Fundamentals of Automotive Systems
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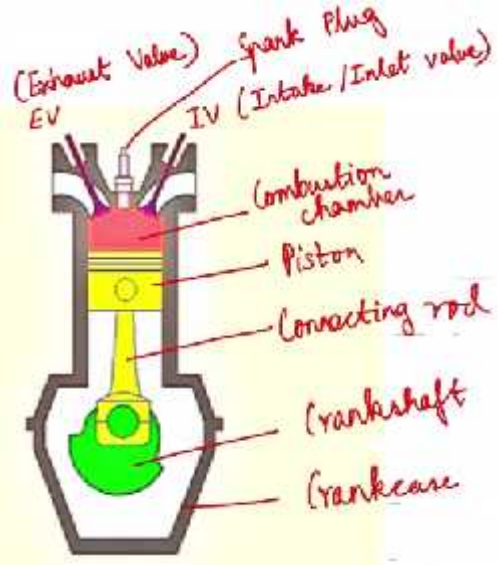
Lecture-06
Operation of 4 Stroke Engines
Part 02

So moving on.

So let us now look at, let us now go back to the 4 stroke petrol engine and then like look at the strokes themselves right. So we are looking discussing the operation of this SI engine and we looked at this diagram.



FOUR STROKE SI ENGINE

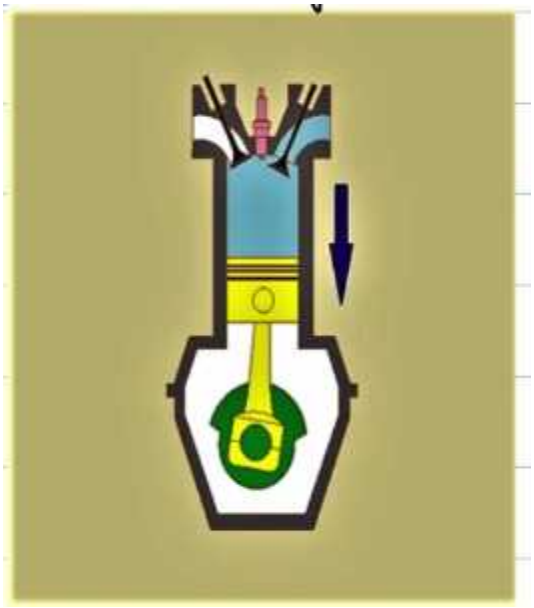
Now let us look at the 4 strokes of a 4 stroke spark ignition engine.

Operation of a Four stroke SI engine

- **Suction Stroke**
- **Compression Stroke**
- **Power/Expansion Stroke**
- **Exhaust Stroke**

One Cycle

So let us see what happens in each of the 4 strokes .



- **Piston travels from TDC to BDC**
- **Intake valve kept open**
- **Exhaust valve kept close**
- **Fresh air fuel mixture inducted inside the chamber**
- **Total crank shaft rotation at the end of the stroke is 180 degrees**

1. SUCTION STROKE

So first, let me take the suction stroke. So what happens in a petrol engine is that when the what to say engine starts one operating cycle as a first stroke the piston starts to move down okay as we can see in this figure. So during the suction stroke the piston starts to move down okay, the piston is going from the top dead center towards the bottom dead center.

And the inlet valve is opened okay. So, what happens is that either air or fuel air mixture is taken into the combustion chamber due to pressure difference during the suction stroke, we are going to see what are the different mechanisms of introducing this fuel air mixture okay in typical petrol engines, when we go to what is called mixture preparation. So either air or fuel air mixture is taken into the combustion chamber during the suction stroke they exhaust valve remains closed right.

