Course Name: Engine System and Performance
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Lec 2: A Focus on Lubrication and Cooling Systems

I welcome you all to the session on engine system and performance, and in continuation of my last lecture on this topic, that is, the engine system, today we shall discuss two other subsystems and their requirements in the context of engine performance. So, in the last lecture, we discussed the ignition system, and we saw that the ignition system is very important for an engine because ignition is necessary to initiate combustion. Not only that, in the ignition system, there are a few components responsible for initiating the spark, depending upon the requirement of the engine, and also the spark produced by the spark plug has to be distributed uniformly inside the cylinder so that the fuel or mixture, or even fuel in the furthest location, should be able to combust properly. So, today, let us discuss another important subsystem. To be precise, I am referring to the system because all these are subsystems.

If we assume that the engine is a system, rather a mechanical system, then ignition, lubrication, cooling, all these are subsystems. So, today, we shall discuss the lubrication system. Now, we know that, even in undergraduate course, this particular topic, that is, the internal combustion engine. When the piston moves between these two locations that we identified even in the previous lecture, that is, the bottom dead center and the top dead center, the piston has or the piston needs to have continuous movement between these two locations. That is the reciprocating movement or reciprocating motion. That reciprocating motion should be converted into rotary motion using again some mechanical linkage or mechanical system. That is, what you have learned in your undergraduate course. But what I would like to, emphasize today is that when the piston needs to move inside the engine cylinder, then these two, I mean, there are mating components. So, there is a relative motion between these two mating components, that is, the piston surface or the outer surface of the piston and the cylinder wall. So, we need to minimize when there are two mating surfaces and there is a relative motion, we know that friction will be there. So, we need to reduce the frictional effect because otherwise, whatever power that will be produced inside the cylinder will be used to overcome those frictional losses. So, it would be, kind of detrimental for an engine system, and not only that, the most important objective is to overcome the frictional losses, we need to supply lubricant, and since there is a relative motion between the piston and the engine cylinder, we also need to take care of several other issues like, wear and tear. So, all these are mechanical problems. So, coolant. I mean, not only coolant.

Lubricants are provided. To minimize the frictional losses. To reduce the possibility of having wear and tear. Not only that the lubricant also, it acts like a coolant. So, if we write that lubrication system.

So, this lubrication system has a few primary objectives. What are those? primary objectives are, to reduce friction. To minimize wear and tear. Secondary objectives are also there. What are those? Secondary objectives are, to provide some cooling effect. The second thing is, it acts as a seal. I will discuss this part. And also, it acts as a cleaning agent. So, all these are basically objectives, primary objectives and secondary objectives.

Now, if we look at this particular box, we can see. Despite all these primary objectives, there are a few secondary objectives. So, to provide some cooling effect that inside the engine cylinder, because of the combustion. The temperature will be excessively high, though we should not allow the temperature to reduce drastically, but still. As I discussed in the last lecture, the cooling system is necessary to reduce a certain amount of heat from the engine cylinder, essentially to prevent all mechanical components from their possible failure. So, this lubricant will provide some sort of cooling effect and acts as a seal.

If we go back to the previous slide, you can see that this is the space where the, combustion will initiate, then this space between the cylinder wall and the piston's outer surface, if it is filled with lubricant, that doesn't allow the combustion product to leak through that passage and go further down. So, that way it acts as a seal. And also, as a cleaning agent because, if there is some sort of debris formation or some sort of carbon deposition, all these will be washed away by this lubricant, so it acts as a cooling agent. We have now understood the objective of the lubrication system, rather, lubricants. So, can you really use anything as a lubricant for an engine system? Essentially, when we will be selecting any particular lubricant, we must be careful about a few aspects, some chemical and physical aspects. So, if we now write here, requirements for a good lubricant. So, this is very important to know for any designer of an engine.

So, you can see that lubricant will be supplied to minimize frictional losses and to prevent mechanical failure through the formation of wear and tear. The lubricant, you can see that, the lubricant will be supplied to the passage which is between the piston's outer surface and the cylinder's inner wall, and that lubricant will experience huge shear stress because the piston will be having continuous movement. So, we really cannot arbitrarily select anything as a lubricant for the engine system. So, one such requirement, is: leave no carbon, then it should maintain the liquid required or the required film.

