Thermal Engineering: Basic and Applied
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Lecture: 43
IC Engines, Classification, Different Parts and SI and CI Engines

All you welcome you all to the session of thermal engineering basic and applied and today we shall discuss about the internal combustion engines. In fact in this module of this course we shall be discussing about several issues related to the operation of internal combustion engines. And of course several other thermodynamical aspects, so before coming to the discussions of internal combustion engines.

Let us first review the concept from here the work output of the internal combustion engine can be related to the basic of thermodynamics that we have learned in thermodynamics course. So in thermodynamics we have studied about heat engine.

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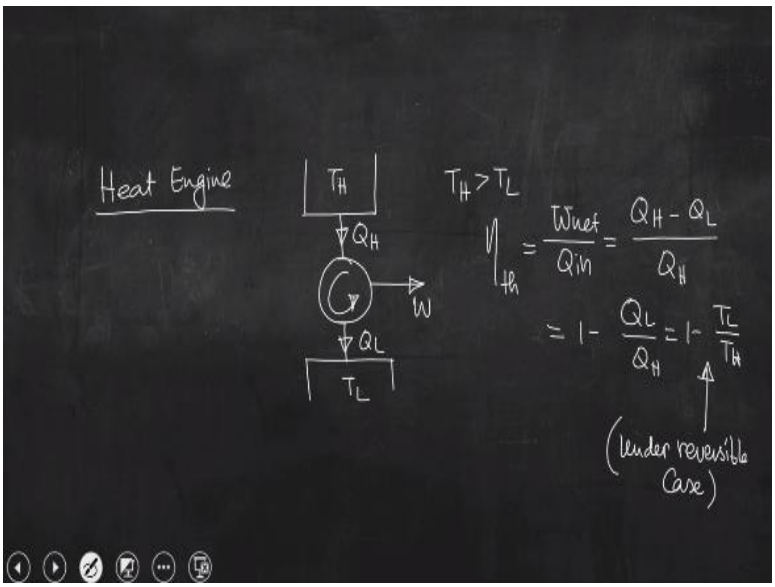

Because we shall be discussing about internal combustion engine, so let us first briefly discuss about the heat engine that we have learned in our thermodynamics course. Schematically we can depict this is the engine which produces work continuously while operating between these 2 temperature thermal reservoirs. One is at higher temperature another one is at lower temperature and definitely we have studied T_H is the higher temperature thermal reservoir and T_L is the temperature of the lower thermal reservoir. Now we are maintaining T_H constant always and if we supply Q_H amount of heat to this engine, we can get W amount of work and essentially to have it in a continuous manner we need to reject this amount of heat to the sink.

$$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H} = 1 - \frac{T_L}{T_H} \text{ (under reversible case)}$$

We can see that heat must be supplied to this device, at the cost of that input energy, we are getting always work output. So cannot we take this concept to develop another engine in which by initiating combustion internally within the engine itself if we can produce some amount of energy that energy can be utilized to produce work. So concept of internal combustion engine is coming from the fact that we have to have some mechanism by which we can produce heat internally by initiating combustion and at the cost of that generated heat, we can get work output so this is the concept and this is coming from the concept of heat engine.

