IC Engines and Gas Turbines

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Lecture – 14
Classification, types of nozzles, Ignition system, Battery and Magneto Ignition systems

So, we will continue our discussion on IC Engine. And today, we will try to discuss about the Classification, and Types of nozzle, Ignition system which is important, whether it is Battery ignition system, or if time permits we will discuss about Magneto injection system ignition system. So, before I go to discuss about the you know types of nozzles, and it why and its functioning, you know that we have discussed about the carburetor in the last lecture that simple flow type carburetor we have discussed, it operational principle also we have discussed.

What will be the mass flow rate of air and fuel, if we try to you know supply air-fuel mixture in a spark ignition engine. So, we have seen that using a simple flow type carburetor, there are a few limitations. And if you need to overcome all those limitation, what would be the objective of the design of a modern carburetor we have discussed. And to and nowadays even you know carburation system is not used rather it is almost absolute, it is used fuel injection system. And whenever we are trying to use injection system rather supplying air and fuel rather fuel injection system, then of course we have to supply fuel through a nozzle.

Because, if we supply fuel in a liquid form, then we would not get economy of the fuel rather maybe combustion will be you know restricted over a very tiny area, and we would not get fuel economy. So, we need to supply fuel through fuel nozzle, and nozzle it you know whenever fuel is flowing through nozzle into the combustion chamber, we need to serve a few purposes I mean whenever we are using nozzle. Today, we will discuss that what are the what are the objectives I mean, because why you are using nozzle, and we have seen that even today you know modern engines are equipped with you know injection system.

And, because of we are having injection system we need to supply fuel through fuel injector, and through fuel nozzle. And we even if we do not think about a simple flow

type carburetor rather elementary carburetor, even if we have a modern carburetor design, but till maybe we will be able to supply fuel air fuel mixture depending upon the requirement of the engine. But, even but the supplying fuel through fuel nozzle or through injection system is always preferable one than using a carburation system.

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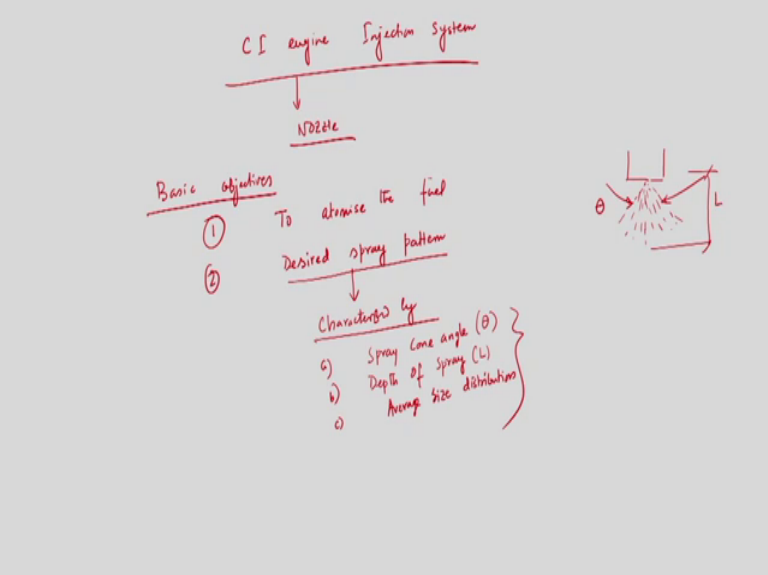

So, in general nozzles are used in a CI engine injection system. So, if I tried to talk about nozzle, then preferably nozzles are used in a CI engine, compression ignition engine, injection system. So, basic objective CI engine injection system. Whenever, we are thinking about the injection system rather we are going to discuss about the injection system in a compression injection engine, of course we cannot nozzle is an integral part of that.

So, we have discussed that even without having nozzle only through only through carburetor only through the carburetor, we can supply air fuel mixture or charge, maybe it is not always possible to supply stoichiometric air fuel ratio or chemically correct air fuel ratio using a simple flow type carburetor. But, modification of a simple flow type carburetor may provide required amount of charge depending upon the engine requirements.

And we have seen that during idling condition, and pushing idling zone, pushing zone, and power zone the requirement of air fuel mixtures changes. So, if our simple flow type carburetor is designed rather adjusted for the satisfactory operation during idling

condition, it may supply excessively higher fuel air mixture during pushing zone and the power zone, so unnecessary wastage of fuel will be there.

And to avoid that probably nowadays you know that a simple flow type carburetor has replaced by modern carburetor or it is better to have injection system, so that we can supply fuel through nozzle. And we will discuss today that if we supply fuel through a nozzle not only that we will be able to supply, we will get fuel economy also that we will have a efficient combustion in the combustion chamber.

