Fundamentals of Automotive Systems
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Lecture-03
Engine Components part 01

Greetings.

So welcome to today's class.

So, just a quick recap of what we did yesterday. So, in yesterday's class we were discussing we started the discussion on internal combustion engines. We looked at various classes of internal combustion engines based on different attributes and the essentially discussed that in this particular course, we would look at reciprocating internal combustion engines both 4 stroke and 2 stoke and petrol and diesel engines.

And after doing that, we started looking at the components of an internal combustion engine. So, in an typical IC engine there are 3 blocks the cylinder block, the cylinder head which is on top of the cylinder block and the crankcase which is at the bottom okay. So, we started with the cylinder block we essentially learned about its construction some features of cylinder blocks. Then we looked at the cylinder inserts or cylinder sleeves.

That is where we stopped in the previous class.

So, let us build on from there and then like let us look at more components today okay. So, the next important component in the which is fit within the cylinder block is the piston. So, the piston is a component you know, like on which the what to say the forces that are generated due to the combustion process act and the thermal energy is converted to kinetic energy okay. So that way it is a very important component in an internal combustion engine.

And if you look at a typical piston okay the construction is something like this. So, if you look at the exploded view first you have the piston itself and that is fit in the cylinder or the combustion chamber using what are called as compression rings okay. So, we have a very tight fit between

PISTON ASSEMBLY

the piston and the cylinder. The reason is obvious right because during combustion, the pressures in the cylinder are going to be very high.

And even if we have a small opening somewhere right between the piston and the cylinder, the hot gases are going to escape and we are going to lose energy right. So we want the gases that are generated due to the combustion process to act on the piston and push it down. So, we do not want any leakage between the piston and the walls of the cylinder. So, compression rings essentially provides us with a tight fit between the piston and the cylinder wall okay to prevent any potential leakages. Then we have what are called as oil rings.

Of course, you can when you will observe and when you watch an engine that this piston is going to move up and down at very high speeds, you know, like typical engines operate wherein

you know the crankshaft is rotated by this piston in order rotates at the few 1000s of rpm. So, we are going to have, you know, like 1 stroke of the piston right in the order of in a time interval in the order of 10^{th} of milliseconds.
So, that is going to be very fast, right. So, in other words you in a matter of second, 1 second we may have you know, like the piston undergoing, let us say strokes in the order of 10 power 2 or 100 strokes. So that is essentially a lot of strokes right in a very small interval of time. And we essentially need to ensure that we lubricate the surface of contact between the piston and the cylinder such that we reduce the frictional effects, which oppose the motion that will reduce the energy loss due to friction.

And not only that you know like enable smooth motion of the piston on the cylinder walls, okay, and an oil ring essentially helps us to wipe the engine oil or the lubricating oil on the inner surface of the cylinder and that helps in the lubrication okay, so that is the function of an oil ring. Then we have what is called as a connecting rod which then connects the piston to the crankshaft okay we will come to the crankshaft shortly connecting rod as the name indicates connects the piston to the crankshaft.

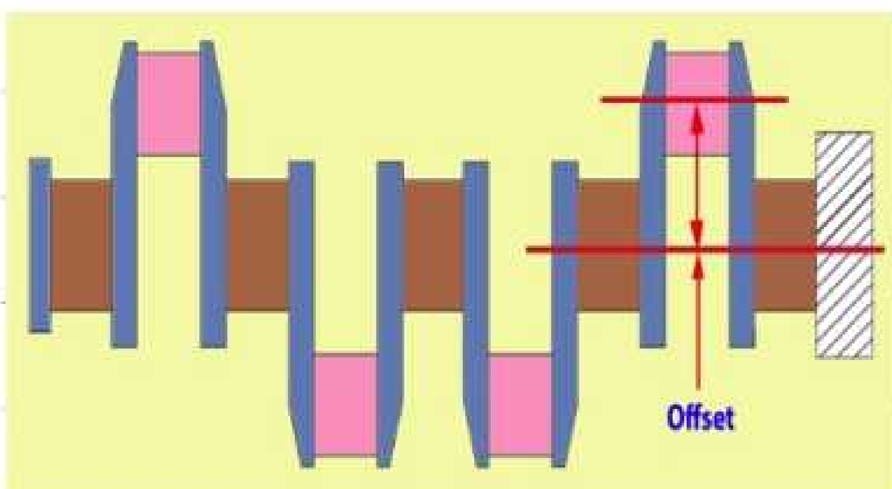
So, the connecting rod is fitted to the piston body through what is called as a gudgeon pin okay. So this is a pin which holds the connecting rod which connects the connecting rod to the piston okay, so insert the connecting rod and then you align the holes on the piston body and the connecting rod which you can see and then this pin is just fit inside, right and held by clips. So that is how the connecting rod is fixed to the piston.

