Fundamentals of Automotive Systems

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Lecture-13
Engine Performance
Part 01

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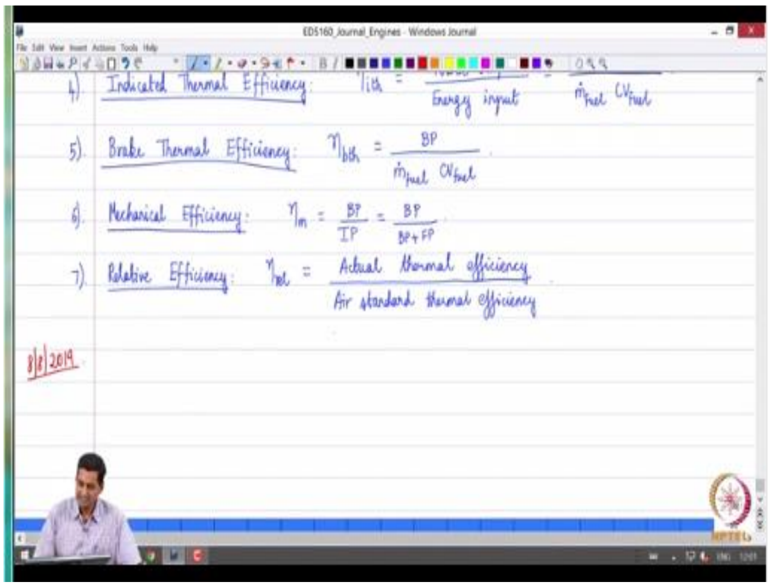

Ok greetings you know welcome to today's class, so a quick recap of what we did in the previous class you know like we looked at engine performance right.

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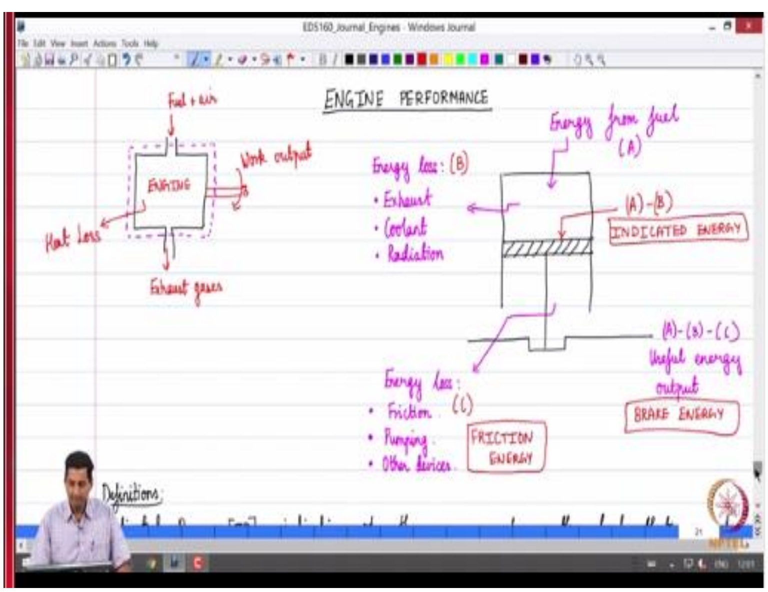

So we saw that the energy obtained from fuel you know like is first spent to what is say over come certain losses you know like some part of the energy you know like from the fuel is lost through exhaust and through the coolant and also engine radiation and whatever is remaining is what acts on the piston and that is what is called as indicated energy. And then like we have another set of energy losses through friction pumping and the energy taken to drive other devices, which are lumped as friction energy or friction power.

