Thermal Engineering: Basic and Applied
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Lecture – 54
Alternative Fuels and Self Ignition Characteristics of Fuel_ Octane Number, Cetane Number

I welcome you all to this session of thermal engineering basic and applied and today we shall discuss about the alternative fuels. In the last class we have talked about the self ignition characteristics of the fuel, we have also discussed about the fuels for both SI and CI engines. So, if we discuss briefly again what we had discussed in the last class is the self ignition characteristics.

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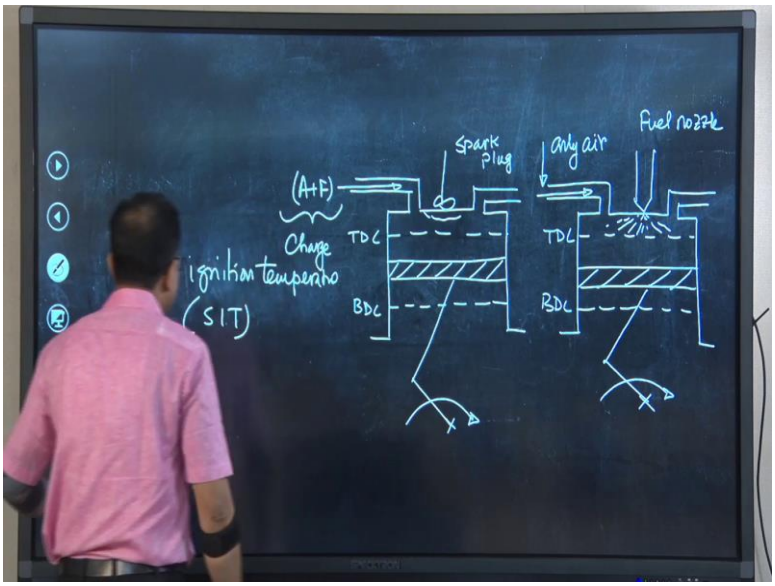

So, before going to discuss this part today again let us first draw the schematic of 2 engines that is SI and CI, this is top dead center and this is bottom dead center. And for this SI engine the name itself suggests that spark plug will be there and if we draw similarly the compression ignition engine, we have fuel nozzle. So, that is used to spray fuel into the combustion chamber.

So, for the SI engine through the intake manifold we take charge that is air plus fuel mixture. So, this is charge but for the CI engine only fresh air is taken into the cylinder during intake stroke. So, this is only air. So, whether it is the charge that is air fuel mixture inside the combustion chamber or if it is only here for the CI engine; Air or Mixture will be compressed during compression stroke. Now for the SI engine during compression stroke the temperature

of the airflow mixture will be increased similarly temperature of the air also will increase during compression Heating and towards the end of the compression stroke we need to supply fuel through fuel nozzle.

The temperature which is developed during compression heating of the air fuel mixture or air is very important that temperature for the compression ignition engine should be higher than the self ignition temperature of the fuel itself. So, what is the self ignition temperature that is the temperature at which fuel will auto ignite.

So, that means rise in temperature due to compression heating should be such that it should be higher than the temperature which is required to auto ignite or self ignite the fuel for the CI engine and that is the principle of the compression ignition engine, for the SI engines that temperature is also having an important role.

So, we have agreed undoubtedly that the self ignition temperature is very important for the CI engines because this temperature should be known before a particular fuel is selected for the engine because the rise in temperature during compression heating should be higher than the self ignition otherwise what will happen that the mixture will simply cool off, it will not take part in the combustion.

On the other hand, we are claiming that the self ignition temperature, SIT is also important for the SI engines why because if we do not know about this particular property of the fuel then what will happen? If the self ignition temperature of the fuel that is being used for the SI engine is very less, then we may not require even spark plug to ignite the fuel. So, what will happen that we are using spark plug that means we are not going to utilize the self ignition property of the fuel. So, the fuels which are normally used for the SI engines are having low self ignition temperature and that is why this external agent is needed, question is if you do not know about this particular property of the fuel even for the SI engines, then it would be very fatal for the engine operation. So if the temperature rise during compression heating is above the self ignition temperature of the fuel which is used for this particular SI engine then one flame front will come from the spark plug because spark plug is there. So, spark plug will ignite the fuel which is there closer to this region.

