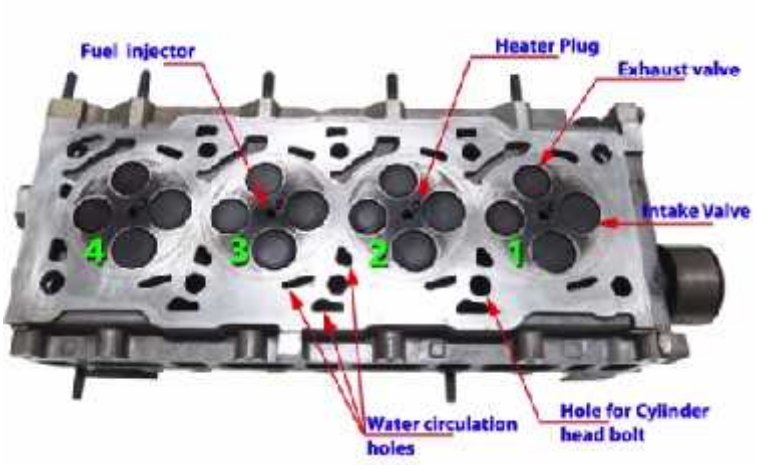
Fundamentals of Automotive Systems
Prof. C. S. Shankar Ram
Department of Engineering Design
Indian Institute of Technology-Madras

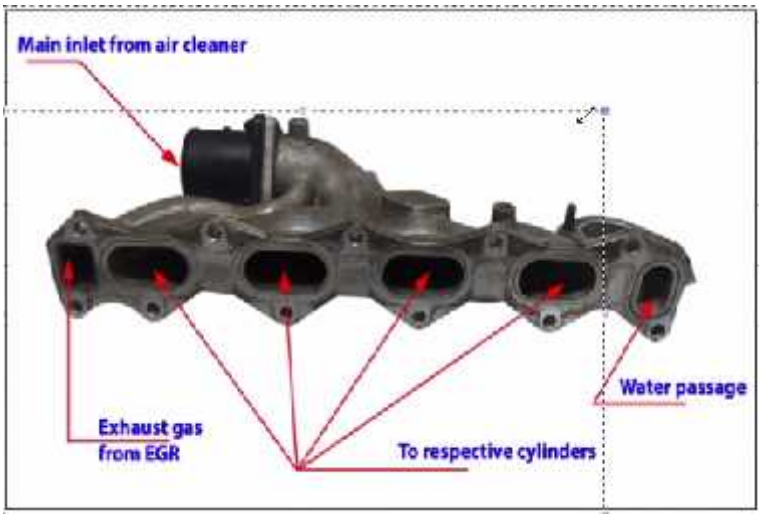
Lecture-04
Engine Components-Part 02

So, you can see that the cylinder head also contains the valves and the valve mechanism.



CYLINDER HEAD

So let us look at the valves and the valve mechanisms, before we go there you know like we are going to look at what are called as the intake manifold and the exhaust manifold okay, so what are these intake manifolds and exhaust manifolds.



Intake Manifold

So let us quickly look at them. So if I want to take an air right from the atmosphere, and let us say I have a multi cylinder engine. So I need to have a series of pathways right and pipes and other flow parts to take the air from the atmosphere and into the cylinders right into cylinder block.

Exhaust Manifold

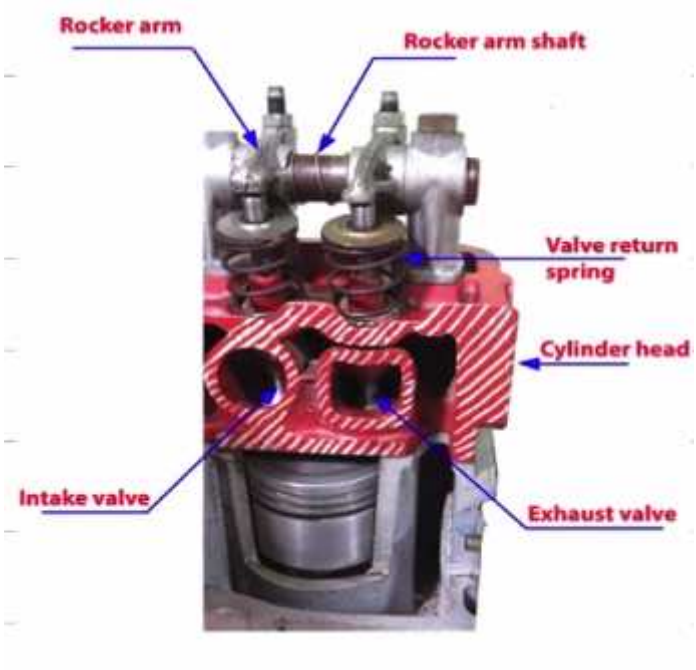
So, the function of the inlet manifold or the intake manifold is precisely that. So the inlet manifolds essentially is a set of pipes or flow parts, right that basically facilitates the flow of air from the atmosphere into the cylinders okay. So that is the function of an intake manifold. So you can clearly see that I have air being taken what to say from the atmosphere okay. So, it passes through a filter or a cleaner to remove dust particles and then like comes in.

