Fundamentals of Automatic Systems
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Module No # 03
Lecture No # 15
Supercharging and Combustion in SI Engines – Part 01

Okay so greetings welcome to today's class so a quick recap of what we were discussing in the last class we completed the discussion on various engine performance parameters and we also looked at the concept of mean effective pressure and how to get an expression for the indicated mean effective pressure for the air standard Otto cycle right. So that is where we stopped and we identified that the mean effective pressure which is indicative of the average pressure in the combustion chamber that will get me a particular power output is of course dependent on the initial pressure right at the start of cycle right.

So as we can observe from this expression IMEP depends on P_1 and P_1 is the pressure inside the combustion chamber at the start of the combustion or the start of the cycle right. So if I want to increase the mean effective pressure one way of doing is to increase the value of P_1 so if I increase the value of P_1 obviously the value of mean effective pressure will increase and so would the power output from the engine. So the question becomes how do we increase the value of P_1 and that is where the concept of supercharging comes into play okay.

So recall that for a 4 stroke engine the brake power output you know like we can write it as some constant multiplied by BMEP multiplied by displacement volume multiplied by N by 2 okay so where N is the number of revolution of the crank shaft per unit time right. So the reason why we are doing N by 2 is that there is 1 cycle for every 2 revolutions of the crank shaft okay that is why we write N by 2 explicitly right okay.

$$BP = const \times BMEP \times V_s \times \frac{N}{2}$$

So we can immediately observe that we can increase the brake power through two choices 1 is to increase the BMEP okay another is to increase the value of N okay so these are the 2 alternatives available to us right to increase the brake power output okay. So we can observe that you know

like increase in BMEP would essentially involve okay increasing the pressure at which air or the air fuel mixture is introduced into the combustion chamber.

So if we can increase the intake pressure that is the pressure at which air or the air fuel mixture is introduced into the combustion chamber are we could increase BMEP as we just discussed right yeah.

So this process is called as super charging and a device used to achieve the same is called as a super charger. So super charging is a process of making sure that the air or air fuel mixture is introduced in the combustion chamber at a pressure higher than atmospheric. So those engines are what are called super charged engines right and device which does this function which is what is called as the super charger okay.

So let us look at what benefits we get out of super charging so the benefits are the following okay so if I increase the pressure which air is taken into the cylinder the density of air would obviously increase right and pressure is in air the density of air increases. So if the density of air increases we can immediate observe that for the same volume I would have a increased mass of air so if take the same cylinder for the same displacement volume if my density is bigger the mass will be density multiplied by volume right that is going to be higher.

Benefits of Supercharging:

i) The density of intake air increases $\Rightarrow$ mass of the air taken into the cylinder increases $\Rightarrow$ Volumetric Efficiency increases.

ii) MEP increases $\Rightarrow$ power output increases $\Rightarrow$ better thermal efficiency.

iii) More Torque/power output is obtained for the same displacement volume.

If the amount of air which I have taken into the cylinder is more, then the volumetric efficiency would increase right so obviously that is one benefit of super charging okay. So the first benefit is there are multiple benefit we will go one by one so the density of the intake air increases so this implies that the mass of air taken into the cylinder also increases this implies that the

volumetric efficiency increase which is beneficial for us okay so that is one benefit of super charging.

So the volumetric efficiency of the engine would increase and as we have just discussed super charging also increases the mean effective pressure okay. If the mean effective pressure increases that means that the power output increases okay which implies that the thermal efficiency also becomes better okay thermal efficiency of the engine increases okay so that is another advantage of super charging.

And we can immediately observe that by super charging we get more torque slash power output is obtained for same displacement problem, So if you have the same cylinder volume right we get more power output okay or torque output and please remember for the same cylinder size the specific power as we defined in the previous class the power output per unit area right. So specific power output also increases with super charging.