If it doesn't maintain the required film, then we won't be able to minimize the frictional losses. You can relate this to the fluid mechanics that you have learned, specifically the concept of a journal bearing. So, if there are two mating surfaces, and one has relative motion, then a thin film is allowed to form so that it can prevent frictional losses as well as several other mechanical issues. Certainly, the most important factors are low cost and chemical stability. Viscosity should ensure sufficient hydrodynamic lubrication.

It won't be chemically stable because you can see that the lubricant needs to face high temperatures, so it should not be chemically unstable. It should not decompose, it should not dissociate, and all these things. And also, it should be physically stable. Chemical stability and physical stability are interlinked. How?

Because if it is chemically unstable, then certainly it will be physically unstable as well. Physically, it should not lose its properties, and it should not be volatile. It should be stable under different temperatures. And the very important point is a high flash point.

A high flash point is very important for any lubricant to avoid the flashing of oil vapor, lubricant vapor and, the last one is, it should contain no sulfur. So, all these are basically the requirements for good lubricants.

Having discussed this, let us now quickly revisit different types of lubricants. As of now, we know that it may be solid lubricant, semi-solid lubricant, or liquid. So, what is a solid lubricant? Sometimes we need to supply a sort of powder to avoid frictional losses. I can give you a practical example.

Have you seen that indoors, on any carrom board, you'll find that sometimes you need to apply some powder on the top of the carrom board to minimize the frictional losses. So, this powder acts like a lubricant to minimize the frictional losses. So, solid lubricant, but it cannot be used everywhere and always. What is semi-solid? So, semi-solid lubricants are also there if we are unable to retain liquid lubricant.

In such a case, we need to have a semi-solid lubricant. A common example is grease. If you go to any motorbike shop or any bicycle shop, or even any four-wheeler repair shop, you will find that mechanics frequently use grease. This is a sort of semi-solid lubricant, and this lubricant is frequently applied to minimize frictional losses.

But the most important and common type is the lubricant, which is liquid lubricant. So, if I talk about liquid lubricant, typically includes several oils. Several oils are examples of liquid lubricant, so you can understand that solid lubricant cannot be used everywhere. Semi-solid lubricant can be used, but again, it cannot be used everywhere. Sometimes we need to use semi-solid lubricant if there is a problem associated with the retention of liquid lubricant.

But in most cases, we use the most common type, which is liquid lubricant, and the examples are several oils. It can be vegetable oil. It can be animal oil, and finally, it can be mineral oil. So, vegetable oil, animal oil, or mineral oil, all these oils can be used as liquid lubricants.

Now, there are a few problems associated with vegetable oil and animal oil. What are those problems? The problem is, that animal oil or animal oils get oxidized very quickly. You understand by this time that lubricants are supposed to experience or be exposed to high temperatures, and at that temperature, there is a possibility that lubricants, will be oxidized.

So, animal oils are very susceptible to that particular undesirable phenomenon, that is, they can get oxidized. Vegetable oils are also similar to animal oils, but they have a little bit more stability in terms of oxidation. But compared to animal oils, vegetable oils are good lubricants. But mineral oils are very commonly used for lubricants.

So, these are the most widely used and lubricants obtained from petrochemicals, and these are cheaper as well. So, these are not only cheaper but also have high chemical stability. So, all these are basically liquid lubricants.

Now, the question is, sometimes we need to add additives to the lubricants. So, why do we need to add additives to the lubricants? And if we add additives to the lubricants, what extra or additional features will we get? So, let us discuss this aspect now. So, basically, if we talk about additives.

So, two questions I would like to discuss. Why do we need to add additives to the lubricants? The second question is, even if we add additives to the lubricants, what are the additional features we are going to get? So, all these things, are important to know.

So, basically, additives are used to provide some additional properties. What are those? One is Corrosion inhibitors. Number two is, sometimes we add Detergents as additives. So, the function is, these detergents Break, Sludges into finer particles.

So that, this can be taken away by the lubricants, and we also need to use the most important: viscosity index improvers. So, you can understand the sole purpose of this is to retain a desired level of viscosity at high temperatures. See, to retain a desired level of viscosity because it is not possible to maintain a unique viscosity of lubricant, but it will maintain within some values so that even at high temperature, viscosity will not reduce, as liquid viscosity reduces at high temperature.

So, if viscosity drops, then that lubricant won't be able to maintain hydrodynamic lubrication. So, these viscosity index improvers are very important just to retain the desired level of viscosity even at high temperatures. So, these are the kinds of types of lubricants we have discussed now. So, we have understood that lubricants are necessary, their requirements, then different types, and finally additives.