So, the compressed mixture would be there and the compressed mixture which is in the vicinity of the spark plug will be ignited first due to this flame front. And then the flame will propagate across the combustion chamber and the entire charge will be combusted but if the self ignition temperature is very less may be the rise in temperature due to compression heating will allow the fuel which is there even at the furthest location of the from the spark plug will also ignite and the resultant effect would be abrupt rising pressure and that is kind of very chaotic. So, abnormally pressure will be developed inside the combustion chamber and the pressure pulses will cause the damage of engine and several parts of the engine.

And this is very undesirable for the smooth operation of the engine because the rise in pressure would be so, high and it would be abnormal. So, it will create an audible noise alongside several other effects like damaging of several parts of the engine and the entire phenomenon is known as knock. So, to prevent the knock of the SI engines knowledge about the self ignition temperature is equally important.

Though it is highly important for the CI engines because the principle of the CI engine is based on the kind of self ignition property of the fuel but we have also understood that it is also equally important for the SI engines to prevent an undesirable phenomenon which is known as knock.

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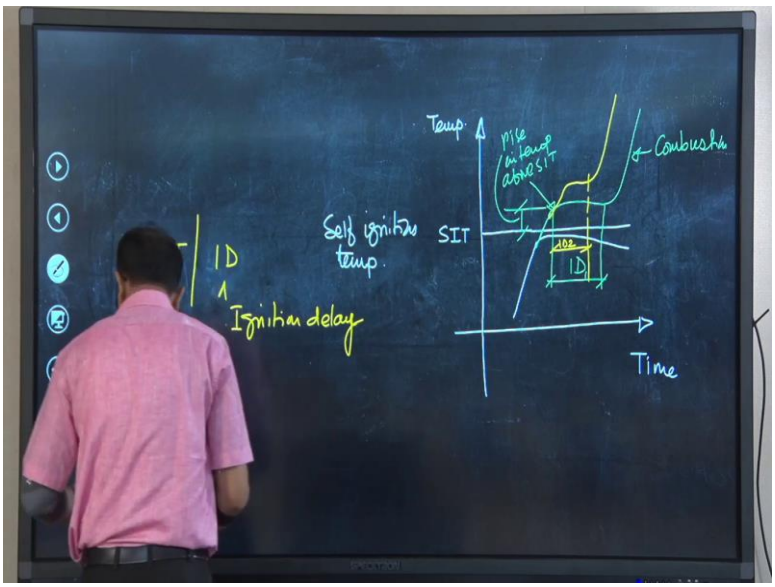

So, we have understood that the fuel property that describes about the self ignition characteristics of the fuel or how well a fuel will ignite or will not ignite is very important. So, let us briefly discuss about the graph that we had discussed in the last class that is the time vs temperature.

So, we had seen if we consider a particular fuel and if we assume this is the self ignition temperature, SIT and if we compress the fuel for the CI engine or if we compress the air for the SI engine, if it is the charge that is air fuel mixture, during compression heating you can understand that with time temperature will increase.

If the temperature rise because of that compression is less than the self ignition temperature then fuel will or the mixture will simply cool off and it will not take part in the combustion. On the other hand if I represent another case rise in temperature due to compression heating is greater than the self ignition temperature.

So, understand this is the rise in temperature and then self ignition will start over here at that point and we have discussed about the ignition delay. So, this is the ignition delay or ID and then this is the rise in temperature due to combustion. So, self ignition starts here it is because of this ignition delay, eventually the entire combustion will start from here and then we can see that abrupt rise in temperature.

And this ignition delay that is having 2 different components one is physical delay another is chemical delay and what will happen that if you can consider another case that the ignition delay period is reducing.

So, basically 2 things are very important, one is self ignition temperature another is ignition Delay to know about any particular type of fuel before we use that fuel for the combustion of internal combustion IC engines.

Now the prediction of SIT or ID that is self ignition temperature and ID for any given air fuel mixture is ambiguous because it is not fixed it depends on so many factors like pressure temperature, swirl, turbulence so many things. So, a perfect knowledge about the ignition delay is also very important for the compression ignition engine because we are going to realize this self ignition or auto ignition property.

So, we had seen that the self ignition temperature together with the knowledge about ignition delay is very important because these 2 things are very important for the efficient and smooth

combustion in CI engines. So, as I told you that even for a given air fuel mixture these 2 quantities are not fixed rather ambiguous it depends on so many factors.

