IC Engines and Gas Turbines
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Lecture – 20
Octane and Cetane Numbers Alternative Fuels – Methanol, Ethanol, Hydrogen, Natural gas (Contd)

So, we will discuss today about the internal combustion engine rather we will continue our discussion and we will discuss, rather we will continue our discussion on fuels, alternative fuels and Octane and Cetane numbers. So, far I can recall that I have discussed about octane number in my last class.

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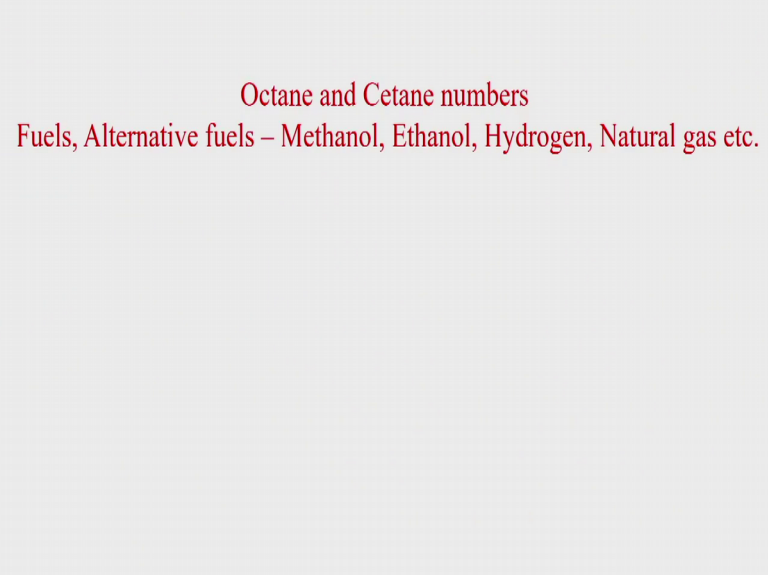

So, today I will discuss about cetane number.

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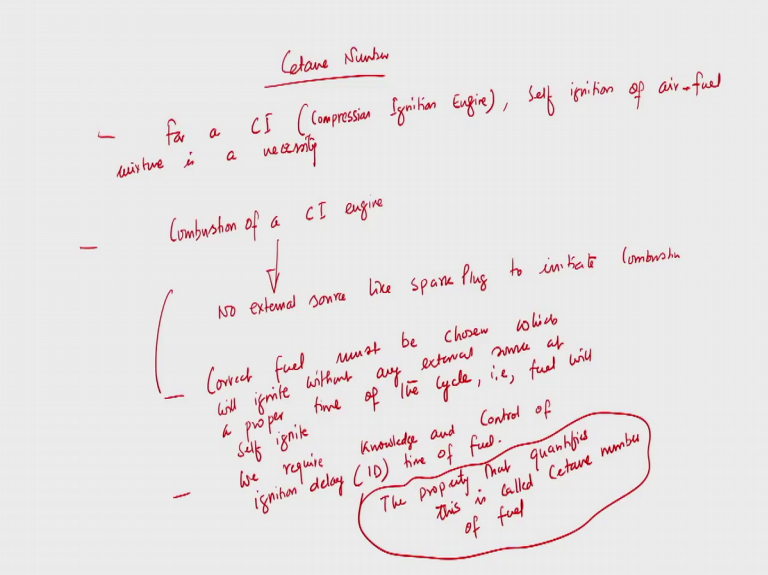

So, what is cetane number that is very important again. We have discussed the self ignition characteristics of a fuel and from there we have seen that the temperature above which you know this you know occur, I mean we have seen that for inter for spark ignition engine, we require an external agent like spark plug to ignite that that to initiate the combustion. But, and if the compression heading of a particular fuel is always less than the self ignition temperature of that fuel of course, we require that external agent. But, if it is possible to raise the temperature because of the compression heating of a fuel above the self ignition temperature then even with then we can ignite fuel, we can start combustion without any without help of an external agents.

So, we have discussed that even when that the initiation of combustion and completion of combustion require finite time and that time is known as physical delay. So, that physical that the ignition delay and ignition has two parts: one is known as chemical delay other is physical delay. So, in particular you know we have seen that for a compression ignition engine we do not have any external agent. So, we are relying on this self you know self, we relying on the fact that the compression heating will be able to raise the temperature of the fuel above this self ignition temperature and the entire combustion will take place.

