Fundamentals of Automotive Systems
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Lecture-08
Two Stroke Engine and Engine Cycles
Part 02

The next topic that we are going to look at is that of engine cycles, so what is engine cycle, just to quickly recap what we have done. We have looked at typical components in internal combustion engine and learned how 4 stroke and 2 stroke engines operate. Now as I explained to you during the introductory part of this course the framework for this course is that first we will learn about components operation right.

And then we will do some analysis, so now let us do some analysis of engines and in that regard you know like using some thermodynamic cycles to do the analysis helps us ok. So how do we analyze engines using what are called engine cycles, what are the various attributes and what are the different ways in which we do that right that is something which we are going to learn.

So let us first look at the word cycle alright and since we are going to look at internal combustion engines you know like where we are going to have what to say conversion of chemical energy into thermal energy and thermal to kinetic energy. We will be looking at what are called thermodynamic cycles you know like which naturally fit up. So first let us ask the question what is a thermodynamic cycle.

So this is something which you would have encountered in basic undergraduate course on thermodynamics right. So in general you know like if you take any system right, the word cycle means you know like is a system is taken through a set of states right and it comes back to it is initial state right that essentially completes a cycle. So a thermodynamic cycle is one where the variables that characterize the state of the system or all thermodynamic variables like pressure, volume, temperature, enthalpy, entropy, internal energy and so on right.

So these are typical thermodynamic variables that we encounter, so we essentially look at these variables and then like take the system through a sequence of states and then we end up with the same initial state right. So that is a thermodynamic cycle right, so we are going to look at what cycles can be used for analyzing internal combustion engine and before we go and look at different cycles you know.

We also has asked a question that would one classify IC engines, an IC engine let me put it this way as an open system or a closed system.

So we would have once again encountered these terms in thermodynamics what is an open system , an open system is one where you can have both mass and energy transfer right between the system and the surroundings. A closed system is one where you can have only energy transfer but no mass transfer right between the system and surroundings. So if we consider the engine from what we have learned till now, would you classify the engine as an open system or a closed system it is an open system right.

So we have fuel and air coming in we have energy transfer and then we have exhaust gases also be given to the surroundings. So let us recall this fact later on ok, so we are going to look at one important class of cycles you know like which is what is called as an air standard cycle ok and which is what we can reasonably do by using a pen and a paper ok. So if you want to analyze get some insights into engine performance and so on.

We are typically what we do is that like we essentially look at what are called air standard cycles right, what is an air standard cycle and how is it going to be utilized for engine analysis. So there are some critical assumptions made when we deal with what are called air standard cycles the following assumptions are made. So the first one is the working fluid is air ok that is an important assumption ok when we deal with the air standard cycle.

So in an actual engine the working fluid is a mixture of fuel and air right but when we analyze engines using air standard cycles now we are going to consider the working fluid as air ok that is an assumption we make right. So obviously you know the equations that we get by analyzing engines as air standard cycle is going to be a mathematical model and as we know a mathematical model is only an approximation of the actual system's performance right.

So the tighter our approximation or assumption that is the less assumptions we make maybe we expect to move closer to the real systems performance right. So in an air standard cycle we assume that the working fluid is air ok, second air is treated as an ideal gas. So what does this mean we are essentially going to treat air as an ideal fluid and we are going to use that equation of state right PV equals MRT ok for our analysis ok that is the ideal gas equation of state right.

Air Standard Cycle: The following assumptions are made:

- **i) Working fluid is air.**
- **ii) Air is treated as an ideal gas.**
- **iii) Combustion process is described by a heat addition process.**
- **iv) A heat rejection process is used to restore the system to its original state.**
- **v) All processes are internally reversible.**
- **vi) Constant or specific heats can be used.**

So that is something which we are going to use in this process, the combustion process ok that is a process of burning fuel and air is described by a heat addition process ok. So that is another assumption we are going to make ok and the exhaust process you know through which the system is brought back to it is initial state is going to be approximated by means of a heat rejection process ok.

So there is a heat addition process to mimic combustion and there is a heat rejection process through which the system is brought back to it is original state to complete the cycle right. A heat rejection process is used to restore the system to it is original state ok that is another assumption made in this process and we assume all processes are internally reversible. So that means that if I go from state A to state B.