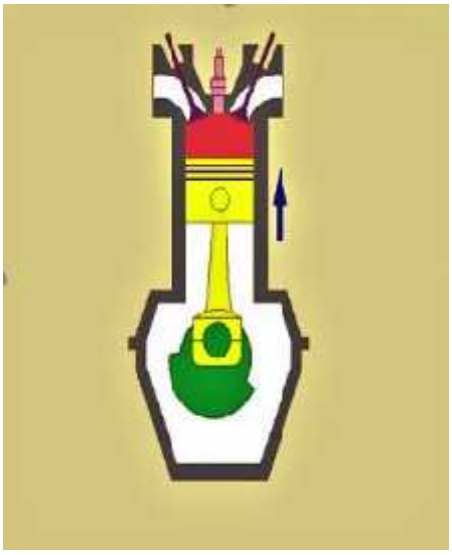
Because we do not want what is called as exhaust gas dilution right. So, the camshaft becomes very critical here it has to operate in such a way that during the intake stroke it opens only the intake or inlet valve but it closes the exhaust valve why. Because if the exhaust valve are open the exhaust gases right which are present in the exhaust manifold may come into the combustion chamber due to the pressure difference. The pressures in the exhaust manifold is going to be

higher right and in the combustion chamber is going to be lower during the suction stroke because volume is expanding right during the suction stroke. So, we do not want the exhaust gases from the previous cycle to come into the combustion chamber and that is why we want the exhaust valve to remain closed during the intake stroke okay. So that becomes very critical.

So, what is exhaust gas dilution it is the process by which exhaust gases mixed with fresh charge okay fuel air mixture is called as a charge right and dilutes it because obviously as you can see you know like mix exhaust gases the combustion process is going to be affected right is it not okay. So the effectiveness of the combustion process will go down. So during the suction stroke, the piston moves towards the BDC.

And when the piston reaches towards closer to the BDC right the inlet valve is closed okay. So, if the air fuel mixture or air has been taken into the chamber and the inlet valve is closed on the suction stroke ends okay. So, just to recap during the suction stroke the inlet valve is open, the exhaust valve is closed and the piston moves from the top dead center to the bottom dead center and the inlet valve is closed when the piston reaches the bottom dead center okay.

So at the end of suction stroke we have the fuel air mixture in the combustion chamber in a spark ignition engine okay. So now what happens in the next stroke, so the second stroke is the compression stroke.



- **Piston travels from BDC to TDC**
- **Intake valve kept close**
- **Exhaust valve kept close**
- **Pressure inside combustion chamber increases**
- **Total crank shaft rotation at the end of the stroke is 360 degrees**

2. COMPRESSION STROKE

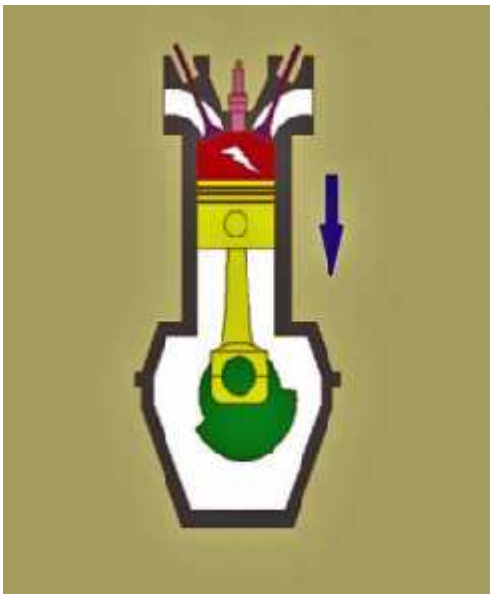
So, in the compression stroke, we can observe that both the inlet valve and the exhaust valve remain closed. So, the piston starts to move from the bottom dead center and starts to go towards the top dead center okay.

So that is what happens during the compression stroke. So, what happens the fuel air mixture is compressed. So, as a result the pressure increases and the temperature in the cylinder also increases okay, the pressure in the combustion chamber and the temperature in the combustion chamber both increase during the compression stroke and during this process we will later observe that the fuel air mixer mixes well.

So that like we get almost what is called as a homogeneous mixture of fuel and air that will promote more efficient combustion when the spark ignites the fuel air mixture okay. So, that is also one important aspect of the compression stroke okay. So, the compression stroke ends when the piston reaches closer to the top dead center okay. And obviously, we want both the valves to be closed right.

