INDIAN INSTITUTE OF TECHNOLOGY KANPUR

NPTEL

NPTEL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

Course Title
Aircraft Maintenance (Engines)

Lecture - 18
Fuel Injection System contd…

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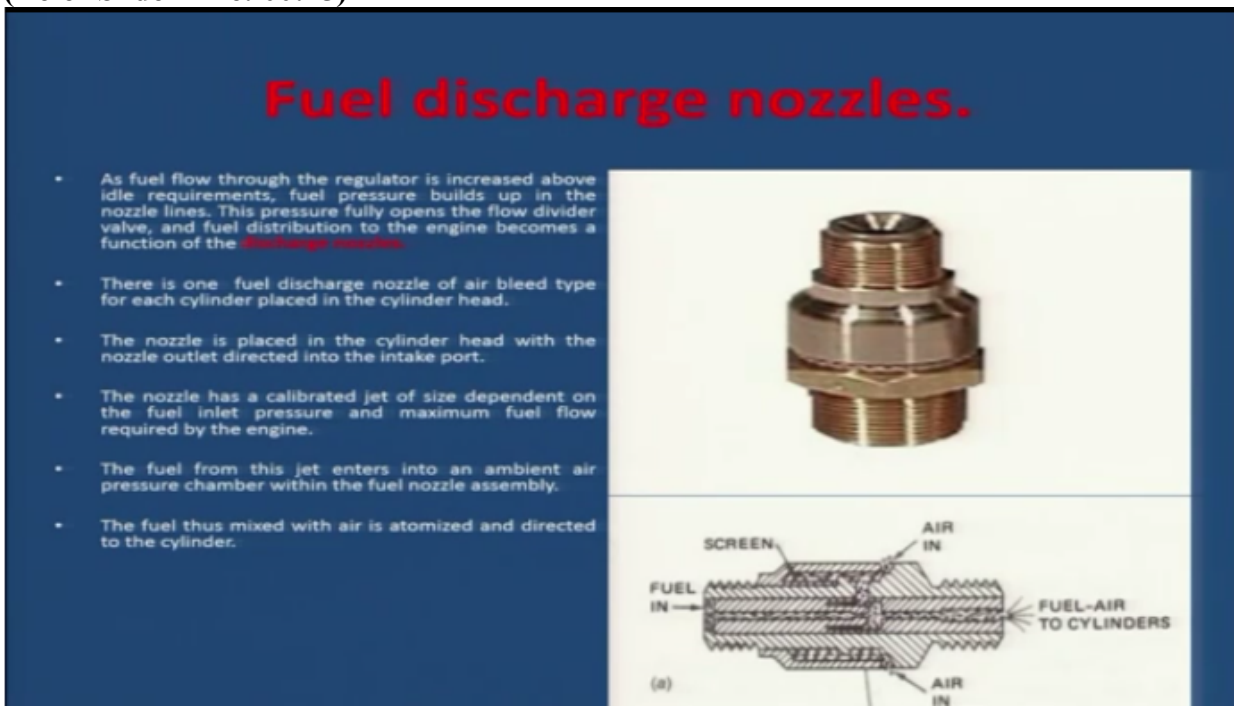

So now let us see what is the fuel discharge nozzle? So we have seen the fuel is coming from the flow divider to the discharge nozzle and as fuel flows to the regulator is this increased above the idle requirements, fuel pressure builds up in the nozzle lines.

Now when the flow from the regulator is increased above idle requirements, the pressure of fuel in the nozzle lines will also increase, this pressure only opens the flow divider valve, and fuel distribution to the engine becomes a function of the discharge nozzles, so we have seen in our earlier slide that the fuel flow, that the fuel flow divider was supplying fuel, was responsible for

fuel distribution and from the idle range up to a certain range, the fuel flow divider was responsible for equal distribution of fuel.

Above a certain range the nozzles take the responsibility of providing equal distribution of fuel to the engine, there is one fuel discharge nozzle of air bleed type for each cylinder placed in the cylinder head, so for each cylinder there is one fuel discharge nozzle and each discharge nozzle is of the air bleed type, so here in the figure if you see that this is a fuel discharge nozzle, this is the place from where fuel is entering in, this is your fuel coming in from the flow divider and then you have air also bleeding in, that is air which is bleeding in and you can see here there is a restrictor, you can see the restrictor we have spoken above the restrictor earlier in our earlier slides, this is the restrictor and above a certain range this restrictor takes care of the equal meter distribution of fuel.

