

IC Engines and Gas Turbines
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Lecture - 01

External and Internal combustion engines, Engine components, SI and CI engines

We will discuss about Internal Combustion Engine Gas Turbine theory. So, as I said that I will discuss about the internal combustion engine different you know aspects of internal combustion engine applications different parts their operation. And principle and gas turbine theory will be taught by my colleague Dr. Vinayak Kulkarni.

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Week-wise Course Plan		
Week	Lectures	Topics
1	L1	External and internal combustion engines, Engine components, SI and CI engines
	L2	Four-stroke and two-stroke engines, Comparison between SI and CI engines; and four-stroke and two-stroke engines
2	L3	Classification of IC engines, cycle of operation, Types of fuel used, Types of ignition, Types of cooling, Cylinder arrangements etc
	L4	Engine operating characteristics - Mean effective pressure, Various efficiency terms, Air-fuel ratio, Specific fuel consumption, etc
	L5	Otto, Diesel and Dual cycles
3	L6	Comparison between the cycles, Actual cycles and their analysis
	L7	Carburetor, Mixture requirements
	L8	Idling, cruising and power ranges
4	L9	Classification, Types of nozzles, etc. Ignition system, Battery and magneto ignition systems
	L10	Engine friction, Lubrication systems, Forces on piston

So, this is the week wise course plan of the course content that I am going to discuss in different weeks are the lecture wise.

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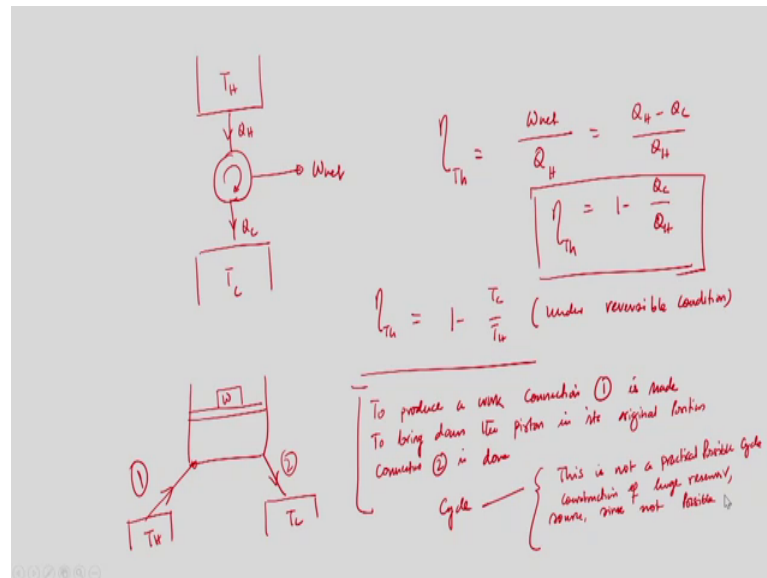
Week-wise Course Plan		
Week	Lectures	Topics
5	L11	Lubricating oils, Thermochemistry and Fuels, self-ignition
	L12	Octane and Cetane numbers Alternative fuels – Methanol, Ethanol, Hydrogen, Natural gas etc.
	L13	Combustion in S.I. and C.I. engines, pressure-crank angle diagram, etc.
6	L14	Energy distribution, Engine temperatures, Heat transfer in combustion chambers
	L15	Air-cooled and liquid-cooled engines, Modern trends

So, today I will discuss about the external and internal combustion engines engine components and S.I and C.I engine.

So, internal combustion engine is very important, because we when we talk about internal combustion engine; that means, the combustion is taking place internally. There is external combustion engine that is you know steam engine, that is what we know that earlier days people used to you know run train by using steam engine, but internal combustion engine that we need to know what are the different parts of the internal combustion engine and what are the operation and principle, what are the you know you know different types of internal combustion engine? And, of course, I will discuss in detail about the combustion and different types of fuel used for internal combustion engine all those things.

Now, very important is that for these subject particularly for internal combustion engine prerequisite is that student should know rather student should have you know knowledge about heat transfer and thermodynamics. So, today I will discuss from the basic things that if you talk about heat engine that is what you have studied in thermodynamics.

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So, we know that if heat engine that is an engine working between two you know temperature reservoir; one is higher temperature reservoir, another is lower temperature thermal reservoir T_L or T_C whatever it is, I will say T_C you know T_H and T_C . And this is you know engine is drawing heat Q_H and this is rejecting heat Q_C and if it runs and it we get W_{net} amount of work from the engine.