So, what next will be discussing today is the 2 important numbers what you have understood till now that the fuel property that describes how well a particular fuel will self ignite or will not ignite.

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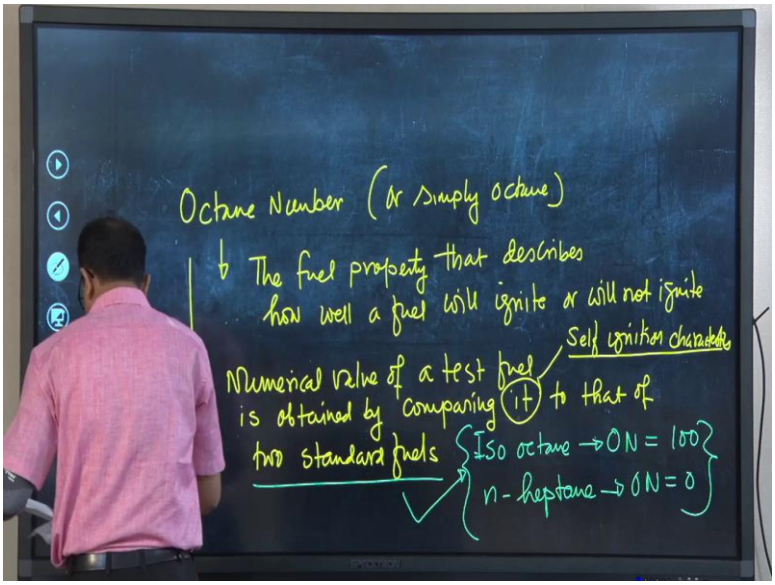

So, if we talk about CI engine, compression ratio is fixed we are increasing the temperature of air during compression heating. And then we are discharging or we are spraying fuel into the combustion chamber, at that prevailing condition whether the combustion will be completed or combustion will be initiated that depends on a property.

So, basically which are those properties that mean whether the fuel will ignite or will not ignite because we are not having any external agent to ignite the fuel for the CI engines. So, the fuel property that describes how well a particular fuel will ignite or will not ignite is known as octane number. So, today we will be defining 2 different number, one is octane number. So, this is the number which is used to describe the property of fuel which indicates whether that fuel will self ignite or not.

So, if you would like to have this number for any if well any test fuel may be that fuel will be used for the SI engine or CI engine. So, to know the numerical value of this number of any test fuel what we need to do. We need to compare this self ignition characteristics or self ignition property of the test fuel to that of 2 standard fields.

So, that means for any fuel if you would like to designate the octane number if you would like to define or if you would like to identify the octane number what we need to do is we need to test that particular fuel. And we need to compare the self ignition characteristics of that test fuel to that of 2 standard fuels for which we already know the octane number.

So, the numerical value of a test fuel is obtained by comparing by comparing it to that of by comparing the self ignition characteristics to that of 2 standard fuels again.

So, two standard fuels are you know Iso octane. So, that means we can compare or we can predict the octane number of any test fuel if we compare the self ignition characteristics of that fuel with the self ignition characteristics of any standard fuels. So, ISO octane whose octane number is equal to 100 and another is n heptane and whose octane number is zero.

So, that means we are considering 2 extreme values of octane number we are considering one fuel n heptene whose octane number is zero. And you are also considering another fuel whose octane number is 100 and if we compare any test fuel and then if we go for testing of considering that particular fuel in a given or specific engine and specific condition.

So, basically say we would like to have the octane number of any fuel X. So, we can consider that fuel X, we can take that fuel for testing in a specified condition in a specific engine and we can compare w the octane number of that fuel with these 2 standard fields and we can generate the numerical data. So, this is the octane number. So, basically you can see that ice octane is having octal number 100 while the n heptane is having octane number zero.

So, what is the physical significance of this number higher the octane number less likely the fuel will self ignite. So, that means if the fuel is having higher octane number it is less likely that the fuel will self ignite. So, if I now ask a question for the compression ignition engine or CI engines the fuel will be having higher octane number or lower octane number.

So, the fuel which will be used for the CI engines must have higher octane number because the fuel with higher octane number is having less tendency to self ignite because for the compression ignition engine we are having higher compression ratio. So, the rise in temperature of the air due to compression heating would be higher.