The nozzle is placed in the cylinder head with the nozzle outlet directed into the intake port, so the nozzle, the location of the nozzle is in the cylinder head and it's outlet is directed towards the intake port.

Now nozzle has a calibrated jet of size dependant on the fuel inlet pressure and maximum fuel flow required by the engine, so this nozzle this has a calibrated jet of size, it's size varies it depends on the fuel inlet pressure and the maximum fuel flow required by the particular engine, so this is decided by the engine manufacturer, and depending on the jet size about the calibrated jet the fuel inlet pressure and maximum fuel flow the nozzle, the type of nozzle is decided for the engine.

The fuel from this jet enters into an ambient air pressure within the fuel nozzle assembly, so within this fuel nozzle assembly you have an ambient air pressure and fuel coming in enters this chamber where you have the ambient air pressure, the fuel thus mixed with air is atomized and directed to the cylinder, so this fuel coming in here and with the air coming here, the fuel is atomized and it is directed to the cylinders, so this was about the fuel discharge nozzles.

We have seen in the injector system, the injector system had a fuel injector, fuel injector in itself had a air flow section, regulator section and the fuel metering section from the injector the fuel was supplied to the flow divider, the purpose of the flow divider was to distribute the fuel equally at idle speeds and above idle speeds and from the flow divider the fuel goes to the fuel discharged nozzle, you have one discharged nozzle for each cylinder which is located in the cylinder head, and directed towards the intake port, so fuel from the flow divider comes to the fuel discharge nozzle, and from the discharge nozzle it is delivered to the engine cylinder where the fuel combustion takes place, so this was about the fuel injection system.

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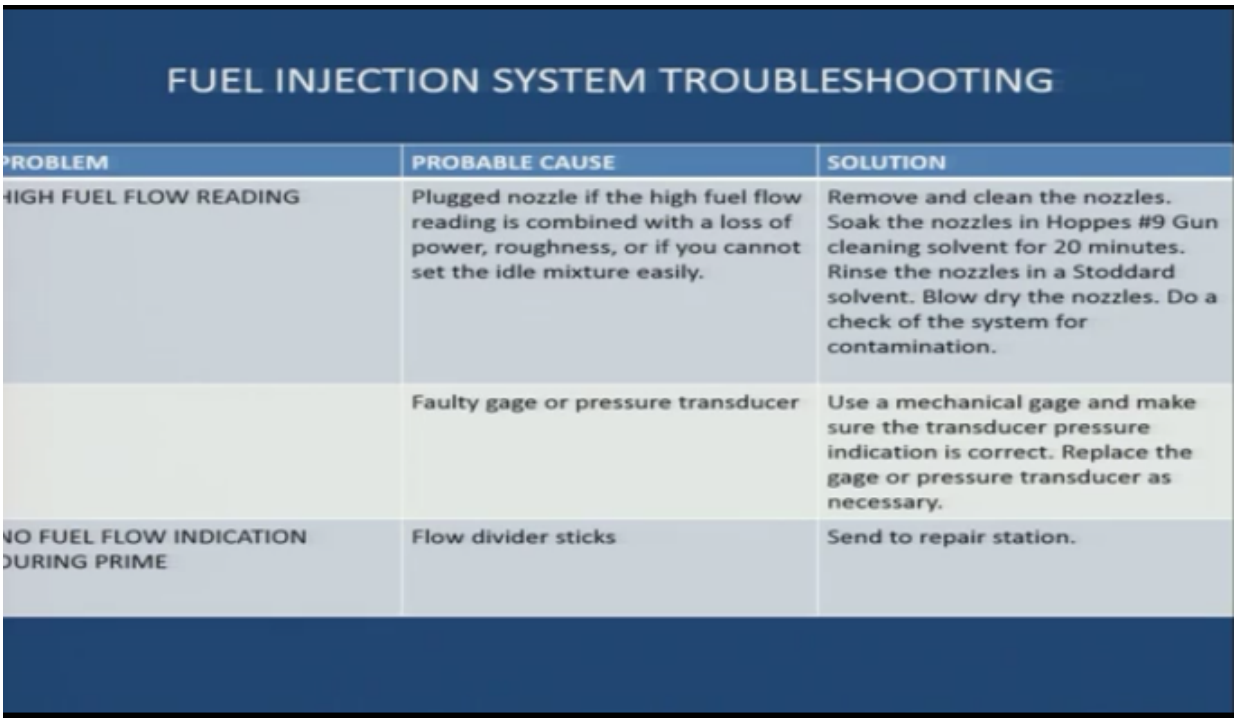

