**Thermal Engineering Basic and Applied**
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**Lecture - 45**
**Comparison of SI and CI Engines, Compression Ratio**

I welcome you all to this session of thermal engineering basic and applied. Today we shall discuss about the basic differences between SI and CI engines and then we shall discuss about the compression ratio that is an important term used in the context of the operation of the internal combustion engines. So, before coming to the discussion of the comparison of SI and CI engines, I would like to recall the differences between 2-stroke and 4-stroke engines that we have discussed in the last class.

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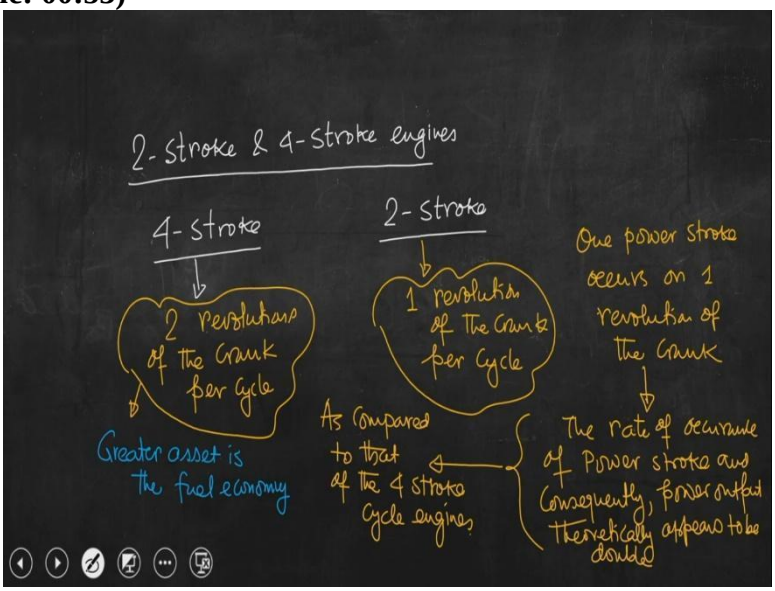


Now, if we write the 2-stroke and 4-stroke engines so, what we have seen that for 4-stroke vis-a-vis is 2-stroke. For the 4-stroke cycle engines whether it is SI or CI engine, we could identify that 2 revolutions of the crank per cycle while for the 2-stroke engine there is one revolution of the crank per cycle. Since 1 revolution of the crank per cycle and we have seen that there is 1 power stroke vis-a-vis 1 ideal stroke. So, 1 power stroke per revolution and 1 revolution per cycle so that means in a cycle 1 power stroke is there while if we consider 4-stroke cycle engine, 2 revolution of the crank.

And we have seen that out of these 4 different strokes 1 is the power stroke, remaining 3 strokes are the ideal strokes. So, I mean for 2 revolutions only 1 power stroke. So, engine is getting enough time to get cooled down but for the 2-stroke cycle engine, 1 power stroke occurs on 1

revolution of the crank. So basically 1 power stroke for 2 revolution and 1 power stroke per 1 revolution that means the rate of occurrence of power stroke and consequently the power output theoretically appears to be double for the 2-stroke cycle engines as compared to that of the 4-stroke cycle engines. So, the rate of occurrence of power stroke and consequently power output theoretically appears to be double as compared to that of the 4-stroke cycle engines, it is because of this reason that power stroke is the stroke during which pressure and of the working substance inside the cylinder is very high. And it is because of this reason I mean several parts of engine or engine cylinder may be prone to mechanical failure due to thermal stress and accounting for this aspect, speed of the 2-stroke cycle engines is reduced.

So, let me tell you once again, since the rate of occurrence of power stroke that means the power output which we have discussed now seems to be theoretically double as compared to that of the 4-stroke cycle engines. And it is because of this reason speed of the 2-stroke cycle engine is reduced, otherwise excessive rise in temperature may lead to the failure of several mechanical components owing to the thermal stress generation or development.

This is the most important fundamental difference between the 4-stroke cycle and 2-stroke cycle engines. This is one important aspect that speed needs to be reduced also we have seen that for the 2-stroke cycle engine significant portion of the fresh charge that is the fuel air mixture if it is SI engine or the fuel for the CI engine will be lost because the intake and exhaust these 2-strokes occur simultaneously.

So, when fresh air is drawn into the cylinder by a suitable pressurizing system, the incoming fresh charge allows combustion products to go out from the cylinder. Now, that simultaneous intake and exhaust stroke leads to loss of some fuel. So, we cannot eliminate that particular aspect. So basically, we have seen that a speed of 2-stroke cycle engine needs to be reduced otherwise excessive rise in temperature may lead to the failure of several mechanical components. On the other hand, large amount of fuel loss will be there due to the two different stroke operating simultaneously intake and exhaust strokes. So incoming fresh charge is allowing combustion to products to go out. So, that particular process will result in a significant loss of the fuel with the combustion products or combustion gases.