So, what are the objectives? So, in a CI engine injection system in general, but fuel nozzle is an integral part, so through which we are supplying fuel into the combustion chamber. So, what are the basic objectives? Basic objectives of nozzles or injection system rather why, because if we try to recall that in a CI engine, we supply air three in only through, we supply only air through intake manifold while fully spread through a fuel nozzle or fuel injector. And complete system is known as fuel injection system. There will be a fuel pump, and of course there will be nozzle. This complete system is known as fuel injection system in I mean, and nozzle is one of the parts of that system.

So, what are the basic objective of having nozzle, we will have fuel pump. But, apart from that fuel pump, because of course we have to you know pump fuel pump fuel ten to the nozzle, and one when fuel is flowing through the nozzle, it the fuel will encounter a huge pressure drop I mean and that and for that we have to have a pump. So, basic objective is to number-1, we supply fuel air mixture into this combustion chamber of a SI engine, and for that we have to we will we need a special device which is known as carburetor, which allow the adhesion mixing of fuel and air, before it goes to the cylinder during intake stroke.

And also it tries to provide you know chemically correct air fuel ratio or maybe it is not always possible using a simple flow type carburetor. But if we modify the design of a simple flow type carburetor, it may be possible to supply chemically correct air fuel ratio into the engine cylinder. But, the basic objective of having nozzle is that to atomize the fuel; to atomize the fuel, to atomize the fuel why atomization is required, because as I said you that I mean whenever we are supplying fuel, maybe we can directly supply fuel to the injection combustion chamber without having nozzle.

In that case, we will be able to supply a liquid fuel in the form of a relatively larger drop. So, when you are supplying liquid drop in the combustion chamber, combustion will be localized over very is you know will be localized rather it we would not be able to supply fuel into the entire space of the combustion chamber. So, maybe a combustion will be efficient. So, the function of the nozzle is to atomize the fuel into some number of smaller and smaller droplets.

And second objective is to have a desired spray pattern; desired spray pattern, which is also an important objective of having nozzle in an injection system. As I said you that without having nozzle, we can supply fuel in the form of a liquid droplet. And in that case liquid drop will be injected in a area over a tiny area in the combustion chamber that are combustion will be localized.

But, if you would like to supply, but our target would be to supply fuel into the I mean area where compressed state is there, because combustion area is not very small area. So, we need to we or target should be to supply fuel over the entire area of the combustion chamber, and to do that we need to supply fuel in a desired spray pattern. So, what do we mean by desired spray pattern rather desired spray pattern is characterized by so this is characterized by, this is characterized by spray cone angle spray cone angle, depth of spray depth of spray, number c is average size distribution average size distribution.

So, to ensure that fuel particle will go rather, it will readily it fuel particle rather the fuel which is being supplied into the combustion chamber will meet more readily with the air. Over the entire area of the combustion chamber, we should have a desired spray pattern, and for that we need to have nozzle that is a second objective. First objective is that whenever you are having nozzle, if we supply fuel in a liquid drop in a form of a liquid drop, it will be a combustion will be localized, and we may not get efficient combustion. So, we need to break the fuel particle into number of smaller and smaller droplets, so this is the first objective.

Second objective that is what that we need to ensure that the fuel which is being supplied using nozzle into the combustion chamber, we will try to you know go into the rather almost it will mix with the air, which is there into which is there in the combustion chamber. So, to have desired distribution that is the fuel particle should not be injected, fuel particle should not you know be sprayed only over a small area in to the combustion

chamber rather it will be supplied over the entire area within the combustion chamber, so that it can readily mix with the compressed air to have a efficient mixing rather efficient combustion, we need to have desired spray pattern. And that is characterized by spray cone angle, depth of spray, and the average size distribution.

So, what do we mean by suppose this is the nozzle; this is the nozzle, then fuel is spread, because we should have high injection pressure. So, this is the fuel spray pattern right. So, this angle is known as theta that is spray cone angle. And this depth that will be L that is known as depth of spray L. And spray cone angle theta that mean nozzle see while you are having nozzle in the system in a injection system, it will be able to supply rather fuel particle fuel will be able to penetrate up certain distance. Not only that, whenever it is fuel is able fuel particle is able to sub able to penetrate a particular distance, we also need to ensure that will be able to penetrate a particular distance with a desired spray cone angle theta, so that we can have efficient mixing with the compressed air that is there, what the entire area within the combustion chamber.

