Course Name: Engine System and Performance
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Lec 24: Electronic ignition system

You all are welcome to the session of engine system and performance. Today we shall discuss about electronic ignition system. And before going to discuss about this particular topic that is electronic ignition system, let us first discuss or recall conventional or battery ignition circuit which was used to produce energy to produce spark. So, if we look at the block diagram or schematic depiction of the ignition coil, that is battery ignition coil, we can see there are several elements or components. And we can see that this is essentially a battery.

So, if we write this battery is basically 10 to 12 volts. We have ignition switch here. And then this resistor is provided to the circuit. And we can see that there are two different circuits in this coil or two different coils rather in the circuit, whatever you'd like to tell.

So, this is primary circuit and the upper one that this coil or circuit is the secondary circuit. So, we can see that there are two coils, primary coil and secondary coil. If we look at the components which are there in the right-hand side, these are the breaker points and these opening and closing of this breaker points are done using this breaker cam and this cam is essentially connected to the engine shaft and in tune with the engine speed, this cam will rotate. This cam breaker will rotate, and it will be used to open and close the breaker points.

While we can see that this is the primary coil, so this is primary coil, ignition coil rather, and the upper one is the secondary ignition coil. And the secondary ignition coil is connected to this distributor shaft. So, this is distributor unit, which is having a distributor shaft. So, this is again distributor cam.

So ideally this would be connected to one of the this point and when this cam will be rotating. Again, this cam is connected to the engine shaft and when the cam is getting connected to these points in a cyclic manner, when it is connected to the upper point, then this point is getting charged and energy is going to the spark plug. If it is a multi-cylinder engine, then essentially the energy will be going to all the spark plug of all cylinders.

Now let me discuss about the functioning of the circuit first and then probably we'll see what are the limitation of this and what is the need of electronic ignition system. So, when these breaker points are in contact, so closed to be precise, and if we switch on or if we turn on the switch, so this is ignition switch. Ignition coil switch, so when the breaker points are closed and if we turn on the ignition switch a battery current not try will flow through this primary coil and it will essentially go to this condenser. So, this is the condenser and condenser will be charged. So, breaker points are closed if we turn on the switch the battery current will flow through the circuit and it will essentially go to this condenser to charge it. Now when a current is flowing through the primary coil then a magnetic field will be induced right and because these are the coils. These coils are made of iron core and the iron core is wound with copper wire. So, these are basically primary and secondary coils. Now, when a magnetic field is getting induced during that building process, the induced magnetic field will cut the primary winding, and that process will create a back EMF, and that EMF will again resist the primary current, which is the battery current. So, when we turn on the switch, a battery current will flow through the circuit. When the current is flowing through the circuit, this coil is made of an iron core, and the iron core is wound with copper wire. A magnetic field will be induced, and that magnetic field will create a back EMF.

Back electromotive force, and that back EMF will try to oppose the primary current or battery current, delaying the building process. Now, this magnetic field will essentially expand. So, the magnetic field will expand, and upon expanding, it will cut the primary windings, and then back EMF will be developed, which will oppose the primary current flow. So, if we look at or try to draw the development of the primary current with time—if this is time *t*, and if this is primary current—then essentially, it would be delayed. So, if we take the slope from there,

So, this is basically the building-up process. Now, the question is, these breaker points are closed and opened by a cam, and that cam is rotated by the shaft, which is connected to the engine shaft. So, the cam will again—if the battery point, these breaker points are, getting disconnected— So, if we open the breaker points, then what will happen? Whatever magnetic field was induced in this ignition coil, that magnetic field will collapse suddenly. And because of this collapsing magnetic field, a current will be induced again. This is electromagnetism. The current will again try to flow in the primary circuit. So, when the breaker points are closed, then also a current is flowing through this primary circuit, which is the battery current.

If we open these breaker points, again current will flow in this primary coil or through the primary coil, that is because of this induced magnetic field. And that current also will try to charge the condenser. Now, what we see, the moment we close the breaker points, the magnetic field will collapse suddenly. and then this current will drop. So, this process, when the magnetic field is induced here, because of this battery current flow, that also will try to produce some emf in the secondary coil.

But that emf or that voltage is too low for a spark plate to produce a spark. But when the magnetic field that would be induced here, that induction of magnetic field will try to create or that will develop a back EMF. That EMF will try to oppose the primary current flow. And when we open these breaker points, magnetic field will collapse suddenly.

It is because of this collapsing the magnetic field; another current will flow and which is in the same direction of the primary current or battery current. And that sudden collapsing of magnetic field also will create huge voltage in the primary circuit or primary coil and even higher voltage in the secondary coil. So, because of this collapsing of magnetic field, the EMF or voltage will produce in the secondary coil is of the order of 10 to 20 kV. EMF/Voltage that will develop in this secondary coil due to collapsing of the magnetic field. This magnetic field is induced.

