Course Name: Engine System and Performance
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Lec 45: Trend of recent technologies to achieve better performance and reduce pollution

I welcome you all to the session on engine systems and performance. Today, we shall discuss recent trends in technologies, essentially to improve the performance of internal combustion engines and to reduce pollution. So, in this context, let us discuss a few things or a few aspects regarding the improvement of internal combustion engine efficiency with reduced emissions. As such, the future of internal combustion engines lies in efficiency improvements, emission reduction, and hybrid integration. These three things are very important. To achieve all of them, we must consider the technological advancements and various aspects of internal combustion engines from the perspective of both fundamental considerations and applications.

So, if we just list three things or three coupled keywords, the future of internal combustion engines. Essentially, if we look at the technological advancements and upliftment required to improve the hardware of internal combustion engines and also several other aspects to achieve, first, efficiency improvements, and second, emission reduction and third is hybrid integration. We need to enhance efficiency while reducing emissions. If we need to achieve this, internal combustion engines should be hybridized. That part I will discuss later. So, let us now discuss all these points: efficiency improvements, emission reduction, and hybrid integration.

You all know by this time that electric vehicles are on the rise, but internal combustion engines will continue evolving to meet the demand for energy and emission guidelines and there are certain applications wherein internal combustion engines play a crucial or vital role. If we need to achieve efficiency improvements, do we need to modify the hardware of the engines, or what are the several aspects to be considered by a designer?

Essentially, to achieve efficiency improvements, let us now discuss these aspects. So, what we know is that efficiency can be improved. So, I am talking about efficiency. So, this can be improved with the use of alternative fuels. So, alternative fuels or the use of alternative fuels. So, here you can see that efficiency—we all know we need to supply

fuel. So, we have discussed this several times. In the fuel itself, chemical energy remains stored. So, that energy is converted to thermal energy in the form of heat inside the engine cylinder, and that thermal energy is converted to mechanical energy, which is available at the output shaft of the engine.

So, this energy conversion, if we try to recall, chemical to thermal, thermal to mechanical. Thermal energy is always low-grade energy, while work or mechanical energy is high-grade energy. Certainly, the efficiency of an engine cannot be increased beyond a certain percentage. And if we need to think about or look for efficiency improvements, certainly an avenue could be to explore alternative fuels, and that is one aspect. For that, what we need to do is think about biofuels, hydrogen, and synthetic fuels. This can essentially enhance efficiency but also reduce emissions. So, these fuels can reduce carbon emissions while using the same or existing infrastructure. So, this is the part that means instead of hydrocarbons, if we look for alternative fuels, then efficiency can be improved. That means output at the cost of input energy can be improved and not only that, these fuels that we have listed down can also reduce carbon emissions by using existing or the same infrastructure. So, this is one.

Number two is advances like turbocharging—we have discussed it in detail—then compactness or downsizing of the engine, so we can integrate a turbocharger or turbocharging unit that we have discussed in greater detail. Particularly in this course. You also have studied this in your undergraduate internal combustion engine course. Downsizing—we all know that turbocharging means essentially you are trying to recover waste heat, or rather energy, which would otherwise be lost into the ambience. So, if we can recover that energy and rotate a small turbine using the enthalpy of the exhaust gases, and the turbine can be connected to a small compressor to pressurize the intake air so that, volumetric efficiency can be improved. Not only that, it can also make combustion more efficient. Because if we can control the temperature and pressure of the intake air, then combustion efficiency can be increased. Downsizing means we need to have a very compact engine. Earlier previous engines—if you have read your undergraduate IC engine course—you will find that earlier, in particular, SI engines used to be fabricated from cast iron and other heavy metals.

And we all know that diesel engines or compression ignition engines are bulky. And these engines have very heavy rotating parts. But nowadays, with the advent of material science research, it is possible to consider lightweight materials like cast steel, so that engine weight can be reduced and also, we can compact the engine, and this downsizing

may enhance engine performance. So, this is all about downsizing. And then it is also important to consider variable compression ratio engines. And this is known as VCR. So variable compression engines enhance efficiency without compromising performance. So, this is all about engine efficiency.