Now again in the fuel injection system we may encounter some snags, some problems, so now let us see what are the problems faced in the fuel injection system, one problem might be a high fuel flow reading, the probable cause maybe plugged the nozzles if the high field flow reading is combined with the loss of power, roughness or if you cannot set the idle mixture easily, so in case if your, we are not able to set the idle mixture we are experiencing power, loss, we're experiencing roughness of engine operation, then the nozzles might be blocked in that case we may face the problem of high fuel flow, in that case if the nozzles are blocked then we have to remove and clean the nozzles, the procedure is given here and once the nozzles are removed and clean that is the system to check the nozzles as per the manufacturers guidelines.

Another problem might be the probable cause of this problem might be of faulty gage or pressure transducer, so the pressure transducer or the gage might be faulty, in that case also we may encounter high fuel flow reading, if the gage or the pressure transducer is faulty we need to replace them and in case of pressure transducer it is better to use a mechanical gage first and ensure that your transducer is operating satisfactorily or not, in case not then we need to replace the transducer, or if the gage is faulty in that case then the gage has to be replaced.

Another problem that might be encountered is not fuel flow indication during priming, so once we are priming the engine and if we see that there is no fuel flow indication in that case the probable cause is that your flow divider might be sticking, your flow divider there is a diafram inside and that flow divider might be sticking in that case we are not supposed to repair the flow divider in the field and it has to be sent to the repair station.

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PROBLEM	PROBABLE CAUSE	SOLUTION
UNSATISFACTORY FUEL CUTOFF	Incorrect installation of the aircraft linkage to the mixture control.	Adjust the linkage.
	Mixture valve leaks.	Refer to the servo mixture valve
ENGINE WILL NOT INCREASE TO THE NECESSARY RPM	Contamination in the air chamber	Refer to Service Information letters
ROUGH IDLE	Small air leaks in the induction system through loose intake pipes or a damaged O-ring.	Do a check of the clamps and connectors. Repair leaks as necessary.
	Large air leaks in the induction system.	Repair leaks as necessary
	Fuel hose fittings loose.	Tighten the fittings.
	Fuel vaporizes in the fuel lines or distributor. Found only in high ambient temperature conditions or after a long operation at a low RPM setting.	Keep temperatures low: Avoid long ground runs. During a hot engine restart: Operate the engine at 1,200 - 1,500 for several minutes to reduce residual heat in the engine compartment.

Another problem is unsatisfactory fuel cut off, now we have moved the mixture control from the rich condition to the idle cut off condition and still your fuel is not satisfactorily cutting off in that case the probable cause is incorrect installation of the aircraft linkage to mixture control, so your mixture control linkage might be not correctly installed and in that case we need to adjust the linkage, and the mixture valve might be leaking.

Another reason for unsatisfactorily fuel cutoff might be that the mixture valve is leaking in that case we need to see that if we can fix the leakage problem, in case not then we have to replace the part as per the manufacturer guidelines.

Engine will not increase to the necessary RPM, now if suppose we are giving the throttle, we are increasing the throttle and the engine RPM is not increasing according to the increased in throttle then what may be the reason, in that case there might be a contamination in the air chamber, in case if there is contamination in the air chamber we need to refer to the information letters which are given by the manufacturers, there may be small air leaks in the induction system through loose intake pipes or a damaged O-ring, so in the induction system also the pipes might be loose, the O-rings might be damaged from there also there may be some air leak, so in that case we need to check the clamps, we need to check the rings, the O-rings, in case if required we need to replace them and fix the air leakage from the induction system. Apart from small air leaks in some cases there might be large air leaks in the induction system, then it needs to be repaired

Fuel hose fitting loose, the fittings, the fuel hose fittings might be loose there may be the reason for rough idle, in that case also the fittings need to be tightened, then another reason might be that the fuel vaporizes in the fuel lines or distributor, now when the fuel vaporizes in the fuel lines or the distributor then also we may encounter rough idle operation, this is found only in high ambient temperature conditions or after a long operation at a low RPM setting, so this is a

very common problem of fuel vaporizing in the fuel lines specially during hot conditions or during the time when we are operating engine at low power settings for a long time, so better to keep the temperatures low and avoid long ground runs.