So, these are the objectives of having a nozzle. And we have discussed that what do you mean by desired spray pattern, and that is characterized by a spray cone angle theta, depth of spray L, and average size distribution, that is also important. So, these are the objectives of having nozzle in an injection; in a injection in a CI engine injection system.

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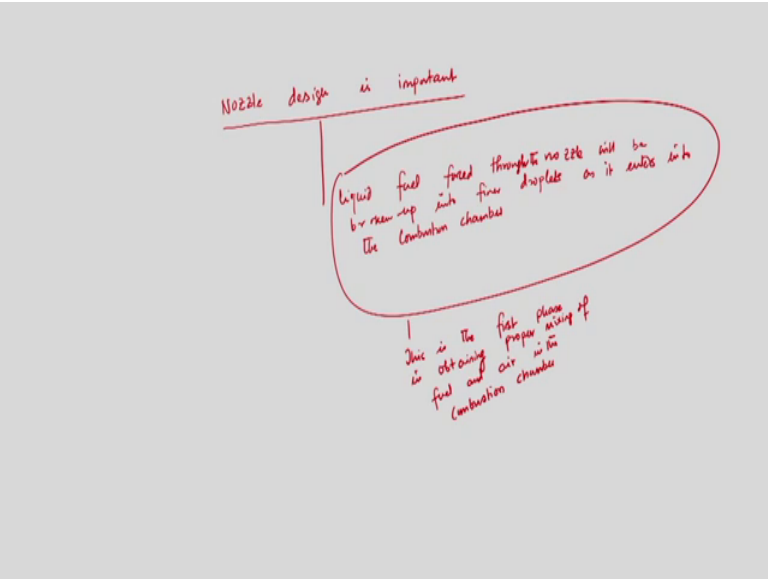

So, now we will discuss that while you are thinking about designing a nozzle. So, the design of a nozzle must be the nozzle design, nozzle design must be nozzle design is important. So that we can fulfill the objectives whatever we have discussed that is desired spray pattern, and the atomization of the fuel droplet that means, nozzle design is important from two different perspective. First one is very important. The liquid fuel, liquid fuel forced through nozzle forced through the nozzle will be broken off into finer droplets. So, we are supplying liquid fuel using a fuel pump which is also an important, which is also one parts of the one of the parts of the injection system, and then fuel is coming in to the nozzle.

So, while fuel is flowing through the nozzle, rather when pump is forcing the liquid fuel to go through the nozzle, then we need to ensure while we are designing the nozzle that the fuel particle will be broken up into finer droplets as it enters into the combustion chamber. Why, because as I said you that entire combustion chamber is filled up with compressed air. So, we have to ensure that fuel particle we will go to the remote corner rather it will occupy, rather it will mix with the fuel all the fuel particle being supplied will mix with the air, which is there in the combustion chamber rather which is there over the entire area of the combustion chamber, and for that we should have a desired spray pattern.

But, if we do not supply fuel into a finer number of smaller and smaller droplet, then what will happen? Combustion will be efficient that that this issue we will discuss in the context of discussion of combustion in the CI engine, so that will discuss in one of my lectures in the next phase we will discuss. So, this is very important. So, this is the first phase; so this is the first phase in obtaining proper mixing of fuel and air in the combustion chamber.

So, nozzle design important from two different perspective. First one is essentially two fragments, the fuel particle fuel liquid fuel into a number of smaller smaller finer droplets essentially to have a proper mixing with the compressed air in a combustion chamber. So, this is the first objective that it will have efficient mixing, rather it will readily mix with their rather compressed air in the combustion chamber. Second objective is so this is the first objective.

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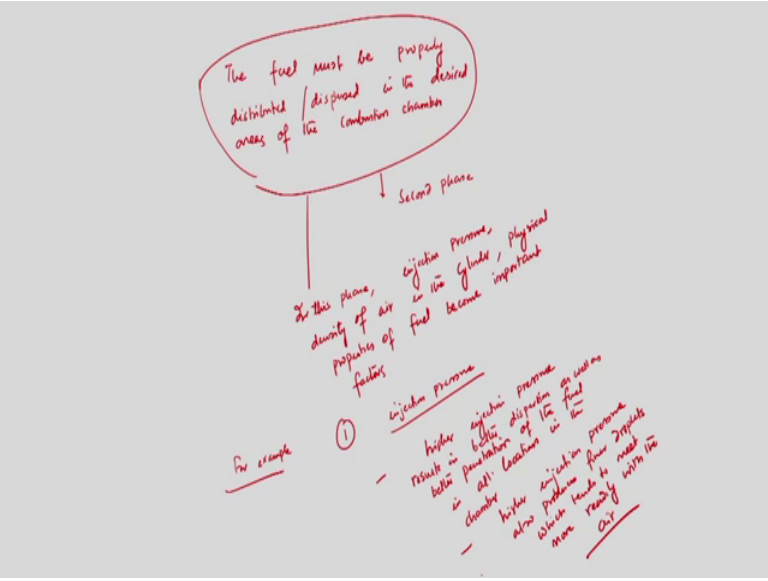

