Engineering Thermodynamics
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Lecture - 42
Applications. Problem Solving: Otto cycle. Diesel cycle.

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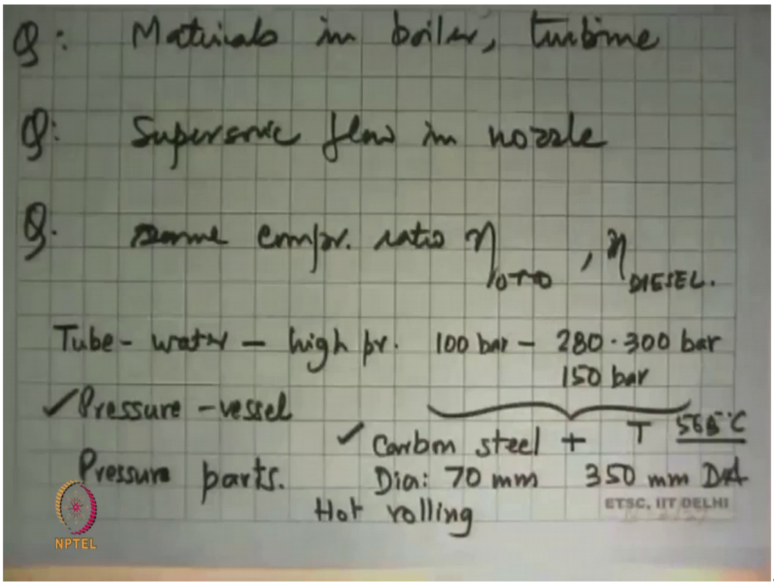

The third question was about compression ratio and Otto cycle and diesel cycle. So, let us take up that.

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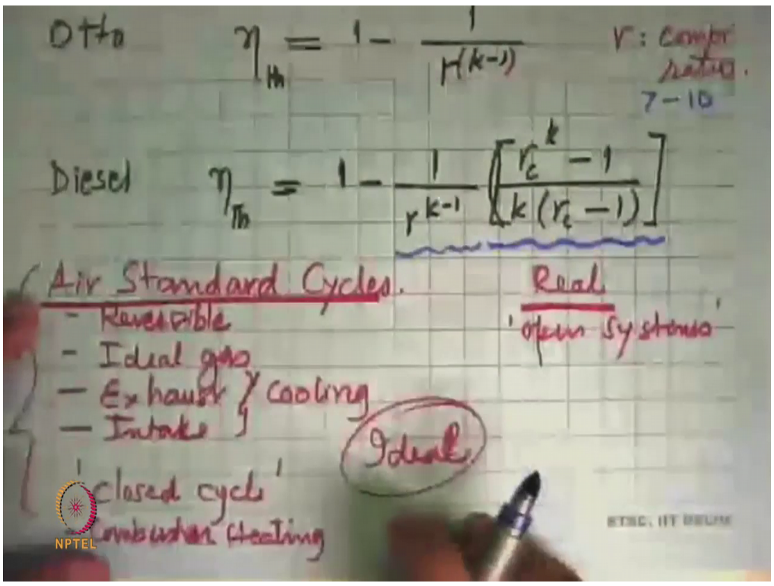

Here analysis of the cycles as describe in a few minutes, but I will not go into the detail arithmetic of it which is there in everywhere on the books, on the web, you can see the full detail derivation. What I have done here is just describe the final formula. In the and now let us be clear what is it that we are talking here about. We are looking at what I started discussing yesterday as Air Standard Cycles. We did not have; firstly, all (Refer Time: 01:02) reversible and we said yesterday that the working substance behaves like an ideal gas we made a differentiation between what happens at the exhaust versus the cooling process.

The cooling process is replaced by exhaust and by the intake. So, air standard cycles are or it is a closed cycle unlike for system that we have looked at and real cycles are open systems because after the combustion is done and of course, the heating is replaced by a combustion process. So, those are all the major differences between real cycle and a standard cycle, three major differences and you should keep that in mind and the reason we convert this real cycle into an air standard cycle is because it gives us a very quick and a easy way to do the analysis and come up with some very quick ballpark numbers, but remember these are this is an idealization and the real cycles will be quite different and definitely less efficient than what these numbers tell us. In a course like this we do not go into analysis of real cycles. We will just look at the first order analysis of these circumstances.

