Course Name: Engine System and Performance
Professor Name: Pranab Kumar Mondal
Department Name: Mechanical engineering
Institute Name: Indian Institute of Technology, Guwahati
Week - 03
Lecture – 09

Lec 9: Types of Hybrid Arrangements

I welcome you all to the session on engine systems and performance. In today's class, we shall discuss different types of hybrid engines and their arrangements. If we recall, in the last class, we talked about what a hybrid is, and then we discussed the operational principles of a hybrid system or hybrid engine. Certainly, hybrid systems have a few distinctive aspects or advantages. Having discussed all these favorable aspects or advantages, we also discussed the demerits.

Those demerits are associated with hybrid systems, and we could also identify them. We are saying that even though those demerits cannot be trivially disregarded or ignored, still, because of the notable advantages of hybrid systems, for the last few years, the concept, rather the new concept of hybrid systems, came into the engine world. Engines are now modified essentially to bring fuel economy, to operate them with higher performance, and also to substantially reduce emissions. As we know, we have also discussed emissions from batteries. So maybe by reducing fuel consumption, hydrocarbons, we can certainly reduce emissions using hybrid systems.

But again, the introduction of hybrid systems also brings another type of emission, which is from the use of batteries. So, to start with, let us discuss the types of hybrid vehicles or engines. Probably we have also briefly discussed these two different types in the previous class, but let me discuss them once again. So, the first example is a parallel hybrid.

What is a parallel hybrid? This type is the most common type typically used in automobiles. So, what a parallel hybrid is? So, in this type, there are two different drives: an electric motor drive and a combustion engine, which are connected to a common transmission that combines the two power sources.

So this is the most common type. And in this type, what we can see from these wordings is that both the electric motor drive and the combustion engine, these two systems, I mean these two power-generating systems, are connected to a common transmission.

Now, what would be the beneficial aspect if we connected them to a common transmission system?

Now, we use the word 'transmission system.' So, now, this transmission, can be automatic, it can be manual or, very importantly, it can be CVT, which is continuously variable transmission.

So, this is the parallel hybrid system or parallel hybrid engine. We can understand that essentially the objective is to use both power developing or power generating systems in a common transmission system so that we can always have a judicious balance between these two powers generating systems and we can compromise with the engine power and we also can reduce fuel emissions depending on the load requirement. If we can reduce fuel requirements, then certainly emissions can be reduced. Now, this is very common in kind of branded automobiles.

So, if I write here, this type is common in branded automobiles like Toyota, Lexus, Hyundai, then Nissan, Honda, etc. So, this is very common in all these branded automobiles.

Next, we shall discuss the series hybrid. So, what is a series hybrid? In this type, the electric motor or electric motor drive system provides all thrust or power.

And most importantly, there is no physical, Mechanical connection between the combustion engine and wheels. So, try to understand that means the electric motor drive system will provide all the power needed to propel the vehicle, while there will be no physical, mechanical connection between the wheels and the combustion engine, but still the combustion engine will be there because the system is a hybrid system. The electric motor drive system will provide all the power needed to propel the vehicle, but still the engine system will be there because it is a hybrid system. So then, what should be the objective or function of the combustion engine? If we write here, then the combustion engine system is there just to recharge the battery.

So, the combustion engine system will be there in compliance with the hybrid system, but the sole function of this system should be to provide power to recharge the battery or batteries. Now, try to understand that we have discussed in the previous class as well, since the electric motor drive system is solely responsible to provide power to propel the vehicle, we can have smoother start-off and stop of the engine. So, why?

Because the arrangement itself will allow the engine to run smoothly with that powerful acceleration. That means since the combustion engine has no role as such, the combustion engine will be there to provide power or to develop power to charge the batteries, but essentially the wheels or engine shaft or crankshaft should be connected to the shaft of the motor. Then what we can have is smoother engine transmission as well as operation, as well as powerful acceleration. So, the engine will run smoothly. So, this is all about the series hybrid. Now, the question is, having discussed these two different times, let us now discuss, variations on the hybrid theme.

Because As of now, we have discussed the concept of a hybrid system. We have understood that in a hybrid system, there are two different power-generating arrangements. Whether we are going to use both of them or either the electric motor drive or the combustion engine alone, there would be some thematic arrangements. So, when should we use both of them?

To generate or to develop power. If we need to use only the electric motor drive, in which situation or in which case should we go for this arrangement? Or if we need to use the combustion engine solely, then in which situation or in which type of arrangement should we go with that type of arrangement? So essentially, this type of arrangement, whether both of them should be used simultaneously or only the electric motor drive or only the combustion engine, we need to discuss the theme of the hybrid system. So, we shall now discuss variations of the hybrid system.

In this context, we shall be discussing two different themes or thematic arrangements. The first theme is called full hybrid. In this full hybrid, what we could write is in this design, the design electric motor drive propels the vehicle most of the time like a series hybrid. The idea is the engine turns the generator most of the time.

But as I wrote to you, at some other times, the combustion engine like a parallel hybrid can also drive the wheels. So, this is the concept of a fully hybrid. So, what we can understand from this is very important that I wanted to write and then I could not complete.

So, in this type, the electric motor is capable of moving the car or propelling the car. The vehicle by itself, even if it is for a shorter distance. So, this is fully hybrid, which means the electric motor itself is capable of driving or propelling the vehicle most of the time, and sometimes you can also connect the combustion engine like a parallel hybrid to drive the wheels. Next, we shall be discussing not fully hybrid but what is called mild hybrid.

