# Fundamentals of Automatic Systems

**Prof. C. S. Shankar Ram**
**Department of Engineering Design**
**Indian Institute of Technology – Madras**

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## Knocking in SI Engine – Part 01

Okay greetings so welcome to today's class a quick recap of what we did in the previous class we looked at the actual combustion process that happens in a spark ignition engine. We learnt what were the different phases of the processes is that happen in a SI engine and then like we looked at normal combustion and what happens if there is a some issue with the combustion process right and we essentially discuss the concept of knocking wherein a part of unburned fuel you know like auto ignites or self-ignites and that leads to a formation of a secondary flame front which then when colliding with the primary flame front you know generates pressure pulses that can lead to potential issues in spark ignition engines okay.

So this phenomenon is also called as detonation by some and essentially can create significant structural damage to the engines component so that is where we stopped yesterday. So we finish the lecture with the few questions you know like regarding the factors that influence the process of knocking.

So let us discuss them today so factors that influence knocking in Si engines so let us discuss a few important factors and find that effect right. The first one which we are going to discuss is that of compression ratio. So as we know you know like compression ratio is a very important parameter right so even when we did the analysis of the air standard cycles we figure out that the thermal efficiency of the cycle was directly dependent on the compression ratio.

And for the air standard Otto cycle higher the compression ratio higher was the thermal efficiency but if we increase the compression ratio okay so the thermal efficiency does increase but what about from the prospective of knocking? We see that even in the air standards cycle right although the actual engine does not follow the air standard process even for the sake of argument and understanding if we recall you know the temperature at the end of compression was $T_2$ equals $T_1$ times R power gamma minus 1 right even in the Otto cycle.

$$T_2 = T_1 r^{(\gamma - 1)} \longrightarrow \textbf{Otto Cycle}$$

So if we look at knocking persay right why does knocking happen? Knocking happens if the unburned fuel air mixture self-ignites right for that to happen the unburned fuel air mixture has to reach it is self-ignition temperature so when would the chances of it reaching the self-ignition temperature be higher? One the temperature at the start of ignition process affects the chances of knocking obviously right higher that temperature at the start of the ignition process higher would the chances for knocking right.

Second is the heat added during combustion right because as we know once the fuel air mixture is ignited we are going to have heat energy being added to the what to say gases present in the cylinder right and as we discuss the burnt gases or hot gases are also going to expand which is in turn compresses the unburned fuel air mixture which may push it towards the self-ignition temperature.

So we can see that these two factors amongst other things affect the what to say chances of knocking. So if we increase the compression ratio we see that the temperature at the start of ignition increases correct, I am sure all of us can agree to that point right. So if we increase the compression ratio the temperature as the start of the ignition process would certainly increase even if you consider $T_2$ equals $T_1$ R power gamma minus 1 as an idealization right if I increase the value of R for the same $T_1$, $T_2$ is going to be higher.

So what that means? So you know the temperature when I give the spark right is going to be higher in that combustion chamber than before if I increase the value of R. So for the same amount of fuel burnt or same amount of heat energy which is released by the combustion process the chances of the unburned fuel air mixture reaching the self-ignition temperature become more with increase in R, I am sure all of us can agree to that point.

So this implies that the chances of knocking or the potentials chances of knocking increase with an increase in the compression ratio. So this is the main factor that limits the compression ratio in spark ignition engines. So consequently the range of R is limited by knocking okay of course range of R in SI engines okay is limited by knocking okay in compression sorry in spark ignition engine so that why typically the value of R is around 6 to 10 in SI engines.

Whereas in compression ignition engines it can go anywhere from you know like 12 to 22 or 16 to 20 and so on right you can go as high as 20 or 22 in compression ignition or spark ignition engines okay sorry compression ignition engines or diesel engines sorry about that. But in spark ignition engines you know like we can only go to what to say 6 or 10 okay. So that is the maximum range okay so that so we can immediately observe what is the effect of compression ratio right on knocking.

