IC Engines and Gas Turbines
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Lecture – 18
Lubricating Oils, Thermochemistry and Fuels, Self-Ignition

We will continue our discussion on IC engine.

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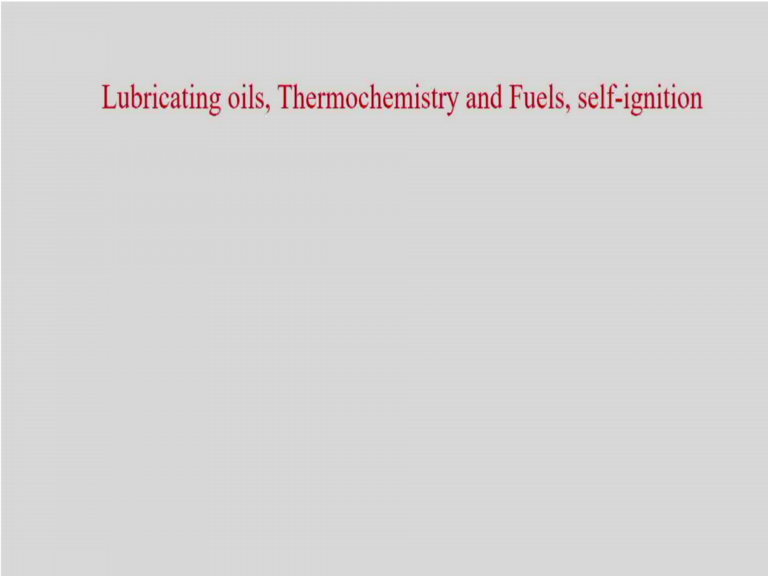

And today I will discuss about lubricating oils, thermochemistry of fuels, thermochemistry and fuels, self ignition characteristics, what do you mean by self ignition? So, before I go to discuss about you know thermochemistry on fuels and self ignition characteristics of the fuels, I will try to a you know discuss about the lubrication system and then what are the forces you know that acting on a piston.

So, you know this very important yesterday I have discussed about the friction and we have identified the sources from where friction is coming and not only that rather we have identified the locations rather locations where force you know frictional effects are very much important and how can I minimize the frictional effect by using lubricating oils and what will be the important characteristics rather important qualities of those lubricating oils.

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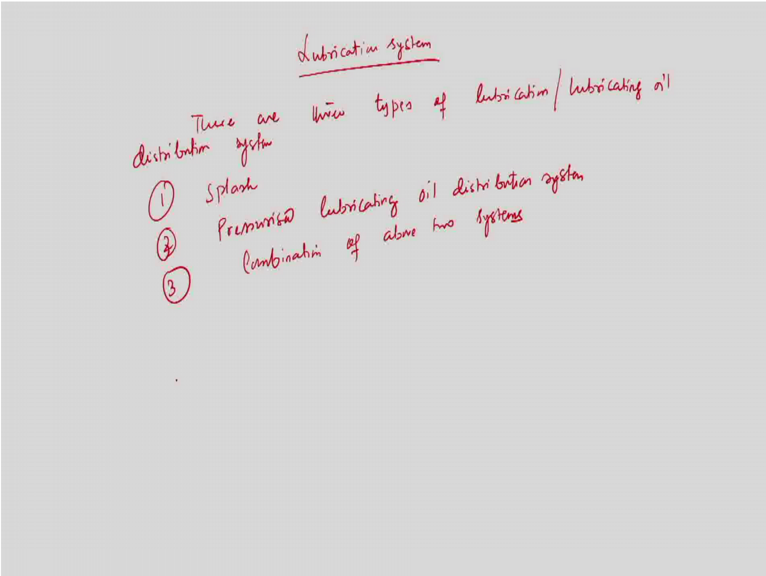

So, today we will discuss about the lubrication system, it is very important that lubricate you know lubrication system. We have seen that we need to provide lubricating oils to minimize the frictional resistance between two meetings surfaces where one surface is in motion relative to the another.