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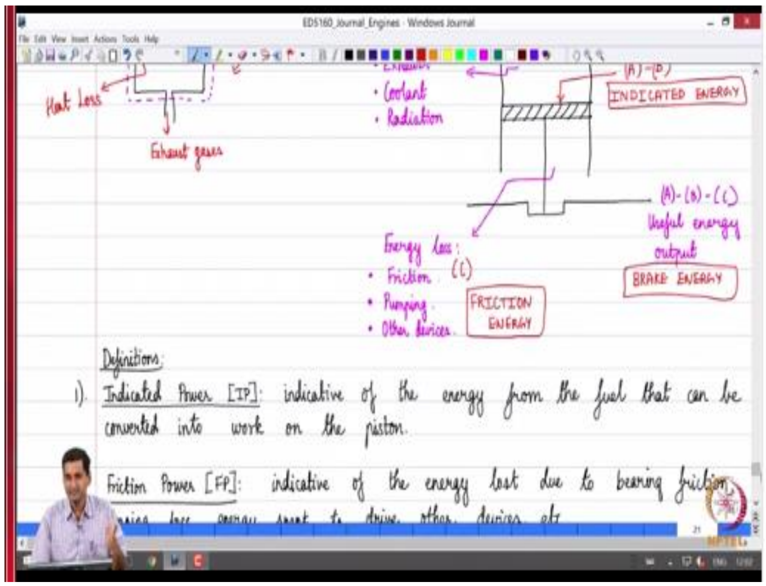

And whatever is remaining and that comes out of the engine is what is called as the break power as a corresponding energy is typically called as the break energy ok. So we defined a few terms power terms indicated power, friction power, brake power and also the corresponding thermal efficiencies indicated thermal efficiency break thermal efficiency, mechanical and relative efficiencies ok. So let us continue from here today.

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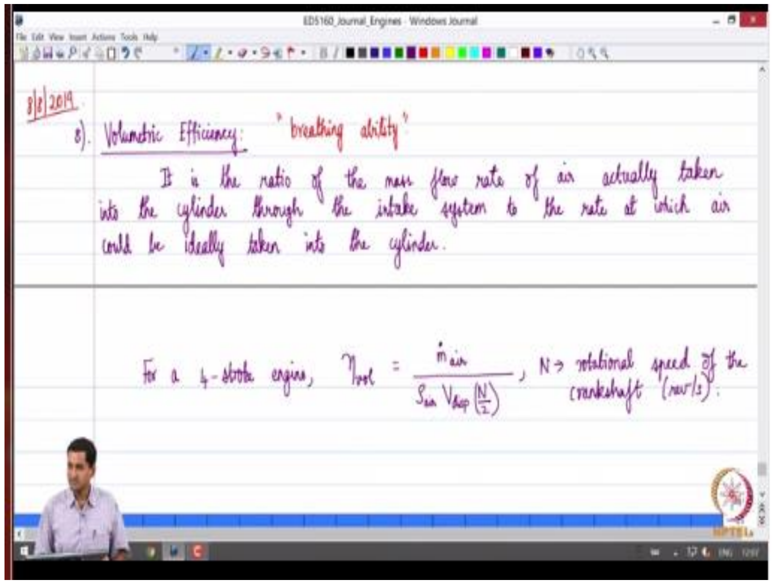

So we are going to define a few more terms, the first one which is an important parameter that characterizes engine performance is what is called as volumetric efficiency. So what is volumetric efficiency ok, so in essence you know like one can say you know like it characterizes the breathing capacity or the breathing ability of the engine ok. So what do we mean by this you know, I am just putting it within codes.

So we already know that you know like the engine takes in air right during the intake stroke through the intake manifold and the intake wall into the cylinder and better is the intake process the more efficient is going to be the engine right. Of course we designed the engine for a certain displacement volume, the question is like can I fill that entire displacement volume with the quality of air and air fuel mixture that I want which will ensure better combustion ok.

So that is what is characterized by volumetric efficiency, so if I have let us say in engine cylinder with a capacity of 300 cc, the question is am I going to take an amount of air that corresponds to 300 cc multiplied by the air density which will give me some kilograms of air or grams right. So that is what can be ideally accommodated in the cylinder but the question that we are asking ourselves is it what is the actual amount of air that is taken into the cylinder through the intake system.