So, because of this collapsing of the magnetic field, voltage that will develop in the secondary coil is of the order of 10 to 20 kV. As such, this much voltage is needed. If we now draw the spark plug is like this. The gap in the spark plug, see the small gap is 1 to 1.5 mm. spark gap.

So, this small gap if we need to break the resistance of this small gap we need this much or high voltage 10 to 20 kV. So, try to understand using the battery voltage which is 10 to 12 volts small emf or voltage we could produce a significantly or significant voltage in the secondary coil or significantly higher voltage in the secondary coil, which is 10 to 20 kV and this is needed to break the resistance of this gap so that spark will be produced in the spark plug and that will be used to ignite the combustible mixture or fuel air mixture in the engine cylinder. Now so what we can understand from the circuit is the primary coil is the main coil for this and the breaking of the primary coil so essentially, we need to turn on the ignition switch when the breaker points are closed then only a current will flow and it will develop. All this initially a back emf magnetic field and then again need to collapse the magnetic field by using this breaker points so breaker points are responsible to close the primary coil and also to break the primary coil

So, closing and breaking the primary circuit is done by the closing and opening of the breaker points. Now, the breaker points opening and closing this process is done by this cam and which is connected to engine shaft. So, any mechanical device, any mechanical component is having some inertia over and above. If engine speed increases, then this closing opening time will be very less.

So that duration between two consecutive closing and two consecutive opening will be less. And if the closing and opening time becomes lesser, then you can understand the current or voltage that will produce in the secondary coil may not be that much high. So, because it takes some time for the development, again you need some time for the collapsing. So, that means you can understand that this much time is needed for the development and this much time is needed for the collapsing. So, this is t_1 and this is t_2.

Now, if t_1 and t_2 are getting reduced because of the engine speed, then the energy that would be available at the spark plug will be less to produce a spark. And hence, it would be very problematic for an engine to operate. Another question is, higher engine speed. So, it is well known that number of faults or spark, I can write spark produced per second is proportional to number of or number of sparks produced per second, or proportional to the engine speed. What does it mean? It means if we increase the engine speed, then number of sparks to be produced per second will be more so basically question is if we look at this this battery ignition coil is so long as the engine speed is low, so if the engine speed is not very high say for example up to 3000 rpm this particular ignition coil is reliable and cost-effective. Because you can see there, in this circuit, we have the primary coil, distributor cam, resistance, and breaker points, but we don't see any very costly elements or components attached to the circuit. So, if the engine speed is up to 3000 rpm.

Then, battery ignition coil is reliable as well as cost-effective. But the question is when engine speed is very high, say for example in racing cars, engine speed is very high and even beyond 5000 rpm, then this particular coil or circuit encounters a few problematic issues, mostly related to inertia. Because you can understand, this cam is driven by a camshaft which is connected to the shaft of the engine, and any mechanical component or device has Some inertial impact or issue. As a result, the closing and opening of the breaker points will be problematic in producing sufficient energy needed to develop a spark by a spark plug. So, if the engine speed increases, this would be so fast that the primary coil. There will be some current flow through the primary coil, but the collapsing of the magnetic field will not be proper, or it will be delayed, or even the building process will be delayed.

So, these two-process building of this current which is flowing through the primary circuit that is building of the current as well as collapsing the current, because of this collapsing the magnetic field will be delayed which in turn will delay the rather which will turn will produce some problems to develop high voltage in the secondary coil. And you can understand if the voltage is not proper, then it is not possible to break the resistance in the gap, small gap which is needed. On the other hand, nowadays the demand is as such this problem becomes even more acute on engine that demands high number of sparks per second.

For say, for example, for high-speed engine. And also, for engine that multi-cylinder two-stroke engines. In those cases, the number of sparks to be produced per second is more. And such a scenario, this battery ignition coil is not suitable. Another important issue is, nowadays, the trend is to have a transitioning from the stoichiometric burn engine to the lean burn engine. So, this is the modern trend. This modern trend is quite realistic because if we try to shift from a stoichiometric burn engine to a lean burn engine, then the requirement of fuel will be less. And if the requirement of fuel is less, emission will be less.

So, we can have highly efficient engine. So, if we need to shift from this trisometric burn engine to lean burn engine, which needs kind of less fuel to produce same amount of work output, and then question is, this particular transitioning or shift this demand for large or wide spark gap. So, if the gap is wide, you can understand if the mixture is having lean mixture. So, if the mixture is lean mixture, so mixture is having less fuel so sparking should be more or energy that we need to supply to the spark plug should be more to ignite the fuel air mixture. In such a case, the spark plugs which should be used to ignite the fuel for a lean burn engine, this gap should be wider. And if the gap is wider, then we need to have spark for a long time.