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PROBLEM	PROBABLE CAUSE	SOLUTION
LOW TAKEOFF FUEL FLOW	Faulty gage or pressure transducer.	Use a mechanical gage and make sure the transducer pressure indication is correct. Replace the gage or pressure transducer as necessary.
	Contamination in the flow divider.	Clean the flow divider.
	Fuel pump pressure is not correctly adjusted.	Adjust the fuel pump pressure.
ENGINE IS DIFFICULT TO START	Incorrect starting procedure.	Refer to the Pilot's Operating Handbook
	Flooded engine	Crank the engine to clear it with the throttle open and the mixture in the IDLE/CUTOFF position
	Throttle valve is opened too far.	Open the throttle to approximately 800 RPM.
	A prime that is not sufficient (usually	Increase the quantity of priming.

Now another problem might be that during taking off we have low fuel flow, so now in case the fuel flow gage is reading low during taking off what might be the reason, again the gage might be faulty or the pressure transducer might be faulty in that case again we need to replace as required.

Another reason might be that the flow divider has contamination in it, we need to clean the flow divider, fuel pump pressure is not correctly adjusted and in that case fuel pump pressure has to be adjusted, so there are several reasons for low take off fuel flow, faulty gage or pressure transducer, fault gage or pressure transducer needs to be replaced, contamination in the fuel, in the flow divider, the flow divider needs to be cleaned, again in the field we are not required to, we are not supposed to clean the flow divider, it should be sent to the respective service agency. Fuel pump pressure is not correctly adjusted in that case your fuel pump pressure should be adjusted according to the manufacturer's recommendation.

A very common problem is we are attempting to start an engine is not starting or engine is difficult to start, then what maybe the reasons? The reasons there may be several reasons, incorrect starting procedure, the procedure through which we are starting might be incorrect. Flooded engine, the engine is flooded that means more than the required fuel has come to the engine. Throttle valve is opened too far, so throttle valve is too much opened in that case the engine is difficult to start, a prime that is not sufficient, so your priming is not sufficient, so several reasons you've seen, why engine is difficult to start in case your starting procedure is incorrect then we need to refer to the pilot's operating handbook to the manufacturers

recommendation, to correct our procedures starting procedure and start the engine as per the manufacturers recommendation.

Another reason might be flooded engine, your engine has been supplied with more than the required fuel, in that case crank the engine to clear it with the throttle open and a mixture in the idle cutoff position, so flooded engine needs to be cleared, it is cleared by the cranking the engine with the throttle open and the mixture control in the idle cutoff position, in case if the throttle valve is opened too far then also you will experience difficulty in starting the engine in that case the throttle should be opened, so that you have approximately 800 RPM and it should be opened, the throttle should be kept in the open condition as per the manufacturers recommendation. In case the priming is not sufficient, then priming has to be increased, the quantity of priming has to be increased.

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PROBLEM	PROBABLE CAUSE	SOLUTION
ENGINE OPERATES ROUGH	Too rich or too lean mixture.	Adjust the mixture control. If the mixture is too rich, the engine will run smoothly when leaned. If the mixture is too lean, the engine will run smoothly when the mixture is enriched. Adjust idle mixture to give a 10 - 50 PRM rise at idle.
	Plugged nozzle(s) (usually combined with high takeoff fuel flow).	Remove and clean the nozzles. Soak the nozzles in a Hoppes #9 Gun cleaning solvent for 20 minutes. Rinse the nozzles with a Stoddard solvent. Blow dry the nozzles. Do a check of the system for contamination.
	Air leak in the induction system.	Do a check for leaks
	Air leak in the fuel line from the fuel tank to the servo.	Do a check for the leak. Connect clear tubing between the servo and the flow divider and look for air bubbles. Find and correct the source of the leak. This can include the boost pump, the engine-driven pump, or any hose or line connection.
	Flow divider sticks	Do an inspection of the flow

Another problem engine operates rough, now when you have rough engine operation what might be the reason, too rich or too lean mixture, now when you have either the mixture is too rich or too lean then also you will have rough engine operation, another reason might be the nozzles are plugged, nozzles are blocked.