This is heat engine that is the engine working between 2 temperature thermal reservoir one is the hot T_H another is a cold T_C . And it is extracting heat from higher temperature thermal reservoir Q_H and producing some amount of work W_{net} and it also rejecting heat Q_C to the low temperature thermal reservoir T_C .

Now, we know that the efficiency of the engine $\eta_{thermal}$; thermal efficiency will be equal to W_{net} by Q_H in W_{net} by Q_H in here Q_H is equal to Q_H . So, now, W_{net} is equal to what Q_H minus Q_C divide by Q_H . So, I can write this is $1 - \frac{Q_C}{Q_H}$. So, this is the thermal efficiency of the heat engine. If, it is I can again write that if it in a under reversible condition.

So, this $\eta_{thermal}$ under reversible condition can be written $\frac{T_C}{T_H}$ this is under reversible condition. So, this is $1 - \frac{T_C}{T_H}$ under reversible conditions, but this is only for the Carnot engine not for other engines.

Now, question is from this if you would like to you know mimic a you know system. Suppose, we have a system and we have a weight let us say W and like a piston. And if I supply heat to the system let us say from our temperature reservoir T_H . And if you have a gas inside the or whatever it is I mean either gas or working fluid is there inside the inside the cylinder. The piston cylinder arrangement then it will expand and way it will try to late now.

And let us say this is one and again if I like to bring back the piston or the weight in it is the original position, then I have to extract heat from the from this and in that case it will take heat T_C . Suppose again I am connecting the system create thermal reservoir, where it is rejecting heat. And in that case if I (Refer Time: 05:07) heat and then it I will be able to bring down the weight piston in the original position.

But, it is not operating in a cycle right. It is not operating in a cycle with any single reservoir because heat must be so, whenever I am raising the piston of course, then piston will move in that case it is not operating with a cycle with the single reservoir. So, we need to bring that the piston it is original position and for that we need to extract heat, you know to bring the piston in the cylinder.

Now, to produce a work so, what we do? So, whenever it is connecting with one it is not a cycle because it is operating with a single reservoir. So, we need to bring down the piston in it is original position for that we need to have in the connection 2.

Now, to produce a work connection 1 is made. So, to produce a work connection one is made because if so, to produce a work connection 1 is made right. To bring down the piston in it is original position. So, to bring down the you know to bring down the piston or other weight. So, to bring down the piston in it is original position connection 2 is done; connection 2 is done or is a made and piston and to work in a cycle. So, it is basically a cycle. So, this is basically a cycle. So, I have connection one from where I am supplying heat to the system piston will move off. If I would like to bring back piston it is original position again I need to connect system through connection 2 and it will reject heat to the T_C .

And, see if I have kind of reciprocating motion that piston is moving up bringing down moving up coming down and if I somehow can make rather if I somehow can convert the reciprocating motion to the rotary one in that case I can red wheel. So, this is a cycle. So,

until and unless you are connecting the system through connection 2, it is not a cycle because it is working with a single reservoir. So, maybe to polish work connection one is made, but again to bring back the piston or to bring back the weight in its original position we need to make another connection through 2 and in that case it is a cycle ok. But, again I am telling in that case again I can have a reciprocating motion of the piston and if I have any you know connecting rod crank and connecting rod mechanism and by which I can convert this reciprocating motion to the rotary 1.

But, I am telling you this is not a practical possible cycle so, why? So, this is I am writing this is not a all the cycle, but this is not a practical possible cycle. Why? That I will discuss because construction of huge reservoir depending upon the requirement of the load we need to construct huge reservoir. So, construction of huge reservoir source sink not possible.

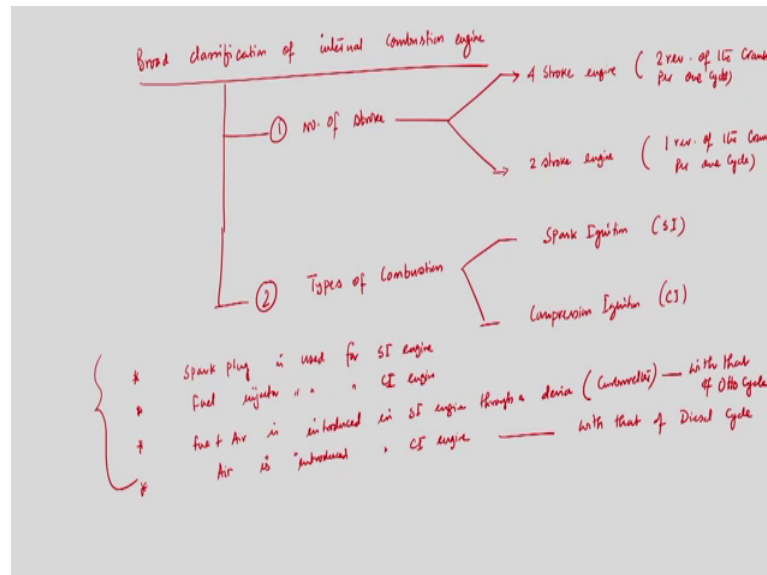
So, this is not a practical possible cycle why, because depending upon the load we need to construct huge reservoir that is not possible again we need to construct source huge source and huge sink. So, this is not you know practical possible cycle, but we can below the concept and if we from that heat engine. And if I somehow construct engine from where it will be working in a cycle and from where I will convert I will have a reciprocating motion of the piston. And if I can convert that reciprocating motion into the rotary one then I can rotate wheel.