And you can see that there is a channel of pipes right or flow through which this air is distributed okay to the respective cylinders okay. So, you see that these are the pass through which they go to the corresponding cylinder. So, once again see this picture corresponds to a 4 stroke engine sorry 4 cylinder engine okay. So, that is what we have been considering when we looked at the cylinder block and also the cylinder head.

So, you can see that there are 4 parts and you essentially go to the corresponding cylinder 1 2 3 and 4, okay. So, in diesel engines you know like when you come to emissions, we will also see that there is something called exhaust gas recirculation that is what is called as EGR okay, we learn about that later on okay and we will see that even the what to say what comes out of the EGR is routed to the inlet manifold okay.

We look at it when we come to emissions, similarly we have what is called as an exhaust manifold. So the function of an exhaust manifold is now very obvious right. So what does it do, it is nothing but a set of pipes that facilitates the removal of exhaust gases from the cylinders okay or the combustion chambers okay. So that is the function of an exhaust manifold okay right.

So once again you can see that there are 4 parts 1 2 3 and 4 okay. So, through these 4 parts they exhaust gases are removed and how this intake manifold and exhaust manifold are interfaced to the cylinder, the element that controls and acts as a door between the manifold and the cylinder is the valve okay. So intake valve acts as a door between the intake manifold and the cylinder, the exhaust valve acts as a door between the exhaust manifold and the cylinder.



VALVE ASSEMBLY

So, obviously they need to be opened at the appropriate time to do the corresponding intake or exhaust process okay. So now we are going to look at valves which are also like one of the important components in an internal combustion engine okay.

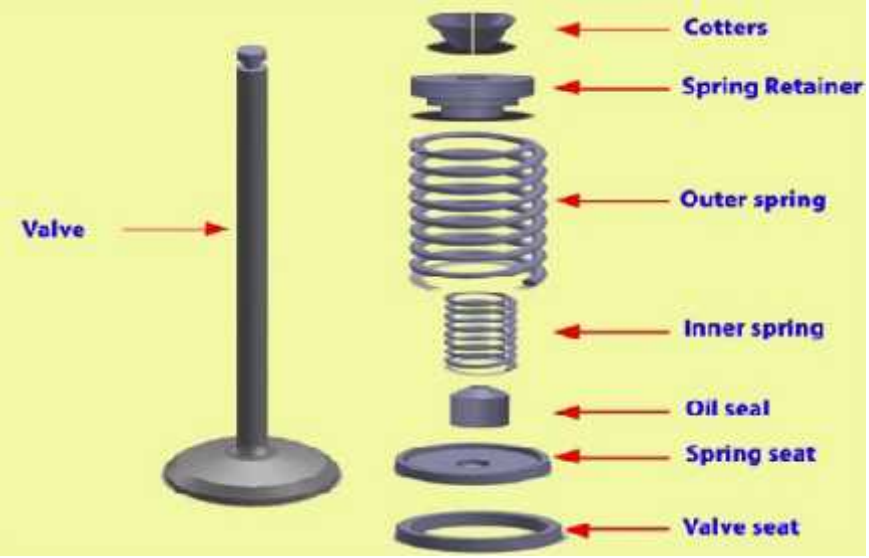
So let us look at the valve assembly okay. So which regulate you know like how these components are interfaced the manifolds and the this one. So, this is a very simple schematic of a valve assembly. So, this is a cut section picture okay let me also include a schematic and then things become clear. So, the valve assembly what is used in typical automotive applications and by and large we use what are called as spring return valves okay.