So, demands for larger wider spark gap, which in turn demands for longer duration spark. So that means we need to produce spark for a longer duration. That means we need to supply more energy to the spark plug. So, this can be achieved.

So, more energy to be supplied to the spark plug. So, question is using a battery ignition coil, we cannot have all these advantages. That is why we need to think about some modification of this ignition coil, and that modification is essentially again with the help of some electronic circuits, electronic gadgets, electronic devices. So, as if we can see, having a look at this schematic depiction, we can see mostly all components are mechanical components, and using these mechanical components or elements, if we would like to overcome all these challenges, that means if the speed increases, we need constant energy supply to the spark plug. If we need to shift, which is the modern trend, from stoichiometric burn engine to the lean burn engine, you can understand to burn that lean mixture, we need to supply more energy. So, the spark plug will be having wider gap. To break the resistance of the wider gap, we need to supply more energy for a longer duration.

So, all these challenging aspects cannot be fulfilled using battery ignition coil or battery ignition coil. So that is why the electronic injection system was introduced. So electronic injection system to be precise not injection electronic ignition system. Let me tell you if we go back to the previous circuit so essentially, we need to have primary coil, secondary coil etc but in electronic ignition system these breaker points are replaced by sensors and so, breaking and unbreaking or closing and opening of the primary circuit.

Now, what we can see in the circuit is in this system is done by these breaker points. But in electronic ignition system, opening and closing of the primary circuit is done by the sensor. So, breaker points are replaced by a sensor. That is all about electronic ignition system.

So, all these problematic issues, I mean, cannot be managed by the battery ignition coil, and that is why this electronic ignition system was introduced. This particular system is different from the battery ignition system from the following perspectives. What are those? First of all, the primary circuit.

This primary circuit is different in the electronic ignition system. This circuit is different in the electronic ignition system. From the perspective of the breaker points being replaced by a sensor, which is called as the pulse generator or trigger.

So, we will not have breaker points. Rather, we will have a sensor, and that sensor is known as a pulse generator or trigger. While The secondary coil—the secondary circuit or coil—is typically the same for both systems. that is, the electronic ignition system and the battery ignition system. Now, in this context, two different philosophies have been proposed: the first one is the constant dual system, and the second one is the constant energy system. So, these two different systems are developed essentially to modify the battery ignition system, and these two strategies have been developed to improve the battery ignition system and to meet the requirements of modern engines, essentially from the perspective of less emission and higher performance. So, let us talk about the constant dual system.

So, if we now focus our discussion on the constant dual system. This term 'dual,' which when applied to the ignition coil—this term 'dual,' when it is applied, when applied to the ignition system, defined as the time duration during which the primary coil is charging. So, this is called dwell, constant dwell.

Now, the question is, we have discussed today that the charging of the primary coil—if we go back to the slide. So, you can see that this is the charging time. So, t_1 is the charging time and t_2 is the discharging time.

I can't say discharging time, when magnetic field collapses still there are some current flowing in the primary circuit and charging the condenser. So, t_2, should not write the discharging time rather so this is the very first, it collapses and this charging time which is very important and that dwell time. So, that is basically the time needed for charging the primary coil. So, even if you have considered battery ignition coil, had we considered the constant movement of the breaker cam, no matter what is the engine speed is rather, that opening and closing time is fixed, then the charging of the primary coil will remain same and the dwell time will remain same. But that is not the scenario in the battery ignition coil because breaker cam is connected to the shaft of the engine speed. So, if the engine speed changes, the closing and opening time will be changed, which in turn will change the building up time or charging time. And then it will disturb the sparking or energy supplied to the spark plug. So, what we can do, we can have one constant dwell system no matter whether the closing and opening time of the breaker points is getting disturbed because of the engine speed, we can have a circuit or electronic system which will allow a constant dwell time.

So even if the engine speed increases, dual time or dual angle will remain same, but the actual time will be reduced. So, this is the concept of constant dual system. So, if the engine speed increases, think about battery ignition coil. Then what will happen?

When breaker points are getting connected, that time will be very short, and the building process will be delayed. Now, if the engine speed is too slow, then it is not possible to even open the breaker points. So, the breaker points will remain almost closed. In that case, the collapsing of the magnetic field will be delayed. That discharging time will be very lengthy.