Second objective we will discuss that the fuel must be, the fuel must be you know properly distributed or dispersed in the desired areas of the chamber. Fuel must be properly distributed or dispersed in the desired areas of the chamber; in the desired area of the combustion chamber.

So, while we are designing a nozzle, which will be equipped with a fuel injection system, then we need to keep in we need to ensure that the first one is that whenever liquid fuel is forced to the nozzle using a fuel pump, the it the nozzle will be able to you know you know fragments the fuel liquid fuel into a number of finer droplets, before it enters in to the combustion chamber rather as it enters in to the combustion chamber. And this is the first phase of first phase in obtaining a proper mixing of the fuel with the compressed air in the combustion chamber.

Second thing fine we have ensured that instead of supplying liquid fuel, we can supply fuel into a number of very small finer fuel droplet, so that we can have a efficient mixing with the compressed air in the combustion chamber. Second is the fuel must be properly, so that is that we have ensured nozzle also have to ensure the while we are designing nozzle; we also have to ensure that fuel must be distributed rather dispersed into the desired areas of the combustion chamber.

Maybe and for that that spray cone angle, and depth of the sprays is important. Because, if we supply fuel only over a localized area in the combustion chamber, then it is not

possible that the compressed air that is there in the remote areas would not take part in the combustion. So, we may not have efficient combustion, and we may not get fuel economy. And for and to ensure that you know proper distributed or you know properly distributed spray pattern is needed, and for that we have to have again nozzle. So, this is very important. So, this is the second phase so, this is the second phase and this is the second phase.

And in this phase, in this phase injection pressure a few important a few you know aspects are there. In this phase injection pressure which is very important injection pressure, then density of air in the cylinder density of air in the cylinder right physical properties of fuel as well as nozzle design becomes important factor; physical properties of fuel become important factor.

So, first phase we have to ensure that nozzle will be able to supply fuel liquid fuel rather you know of very small and finer droplets. Instead of having liquid fuel, we can supply fuel of very small and finer droplets. Second phase that what you need to ensure that we have to ensure that that we will get proper distribution of the fuel rather dispersed phase of the fuel in the combustion chamber, so that instead of having localized combustion, we may have combustion what the entire area of the in the combustion chamber, so that the compressed air that is there in the remote area can mix with the fuel that is a introduced are injected.

And while you are talking about proper distributed properly distributed dispersed phase of the liq you know fuel, then a few important aspects you need to take into account that is injection pressure density of the air in the cylinder, and physical properties of the fuel, because this three I mean are important you know you know factors, which we which we will govern rather which will dictate the whether we will get a properly distributed or dispersed phase of the liquid or not. So, and these are very important issues, we need to take into account while you are designing the nozzle. For example, so for example because we have discussed that fine example, for example what is the you know what is the role of injection pressure what is the role of the injection pressure.

So, higher injection pressure results, so what is the role of injection pressure? If we have higher injection pressure higher injection pressure, it will results in better dispersion as well as better penetration of the fuel into all location of results in better dispersion as

well as better penetration of the fuel in all location in the combustion chamber that is very important in all location in the chamber is very important that the we need to ensure that the dispersed or you know distributed phase will be such that, so that the air which is there in the remote corner also will be able to take part in the combustion.

So, otherwise we should not get efficiency of the higher efficiency of the higher combustion efficiency. So, this is very important. This is one not only that higher injection pressure, so higher injection pressure ensure that the better penetration of the fuel in all location of the combustion all locations in the combustion chamber higher injection pressure, this is also very important.

Higher injection pressure also produces finer droplet also produces finer droplets, which readily mean which tends to which tends to meet readily with the air more readily with the air. So, injection pressure the role of injection pressure is that higher injection pressure injection pressure results in better dispersion at distributed phase in all locations at a chamber not only that, it also produces finer droplets which tends to meet more readily with the air.

So, I mean if we try to fragments fuel liquid fuel into number of you know smaller and smaller droplet, we will have better air combustion, because it will try it will tend you know the droplets, we will tend to meet readily with the we will tends to meet more readily with the air right. So, we will have a better mixing, so this is important issue.