So, by and large in automotive applications we use what are called a spring return valve as the name suggests, the return of the valve is enabled by the restoring force of a spring okay, that is why they are called spring return valve okay, so how do they operate. So, in this picture you can clearly see how it works. So, this is our cylinder okay and you can see that this is the piston right.

So, this is the cylinder block, this is a cylinder head, cylinder head is shaded in red okay. So, you can clearly observe that there is an exhaust valve and an intake valve okay which are actuated by the springs and a cam which is connected to what is called as a rocker arm shaft okay we are going to what to say clearly look at this operation what to say in a short time okay. So, what happens is that like when you want to open the inlet valve and allow air to come in into the cylinder, this valve is pushed on okay.

So there is an opening which is created here. And air starts to flow within the cylinder, okay, so that is what happens okay when you have the intake valve and when the intake valve needs to be closed the contact between the intake valve stem and the rocker arm is removed and the intake valve goes and closes the gap due to the spring force, that is why it is called a spring return valve. The same story for the exhaust valves okay.

So if we look at this component take it apart and have an exploded view of the components. This is what will happen okay. So these are what are called as mushroom shaped valves.



EXPLODED VIEW OF SPRING RETURN VALVE ASSEMBLY

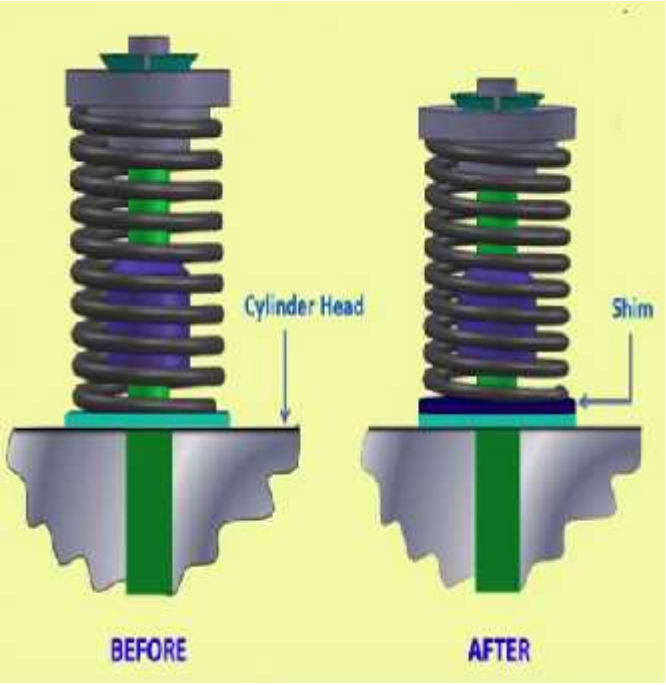
So because this surface of the valve is shaped like a mushroom, okay, it is like a curved surface, right. So these are what are called as mushroom shaped valves okay. So, this is what is called as the valves stem okay and what happens is that you take this valve and inserted from the bottom of the cylinder.

So, if we saw the bottom view right if you have the cylinder head you just inserted like this okay, so what happens then the stem comes to the top of the cylinder. So, let us say this is the thickness of the cylinder head, the stem part of the stem projects on top, you put the valve seat here, so that the valve sits on the valve seat okay. The valve seat is put at the bottom surface of the cylinder head where the valve head this is what is called as a valve head okay which is the shape of a mushroom will sit.