So, in particularly for a compression ignition engine, that is for a compression ignition engine self ignition of an air fuel mixture is a necessary condition. So, for a compression ignition engine for a CI engine or compression ignition engine self ignition of air fuel mixture is a necessity. Since, we do not require any external agent we rely on the you

know temperature and pressure of the air fuel at the of the air at the end of the compression that the temperature, will allow to self ignite the fuel when fuel is being injected through fuel injector. So, this self ignition characteristics or a self ignition of air fuel mixture is a necessity for a CI engine for a compression engine ignition engine.

So, now what is very important; that means, we have seen that if I try to recall the figure that you have drawn in my last lecture that, whenever we are having compression heating we can raise the temperature above the self ignition temperature. But, may be whenever temperature goes above the self ignition temperature ignition might ignition may initiate, but entire combustion will not be completed. So, initiation of ignition and completion of the combustion before finite time and that time is known as ignition delay, that shorted will be the delay we have seen this; we have seen that we can reduce the delay by increasing the compression heating temperature. That means, if you can raise the temperature of the air due to compression heating to a level and that temperature is so high that we can reduce that ignition delay to complete the combustion.

So, that means, and that also varies from fuel to fuel because that depends upon fuel composition the number of carbon and hydrogen atom present in the fuel. So, the correct fuel must be chosen in a compression ignition engine with which we will ignite without any external agent rather which we will self ignite at a proper time in a engine cycle. So, if you talk about the combustion of a compression ignition engine, then we have seen that there is no external agent. So no external source like spark plug to initiate combustion; that means, in a compression ignition in ignition engine, you know the correct fuel must be chosen which will ignite without any external source at a proper time of the cycle; at a proper time of the cycle.

So, correct fuel means we need to provide that I know that the compression ratio for a compression ignition engine is this. So, knowing the compression ratio if you can estimate that what will be the rise in temperature due to compression heating. And, if we know that the fuel we are going to supply in a compression ignition engine is having this is the self ignition temperature of that particular fuel. Then, we can tell that without any external agent entire combustion will be completed and for that we need to know that which fuel must be supplied; that means, correct fuel must be chosen which will ignite without any external source at a proper time of the cycle that is if the fuel will self ignite that is; fuel will self ignite very important, this is important.

Now so, if you know that if you supply correct fuel and if we raise the temperature due to compression heating above the self ignition temperature then perhaps we can say that without any external agent entire combustion will be completed. So, for that we require; knowledge and control of ignition delay. This is ID Ignition Delay, ignition delay time of fuel right. So, if we know that fuel will self ignite because of the compression heating so, correct fuel must be chosen this is important not only that we require knowledge and control of the ignition delay of the fuel. So, how can reduce the ignition delay and what will be the ignition delay for particular type of fuel we need to know.

So, the property that quantifies this is called ignition, this is called cetane number. So, the property that quantifies; that quantifies this info is called cetane number of fuel. So, it is very important; that means, since no external agent is there for the initiation of combustion in a compression ignition engine, we should select proper fuel, not only that we should have an understanding and control about the; we should have a knowledge and control about the ignition delay of that particular fuel. So, the property that quantifies that describes this is known as the cetane number of the fuel.

So, just like an octane number again cetane number is a numerical value and the scale a numerical scale and you know the cetane number are established for any particular fuel by comparing the test you know that fuel to two different fuel. So, just like octane number, if I like to know the cetane number of any particular fuel then we have to take that fuel for you know for a test in a engine at certain specific condition and we need to know the cetane number to two reference of fuels.

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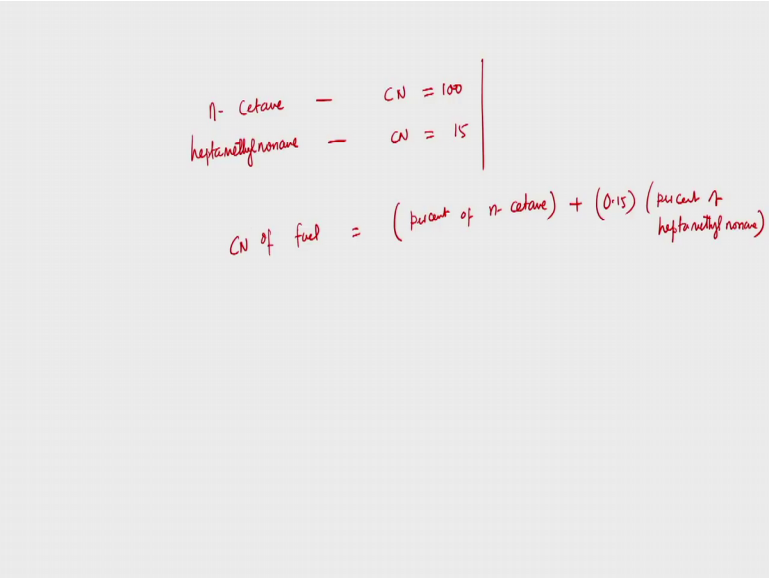