The other end of the connecting rod has these what to say bearing shells you know like which will go and rest on the so called journals, you know, like of the crank pins on the crankshaft, we will come shortly to the crankshaft okay, so this cavity you can see will go and sit here for example okay on the journals you just fit it that is it right. So this is like a simple mechanism right. So what we learn as a slider crank mechanism in basic kinematics right.

The piston essentially forms the slider okay. So the translational motion of the piston is converted to a rotation of the crankshaft okay through the connecting rod okay, this connecting rod is mounted on these journals, okay.

What are called as crank pins journals, this is what is called a crank pin okay. So this the crankshaft, the piston essentially, is connected to the crankshaft.

CRANKSHAFT



CRANKSHAFT OFFSET

And this connecting this end of the connecting rod rests on the crank pin okay, it is mounted through some bearings, okay. So you can see a very simple 2D diagram. So this is the axis of rotation of the crankshaft, let us say the central axis.

So you can see this pink coloured elements, right, those are the crank pins okay, so each piston goes and sits on this crank pin. So if you have a multi cylinder engine, in this case, there are 4 cylinders. So consequently, there will be 4 pistons, and 4 crank pins. So each of the pistons will be fitted to each one of these crank pins. And as the pistons move up and down, they are going to rotate this crank shaft through the respective connecting rods okay.

So that is what is going to happen. So, this is what is called as a crank pin and what to say other end of the connecting rods sits on a bearing on this crank pin journal okay and you can immediately see that there is a distance between the axis of the crank pin and the central axis of the crankshaft okay, that is what is called as the offset of the crankshaft. So, this component is a crankshaft what we are now discussing.

And there is something called as a crankshaft offset. So, what is the crankshaft offset. It is the distance between the axis of this crank pin and the central axis of the crankshaft okay. And twice the crankshaft offset is going to be equal to the distance traveled by the piston in 1 stroke okay. So obviously you know like if my piston is that what is called as a top dead center will what to say define what is called as a top dead center and the bottom dead center shortly.
And let us say the piston is at top of the cylinder it moves to the bottom of the cylinder during that motion this crank pin is going to rotate by 180 degrees. So, the stroke or the piston is going to be equal to 2 times the crankshaft offset okay. So that is the definition of this crankshaft offset okay, and we can see all these counterweights or what are called as balancing weights which are essentially attached to the what to say basically included in the crankshaft just opposite to that of the crank pin.

So, if you see the crank pin here you know you can see these balancing weights on the other end, why is that you know like because the connecting rod will apply a force on the crank pin that will have 2 components, 1 will be a tangential component which will rotate the crankshaft and there will be a radial component which can cause vibrations okay. So, what we do is that like we attach these counterweights or balancing weights to reduce those vibrations to the maximum possible extent okay.

So, that is what and additionally, the crankshaft is also mounted on bearings. So, you can see what is called as a main bearing journal. So, the crankshaft is also mounted on bearings to support the crank shaft, because crank shaft is going to rotate at 1000s of rpm and you can imagine a multi cylinder engine there are going to be different connecting rods that are going to apply forces on the crankshaft right.

So it should be well supported and this entire crankshaft is placed in the crankcase okay, and the crankcase acts as a sump for engine oil okay, so by and large this crankshaft is going to be immersed in that sump of oil, so, it is going to be well lubricated okay. As a result, we have what is called as an oil slinger. So, what happens, you know, like imagine the crankshaft rotating 1000s of rpm, what is going to happen, it is going to churn the oil right.