On the other hand, though there is only 1 power stroke vis-a-vis 3 ideal strokes, yet the greater asset of the 4-stroke cycle engine is the fuel economy. So, that 4-stroke cycle engine we are

getting only 1 power stroke. So, the power output theoretically lesser as compared to that of the 2-stroke engine that is there, but the greater asset is the fuel economy. Because the loss of fresh fuel that is inducted into the cylinder during into the strokes through charge if it is SI engine, the loss can be prevented. So that is why 2-stroke cycle SI engines are not recommended. So, it is because of the loss of significant amount of fuel 2-stroke cycle SI engines are not recommended.

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Next, we shall discuss about the differences between SI and CI engines so that 4-stroke vis-a-vis 2-stroke this classification is based on the number of strokes, while the classification of internal combustion engine as SI or CI is based on the types of combustion. If we try to recall internal combustion engine nomenclature, that time we have discussed that except two parts spark plug and carburetor, other part are same for both SI and CI engines that means for the SI engine we have seen that there is a spark plug that is used to initiate spark for the combustion and another component is the carburetor that is provided to supply homogeneous mixture of fuel and air. The same nomenclature can be used for this CI engine provided carburetor is removed and instead of spark plug there will be a fuel nozzle. So, from that particular point if we discuss the differences between SI and CI engines. We must say that both SI and CI engines have much in common.

But still there are a few fundamental differences and those differences make the operation of both SI engine and CI engine to be different. So, while we are trying to figure out the fundamental differences, we need to find out a few common point.

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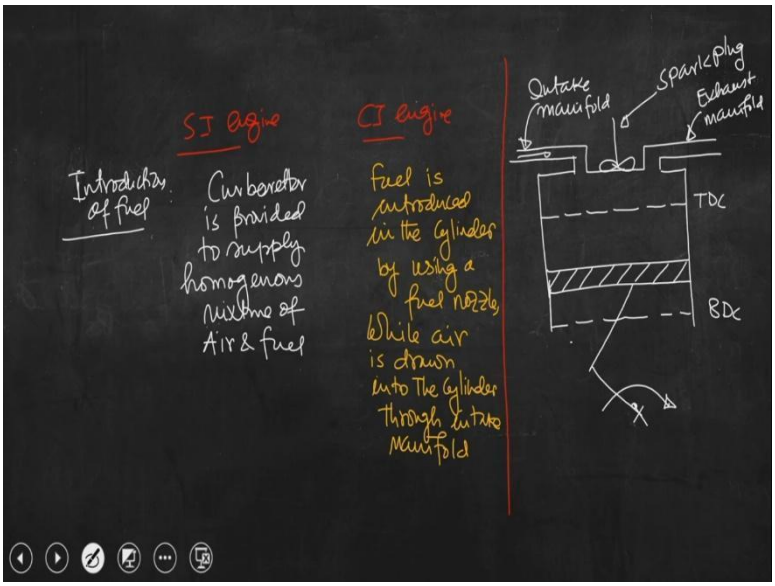


Say this is top dead center, this is bottom dead center and we have one spark plug. So, this is intake manifold, this is exhaust manifold, we have seen that during intake stroke the piston is coming from TDC to BDC fresh charge is coming through intake manifold into the cylinder. If we consider 4-stroke cycle engine, next stroke is piston is again traveling back from BDC to TDC. Both the valves are closed and the inducted fresh charge is now getting compressed towards the end of the compression stroke if we switch on the spark plug, spark will be initiated and that spark will help to ignite the compressed charge. Combustion will be completed and because of the combustion, the thermodynamic state inside the cylinder is the high pressure and high temperature of the working substance.

That will create a thrust on the piston face and piston will again travel back from TDC to BDC and that is the power stroke and since the movement of the piston is spontaneous because the amount of power that we are getting during power stroke will remain stored in the flywheel, because this is crank and this is connecting rod. So that crank will be rotating and that flywheel is connected to the crank shaft.

And that crank shaft will again borrow energy from the flywheel for the movement of the piston between TDC and BDC during 3 different ideal strokes. Now if we need to estimate the efficiency of the internal combustion engine, how much power is available at the crankshaft, we need to know the change in pressure, volume and other thermodynamic properties.

To map the functioning of 4-stroke cycle engine whether it is SI or CI engine, we need to map all the processes in different thermodynamic planes, we have understood that intake

compression, power and exhaust. So, this 4-strokes will occur in a cyclic manner. So, that means all the processes if we can map in a thermodynamic plane.