Another reason air leak in the induction system, leakage in the induction system that is the reason, air leak in the fuel line with the fuel from the fuel tank to the servo, so there is air leak in the fuel line also flow divider sticks and the flow divider is sticking, so several reasons you have seen for rough engine operation too rich or too lean mixture plugged nozzles leak in the induction system, air leak in the fuel lines and flow divider sticking, so let us see one by one, in case if the mixture is too rich or too lean we need to adjust the mixture control as per the manufacturers guidelines, the procedure is given and we will discuss also about the mixture adjustment, in case if the mixture is too rich we need to lean it slightly, if it is too lean then also we need to rich it slightly.

Now in case if the nozzles are plucked, nozzles are blocked then we need to remove the nozzles clean the nozzles and there is a procedure how to clean the nozzles and after cleaning we need to check the nozzles as per the manufacturers guidelines, was the nozzles are okay we need to install them back.

If there is a leakage in the induction system there is a air leak in the induction system then also your engine will operate rough in that case we need to check for the leaks and fix the leaks accordingly, in case if there is an air leak in the fuel line we need to check for the leak and there is a procedure given how to check we will check for the leaks as per the manufacturers guidelines.

Flow divider sticks in that case we need to inspect the flow divider and inspect the flow divider installation for looseness for any physical breakage in case not we need to replace the flow divider because we are not supposed to do any maintenance in field on the flow divider so it is better to send the flow divider to the servicing agency and replace it with a new flow divider, these were the several reasons why the engine was operating rough, too rich or too lean mixture plugged nozzles, leak in the induction system, leak in the fuel line, flow divider sticking, flow divider faulty, so we need to take rectification actions accordingly as per the manufacturers guidelines, so these were some of the problems encountered in the engine injector system.

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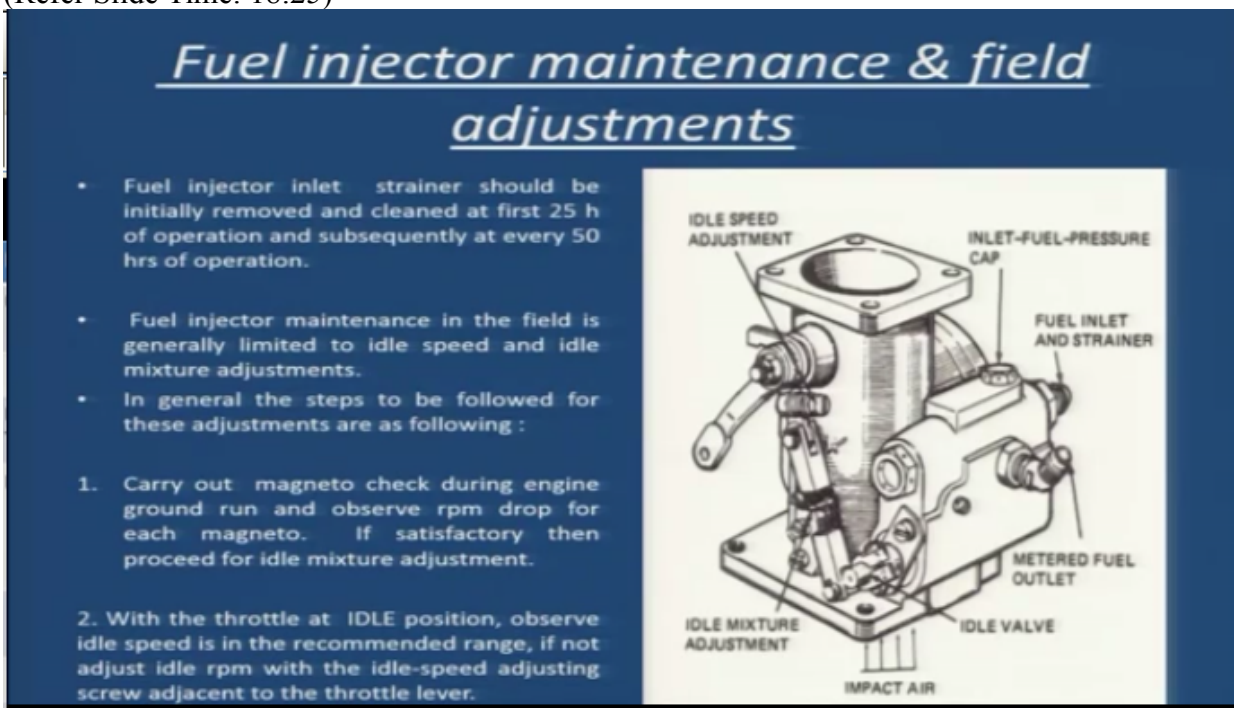