The second one that we need to look at is the mass of the inducted charge so what do I mean by mass of inducted charge in essence a quantity of fuel that I am introducing in the combustion chamber. Please remember charge means fuel air mixture okay for combustion I need fuel I need oxygen in the correct proportion and the mechanism for initiating the combustion processing. The word charge in engines is used to refer to the combustible fuel air mixture right.

So now when I increase the mass of the charge which is introduced into the engine what do you think would happen let us say for the same compression ratio the temperature is at the start of ignition would be by and large are same because there is no ignition yet but what would happen once combustion starts with a higher amount of charge inside the combustion chamber more heat energy is going to be released right.

The rate at which heat energy would be released will become more then the chances of the unburned fuel air mixture reaching it is self-ignition temperature also would be higher right because we are releasing heat energy at a larger rate so that means that whatever fuel air mixture is unburned may also reach its self-ignition temperature potentially right. So we can immediately see that increasing the mass of inductor charge increases the tendency for knocking potential right.

So this also limits how much quantity of fuel right or the charge the fuel air mixture I can introduce into the combustion chamber in a spark ignition engine okay so that becomes important so for this reason right. So because we introduce more charge more heat energy is released and the chances of unburned fuel air mixture reaching the self-ignition become higher okay.

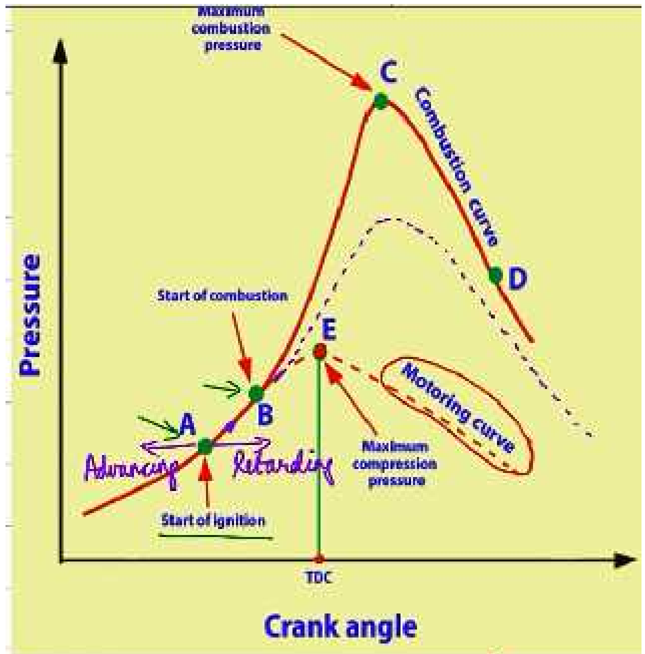
So then the next factor is the inlet temperature of the fuel air mixture so let us say I keep the compression ratio the same right the amount of heat energy released during the combustion to be the same but now what I am doing I am increasing the inlet temperature of the fuel air mixture when can the inlet temperature potentially increase for example during super charging right. If we super charge we are pressurizing the intake air yes although we may use air after cooler or a intercooler to reduce the temperature of air but still it is not going to come to the same level as that of the ambient air which is used in a naturally aspirated engine.

So now if I increase the temperature of the intake air what can we say we are going to increase the value of $T_1$ is it not correct? So if I increase the value of $T_2$ what is going to happen? The chances of the charge reaching the self-ignition temperature become more right because for the same compression ratio $T_2$ would be higher then the chances of the unburned fuel air mixture reaching the self-ignition temperature would also increase right.

So increasing the inlet temperature of the fuel air mixture increases the tendency for knocking okay. So this is one reason why super charging is limited in SI engines because this inhibits the application of super charging although we know that it has its benefits super charging is limited in SI engines. Okay so this is one reason for example you know like we do not use a turbo charger typically in a petrol engine right it is used along with the diesel engine the main reason is this okay.

So now what about next factor? The next factor is what is called as retarding the spark timing so what do we mean by spark timing? You know what is mean by retarding spark timing? What is mean by advancing spark timing?

