated. When the opaque portion or part comes between the light source and the light sensor, no pulse is generated. So, using this, what we can say is the frequency of the pulses. Now, the frequency of the pulses generated because of this particular phenomenon—the frequency of these pulses depends upon the number of holes and the speed of rotation of the disc. Using the relation that is speed N

$$N = \frac{f}{H}$$

So, this H is the number of holes, and f is the frequency of pulses. So, because we know the number of holes, we can count the frequency of pulses being produced by the light sensor. Then certainly, we can use this relation to calculate the rpm of the disc, which is equal to the rpm of the shaft itself. The number of these pulses—so we need to know the frequency of the pulses, that is, the number of pulses we need to measure. We can also measure the time.

So, the number of these electric pulses or the number of these pulses, is measured with the help of an electric counter, which is a measure of the speed of the shaft. Following this relation. So that means we can use this particular type of tachometer to measure the speed by calculating the number of pulses, which can be measured using an electric counter. With the advent of digital technologies, it is possible to measure so many things with low-cost and high-precision sensors.

So, to summarize today's discussion, we talked about engine performance and saw why it is so important. To quantify engine performance, we need to measure a few quantities or parameters. We saw what those parameters and then discussed the measurement of an important parameter: engine speed. We discussed the tachometer, which is used to measure engine speed in modern engines.

So, with this, I will stop here today, and we shall continue our discussion on measuring several other parameters in the next class.

Thank you.