Fundamentals of Automotive Systems
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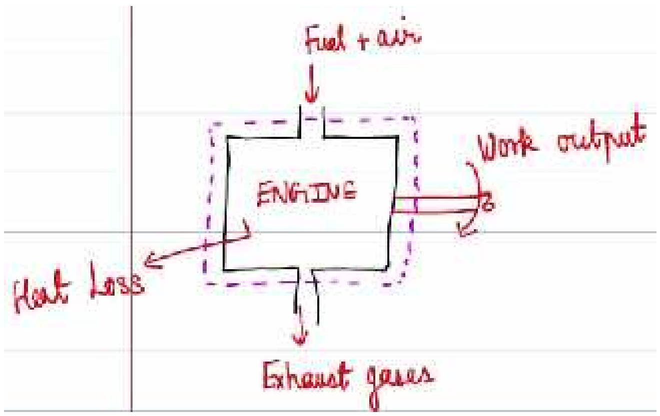
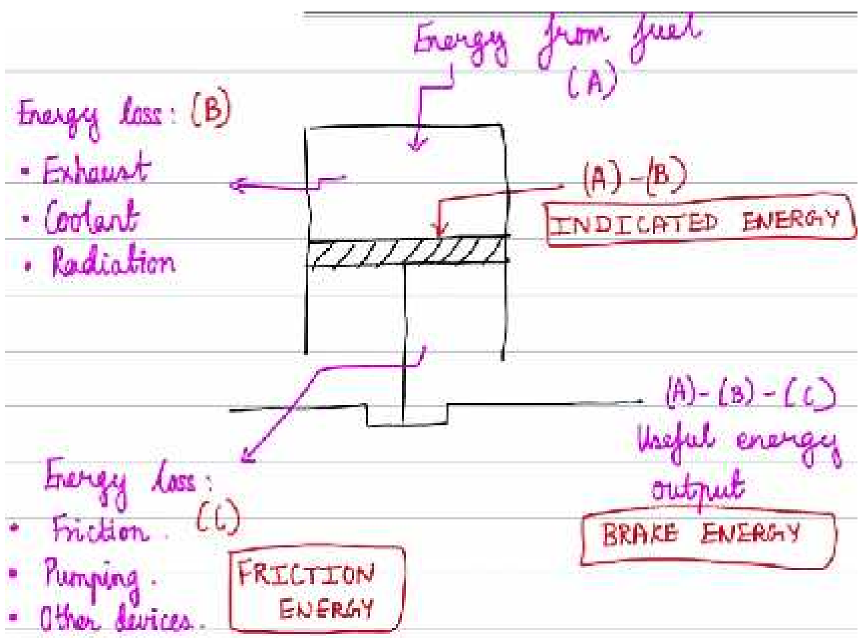
Lecture-12
Dual Cycle and Engine Performance
Part 02



INPUT SOURCES AND OUTPUT POWER FROM IC ENGINE



DIFFERENT ENERGY GENERATED AND LOST FROM IC ENGINE TO THE SUPPLIED HEAT ENERGY

The next topic that we would discuss is engine performance ok, so we are going to look at how to quantify the performance of an IC engine, what parameters can be used to evaluate the performance characteristics. So as we already discussed we can view an IC engine as an open system to which we provide fuel and air right we get we remove exhaust gases from the engine ok.

So this is the engine and we get some work output, of course there is some heat loss from the engine ok. So if I draw the system boundary around an engine, so we can immediately see that the engine is an open system right, so there is both mass and energy transfer across the system boundary ok. So that is the way in which we are going to visualize the engine, now if we were to look at what are all the different energy terms that we would encounter and how these can be used to quantify engine performance.

So let us look at what are the different energy terms which are significant you know to analyze a engine performance. So I am just drawing a very simple line diagram to just a indicate the cylinder piston and the crankshaft ok, so just a simple line diagram okay, now all of us know that there is some energy input from the fuel ok, let me call it as some quantity A. So I received some A joules from the fuel by combusting it right.

So there is some chemical energy which is stored in the fuel ok, so we will shortly see that we are going to define a parameter called calorific value of a fuel which will tell me how much energy content that fuel has and which can be used in this engine ok. So I get that and when we combust this fuel, of course, there are going to be some energy losses, what are the main energy losses even if we have perfect combustion.

And let us say you know like all the chemical energy in the fuel is converted to heat energy still in an internal combustion engine, we are going to have heat energy lost due to exhaust gases right. Because I even the exhaust gases that come from the engine of hot right, so some thermal energy is wasted or given out by the exhaust through the exhaust gases. We also have some heat energy escaping or being taken out of the engine through the coolant.

As we have seen you know there are parts or jackets for the coolant in the cylinder head in the cylinder body and so on right. So, through which we absorb heat energy from the engine components right to maintain the temperature of the engine components right. So that is some heat energy which is removed from the components of the engine by the coolant and still the engine is going to radiate some energy because as we will see, you know, like even when we stop a car right and we go near the hood of a car, we will see that it is radiating heat right.

So the engine gets hot ok, so and then we are going to lose some thermal energy due to radiation. So let us say we lump all these energy losses and we called it as some quantity B ok, the quantity A - B is what is available to push the piston acts on the piston and essentially results in kinetic energy of the piston ok. So this energy is what is called as a indicated energy, so you subtract the quantity B from the quantity A.

So what is left behind is the energy which can be used to push the piston right. So that is termed as indicated energy now we are going to have other losses. So let us discuss what other energy losses can happen, so let me write down another set of energy losses. So as we already realized you know the piston moves within the cylinder and there is going to be some friction right.

