Fundamentals of Automatic Systems
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Knocking in SI Engines – Part 02

Now we will look at you know like how we can quantify knocking and other what to say aspects related to that right so one important concept which we will definition which we will look at is what is called as a octane number okay. So as we can readily observe knocking is influence by or knocking is the phenomena where the fuel self-ignites. So the question is you know like how can we characterize a fuel you know like for it anti-knock tendencies or anti-knock properties okay

So the quantity which is used what is called as an octane number so octane number is indicative of the anti-knock characteristics of a fuel okay used in SI engines. So what is that definitions let me write down the definition it is the percentage by volume of iso-octane okay whose chemical composition is C_8H_{18} iso-octane has a very good anti-knock characteristics so that is taken as a base okay.

So iso-octane in a mixture of iso-octane and normal heptane whose chemical composition is C_7H_{16} which exactly matches the knocking intensity of the fuel in a standard engine under a set of standard operating conditions okay. So that is the definition of octane number so what are these standard operating condition and what is the standard engine so the reference would be this and the annual book of ASTM okay ASTM stands for American Society for Testing and Materials okay.

ASTM standards okay and volume 05**-04** and a title of a standards is test methods for rating motor diesel and aviation fuels okay. So people do a standard test in the standard engine under the standard operating condition you are let us say someone gives us a gasoline fuel we figure out you know like what is the knocking intensity of the fuel in terms of the pressure pulses which are felt and the engine knocks.

And we then you know like have to adjust the percentage of iso-octane and normal heptane right such that we get the same knocking intensity experimentally right so then the percentage of iso-octane in that mixture will give us the octane number. Obviously a higher octane number is better right so a higher octane number what is called ON which is octane number is desirable and it implies that the fuel can be used at higher compression ratio's okay this implies better efficiency and fuel economy right.

So these are the benefits of having a higher octane number okay so that is the phenomenon of knocking and octane number is a parameter which is used to characterize the anti-knock characteristics of a fuel okay.

Combustion in CI engines

- Self-ignition of fuel
- 2 Attributes
  - Atomization of fuel → splitting of fuel droplets into smaller entities.
  - Vapourization of fuel → conversion of liquid fuel to its vapour form

So the next topic that we are going to look at is the combustion process in CI engines compression ignitions engines or diesel engines. So we looked at how the combustion happens at SI engines let us go and now look at what happens in a compression ignition engine. So just a few concept before we go to the actual process in a CI engine so if we recall the main difference in a diesel engine or a compression ignition engine is that the fuel is sprayed into the combustion chamber towards the end of the compression stroke.

So that is what happens in the diesel engine so let us say we have a fuel injector and fuel is sprayed into the combustion chamber. So let us say we have a jet of fuel okay I have just exaggerating the diagram to drive home the concept okay. So let us say we have the nozzle and we spray a jet of fuel okay into the combustion chamber. Now for proper combustion you know as we have already discussed we need fuel we need oxygen in the correct proportion and we need a mechanism for initiating the combustion process right.

In a compression ignition engine the initiation of the combustion process happens due to self-ignition of the fuel so here the mechanism of combustion is by self-ignition of fuel okay or the

fuel reaches its self-ignition temperature and burns by itself so that is how it happens and in a spark ignition engine right if we recall what was the mechanics we took in the fuel air mixture during the suction stroke and we compressed the fuel air mixture during the compression stroke.

So we gave enough time for the fuel air mixture to mix well together you know for the fuel to vaporize during the compression stroke so that a homogenous mixture is formed. So obviously a homogenous mixture helps because a homogenous mixture will ensure that the combustion process is smooth right on the other hand in a compression ignition engine you know the fuel is sprayed towards the end of compression right and we have very little time to spread the fuel throughout the combustion chamber okay.

So there are some other additional what to say effects or attributes that one needs to consider okay so 2 important attributes that we need to consider not only for compression ignition engine but for all engines for that matter you know like is the first one is atomization of the fuel so what do we mean by atomization of fuel. So we want the fuel droplets to be split into finer particles right into smaller entities okay.