We do not want any fuel air mixture to escape through any of the valves and this is where the importance of compression rings is also felt right because we should have very good compression rings such that there is no leakage between the piston and the cylinder wall right. So that becomes very important okay. So these are the critical attributes of the compression stroke. So, once the compression stroke is completed the towards the end of the compression stroke, the fuel air mixture is ignited by means of the spark plug.

So, what happens here. So, the piston goes closer to the top dead center and the spark plug gives a high voltage spark which ignites the fuel air mixture. So, the fuel air mixture combust right. So, close to the top dead center the fuel air mixture is ignited and obviously combustion happens. We are going to generate a lot of thermal energy, high pressure gases that are going to push the piston okay.So the pressure and temperature increase tremendously during the stroke okay, I am using P for pressure and T for temperature, right. So the pressure and temperature of the fluids inside the combustion chamber increase tremendously during this expansion stroke or the power stroke. And obviously we want both valves to be closed. We do not want any leakage. And once again the importance of compression rings can be felt here, right because we do not want any leakage once again right.



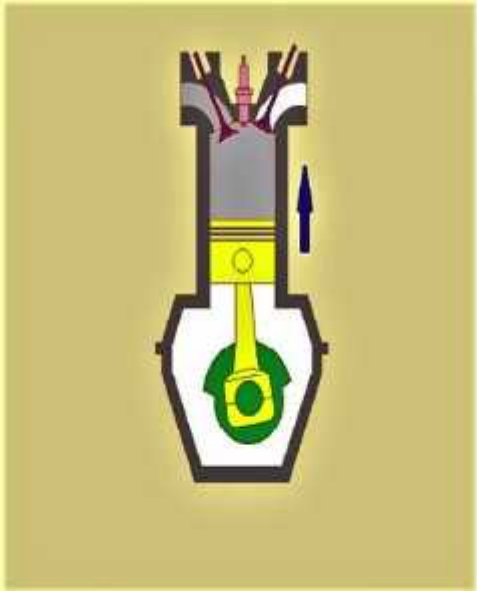
- **Piston travels from TDC to BDC**
- **Intake valve kept close**
- **Exhaust valve kept close**
- **Ignition takes place in combustion chamber.**
- **Total crank shaft rotation at the end of the stroke is 540 degrees**

3. POWER STROKE

If there is a leakage then the effective work that is done on the piston would reduce. So we do not want that also to happen. And this is the main stroke where energy is transmitted from the fuel to the piston and that is why it is also called as a power stroke. The term expansion stroke is very obvious. Because the hot gases expand the piston moves from top dead center to bottom dead center. Power stroke because the energy to drive the other strokes is and also the vehicle is obtained during this particular stroke okay. So that is the power stroke or the expansion stroke. So, let me so this is the power stroke okay this diagram. So, the last one is the exhaust stroke.

So, when the piston reaches close to the bottom dead center towards the end of the power stroke the exhaust valve will be open.

And the hot the gases which are the products of combustion are now going to be pushed up okay, so that is what will happen during the exhaust stroke. So now you can see that the exhaust valve is open the inlet valve remains closed, right because we do not want the exhaust gases to pollute the next cycle's fresh charge right. So, the exhaust valve is open and the piston moves from the bottom dead center to the top dead center and pushes out the exhaust gases right.



- **Piston travels from TDC to BDC**
- **Intake valve kept close**
- **Exhaust valve kept open**
- **Burnt exhaust gases pushed away**
- **Total crank shaft rotation at the end of the stroke is 720 degrees**

4. EXHAUST STROKE

When the piston goes towards the top dead center, the exhaust valve is closed and the inlet valve opens and the next cycle starts yes. So, the first stroke is a suction stroke right. Although the volume in the cylinder is expanding, energy is not transferred to the piston okay, energy is transferred to the piston only in the power stroke or the expansion right. In the what to say case where, the strokes where the volume is decreased in the compression stroke and the exhaust stroke.

