MARINE ENGINEERING

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Lecture44

Combustion

Good morning everybody. Today, I will start the topic combustion. combustion means chemical reaction. So, inside cylinder, let us see the piston cylinder arrangement. This one crankcase, I have cranked this one.

This is a piston. Now, combustion will be occurring here in the top portion. I am putting lots of dots here. So, combustion will be happening here. Now if I draw this one in PV diagram you have seen it previously PV if it is auto cycle it will be a vertical line then coming like this now 1, 2, 3, 4.

Now combustion will be occurring at 2 to 3 location and if it is dual cycle it will be looking like this but if it is dual cycle it will be like this 1, 2, 3, 4. this is auto, this is diesel, this is dual. There may be many other cycles, but just consider only this basically auto cycle and diesel cycle 1, 2, 3, 4, 5, E, V, T, V. Now, in auto cycle combustion is happening in constant volume process, but in diesel cycle combustion happening in constant pressure process, but in dual cycle combustion happening in a few portion of fuel will be burned in 2 to 3 or constant volume process, then remaining portion will be burned during 3 to 4 or constant pressure process. Now, ideally the combustion will be occurring during 2 to 3 only.

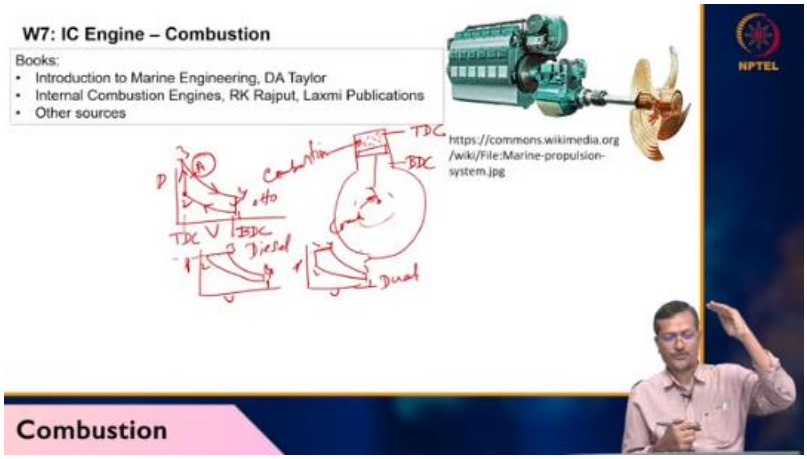
Combustion will start at nearby 2 and it will be completed at 3. But in certain situation, let us say combustion is occurring before 2, what will happen? So, if it is happening before 2, means my piston, this is BDC, this is TDC in piston alignment, BDC, TDC. So, piston is BDC, is at BDC, then you are compressing the gas, after compression combustion will be occurring. Now, combustion will be occurring at certain specific calculated time.

Now, your combustion occurring before piston reaching to the top or TDC, what will happen? Your combustion gas will start pressurizing the piston to move downward, but

piston is trying to move upward. So, what will happen? the burn gas is pressurizing to move piston down, but piston is still moving up. So, what will happen?

Some energy will be lost because this is forcing, this is also forcing. So, pre-combustion not allowed. Before reaching the piston to the top, if combustion occurring, then it will be loss of energy, even system can fail also. when you are getting maximum temperature. So, if 3 is not occurring at top position rather 3 is occurring let us say A at location A piston is little bit moved down after that fuel is giving highest temperature and highest pressure.

So, again piston already move when you are creating pressure. So, that is also not economical or efficient. So, your piston will be moving from 3 to 4 and it will get maximum pressure when it is at top dead center or TDC. And only combustion will be occurring at 2 to 3, not before 2, not after 3.



Now, engine knocking. this term very much familiar by IC engine designers or IC engine users. So, this is called knock or detonation or spark knock or pinging or pinking. So, different names are there. So, you should be familiar with the different names.

Combustion of some of the air-fuel mixture, so here every time I will be writing A by F means air-fuel mixture. So, air-fuel mixture in the cylinder does not result from the flame front propagation by ignited by the spark plug you have eastern cylinder arrangement okay now you are compressing the cylinder gas in SI engine especially you are compressing air-fuel mixture then spark will be happening but before spark starts your combustion started because of engine because of certain useless engine is very much hot then before spark plug firing your fuel will be burning. So, what will happen?