Let me discuss if there is any other aspect to be considered to enhance or improve the efficiency. As of now, we have talked about the use of alternative fuels advancements like the use of turbocharging units, the design of variable compression ratio engines, and most importantly downsizing, that is the use of lightweight materials and compactness, which will also lead to enhancement of engine efficiency. So, if we go to the next slide, there is another fundamental aspect that should be considered for future development of engines: can we look into the alteration of the fundamental cycle? Typically, we all know we have studied the Otto cycle, diesel cycle, and all these air standard cycles. These are used to compare the performance of internal combustion engines. Now, the question is: is it really possible to fundamentally change the cycle so that engine efficiency can be improved? There are a few cycles already, but I should say all these cycles are still at the research level.

Their application, or rather their utilization or employment in real-life applications, has not yet begun. So, alteration of the cycle, which is again very fundamental, can be considered or used as a research endeavor to explore the possibility of enhancing engine efficiency. So, I am writing here just that if we go to the previous slide. So, this is point number 3, which is a exploration of new cycles used to map and compare the processes of internal combustion engines. So, that way, we can also look for new advancements in the design or development of internal combustion engines. Then, most importantly, these are fundamental aspects again. So, if I write point number 4. So, this is again a fundamental aspect: the advancement of combustion techniques. So, advancement of combustion techniques, then, as I said before, the use of composite materials.

Lightweight materials like cast steel, aluminum—all these are already in practice essentially for the enhancement of internal combustion engine efficiency. So, to this end, let me tell you one thing: the advancement of combustion engines includes homogeneous charge compression ignition. So, number one is homogeneous charge compression ignition. This is known as, HCCI. This, together with, Reactivity-controlled compression ignition, in short, RCCI. So, these two techniques not only improve fuel efficiency or engine efficiency but also reduce NOx emissions.

So, these are several avenues to be considered or to be looked into essentially for the improvement of engine efficiency. So, now let us come to another point. So, this part is over—the future aspect of internal combustion engines, rather, future, advancement of internal combustion engines. One aspect is to look into the efficiency improvements that we have discussed; next is emission reduction. So, now let us discuss this particular point: emissions reduction because we all know that certainly if we need to look for enhancement of engine efficiency that would be good practice but this should be achieved without compromising the emission level or environmental regulation to the extent possible that means designer should consider aspects to improvise or increase engine efficiency. But in parallel, designers should also look into this important aspect in tandem. That means we or anyone designing engine should not go for efficiency enhancement with compromised or compromising the emission reduction or emission level so that means this is very important that emission level, so first of all use of biofuels that already I told that these biofuels can reduce emission.

Number two is combustion control. This means that combustion should be such that fuel economy can be achieved at the same time NOx emission can be reduced. So, this part is also important and there are many things available one such avenue could be that if we use catalytic converter that you all know then, nowadays the most important part should be the integration of electronic control unit because if we can reduce manual intervention to the extent possible, efficiency can be improvised.

In this context, let me tell you one thing. We have talked about one particular sensor and that sensor is responsible to measure the concentration of oxygen in the exhaust gases. So, nowadays it is really possible to control everything with the help of engine management system or engine control unit so as to regulate the emission level to meet the environmental guidelines or regulations. So, these aspects should be taken into account while designing. So, just I want to include that integration of Electronic control unit. So, this unit is responsible for controlling the combustion. This unit is responsible for monitoring the NOx level in the exhaust gases. This unit is responsible for providing an adequate amount of fuel-air mixture to the engine cylinder to ensure better fuel economy. So, this is one thing.

Now, let me tell you one important point: the hybrid integration. What does it mean? Hybridization is needed. That means internal combustion engines can work alongside an electric motor. Internal combustion engines work alongside an electric motor. If we can have this arrangement, it plays a crucial role in reducing fuel consumption if the fuel

consumption can be minimized automatically emission level can be controlled right so to this end we all know by this time electrical vehicles have promising potential. Now, the question is internal combustion engines, IC engines are considered to be point sources of environmental pollution. Because in the road, if we have 10 cars, so 10 different sources of environmental pollution. So, this is known as point source, rather distributed source. So, in a city, if there are 1000 cars, 1000 different or 1000 distributed sources of pollution.