This is while about the you know concept and that is what I am getting from heat engine. Now, question is I will discuss in detail that although it is a cycle, but I cannot call it a thermodynamic cycle, why that I will discuss in the context of operation of different engines in the in our subsequent lectures. So, external combustion engine that is what I told that in that case combustion takes place externally and from there we can somehow have again reciprocating motion we can convert that into the rotary one and it will that it will allow to have a rotary motion. So, that I can run any you know either train or whatever it is.

But, internal combustion engine where combustion takes place internally. So, there will be some you know constructional difference between external combustion engine and internal combustion engine that I will discuss, but before I go to discuss about those let

us first deeply discuss about the types of engine. If I talk about internal combustion engine then what are the types of engine?

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So, broad classification of internal combustion engine so, broad classification of internal combustion engine. So, this is broad classification of internal combustion engine, I can classify engine into different categories number 1, I can classify into first one is number of strokes right.

Again number of stroke it can be sub classified into 2 categories, 4 stroke engine and 2 stroke engine right, 4 stroke engine means we have 2 revolution of the crank per cycle per 1 cycle. So, I am writing here there will be for 4 stroke engine we will have 2 revolutions of the Crank per 1 cycle and for 2 stroke engine will have 1 revolution of the crank per 1 cycle.

So, this is all about 2 number of strokes I can classify engine based on the number of stroke and for that I have, I we may have 4 stroke engine 2 stroke engine will discuss about what is a 4 stroke and what is a 2 stroke engine? 4 stroke engine will have a 2 revolution of the crank per 1 cycle, in case of a 2 stroke engine will have only 1 revolution of the crank per 1 cycle.

So, because of 2 revolution of the crank per 1 cycle, we will discuss what are the different strokes and probably how many ideal strokes are there? How many power

strokes are there that will discuss and I will discuss what are the benefits of having 4 strokes instead of 2 stroke in a internal combustion engine. Second is that can be again engine can be classified based on the types of combustion. Types of combustion, it is again spark ignition engine, spark ignition, that is SI engine and compression ignition. And this is compression ignition engine C I.

So, compression ignition and spark ignition engine, spark ignition engine is used you know I am writing here very a few points. Spark plug an external agent which is used to initiate combustion, spark plug is used for SI engine number 2 fuel injector is used is used fuel CI engine. Fuel plus air not only air fuel plus air is introduced in SI engine, through a special device is not it is carburettor through a device through a device you know which is known as carburettor is very important part of the SI engine and it is with that of so, SI engine or working with that of Otto cycle.

But, in case of a CI engine only air is introduced, when air is introduced in CI engine no carburettor for SI CI engine no spark plug, we use the high pressure and temperature of the fuel itself to initiate the combustion. And this engines when you are talk about C I engine, that is we need to you need to map the thermodynamic processes in a we need to map the processes, which is occurring in a CI engine, in a thermodynamic plane. And through which we compare I mean in which we need to map say if it is 4 stroke engine different stroke and add each and every strokes, what are the state thermodynamic state that is pressure temperature in a thermodynamic plane. And that is compared with that of the diesel cycle with that of the diesel cycle.

So, these 4 are these are the few fundamental points that we should be remembered I mean we should remember rather. For SI engine spark plug and external agent which is used to initiate the combustion, because we need to initiate combustion through this spark plug. We cannot use the high pressure temperature high pressure and temperature the fuel itself. On the other hand fuel injector is used for the compression ignition engine that is CI engine. In case of a SI engine, because your fuel itself cannot you know can be you know ignited.