So that is characterized by this parameter called volumetric efficiency, so let me write down the definition then we will get clarity on what it describes. So volumetric efficiency is nothing but the ratio of the mass flow rate of air, actually taken into the cylinder through the intake system. By the intake system we are referring to the inlet intake or inlet manifold and intake walls and so on right.

So through the intake system to the rate at which air could be ideally taken into the cylinder ok, so there is a definition of the volumetric efficiency ok. So let me write down an expression and that will clarify this concept better, so if we consider a 4 stroke engine we can consider volumetric efficiency to be m . air. So suppose if I measure the mass flow rate of air which is coming into the cylinder, kindly recall that if I put a dot over a variable that indicates one derivative with respect to time right.

So m . air is the mass flow rate of air which is taken into the cylinder through the intake system divided by the rate at which I could have ideally taken air into the system. So that is characterize by the displacement volume of the cylinder, the density of air and also the speed of rotation of the crankshaft because we are talking about rate quantities right. So the rate at which air could have ideally been taken into the cylinder can be written as density of air times the displacement volume times n by 2, where n is the rotational speed of the crankshaft in revolutions per second ok.

In this particular the way I have written this particular expression is not rpm but revolutions per second why am I dividing by 2 kindly known that we are considering a 4 stroke engine right. In a 4 stroke engine that is 1 intake stroke or intake process for every 2 revolutions of the crankshaft. So if my crankshaft is rotating n revolutions per second, I am going to have n by 2 intake strokes right. So that is why we have N by 2 in the denominator ok.

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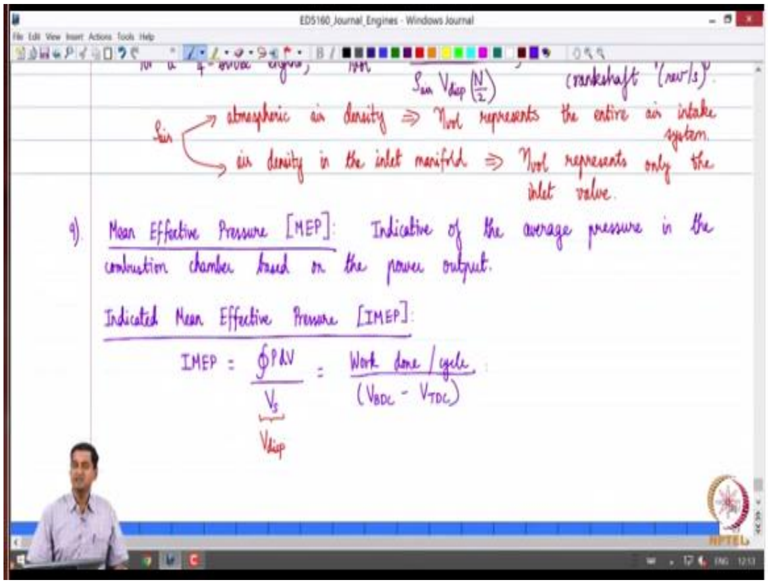

Of course, the question becomes you know, like another question that can immediately come to our mind is that like, what about this density of air you know, like we know air is a compressible fluid which tendency do a take right. So if the value of the density of air is taken to be the atmospheric air density depending on the local operating conditions then this implies that the corresponding volumetric efficiency represents or characterizes the entire air intake system right.

Because like we are essentially taking the density of air outside the engine, so that means that you know like I am characterizing the entire intake system which consists of the intake manifold, the walls and so on right by when I calculate this volumetric efficiency. If I take row air the value of the this density as the air density in the inlet manifold or closer to the walls I am representing or characterizing only the inlet wall or inlet port ok.

