Course Name: Engine System and Performance
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Lec 8: Concept of Hybrid Engines and Working Principle

I welcome you all to the session on engine systems and performance. Today, we shall discuss the topic of hybrid engines. You have studied internal combustion engines, where power mostly comes from the combustion of fuel, but the concept of hybrid engines is relatively new. Today, we shall discuss this topic and then explore the working principle of this type of engine. So, do you know what a hybrid engine is? Basically, a hybrid engine consists of two different systems.

One system is, of course, an electric motor and drive system, and the other system is again the combustion engine. Now, the combination of these two systems brings fuel economy and also ensures lower emissions. Considering these two important favorable aspects—greater fuel economy and lower emissions—this concept was introduced years ago to improve the combustion engine. So, what a hybrid engine is?

Hybrid engine, and then we shall discuss its operational principle. This is again a type of engine used in new types of vehicles, utilizing the beneficial aspects of combustion engines. So, this is a type of engine used in new kinds of vehicles utilizing a combustion engine.

So that means we need to use the combustion engine, but still, using the combustion engine, we can have a new type of engine which will have better fuel economy and lesser emissions. So now the question is, what is the need? I mean, certainly we have seen in the combustion engine. There are several mechanical components, several subsystems, and design aspects are there. So, if we need to keep a combustion engine intact, and over and above, if we need to install a new system, that is an electric motor or electric motor and drive system, so again, you are trying to or again, you are bringing complexity, and the system will be more bulky. So then, having said all these things, what is the need of introducing this type of engine?

So, then we need to know that the basically, I should say, objectives of developing a hybrid engine or hybrid engines. What is the need? So, what I said a few minutes back,

though we are trying to have more complexity in the system because now these two systems will be coupled together, and if we need to install two different systems, maintenance of these two different systems will be there, and operational aspects will be there.

So then operational cost will be there, but as I said to you, the sole objective of having the concept of a hybrid engine is to bring greater fuel economy and, most importantly, to reduce emissions so that the environmental aspects should be, environmental pollution would be under control, so the objective is, as I told you, to provide better fuel economy, number two, to reduce, emissions, so these two are the objectives. Now the question is, hybrid engines or hybrid engines use two different systems. A combustion engine will be there.

Over and above, there will be an electric motor drive system just to provide additional power to propel the vehicle. So, that is the objective. So, in a hybrid engine, combined electric motor drive system and combustion engine will be there to provide, adequate power to run or propel the vehicle.

So, that means the objective is to had we only considered the combustion engine, we could have generated or we could have developed more power, even power which is much much higher than the average power typically used to run an engine. But then, if we would like to have or if you would like to get more power from a combustion engine, then the engine should be bulky, it should be, heavy.

So, instead, we can have an equal amount of power output just by introducing the concept of a hybrid engine because if we can now, if the combustion engine is not, if we try to reduce the size of the combustion engine, certainly power will be reduced, but that reduction in power would be, compensated by the electric motor drive system, so that the overall engine weight, the overall engine would be, less bulky and it would be having less weight. So, that is the objective of having a hybrid engine. So, now, let us, discuss different methods.

I mean, we have talked about, yes, in a hybrid engine, two systems would be there. One is the electric motor drive system, and another is the conventional combustion engine. So now the question is, can you really add them arbitrarily, or can we really have these two systems in series? Can you really have these two systems in parallel?

So, all these are very important to know, and what should be the configuration of these two systems? Can they be connected, or can they be installed without having, a proper design, without having any proper, without having proper calculation of power output? So, the next is, different methods of, electric motor drive and combustion engine combination. So that is very important.

So, towards that, let us first talk about the most common scenario. So, what is the most common scenario? So, the most common scenario is we will be having certainly an electric motor drive system, and this electric motor drive system is the main driving mechanism. So, this is the electric motor drive system that would be there in a hybrid engine. This drive system would provide maximum power, or rather we can call it the main driving mechanism, right, while the combustion engine would be there.

So, a combustion engine would be there. Otherwise, we can't call it a hybrid engine. So, this combustion engine will be used to run at a steady state operation, at a steady state. So, if we run the combustion engine, that again it will be powered. That power will be used to charge the batteries.