I can come back from state B to state A in that is along the same path right, so that is an assumption ok. So these are all approximations ok which help us getting this model and when we want to deal with the thermodynamic relationships right. So even when we use a conservation of energy and other laws of physics, so many times we encounter change in internal energy, change in enthalpy and so on. And we write change in internal energy as the product of the specific heat at constant volume times the corresponding change in temperature right.

Change in enthalpy as a product of specific heat at constant pressure times change in temperature and so on. So and the specific heats themselves can vary with temperature, so in this analysis we can either use a constant or variable specific heats you know both this method can allow for both ok constant or variable specific heats can be used in this process ok. So these assumptions characterize the air standard cycles.

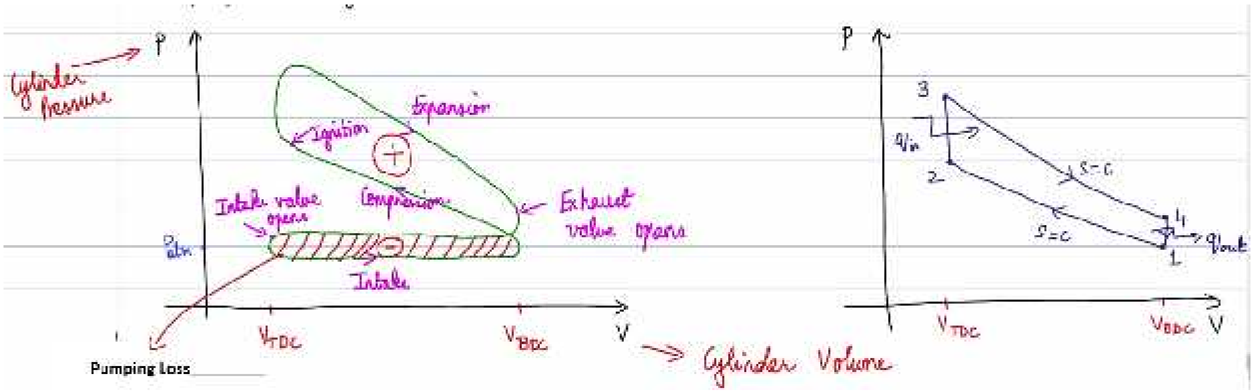
So as the name indicates the working fluid is air, we treat air as an ideal gas and then we are replacing the combustion and the what to say combustion process by a heat addition process and heat rejection process is used to bring the system to it is original state and we assume all process the processes is to be internally reversible ok. Suppose if we consider the working fluid to be both fluid and sorry fuel and air and we want to analyze the effect of this mixture on engine performance.

Then we need to study what are called we need to analyze engines using what are called fuel air cycles ok. So in this course we shall consider only air standard cycles ok, so obviously as we know in air standard cycle we cannot account for the presence of fuel. So we would not be able to study the impact of the fuel air ratio or the characteristics of the fuel air mixture on engine performance, so that is a limitation.

So but anyway we will see what can we learn and in what respect we can use the air standard cycle ok.

So the first cycle is the otto cycle right, so this cycle is use to characterize the operation of a spark ignition engine what we call as a gasoline engine or a petrol engine it was proposed by Nicholas Otto around 1876 ok around that timeframe this one the as we know. Nicholas Otto is a

German right, German automotive engineer who proposed it around 1876. So what is the motivation right behind this otto cycle.



So if we look at a typical PV diagram ok of a gasoline engine right and we want to look at the various processes that happen. We typically get a curve which is in this manner, so P is the cylinder pressure of course alright and V is the cylinder volume. And naturally the volume of the cylinder varies between the clearance volume and the total volume, this is the volume at top dead center and volume at bottom dead center right.

Volume at bottom dead center is a total volume, volume at top dead center is the clearance volume alright, so that is the range of the cylinder volume. So if we look at the PV diagram of a typical sorry 4 stroke spark ignition engine. Let us go through all this strokes, let us say the suction we start with a suction stroke. During the suction stroke the pressure is going to be slightly below atmospheric, let us consider a naturally aspirated engine.