So let us say I have a droplet of fuel I wanted to be broken down into finer particles and finer entities and then like spread throughout the combustion chamber right. So the next one is vaporization of fuel so vaporization of the fuel is conversion of fuel from its liquid form to its vapor form right so that is the process of vaporization why is it important only when it reaches its vapor form it can also mix well with its what to say with air and the combustion process can be more efficient okay.

So both these are extremely important okay in ensuring proper combustion so another attributes which becomes important in compression ignition engines is this phenomenon of air swirl. What is air swirl? Suppose let us say I essentially spray fuel into the combustion chamber what I want is that I want some circulation of air in the combustion chamber so that the fuel particles and droplets get spread evenly in the combustion chamber right otherwise they will be concentrated in an narrow domain right local to the injector’s path right this is the jet’s path right.

So we want a controlled air swirl such that the fuel particles are not only broken down into smaller entities having a proper as well will break down the particles into smaller entities it will help in atomization of fuel but also it is spread the fuel more uniformly in the combustion chamber. So air swirl becomes very important so air swirl is nothing but a motion of air in the combustion chamber to ensure the formation of a near homogeneous fuel air mixture okay.

So that is the concept of air swirl okay so another important attribute is the following so let us say I am just exaggerating let us say I have a droplet of diesel fuel okay like this right so let us assume that there is a periphery which vaporizes and it burns okay so let us say it combust and burns right. So there is an un-burnt core okay and if the combustion process happens in this way not only are we going to be left with lot of un-burnt fuel in the engine exhaust that will affect the fuel economy but it will also have a series **repercussion** as far as emissions are concerned.

So typically we will get this black smoke right from diesel engines you know like due to this factor right there is if you have this significant amount of un-burnt fuel or partially burnt fuel right in the diesel engine and that is going to be essentially given to the exhaust system and to the atmosphere we will see this un-burnt fuel in the exhaust which get visualized as black smoke right in the diesel engine's exhaust and that is something which is undesirable as we can see because it is not only waste fuel it also results in a series emission problem.

That is why not only we want to we want proper atomization and vaporization of fuel we also want this air swirl to help these processes but even after this please recall that the process of this distribution of this diesel fuel in the combustion chamber it is atomization it is vaporization formation of a homogeneous mixture all these events must happen in a relatively smaller amount of time why because the fuel is injected towards the end of the compression stroke whereas in a SI engine we had like almost like 1 to one and half, strokes for a homogenization to happen right because the suction stroke was the one where the fuel air mixture was taken in right.

Even assuming that the fuel air mixture was taken in during the suction stroke completely we at least have the compression stroke where the fuel could mix nicely with air you know like get homogenous properly right. But in a diesel engine we have very little time okay so in order to tackle this problem also typically a leaner mixture is used in diesel engine right to essentially

safe guard against this phenomenon right of unburned fuel being there right despite our best effects.

So diesel engines typically are operated with leaner mixture that means that we have less fuel in the mixture than the stoichiometric fuel air mixture. So this is mainly done to prevent incomplete combustion and the consequent presence of unburned fuel in the exhaust so that is what happens that is why we want to use it with a leaner mixture. So today in modern diesel engines what happens is that the fuel is injected you know to overcome these aspects also and address these issues.

Fuel is injected at very high pressures okay using as multiple jets into the combustion chamber okay the fuel injection system itself is very complex and in multi cylinder diesel engines you know like what is called as the Common Rail Direct Injection system is utilized to facilitate this where wherein the diesel fuel itself is pumped to very high pressures and then sprayed as the fine mist into the combustion chamber.

So when we spray it as the fine mist due to the high pressure difference it helps the atomization process right. So we do not have this diesel as lumps you know like which can what to say accelerate this unburned fuel and the black smoke in the exhaust right. So we have a fine mist so atomization is better, mixing is better, vaporization is better and the combustion process is much more cleaner okay. So that is what is called as Common Rail Direct Injection okay so where the fuel is introduced in Common Rail Direct Injection okay.

So it is introduced at very high pressures okay into the engine so let me stop here we will look at the stages of combustion in a CI engine in the next class and discuss what is normal combustion and when can combustion become abnormal in CI engines and then continue with combustion process discussion okay thank you.