INDIAN INSTITUTE OF TECHNOLOGY KANPUR

NPTEL

NPTEL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

Course Title
Aircraft Maintenance (Engines)

Lecture - 13
Cooling and Exhaust Systems (Lab Session)

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So we are again in front of our Cessna-206-H aircraft. This aircraft has got an air cooling system for its engine, you can see the cowling, it has an aerodynamic shape, this is you lower portion of the cowling, this is the front portion and this is your top portion.

The portion is divided into two halves, the right half and the left half, and the cowling is fastened by means of a fasteners, this fasteners we need to open this fasteners to remove the cowling.

And the bottom portion is fixed, in front of the cowling you can see these openings, one opening on this side and one opening on the other side, so this opening is for the air to go inside the cowling for cooling purpose, this is your spinner, this is your propeller, and this is your spinner you can see the spinner is also given an aerodynamic shape so that the air which is coming and going inside this opening gets an aerodynamic part to enter the engine, so now we will remove the cowling and we will show you how the engine is air cooled, now let us remove the cowling.

So now and cooling has been removed, the bottom portion is fixed, the front portion is also fixed and the upper portion has been removed, the two upper portions, the left portion and the right portion has been removed, here you see these are the three cylinders on the right side, three cylinders on the left side this is the 6 cylinder engine, and these are your aluminum sheets, these are metallic sheets they are called baffles, and on top of the baffles you have the flexible baffle seals, they are the seals this is made of silicon rubber, they are high temperature silicon rubber material and these seals they seal the area between the top of the cowling and the baffles, so basically these are the seals.

As these are the cylinders I just now told you that these are the cylinders, 3 cylinders on the right side, 3 cylinders on the left side so apart from these baffles on the upper side we have the baffles in between the cylinders also, so you can see here these are the inter-cylinder baffles,

these are the baffles in between the cylinders, and you can see here, you can see this thing these are your deflectors, we will tell you what is the purpose of these deflectors, what is the purpose of inter cylinder baffles, in fact we have seen it in our slides also these are the deflectors.

Now we will see the cylinder, the cylinder has got the fins, we can see it on the top portion, here you can see the cylinders on top, on the top side you can see the cylinders have got the fins, the fins are provided so that you have more surface area exposed to air which can provide better cooling to the cylinder, so here you can see these are the cylinder fins, you can see this, these fins they are exposed to air, air flows over these fins and extract the heat from the cylinders, so you have seen the baffles here, the flexible seals these are the flexible seals the orange colored they are high temperature silicon rubber material these are the seals, and these are the metallic fittings, these are aluminum sheets which are baffles so you can see the baffles all around the engine and the flexible rubber seals.

The cowling comes on top of this and this seal, seals the area between the baffle and the upper cowling and it provides a sealed chamber for cooling. Now air enters through this side you have seen the opening in the front, the air enters through this side, now when the air enters from this side a high pressure is created over the cylinders, the air is flowing over the cylinders, it's flowing over the fins of the cylinders and a high pressure is created over the cylinders and a low pressure is created at the bottom of the cylinders and at the half portion of the cylinders.

Now because of this pressure differential between the upper side and the lower side the air flows from top to bottom and cools the engines, it is passing, it is flowing over the fins and it will cool the engine, so because of the pressure differential the air is flowing and it's cooling the engines from top to bottom, mind it the air flow is from top to bottom, it is not from front to back.

Since the flow of air is from top to bottom, the air will move out of the engine through these openings, they are the cowl flaps, they are cowl flaps and this helps in moving the air out of the system, this flap is operated from a control in the cockpit, you can see this flap being operated, now this is flush, we have seen in our slides at on what occasions we can open the flaps and on what occasions we can close it, but these flaps can be opened and closed in different kinds of operations, so the air is ejected out of these openings out from the cowling.

As I mentioned that the air is flowing from top to bottom it is flowing over the cylinders, over the cylinder fins it is cooling that top of the cylinders and the side of the cylinders, but the bottom of the cylinders are also to be cooled, so the purpose of the inter-cylinder cooling baffles here you can see is to direct the flow of air on the lower portion of the cylinders also, so that the lower portion of the cylinder is also cooled and you can see the deflectors here, here you can see these deflectors, these deflectors they direct the flow of air to the bottom side of the cylinder also, so we have seen the cylinders are being cooled from top side, from sides and also from the bottom side.

These cowl flaps they help in creating a pressure differential, they in fact add to the pressure differential between the top portion and the lower portion, when the cowl flaps are opened the pressure is reduced and in the bottom portion of the cylinders this lowering of pressure also

further adds to the pressure differential between the top chamber and the lower chamber. These cowl flaps they also modulate your air flow, so this is how your air cooling is taking place in this engine, you can see here the flexible rubber seals, the flexible rubber seals they are directed, they are curved towards the high pressure area, we have seen in our slides that the rubber seals they need to be curved towards the high pressure area so that they provide a proper sealing of the complete area over the cylinders, so here you can see the proper curving of the baffles.