So, that two reference fuels are you know you know one is known as n cetane, one is n cetane whose cetane number is 100 another is heptamethylnonane HMN heptamethylnonane whose cetane number is 15. So, knowing the value of cetane number of two standard fuels: one is n cetane whose cetane number is 100 another is heptamethylnonane whose cetane number; if 15 we can you know calculate cetane number of any given fuel on doing a test in a engine at certain specific condition with reference to this particular fuel.

So, there is an re formula. So, if you would like to calculate cetane number of any fuel; any fuel is equal to percentage of percent of n cetane plus 0.15 into percent of heptamethylnonane. So, knowing this two standard cetane number 2 standard fuel we can calculate cetane number using this of course, we need to do test in a certain engine at certain specific at certain condition ok. With this now we next move to fuel for the engine.

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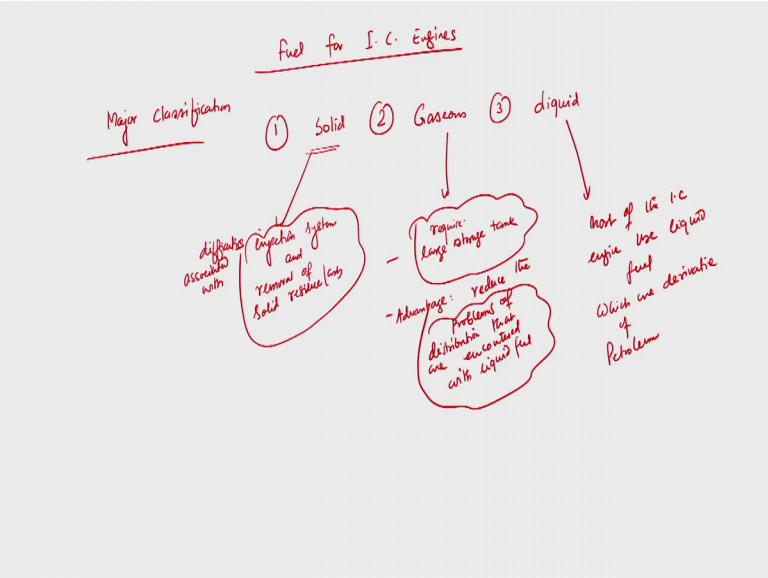

So, fuel for internal combustion engine very important. So, major classification is; major classification is number 1 solid fuel, number 2 gaseous fuel, number 3 liquid fuel. So, we can have internal combustion engine can be aparted on different kinds of fuel including solid, gaseous and liquid.

Now, the use of solid fuel is creates rather presents problem what kind of problems we are having if we use solid fuel, one is it is completed at injection system because if we use solid fuel we have to inject fuel in a engine. So, it is a complicated injection system not only that a difficulties associated with the solid residue or ash. So, if we use solid fuel one problem is the injection system and another problem is the; another problem is after combustion we will have in a solid residue or ash. So, there you know I mean removal of that and you know from the engine is again a problematic.

So, solid fuel cannot be used in internal combustion engine, although for external combustion engine we have seen that we can use solid fuel like coal. So, another problem another fuel is gaseous fuel it is very important. Gaseous fuel I mean create problem concerned with storage and handling. So, solid fuel is having problem with injection system and removal of solid residue or ash, gaseous fuel is having problem that handling and storage. Because, it require you know bulk storage tank to store the gaseous fuel also the you know handling of large volume so, I mean volume will be large. On the other hand, you know the seriously this you know handling rather I mean a of gaseous

fuel require I mean bulk and large storage tank which you know seriously restricts the use of such fuel in mobile equipments, I mean in a we cannot use because it requires a huge and large bulk storage tank. But, if we use gaseous fuel such fuels reduce many of the problems of starting and distribution that are encountered with liquid fuel.

So, as compared to liquid fuel if you compare I mean as compared to liquid fuel, the use of gaseous fuel to some extent advantageous in a sense that I mean starting and distribution of the fuel some gaseous fuel cannot be liquid I mean it is not because liquid fuel is having inertia. So, it is not easy to distribute and transport one point from one point to other point, on the other hand gaseous fuel can be easily distributed. So, this is one of the advantageous features of using gaseous fuel. Some gaseous fuel can be liquefied at high pressure, but it is costly. So, we do not use gaseous fuel we require.