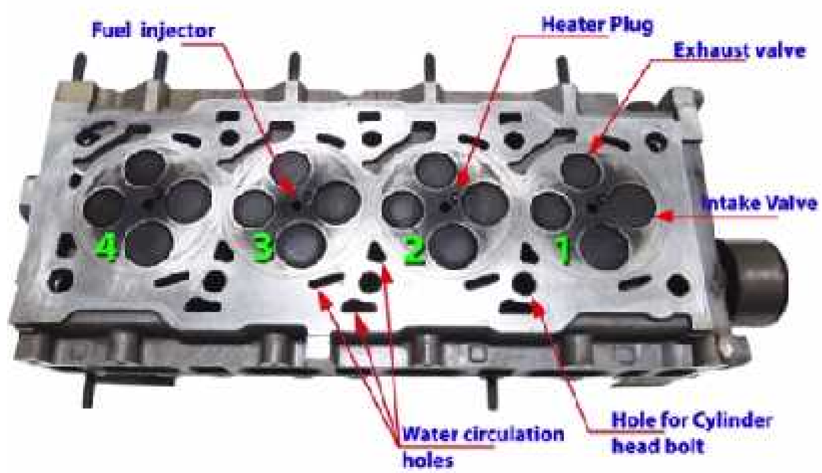
And the oil may just splash around. So when we come out of the crankcase, you know like this end of the crankshaft is going to be attached to what is called as a flywheel okay, which will be then connected to the clutch okay, we look at the flywheel more carefully when we come to the clutch right. So that is going to be connected to the flywheel. And so when this entire assembly is placed in the crankcase, there are seals at both ends to ensure that the engine oil does not leak right from the crankcase.

But when this what to say crankshaft rotates at high speeds and the engine oil is going to be splashed around there is a chance that the seal may get damaged and what to say the oil may start to leak. In order to prevent that, you know, we have what is called is an oil slinger, which will reflect those waves the engine oil waves which are generated due to the fast rotation of the crankshaft okay.

So that is a surface which will basically ensure that the waves do not cause significant what to say damage to the oil seals and the crank case okay, so that is a function of an oil slinger. And of course, you can see these oil holes through which you know engine oil flows. So that like crankshaft is also well lubricated okay. And there is something called as a timing gear which we will see shortly because in a 4 stroke engine in the cylinder head there is something called as a camshaft which will operate the inlet and outlet valves, okay.

And that is operated by the crankshaft through what are called timing gears or timing belts okay. We will look at the significance of the timing gear shortly when we come to the valve assembly and it is actuation fine. So, these are the different components of the crankshaft.

So we have looked at the cylinder block, the crankcase, now let us go to the cylinder head okay, so that is the other that is the third chunk or block as far as the 4 stroke engine is concerned, right.



CYLINDER HEAD

So, what happens in the cylinder head this is a bottom view of the cylinder head. So, imagine that you flip the cylinder head, place it on top of the cylinder block and then bolted okay using a gasket in between to prevent leakages right.

So, we are looking at the bottom view of the cylinder, you can immediately see that there are of course, this is a 4 cylinder engine once again. So, you can see the numbers 1 2 3 4 refer to the corresponding cylinder number and you can see that there are what are called as intake or inlet valves okay, these are also called inlet or intake valves and there is what is called as an exhaust valve for each cylinder.

And you know like there are parts for circulating the engine coolant you know like water for cooling the cylinder head also because all engine components are going to get hot, so we need to cool them right. So, the coolant or the water is pumped through even the cylinder head to keep its temperature under what to say the operational limits and you can see that there are holes through which you bolt the cylinder head to the cylinder block right.

You keep a gasket in between and bolted together okay. So what is the function of this intake valve intake valve, or the inlet valve is used to take air or fuel air mixture depending on the type of engine, we will discuss these aspects shortly when we go to what is called as mixture preparation and charging of engines and so on. So used to take air or fuel air mixture into the cylinder slash combustion chamber okay.

So we will use the words cylinder and combustion chamber interchangeably in our discussions in the scope of combustion okay. So that is what, so that is the function of an intake valve okay. Similarly, as the name what to say indicates the exhaust valve is used to remove the exhaust gases, what are the exhaust gases they are the products of combustion right because as we discussed combustion is a process by which the hydrocarbons in the fuel are oxidized into H_2O and CO_2 if the combustion is ideal.

But then like we are never going to have an ideal oxidation that will be like other byproducts also like carbon monoxide and unburnt carbon, right. And other what to say gases also like which we will look at when we look at emissions right. So, the exhaust gases which are the byproducts of combustion right from the cylinder okay. So that is the function of an exhaust valve. So, the intake valve and the exhaust valves along with their actuation mechanisms are assembled in the cylinder head okay.