Piston not reached to the top, but your fuel burnt. So, what will happen? It is pressurizing, piston moving up, so some energy will be lost. So, instead of one or more pocket of air-

fuel mixture explode outside the envelope of standard combustion front. So, spark will be started, then that fire will be

propagating in few micro or nanosecond. Before that if spark or fire is happening, then there will be a problem. So, then knocking will be created, engine knocking. The spark plug should only ignite the airfield charge at a precise point, not before or not after in the piston stroke. knocking occurs when the peak of the combustion process no longer occurs at the optimum moment of the four stroke cycle.

In four stroke cycle also, four stroke cycle what you are doing? You are compressing air only, fuel is not there. Fuel will be injecting then because of air temperature it should be burnt. Now before that reaching to peak temperature if it is burning then again it is a problem. This shock wave created

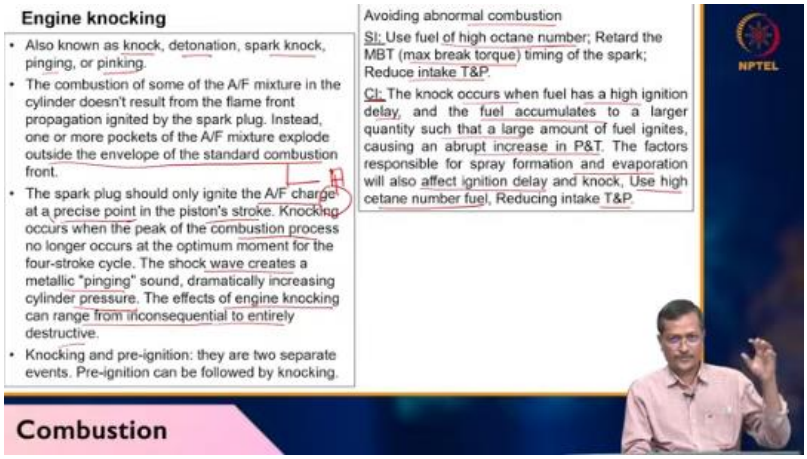
It will be creating metallic pinging sound, dramatically increasing the cylinder pressure. The effect of engine knocking can range from nano inconsequential to entire destructive system. So, whole system can fail and a bang noise will come. Knocking and pre-ignition, they are two separate event. So, knocking is not the pre-ignition here.

The definition is different. Pre-ignition can be followed by knocking. So, avoiding abnormal combustion. Abnormal combustion means knocking or pre-ignition with abnormal combustion. Normal combustion means exact time you have decided that time only fuel is burning.

So, SI unit use fuel of high octane number, retard the maximum brake torque timing in the spark and reduce intake temperature and pressure. If intake temperature pressure is very high, then before you give a spark, it will be burning quickly. So, you have to use high octane number fuel. In compression ignition engine, The knock occurs when fuel has high ignition delay and the fuel accumulates to the larger quantity such that large amount of fuel ignites causing abrupt increase in pressure temperature in the cylinder.

The factor responsible for spray formation and evaporation will also affect ignition delay. If engine is too much hot again pre-ignition can occur and that will be giving a knocking also. Use of high octane number fuel, so high octane number fuel you have to use. and reducing intake temperature pressure intake temperature pressure is very high because of certain reason you are getting high temperature air so you have to reduce it so that way you can avoid engine knocking or abnormal combustion auto ignition and pre-ignition auto ignition is called knocking actually auto ignition or detonation or knocking same term

spontaneously combustion of remaining air-fuel mixture in the chamber after the spark plug initiated normal combustion spark plug initiated but it will be igniting quickly so that will be creating a bank noise during normal combustion the spark plug ignites fuel mixture burns control manner however at some point during the burn due to the combination of heat and pressure the chamber ahead of the frame front



end gas in the chamber spontaneously be burning and will be giving very big high pressure and high temperature. Auto ignition occurs after spark plug has initiated normal combustion. So, here the term auto ignition will be occurring after spark plug has initiated combustion. But pre-ignition, the pre-ignition, ignition air-fuel mixture before the spark plug firing. So, this see the definition auto ignition means after spark plug started firing the