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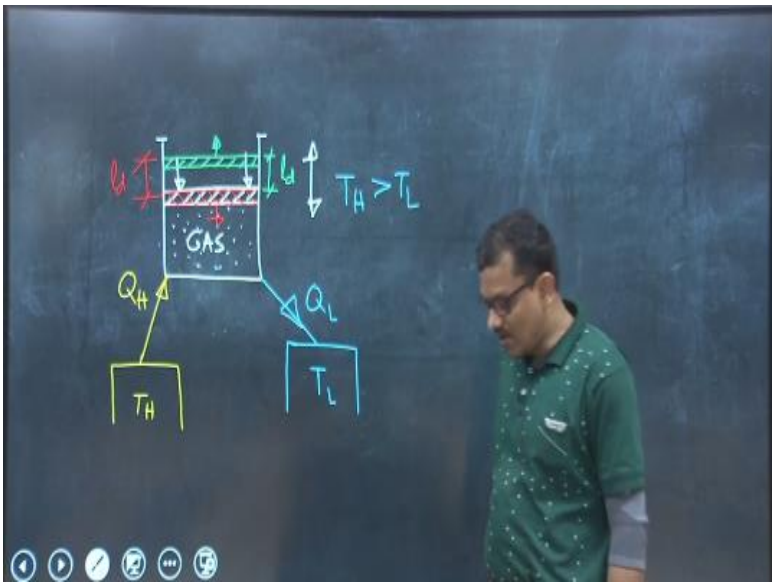

Say we have one cylinder and the cylinder is fitted with one piston. Now the cylinder contents gas one working substance. If we consider that a cylinder piston assembly is in equilibrium, that means internal gas pressure is able to stand the weight of the piston along with the pressure that is due to atmospheric pressure. So see atmospheric pressure is acting on the piston and internal gas pressure is such that it balances the weight of the piston plus the force due to atmospheric pressure. If you would like to have little a uplift of the piston say l_d, definitely the gas inside the cylinder should be expanded.

We can supply heat to the cylinder to be precise to the gas that is there inside the cylinder say this is one thermal reservoir and the supply heat is Q_H at the cost of this amount of heat which is supplied to the gas that is there inside the cylinder we can raise the piston l_d, we can have uplift. Now issue is again we are trying to bring back the piston in its original position and for that what we need to have downward moment of the piston and that is again l_d. So, we need to

extracts have amount of heat from the gas that is there inside the cylinder say if we can do it using this mechanism say we have another thermal reservoir and we are taking back the same amount of heat which was supplied to the reservoir. So if we can extract Q_L which is equal to Q_H then perhaps we can bring back the piston from new configuration to the original configuration.

What you can understand exactly what we have seen in the context of the operation of the heat engine if we supply Q_H amount of heat we will be getting work output ,of course second law of thermodynamics puts a restriction that some amount of heat must be rejected to sink to have work output in a continuous fashion. So in a similar manner we are supplying heat from a thermal reservoir in which temperature is maintained at T_H definitely T_H is greater than T_L.

A limiting case should be that the amount of heat which is supplied to the gas and at the cost of that heat we have uplift of piston by a distance l_d. Next task is to bring back the piston to its original configuration we are extracting same amount of heat from the system that means if we can connect this piston cylinder arrangement to this two temperature thermal reservoirs, by supplying heat we can expand gas we can have upward movement of the piston.

Extracting heat from the gas we can have compression and piston will come back to its original position that means by doing this arrangement we can have a reciprocating motion of the piston that is there inside the cylinder. So our objective was at the cost of this energy and by making such an arrangement we can have reciprocating motion of the piston. If we convert this reciprocating motion of the piston to the rotary one by connecting crank and connecting rod mechanism we can drive wheel.

So this is what is the concept of internal combustion engine, the name itself is internal combustion as I told you this amount of energy should be supplied to the working substance. So this is the gas, if we can generate this amount of it by initiating a combustion process inside the cylinder itself, then perhaps we can have that heat energy to have the uplift of the piston. And you also can have some arrangements, so that heat should be extracted or taken away from the system and will be having downward moment of the piston.

And if we can have this process in a cyclic manner, we will be having this reciprocating motion and that should be converted into the rotary one by using crank and connecting rod mechanism

so this is what is internal combustion engine. So the concept of internal combustion engine is coming from a basic thermodynamics that we have learned and that is why it is the subject which is thermal engineering basic and applied.

So these two are correlated so whatever we have learned from our basic thermodynamics course that will be applied to have several processes. So why it is internal combustion? Combustion should be initiated internally inside the cylinder and it is because of this combustion the amount of energy that will be getting that energy would be utilized to have the movement of the piston. So with this basic understanding let us now look at the basic components of the internal combustion engines.