And if you are using a particular fuel at that temperature fuel will self ignite then it will lead to knock that I have discussed already. So, that is why to prevent knocking the fuel which is having higher octane number are preferred for the CI engines.

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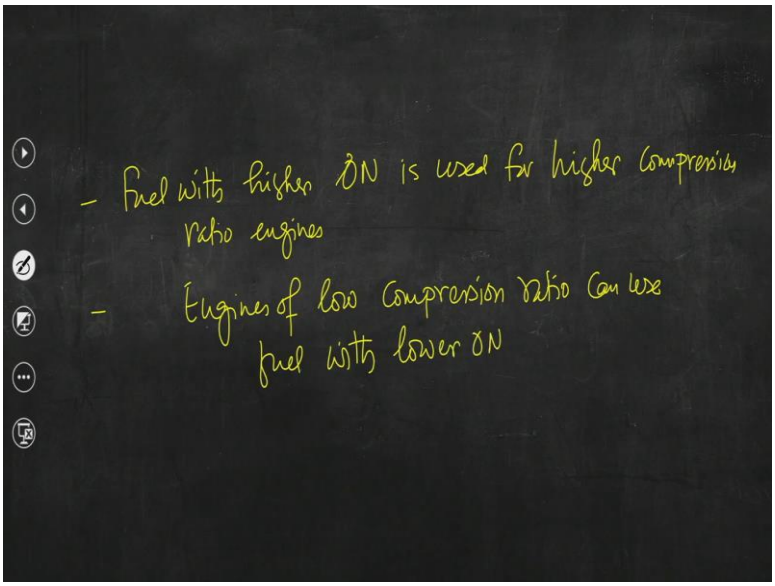

So, fuel with higher octane number is used for higher compression ratio engine higher you know compression ratio engines like CI engine. So, naturally the fuels which will be used are those will be used for the CI engines you know must have higher octane number because we can prevent the detonation.

So, this is very important that means it simply indicates engines of low compression ratio can use low octane number field with lower after number.

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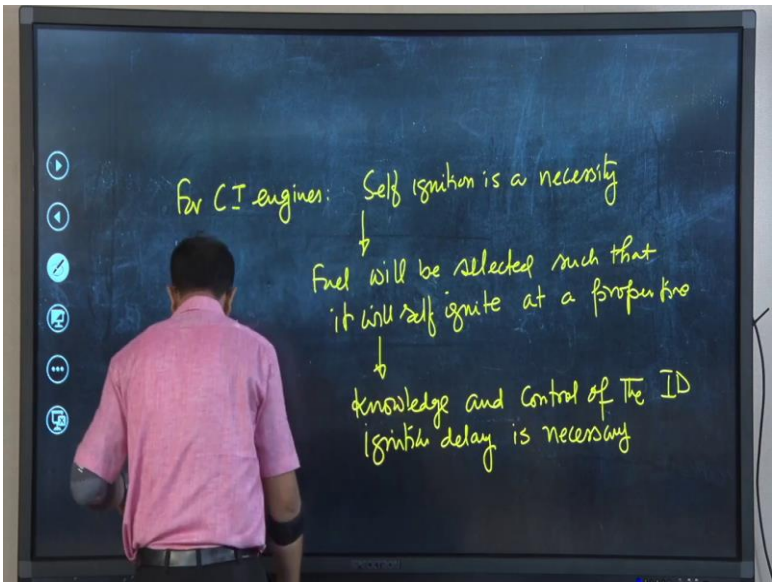

So, we are supplying fuel into the combustion chamber and the compressed air temperature is such that the moment at which fuel is supplied, combustion will initiate. And combustion will be completed within the stipulated time.

So, for the selection of fuel typically for CI engine, a knowledge about the ignition at precise time is very important. So, basically we are compressing here and towards the end of the compression stroke fuel is supplied into the combustion chamber through the nozzle and then entire fuel will mix with the air and combustion will be completed.

So, what is most important for the CI engine is self ignition is necessity. Now the fuel will be selected such that it will self ignite at a proper time which indicates that knowledge and control of the ID.