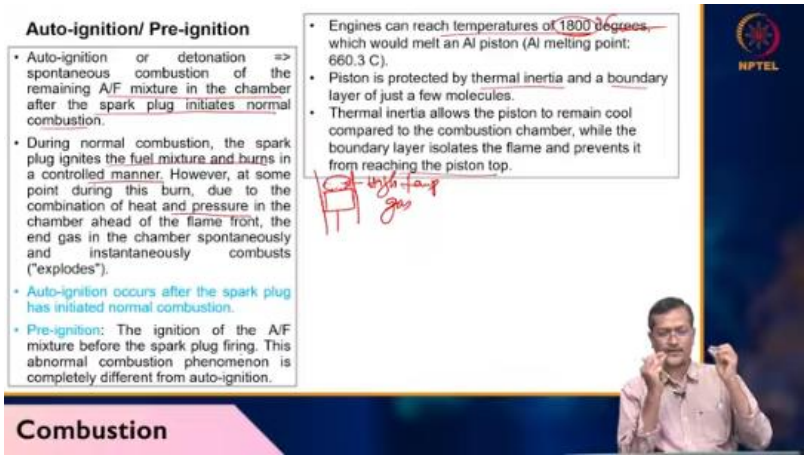
Auto ignition means after spark plug gave energy to the fuel, but pre-ignition means before spark plug your fuel will be starting burning. The abnormal combustion phenomena in completely different from auto ignition. Engine can reach temperature of 1800 degree centigrade, degree centigrade I can say. which would melt aluminium piston. So, piston normally it will be made up of aluminium cast iron or some alloy steel.

And this aluminium melting point is 60.3 degree centigrade. And steel will have some more. maybe 1200 maximum melting point will be there. But your engine temperature is becoming 1800 degree centigrade. That means at this temperature system will not sustain.

you have to remove heat as soon as possible. Piston is protected by thermal inertia. and boundary layer of just few molecules. So, when you have a piston, so piston will have one boundary layer actually all around, fluid boundary layer. So, that will be preventing heat directly reaching to the piston metal.

If it is directly metal, then it will be melting. So, that small boundary layer will be helping you. Thermal inertia allows piston to remain cool compared to the combustion chamber, while the boundary layer isolates the flame and prevents it from reaching the piston top. So, piston top especially this portion is filled with high temperature gas, high temperature gas. So, that high temperature gas should not reach the piston top directly.

So, that some boundary will be created and thermal inertia because of fluid momentum inertia will be created that also will be preventing increasing temperature of the piston. Now, CTN number, octane number two numbers will be coming when you are talking about engine combustion and detonation. CTN number, a scale used to determine the ignition quality of a diesel fuel. octane number will be used for petrol or gasoline engine. C10 number is based on the ignition characteristics of two hydrocarbons N-hexadecane or C10



and 2, 3, 4, 5, 6, 7, 8 heptamethylnonane equivalent to the percentage by volume of C10 in the blend with heptamethylnonane which matches the ignition quality of the test fuel. A common method of estimating the C10 number is to distillate fuel is based on the calculated C10 index formula. The formula used API, API formula actually American Petroleum Institute uh yeah here i have written that api means american petroleum institute okay american petroleum institute actually normally they will be standardizing things and they will be giving lots of formula if you are designing any machine or petroleum related any product so they will have certain formulas and instruction you have to follow that one so here because you are using petroleum fluid for your offshore machinery or ship fuel so in that case you have to follow api formula So, formula uses, this CETA number formula uses API gravity and mid boiling point to estimate the fuel CETA number.

The CETA number measures the fuel's ignition quality. Ignition delay is the time between the start, ignition delay, the definitions also you should remember, is the time between start of ignition and the first pressure increase during the combustion. In diesel engine, fuel with high CETA number have shorter ignition delay, okay. resulting from better performance. The CTL number scale ranging from 0 to 100 with higher number being better.