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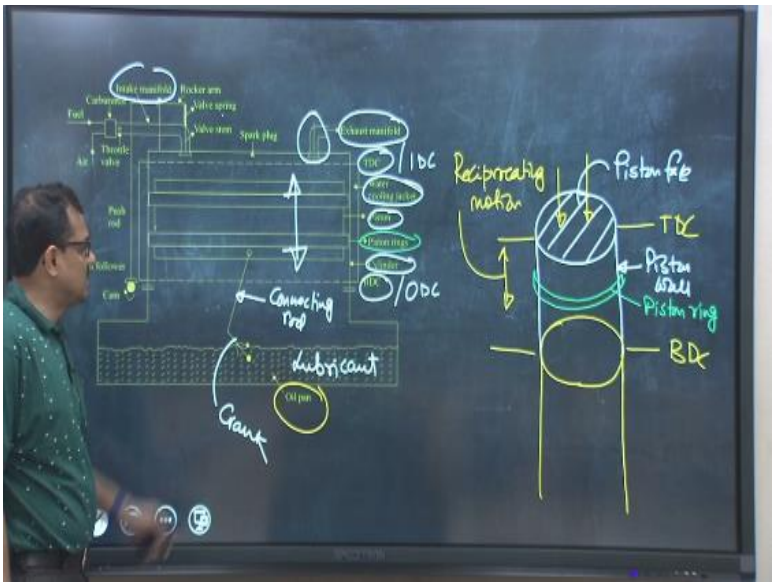

So I have tried to represent a schematic of the internal combustion engine essentially to show you the nomenclature or rather to identify several parts, because depicting this arrangement we have understood that combustion should takes place internally. It is because of this combustion the amount of heat that will be leverated that heat should be utilized to have the reciprocating moment of the piston. So, this is engine cylinder and inside the cylinder we can see that is piston.

So the piston will be having to and fro moment between the between 2 spots and those are known as top dead center and bottom dead center in some books it is also known as inner dead center and this is outer dead center. So top dead center or bottom dead center, these two are two different locations and the piston movement should be restricted between these two locations. Then we also can see intake manifold.

Again if we go back to the previous slide, we are supplying heat to a working substance that is gas. So this working substance should be heated it will expand and at the cost of this expansion we are getting a uplift of the piston. Similarly if we take away certain amount of heat from the gas it will compress and at the as a result piston will come back to its original position. Similarly when you are talking about internal combustion engine, definitely there must be combustion and because of which we are getting energy.

So we can see from the schematic through intake manifold fresh air is drawn into the cylinder, then intake valve is there. So it is spring loaded valve so, normally the valve will be closed. But we have to open it by applying force on it so that is why cam follower mechanism is there, so depending on the requirement and as and when needed the valve will open. So when valve is open, air will go into the cylinder. Then we also can see exhaust manifold, so if we go back to the previous slide I have discussed we are supplying heat to the gas then because of this expansion of the gas piston will go up. If we need to take the piston to its original position we must extract certain amount of heat. So here exhaust manifold is provided that after the combustion is completed, the combustion gases should go out to the surroundings while the combustion gases are leaving the engine cylinder they are carrying some amount of heat and that is nothing but the loss of heat from the system.

So this is exhaust valve, it should not be open always, so as and when needed, the valve will open and you can see this is the connecting rod that you have studied in machine design course and this is crank. So this connecting rod crank mechanism is very much essential to convert the reciprocating motion of the piston to the rotary motion of the crankshaft.

And if wheels are connected to this shaft and we can rotate wheel. That means piston will be having reciprocating motion between these two locations what are those top dead center and bottom dead centered. So once piston reaches at this location there will not be further movement of the piston, so movement of the piston should be arrested when it reaches either at BDC or TDC.