So, now there might be three basic types of distribution system; that means, we need to distribute lubrications that is essentially lubricating oil and which are in different parts of the engine. So, there are three basic types of oil distribution system, so, there are three types of lubricating system lubricating oil distribution system, 1 is known as splash we will discuss, number 2 is very important pressurized lubricating oil distribution system and number 3 is very important that is known as combination or you know combination of these combination of above 2 systems.

So that means, we have we should have lubrication system in built with the engine only to provide lubricating oil in different parts to reduce the frictional effect and there are three basic types of this lubricating oil distribution system; one is splash, other a pressurized lubricating system for which you should have one pump to pump lubricating oil in different parts of the engine and last one is a combination of these 2 types; that means, we can have either both splashing system as well as the pressurized lubricating system.

So, if I discuss that, what is splashing system? So, you know splashing is very I have when I just you know at the beginning of this lecture at course in my first lecture probably I have identified that different parts of the SI engine. Where I have shown that there is a you know you know crank case rather known as reservoir and while crank is rotating by charging action it provides lubricating oils in different parts. So, that we should not have we do not require an external pump to be there for supplying lubricating oil.

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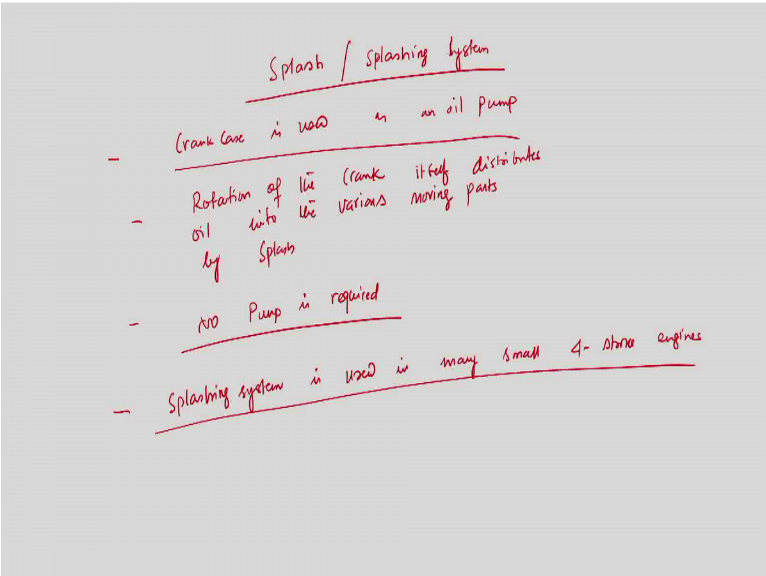

So, this is known as splash or splashing system; splashing system, very important that is here the crank case is used as the oil pump as an oil pump, crankcase is used as an oil pump in this splashing system and the rotation of the crank; rotation of the crank you know at high speed rotation of the crank itself distribute oils production of that crank itself distributes oil into the various moving parts by splash. That is the rotation of the crank itself you know allow rather distributes oil into different parts and we should not require an external additional pump for this distribution system, so, no and no pump is required; no pump is required very important.

So, by virtue of you know (Refer Time: 05:48) we can get lubricating lubrication oil in the parts where it is the required or needed without any external pump. So and physically small 4 stroke engine use splash distribution of oil and I mean because only by the rotation of the crank it is not a very efficient system and it is not possible at all to supply lubricating oil even all the places where we require lubrication oil.

So, it is used for small engines you know many small you know 4 stroke engines, this splashing system; this splashing system is used in many small 4 stroke engine; in many small 4 stroke engine. So, this is very important and but a pumping system is required because if we need to supply lubrication oil in places where it is not possible to supply using only by the rotation of the crank then we should require one pump to be there only for the pumping of the lubrication oil. So, next will discuss about the you know pressurized oil distribution system.