So, these are the formula. Thermal efficiency of Otto cycle is 1 minus 1 over r to the power k minus 1 where r is called the completion ratio. So, what is compression ratio?

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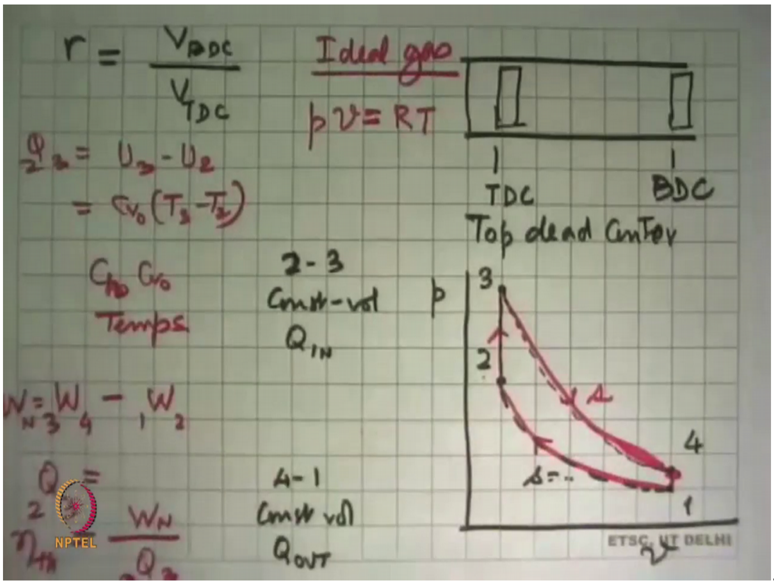

You just take a in this cycle is that they have a cylinder piston arrangement where the piston moves between this extreme position and these extremes and this is the stagnant machines whether it is a compressor or whether it is a press look at in into the combustion engines . So, this is called the top dead centre and this is called the bottom dead centre and this much volume got compressed.

So, the ratio of this is called the compression ratio. So, we can say this is volume at the bottom dead centre divided by the volume at the top dead center. The touching how much you compress that gas and you may look at the complete analysis of this cycle, the air standard water cycle we will look like this. I am plotting v here and pressure here and he said when the piston goes up and down, how does pressure varying and what is heat transfer in this process , what is work transfer in this process. This is what we want to know. So, what happens here is in the compression process please and we reach the point over there this will be a solid line, but right now I am just showing this. This is state 1, this is state 2 then the ideal cycle we have constant volume heating.

So, from here it goes and bends to stay 3. This is the; this is constant volume iteration and after that the piston has to come back to its original position. So, it expands from here and it comes back to this state which is 4 and from 4 to 1 this is, so this was 1 to 2, 3 and 4 to 1 is again a constant volume Q out cooling process. So, this cycle and whatever in the substance inside this I mean all these cycles we assume that that substance is an ideal gas.

So, p V equal to RT the equation of state this can be applied; this is isentropic process, this is an isentropic process and we can start doing the complete analysis from everything that we have learnt. Process by process we write the equations and we say this is from process 2 to 3 this is of closed system we write Q 2 3 is W 2 3 which is 0 plus u 3 minus u 2 which is CV 0 T 3 minus T 2. So, similarly every process can be written in terms of CPC V 0 and the temperatures and then the network output we can calculate that there was no work here, there is no work here. So, the work output network output is W 3 4 minus W 1 2 and the heat input to the system was happening between Q 2 3 and this is the network of the cycle.

So, the ratio of this network WN divided by Q 2 3 this is the thermodynamic efficiency of the air standard, Otto cycle and when you solve all these things by putting all this Tsand TPs and CVs, we get relation which is the first equation here; this one; 1 minus 1 upon r k to the power r to the power k minus 1. So, this is; the exponent when you keep increasing r the efficiency goes up and r gets higher and higher. The thermal efficiency increase of is getting lost.