Although we lubricate the compression rings, the oil rings contact the cylinder surface right and that is going to be some friction and there is going to be some friction in the bearings right and the connection between the connecting rod piston right and the connecting rod on the crankshaft or the what to say journals and so on right the crank pens journals and so on right. So there are going to be losses due to friction at those locations, so there is frictional losses right.

We have already looked at what is called pumping losses right, what is pumping loss you recall that negative energy in the PV diagram right which is required to take in the air fuel mixture or air during the suction stroke and then push out the exhaust gases during the exhaust stroke right. So the energy for those strokes also need to come from the engine right, so that is a pumping loss right and the engine also drives other devices.

So for example, the engine crankshaft will drive the coolant pump right, so because the coolant needs to be circulate the engine crankshaft will also drive the lubrication oil pump right. The engine crankshaft will also drive the camshaft and the valve assembly right, so there are a lot of components which will be powered by the engine. So you have to take into account other devices ok which are powered by the engine.

So all these losses let us say we call it as we lump and call it as some quantity C ok. So this quantity which is lost is essentially lumped you know although it is a combination of various components we use typically lump them and call them as friction energy ok, although it has multiple components ok just for the sake of naming and we call it as friction energy and there is something called friction power ok we are going to come that shortly ok.

So the net output which is the useful work, which comes out of the engine is called as brake energy. So this is the useful energy output ok that is you take the quantity A which is available from the fuel subtract B which includes all these losses the first set of losses then you subtract C which includes the second set of energy losses, whatever is remaining is the useful work which is coming out of the engine ok and this is called as the brake energy.

So the brake energy indicates the net useful energy that comes out of the engine and that can be used to drive the vehicle ok. So this is what is transmitted onwards to what is called is the drive line ok which we will study our next ok the clutch, gearbox, final drive and finally to the wheels and then the traction forces for propelling the vehicle or generator ok. So the brake energy is the net energy useful energy that comes out of the engine.

So, we are going to define some terms and then use them in our analysis of engine performance. So the first term is what is called as indicated power, what is indicated power. It is indicative of the energy from the fuel that can be converted into work on the piston ok, so that is indicated power ok. So we label something as indicated energy right, the quantity A - B the power corresponding to that quantity is what is called as indicated power.

The next one is friction power, so it is corresponding to that energy loss C right, so the friction power is indicative of the energy lost due to bearing friction, pumping loss, energy spent to drive other devices including valve mechanisms ok etc. ok, so that is friction power. So this is that energy loss, C sorry yes the corresponding power term is what is called as friction power.

Indicated power (IP)

$IP = FP + BP$

Then the third power term which is typically used in engine performance analysis is what is called as break power ok abbreviated as BP. So this is indicative of the energy obtained from the engine that can be used to drive the vehicle ok, so that is brake power. So obviously the indicated power is equal to the friction power plus brake power right. So that is something which we can immediately realize.

So the energy output that ultimately comes out of the engine right, is a brake power right. So and that is what we are interested in right because that is what we can transmit further on and then can be used to drive the vehicle ok.

So, these power terms are used to define the corresponding efficiency terms. So what are the corresponding efficiency terms there is something called as a indicated thermal efficiency. So that is eta I_{th}, I stands for Indicated, th stands for thermal efficiency, it is the power output divided by energy input right. So that is the general definition of efficiency ok, so here the power output that we are talking about is the indicated power IP.

Indicated Thermal Efficiency: $$\eta_{ith} = \frac{Power\ output}{Energy\ input} = \frac{IP}{m_{fuel} \times CV_{fuel}}$$

And what is the rate at which energy is given, it is nothing but the mass flow rate of fuel multiplied by the calorific value of fuel because even in the denominator we should have a rate quantity right energy rate quantity because power is the unit of power will be in watts right. So I also need a quantity which has the same unit in the denominator, so we have to give the rate at which we are supplying energy to the engine that is essentially the mass flow rate of fuel ok which will be in kilograms per second times the calorific value which will be in typically written in joules per kilograms.

So we will get joules per second and the unit will be in watts ok, so that we get a non dimensional term for efficiency ok. So that is how we define indicated thermal efficiency, so there is another efficiency term which is called as the brake thermal efficiency. So which is eta B_{th} of course now it is pretty straightforward, it is going to be the ratio of the break power divided by the mass flow rate of fuel times the calorific value of the fuel right.

Brake Thermal Efficiency: $\eta_{bth} = \frac{BP}{\dot{m}_{fuel} \times CV_{fuel}}$

So that is the break thermal efficiency, so another efficiency term is what is called as the mechanical efficiency. The term mechanical efficiency is nothing but the ratio of brake power and indicated power right, so it is indicative of how much energy am I losing, you know like due to the quantity C right which we are quantifying as friction power. So this is going to be break power divided by break power plus friction power right.

Mechanical Efficiency: $\eta_m = \frac{BP}{IP} = \frac{BP}{BP+FP}$

So that is mechanical efficiency ok and then we have what is called as relative efficiency which is nothing but the actual thermal efficiency of the engine divided by the corresponding air standard thermal efficiency ok.

Relative Efficiency: $\eta_{rel} = \frac{Actual\ Thermal\ Efficiency}{Air\ Standard\ Thermal\ Efficiency}$

So suppose if I say the actual you know like the thermal brake thermal efficiency of a petrol engine, let us say it is 28% right and the corresponding air standard thermal efficiency by considering the auto cycle is 56%.

So the relative efficiency will be 28 by 56, which is 0.5 or 50% ok, so that is how we should look at the relative efficiency. So this gives us the feel of by what factor should I multiply the efficiency of the air standard cycle to get the actual engine efficiency ok. So that is what is called as relative efficiency ok. So I will stop here and then like, in the next class we will look at a few more energy performance parameters before we continue further into engine analysis ok thank you.