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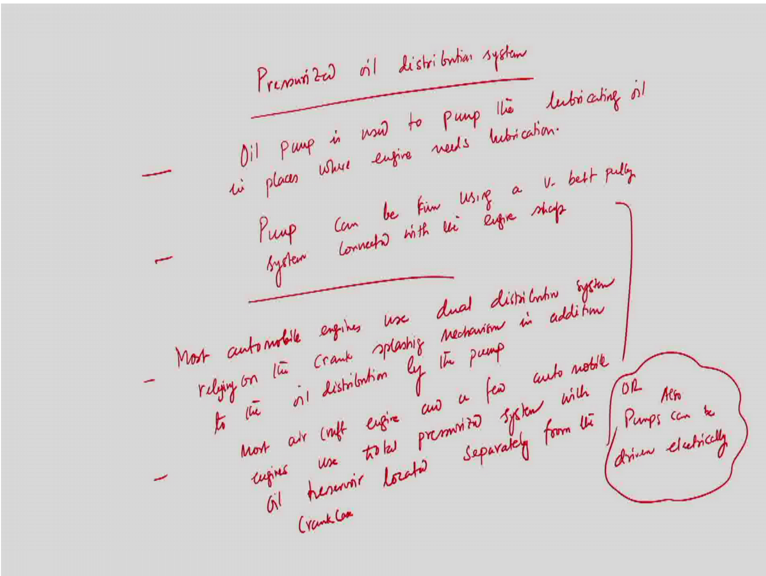

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Pressurized oil distribution system, so, for this pressurized oil distribution system rather pressurized lubrication lubricating lubrication system a pump is essential. So, oil pump is used to pump the lubricating oil in places where engine needs engine lubrication we have to supply this is very important. And sometimes this pump is we have discussed that for the cooling system sometimes we there are 2 different types of cooling system, air cooling air cooled engine or water cooled engine.

Air cooled engine means the forward movement for the engine itself allows the air to you know suck into the engine and then through the proper path air moves into you know engine cylinder and it tries to cool down the cylinder temperature. On the other hand there is another system what is water for water cooled engine normally water cooled because it is very difficult, because normally if I use water as a coolant if that engine goes into the places where temperature is very less than it is highly chances are there that water may start freezing.

So, sometimes reagent ethylene glycol is mixed with water only to it reduce the freezing point only to increase the freezing point, so, that you can use water as a coolant even in those places. So, whenever you are having water cooled system one pump is there and. So, that pump is connected with the you know crank shaft I mean engine crank by a V belt pulley mechanism so, that we need not to have an external source of power to run the pump. Similarly, the pump which is required for the pressurized oil lubrication system we can connect that pump in the crank shaft. So, that we can using you know V belt pulley mechanism. So, that we can run pump to you know to distribute oil in the different system.

So, pump can be connected pump can be run using a V belt pulley system connected with the engine shaft. So, this is very important system and this engine this is very common that as I said you that most aircraft engines and a few automobile engines use a total pressure system with oil reservoir located separated from the crankcase. Otherwise, most automobile engine very important that I am telling most automobile engine; most automobile engine use dual distribution system and rely on the cranks case splashing, splashing within crank splashing mechanism.

So, most automobile engines use dual distribution system and mostly they rely on the cranks splashing mechanism, on the other hand in addition; in addition; in addition to the you know oil distribution from the by the pump; by the pump right. On the other hand most aircraft engines; most aircraft engines and a few automobile engines; and a few automobile engines use you know a total pressurized system use total pressurized system with the oil reservoir located separate from with oil tank oil reservoir; with oil tank with oil reservoir; reservoir plus separately located separately; located separately from the crank case.

So, crank case itself a oil reservoir from there the rotation of the crank itself distribute oil into the different parts of the engine when engine is required; when engine is required lubrication oil and as I said that most automobile engines are used dual distribution system and that are relying on the cranks shaft cranks; relying on the cranks shaft cranks splashing mechanism in addition to the oil distribution by pump. On the other end most aircraft engines because in aircraft engine it is very important to reduce the friction and they can not rely on the cranks case splashing mechanism. So, they use mostly the total pressurized system and with a separate oil reservoir which is located apart from the crankcase and a pump will be there and that will be used to distribute to where lubrication oil in different parts.