And now let us see what are the maintenance and field adjustments we carry out on the fuel injector, this fuel injector inlet strainer, you see here in the figure this is your inlet through which the fuel is coming inside the injector and inside this you have a strainer, you have a filter which will filter the fuel, so there has to be some inspection on the filter, the fuel injector inlet strainer should be initially removed and clean at first 25 hours of operation, so at first 25 hours

of operation we will remove it and clean it, inspect it, and after first 25 hours of operation at every 50 hours of operation we need to remove the fuel inlet strainer and clean it, inspect it and install it back as per the manufacturers recommendations.

Another maintenance and field adjustments on the fuel injector is generally limited to idle speed and idle mixture adjustment, so basically on the injector apart from doing visual inspections, checking the unit for satisfactory installation for any loose connections we can only do idle speed and idle mixture adjustments.

Let us see what are the steps when we do these adjustments? The general steps are carry out magneto check during engine ground run and observe RPM drop for each magneto, so before attempting to do any adjustment on the injector we need to do a proper engine ground run up, during the engine ground run up we will check the magnetos, we will study about the magnetos in our next lecture, and we will check the magnetos, we will do an ignition check and check the drop in the magnetos, if everything is satisfactory then also, then only we will proceed for idle mixture adjustment.

Now with the throttle plays that idle position observe idle speed is in the recommended range, now during the ground run we have put the throttle in the idle position and let us see the idle speed, if it is in the recommended range, fine, if it is not then we will adjust the idle RPM with the idle speed adjusting screw, here in the figure you can see this is your idle speed adjustment screw, through this screw we will adjust the idle speed and see if it is in the satisfactory range.

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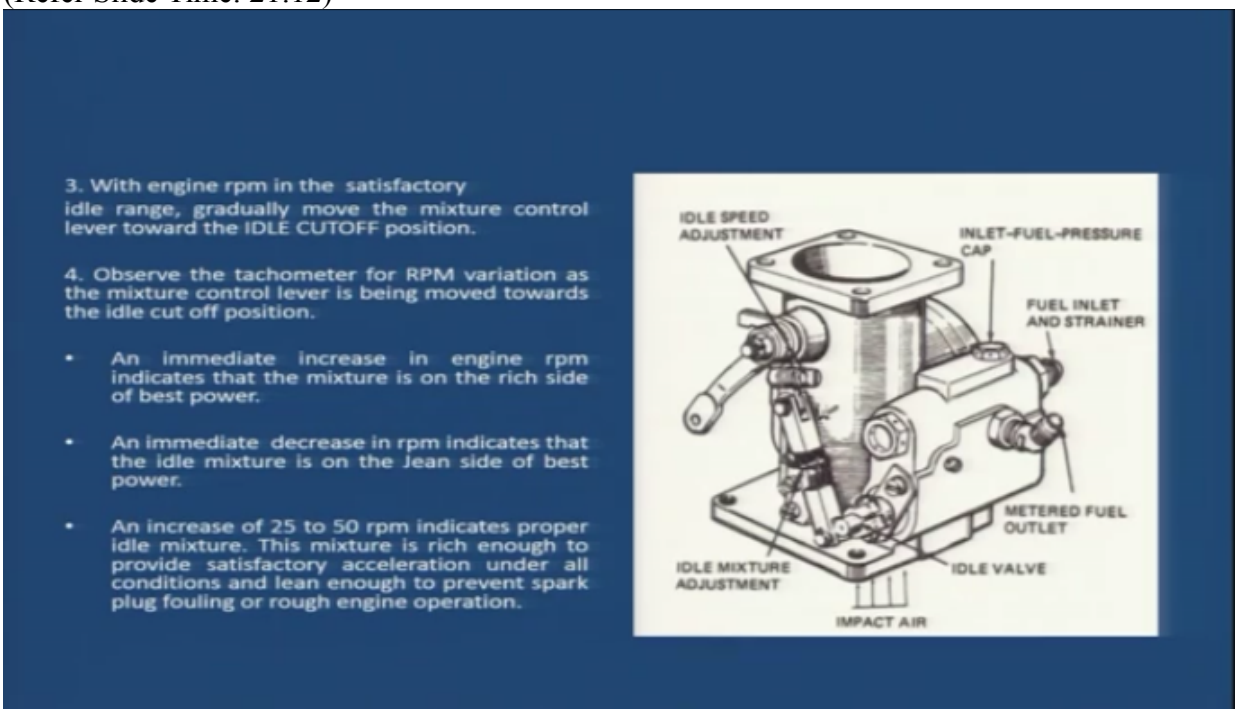