So, we had seen that higher the rise in temperature above the self ignition temperature, shorter is the ignition delay right, if shorter is the ignition delay, quick completion of the combustion and this is desirable. So, for the CR engines in which self ignition is necessity we must have a knowledge and control over the ignition delay to ensure that combustion is completed smoothly and that too quickly.

Now we cannot even select any particular fuel for the SI engines unless we know that that is suitable. So, that means again unlike the octane number there is another number which is called as cetane number which is used to describe about the ignition delay about a particular fuel. So,

what I had written over here is that the knowledge and control of ignition delay is necessary and the property that quantifies this particular aspect is the cetane number.

So, for any fuel we must know about the ignition delay as I told you the ignition delay even for a given air fuel mixture is very ambiguous it depends on so many things. So, the property that quantifies about the ignition fuel is the Cetane number.

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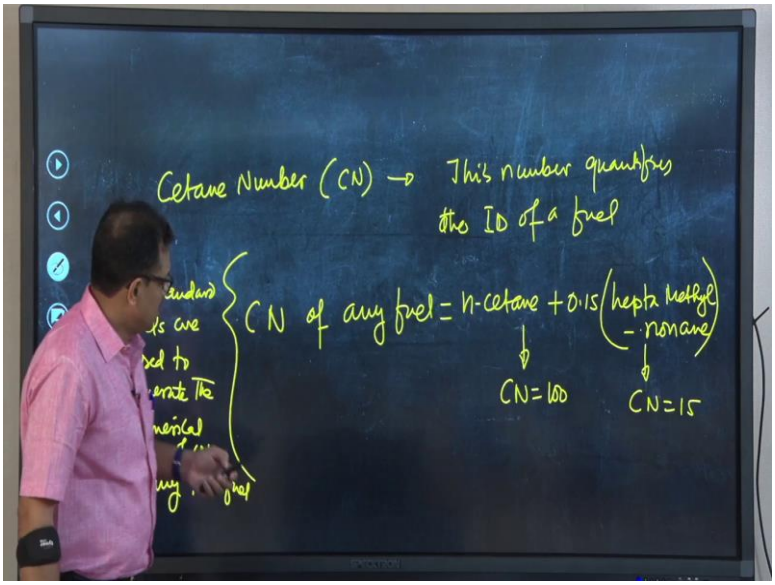

So, cetane number or CN basically quantifies the ID of fuel. So, this is not only the ignition delay but also about the knowledge. So, this is the Cetane number. And if we need to go for the calculation of cetane number of any particular fuel we need to compare the ignition delay of that particular fuel with 2 standard fuels.

So, again we need to take the test fuel for testing in a specific engine in a specified conditions and we need to compare the ignition delay to that of 2 standard fuels and then we can generate this numerical number. So, the cetane number for the 2 standard fuels used to generate the numerical value of CN of any test fuel are nCetane having cetane number is 100 and another one is hepta methyl nonane. So this is having cetane number 15.

$$CN\ of\ any\ fuel\ =\ n-octane\ +0.15(hepta\ methyl\ nonane)$$

So, we have talked about the kind of self ignition characteristics of fuel and also we have tried to understand why this particular property of the field is very important even for both the engines CI and SI engines.

And finally we could define 2 important numbers that is the octane number and cetane number and numerical value of these 2 numbers are very important to know about the self ignition properties as well as the knowledge about the ignition delay to prevent the undesirable phenomenon like knock.

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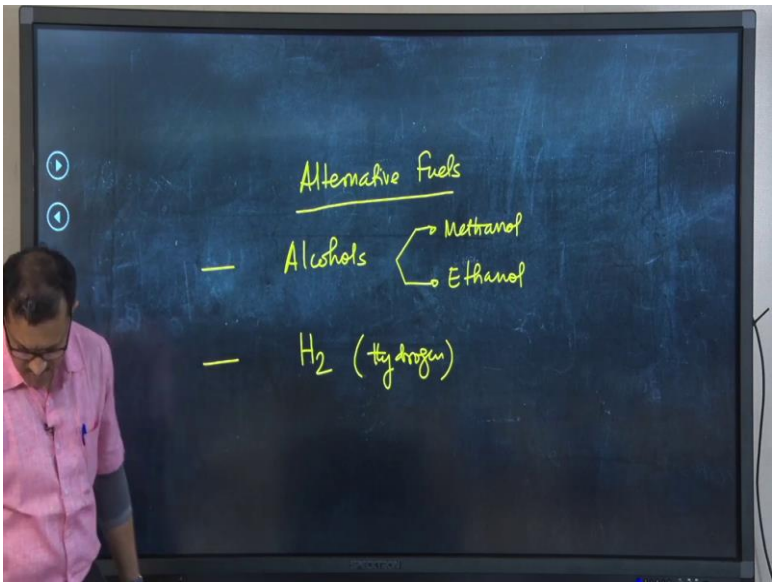