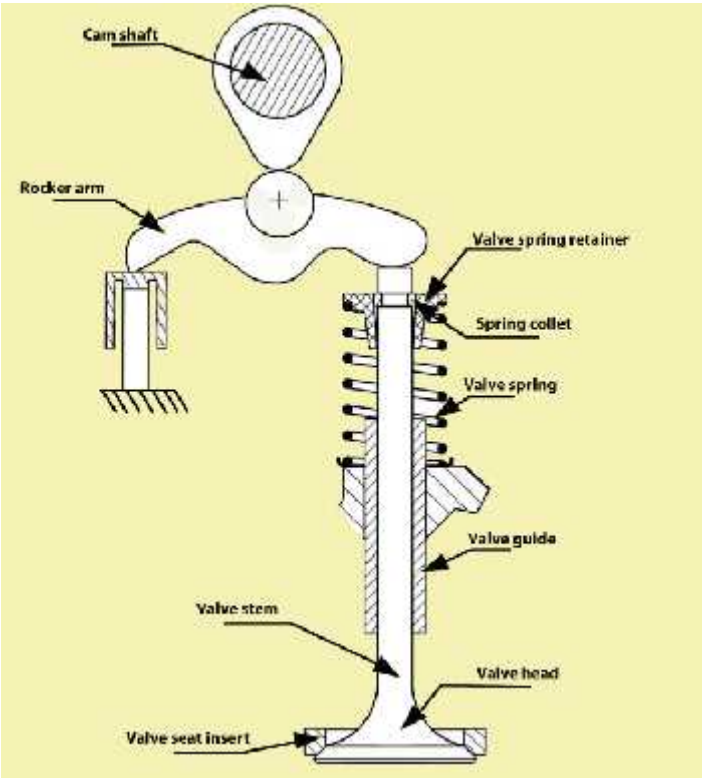
So the stem will go through the thickness of the cylinder head and on top you put this first assemble the spring seat. Then what you do is that you put the oil seal then you assemble these what are called as dual coil springs, there two coil springs to increase the stiffness of the springs, okay. You put the dual coil springs, put the spring retainer and assemble everything through a cotter okay. So that is how it is assembled.

I hope it is clear how this exploded view is assembled okay, so you insert the stem from the bottom of the cylinder head, the valve head sits on the valve seat at the bottom, then you essentially put the spring seat and the 2 coil springs and then put the spring retainer and hold everything through this cotters okay, that is how it assembled. Now, you can immediately see that the spring seats are very important why.

Because when we analyze coil springs, we assume that if I press a coil spring, its displacement is instantaneous. And if I release a coil spring once again it is restoration is also practically instantaneous. But in real life we are not going to have that effect point number 1, right. Second point is that although if you hold the coil spring between my 2 palms, right, if I press it the displacement will not exactly be on this axis all the time right.



The spring may move a little bit on the surface. So we do not want that right the offset vibrations right, or the later vibrations. So in order to prevent that and hold the spring in its position, we use the spring seats and spring retainer okay. So those are the main functions of the spring seats and spring returns. So let me show you another schematic to clearly illustrate how they are fitted okay.



OPERATION OF VALVE ASSEMBLY WITH CAM SHAFT AND ROCKERARM

So, now, you can immediately observe as to how these components are assembled and then actuated okay. So, in this schematic you know like we show the entire assembly let us first discuss this schematic then we will go to the other one. So, if you look at this schematic right. So, you can observe that this is a valve stem, this the entire valve assembly as I told you this the thickness of the valve cylinder head right.

So, you can see that the valve stem projects up and then like you hold the what to say springs right here and then you essentially keep them compressed like this. Now, you can have what is called as a cam which directly operates on this valve stem and then whenever you want the stem to be open the profile of the cam is change such that the valve stem is pushed on. So, this will open and when the profile of the cam changes there will be a small gap which will be introduced between the cam surface and the valve stem.

And due to the restoring force of the spring, the valves stem will move up okay, that is the function. In some cases a rocker arm is used okay. Particularly when you have multiple valves, right you can have more than one inlet valve and one outlet valve per cylinder.

Then you can also use a rocker arm wherein this what is called as a rocket arm, the cam does not directly act on the valves stem but then it acts on the rocker on which is piloted here.

And then it pushes it okay, so then this end of the rocker arm applies a force on the valve stem and the same action happens okay, so this is how the valve assembly works. Now, there are a couple of important issues associated with this operation. The first thing is that let us say I open the valve okay the cam pushes the valve or the rocker arm pushes the valves come down, okay the valve is open.

Now, the profile of the cam changes such that the contact between the rocker arm or the cam is momentarily lost or becomes the force becomes lower right, then what happens you know like this spring should push the stem assembly instantaneously. So that like there is a contact but that never happens in practice, right. Because these components are not welded together, right.