Now coming to the inspection part, what are the inspections to be carried out on these, we need to ensure that these baffles are secured properly, there are no cracks, no leaks, these baffles they do not have any wrinkles, they are sealed, they are properly curved, there are no tears, no cracks, and no leakage, so proper sealing of the complete area over the cylinders is essential.

In order to ensure one method to ensure whether your cooling is taking place properly or not we also inspect our cowlings, so you can see the inner portion of your cowling, this is your top cowling, the two halves and this is your inner portion, here you can see these lines, these lines they are smooth lines, continuous lines, these lines indicate that your leaking is proper, your sealing is proper and air is doing proper cooling, because it is completely sealed there are no irregular lines, so that means your air is completely sealed over the cylinders and it is cooling properly, it is moving from top portion of the cylinders to the lower portion and is being vented out properly, so this is an indication that your air is doing its job, and the sealing is proper.

So coming to the cowling inspection part you see the internal portion of the cowling, these are you can see the ribs here, they are there to provide reinforcement to the cowling portion and you need to check whether there are no cracks, everything is okay, there should not be any dents and no cracks, the fasteners should be in place and they should not be any cracks on the adjacent areas of these fasteners.

So now we are in front of Sinus 912 motor glider which is equipped with our Rotax-912 engine, this is our Rotax-912 engine which has got liquid cooling, the system, the engine has got a liquid cooling as well as air cooling, we have seen in our slides that it is the combination of two coolings, liquid cooling and air cooling. Liquid cooling is used for cooling of cylinder heads whereas the air cooling is for cooling of the cylinders, so first I'll show you the basic components of the cooling system the liquid cooling, this is your radiator here you can see this is your radiator, then another important part of the liquid cooling system is the water pump which is at the back which we will not be able to show you in this engine, but we will show you in another similar Rotax engine which is not installed on the aircraft, we will show you how the water pump is like, so this is your radiator.

Another important part is water pump, then is your expansion tank, so this is the expansion tank we have seen in our slides the expansion tank it is just mounted in this particular engine, it is mounted on the radiator, so this is your expansion tank, and on top of the expansion tank you have the pressure cap, so this pressure cap I have the pressure cap in front of you, you can see this is the pressure cap it has got valves inside, it has a high pressure valve where we have seen what is the purpose of this pressure cap, it has a high pressure valve, and then another important

part is your overflow bottle, so this is your overflow bottle you can see here there is coolant, liquid coolant inside this overflow bottle.

Now how this liquid cooling is working we have seen in our slides the radiator, the water pump, the cylinders, the expansion tank, the pressure cap and the overflow bottle, now the water pump will push the coolant from the radiator, it will create section, the water pump will create section in the center of the pump and it will draw the coolant from the radiator the coolant through the water pump goes to the cylinder head, the coolant is going to the cylinder head and from the cylinder head the coolant flows to the expansion bottle, now since the coolant is flowing through the cylinder heads it extracts the heat of the cylinder head, it will extract the heat of the cylinder head and the coolant temperature increases.

Now once the coolant temperature has increased this high pressure valve will open and the coolant will flow from the expansion tank to the overflow bottle, now once the temperature of the coolant reduces thus coolant is sucked back into the system, so I'll show you on another engine, what is the water pump like, so basically the liquid cooling is a very simple system where you have the radiator, water pump drawing coolant from the radiator and forcing it to the cylinder heads, from the cylinder heads the coolant goes to the expansion tank, from the expansion tank through the pressure cap it goes to the overflow bottle, once the temperature reduces the coolant is sucked back into the system.

Now coming to the coolant we have seen there are waterless coolants, there are coolants with water base, in this particular engine we are using Evans NPG+ coolant, and the coolant is filled from this port we remove the cap and the coolant is filled in, the water pump is drawing coolant from the radiator through this hose, you can see this hose the coolant is been drawn from the radiator, the water pump is creating section and it is drawing coolant from this, from the radiator through this hose and this coolant is coming to each cylinder head through these lines, you can see there is a line, this line on each cylinder and each cylinder the coolant is coming, it is cooling your cylinder head, the cylinder head is been cooled from once the cylinder head is cooled it goes, you can see this line here, there is another line, this line the coolant goes from this cylinder after cooling the cylinder head the coolant moves out from these lines from each cylinder and goes to the radiator, it goes back to the radiator in the radiator it gets cooled if the temperature of the coolant is more, is high, this high pressure valve opens and the high temperature coolant moves to the overflow bottle, once the temperature of the coolant reduces the coolant is sucked back into the system, this is a very simple system of cooling the cylinder heads.