Then perhaps we can represent the cycle to be precise. So, in other word we need to know a particular cycle which will allow or which will map all the processes in different thermodynamic planes or ordinate diagram. So, the basic cycle for analyzing the performance of SI engine the is Otto cycle. So, I am writing over here that is the Otto cycle, see the name Otto is coming, because a German inventors Nikolas Otto who invented this.

And Nikolas Otto is credited as the first creator of the operation of 4-stroke cycle SI engines using one particular cycle and that cycle is Otto cycle. The basic cycle for the CI engine is Diesel cycle.

Again, let me tell you if this is the schematic for CI engine, then the spark plugs should not be there, instead of spark plug a fuel nozzle will be there. And if we need to describe the functioning of the 4-stroke cycle CI engine, we need to map all the processes in several thermodynamic planes and German inventor or mechanical engineer Rudolf Diesel first described the functioning of CI engine using a cycle and that cycle is known Diesel cycle.

Next basis on which we can differentiate the operation of CI and SI engines is the introduction of fuel, for the SI engines we have seen that carburetor is there. So, carburetor is provided to supply a homogeneous mixture of air and fuel while for the CI engines as I said that instead of spark plug will have fuel nozzle. So, fuel is introduced in the cylinder by using of fuel nozzle while air is drawn into the cylinder through intake manifold. So, this is the difference between SI and CI engines on the basis is the introduction of fuel. So, next basis is the ignition system.

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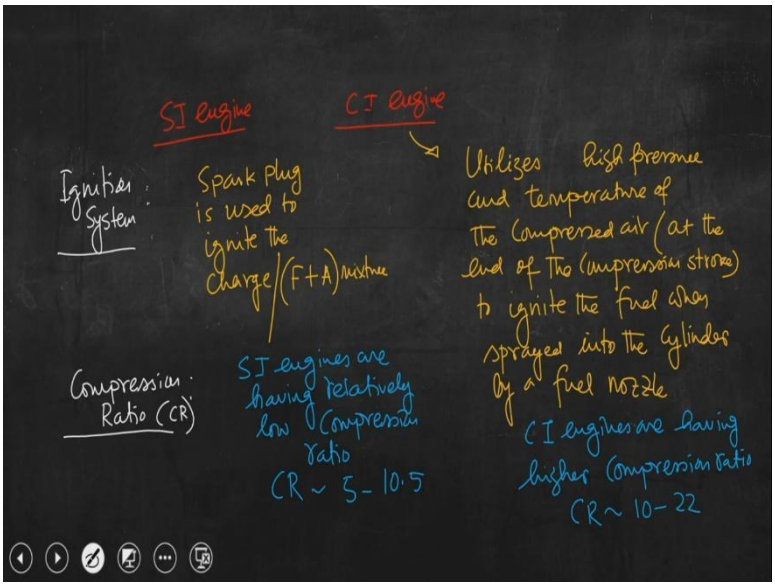


For the SI engine, we know that spark plug is there. So, spark is initiated by the spark plug and that spark initiate combustion while for the CI engines we have discussed that air is drawn into the cylinder through intake manifold that air is compressed and at the end of the compression stroke, thermodynamic state of the compressed air is such that when fuel is spread into the compressed air that thermodynamic state allows fuel to ignite. So that is called Auto ignition. So, essentially fuel is sprayed into the compressed air by a fuel nozzle and CI engines utilizes high pressure and high temperature of compressed air to auto ignite the fuel.

Next basis is compression ratio, SI engines are having relatively low compression ratio. So, the CR, compression ratio is 5 to 10.5, while CI engines are having higher compression ratio and CR is 10 to 22 CR.

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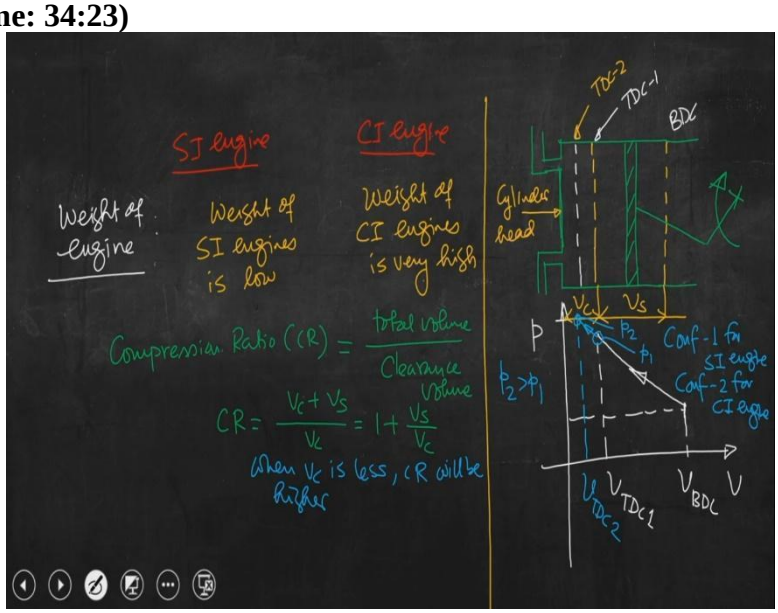