The oil pumps as I said you that pumps can be connected using V belt pulley mechanism with engine shaft or this pump also pumps can be you know driven electrically or the pumps can be driven electrically. So, it is not mandatory that pump the pumps you know has to run using mechanically using the V belt pulley mechanism which is connected to the engine shaft pump can also be run using a electrically using a battery fine.

So, this is the complete you know lubrication system which is required for an engine that sometimes most automobile engine they rely on the they use dual lubrication system and mostly rely on the you know splashing system. So, that the you know speed of the you know connecting rod or crank shaft that is what I wrote here that rotation of the crank itself distribute oil into the various moving parts by splashing or by splash only by splash or we should why we can have separate pump and separate desirable altogether and that is what we have discussed.

So, now we will see that the you know forces on forces acting on the piston because you have seen that we get power only in the power stroke and during that stroke because of the combustion we have know normally we have seen that there is a high pressure and temperature and that high pressure creating thrust on the piston phase as a result of which piston is having movement from top dead center to bottom dead center. So, then whenever piston is coming from TDC to VDC again it is going back from VDC to TDC; that means, the forces acting on the piston.

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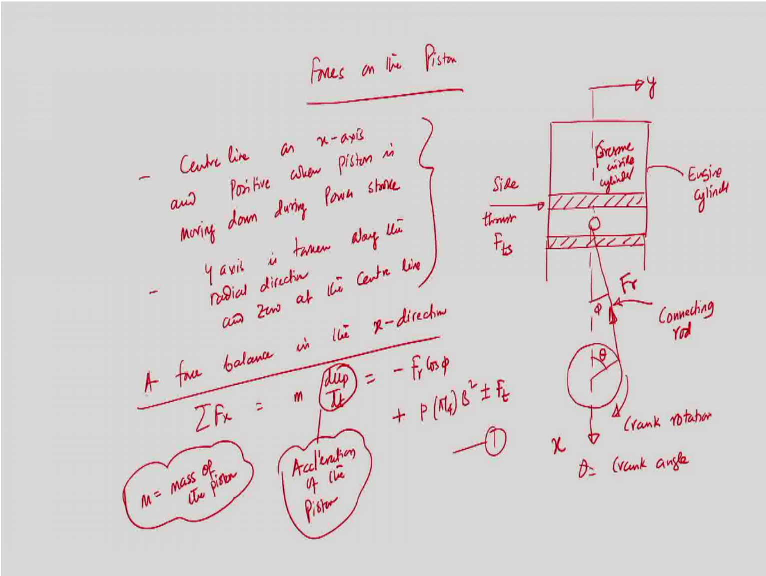

So, now we will discuss about forces on the piston you know forces on the piston, it is very important. So, if I try to draw and to obtain the forces on the piston we have to draw a schematic and we can see that during the power stroke. So, we will now draw a schematic that maybe we have a engine cylinder and piston is moving between top dead center bottom dead center and so, this is piston so, if I now draw the connecting rod and crank then. So, maybe this angle is theta, this angle is phi, this angle is theta and it is rotating in this direction right. So, this is connecting rod, this is engine cylinder and this is crank or this is crank rotation and theta is equal to crank angle, so, if this is the x direction and this is the y direction.

So, this is the you know schematic that we have drawn many a times that when piston is coming from TDC to VDC then we have that we can convert this you know reciprocating motion to the rotary one using a crank and connecting one mechanism. So, this is the you know I have used central line as the x axis with positive being drawn in the direction of piston motion during the power stroke. So, we have used central line central line as x axis and positive when piston is moving down during power stroke.

So, central line we are considering centerline as x axis and x axis is for positive x axis in the direction when piston is moving down during the power stroke. And y axis is taken along the radial direction is taken along the radial direction y axis is taken very important and we need to know that what are the thrust force acting in the y direction.

So, that is why you have taken so, and with 0 at the center line and radial direction outward taking around the radial direction and 0 at the center line. So, consider this is the consideration of coordinate system. So, now, a force balance x direction, so, if I now a force balance x direction. So, force balance in the x direction, it will yield a equation that we need to know. So, net force acting in x direction summation of F x net force acting in x direction that will be equal to you know m into d up dt where up dup dt is the acceleration of the piston.