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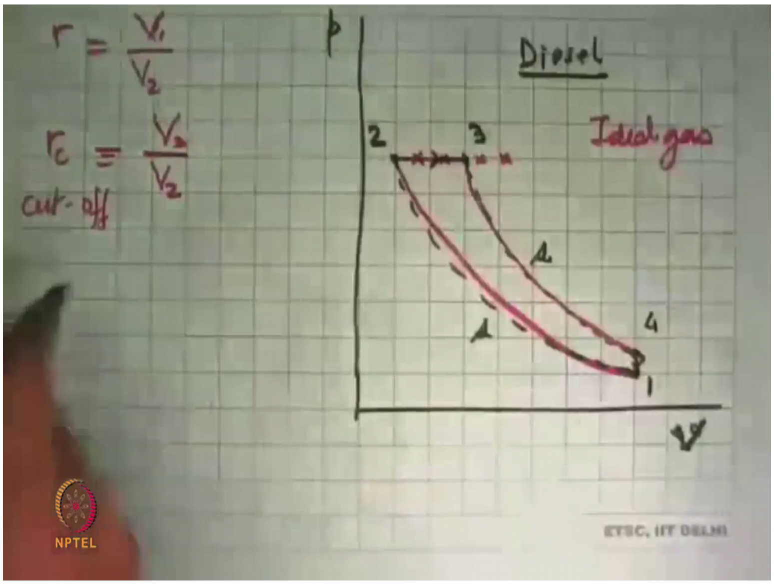

The second part was what happens in a diesel cycle and here this 2 T cycle, but the heat addition now is at constant pressure. So, it goes there and this is heat addition at constant pressure to be 3. After that we have exactly the same story expansion which is isentropic and then a constant volume cooling.

So, these two processes and the cooling process are the same features as the Otto cycle, but this is a diesel cycle the heat is at constant pressure. So, cycle was heat, this is heat transfer constant. The early cycle we turn right constant volume, the Carnot cycle discredit to be a constant temperature that we yesterday is not possible a point or this point or that point. That is a choice we have to make in addition to this and this distance.

So, first is the compression ratio r which was again V 1 divided by V 2 or that V 4 by V 2 does not matter. The second cut off ratio that is this is defined as V 3 upon V 2 and when you do all the again the same IV concept apply. We look at it to a this is the closed system and ideal gas is the working substance again and when you do all of that we can get a formula with this like the second one here. A thermal efficiency is 1 minus 1 upon r to power k minus 1.

So, this part is same as the Otto cycle, but not we have, but sitting there r c we took the cut off ratio that has come. So, depends on what r t 1 takes and which is to compare these two, but in general if you just take these two and see which has got the efficiency, it will turn out that the Otto cycle efficiency is slightly greater than the diesel cycle efficiency, but there the problem here Otto cycle use which is in the range of 7 to 9 or 7 to 10, not more than that and that is because what in the cycle in the real cycle. In fact, we have a intake stroke which starts from here and it takes in the substance and what intakes is air plus vaporized fuel or fuel vapour mixture and then, it is compressed to this point where the temperature is T2 and this T2 is less than the Otto ignition temperature of this mixture.

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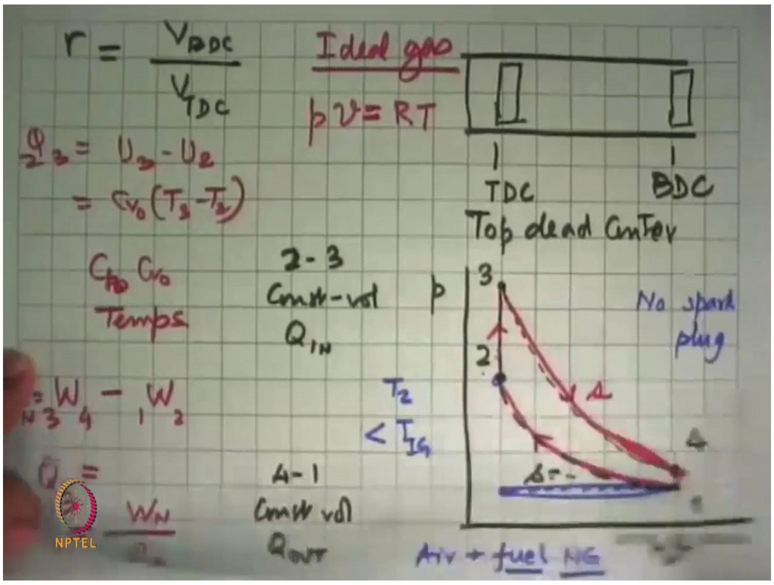

Otherwise it can explode by itself and the rest thing can happen and for that reason the pressure ratio here is kept 7, 8, 9 in that type of range.