So, let us briefly discuss the types of lubrication systems. Just I am writing the name, you can get it from any textbook on internal combustion engines. So, this is basically, first is mist or charge type, second one is wet sump type. It has again three different subcategories: the first one is splash type, the second one is, fully pressure, that is, fully pressurized system. So, splash type and fully pressure system, these two are very important. And finally, we have wet sump, so accordingly, we can have dry sump type.

So, these are three different types of lubrication systems. So, now we can discuss another important system, that is, the cooling system. So, if we go to discuss the cooling system, that is, the engine cooling system. Engine cooling system. We need to supply fuel, and we need to have some arrangements to initiate combustion so that the fuel being supplied to the engine will be able to combust properly in the presence of sufficient air. If combustion takes place efficiently and properly, we can run the engine economically, and the engine will have high efficiency.

And what is the combustion that I discussed in the last class? Though combustion is a very complex subject to understand, you should understand that combustion is basically some sort of chemical reaction. Those chemical reactions are basically exothermic reactions, out of which we are getting some amount of energy in the form of heat. That

heat energy will be converted to another form of energy, which is work, using some system, and that is basically the engine system. So, when there is heat energy developed or generated inside the engine cylinder, it is very unlikely that we can convert that same amount of heat into an equivalent amount of work. It is not possible, due to thermodynamical constraints. So, though it is not possible to utilize the total amount of heat that will be produced out of this combustion, there must be a provision that a certain amount of energy, which is in the form of heat, should be taken away.

Otherwise, the mechanical system, mechanical components, the components which constitute together to form the entire engine system, will be having high temperature, and that high temperature may lead to some sort of mechanical issues through the formation of thermal cracks. So, the cooling system is very important because some coolant should be supplied so that the coolant can take away or reduce a certain amount of temperature from the surfaces or hot surfaces. That is very important again for the engine. So, the engine coolant system, you can understand very well from your undergraduate understanding of this particular course, which is internal combustion engine. There are three different types of cooling: First is air cooling, second is water cooling, and third is basically thermosyphon cooling. If it is air cooling, then we term it as an air-cooled engine.

If it is water cooling, we term it as a water-cooled engine. Thermosyphon cooling and water cooling, the coolant is the same, but still, some mechanical transportation or transport of that coolant from the sump into the engine, that arrangement somehow allows us to differentiate these two cooling systems. So, now let us discuss what an air-cooled engine is?

Air is available in plenty. So, when an engine, any four-wheeler or two-wheeler moves, the forward movement of any four-wheeler allows the engine to intake a certain amount of air. And if that air can be drawn properly into the engine system, then that incoming air can be used as, a coolant. And that air, after taking a certain amount of heat from the engine, can be exhausted from the engine into the ambience again. Certainly, you are going to have some sort of air pollution, but this is the concept of air cooling. Whereas for water cooling, this water cooling is some sort of, secondary cooling system because water will be stored in a sump, and that water will be pumped from that sump into the engine, and while water is circulated through the engine, it will take a certain amount of heat, but that heated water or hot water will again come back to the sump.

So, we cannot use that hot water again for further cooling. So certainly, there must be a secondary cooling system, and again, we need to rely on this air cooling. So, the incoming air, because of the movement of the four-wheeler which is moving forward, the air that will be sucked into the engine, that air can be used again further in a secondary circuit to reduce the temperature of water which has come after taking a certain amount of heat from the engine cylinder. So, this is water cooling, and thermosyphon cooling is again, basically, the coolant is the same, but in water cooling, you can understand if water needs to be circulated from a sump into the engine system, then we need to have a pump because without a pump, we cannot circulate water. There is a possibility that we may have a natural circulation loop; in that case, the water sump or water tank must be situated at a higher level than the engine.

So, that also creates some additional problems. In a thermosyphon cooling system, we can eliminate the need for a pump. So, you have studied, I guess, in your undergraduate course. So briefly, let us discuss a few issues. Maybe even for an air-cooling system or a water-cooling engine system, there are some advantages and disadvantages.

So, let us briefly write about all these. So, air cooling system. We need a larger fan, so a larger fan will absorb more power. Number three is when a large amount of air passes through the engine, it will create or produce audible noise. So, a large volume of air, when that volume of air passes through some system into the engine, it will create some audible noise. So, these are the disadvantages.