So depending on what engine we are talking about right, so if I take the density of air closer to the inlet wall. I am only going to characterize the local volumetric efficiency that is volumetric efficiency of the wall system ok. So depends on what we plug in typically we will plug in the we will substitute the atmospheric air density and try to quantify the volumetric efficiency of the entire intake system ok.

So that is what we would typically do ok, so that is volumetric efficiency which is a very critical parameter you know like to characterize internal combustion engines. So moving ahead, we are going to define a few more parameters, so the next one is what is called as mean effective pressure ok abbreviated as MEP ok. So as a term suggests it is indicative of the average pressure in the combustion chamber or cylinder based on the power output.

So we are going to use this parameter to represent what is the average pressure you know like that exists in the combustion chamber during a cycle. Of course as we know during the operating cycle the pressure is changing within the cylinder but what is the average pressure which will give me the same power output as what I am obtaining now from the engine right. So there are 2 measures once again you know like as far as mean effective pressure is concerned.

The first one is what is called as the indicated mean effective pressure which is abbreviated as IMEP ok indicated mean effective pressure IMEP is defined as the following. IMEP is going to be integral over the cycle ok integral pdv is the indicated work done in 1 cycle ok, if you consider the ideal cycle right divided by the swept volume or the displacement volume ok. So please know that this is the swept volume.

Sometimes this may be even represented as displacement volume right, so we V disp or V s subscript d and so on. So this is the work done on the piston in 1 cycle divided by the swept volume that is essentially the difference between the volume at BDC and the volume and TDC ok, so that is the indicated mean effective pressure ok.

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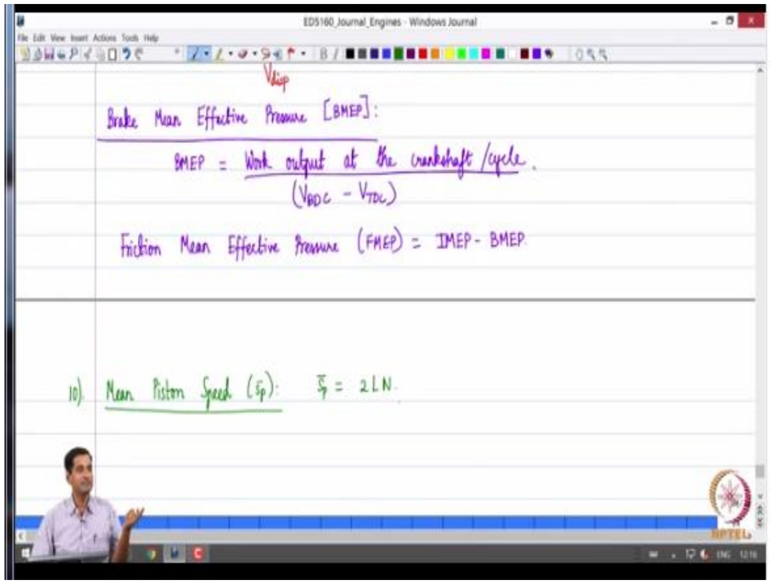

So the other mean effective pressure obviously will come from the break power right. So the other mean effective pressure term is what is called as brake mean effective pressure abbreviated as BMEP. So BMEP is defined as the work output provided by the engine at the crankshaft per operating cycle divided by the displacement volume which is VBDC - VTDC ok, so that is the brake mean effective pressure.

Obviously the brake mean effective pressure is lower than the indicated mean effective pressure and the difference between the two is indicative of the energy that is overcome in sorry in used in overcoming friction and running other devices and so on right. Do you remember the term C that we looked at right during that energy analysis, so that is what it is. So there is another term called friction mean effective pressure abbreviated as FMEP that is going to be IMEP - BMEP ok.

So that is what is called as friction mean effective pressure, so the term mean effective pressure gives in indication of what is the average pressure in the cylinder know like that gives me a particular power output ok. We are going to come back to this in today's class and derive an expression right for the otto cycle as an illustration, so that we will get a better picture of what this quantity actually tells us ok.