And the ram air is further cooling the cylinders, I'll show you a water cooler in another engine, so we are on another Rotax-914 engine, it has the same engine, similar engine that we had seen on the Sinus 912 motor-glider, here you can see this is the rare portion of the engine you can see the water pump, this is your water pump here, and I have removed these screws to show you the water pump you can see the water pump inside, from inside you can see the impellers inside and this is your water pump, this creates section inside and draws the coolant from the radiator.

Now the coolant once it comes in this water pump here you can see the outlets, two outlets on the left side, two outlets on the right side, these outlets they are directing the coolant to the

cylinders, to the bottom portion of the cylinders you can see here this line going in this cylinder, similarly another line going to another cylinder, so two lines going on the left side, two lines going on the right side they are going to the cylinder heads to cool the cylinder head.

So once this coolant has cooled the cylinder head it is moved out of the cylinders you can see here, so these lines, this is on top of the engine the coolant, after cooling is moving out of the cylinder and is coming to the expansion tank, in this engine the expansion tank is separate it is not on the radiator on that Rotax engine the expansion tank was on the radiator, but here you have a separate expansion tank the coolant after cooling the cylinder head has come to the expansion tank on top of the expansion tank you have the pressure cap, we had just seen on that engine also the pressure, this pressure cap is a high pressure valve, so once the temperature of the coolant is increased because it has extracted heat from the cylinder heads that high pressure valve will open and direct the coolant from the expansion tank to the overflow bottle, we have seen the overflow bottle in that engine and the coolant will move to the overflow bottle, once the temperature reduces the coolant gets back into the system.

On the water pump you can see this point, this is your dream point so during servicing, during inspections, during replenishing, during removal of the coolant we open this point and drain the coolant from this point, this is the lowest point on the system.

Now coming to the exhaust system, we are again on Cessna-206 aircraft, we will see different exhaust systems on different aircrafts, let us see on this aircraft, here you see this is your exhaust manifolds, your exhaust pipes coming from each cylinder, these are three cylinders you can see, these are three cylinders and this is your exhaust port of the first cylinder, this is the exhaust port of the second cylinder and this is the exhaust port of the third cylinder, so the exhaust gases are coming out of the cylinder through these pipes, through these manifolds, these are your exhaust manifolds, we call them exhaust stacks, these are your exhaust stacks, similar stack is on the other side because you have 3 cylinders on the left side, 3 cylinders on the right side, similar exhaust stacks are there on the other side, now the exhaust gases have come through these stacks and here you see this is your muffler, inside here you can see this is your exhaust muffler, these exhaust mufflers we have seen in our slides they are covered with heat shrouds, so these are exhaust heat shrouds and inside is your muffler.

The purpose of the heat shroud is to direct the ram air, the ambient air to pass through these mufflers so that we can utilize the exhaust gases heat to heat the cabin air.

Now this pipe you can see here, how does the exhaust muffler, you can see this pipe this is your tail pipe through which your exhaust gases are rooted out of the engine, the combustion is taking place in the cylinders, after combustion the exhaust gases are coming out of the exhaust ports, from the exhaust ports through these exhaust stacks, through these pipes it comes to the muffler from the muffler it is going through the tail pipe out of the system, so you've seen the exhaust gases moving out of the engine, the exhaust gases they are also utilized the heat, in fact the heat of the exhaust gases is utilized to warm the cabin air, so this is your ducting, the air which is coming from outside you can see this, this opening, this opening the air is entering this ram air is coming inside and this ram air is moving inside the heat shroud and from here this

ram air becomes warm due to the exhaust heat and this warm air goes inside the cabin for maintaining the cabin temperature.

Now here you can see on the exhaust there are welded joints, you can see the welded joints here there are various welded joints as part of inspections we need to ensure that there are no cracks in these welded parts, in these your welding seems are intact, the elbows, the bends in the pipes you need to ensure there is no pitting, there is no thinning of the material on the bends.

Here you can see this is your flange area, and you can see the hold down nuts and a gasket, you can see here this is a metallic gasket also here, we need to ensure that there is no leakage in this area, in case if there is any leakage, if the exhaust gases are leaking from this point then it will cause erosion of your aluminum cylinders, so since your cylinders are made of aluminum, so it will erode those the cylinders, so we need to be careful that there should not be any leakage in this area, the proper torquing of these nuts is very essential, we need to ensure that these nuts, these hold down nuts are properly talked as per the manufacturers recommendation and the gaskets, the flange gaskets are intact.

In case if there is any leakage we need to replace this gaskets, apart from the welded joints we also have a slip joint, we have seen in our slides what is slip joint is, so this slip joint we need to be careful that these slip joints should not cease because the slip joints are there to provide some movement because of the vibration, because of the temperature variations, because of contraction and expansion of the metal due to temperature variations, this step joints should not cease, in case if the slip joint ceases then there are chances of cracks getting developed in the exhaust system, so we need to be careful that we need to inspect this area that there should not any discoloration, there should not be any residue formation in this area or in the adjacent areas, in case if we point any discoloration if any residue formation that means your joints are leaking and we need to take proper rectification action.