So that means certainly you can understand if it is not a fully hybrid, then the electric motor itself won't be able to drive or propel the vehicle always.

So, in this case, the electric motor cannot drive or propel the car or vehicle, but still, this electric motor is there to assist the combustion engine for the purposes of what we have discussed many times: bringing fuel economy and better performance or both. So basically, that is the case now. Why? Because this is hybrid, so the combustion engine is there, and the electric motor is there to assist the combustion engine for the purposes of bringing fuel economy and also better performance, to reduce emissions, all these things. But then the electric motor is there; still, the electric motor can assist the combustion engine, but the presence of the electric motor will ensure a smooth start and stop arrangement.

That means the engine can be started very smoothly, and most importantly, when the engine needs to be shut off, the vehicle needs to be shut off, and we can stop the engine even before. It gets fully stopped, and then it will again bring fuel economy because the electric motor is there to assist in stopping and starting the engine or vehicle. So, this is all about the thematic arrangements of the hybrid system. So, having discussed different types of hybrid systems, or engines, then the thematic arrangements of the hybrid system, let us now briefly discuss, several arrangements very quickly. I will discuss schematically, so one could be that start and low-speed driving. So, that is start and low-speed driving. Then, what should be the schematic arrangement.

So, what we have is the engine block. So, this is the engine, then we have the inverter. The battery will be there, and then this is connected to the motor, and then this is the belt drive, and so these are the wheels. So, this is the schematic arrangement. So, this is the belt drive.

So, these are the wheels, and this is the belt drive. So, this is the arrangement for start and low-speed driving. So, you can understand that the engine and motor, these two are connected, and this is the belt drive. So, the inverter is allowing the battery to charge, the inverter is supplying power to the motor, the motor is running, and then through the belt drive, the power is coming to the wheels. We shall be using the schematic deflection to describe a few other arrangements.

So, now if we go to discuss about it. Power generation during driving. So now, let me erase this arrow direction. So, this is the schematic depiction of the hybrid system. We

can see the engine is there, the combustion engine, the electric motor is there, the battery is there, and this inverter is used to supply power to the motor.

And this is the wheel drive, and then these are the wheels. So, what should be the arrow direction? Now when we need power during driving. So, this should be the arrow. Then the engine is running the inverter.

So, it will go to the battery. The battery will get charged. And then power is coming from the engine to the motor, and then the belt drive, and finally the wheel. So, try to understand the arrow direction. So, both the engine is supplying power to the motor, the motor is, or the engine, these two are connected, and when power generation, so basically we have to generate power, the engine is supplying power.

Some power goes to the inverter, that inverter is now supplying power to the battery, the battery is getting charged, and the engine is running the wheels through this weld high mechanism. Next, we shall go for engine start. Engine start. So, let me erase the arrows or arrow directions. Now, in this case, the battery will supply power to the inverter, the inverter will supply power to the engine and also to the motor, and then through the belt drive, it will finally drive the wheels.

So, this is engine start when you need to start the engine. So, this is the arrangement. Just try to note the arrow directions for this particular configuration. That means the battery is responsible for starting the engine. That is what is depicted here.

The battery is solely responsible for starting the engine. In that case, we will start, the engine or vehicle will start to run. The next arrangement is full throttle acceleration. In this case, again, let me erase the arrows or arrow directions, then I will be using a new set of arrows. So again, this will come from the battery. The inverter, from the inverter, then it will come to the motor. The engine will supply power to the motor again, and the belt drive. So, try to understand, this is full acceleration as if the engine is not charging. So, the battery is supplying power to the inverter, and through that, motor power is coming to the motor to run. The engine is also providing some power.

The belt drive is connected to this wheel. So, basically, we are getting a vehicle that will run or accelerate rather. So, this is basically the arrangement for full throttle acceleration. We have another two different types. Next is propulsion by the engine. Again, let me erase all the arrows or arrow directions. The arrangement is the same. Now, what we will

do is draw a new set of arrows. So, yes, in this case, just the engine will supply power to the motor and belt drive.

So, this is the case. So, the battery remains non-functional because the entire engine is for propulsion by the engine. We need maximum power, as I discussed in the previous class. The combustion engine can generate maximum power, even much higher than the average power obtained at a steady state operation. So, as if we need to generate a huge or substantial amount of power by the engine.

And so, the engine would be able to develop a substantial amount of power, and in that case, the engine is connected to the motor, and the motor is supplying power to the wheels through this belt-driving mechanism. So, we are left with the final one, which is the arrangement or hybrid arrangement of power generation. So, we have discussed power generation during driving, but now we have to have a power generation arrangement. So, let me again erase all the arrows or arrow directions. So, in this case also, the motor is supplying power to this inverter, and as if the belt drive is used to run the motor, and the motor is supplying power to the inverter.

So, we have discussed, maybe in the last class that when the engine slows down or comes to rest, then we can still use the kinetic energy of the engine just to regenerate power through the inverter. So, basically, the battery would be charged. So, that is called power generation.

So, to summarize what we have discussed in today's class, we have discussed the types of different hybrid engines or systems. Then we have discussed the thematic arrangements of different hybrid systems. And finally, we have schematically shown or represented different arrangements of the hybrid concept or hybrid engine arrangements.

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