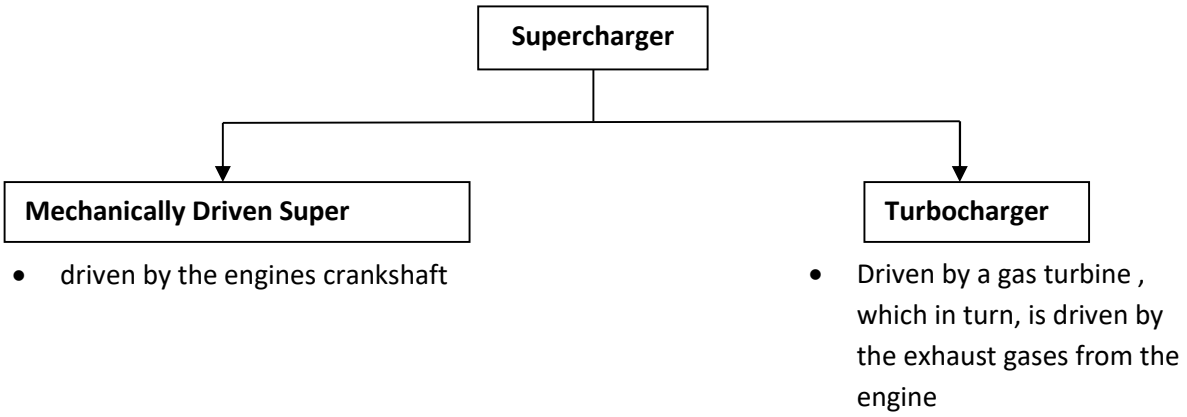
So we can alternatively interpret as right if I want a fixed value of power output or torque output I can work with a reduced displacement volume right so that is an alternative view point. If you have the same engine the same displacement volume the power output increases if know the same power output it is super charging I can work with the smaller displacement volume okay so though that is another advantage of super charging.

So in other words the specific power output increases and we get more power output for the same engine size right. So those are all benefits of course nothing comes free there are how to say challenges in super charging the engine also right because if we increase the operating pressures we need to ensure that the engine structure the cylinder block right and other components have to be strengthened such that they can withstand the higher mechanical loads right that come about due to increase pressures.

And obviously the cost of the engine increases because super charging involves the introduction of more components so the cost and complexity of the engine increase with super charging okay. So these are the what to say essentially requirements right that come about with super charging okay that is we need to ensure that the mechanical loads are accounted for and withstood by the

engine components and the structures and we have to essentially introduce more components and that will increase the cost and complexity of the engine okay.

So please note that more mechanical loads on the engine okay and cost and complexity increase so we can say these are the cons of super charging right. And of course by the end of today's class we also discuss one more phenomenon which is going to what to say influence which engines are super charged and under what conditions and so on right okay. So if you consider a super charger persay broadly please remember super charger is a device that achieve this task of super charging.



So typically they are classified into what are called as mechanically driven super charger okay and what are called as turbocharger. So would have encountered this term turbo charger in practice right more frequently so we will see what it is right. So what is a mechanically driven super charger a mechanically driven super charger is one where the super charger is driven by the engine crank shaft. So please note that you know like if I have to compress the intake air and increase its pressure I need to impart some energy to it right so the energy should come from some place.

Now the question becomes you know like if I use the energy which is available at the crankshaft output to power my super charger that super charger is what is called as a mechanically driven super charger please note that when we discuss the energy balance in an engine if you recall the term C where we told that look that is a component which is used for overcoming friction and also to drive other devices and so on right in the engine.

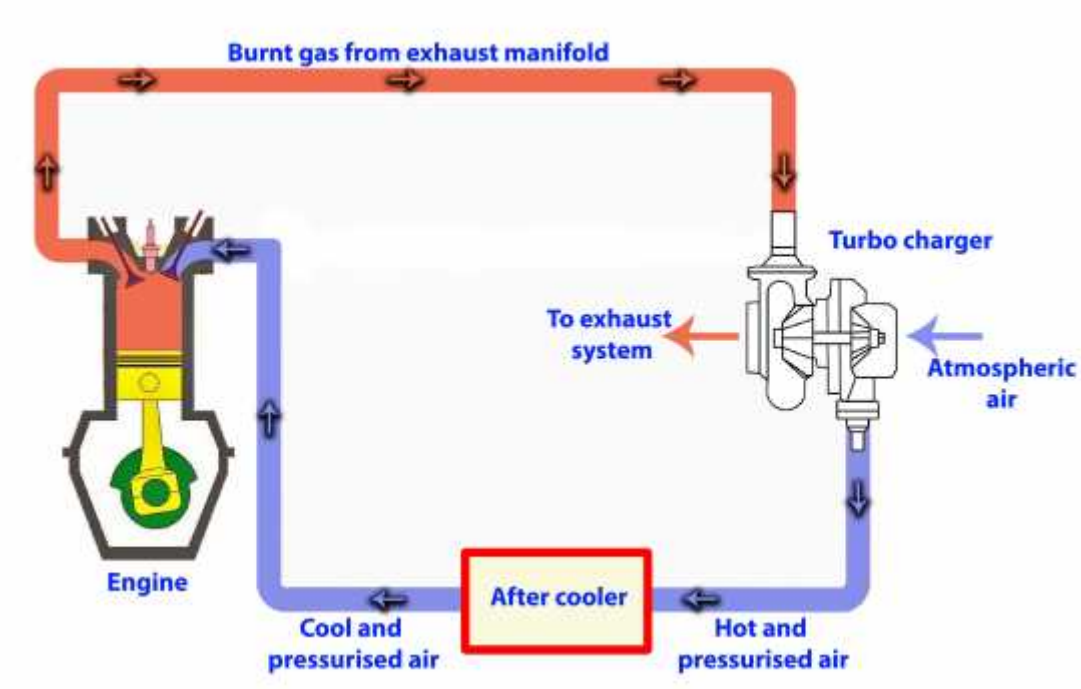
So if we use a mechanically driven supercharger the crankshaft also would be driving this device right so energy is taken out from the engine output right for this purpose. So obviously the what to say the limitation of this super charger is that we are going to expand energy right to pressurize the air so the useful energy which is available at the engine crankshaft output is provided as input to the super charger to pressurize the air which is taken into the engine.