You can see that in the compression strokes the valves are closed, whereas in the exhaust stroke the valve is open. So, what you need is the correct sequence of strokes right. So, when you start the engine the piston is going to be at some location and there is going to be a mechanical what to say a marking of the stroke yes. So, there will be like the mechanisms which are there will be sort of coded right with information of these strokes.

When you come to the lab you will look at all these aspects right the exact mechanism by which it makes, for power stroke as you have already said why temperature increases because it is an exothermic reaction and the expanding the volume increases how exactly is the pressure also

increases, pressure increases because the volume increase is not so significant when compared to the amount of thermal energy you release.
So, even if you look at the ideal gas equation of state PV equals MRT right temperature increases due to the tremendous increase in the energy right which is thermal energy is created from the chemical energy of the fuel. So, if you keep the M and R to be the same, PV is increasing. So, but the volume is increasing but not to the extent to balance it off, so, pressure also increases okay ok.

That is an important factor we will come back to and we study emissions. So, her question was when I want to push out the exhaust gases through the exhaust manifold to the exhaust valve into the exhaust manifold and to the what are called after treatment systems what happens is that like I need a pressure difference right. Because the pressure there should be lower otherwise the gases are not going to move correct.

So how do we what to say assure that ultimately you can see that if you do not have any of those, you just have a pipe in obviously you are dumping to the atmosphere, right and that is going to be a significant delta P which will enable that flow, but when once you start adding all these elements, you are going to have what is called a significant backpressure. Then we need to start worrying about what will happen right.

So that we will figure out no it will not right okay so we are going to exactly the next point which I am going to discuss . So, we have looked at all these 4 strokes, the strokes do not happen in phase in all the cylinders, what do I mean by that. You will not let us say you consider a 4 cylinder engine, the suction stroke will not happen at the same time in all the four cylinder and so on, they will be spread out okay.

So there are multiple reasons for that, because you want the power stroke to be spread out, right so that like you sort of get a uniform energy output on the crankshaft. And imagine another reason is that like imagine that all 4 cylinders are going through the power stroke at the same time that is going to create a lot of mechanical load on the crankshaft at the same time, right. So that is also something which is undesirable right okay.

So the point is the energy obtain from the expansion stroke is essentially providing the energy for the compression suction and the exhaust stroke, we look at that when we do the analysis even if you have a single cylinder engine that is what happens right, if your perspectives okay if you have a multi cylinder engine but I will slightly reoriented because even if you have a single cylinder engine, the suction compression and exhaust stroke in that single cylinder engine has to have to be sustained right.

A flywheel smoothness out the torque, but the energy obtained from the expansion stroke sustains okay which one not only that because the you have a lot of kinetic energy right, that essentially ensures that it provides energy to the other strokes, okay. When we do thermodynamic analysis using the PV diagram it will become clear okay. So, these are the 4 strokes in a 4 stroke engine and the power stroke or the expansion stroke provides the energy.

And the other 3 strokes are what to say take energy you know like from the crankshaft right. So, we will when we do the engine analysis, we will calculate expressions for the net energy output or the network output from these 4 strokes. Now, that is an analysis that we will do when we come to what are called air standard cycles analysis in a few classes. The next before I go to the next topic of 2 stroke engines, a quick discussion on how a 4 stroke compression ignition engine works.