So, this is acceleration of the piston and m is the mass of the piston; mass of the piston. So, m is the mass of the piston and this is the acceleration of the piston that will be equal to the net force that will be equal to what. So, I am writing minus F r cos phi plus p into pi by 4 in to B square plus minus F t. So, am writing what is p, where this p ok, I am writing.

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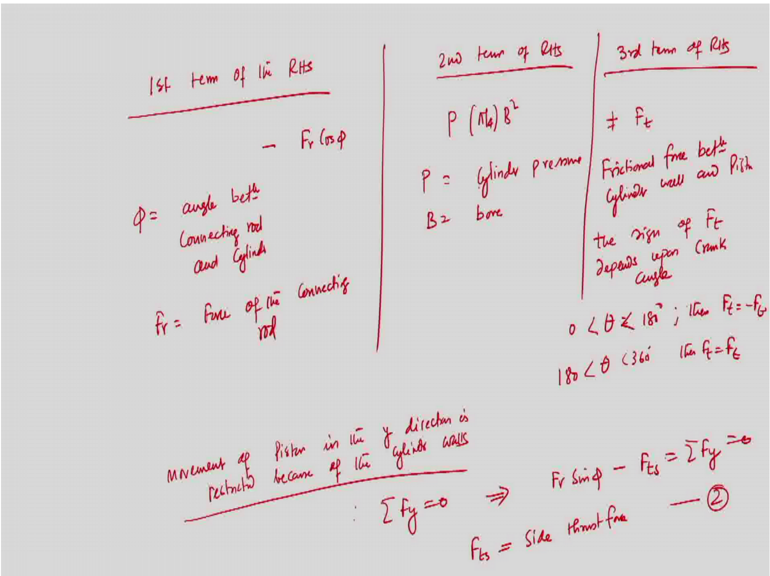

Now, so, first term on the right hand side first term of the RHS of the right hand side that is minus F r cos phi. So, what is phi? Phi is the angle between the connecting rod and central angle cylinder. So, phi is the angle between connecting rod and cylinder. So, and this is very important. So, F r is the force of the connecting rod and F r is the force of the connecting rod. So, if I go to schematic I can write that the force on the connecting rod is F r. So, F r cos phi minus F r acting in a direction of the piston in the connecting rod force on the connecting force on the connecting rod.

So, minus F r cos phi is the force of the connecting rod in the x axial direction rather in the direction when piston is coming down from during the power stroke so, that is written. So, 1st term that is a written, 2nd term of the right hand side second term of RHS right hand side is what that is, P into pi by 4 into B square, P is the cylinder pressure, because of this high pressures piston will move from the TDC to VDC during power stroke.

So, this is cylinder pressure and B definitely is the bored B is the bored diameter bore. So, pi by 4 this because the area, so, P into force and 3rd term is very important 3rd term of RHS that equal to plus minus we have written plus minus F t, so, plus minus F t it is thrust force that are frictional force between piston and the cylinder works. So, this is frictional force that is we have discussed last class between cylinder wall and piston.

So, because of the first force acting on the piston it will come down and while it is coming down we cannot ignore the frictional losses that is between the cylinder walls and the piston and this plus minus F t is this. So, now this plus minus sign is it depends upon the crank angle, so, the sign of F t depends upon crank angle. So, when theta is equal to theta less 180 degree greater than 0 then F t will be minus F t, when theta less than 360 greater than 180 then F t will be F t plus positive F t.

So; that means, when piston is coming between piston crank location is from 0 to 180 degree then it is negative because it is coming down and then how it is going up again in the next stroke that is exhaust stroke and it will be positive. So, this is the you know forces note that we have seen the coordinate system. So, piston is having movement only in the x direction, but there is no movement in the y direction, because movements in the y direction it is not restricted because of the cylinder wall.