Last common basis for this comparison is weight of the engine. Weight of SI engines is low while weight of the CI engines is very high. So, we had started discussing about the fundamental differences between SI and CI engines, we had identified 5 common basis, one is the basic cycle another is the introduction of fuel third one is the ignition system, fourth is the compression ratio and last common basis for this comparison is the weight of the engine. Now, the last point weight of the SI engine is low while weight of the CI engines very high. So, the difference between SI and CI engines based on the weight can be directly related to the compression ratio.

So, now let us quickly discuss about what is compression ratio. So, I am writing here compression ratio that is CR. So, if we try to draw the engine cylinder so these two points, this is top dead center and this is bottom dead center and so this is intake, this is exhaust. So, this is volume V and this is pressure P.

So when piston is at BDC, this is $V_{BDC}$ and this is the volume, so this is the base pressure. So, when piston is coming from BDC to TDC both valves are closed in the compression stroke volume will reduce. So, when piston is at BDC that is in the beginning of compression stroke cylinder space is filled with fresh charge, both values are closed, piston is traveling back from BDC to TDC, volume will reduce pressure will increase.

So now if we say this is the point and so this is $V_{TDC\ 1}$ and pressure will increase. So, this is the change in pressure. So, you can see that as piston travels from BDC to TDC during compression stroke, definitely volume of the charge will be reduce, pressure will increase. So, if we now look at this 2-dimensional schematic this length over which piston is having to and fro movement is known as stroke length.

And the volume in 3-dimensional space is the swept volume Vs. So if we now look at the 2 dimensional schematic we can see only the length and this is the length over which piston is having reciprocating movement and that length is stroke length, in 3 dimensional space, it is the volume and that volume is stroke volume Vs while the volume between the top dead center and the cylinder head is the known as clearance volume, so this is a clearance space. So, when we are trying to compress the fresh charge if it is SI engine or compress only air for the CI engines, the compressed charge or air will occupy the space that is known as clearance space. So, this is the volume between top dead center and cylinder head. Compression ratio is defined as the ratio of total volume by the clearance volume.

$$CR = \frac{V_c + V_s}{V_c}$$

Now let us consider another configuration and this is TDC-2. So, what you can see from this schematic depiction is that we are trying to reduce Vc, BDC is remaining same so that means we are increasing Vs that is the stroke volume. So, if we now look at this case, then we can see volume will reduce during the compression stroke definitely, so pressure will increase further. So, now if we consider that configuration 1 for SI engine and configuration 2 for CI engine what we can see so that means for configuration 2 Vc is less, when Vc is less CR will be higher.

So to have higher compression ratio we need to reduce Vc and that is the configuration 2, that is for the CI engine. So, for the CI engine what we can see when we are compressing to the extent, we are trying to compress the you know fresh air up to V TDC-2 and increase the pressure till $P_2$ and $P_2 > P_1$.

So, the pressure at the end of the compression stroke will be definitely higher for configuration 2 that is the CI engine we have considered over here because compression ratio will be high. So, if we increase the compression ratio, what we can see Vc must be reduced, the consequences that pressure will increase and that high pressure will allow fuel to auto ignite the moment when it is sprayed into the cylinder by a fuel nozzle.

But issue is if the compression ratio is high, then we have seen that the weight is also very high because for the higher compression ratio, pressure developed inside the cylinder is very high. So, to withstand that pressure, basically that time both valves are closed and engine cylinder is acting like a presser vessel. So, to withstand that high pressure cylinder will be thicker, to be precise wall of the cylinder will be thicker and weight will automatically increase.

So that is why if compression ratio increases, weight also will increases that is what we had written earlier. So, to summarize todays discussion we have tried to discuss about the most important difference between 4-stroke and 2-stroke cycle engines. Afterward we have discussed about the fundamental differences between CI and SI engines and finally we have introduced one important terminology that is compression ratio we have defined.

And then we have discussed the consequence of the higher compression ratio in the context of internal combustion engine. With this I stopped here today we shall continue our discussion in the next class. Thank you.