So, most of the engine com IC engine therefore, utilizes the liquid fuel which a derivative of petroleum. So, we have seen that solid fuel is having problem, this is having problem of injection system, difficulties associated with injection system and removal of solid residue or ash. So, this is very important. Gaseous fuel requires large storage tank which seriously restrict a use of gaseous fuel in mobile equipments require large storage tank. But, it is having advantageous feature, advantages I mean it is very important you know reduce the problem of distribution, distribution that are; that are encountered with liquid fuel.

So, this is the advantages of using gaseous fuel; so, most of the internal combustion engine use liquid fuel; most of the internal fuel which are derivative of petroleum. In some countries where natural petroleum is scared, fuel having very similar compositions and characteristics are being produced by hydrogenation of coal. There are countries where natural petroleum is scared they use you know is very similar and similar composition and characteristics of you know fuel they use fuel having similar compositions and characteristics and those are produced by hydrogenation of coal.

So, most of the internal combustion engine use liquid fuel which are derivative of petrol, but where natural you know petroleum is scared their fuel of similar compositions characteristics are being used or produced by hydrogenation of the coal. As I said that liquid fuel are basically a petroleum product. So, normally I will just give you a basic

idea how we get you know product you know several you know petroleum product from you know crude oil.

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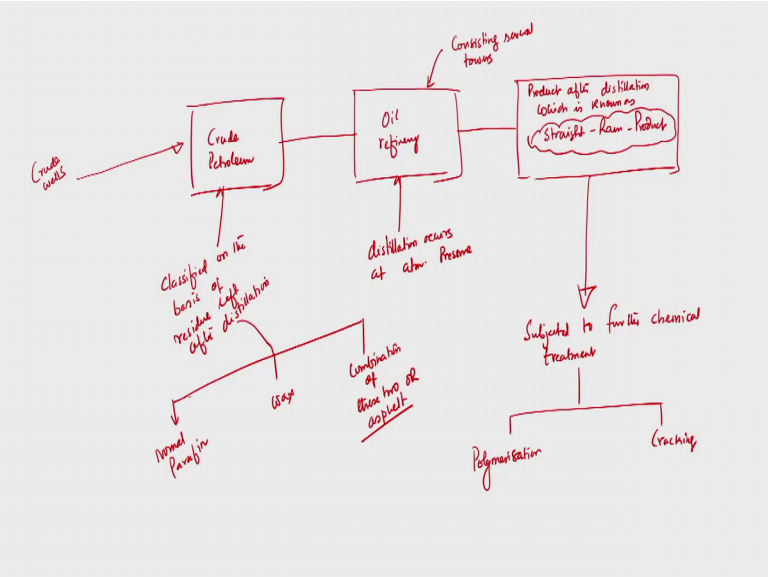

So, now, I can write this is crude petroleum that is obtained from crude oil; crude oils and a crude petroleum which is classified on the basis of residue left after distillation classified on the basis of residue left after distillation, then this crude petroleum is taken into oil refinery this is taken oil refinery. So, this will give you how we can extract petroleum product derivative of petroleum from crude oil or crude petroleum since this crude a petroleum product are mostly used as a fuel for the internal combustion engine.

So, this is oil refinery, here distillation you know occurs at atmospheric pressure and this oil refinery consisting several towers of refinery; consisting several towers then we get which is known as state ram product; we get straight ram product that is product after distillation which is known as Straight Ram Product. So, product after distillation is known as straight ram product and the straight ram product from there we can obtain the final derivative. And, for that we may be we may require you know certain chemical processes or chemical treatment so subjected to further chemical treatment; chemical treatment which are which is required that those are basically known as polymerization or cracking.

So, subjected to further chemical treatment we can get the final petroleum derivative which is required for any for SI and CI engines. So, depending upon the as I said you a

few minutes back that we need we need proper fuel. So, proper fuel means with self ignition temperature I know so and I know the ignition delay because ignition delay has two parts as I said last class, physical delay and chemical delay chemical delay is highly associated with the chemical composition of the fuel.

So, depending upon the structure of you know carbon and hydrogen atoms and number of hydrogen carbon atom we can tell what will be the ignition delay a chemical delay and what will be the self ignition temperature. So, to obtain that a special or particular fuel for any particular engine, we need to do a further chemical treatment of the straight ram product and those treatments are polymerization and cracking. So, this is essentially you know flow path you know process you know from which we can obtain the final petroleum product from the crude petroleum. As I said you that this crude petroleum comes from the, this is the raw petroleum comes from the oil wells. So, whenever we are getting crude petroleum it consist many hydrocarbon is many hydrocarbon of different molecular weight.