So, movement of the piston; movement of piston is you know restricted in the y direction is restricted because of the cylinder walls so; that means, summation of F y equal to 0 that gives that of course, force is acting in the radial direction, but the movement of that only the forces are acting the force the movement of the piston is restricted because there is no movement of piston at all in the radial in a direction. So, F y 0 so, the force in the force of the connecting rod F r, so, F r sin phi minus F t that is that I mean 0 that gives that is equal to summation of F y right is equal to 0. So, there is no net force acting on the y direction, so, F r sin phi minus F t, that will be equal to 0 and if I try to combine these 2 equation that is this equation 2 and this equation 1; this equation 1.

So, if I combine equation 1 and 2. So, this you know side thrust force this F t is given sorry this that F ts or F ts is the side thrust force. So, if I write that when piston is moving will have a side thrust, so, this is side thrust F ts. So, this F ts if I now F r sin phi minus F ts will be equal to 0 and if I combine equation 1 and 2 and so, this is the pressure inside cylinder.

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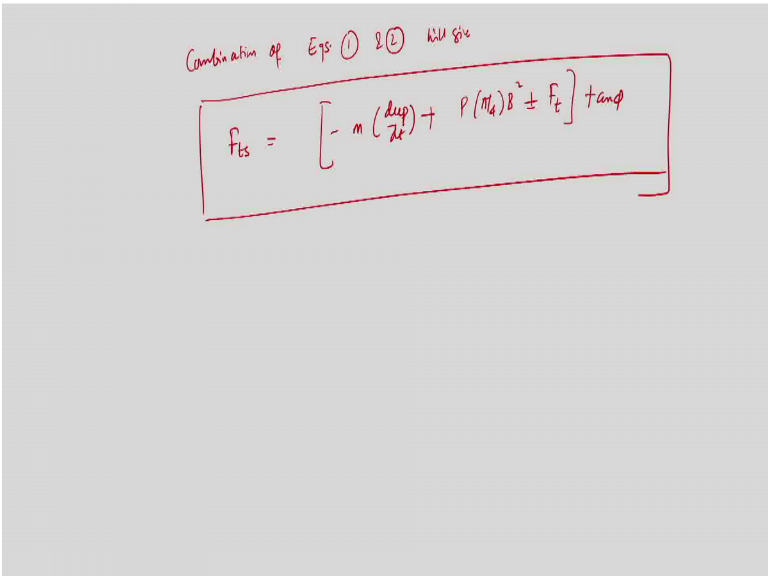

So, now, if I combine equation 1 and 2 so, combination of equation 1 and 2 will give that F ts that equal to minus m du p dt plus P in to pi by 4 B square plus minus F t into tan phi. So, this is the expression of the side thrust force that depends upon the pressure inside the cylinder, frictional forces and also the acceleration and phi angle. So, I mean so, this is the side thrust phase which is acting this only because of the rotation of the piston between 2 locations TDC and VDC.

So, with all this with this I will now next we will go to next I will go to discuss about the you know some other aspect of thermochemistry of the fuel. So, we have discussed this now today we will discuss about thermochemistry I have discussed a little bit this aspect in the context of discussion of carburation carburetor of the system. We have discussed that what do you what why you need to know thermochemistry of the fuel I mean when we are discussing about the internal combustion engine there are different aspects of internal combustion engine.

Basically, you know that I have seen that we have discussed that the I mean whether you are providing carburetor or you do not provide carburetor we need carburation you know in spark ignition engine, but again in modern days engine we do not require carburation, but some, but we need a modern days fuel injection system multiple port fuel injection system PFI. So, but we need to ensure that the you know whatever amount of fuel is being supplied in to the combustion chamber and then at the end of the compression stroke you will have a combustion.

So, combustion is essentially when the combustion reaction. So, combustion fuel is essential fuel is essentially a family of hydrocarbon right. So, family hydrocarbons fuel that during the combustion reaction the hydrocarbon fuel acts with the oxygen present in the air and then it produces carbon dioxide water vapor and we are getting some amount of heat it is exothermic reaction so, reaction which is exothermic reaction. So, you know we know to know the combustion reaction so, we will discuss about thermochemistry.