So, essentially what happens is that there can be some vibrations right, there can be some impact between the 2 and that can create some noise okay. So, that is present in the spring return valves, where you have what is called as some significant valve train noise particularly when they operated at high speeds. So, how have people solved it, they use what are called tappet valves. So, what they do is, they put what is called as a tappet on top of the valve stem.

A tappet it is nothing but an oil filled container, which is just put there, okay. So the contact between the cam or the rocker arm does not happen on the valve stem but on the oil filled tappet. So that dampens out the vibrations, okay. So it includes essentially increase the dampens. This is like a mass spring damper system right. You have inertia here right, that is why you cannot close instantaneously right.

So, you have a spring return spring. So, what people do is that they introduce a damper. And as we know from a basic dynamic systems also that if you put a damper and you increase the

damping ratio, the oscillations will be right. So, that is what people do right by putting a tappet okay. So, then what happens is then there is another issue okay. So what is the next issue. If you keep on increasing the speed as we discussed at 3000 rpm for the crankshaft.
We had 10 milliseconds, right for the valve to open and close in 1 stroke, right. So, let us say I increase the speed you know like let us say to 4000 rpm. Now what is going to happen. How much time will I have, around 6, what to say now the thing will reduce by 30% right. So, I will have sorry 33 one third right. I will have two thirds of the time right to essentially do the opening and closing operation.

Now, you see that it has decreased. So, just to take round numbers, let us say I increased from 3000 rpm to 4500 rpm that means that I have increased by 50%. So, what is going to happen 10 milliseconds also is going to decrease. So, in other words if you increase the speed the time available is going to decrease. So, what happens is that you need some response time see as we also learned from our dynamic system schools you know like that even if I have mass spring damper system.

There is a raise time, there is a response time and so on right things do not close in immediately. So what happens is that like as the speed increases and the time available for your opening and closure comes down your valve maybe commanded to open the valve assembly, the camshaft the cam will be commanding the valve to be open and it will command it to close but before it closes completely the next cycle will start.

The control mechanism will say oh, hey open the valve once again. So, what will happen is that an issue called as valve float arises, okay. So what is valve float. That is the valve will seem to be floating. That is it never closes completely and never opens completely because by the time it opens it goes to opening completely the command has reversed to closing it, but the time it starts to close, the next cycle would have started and it would have been commanded to open.
So that is going to be a challenge right, what people can that is have done you can never eliminate valve float in the spring return valves because that is how they work right, it is inherent to them. So, what people have done is that like they have increased the stiffness of the spring okay. So, people can either use high stiffness springs you replace things when they become soft

with the operation you can increase the preloads as you can see in this before and after curve right.

And then like people also introduce these shims okay, Shims are nothing but accurately machine washes okay on which you mount the springs. So that you even avoid any lateral vibrations and then you ensure that the what to say spring does it is operation very, very optimally okay as far as restoring the valve to its original position is concerned, okay. So all these tools have led to the reduction in valve float, okay.

But in a spring return valve, you can never completely eliminate valve float okay. So that is a limitation, then if you want to completely eliminate valve float, what is it that we can do. We have to use a different closing mechanism, right. So because imagine a door for example, you know most of the doors that we have today are these automatic closing ones right. So let us say I open a door I grip the handle, I pull the door open right.

So, then what happens, if I go outside I leave the handle and the door closes slowly. But on the other hand, I want to close the door also fast enough, what do I do. I can grip the handle on the other side and pull it right not depend on any spring or any automatic closing mechanism and so on right, same story. So what happens is then, there is something called as a desmodromic valve used in a very, very few road vehicles where you want very accurate control, particularly at high speeds, and so on okay.

What is called as desmodromic valve, okay desmodromic okay valve. So what happens is that in a desmodromic valve you do not have this return spring, but you would have a rocker arm for pushing it down, you will have a rocker arm for pulling it up okay. So, in both sides you will essentially open and close the valve without a spring because with the spring you have compliance and then you have these dynamic effects coming in right.

So, essentially when you have this rigid contact, right you can push and pull to the best possible extent okay, so that way, this desmodromic valve uses a rocker arm to essentially both open and close the valve okay, and this eliminates valve float, okay. So this mechanism essentially can

completely remove valve float okay. So we have looked at the valve assembly we will continue from here in the next class and then like look at other components you know like camshaft and other components that make up an engine and then we will continue right okay. Thank you.