Which are there in this electric motor drive system to charge the batteries. I'm referring to batteries depending upon the work output or power output. An engine may have more than one battery. So, the combustion engine would be there, but it will run at a steady state to charge the batteries. And the batteries would be used to again run the motor in the system.

So, this is the most common scenario. So, then these batteries will be used to drive the electric motor. But it is not the only case. Depending on the requirement, some power can also be taken from the combustion engine to propel or to drive the engine. So, this is the most common scenario. Let me repeat once again: the electric motor drive system would be there, and that is the main driving mechanism. A combustion engine would be there because this is a hybrid engine. So, a combustion engine would be there, and it should run at a steady state just to charge the batteries that are there in the electric motor drive system.

Those batteries get charged by the combustion engine, will operate an electric motor, and that motor is the driving mechanism. But as I told you, depending on the power requirement and the speed requirement, sometimes a combustion engine can also be used to propel the engine or propel the vehicle. So, that is the most common scenario. Now, as I told you, what should be the next one?

So, next is 2). The question is, if there is no combustion engine, then certainly we cannot call it a hybrid engine. Even if we have a combustion engine and the combustion engine is so small, then what would be the ultimate consequence? So, if there is no combustion engine, then the electric motor drive system would not be able to produce or provide power and its range.

I should write adequate power, and its range. Even, even when higher fuel economy and fewer emissions are ensured. So, that means if we do not use any combustion engine, certainly there is no need of supplying fuel, so we will be having fuel economy. As such, we have no need of fuel supply, and that too, fuel. Since you are not going to use hydrocarbon, so emission will not be there. So, even if there is no fuel supply, still, if we do not use a combustion engine, the electric motor drive system won't be able to provide adequate power depending on the load, that means high speed when the engine is off-healing in all the scenarios.

From this, you can understand that we must have a combustion engine system in a hybrid engine. It must be there. Even if we use a small part of the combustion engine, or even if there is no combustion engine, the problem should still be there. Even if we use a small combustion engine just to supply some power to charge the batteries, even then, if we bring greater fuel economy and have lesser emissions, the engine still won't be able to provide adequate power as and when the need arises.

So, basically, it is not always the case that the engine should run always in a steady state. The engine may require high speed, or it may need to supply adequate power when the engine or the vehicle would be off-filling. So, in all these scenarios, this is not viable. So, what we understand is that in a hybrid engine, a combustion engine system must be there.

Now, the question is, if we use, as I told you, the combustion engine as the only part which will supply adequate power, in that case, the engine size will be bulky, and we need to supply more fuel to get that power. Eventually, if we supply more power, more emissions will be there. So, in that case, we need to have a judicial balance between these two systems: how much power we need to draw from the electric motor drive system and how much power we need to draw from the combustion engine. So, considering that, even if we use just a very small combustion engine, maybe if the combustion engine is running in a lean burn steady state condition, even then, we can have better mileage, better fuel economy, and we can reduce emissions, but still, we can supply power depending on the requirement. So, that is what we can understand.

So, basically, even when the combustion engine is smaller, we can still optimize the system to have higher efficiency at the cost of lesser emissions. So, that is the concept. So, I am writing, even when the combustion engine system is smaller, even when the combustion engine system is smaller, the hybrid engine can provide adequate power, for a given operating condition.

So, that is, the take-home message: even if we have a smaller combustion engine, we can still supply adequate power using the concept of a hybrid engine, ensuring fewer emissions. So, what is a hybrid engine? If we need to answer this question, then we should write some points that are quite simple. A hybrid engine combines, an electric motor with a combustion engine. To provide power to propel the vehicle and system.

Recaptures energy. By regenerative braking. I will tell you what this is. Sometimes the electric motor does all the work, and sometimes they work together. So that is what we have been discussing for the last few minutes. So, it's a hybrid engine, combining two systems to be installed. That is one electric motor drive system and one combustion engine system to provide power, I should say adequate power, depending on the requirement to propel the vehicle.