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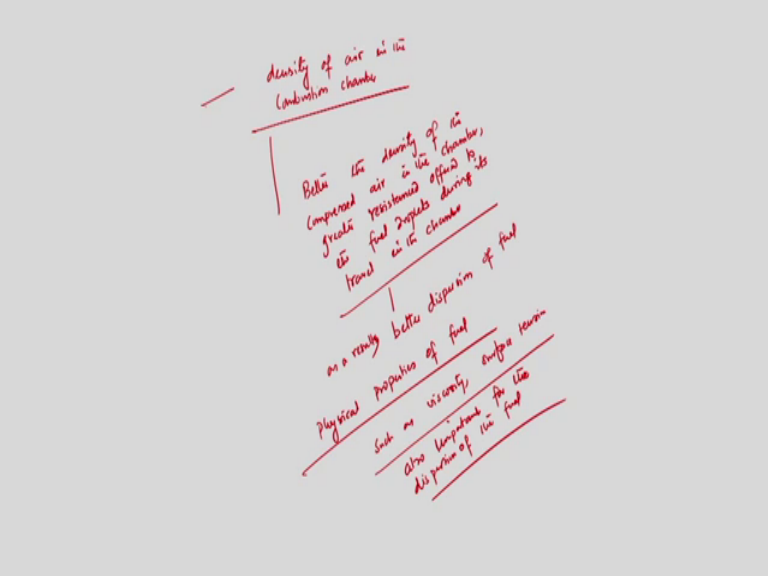

Now, what about so we have discussed about the injection pressure, so then what about density? The as I said you that another aspect is density of the air in the cylinder. So, next is density very important that density of air in the combustion chamber why, so density of the air in the combustion chamber is very important how? So, higher the density of the air higher the density of the compressed air rather better rather I write better the density better the density of the compressed air in the chamber in the chamber right the greater the greater the resistance greater resistance offered greater resistance offered to the fuel droplets during its struggle in the chamber.

If we have a higher density better density that means, whenever liquid droplets is coming from the nozzle, it encounters relatively higher resistance during its travel, as a result of which what will happen? And as a result of which better dispersion of the fuel as a result of which we will have better dispersion so as a result as a result we will get better dispersion of fuel. As if liquid droplet is coming while its coming from nozzle, and if it encounters relatively higher resistance being offered by the compressed air, then it will have a better dispersion rather it is spray we will get a desired spray pattern, and that is very important. So, this is the you know role of the density of the air in the combustion chamber.

And you know last is physical properties of the fuel physical properties of fuel, so this is the last one. So, this is a density of the air we have seen that higher the density the greater will be the dispersion you know of the fuel, how physical properties. Physical properties such as viscosity surface tension viscosity surface tension, these are very important, because these properties are very important also important for the dispersant of the fuel.

And surface tension also plays an important role for the formation of smaller and smaller droplet, droplet breaking all those things. So, these are very important issues, while you are discussing while you are thinking of nozzle design. So, nozzle design that we have discussed that there are two objectives to have atomization of the fuel, and you know desired spray pattern.

We have discussed about the first phase, and the second phase while you are having fuel injection rather while fuel is you know flowing through the nozzle that our first phase and second phase, what are the issues during first phase and second phase. And, what are

the objectives of having rather what objectives we need to you know fulfill during first phase and second phase that is what we have discussed.

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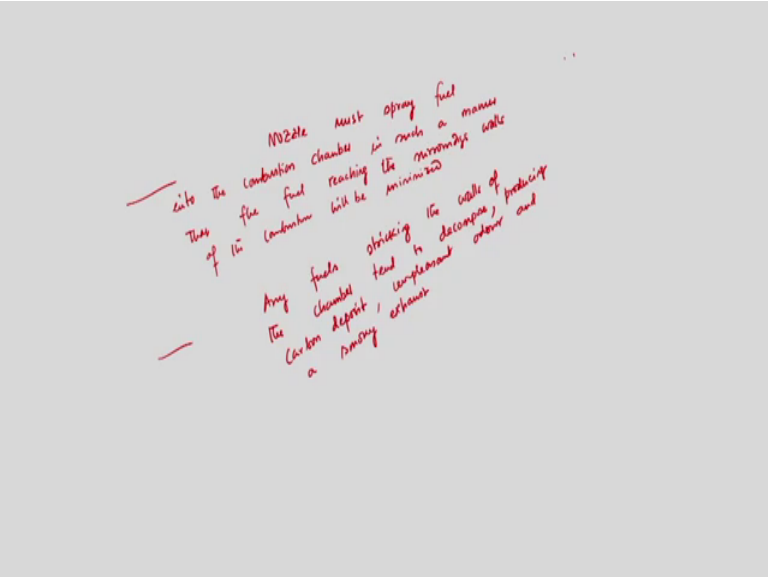

So, now we will come to the discussion. So, from this discussion, we have seen that the nozzle must spray fuel the chamber in such a manner. So, from the discussion we have seen that that nozzle must spray the fuel nozzle must spray fuel into the combustion chamber in such a manner, in such a manner that the you know that the fuel reaching the surrounding walls surrounding walls of the combustion chamber.