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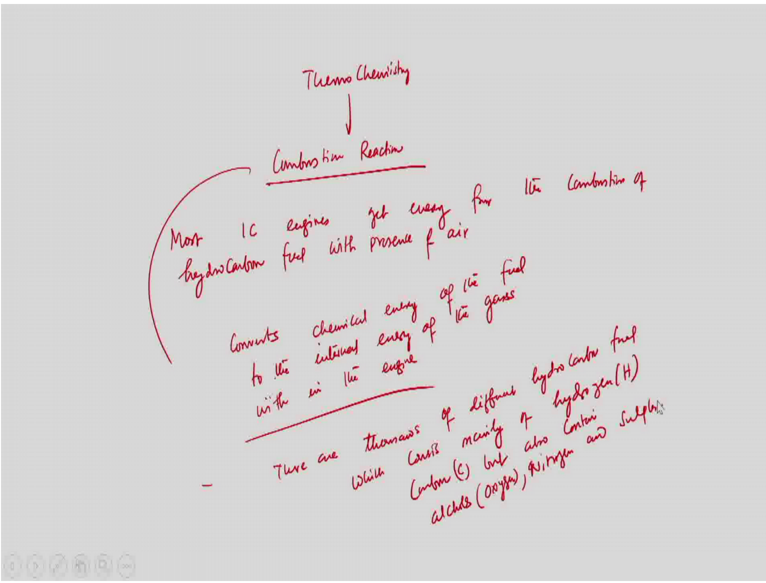

So, essentially this gives us an information about the combustion reaction very important that because most of the IC, most of the engines or internal combustion engines most internal combustion engines you know get energy from the combustion; from the combustion of hydrocarbon fuel with air with presence of air.

So, we need to know that what is the amount of oxygen air required for the efficient combustion of the for a particular fuel and if I need this much amount of oxygen for complete combustion of the particular fuel then what will be the amount of air you need to supply because we know that the amount of oxygen present in a particular air. So, to know the history of it we need to know the combustion reaction and which we get from a thermochemistry.

So, you know and this combustion reaction what it does is sincerely. So, as I said that internal combustion engine get energy from combustion of hydrocarbon fuel with presence of air and this combustion what essentially does, it converts chemical energy; it converts chemical energy of the fuel into the to the internal energy of the gases within the engine, to the internal energy of the gases within the engine right. So, combustion reaction as I said you that most of the internal combustion engine get energy because we need power stroke and we need energy that energy comes from the combustion of the fuel being supplied hydrocarbon fuel in presence of air. So, to have a complete combustion because this energy basically you are getting from chemical energy of the fuel into the internal energy of the gas that is there in the inside the cylinder to get maximum to maximize the energy conversion we need to know the combustion reaction.

And whenever we are trying to obtain a time to trying to get maximum energy out of this combustion we need to know what is the, what will be the amount of oxygen required for that in a particular combustion and that what will be the amount of air that amount of air to be need to be supplied to supply that amount of oxygen to have a complete reaction. So, that we get the maximum energy this entire history is obtained from the thermochemistry of the fuel.

So, and as I said that there you know fairly reasonable families have hydrocarbon there and mainly you know there are thousands of hydrocarbons there are you know many thousands of hydrocarbons, different hydrocarbons fuel component which consists mainly of hydrogen carbon, but also content oxygen nitrogen etcetera and the maximum possible amount of chemical energy is released from the fuel.

That is what I am telling very important that there are thousands you know different in thousands of differents of hydrocarbon and we will discuss this issue that depending upon the presence of hydrogen and carbon atom will also get that we also obtained different rate of energy from different combustion reaction. So, fuel hydrocarbon fuel which consists mainly of hydrogen, carbon, but also content alcohol that is oxygen, nitrogen and sulphide. So, depending upon the fuel that is being used we may get different rate of energy transfer you know obtained.