Now with engine RPM in the satisfactory idle range, we have adjusted the idle RPM engine idling satisfactorily, gradually move the mixture control level towards the idle cutoff position, now with your engine idling properly we will gradually move the mixture control from the full

rich position to the idle cutoff position and observe the tachometer for RPM variation as the mixture control level is moved towards the idle cutoff position, so as the mixture control level is moved from the rich condition towards the idle cutoff condition we will observe the variation in the engine RPM, and immediate increase in engine RPM indicates that the mixture is on the rich side of the best power, so as we are moving the mixture control level from the rich condition towards the idle cutoff condition and your RPM immediately increases that indicates that your mixture is on the riches side. And immediate decrease in RPM indicates that the mixture is on the leaner side, the proper thing the indication that your mixture is set properly, the mixture is okay, this mixture is rich enough to provide satisfactory acceleration under all conditions and lean enough to prevent spark plug fouling or rough engine operation.

So during the movement of mixture control level from rich position to idle cutoff position if the RPM increases from 25 to 50, and then drops this indicates that your mixture is correctly set and this mixture gives you satisfactory acceleration under all conditions and is also lean enough to prevent spark plug fouling or rough engine operation.

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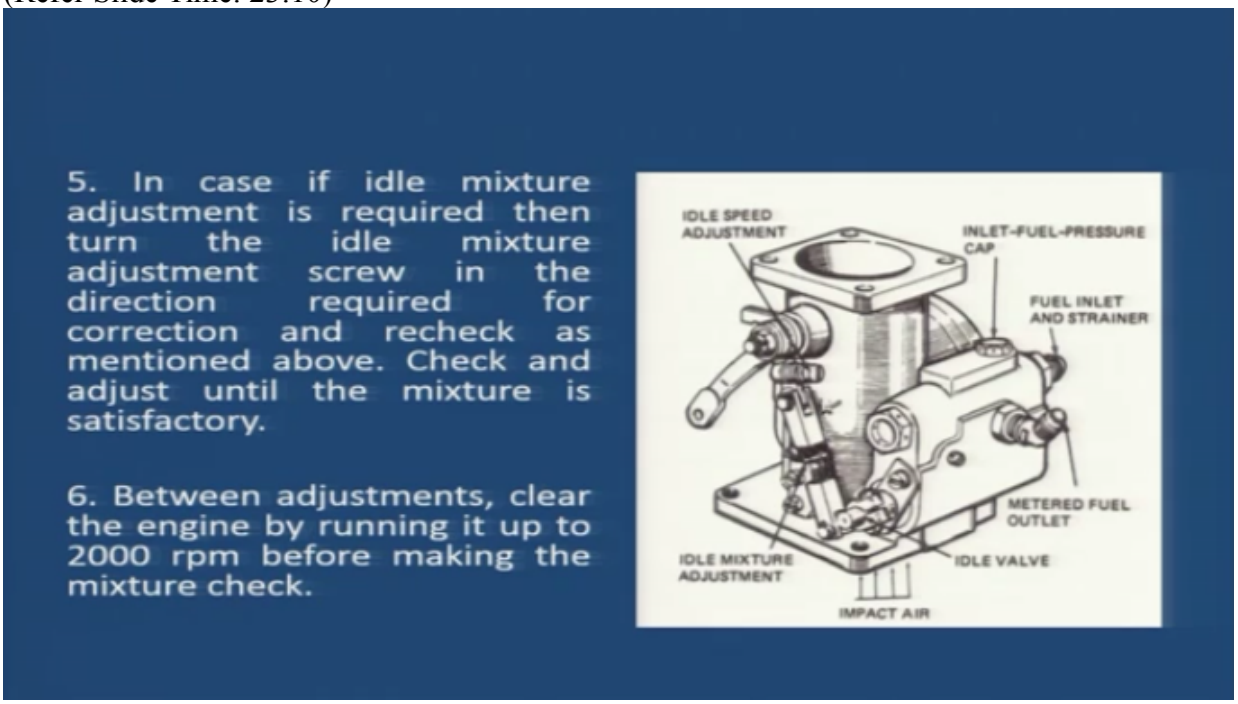

In case if idle mixture adjustment is required then turned the idle mixture adjustment screw in the direction required for correction, so this is your idle mixture adjustment, in the figure you can see here this is a wheel through which you can adjust the idle mixture adjustment, so in case if the idle mixture adjustment is required then turn the idle mixture adjustment screw in the direction required for correction and recheck as mentioned above, check and adjust until the mixture is satisfactory.