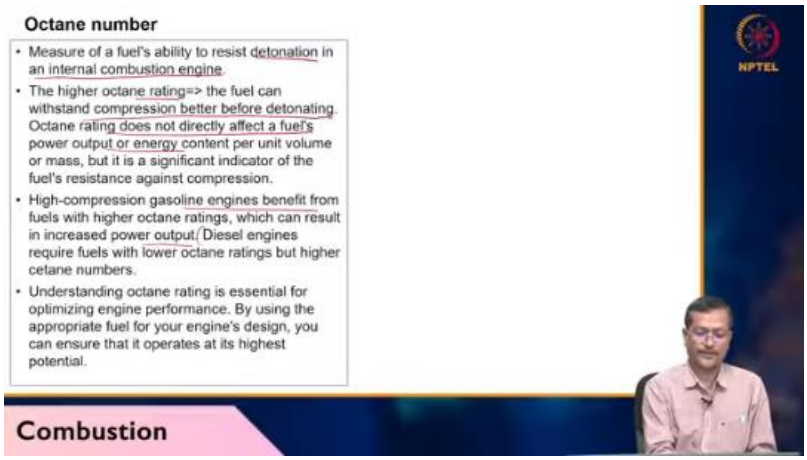
For modern highway diesel engines, fuel with CTL number 45 to 55 is usually required. So, you should remember these digits also. So, just you have to give approximate values also sometime we ask in exam. API gravity I told that API gravity defined will be defined like this. API gravity is measured in terms of degree API.

So, we write degree API. higher API gravity lower the density, 10 degree API equal, API equal density as water. If I say 10 degree API of oil, it will be equivalent density of water. So, it will be submerged, it will be floating inside water, it will not be going down or it will be floating on the top of the water also. The basic variation tendency of octane number for different types of component.

So, octane number like if you are you see this curve if you are changing chemical parameter like say in simple long chain hydrocarbon to more aromatic level. So, your octane octane number increasing. So, you add more octane more aromatic component in the fluid. So, you will get better fuel ok. octane number of fuel is able to resist detonation in an internal combustion engine.

High octane rating, the fuel can withstand compression better before detonating. Octane rating does not directly affect fuel power output or energy content. So, octane rating is not affecting the power output or energy content per unit volume of mass, but it is a significant indicator of fuel's resistance against compression. So, during compression suddenly it should not burn or it should not create any burst High compression gasoline engine benefit from the fuel with high octane rating which can result in increasing power output.

Diesel engine requires fuel with lower octane rating but higher C10 number. Here one point you can remember higher octane rating but lower C10 number. Understanding octane rating is essential for optimizing engine performance by using appropriate fuel for engine design you can ensure that it operates at its highest potential. combustion in SI engine, fuel air mixture from carburetor. So, I said like in SI engine you will have one carburetor, carburetor will be mixing fuel and air after that it will be injected into your cylinder.



So, carburetor will be outside then it will be injecting fuel air mixture to the cylinder. So, cylinder is not getting directly air separately or fuel separately that the carburetor will be mixing it then it will be supplying to your engine. At the end of a compression stroke You draw the P-V diagram, P-V. So, end of compression stroke, point 2 is the end.

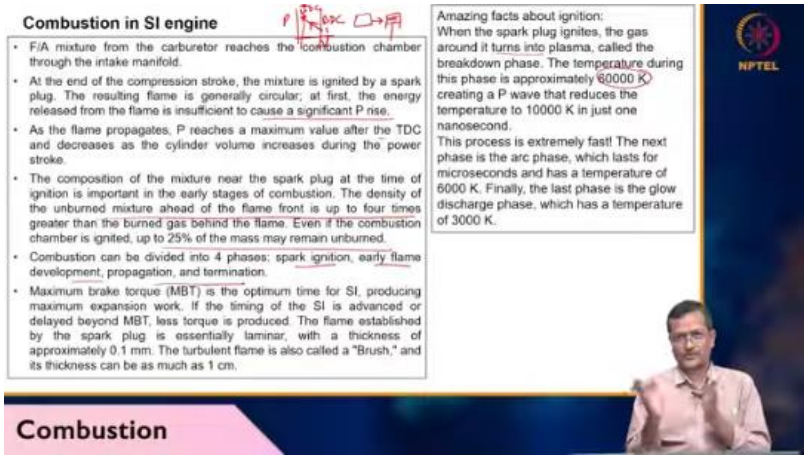
The mixture is ignited by spark plug. So, at point, spark will be created. The resulting flame is generally circular. At first, the energy released from the flame is insufficient to cause a significant pressure rise. Initially, it is not producing any pressure rather it is creating ignition of small, certain amount of heat that will be helping to burn other particles.