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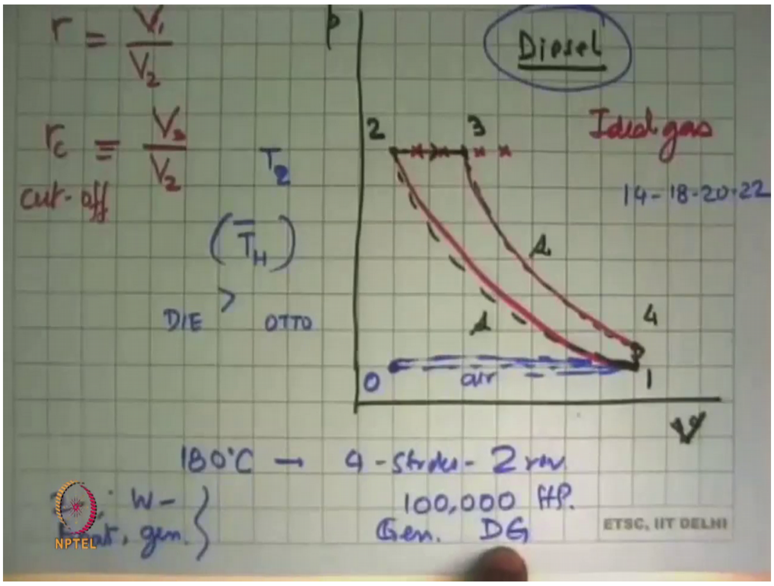

In diesel cycles what we have drawn here; the index trunk is there when it takes in only air. So, there is no danger that you can compress it as much as you want, there will be no explosion or no ignition. So, compression ratios here could be anything from 14, 18, 20 even 22. So, the temperature here T 2 in the diesel cycle will be much larger than the temperature at the end of the compression process in the Otto cycle. So, that gives an advantage to diesel cycles that because of this higher temperature at which then it will who takes place overall the average temperature at which T H takes place is greater for diesel cycle than for Otto zone and that is why diesel engines in general have higher efficiency than Otto cycles. To complete the real life treatment a standard cycle is what we do here. The real cycle gets an addition thing. It takes in air, then compresses it, go through it and then it goes back over there and comes back to this state.

So, this we can call it zero state. We take a break, there are two strokes, then there is one stroke for compression and one is for power stroke. So, each stroke is 180 degree rotation of the crankshaft and so, to take four strokes you need two revolutions. There was two stroke petrol engines. I will not go into the details of it what the problems are. There also even the same thing you got two more stroke sitting over there, but those are now pretty much on the way out because of the pollution effect and the more thermal efficiency, but push drop diesels are very much alive in big numbers and all the big engines are all diesels. The next thing you should remember is that it is the same engine which instead of burning fuel as a petrol vapor is also used with natural gas and this ignition here happens by putting a spark into it which will cause it to explode.

So, if a gas engine is essentially a spark ignition engine, but in many cases in our country when diesel engines got banned, many people tried to convert a diesel engine into a spark ignition. The last thing I will speak about this; is that the idea that it can explore by itself is now being researched and we say when what we will do is, we will compress it to a higher level, so that it explodes by itself and continued by. So, I do not know spark plug, but such engines are not yet anywhere in the market. They are in the research laboratories. There is no practical way of exactly controlling when it will explode. That is one of the challenges the search is going on.

We do not know if and when it will come in the market. The important thing to remember is that a vast majority of the horsepower that you get is from major engines. Petrol engines are very largely used for two and four wheelers and in some cases for some types of say boats; boat engines and some generators, the capacity they are relatively modest 200, 300, 400 horsepower is about the upper limit to which one starts getting diesels. Diesels they generally do not go to very small sizes, but on the upper side the biggest diesel engines are like 100000 horsepower and these are used likely in marine Propulsion. Almost all your generator sets except the very small ones.

They are called diesel generators because they are diesel engine coupled towards electric generators and wherever in your city you see a exhaust pipe coming out be certain that it starts off in a box which is got a diesel engine what we do, because of cell phones on every cell phone tower if you do not get reliable electricity supply and this own diesel generator once provide electricity for the electronics and also electricity for keeping it cool which is there and across the country, there are more than lakh cell phone towers using diesel engines. So, you can think that cell phone which was not just a great thing as far as environmental is concerned and have a huge impact on the digital (Refer Time: 17:20) of that.