Now this is essentially the nomenclature of a special type of engine, special parts which are there here essentially for the a particular type of engine that I will be discussing later. So what we can understand if we take fresh air into the cylinder and if we can supply some amount of

fuel and the stored energy within the fuel that is chemical energy that would be converted to the heat energy.

So that heat would be utilized to create a thrust on the piston face and piston will have downward movement so if we draw piston like this, so this is piston face. Because of the combustion, the temperature of the combustion gases as well as pressure will be very high and that high pressure of the combustion of working substance at that condition will create a thrust on the piston face.

So piston will come from TDC to BDC because now pressure acting on the piston face is high as result of the combustion and again arrangement should be there so that piston can be taken back to the TDC and that is why you have studied that whatever amount of power we are getting because of this thrust created on the piston face, that energy will be stored in the flywheel that you have studied in the context of dynamic of machine and again you need to bring the piston back from BDC to TDC because we need reciprocating motion of the piston so that means once the combustion is completed, thrust which is acting on the piston face will allow piston to go back from TDC to BDC.

But we need a continuous as a procreating motion so that means piston will come again from BDC to TDC, to bring piston from BDC to TDC we need to borrow energy that energy should be borrowed from the flywheel, so flywheel will get energy from power that we are getting after the combustion is completed.

We shall discuss all those aspects later. Now we also can see this oil pan, this is very important because you can see that the piston will be having reciprocating motion inside the cylinder. So these 2 are the mating components cylinder wall and the piston outer wall. So piston is moving inside the cylinder so it is very likely that frictional effect will be there.

So to reduce the frictional losses, the amount of power that we are getting, a part of that power will be utilized to overcome the friction, not only that because the motion is continuous, so frictional heating may lead to drastic damage of the piston material. So is lubricant and because crank is continuously rotating so by virtue of churning action lubricant will be supplied to the cylinder wall and that lubricant will try to reduce the friction also it will try to keep the temperature of piston wall to tolerable limit. And as I told you that when we are supplying lubricant to the engine cylinder wall, but continuous motion may reduce the piston life, piston

material is very costly you can understand because it will withstand high pressure high temperature always.

And if we need to change piston frequently, then it is not economically viable, we can see that rings are provided at the outer periphery of the piston and these are known as piston ring and depending on the requirements, number of piston ring is decided, what we can understand that if we provide piston ring perhaps it is preventing piston to be in contact with the cylinder wall.

So because of frictional effect piston ring life will be destroyed but not the piston life, we can change piston ring maybe after certain interval of time. So this is the objective of piston ring that you also can see from the schematic depiction and finally we also can see the cooling water jacket. So let me tell you because we have our entire objective is to create high pressure and high temperature yet we are providing cooling water jacket why?

Because if we provide cooling water jacket cooling water should be supplied and that water will reduce temperature of the cylinder wall, this is provided only to increase the life of the cylinder wall otherwise thermal pack may generate but we also need to keep in mind that temperature reduction by supplying cooling water jackets should not be very much otherwise we need to compromise the engine efficiency.

So amount of cooling water that should be circulated through this jacket is also important aspect of the internal combustion engine operation. So the entire purpose of this particular arrangement is to reduce temperature of the engine cylinder so that engine cylinder life can be increased.