The nozzle must spray fuel into the combustion in such a manner that the fuel rather the nozzle must spray fuel in the combustion chamber in such a manner as to minimize as to minimize the you know as to minimize the quantity of fuel as to minimize rather I can write that as in such a manner that the fuel reaching at the surrounding wall of the combustion chamber will be minimized. So, this is an important issue.

Any fuel, so this is very important what will happen if we if a fuel strike the fuel drop the fuel which is being coming or rather that you know injected fuel you know reaching to the surrounding wall, then what will be the problem? So, nozzle will be nozzle will ensure that will have a desired depth of the spray not only that, it will have a you know desired spray patterns that is characterized by the depth of the spray, spray cone angle, so that first phase it will ensure will have a sufficient number of smaller and smaller

droplets, so that it can readily mix with air in almost in all the areas in the combustion chamber.

Second phase not only it will you know fragments the fuel into more smaller and smaller number of droplets, rather it will be able to provide sufficient you know you know desired spray pattern, which is characterized by the spray cone angle, and this depth of the spray. While we are ensuring that fine we will have a desired spray pattern, at the same time also we also need to ensure that the nozzle must spray fueling the combustion chamber in such a way that it will minimize you know fuel particle, it will minimize the quantity of fuel reaching to the surrounding walls.

I cannot completely stop it, rather I cannot completely you know make it zero I mean some fuel you know some amount of fuel rather some fuel droplets will try to strike the surrounding walls in the combustion chamber, rather we need to ensure that the quantities of fuel striking the surrounding walls of a combustion chamber will be minimized, but I cannot make it 0, what will happen?

Importantly, any fuels striking the walls of a cylinder striking the walls of the chamber tends to decompose tend to decompose producing carbon deposit producing carbon deposit, unpleasant order and a smoky exhaust and the smoky exhaust. So that means, we need to ensure that a minimum quantity a minimum quantity rather the quantity of fuel droplets striking the walls surrounding walls of the combustion chambers should be minimized. Otherwise, we will have a if a large you know number of fuel droplets strike you know the walls of the combustion chamber, we will have a carbon deposit not only that we will have unpleasant order, and we will get a smoky exhaust.

So, to avoid that I mean we have to design nozzle in a proper way. So, now we will come to the discussion of types of nozzles. So, we have seen that what are the objective of nozzles, why you should have nozzle fine that we have to spray a nozzle, we have to break the liquid fuel into smaller and smaller number droplet. First of all you have to make the fuel into form of a drop, and then the droplets would be you know the liquid fuel will be broken up into a number of smaller droplets, and also we need to ensure that the combustion would not be localized, and to do that we have to have a desired spray pattern. And while we were having desired spray pattern, also we have to keep in mind

that that a large portion of the fuel droplets would not strike the walls of the surrounding should not strike the walls of the combustion chamber.

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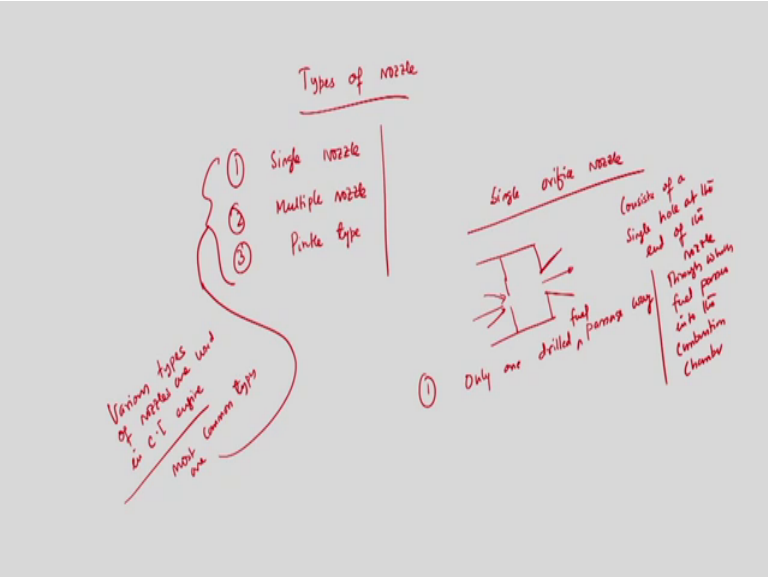