The system recaptures energy via regenerative braking. What does it mean? Even if we use, so the idea is to, absorb or capture the kinetic energy of the moving part of the engine when the engine slows down or is getting fully stopped. So, when the engine is not moving or is slowing down, then the kinetic energy from the moving part of the engine should be used to, charge the batteries.

And that battery will operate an electric motor again. So that is regenerative braking. So, let me tell you one thing, the most common scenario is to run a combustion engine, and the kinetic energy of the moving parts would be used to charge the battery. So, we can have one generator motor generation system, and that battery is getting fully charged. The battery or batteries will be used to supply or to run the motor, and that motor will drive the vehicle rather. It may be the case that only the electric motor will do all the work. Sometimes it is the combustion engine, depending on the load, and sometimes, or rather very often, they work together.

So, if the vehicle needs to attain an altitude or height, or the engine or vehicle needs to go uphill, in that case, we need more power. Probably, by running only the electric motor system or electric motor driving system, it won't be possible to get that much power. So, we need to either use only the combustion engine or a combination of these two. But the

most important part is that we can regenerate. We can capture energy through regenerative braking, just to charge the batteries, and those batteries will be used to drive the electric motor now, to run the electric motor. So, what is the beneficial aspect of having this particular concept? It is to bring fuel economy and, most importantly, to reduce fuel emissions.

Now, let us discuss, different ways of combining the electric motor and the combustion engine. So, that is what we should now learn. In most cases, this electric motor is attached rather, the electric motor drive is attached to the front wheel, or front wheels, and the combustion engine is attached to the rear part of the engine, that is, the rear wheels. So that is what we have seen. We can also use the electric motor drive and the combustion engine, rather.

It is not only a case that we will be having only one electric motor drive system and one combustion engine. Depending on the requirement, we can have two combustion engines, two electric motor drives, or drive systems. So, the electric motor drive and combustion engine can be connected in series. If it is connected in series, you can understand then what is done, that is very important. The crankshaft of the engine or the extended part of the crankshaft would be used or should be connected to the rotating output shaft of the electric motor.

Try to understand if we connect the electric motor drive and combustion engine in series, then suddenly you are trying to add the power, so the power will be doubled. I mean, just whatever power would be obtained from the electric motor drive and combustion engine should be added together. In such a case, what is done, the crankshaft is extended so as to connect the rotating shaft of the electric motor. Then we can fluctuate the total power output, and we can simply add the total power output. That means we will be having the crankshaft also extended to accommodate the rotating shaft of the electric motor. Next is, we can also use, that the electric motor drive and combustion engine are connected in parallel with various ways or various avenues or ways of using one or more, I mean these two, under different driving conditions.

We shall discuss all these statements. It would be okay if we can have or if we can discuss all these using some schematic depiction of the drives, both the electric motor drive and combustion engine, so that also be a possible case. Now the question is, having discussed all these possible configurations, or possible configurations of hybrid engine we have understood that the hybrid concept brings about, or the hybrid concept brings

greater fuel economy, ensuring lesser emissions. But we should ask again an important question: is it really, or is there no detrimental effect, or is there no disadvantage with this concept, that is, the hybrid engine. So, certainly, if we go for the hybrid concept, straight away you can tell it will certainly bring fuel economy, then will reduce emissions. That is true, then the hybrid concept will also reduce, the bulkiness of the engine because, as I said, if you need to have, if you need to produce maximum power or much more power from the combustion engine, then the combustion engine would be much more or more bulky.

So, instead of using a more bulky combustion engine, if we introduce this concept, then we can reduce the size of the vehicle and the size of the engine. But the question is, will it have. Having discussed all these favorable aspects, or rather advantages, can we really say that this concept will not have any disadvantages or demerits? So, now, let us look into the favorable aspects or advantages and disadvantages of this particular concept. So, if we write that advantages of the hybrid engine or concept: one is that, greater fuel economy.

So that means, if we optimize the engine, even if we use a lean burn steady-state combustion engine, we can have greater fuel economy even after using a lean burn steady-state engine. And as combustion engines are phased in, we can expect that combustion engines will have higher thermal efficiency. So, introducing the concept of a hybrid engine, or rather the introduction of this concept, will help to get more fuel economy from the combustion engines as their thermal efficiency is higher. So, roughly, I can tell you that the concept of a hybrid engine, or rather present hybrid automobiles, have a fuel mileage.