So, that is a very, very important set of components because they need to be controlled very accurately for the proper operation of this cylinder okay. So, typically, let us say you know, like to just give you a rough idea you know like how fast these components operate. Let us say, you know we consider a simple example where let us say the crankshaft is rotating at 1000s sorry, 3000 revolutions per minute okay.

So 3000 revolutions per minute is going to be what how many revolutions per second 50 revolutions per second right, I divided by 60 right. So then how much time would one revolution take 1 by 50 right. What is that 1 by 50 is going to be 1 revolution of crankshaft is going to occur in 20 milliseconds, right do you agree, okay. So typically these valves need to be opened and closed in half a revolution.

That means around 10 milliseconds. So imagine that you know again, 10 milliseconds you know the valve needs to be open and closed right. And let us say the speed of the engine increases, it is going to be even tighter right. So typically when you start an engine and let us say it idles around, like let us say 1000 rpm, okay. So you are going to have around 1 revolution in 60 milliseconds and you can open and close the valve in 30 milliseconds still it is a small interval of time, right.

But as the engine speed keeps on increasing, you are going to have lesser and lesser time to keep on opening and closing the valve right. So that presents a unique challenge you know like for us, okay to essentially control these valves okay. So we are going to learn how these valves are controlled okay. And you can notice that many times the intake valve is larger in size, then the exhaust valve why do you think that is the case.

So, even in this figure you know like by the way this is a cylinder head of a diesel engine, okay . So that is why you have a fuel injector a spot for a fuel injector. In diesel engines you have fuel injector if you had a petrol engine or a spark ignition engine, we will have a spark plug in that position right and we have something called as a heater plug was also typically used in a diesel engine okay.

So you can observe even from this photograph that the intake valve seems to be slightly bigger than the exhaust valve right. Why do you think that is the case. Please note that most of these intake and exhaust processes are pressure driven flows. What do I mean by pressure driven flows, there is a difference in pressure between two regions drives the flow process okay. During the intake process, you will see that the difference in pressure is going to be smaller than the pressure difference that you will encounter during the exhaust process.

Even in basic fluid mechanics we would have studied about pressure driven flows, even if you use the simple Bernoulli's equation right, you will see that you know like that if you consider a reservoir and what to say a restriction, the speed at the restriction will be proportional to the essentially square root of the pressure difference right between the two points, correct if you use Bernoulli's equation. So, you see that higher the pressure difference higher will be the speed.

So, for the same area you will have higher flow rates correct. So, now typically what happens is that the change in pressure okay, the pressure difference during the inlet process is typically lower than the pressure difference during the exhaust process okay. So you see that you pretty much have the same time, you know, let us say around 10 milliseconds for both the intake and the exhaust process.

Let us assume that the crankshaft is rotating at 3000 rpm, then I have 10 milliseconds for the intake process, 10 milliseconds for the exhaust process. So in pretty much the same time, I need to take in the same amount of mass of let us say air and fuel and mass is conserved, although the composition of the gases is changed, I need to pump out the same quantity right during the exhaust stroke, right exhaust process.

So the mass flow rates are pretty much the same. Then what do I do right, I increase the area because my pressure difference during the exhaust process is higher than the pressure difference during the intake process. And so, what I do is like I would increase the area of the inlet valve to overcome this difference in a pressure difference okay. So, obviously this difference in size would be more pronounced in a naturally aspirated engine.

Because we will shortly see that we already seen yesterday right in a naturally aspirated engine the intake what to say fluids are taken at near atmospheric pressure air or air fuel mixture, right.

So, obviously, the pressure difference is going to be smaller in a natural aspirated engine during the intake process, so they will obviously require a bigger valve right. So that is the main reason okay.

And we will also see that having a bigger valve, you know like benefit says by increasing the so called volumetric efficiency which we will define when we go for engine performance analysis okay, we will come to that later, but the primary reason is this you know because the delta ‘P’$_s$ or the change in pressure during the intake and the exhaust process are different okay. So you need different sizes right.

Because you want to exhaust this push in and take out the same amount of mass or matter right yeah, same time because you need to accommodate other strokes we are going to look at that shortly right. So because typically we want to what to say complete the intake process in one stroke of the piston and exhaust process also in 1 stroke of the piston okay. So you see that the time available is pretty much the same. So you need what to say a larger intake valve right. So that is the what to say cylinder head okay.