So, as the flame propagates, pressure reaches to maximum. So, flame propagates means lots of combustion or reaction will be happening. So, that will give more gas. So, the gas will be pressurizing or it will be creating more pressure. So, pressure will be reaching to maximum value after Tdc.

This is Bdc, this is Tdc. So, 0.2 is Tdc, 0.1 is Bdc. The maximum value after the TDC and decreases as the cylinder volume increases during the power stroke. Again, it will be decreasing when power stroke will be starting. Power stroke means that time a gas will be expanding and piston also moving backward towards BDC.

When it is going to BDC, volume increasing, so pressure will be going down. The composition of mixture near the spark plug at the time of ignition is important in the early stage of combustion. The density of unburnt mixture ahead of the flame front is up to four times greater than the burnt gas behind the flame. If the combustion chamber is ignited, up to 25% of the mass may remain unburnt. With a certain amount of mass, still it will be remaining unburnt.

Combustion can be divided into four phases, spark ignition, early flame development, propagation and termination. Amazing fact about ignition, when spark plug ignites the gas around it forms a plasma, it will be so high temperature will be there, so it will be forming a plasma. okay the temperature will be is 260 000 kelvin okay this process is extremely fast in few nanosecond the whole combustion be occurring this piston is moving at so high rate if it is not burning within a few nanosecond then your combustion will be incomplete so the system will be very fast and quickly be burning okay so especially in diesel engine in we need atomization or particle must be very very small so that combustion will be proper During atomization process, fuel is sprayed into combustion chamber. we have piston cylinder arrangement.

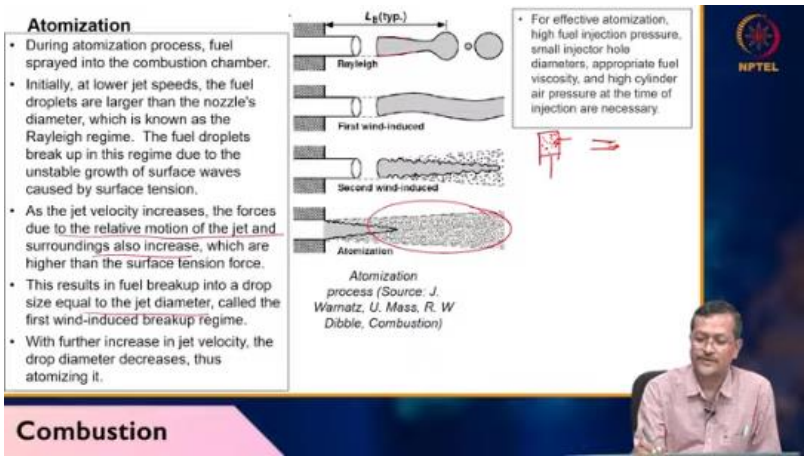


This is combustion chamber. You can see I am making lots of dots. So, we need lots of small-small particle in the form of atomized or very small-small particle. So, you are injecting fuel in terms of the forming spray. Initially, lower jet speed will be there.

you have one nozzle. initially you will have lower jet speed. So, when lower jet speed is there, fuel droplet will be breaking up due to the unstable growth of surface wave called surface tension. Surface tension property is that it will try to make a circular particle. Now, you have high pressure fluid passing through the nozzle.

initially it will be creating long jet And because of surface tension, it will try to create smallest surface, then particle will be broken, high outside pressure and instability, the small particle will form, it will be completely circular. And the jet velocity increases, forces due to the relative motion of the jet and surrounding also increases, which are higher than surface tension of the surface tension force. If surface tension higher, it will create small, small particle, it will make a smaller circle. The result of fuel breakup into drop size equal to the jet diameter called the fast wind induced breakup.

With further increase in jet velocity the drop diameter decreases thus atomizing happens. So, final stage will be atomization. So, you can see lots of small particles are created. So, initially long jet you can see this one, wind induced jet is there. So, gradually the jet will be broken.



After jet, it will create very small tiny particle, mist or small atomized particle. For effective atomization, high fuel injection pressure, small injection hole diameter is required and again viscosity plays a very important role. If viscosity is very high, the atomization will be difficult. So, low viscosity also very good for you and high cylinder air pressure at the time of injection are necessary.