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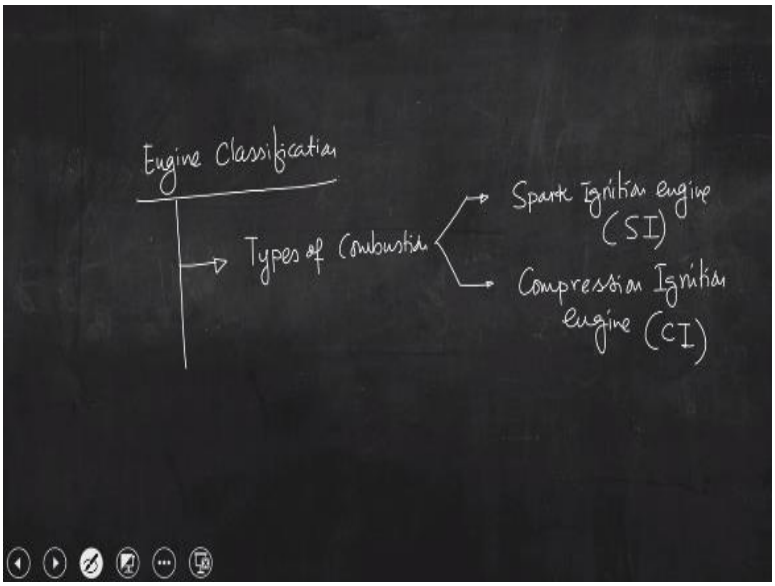

So if you try to classify engine, you can understand a working substance will be there and the working substance should be combusted to produce energy. Now when you are talking about combustion, of course that combustion should takes place internally and that is why it is known as internal combustion engine so depending on the combustion type engine can be classified.

We can write one sub classification which is based on the types of combustion and sub classifications are spark ignition engine or SI engine, another type is compression ignition engine or CI engines. So this classification is based on the types of combustion because we need to supply fuel, we need to supply air because without air we cannot complete even combustion.

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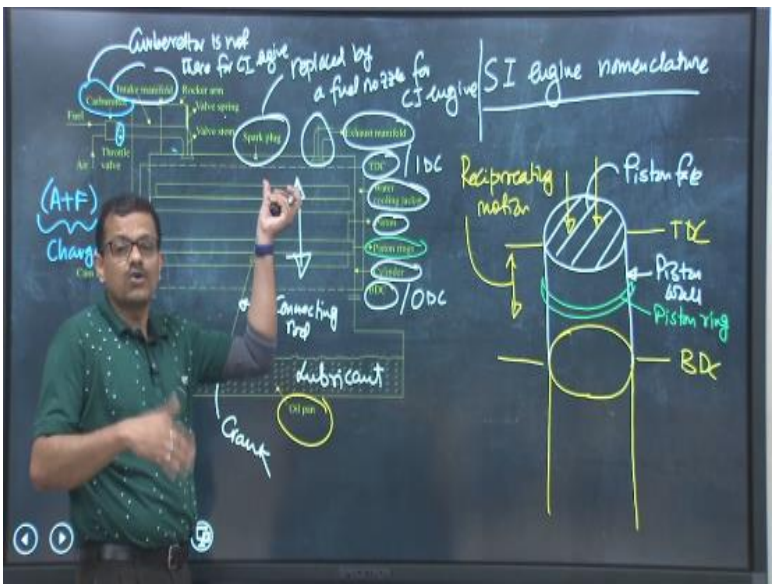

So the nomenclature that we can see from this particular schematic depiction is for the SI engine. So now let me write so, this is SI engine nomenclature, why it is SI engine, you can see that I did not discuss one special device that is called carburetor so this is carburetor. And this is throttle valve, so the function of the carburetor is to provide homogeneous mixture of air and fuel. So in the context of this park ignition engine, it is not only the air which is coming through the intake manifold into the cylinder instead it is the fuel air mixture, so for the spark ignition engine the purpose of this particular device though it is nowadays almost obsolete but the entire purpose of this particular device is to supply homogeneous mixture of air and fuel to the engine cylinder. And that mixture of air and fuel will go through the intake manifold that means the intake manifold is provided to have flow of air to the cylinder but pertaining to the spark ignition engine we also need to supply fuel air mixture not only air, so this air fuel mixture which is also known as charge is supplied.

So basically this air plus fuel mixture which is known as charge is supplied to the engine cylinder through the intake manifold. So the presence of this particular device indicates that it is spark ignition engine not only that most important part that I should now discuss is this spark plug, so we know that combustion should initiate and combustion should be completed and it is because of this process will be getting some energy and that energy will allow piston to go back from TDC to BDC that is all we have understood till now.