Similarly, you can still have some advantages. So, what are those advantages? Number one is, air-cooled engines operate satisfactorily both in hot and cold climates. Air-cooled engines can work at high operating temperatures. And if we consider the air-cooling system, you can understand that we have no need for any sump to store water.

So, the system is a little lighter. So, I can write the system is lighter or less bulky than water-cooled. So, these are the advantages. So, we have discussed the advantages and disadvantages of air-cooled engines. Now let us look into the engine or water-cooling system.

So, the last is the water-cooling system. So, what the advantages are? I mean, you can understand that. So, I am writing the advantages. Even if we consider air as a coolant, it may not be possible to have uniform temperature distribution from the engine cylinder using that coolant.

But water, if we can supply, if we can circulate water, we can have uniform temperature reduction from everywhere in the engine system. So, that is called greater temperature uniformity around the cylinder. So, number one is greater temperature uniformity around the cylinder. So, that means, if we consider air-cooled engines, maybe where air velocity will be more, there we can have lower temperature, but in some parts, maybe the velocity of air is not that much.

So, maybe we would not be able to reduce the temperature drastically there. So, I mean, non-uniform temperature distribution will be there, but in the case of a water-cooled system, we can ensure that the temperature uniformity or temperature should be uniform around the cylinder. Number two is, even if we have power consumption, because for a water-cooled system, we need to have sump, and from that sump, we need to supply water using a pump to the engine cylinder or engine system. So, despite having a separate pump, the power consumption would be even less as compared to the air-cooled engine because, for an air-cooled engine, we need to have a larger fan. So, to operate or to drive that larger fan, we need to have a substantial amount of power consumption requirement.

Number two is, power consumption is less than an air-cooled engine, even after having a separate pump, which is needed to circulate water from the sump to the engine cylinder. Then the third thing is that the cooling water jacket, if you try to recall the schematic depiction that I showed you today, the presence of the cooling water jacket will absorb Some noise from the engine, so that is again a very important aspect. So, it absorbs noise,

which is very important, and the unit is rigid and can be used for heavy-duty work. So, these are the advantages. Despite having all these advantages, still, if we use a water-cooled system, there are some disadvantages. So, let us quickly write all this.

So, disadvantages are: number one is, it is liquid. So, we really cannot trivially ignore the possibility of having leakage. So, there must be some joint. It is not possible to have a straight connection. So, there must be a 60° bend, a 90° bend, or a 45° bend. So, through this joint, there will be a possibility of leakage.

So, that is called leakage through joints. Number two is care must be taken to avoid the freezing of water. If we take a water-cooled engine in regions where the temperature is below 4℃, the coolant will freeze. If it freezes, then again, you can understand what the problem will be.

So, the entire line, the entire sump will buckle. So, number three is more time is needed to warm up than an air-cooled engine. Then, number four is the last point, a very important point. The boiling point limits the maximum temperature of operation.

So, the boiling point of the liquid coolant. So, basically, what we have discussed today is that, this liquid air-cooled engine also has some distinct advantages and some disadvantages. For the water-cooled engine, we have listed down a few serious advantages. Still, we have noticed or observed a few disadvantages. Now, the thermosyphon cooling is again another system.

Wherein the requirement of an additional pump to supply water from that sump into the engine system will not be there. So, having a thermosyphon cooling, we can eliminate the need for an additional pump. So, we can reduce the first-time installation cost. But at the same time, there will be some sort of disadvantages because we need to rely on natural circulation. So, if we need to rely on natural circulation, perhaps you have studied natural convection.

We need to have a certain height difference, otherwise, the efficiency of cooling will not be that much. So, knowing the advantages and disadvantages of the water-cooled system, you can really relate that the thermosyphon cooling is, kind of an extension of water cooling wherein the need for an additional pump to supply water from the sump into the engine system will not be there; rather, the system will rely on a natural circulation loop, and again, if it is based on the natural circulation loop, some additional problems or issues will be there. So, if we summarize today's discussion, we have discussed the lubrication system, then we have discussed the requirement of lubricants, and several types of lubrication systems. And then we have talked about the cooling system, which is again an important system for an engine because we have repeatedly discussed that we need to take away a certain amount of heat.

But we must be careful when someone is designing or a designer is designing a cooling system; he or she must be careful that, the coolant or cooling system would not be able to take away the maximum amount of heat, otherwise, it will reduce the engine performance. So, with this, I stop here today, and we shall discuss the next topic in the next class.