So, it also contain sulphur nitrogen also. So, crude petroleum contains many hydrocarbons of different molecular weight also contains sulphur nitrogen. So, basically crude falls into 3 classes depending upon so classified on the basis of residue left after distillation crude petroleum. So, this crude petroleum can be classified basically fall into 3 classes depending upon whether the residue left after distillation many para is mainly. So, depending upon the classified it is basically 3, one is known as normal paraffin; normal paraffin, wax or something combination of these two sometimes combination of these two or asphalt.

So, depending upon you know residue left, we can classify the 3 categories normal paraffin, wax and or a combination two. And the corresponding crude corresponding crudes are known as either paraffin based or wax based or the combination of these two, then we take that crude oil into oil refinery where, distillation process takes place in atmospherics pressure. And during this process distillation separate into various factors according to the volatility right because then, we take crude oil into the oil refinery. And, there we do distillation at normal you know at atmospheric pressure and there this you know the distillates is separated into various factors according to volatility and then finally, you will get straight ram product the distillates are called straight ram product. And, then again we need to go for various chemical treatments like polymerization

cracking to obtain the desired fuel which is required for the operation of either SI or CI engines fine.

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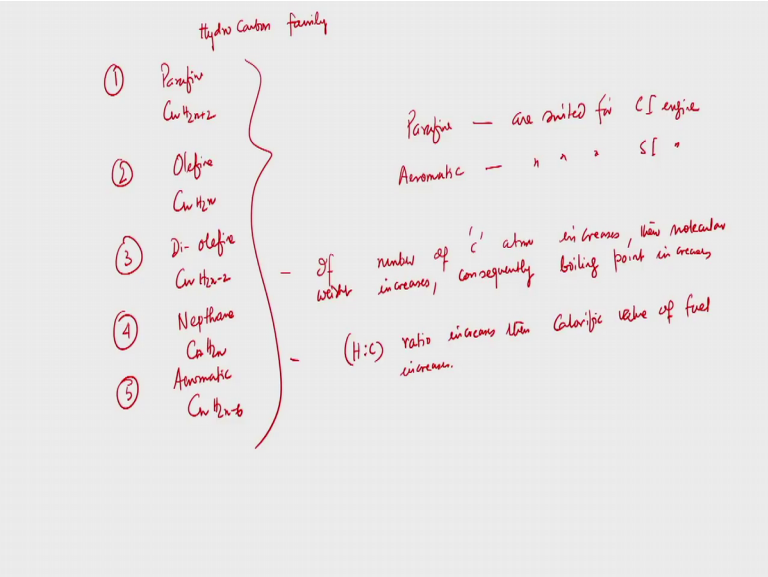

So, normally these fuels are basically they are the above fiber hydrocarbon family, one is the hydrocarbon family as I said you the hydrocarbon family one is paraffin you know paraffin whose formula is C n H 2 n; C n H 2 n plus 2, number 2 is olefin C n H 2 n, number 3 is di olefin C n H 2 n minus 2, number 4 is nepthane again C n H 2 n and number 5 is aromatic C n H 2 n minus 6. So, these 5 words, these 5 are you know above 5 are hydrocarbon family.

So now, I am writing a two important normally this paraffin are suited for CI engine and aromatic are suited for SI engine. A thumb rule is that if number of carbon atom increases their molecular rate increases then, molecular weight increases consequently boiling point increases right. Second is if hydrogen is to carbon the ratio of hydrogen is to carbon ratio increases so H is to C ratio increases then calorific value of fuel increases; calorific value of fuel increase.

So that means, if the number of carbon atom increases, the molecular rate will increase, volume will point will increase on the other hand if hydrogen is to carbon ratio increases then calorific value of the fuel will increase. As I said you that the crude petroleum which consist of large number of hydrocarbon compounds differing as I said you that crude petroleum consist of a mixture of hydrocarbons differing widely in molecular

structure. It is reasonable to arrange the hydrocarbon compounds into families based on the hydrogen carbon at arrangement within the molecule right.

So, crude petroleum which consist of a mixture of large number of hydrocarbon of different molecular weight of different molecular structure of it is desirable to arrange this hydrocarbon compounds into families crude petroleum consist of a large number of hydrocarbons differing widely in molecular structure. So, it is desirable to arrange you know the hydrocarbon compounds into families based on the hydrogen and carbon atom arrangement within the molecule.