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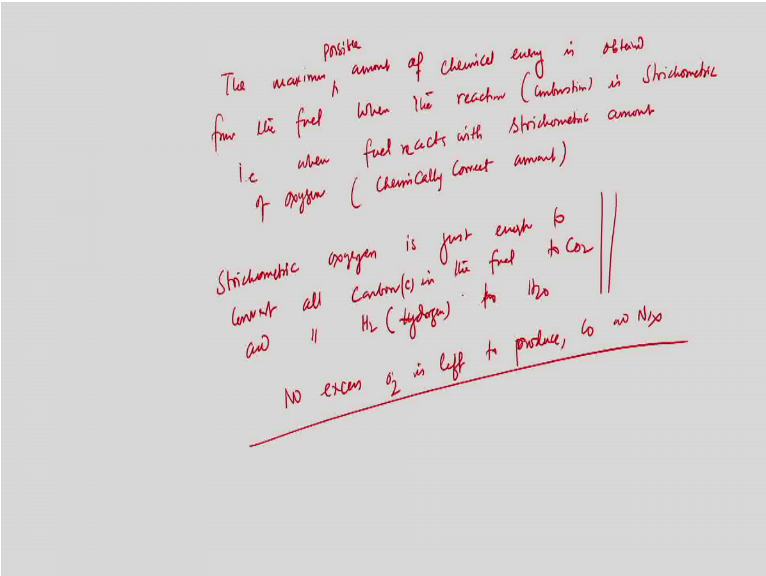

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So, the maximum possible amount of chemical energy so, the maximum as I said that, we would like to maximize the energy conversion rate during the combustion reaction. So, the maximum amount of maximum possible amount of energy conversion or chemical energy is obtained from the fuel. So, as I said that since there are thousands of hydrocarbons so and which consists hydrogen, carbon mainly and up to some extent oxygen, sulphur, nitrogen.

So, depending upon the presence of hydrogen atom also carbon atom we may get different rates of energy transfer not only that even for a given fuel or a particular fuel our target will be to maximize the energy transfer rate. So, maximum possible of chemical energy is obtained from the fuel when it reacts, so, when the reaction is when the reaction that is combustion reaction is stoichiometric that is what I discussed up in one of my previous lectures where we have discussed about the carburation so, is stoichiometric.

That is chemically correct oxygen as in stoichiometric that mean that is when fuel reacts with stoichiometric amount of oxygen; stoichiometric amount of oxygen that is chemically correct stoichiometric is chemically correct amount oxygen. So, this stoichiometric oxygen or chemically correct oxygen is just enough to convert all carbon and in the fuel all carbon in the fuel to CO 2 and all hydrogen to H 2 O, no excess oxygen O 2 is left to produced CO and N O x.

So, what is thermochemistry and why it we need to know it? As I said that most of the engines gets energy from the combustion of hydrocarbon fairly presence of air that is what the combustion reaction does, I mean it converts chemical energy of fuel into the internal energy of the gases into the cylinder. So, now there are different there are 2 aspects they had thousands of hydrocarbon which is having you know which consists mainly hydrogen carbon and apart from there are little amount of oxygen supply nitrogen.

So, the structure of the fuel itself carbon hydrogen atom will discuss in detail that this structure between carbon hydrogen atom also the number of depending upon the number of hydrogen atom this energy conversion rate varies, so, this is one aspect. So, different fuels will have different rate of energy conversion, but if we have a particular fuel from that particular fuel how can we maximize the energy transferred that maximum amount of internal energy we can get from the chemical reaction from this combustion reaction. And that information will be provided by the thermochemistry and that is obtained by supplying only the required amount that is chemically corrected amount of oxygen that is known as stoichiometric amount of oxygen during the combustion reaction.

So, this stoichiometric oxygen will be will is just not to convert all the carbon into carbon dioxide and all the hydrogen into a H 2 O and no oxygen is left excess oxygen is left to you know produce CO and N Ox. And what will be the required chemically correct amount of oxygen required for the complete or the efficient combustion in particular fuel that information is obtained from the thermochemistry and that is what we will need to discuss.

And we have discussed this issue maybe in the context of carburation and taking one example, but again we will discuss this issue in detail by taking another example and we will see that what will be the combustion reaction and what will be the corrected amount of oxygen required for the complete combustion of that particular fuel and that problem will discuss in the next class. So, this I stop here today and will continue our discussion the next class.

Thank you.