So then the question is what is the benefit that we will get right? So that is becomes an important question for a mechanically driven super charger. So in that regard turbo chargers have become very advantageous today what is the turbo charger? A turbo charger is a device that uses the energy that is available with the engine exhaust gases to pressurize the air which is taken into the cylinder so a turbocharger is a charger is a device where which is driven by a gas turbine which in turn is driven by the exhaust gases from the engine.

So please note that you know like when we discussed even like indicator power right or indicated energy there was one term B right which included the loss to coolants right the energy loss due to engine exhaust right and so on okay. So you we can immediately observe that the engine exhaust is also like possessing a significant amount of energy right. Now the question is that can we tap into that energy and pressurize my intake air that is what a turbo charger.

So a turbo charger essentially uses this energy which is available in the engine exhaust to drive the gas turbine which in turn pressurizes the intake air. So let us look at how a turbo charger works okay and then we will discuss some aspects of it okay. So this is just a broad schematic to explain how a turbo charger functions okay so we can see that this is the intake valve okay and this is the exhaust valve right so this is a schematic where we can observe that the exhaust gases travel to the exhaust manifold and from that into this device which is called as the turbo charger right.

The turbo charger takes an atmospheric air and the energy which is available from the exhaust gases is transferred to the air taken from the atmosphere that air is pressurized and the pressurized air is than fed to the engine intake manifold right for distribution into the cylinders if you have a multi cylinder engine okay.



TURBO CHARGER CIRCUIT

Now we can immediately observe that here I am not tapping into the crankshaft right for pressurizing my intake air.

So we are only using the energy from the exhaust gases to pressurize the air taken into cylinder so that is an advantage that is the very big advantage for us okay. So we can immediately observe that once I pressurize the air in the turbo charger its pressure increases but also its temperature increases right once we compress air you know like we look at a reservoir of compressed air you know like we will see that you know if you pressurize air and store it in reservoir the air gets pressurized but its temperature also increases.

So if I supply that air at high pressure and temperature directly to the engine what would happen? See with pressurized air the density will increase but the with the simultaneous increase in temperature this increase in density will not be significant right there will be tradeoff between the increase in density due to pressure and decrease in density with increase in temperature. So the increase in density may not be to the level that we would want and if the increase in density is not significant what is going to be affected volumetric efficiency.

Because I want my also like intake air to be sufficiently dense so that the mass of air in for the same displacement volume is more that would increase the volumetric efficiency of the engine correct. So that is why we have what is called as an after cooler or inter cooler so an intercooler these are names given to this unit which is placed at the outlet of the turbo charger is used to decrease the temperature of air coming out of the turbocharger okay.

So that density of air which is supplied to the intake system is more and that increases the volumetric efficiency of the engine also okay. So this is how the typical turbo charger works so it uses the energy from the exhaust gases and essentially pressurizes atmospheric air and a turbocharger with intercooler is the system where you use an after cooler or intercooler to reduce the temperature of that pressurized air and supply it to the intercooler okay. So this is the turbocharger.