So, from that point of view, certainly, hybridization that is nothing but the integration of electric motor with the internal combustion engines can reduce emission together with enhanced efficiency but the question is that there are certain applications wherein internal combustion engines are very much necessary even with the advent of electrical vehicles. So, what are those places? Even for heavy vehicles, then aviation, and there are even areas wherein it is very difficult to have electrical vehicles or electrical vehicles cannot reach in those places.

So, there are certain applications, there are certain areas wherein still internal combustion engines play a crucial role. So, even if we need to use internal combustion engines for those applications, perhaps hybridization could be an alternative and hybridization can have even a promising potential to increase efficiency together with reduced emission levels. So, this is all about the future of internal combustion engines. Now, having all said and done, IC engines will likely remain essential in aviation, heavy transport and remote areas, where EVs (Electric vehicles) are less feasible. So, because we have discussed several aspects to be considered, essentially to increase engine efficiency, to reduce fuel emissions, and the concept of electric vehicles is there in practical applications. But still, there is a need for internal combustion engines in places where electric vehicles are not feasible. That too, there are sectors like aviation and also applications like heavy transportation. In all these areas, internal combustion engines still have promising potential. So, considering this, several aspects that we have discussed in today's class should be taken into account. Initially at a research level, certainly, then that should be implemented in practical applications.

So, fundamentally, if we can really look for alternative cycles—if we can replace the auto cycle, the diesel cycle, or the dual cycle. And then, fundamentally, if we can have a better cycle to improve thermal efficiency, that could be a breakthrough. In this context, probably you all know about the Rankine cycle. So, there is some advancement of this cycle, and that cycle is known as the Kalina cycle. In this cycle, two components are

used: water and ammonia. Though this cycle is still at the research level, maybe after a few years, the Rankine cycle could be replaced by this cycle.

And that would be a real breakthrough to improve the efficiency of the Rankine cycle—the cycle you all studied, which is used to compare the performance of steam power plants. Similarly, if there is a breakthrough in terms of the fundamental of internal combustion engines—that is, the alteration of the cycle itself, then it can really enhance the efficiency of the engine. That could be the most important point or the most important future trend for internal combustion engines. Now, what have we discussed about electric vehicles? Nowadays, the focus is to learn more about electric vehicles, and we all think perhaps electric vehicles will replace internal combustion engines.

But that is not true, and it will not happen because, there are many applications where EVs are not suitable at all. EVs are not feasible. Let us discuss now for a few minutes—though electric vehicles can be considered as a replacement for internal combustion engines, and though they can reduce tailpipe emissions, in the long term, or if we look much deeper into this particular engine, we will see that emission levels will still exist with this particular concept. And those emissions are also very detrimental and should be accounted for. Internal combustion engines are considered as distributed source of pollution because if we have more number of IC engines or vehicles, we will be having more number of pollution sources. So, now question is electrical vehicles really can reduce emission at tailpipe emission. So, this can reduce tailpipe emission, but this electrical vehicle they have several this particular vehicle or electrical vehicles have several drawbacks rather I should say environmental drawbacks and those are related to battery production and disposal of batteries.

So, we all know that electrical vehicle efficiency should be higher there is no doubt about it because electrical energy is always high-grade energy. What do we do with. In an IC engine is that we supply fuel and the chemical energy is converted to thermal energy and the thermal energy is converted to mechanical energy. But in electrical vehicles, we need to supply electrical energy. Essentially, electrical energy would be converted to mechanical energy or work output.

Since electrical energy is high-grade energy, certainly efficiency will be more, there is no doubt. But the issue is having ensured more efficiency with these vehicles, there are severe or several environmental drawbacks, and those drawbacks are associated with the source of electricity that will be there in electrical vehicles. So, batteries are used, and

most importantly, these batteries are lithium-ion batteries. So, battery production together with disposal of batteries are very problematic and this aspect should be again taken into consideration for future design of electrical vehicles and the use of rather extensive use of electrical vehicles. So, they have several environmental drawbacks particularly due to battery production and disposal. So, this is very important. Now, let me tell you one thing batteries are lithium ion batteries and these batteries require lithium, cobalt, nickel and all these are extracted from extensive mines. Now, if we need to extract or if we need electrical vehicles rather electrical vehicles if we think that electrical vehicles maybe a few years down the line will replace internal combustion engines, certainly there will be a need of extensive production of lithium ion batteries and for that lithium together with nickel cobalt should be extracted from extensive mines.