Okay so let us go back to the diagram that we considered here okay so if we shift point A closer to TDC we mean that implies that here sorry we are retarding the spark timing okay.




**NORMAL COMBUSTION**

Shift 'A' closer to TDC ⟶ retarding the spark timing.
Shift 'A' away from TDC ⟶ advancing the spark timing

So we shift point A which is the start of ignition right where we provide the spark right closer towards the TDC okay that is we push point A to the right that means that we are retarding the spark timing okay if we put push point A to the left away from the top dead center okay that is what is called as advancing the spark timing okay.

If we shift point a away from TDC we are essentially doing what is called as advancing the spark okay or advancing the spark timing okay. So that is the definition of retarding the spark timing and advancing the spark timing very intuitive so now suppose if we retard the spark timing whereas instead of providing the spark here I provide the spark somewhere here what do you think will happen the entire curve is going to be shifted you know like point B may be shifted here and the curve may go something like this right the pressure theta curve will go something like that.

Now why is the pressure decreased relatively because if I retard the spark timing I am going to push the process of ignition closer to the top dead center by the time the spark is given and by the time the ignition lag is overcome I am even closer to the top dead center by the time a significant amount of heat energy is released by combustion my piston as starting moving towards the bottom dead center that mean at that the volume in the combustion chamber as started increasing significantly.

So for the same amount of heat energy released if I have more volume then the equivalent increase in pressure will be lower so the peak pressure in the cycle would decrease okay so that is the effect of retarding the spark timing so if we retard the spark timing the peak cycle pressure would decrease the peak cycle temperature also would decrease right and the chances of knocking would obviously come down because if the peak temperatures are coming down the chances of knocking will come down.

But what is the price is that we need to pay we see that the peak pressures are decreasing so what we can say about the mean effective pressure that will also decrease. If the mean effective pressure decreases what can be say about the power output and specific power output they come down. So in essence with everything else remaining the same if we retard the spark timing yes the chances of knocking come down however the price that we pay is that the engine’s power output also will come down okay the mean effective pressure decreases the engine’s power output will decrease so that is the tradeoff.

So we do not want to retard the spark too much then the performance goes down what about the advancing the spark? Advancing the spark a little bit will initiate the spark little bit earlier so the peak pressures may be reached even before where it is currently right so if the spark is advanced a little bit the tendency for knocking may potentially increase right depending on how we are advancing okay.

So that is the counter effect okay of advancing the spark timing okay so retarding the spark timing decreases the peak cycle pressure and temperature this implies that the tendency for knocking decreases okay however the MEP will decrease power output specific power output all other engine performance matrix’s will also come down right. So that is a price to pay specific fuel consumption will increase because specific fuel consumption is a mass of the fuel consumed per power divided by the power delivery.

So the power delivered decreases for the same amount of fuel specific fuel consumption will increase right. So we do not want too much of retardation okay at the expense of avoiding knocking okay.

So what about the next factor so increasing the flame speed so we are just looking at various factors and a effects so let us say if I increase the speed of the flame right so the chances of the fuel air mixture being burned even before they have a tendency to reach the self-ignition temperature would be lower right because the flame is going to go and burn all the fuel air mixture in the combustion chamber much faster right is not it?

So increasing the flame speed would decrease the tendency for knocking okay so that is one more factor that can be considered. And if we decrease the engine size obviously the tendency for knocking will decrease why because now the flame as a smaller volume or region to travel right so it will travel much fast that is it is going to burn fuel air mixture in a smaller time interval right for a smaller cylinder volume correct.

So then you know the tendency for even any portion of the unburned fuel air mixture to self-ignite or auto-ignite is going to go down. So decrease in the engine size decreases the tendency for knocking so we can immediately observe how you know like all these factor affect the spark ignition engine right so due to knocking the compression ratio in spark ignition engine is limited right.

So the amount of charge that is taken in per cycle is limited super charging is limited we may need to limit the engine size you know like because we want to avoid chances of potential knocking right. So, all these attributes get affected because we want to prevent knocking in spark ignition engines okay so that is the consequence.