Between the adjustments clear the engine by running it up to 2000 RPM before making the mixture check, so in between the adjustments we also need to continuously clear the engine by moving the throttle to 2000 RPM and then moving it back.

Once the mixture has been adjusted and mixture is set we again check the idle speed and in case
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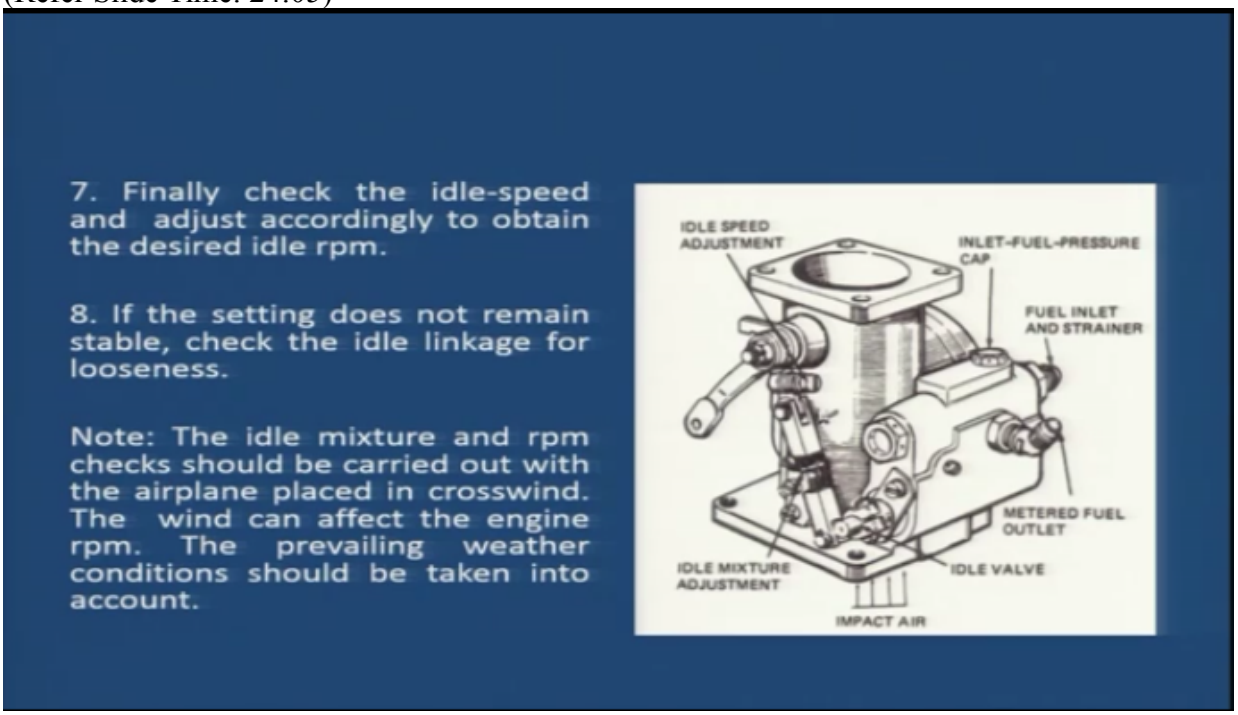

if any adjustment is required we will adjust it accordingly, if the setting does not remain stable, check the idle linkage for looseness, in case after doing all this thing we still we are facing any problem, then we also need to see whether your linkages and everything is not loose and everything is properly attached.

The idle mixture and RPM checks should be carried out with the airplane placed in the crosswind, so we need to take some precautions while we are doing these adjustments in the field, the aircraft should be placed in the crosswind because the wind blowing can affect your engine RPM and we should also take into account the prevailing whether conditions while doing these adjustments, so this was about the fuel injector, the fuel injection system, the problems being faced in the injection system and some of the maintenance steps and adjustments that are required on the injection system. Thank you.

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