So if you go to kitchen room and you will see that if you open the gas knob and by opening the switch you need to bring a lighter to initiate combustion. So basically spark plug is acting just like an external agent to initiate combustion for this particular type of engine. That means we are taking fresh air and fuel that is charge into the cylinder.

And that charge will not ignite automatically instead we need to initiate ignition by making use of this particular device that is spark plug. So spark plug is an external agent which is provided to this spark ignition engine essentially to initiate combustion and it is because of the presence of the spark plug it is known as park ignition engine so the ignition is not taking place automatically rather ignition is initiated by making use of this particular device and which is spark plug.

So this is spark plug engine nomenclature now is if you would like to see what are the components for the compression ignition engine, the same parts will be there except spark plug

and carburetor, for the compression ignition engine the use of spark plug will not be there instead there will be one nozzle, so the spark plug should be replaced by a fuel nozzle for CI engine.

And carburetor is not there for CI engine so this is the difference. So that means we can use the same schematic for the nomenclature of CI engine provided spark plug is replaced by a fuel nozzle and carburetor is removed from this intake manifold. So in compression ignition engine only air should be drawn into the cylinder in one stroke and that air should be compressed.

And when the air is compressed at the end of the compression process pressure and temperature of the air is sufficient to initiate combustion without any help of external agent like spark plug so this is the difference between CI and SI engine. So fuel will ignite automatically at that prevailing thermodynamic condition of the compressed air. So for the compression ignition engine only air should be taken through the intake manifold to the cylinder.

And at the end of the compression process the thermodynamic state of the compressed air is good enough to initiate combustion when fuel is spread by a fuel nozzle into the cylinder. So, this is basically auto ignition, so fuel will auto ignite at that condition of the compressed air. So this is basically the fundamental difference between spark ignition and compression ignition engine.

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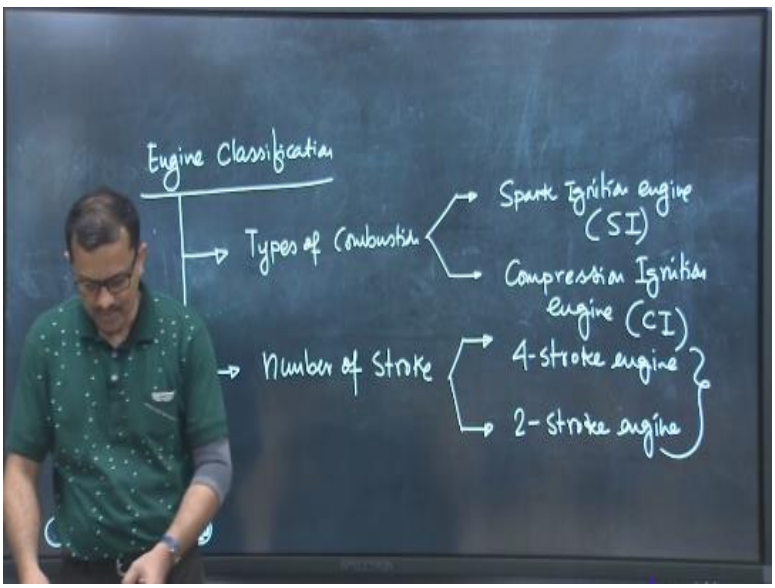

So now we also can classify another type that is depending on the number of stroke. So this can be classified into 2 categories one is known as 4 stroke engine, another one category is known

as 2 stroke engine. So, though we have discussed very little about the spark ignition and compression ignition engine today in the context of the nomenclature. We have also seen that engine can be classified based on the number of stroke that is whether 4 strokes are there to execute the total cycle or only 2 stroke can be designed to complete the cycle, so that part together with the you know fundamental difference between spark ignition compression ignition engine will be discussed in the next class. So, with this I stop here today thank you.