So, now what are the types of nozzle types of nozzle very important. Single nozzle, multiple nozzle, and pintle type pintle type. So, what is single nozzle, single orifice nozzle rather single orifice nozzle. So, single orifice nozzle is like this that it is single orifice nozzle. So, in a single orifice nozzle, we have only one that the single drill passageway. So, this is only one drilled you know will have only one drilled fuel passes way, this is called you know only one and what is so at the end of the nozzle.

So, I am writing that various types of nozzles various types of nozzle are used in CI engine right. But, the most common types are but various types of nozzles are used in CI engine most common you know most common types are most common types are these that is single nozzle single orifice nozzle, multiple orifice nozzle, pintle type.

Single orifice nozzle consist the single orifice nozzle which consists you know of a single hole in the end at the end of this thing consider a single hole at the end of the nozzle at the end of the nozzle through which fuel passes into the combustion chamber through which through which fuel through which fuel passes into the combustion chamber. And if we so this is single orifice nozzle only, we have only one drilled fuel passageway, and which is located at the end of the fuel through which fuel passes into the combustion chamber.

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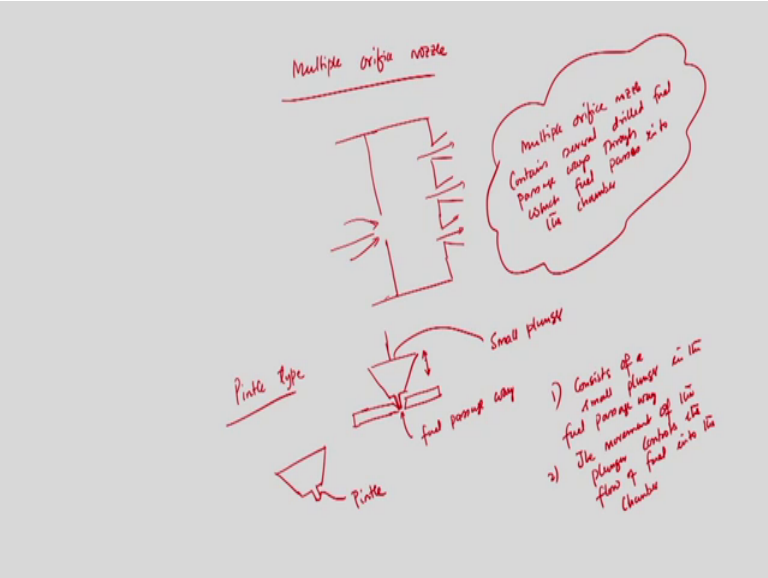

Number-2 is multiple orifice nozzle multiple orifice nozzle. So, instead of having a single drill passageway, we have a we will have multiple passage drill passageway, so this is the nozzle. So, this is multiple orifice nozzle right. So, the multiple orifice nozzle contains several such several drilled fuel passage ways several drills fuel passageways. Instead of having single drill passageway, we are having multiple drill passageway through which through which fuel passes into the chamber. So, this is very important multiple orifice nozzle.

And last one is pintle type last one is pintle type right. So, we have this is small plunger, and this is fuel passage way. So, multi you know the pintle nozzle, so pintle type nozzle consist of a small plunger in the fuel passage way in the fuel passage way. And the movement of the plunger controls the flow of fuel into the chamber the movement of the plunger controls the flow of fuel into the chamber.

So, we have in a pintle type is we have a small plunger, and this is known as pintle this is known as pintle. So, the movement of the pintle which controls the flow of fuel into the chamber, and they and will have a small plunger, and the movement is I mean it is having to and from movement I mean we can control the movement essentially to maintain the gap through which fuel will be injector fuel will be flowing into the combustion chamber. So, by controlling the movement of the plunger we can control the flow of fuel into the combustion chamber.