So, in that case, it is not possible to meet the requirement. But now, using this constant dual system, we can have, constant dwell time—that is, the charging time required for the primary coil is the same irrespective of the engine speed. If that is the scenario, we can always supply a certain amount of power to this spark plug through the secondary coil or secondary circuit. Second, but this particular constant dwell system is now almost replaced by, without exception, a constant energy system. So, if I write here, constant energy system.

So, in the constant dual system, if we need to have constant charging time, that is, the primary coil charging time will remain constant irrespective of the engine speed. Certainly, we have to have an alternative way out so that closing and opening of the breaker points will not be there. Rather, that primary circuit would be controlled by an electronic control unit. So, we need to supply some pulses to the primary circuit to open and close, irrespective of the engine speed.

And that is what is done using this electronic ignition system. Now, the constant dual system is also totally or say almost replaced by without exception, the constant energy system. What is this constant energy system? So, if we go to the next slide, then we can say this constant energy system, the modern trend is to shift stoichiometric burn engines to lean burn engines. So, if it is a stoichiometric burn engine, and the energy that we need to supply to the spark plug is 0.3 mJ. So, for a stoichiometric, that is chemically correct air-fuel ratio, stoichiometric burn engine, energy requirement to the spark plug to produce a spark is 0.3 mJ. You can understand very little stoichiometric air-fuel ratio, that is chemically correct air-fuel ratio. Now, if we shift, so shifting to a lean burn, it is not always a lean burn, even, if it is a lean burn engine or rich burn engine, rich means the mixture is far away from the stoichiometric ratio. So, either fuel is rich with the air or the air is having less fuel. So, the air will be having more fuel or less fuel. So, in such a scenario, our energy requirement is, 3 to 5 mJ, that is 3 to 4 mJ, so you can understand.

If we do not use an electrically or electronically operated ignition system, if we need to rely on a mechanically operated battery ignition coil, then if we need to shift from a stoichiometric burn engine to a lean burn engine, the energy requirement also changes, and that energy requirement will not be fulfilled by the mechanical components or mechanically operated battery ignition system. So, what is done essentially? Can we supply constant energy irrespective of lean burn or rich burn? So that the engine will always supply a fixed amount of energy to the spark plug, and that much energy will be obtained from the ignition coil. So, if we need to have such favorable or such advantages, then the opening and closing of the breaker points will not be there. The primary circuit will be activated, and the primary circuit will be deactivated using a sensor, and that sensor is essentially a pulse generator trigger. So, from here, we can say the name is to have a constant energy system accounting for this aspect: the mixture can change from stoichiometric to lean or rich. This is a constant energy system to meet the emission, or say, emission criteria and expected or desired performance. In fact, all modern engines are now equipped with an electronic ignition system of constant energy type. So, in an electronic ignition system, breaker points are replaced by a sensor, which is known as a pulse generator trigger, and this device generates a pulse to signal to inform the spark plug when a spark is needed.

So, in Electronic ignition system, breaker points are replaced by a sensor, which is called a pulse generator or trigger. By a sensor, this device generates a pulse to signal to inform the control unit, that is, the ECU, rather to develop or, I should write, unit, when a spark of required energy is needed at the spark plug.

So, this is the difference between the electronic ignition system and the battery ignition system. Now let me tell you, when the trigger produces a spark, so when the pulse generator trigger produces a pulse, using that pulse, the control unit breaks the primary circuit and gives some information or some level of energy to the secondary circuit to produce the desired spark.

When the trigger or pulse generator produces a pulse, that pulse is able to break the primary circuit and that circuit will be able to produce sufficient voltage in the secondary coil that is required to produce a spark. Three different types of pulse generators are typically used for the electronic ignition system. So, three different types of pulse generators or triggers are used in the electronic ignition system. Number one is, the inductive type. Number two is the Hall type, and number three is the optical type. So, these are the three different types.

So, to summarize today's discussion, we have discussed the battery ignition system, which was used in old engines. We have identified the functioning of the battery ignition system. Thereafter, we have discussed the limitations of this particular system in the context of variable-speed engines and also, the present requirement of shifting or transitioning from stoichiometric burn engines to lean burn engines necessitates some amendments to the battery ignition system. Considering all these aspects or other challenging aspects, those are not really possible to meet here.

Those challenging aspects are not possible to overcome using a battery ignition system. The concept of the electronic ignition system was introduced. And then we had seen in the context of the electronic ignition system, there are two different philosophies. One is the constant dual system, and another one is the constant energy system. Thereafter, we had seen that in the electronic ignition system, breaker points are replaced by the sensor and the sensor is a very important part to break the primary circuit, which is responsible for the development of huge voltage in the secondary circuit.

Finally, we had listed down three different types of pulse generators that are typically used in the electronic ignition system.

So, with this, I stop here today, and we shall continue our discussion in the next class.

Thank you.