So a few more definitions before we go to that derivation, the next quantity is what is called as a mean piston speed, as we know the speed of the piston keeps varying right during the strokes of the piston in the cylinder. But the mean effective sorry mean piston speed SP bar is defined as 2 times L times N again ok. So L is the stroke of the piston, so 2 times L is the stroke is the distance travelled by the piston and 1 revolution of the crankshaft and the crankshaft rotates, N revolutions per second. So 2 L times N will give me the mean piston speed right, so that is what this parameter will give.

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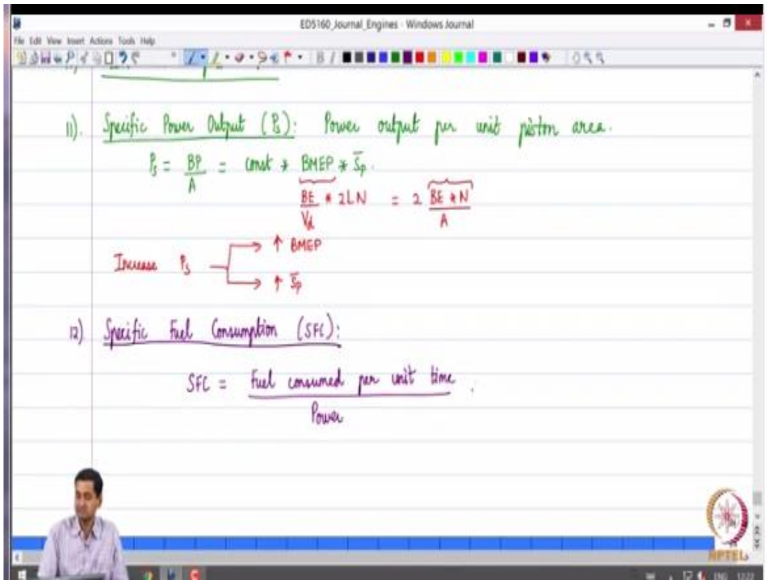

Now there is another parameter which is called as the specific power output P subscript s this is the power output obtained from the engine per unit piston area. So this essentially tells us you know like what is the power output that I get from a particular engine now given it is size right. So there is a piston area you know like in a certain sense, you know like quantifies the size of the engine right.

So the point is, you know like how can I relate the power output to the distance size and here the power output is the break power ok. So that is what we would take and one can easily show the this is going to be some constant multiplied by the brake mean effective pressure multiplied by Sp bar ok. So you just use the definition of brake mean effective pressure and Sp bar, you will easily get this it is going to be some constant times, B a maybe times the mean piston speed.

So how can we justify this, please note that V MEP you know like corresponds to essentially the, I will say break energy right, times V displacement right. So S p bar is nothing but 2 times L times N, now V d by L is going to be A right displacement volume will be L times the area of the piston right. S, this I can rewrite this as 2 times B break energy per unit cycle times N divided by A and what is this term, this what is obtained in one cycle.

So let us say you do N by 2 cycles right, so what will you get, so you will get the break power alright, of course you need to adjust some constants right. But then like you will get the break power output, so I hope it is clear how we got the correlation right. So the important thing is to notice the specific power output is directly proportional to the brake mean effective pressure. So if we want to increase specific power output, we can do it in 2 ways ok.

We can increase BMEP ok or increase Sp bar that is the speed of the engine right in essence N right. So if I want to increase V MEP for a given engine right, what can I do, I want to increase the average pressure sort of like in the engine of course, I need to maybe like burn more fuel right release more energy the expectation that I will get more work output ok. So but then there is a limit on that also when we look at the actual combustion process and engines ok.