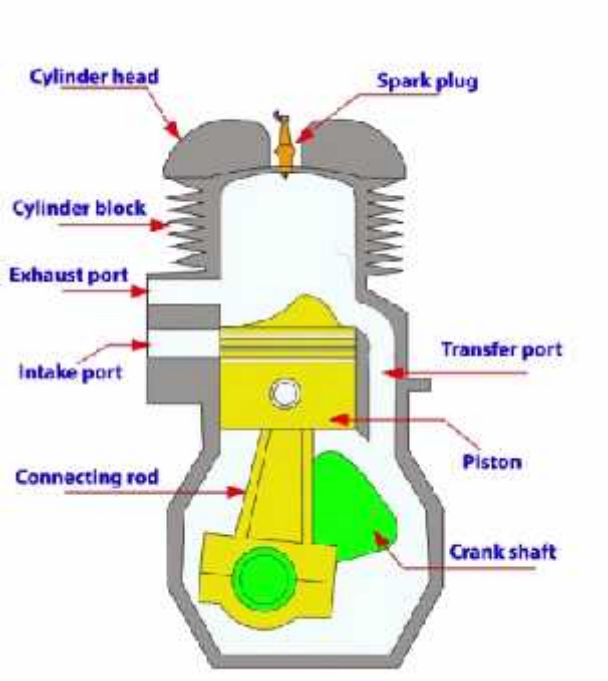
The strokes remain the same, but the main difference is now that the spark plug is going to be replaced by a fuel injector and during the suction stroke only air is taken into the combustion chamber in a compression ignition engine okay. And during the compression stroke only air is compressed okay, no fuel only air is compressed during the compression stroke in a diesel engine or a compression ignition engine.

And towards the end of the compression stroke when the air has been compressed to a high pressure and temperature fuel is injected into the combustion chamber by means of fuel injectors. It sprayed in at high pressures and the fuel self ignites and that phenomenon leads to the power or the expansion stroke and the exhaust stroke follows. So that is the fundamental difference

between the petrol the 4 strokes in a compression ignition engine as opposed to a spark ignition engine okay. So, those are the main pictures okay.

So, let me present a brief overview of 2 stroke engine and then we will see how it works right. So, let me just write down what I orally told about the strokes in the compression ignition. So, first differences the presence of fuel injector right no sparkplug. The second main difference is only air is compressed okay not fuel air mixture okay and fuel which is injected towards the end of the compression stroke self ignites okay.

So, that is another important aspect in a compression ignition engine okay. So let me give you a brief overview of 2 stroke engines and then like we will continue the discussion in the next class.



One cycle is completed in two strokes of the piston ⇒ 1 revolution of the crankshaft.

- **No valve assembly, camshaft.**
- **Intake/inlet & exhaust ports**

CONSTRUCTION OF TWO STROKE ENGINE

So, how does a 2 stroke engine differ from a 4 stroke engine. So this is just a simple schematic of a 2 stroke engine. Of course, I am just taking a spark ignition engine once again and draw we can a similar schematic for a compression ignition engine as we have already discussed, main

difference is going to be the sparkplug being replaced with a fuel injector, right. So we can immediately see some big differences.

The crankshaft is still there right. The piston and the cylinder and the connecting rod are all still around, right. We still have the spark plug, we still have the cylinder head. However, what is missing is the valve assembly right. So, no valve assembly camshafts right as a result no mechanisms for driving the camshaft timing belts gears and so on right. So then how are fuel air mixtures and taken into the combustion chamber.

And how are exhaust gases removed from the combustion chamber, we have what are called as the intake port or the inlet port the exhaust port and what is called as a transfer port okay. So, rather than valves in place of valves, we have intake or inlet ports and exhaust ports okay. So these are the mechanisms by which the fuel air mixture is taken in and exhaust gases are removed respectively.

Now, of course a ports means that they are also like some openings or channels right. So, we will shortly see when we discuss the operation of a 2 stroke engine that the piston itself covers and uncovers the ports at the appropriate time okay we are going to look at that aspect. And anyway as the stroke indicates, we have already discussed right one operating cycle is completed in 2 strokes of the piston.

So, this corresponds to how many revolutions of the crankshaft implies, 1 revolution of the crankshaft. So, we can see immediately that one cycle is completed in 1 revolution of the crankshaft whereas in a 4 stroke engine, 1 revolution is completed in sorry 1 cycle is completed in 2 revolutions of the crankshaft right, that is a primary difference okay and something called as a transfer port in a 2 stroke engine, okay.

We look at what is the role of this transfer port okay in the functioning of a 2 stroke engine in the next lecture okay. So, in the next class we will discuss some more critical aspects of the 2 stroke engine and look at its operation fine. Thank you.