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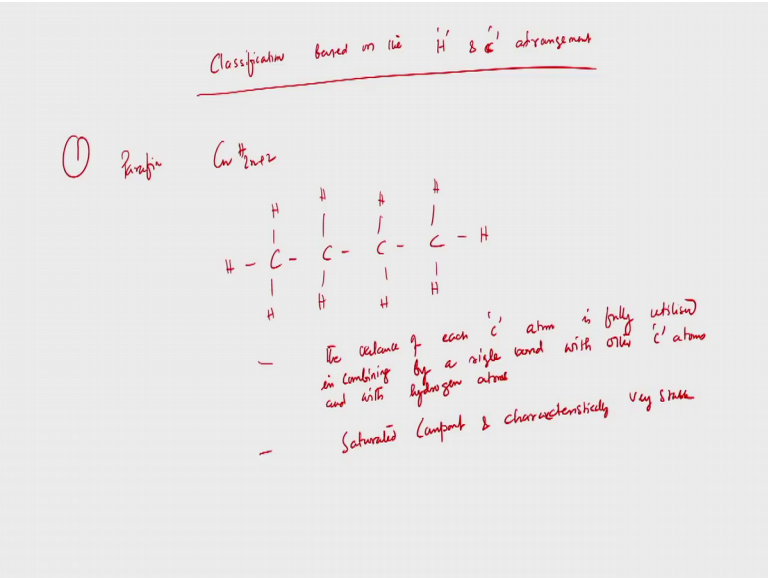

So, if we classify so, the classification based on the based on the hydrogen and carbon atom arrangement; arrangement. So, as I said you that number 1 is paraffin whose formula is H C n H you know 2 n plus 2. So, if I take that for normal paraffin the carbon atoms are connected together as a chain with hydrogen atom filling the empty valances. So, if I take you know normal paraffin so the chemical formula this type is C n H 2 minus 2, the normal paraffin carbon atoms are connected together with as a chain; normal paraffin carbon atoms are connected together as a normal change normal chain with hydrogen atom filling the empty balances.

That means what we can see the balance of each carbon atoms of each carbon atom is fully utilized in combining; in combining by a single bond; by a single bond; with other carbon atoms and with hydrogen atoms. The stretch in paraffins are saturated compounds

and characteristics is stable. So, this is very you know saturated compounds. So, this is saturated compound no empty balances, no double one and characteristic is very stable; very stable right. So, this is paraffin and we will discuss that this paraffins you know we will discuss in later.

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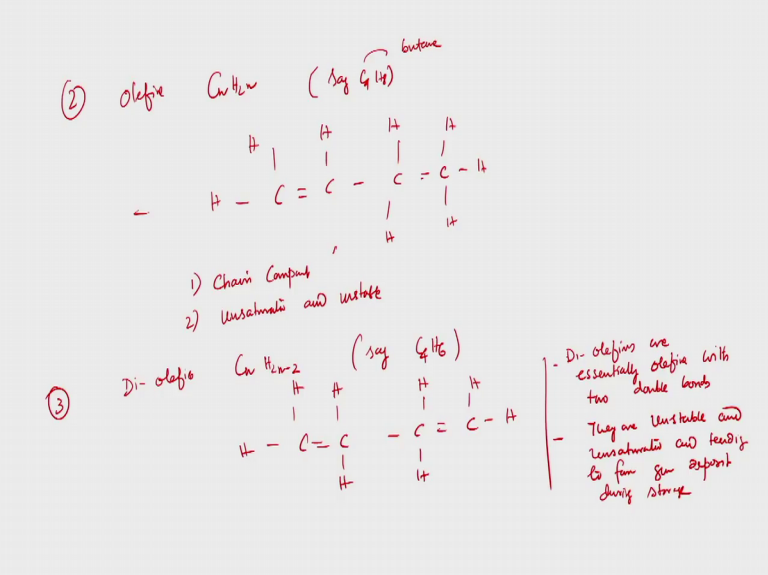

Similarly, if you take olefin number 2 olefin, that is C n H 2 n so, say C 4 H 8. So, we will have the structure is like this. This is chain compound similar to paraffin, but unsaturated and unstable because the container 1 double 1. So, similar to normal paraffin they are chain compound; chain compound 1, but unsaturated and unstable because they are having one double 1. So, butane is a typical example. So, this is butane that is butane the typical example. 3 is very important so this is unsaturated and unstable, 3 is diolefin say C n H 2 n minus 2.