So, now finally we shall discuss about the alternative fuels. Question is we have talked about the gasoline in the last class. So, keeping in mind the possible scarcity together with the cost associated with the gasoline extraction, effort has been taken to explore several avenues of the alternative fuels. Though attempts have been taken to modify the design to bring the fuel economy even then the dwindling supplies of the gasoline allows to figure out several alternative fuels.

So, today we shall discuss about 2 alternative fuels which are also used not in a pure form but in blended form with different proportion with gasolines. So, one is alcohol. So, here will be having methanol, ethanol and another one is hydrogen. So, we have talked about normal paraffins.

So, if we replace one hydrogen atom with the hydroxyl group so, will we get will be getting alcohol. So, alcohols like methyl alcohol or ethyl alcohol that is methanol and ethanol as well as hydrogen they are used as alternative fuels for the internal combustion engines.

Certainly if you try to recall in the last class we have talked about the limitations of gaseous fuel, one is the storage and also there is a possibility of having leakage. So, if we now try to

discuss about advantages as well as disadvantage of alcohol as well as hydrogen. So, why not alcohol is used in a pure form or even though hydrogen is having promising potential to be used as an alternative fuel.

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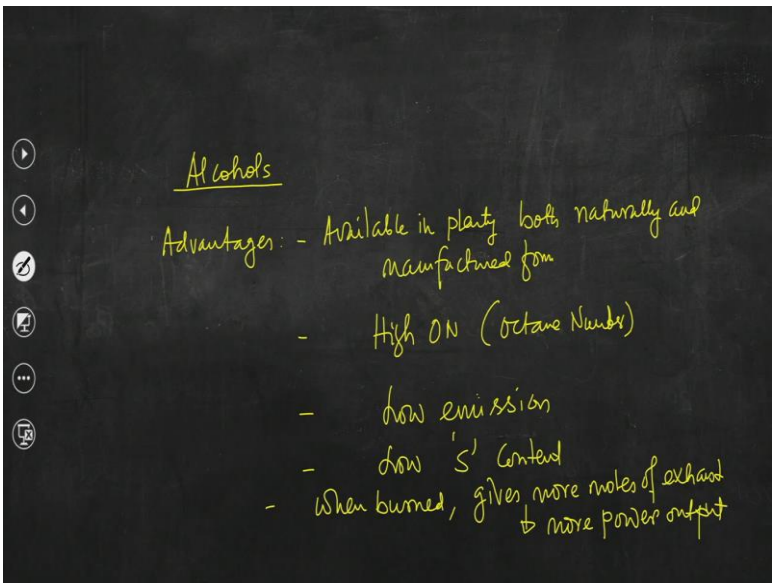

So, first we start up talk about alcohols. So, advantages first number one is this is available in plenty both naturally and manufactured form. Second is it is having high octane number we have talked that if a particular fuel is having high octane number that means it has less tendency to self ignite and this is good for the engines having higher compression ratios.

That means even if we use that particular fuel for the engines having higher compression ratio tendency of having knock is not there. High octane number and then most importantly low emission and low sulfur content and finally which is very important is that when burned gives more moles of exhaust that is it simply indicates more power output.

So, when Burned it gives more moles of exhaust. So, pressure will be more, definitely power output will be more. So, all these are advantages if we use alcohol as an alternative fuel but at the same time we cannot deny several disadvantages as well.