That is, in SI units, that is 20 to 35 kilometers per liter. So, if we use one liter of fuel, we can have 20 to 35 kilometers of mileage, depending on the requirements. This is number one. Number 2) is certainly lesser emissions.

Number 3) is, we use a hybrid concept. It is not the case that we always have to skip the combustion engine in on mode. We can turn off the combustion engine. And even if we turn off the combustion engine, if the load requirement is not too high, then only we can get, power from the electric motor drive system.

And that too, since it is a hybrid engine, so the presence of the electric motor drive system will allow a smoother startup. So, these two aspects are there. That means we can really turn off the combustion engine if the requirement is not that high. On the other

hand, when we need to start the engine, the presence of the electric motor drive system will allow a smoother startup. So, these are there.

So, the combustion engine can be turned off when the load requirement is not high. This is one, and also the electric motor drive system will ensure, this is very important, a smoother start of the engine. So, this is number 3. And number 4 is, we still can, rather, we have the provision of, recapturing the energy or capturing energy using regenerative braking.

So, when the engine is getting stopped or the engine is getting slowed down, we still can use or we still can convert the kinetic energy of the moving component of the engine or vehicle. To charge the batteries, we have to have an electric motor generation system and an electric motor generator system, and by charging the batteries, we can again run the electric motor to drive the vehicle. So, this is something. Now, the question is, having discussed all these advantages, we also need to know what the disadvantages are of the hybrid concept.

So, we have discussed until now all the favorable aspects, but still, there are some demerits, some problematic issues with this concept again. So, let me write them down. One is high cost. It is very important, that we need to have a combustion engine system. So, the combustion engine system is basically, too complex; there are so many components.

Over and above, if we need to have one electric motor drive system, we need to have or we need to design accordingly, as we are going to have another system. So many auxiliary subsystems will be there, so many components will be there. So, together with that, the cost of the engine would be more. So, high cost. Number 2, that is very important, that vehicles will be having two systems.

If we do not use the combustion engine, as I said, if the load requirement is not too high, then simply by running the electric motor drive system, we can propel the vehicle. In such a case, the combustion engine weight would be dead weight. So, this is some sort of, problematic issue because even if we really do not need to run the combustion engine. Still, we need to carry the weight related to that engine system. I mean, there are several parts.

So that is, and it will appear as if the combustion engine is a dead system when there is no requirement of mass load, and we have, turned off the combustion engine. So, in such

a situation, it is as if the combustion engine system would be a dead system. So that is one thing. So, the most important disadvantage is that all battery systems will have a negative environmental impact.

So, this is very difficult, I should say, a very important disadvantage. So, having discussed several, favorable issues, favorable aspects, the most important drawback or disadvantage is that all battery systems will be having a negative or adverse environmental impact. And number 3 is, nowadays, luxury cars or even if we need to have any large vehicle like buses and big cars, we need an air conditioning system, we need several other auxiliary systems.

So, if we need to run the air conditioning system inside the car or inside the vehicle, if we need to run several other auxiliary systems, it is very difficult to get energy if we do not use a combustion engine. So, that is again a problematic issue with the hybrid concepts. Just for the sake of completeness, air conditioning unit and other auxiliary units require power, certainly, and it becomes difficult to supply power from the electrical system.

That means we know that in a vehicle or in luxury cars, there will be an air conditioning unit, not only an air conditioning unit, but there will be several other sub-units, auxiliary units, and to run all these auxiliary units, we need to supply power. If we need to supply power from the electric motor drive system, sometimes it may not, be possible. So, this is again a disadvantage of this particular system, that is, the hybrid engine or hybrid concept.

So, to summarize today's discussion, we have discussed what is a hybrid or what is a hybrid engine. And then we have introduced several configurations of the hybrid system or hybrid engines. And thereafter, we have discussed the favorable aspects or advantages of the hybrid system or hybrid engine. And having discussed all these favorable aspects or advantages, we could also identify a few problematic issues with this system or with this concept, that is, the hybrid concept.

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