And this extraction process again will be associated with degradation of soil, environmental pollution, water contamination, all these things. So, if we think about, then we can see that electrical vehicles, though they can reduce tailpipe emission, they can eliminate or they can reduce or they can suppress distributed source of pollution, but still there is a possibility of having pollution or environmental pollution and those are associated with battery production and that we have understood. So, environmental pollution associated with battery production. battery production because this battery requires lithium (Li) cobalt (Co) and nickel (Ni). All these materials are extracted certainly from mines and these materials are extracted through energy intensity mining. What does it mean?

That means the extraction process itself requires an extensive amount of energy. So, otherwise, it is difficult to extract all these materials, and if we need to extract all these from the mines—certainly, if we need to have extensive production of lithium-ion batteries—we need an ample amount of lithium to be extracted from the mines, and the extraction process leads to deforestation, soil degradation, and water contamination. So, you can understand that essentially, if the objective is to reduce emissions—of course, efficiency can be increased, because electrical energy is high-grade energy—but to achieve better efficiency, though we can really suppress distributed sources of emissions by using electric vehicles, electric vehicles are associated with the extensive use of lithium-ion batteries. To produce lithium-ion batteries, we need materials like lithium, cobalt, and nickel, and the extraction of all these materials from mining is associated with deforestation, soil degradation, and water contamination. And all these are associated with environmental pollution. So that means designing or having electric vehicles, though

we can really suppress distributed sources of pollution, we are still trying to enhance pollution or environmental pollution from the perspective of the extraction process of materials.

Now, this is about production, and then what is disposal? So, battery disposal. So, any battery cannot be used for a long time because a battery will have a certain lifetime. Now, if we need to dispose that batteries rather unused, when the battery will not or rather cannot be used. So, those batteries' disposal is again very-very problematic because the degradation of lithium-ion battery is a long-term process. So, lithium-ion batteries degrade over time and require proper disposal. That means we cannot dispose of lithium-ion batteries arbitrarily because we need proper disposal, and if the infrastructure is insufficient, then this disposal process leads to soil and water pollution from toxic chemicals. So, that means, what you can see. That the production of lithium batteries is also associated to the environmental pollutions. Because extraction of all these materials needs energy intensive mining, then these materials, if we need to extract, it will be associated with deforestation, soil degradation and water contamination. Then we can see finally, even if we can produce lithium-ion battery, then we need proper disposal because lithium-ion battery degrades over a time and the disposal process requires sufficient infrastructural development. If the infrastructure is insufficient, then this disposal process will lead to the soil and water pollution from the toxic chemicals, this is one thing. So, that means what we can understand though electrical vehicles are efficient more than the internal combustion engines and also electrical vehicles really can suppress distributed source of pollution but if we look at carefully we can see electrical vehicles are also associated with environmental drawbacks and those are associated with battery production and battery disposal.

So, challenges are there to have proper infrastructure for the disposal of lithium-ion batteries is needed, and when the demand becomes very high, we will need to produce extensive amounts of batteries, which will inherently be associated with environmental pollution, as we have discussed.

So, to summarize today's class, we can say that we have talked about the future of internal combustion engines. We discussed several aspects a designer must consider to improve engine efficiency, reduce emissions, and certainly the hybridization of internal combustion engines. Then, we discussed electric vehicles because, as I mentioned, you all have studied or know by now that electric vehicles can replace internal combustion engines. However, there are some challenging issues to address before electric vehicles

can truly replace them. Finally, I mentioned that there are certain areas and applications where internal combustion engines still play a crucial role.

So, I will stop here today. This is the last class of this course, and I hope you all have enjoyed learning the various modules. I believe you will enjoy the remaining modules as well. If you have any questions or doubts, please feel free to email me. I will be happy to answer your queries.