Another way is by also increasing the pressure at which the air or air fuel mixture is taken into the cylinder. So we are talking about the mean pressure or average pressure right, so look at the even if you consider the otto cycle right, if I increase the pressure at point 1 which is the initial state of the fluid. Then the entire curve will shift up then the mean pressures also would increase.

So what is that engine called as, you know like where we introduce the fuel or air fuel mixture or air at a pressure higher than atmospheric this called a supercharged engine right. So we will come to that later, so now you can see why we have a supercharged engine right. Supercharged engine can be use to improve the output from the engine right because it can increase the mean effective pressures leading to a higher output for the same engine other specs remaining the same.

So that is another way of increasing the brake mean effective pressure but there is a trade off always there is a price to pay we look at what are the tradeoffs later on. If I want to increase S p bar, I need to increase the speed of the engine, right. So that also brings challenges right, so what are the challenges in increasing the speed of the engine as we already seen it results in more mechanical load.

And if I increase the speed of the engine, the number of cycles per unit time also will increase. So the power output increases but the rate at which I need to dissipate heat and other effects also would increase right. So there is a always a trade off right between all these conflicting factors but a specific power output is a useful term to quantify in general (()) (21:29). There is one more important parameter which is use to quantify engine performance is what is called as specific fuel consumption.

So that is abbreviated as SFC, so what is a specific fuel consumption, it is the fuel consume per unit time divided by the power output, so that is the specific fuel consumption.

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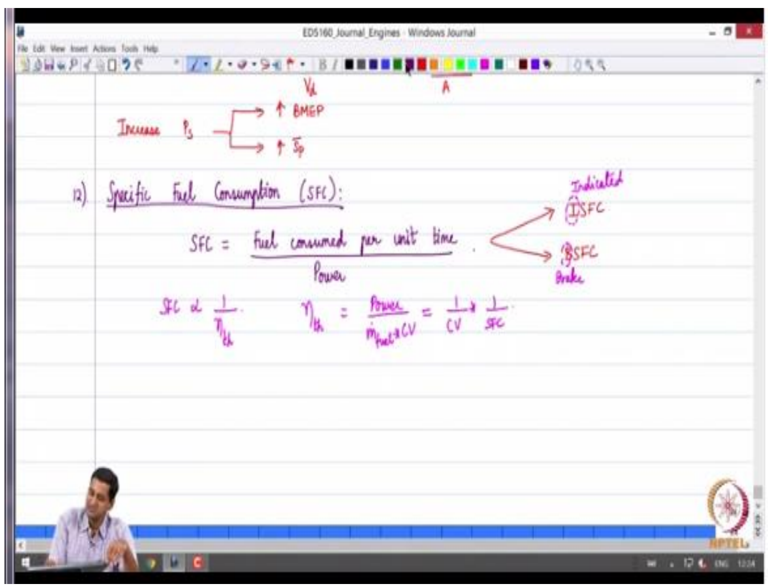

So immediately we can see that there are going to be 2 measures depending on what power quantity we substitute in the denominator. So specific fuel consumption can be either ISFC or BSFC, ISFC standing for indicated specific fuel consumption, BSFC standing for brakes specific fuel consumption right. So that is something which we can easily figure out right I standing for indicated B standing for break specific fuel consumption.

And we can immediately see that specific fuel consumption is inversely proportional to the thermal efficiency inversely proportional to power. But you recall what are the thermal efficiency, you know like irrespective of whether it was power or indicated power or break power it was this. So specific fuel consumption in a certain sense it is 1 by CV times 1 by SFC right. So you take the calorific value out you get power by m . fuel that is one inverse of specific fuel consumption.

So you can immediately see that specific fuel consumption is inversely proportional to the thermal efficiency of the engine. So obviously, you know higher the thermal efficiency, lower is a specific fuel consumption and that is what is desirable to us right. Because I want to consume as less fuel as possible for delivering it given power output ok, so we want low specific fuel consumptions ideally right to the maximum process extent.