So, diolefin C n H 2 n minus 2 and say butadiene C 4 H 6, butadiene and if I try to write the so, this is a chemical structure. So, this is essentially olefin with 2 double ones and the unsaturated and other unstable tending to form gun deposit during storage and their general formula. So, this is diluting essentially. So, these are diolefin are essentially olefin with 2 double ones; with two double ones. Number 2 is, they are unstable and unsaturated and tending to form gun deposit during storage. They are so unstable and unsaturated they tends to form gun deposit during storage so, this is diolefin.

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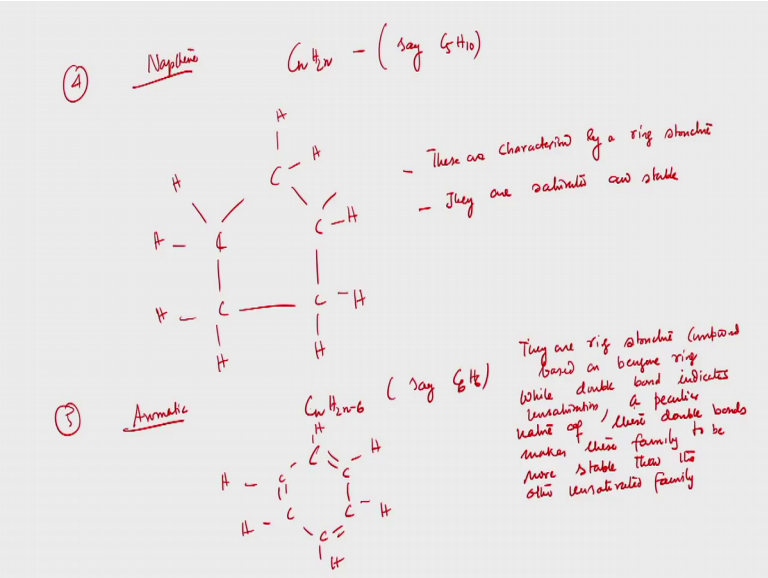

Similarly, 4 is naphthene whose formula is C n H 2 n that is C 3 C 5 H 10 C, say C 5 H 10. So, if I write the, if I draw the structure so this is the structure these are characterized by a ring structure as so many as follow. So, these are characterized by a ring structure they are saturated and stable, since they do not have double ones, they are saturated and stable. And finally, we are having aromatic that is C n H 2 n minus 6, say C 6 H 6 benzene ring. So, you know their structure. So, basically they are ring structure; ring structure compound ring structure compound based on benzene ring while double; while double bond indicate unsaturations indicates unsaturation.

Although while double one indicates unsaturation, a peculiar structure a peculiar nature of these bonds double ones cause this family to be more stable than the other unsaturant family; a peculiar nature of this one makes these you know family to be more stable than the other unsaturated family right very important. Although they are having double one that indicates unsaturation, but the peculiar nature of these structure makes you know these family to be more stable than the undearac unsaturated family ok. So, out of these discussions I would like to make a few more general characteristics.

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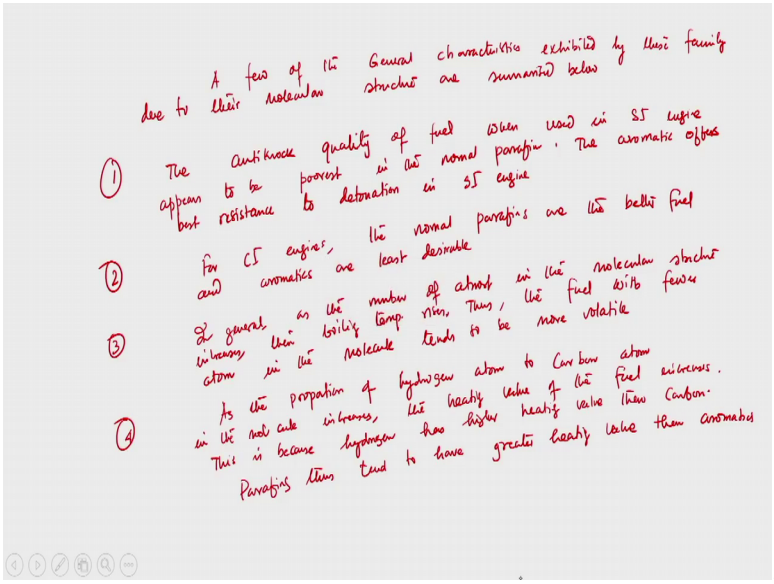

A few you know few of the general characteristics exhibited by this family due to their molecular structure and due to their molecular structure; due to their molecular structure are summarized below so, very important. So, we have discussed about the character with different families of hydrocarbon normal paraffin, olefin, diolefin, naphthene aromatic. So, few of the from the discussion we have done we can make a few more general characteristics exhibited by this family because of their due to their molecular structure.