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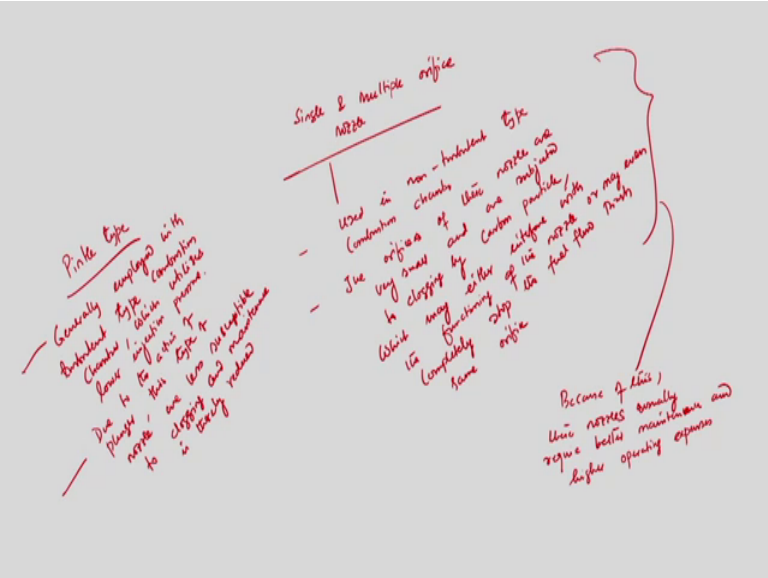

Now, the single and multiple orifice nozzles are used with so we have discussed about single orifice nozzle, multiple orifice nozzle, and the pintle type. The single and multiple orifice nozzels are used with non-turbulent type combustion chamber. This single and multiple orifice nozzle, these are used in non-turbulent type combustion chamber right.

The orifices are very small the orifice the orifices of the orifices of these nozzles are very small, and are subjected to and are subjected to clogging by carbon particle clogging by carbon particle, which may either interfere with the function with the nozzle stream. Or, may even completely stop fuel carbon particle which may either interfere with the functioning of the nozzle or completely or may even completely stop completely stop the fuel flow through the fuel flow through same orifice through same orifice.

So, if we have a singular multiple fuel orifice type, which are normally used in non-traveling type combustion chamber, the orifices are very small. And sometimes they are subjected to you know subjected to clogging by carbon particle, because whenever you are having you know combustion chamber that is very close to combustion chamber, so sometimes they are subjected to plugging of the carbon particles.

So, when they are you know clogged with the carbon particle, the clogging of the carbon particle either may you know interface interfere with the functioning of the nozzle or sometimes it may completely stop the supply of fuel flow through the same orifice. So, and that is why, because of this because of this because of this a proper you know this

because of this these types of nozzles these nozzles usually require these nozzles usually require, you know better maintenance and higher operating better maintenance tenance and higher operating expenses. So, because of these nozzles usually require better maintenance and high higher operating expenses. So, these are important aspects.

On the other hand, if we discuss about pintle type, this pintle type nozzles are generally employed with turbulent type combustion chamber with turbulent type combustion chamber, which utilizes which utilizes lower injection pressure lower injection pressure. And due to the action of that plunger due to the action of the plunger, these type of nozzle are less susceptible to clogging to clogging thereby and maintenance is thereby reduced. So, these type of nozzle very important that small pintle which have the since that moment of the plunger is there by changing the moment of the plunger by controlling the movement of the plunger, you can control the fuel flow.

So, whenever you know that plunger movement is there, the moment of the pintle itself pintle itself even though there will be a deposition of carbon clogging at the deposition of carbon particle or clogging by carbon particle the movement of the plunger itself will allow to remove rather will you know cleared the carbon deposition. And that is why, they are not they are less susceptible to clogging and thereby maintenance is reduced.

So, these are very important types of nozzle normally used in CI engine single orifice type, multiple orifice type, and pintle type. Single and multiple orifice type, we have discussed either we have single drill passageway or multiple drill passageways. But, these nozzles are normally used with you know non-turbulent type combustion chamber, where injection pressure is will be high rather which non-turbulent type combustion chamber utilizes higher injection pressure.

And you know the orifices of these nozzles are very small, and subjected to clogging up carbon particles that is what we have discussed. And this carbon clogging of the carbon clogging by carbon particle sometimes may interfere with the function of the nozzle or sometimes it may completely stop the fuel flow, and because of this we need a better maintenance and operating costs will be higher.

On the other hand, the nozzle would fit nozzle fitted with the plunger type, it is normally employed you know turbulent type combustion chamber which utilizes lower pressure not only that even though there is a probability of having clogging up carbon clogging by

carbon particle, the movement of the plunger itself, we will try to clear the carbon deposition as a result of which we maintenance is reduced thereby reduced.

So, with these I stop here today. And we will continue our discussion in the next class, and we will discuss about the ignition system, better ignition system. And if time permits, we will discuss about magneto ignition system, and also we will try to work out a few example that is what we have discuss of in the last lectures.

Thank you very much.