Similarly on the flange area also we need to see that there are no residue deposits which indicates that there is a leakage in that area, we need to inspect the muffler portion, we need to inspect the baffles inside the muffler, in case if there is any dislodging of the baffles, if there is any breakage inside it will obstruct the exhaust and power loss will result, we have seen in our slides that in case if your exhaust is obstructed then we will experience power loss, so we need to be careful about the exhaust muffler about the baffles inside, you can see the weld seams here, all the weld seams should be very carefully inspected to see if there is any crack.

Apart from the visual inspections we have also seen that some pressure testing is also required to be done, and the pressure test is done by means of water and soap method to see if there are any leaks in the system, this is another engine you can see this is Rotax-914 engine you can see the exhaust system in this engine, this is fitted with the turbo charger unit, this is the turbo charger unit we have seen what a turbo charger is, here you can see this is your exhaust port, the exhaust gases are coming out of this pipe and you can see there slip joint here, we need to be careful about the slip joints need to inspect the slip joints for any discoloration in this area, the exhaust pipes coming out of the exhaust port are going in this manifold, you can see here this is the exhaust manifold, the exhaust gases are coming from each cylinder, in this particular engine you have 4 cylinders, 2 on the right side and 2 on the left side so you have the exhaust gases

coming out from all the 4 cylinders and coming to this exhaust manifold, from the exhaust manifold the gases, the exhaust gases are coming to the turbo charger to drive the impeller, we have read earlier what a turbo charger is, how does it function, so it utilizes the exhaust gas energy to drive the impeller which further drives the compressor, so this exhaust gases from the exhaust manifold comes to the turbo charger drives the impeller and the exhaust gases then are sent out of the system through the exhaust pipe, so this is the other side of the engine, you can see this is your exhaust manifold, the exhaust gases from each cylinder have collected in the exhaust manifold, from the exhaust manifold they have entered the turbo charger after driving the impeller, the exhaust gases are sent out of the engine through this tail pipe, the exhaust gases are sent out of the engine to this tail pipe.

So this is the exhaust system for Rotax-914 F3 engine which is a 4 cylinder engine, again you have the welded joints, the slip joints, on the exhaust system, the inspection part is going to be the same as it is on other engines, you need to check for the leakage in the flange area, you need to check the gasket, you need to check the proper torquing of the nuts, you need to check the band areas for proper pitting, corrosion, thinning of the material we need to check the slip joints whether the slip joints have ceased or not, in that we need to check about the discoloration, about the cracks and leaks in the complete system.

This is another type of a muffler of a Rotax-912 engine which is used on our Sinus-912 glider, you can see this is muffler of another type, you can see the inside area, you can see the perforated section inside, so this is a muffler of Rotax-912 engine, this is one kind of a muffler, now we have removed one exhaust system from another Rotax engine, this is the exhaust system of a turbo charger fitted unit, we had just seen on the aircraft, how the system had worked, this is the exhaust system of the same aircraft, this is your turbo charger unit, and your exhaust is connected to the turbo charger unit in this way, this is your exhaust manifold you can see this is your exhaust manifold, this exhaust manifold is connected to the turbo charger unit like this, this is the turbo charger unit and these are the individual exhaust pipes going to the individual cylinders, so these are the pipes which go to, which connect to the individual cylinders, you can see this, that is a 4 cylinder engine so we have 4 exhaust pipes which connect to the exhaust port of the cylinder.

And this unit which is the, this is the muffler connected with the tail pipe, and this attaches, this connects to the turbo unit here, now the exhaust gases after combustion from the engine these exhaust gases come through these pipes from individual cylinders, they come through this pipe, they collect in this intake manifold in this, sorry exhaust manifold, these exhaust gases after collecting in th exhaust manifold enter the turbo charger unit, the exhaust gases drive the impeller of the turbo charger unit, the impeller is driven by the exhaust gases and after driving the impeller the exhaust gases come to this muffler and from the muffler it is sent outside the engine through the tail pipe.

So in the exhaust system we have seen in our slides some of the important instruments and the temperature sensor, this is your exhaust gas temperature sensor, this is the probe, and this is you can see on each cylinder there is one probe here, one probe in this one, and one probe in another, so each cylinder has got the exhaust gas temperature probe, this probe will sense the temperature of the exhaust gas and we can read that exhaust gas temperature on the gauge

inside the cockpit, so this is your exhaust gas temperature, another important parameter is the cylinder head temperature, this you can see is the cylinder head temperature and this is also there on each cylinder, so this is the probe here for the cylinder head temperature and we can see temperature of each cylinder on the cylinder head temperature gauge.

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