Let us say that I am drawing a very simple curve, let us say the during the suction stroke the pressure is slightly below atmospheric right. And then I close the inlet valve and then I start compression, so the pressure is going to increase. And what is going to happens is that, as I come closer and closer to the top dead center let us say I start the ignition and then the pressure will increase due to the tremendous amount of heat energy which is released ok.

And then there is an expansion or a power stroke during which the gases are going to push the piston down and then closer to the bottom dead center I open the exhaust valve. And then the gases are exhausted and then I come back to the same state. So if I were to mark the critical points here, so somewhere here let us say I open my intake valve right, so this is the intake stroke.

Then I go here and then I go and start compressing the fuel air mixture that is the compression stroke. And let us say I start the ignition somewhere here towards the end of the compression stroke and then there is a combustion and then there followed by expansion. And towards the end of the expansion stroke let us say I open the exhaust valve and this keeps on repeating ok, the cycle keeps on repeating you know I am just drawing a very simple PV diagram of a 4 stroke gasoline engine.

So how is this simplified and visualized in the otto cycle, in the otto cycle which is an air standard cycle we are not going to be worried about the constitution of the mixture right as I said we are only going to consider the fluid as air. So consider a closed piston cylinder combination which has the same quantity of air corresponding to this fuel air mixture alright. Now what we do is that we are not going to be worried about the intake and exhaust strokes right.

Because we have sealed that cylinder and piston right, so there is no leakage. So what we do is that we start with the compression stroke right. So let us say we have volume at top dead center and volume at bottom dead center these are the 2 points. We start with the compression stroke ok we are not going to be worried about the intake stroke and the exhaust stroke when we consider the otto cycle.

And before I go to the Otto cycle please note that if I look at the approximated actual cycle. In this cycle in this thing whatever work which I get will be the work output right but this area as we know in thermodynamics the area of the PV diagram right gives me work either work input or work output right. But this small area is something where I need to provide energy that is the engine needs to provide energy right.

And what is indicated by the positive sign is the one which is obtained as output, so you can see that you know like the work output obtained during the expansion stroke is used to essentially in the certain sense drive the other strokes. And this area is typically referred to as pumping loss or pumping work you know like because that is essentially use to pump the fuel air mixture either into the cylinder or pump out the exhaust gasses right using that word pump right.

So that is why it is called as a pumping loss or the pumping work ok, so that area right there which I have shaded in red ok. So that is something which the engine should give ok, so when I crank the engine before it starts, we are providing that energy externally and even the energy for compression right, so till the engine can sustain by itself. So in the air standard otto cycle what we say is that look I am going to not consider this intake and exhaust stroke.

Because I have a closed volume which is sealed and where the working fluid is only air, I start when the piston is at the bottom dead center ok. So what I do is that like I compress the fuel air mixture and then I go to the top dead center ok and this is a process in which I keep the entropy constant ok. I assume that you know like it is a constant entropy process or an isentropic process.

So the compression process is assume to be isentropic ok from 1 to 2 then looking at this ignition and the mechanism of combustion the equivalent heat addition process is assume to take place at almost constant volume ok. So the heat addition process is use to mimic the combustion process and that is assume to take place at almost constant volume. So the process 2 to 3 is a constant volume heat addition process that is how it is approximated ok.

Then comes the expansion, the expansion process is also taken to be a constant entropy expansion process or what is called is as the isentropic expansion process. Then the process 4 to 1 closes the cycle right, so this is the process where heat is rejected. Once again it is assumed to be a constant volume heat rejection process ok, this is how visualized and simplified. So these are the 4 processes, we can immediately observe that we are not going to look at the intake and a exhaust ok.

We will factor that one in later you know we are going to see how that affects the analysis right. So it is interesting if you look at the otto cycle philosophically we are considering the working fluid as air and that is contained in a sealed piston and cylinder assembly. So we are idealizing the system as a closed system but as we just discussed an engine is an open system. So we can see that when we do these engine cycles you know like we are going to deal with an approximation of a closed system.

But then yet applied to open systems ok, so the there an approximation which is done but we need to be aware of the assumptions. So I would stop here for this class and then like we will continue with the otto cycle tomorrow we look at more features of the otto cycle and then like we will do an analysis thank you.