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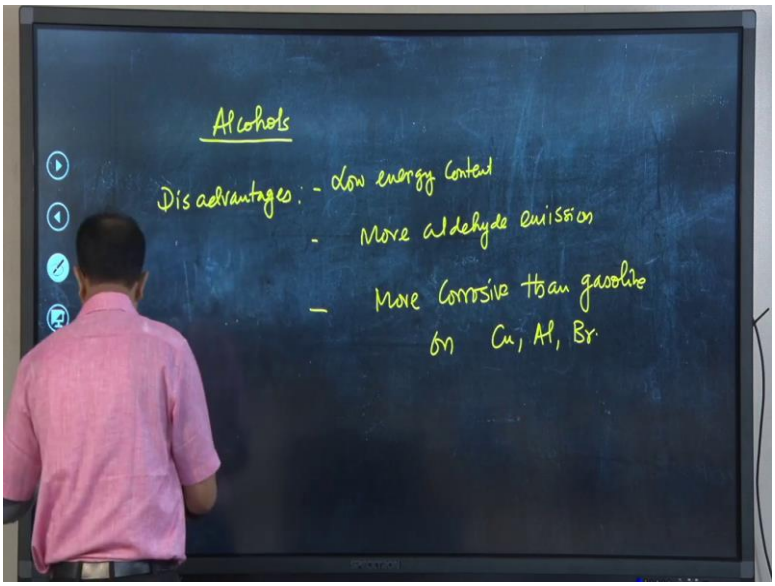

So, they have low energy content if we compare a particular alcohol with the gasoline then definitely the energy content of alcohol is almost half than that of the gasoline and one serious disadvantage is that more aldehyde emission because of this chemical structure of the alcohol and it is also more corrosive than gasoline on several materials like copper, aluminum, brass.

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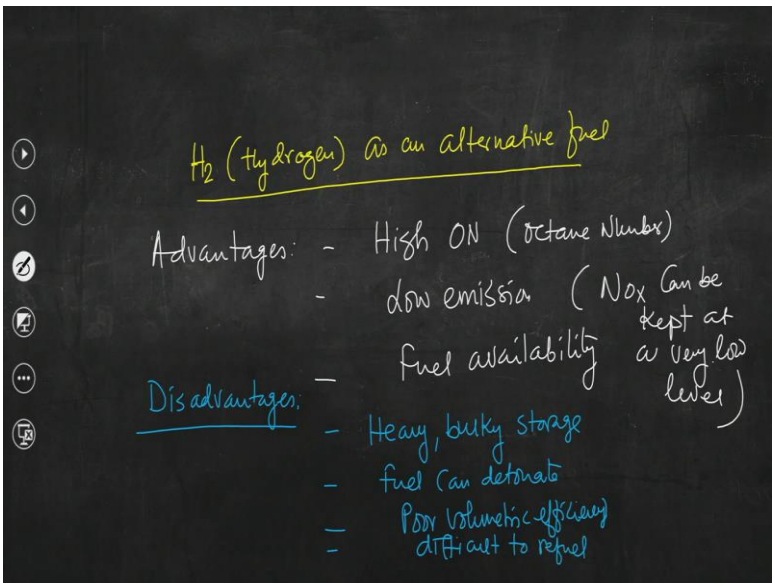

So, now if we look at the promising potential of hydrogen as a fuel as an alternative fuel. So, it is having again high octane number. So, we have already discussed about the benefit of having high octane number of any particular fuel then low emission. And finally fuel availability, we can again have natural sources we also can get hydrogen through the electrolysis of water.

So, the availability, emission as well as high octane number all these are basically low emission particularly Nox emission can be kept at a very low level. So, this is very important advantage

of hydrogen to be used as a as an alternative fuel but at the same time we cannot deny several disadvantages.

That is storage issue that is heavy and bulky storage and fuel can detonate as well, number three is poor volumetric efficiency. Because to burn certain amount of hydrogen to get equal amount of power we need huge amount of air.

If we use hydrogen then to get certain amount of power if we compare with gasoline then we need to supply huge amount of oxygen. So, that simply indicates that it is having poor volumetric efficiency and also it is difficult to refuel. So, all these are the disadvantages.

So, though hydrogen is having promising potential for an alternative fuel but we also can see today that still it is having several disadvantages, research is going on for efficient use of hydrogen, most important concern is the storage. So, that gasoline can be replaced by this particular fuel and we can bring fuel economy.

So, to summarize today's discussion we have talked about the self ignition characteristics of the fuel then we could define 2 important numbers and the numerical value of these 2 numbers is very important to select a particular fuel for any particular type of engine, finally we could discuss about the alternative fuels which are typically used for the internal combustion engines. So, with this I stop here today and we shall continue our discussion in the next class, thank you.