Number 1, the anti knock we will discuss what is antiknock, this antiknock quality of a fuel when used in SI engine refers to poorest in the normal paraffin the antiknock quality the we will discuss the combustion and then we will come to know the while what is antiknock quality of a fuel. So, the antiknock quality of fuel when used in SI engine appears to be poorest in the normal paraffin; in the normal paraffin. The aromatic offers the best resistance to detonation in SI engine; the aromatic offers best resistance to detonation in the engine; to detonation in SI engine. So, very important the antenna quality of the fuel if we use normal paraffin as a fuel in SI engine the antenna qualities appears to very very poor appears to be poorest.

So, the aromatic is the best solution for this for this and because of this molecular structure fine. For CI engine, for CI engines a normal paraffin at the better fuel and aromatics of the least desirable the normal paraffin's are the better fuel and aromatics are

least desirable. 3 what is 3? In general as the number of atoms in the molecular structure increases; as the number of atoms in the molecular structure increases the boiling point temperature rise then the fuel with fuel atom in the molecular tend to be more volatile, then boiling temperature rises. Thus, the fuel with fewer atom; fewer atom in the molecular; in the molecule the fuel tends to be more volatile.

And finally, 4 very important that as the perfection of hydrogen atom to carbon atom increases, heating value increase, this is because hydrogen has a higher heating value than the carbon. So, paraffin at paraffin to have better heating value than the aromatic. So, if you know the sorry as the proportion; as the proportion of hydrogen atom to carbon atom in the molecule increases, the heating value of the fuel increases, this is because hydrogen atom the hydrogen molecule increases because hydrogen has higher heating value than carbon.

So, paraffin does tends to have; paraffins does tend to have greater heating value than aromatics. So, we have discussed about this molecular structure of the different hydrocarbon and we have discussed that whenever we are getting you know straight ram product. And further after treatment with either polymerization, cracking we can in we can may obtain different hydrocarbon of different structure. So, since crude petroleum consists of family of hydrocarbon that is a mixture of hydrocarbon of mixture of large number of hydrocarbon compounds differing you know widely in molecular structure.

It is desirable to adds this hydrocarbon into families based on their hydrogen and carbon atom arrangement within the molecule so and based on that arrangement, we have you know defined paraffin, olefin, diolefin, naphthene, aromatic. And we have seen that that paraffin is you know stretch you know we have discussed that paraffin is basically chain compound and is very stable than saturated compound because we did not see any double bond over there.

Olefin is same compound, but because of the presence of double bond it is unstable, diolefin is essentially olefin is up to double bonds, but they are unstable and tend to form gun deposit even during storage, although naphthene is not as chain; is not chain structure rather it is ring structure. And they are saturated and stable, aromatic although we are having double ones they are essentially ring structure based on benzene ring although we are having double we are there are double bonds. But, because of the

peculiar nature of the peculiar structure of these double one these family are more stable than the other unsaturated family.

From this we have obtain a few general characteristics those are, that if I use paraffin in a SI engine since the antenna quality with antenna quality of the paraffin appears to be poorest. So, aromatic while aromatic offers best resistance to detonation in the SI engine. For CI engine normal paraffin's are better fuel than an aromatics are least desirable and because aromatic are very stable is not we cannot it decompose it, because in CI engine we need to have self ignition characteristics. So, it will easily you know decompose.

And, I have discussed beginning that if the number of carbon atom increases molecular, the molecular the number of carbon number of atoms in the molecular structure increases volume point temperature will rise. So, the fuel with clear hydrogen atom in the molecular tend to be more volatile and as the proportion of hydrogen to hydrogen is to carbon atom increases, heating value will increase. Because, hydrogen has higher heating value than carbon and paraffins does tends to have greater heating value than the aromatics.

So, with this I stop my discussion today and we will continue our discussion, we will discuss about the alternative fuels like methanol, ethanol and natural gas in the next class. And, also we will discuss about you know the antenna quality of course, when we will discuss or about the combustion of CI and SI engines. So, with this I stop my discussion today and I will continue my discussion next class.

Thank you.