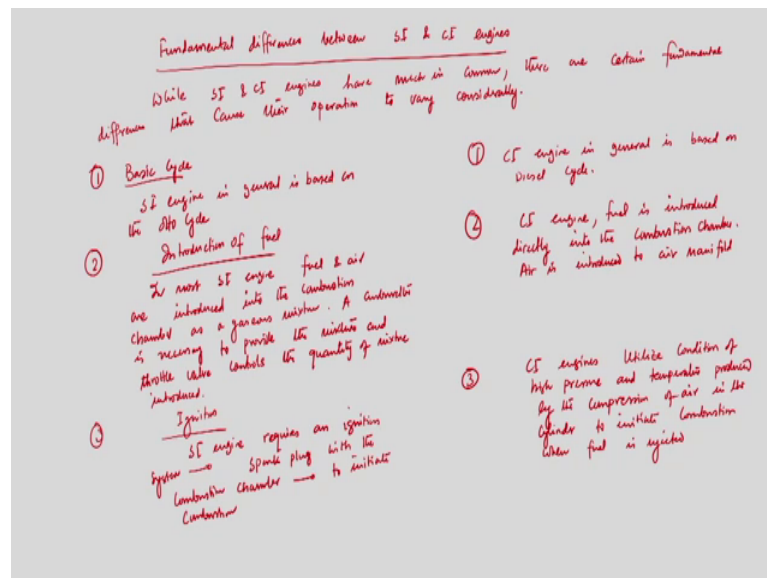
So, when I talk about combustion fuel itself cannot take part in the combustion we need to supply air. So, in case of a SI engine fuel plus air is introduced into the cylinder through a special device, which is known as carburettor and again I am telling that

whenever an engine is operating. So, thermodynamic state will change at each and every stroke, whatever it is if it is 4 stroke engine or 2 stroke engine. So, we need to map the thermodynamic processes rather thermodynamic we need to know the thermodynamic state at the end of stroke. And for SI engine though those are compared with that of the Otto cycle.

In case of a CI engine only air is introduced fuel is introduced through fuel injectors separately. And the thermodynamic states are mapped in a plane rather thermodynamic plane and which is compared with that of the diesel cycle.

So, now we have talked about CI engine and SI engine. So, I will now we will be discuss about that fundamental difference between spark ignition and compression ignition engine.

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So, fundamental difference between SI and CI engines. So, based on the types of combustion we can classify engines, spark ignition CI ignition engine, we have discuss about that for spark ignition engine we should have spark plug, because we cannot use the high pressure temperature of the fuel itself to initiate combustion. And we need to supply air plus fuel through a special device carburettor, but in case of a CI engine only air is introduced through air intake line, while fuel is introduced through fuel injector. And we use the high pressure temperature of the fuel itself for initiating combustion and because of what we need not to have spark plug external agent?

But, there are although so, in a CI engine we should not have a spark plug, we should not have carburettor, but now I will discuss about what are the fundamental differences between SI and CI engines, you know while SI and CI engines are much in common. So, I am writing that while SI and CI engines, while SI and CI engines have much in common features. Their there are certain fundamental difference differences rather, but cause their operation to where considerably, that cause their operation to vary considerably.

So, why SI and CI engine have much in common because so, for we have discuss about a few features; that means, in CI engine we should have a fuel injector in SI engine you should have carburettor and spark plug, but still there are certain fundamental differences that cause their operation to vary you know considerably. So, now, we will list down what are the difference, if I can tabulate if I can tabulate those differences. So, I am writing first one is basic cycle; based on basic cycle. So, number one basic cycle if I talk about the SI engines in general is SI engines in general is based on the Otto cycle that is what I have discussed.

So, SI engines in general is based on the Otto cycle right. So, this is basic cycle I am comparing number 1, while CI engine in general is based on diesel cycle right. So, this is very important. So, of if you talk about basic cycle there is a difference that SI engine in general based on the Otto cycle, while CI engine in general is based on the diesel cycle. Number 2 is very important that is the interaction of fuel, that is what we have discuss, introduction of fuel how?

In most CI engine the fuel and air mixture is introduced into the combustion chamber as a gaseous mixture. So, I am writing again that in most SI engine in most SI engine fuel and air are introduce into the combustion chamber, chamber as a gaseous mixture, as a gaseous mixture a carburettor is necessary to provide mixture and (Refer Time: 21:32) verb controls are quantity or mixture introduce.

So, I am writing a carburettor that I already told that a special device a carburettor is necessary to provide the mixture and throttle valve controls the quantity of mixture introduce right. So, in most of the SI engine fuel and air are mixture fuel and air are introduced into the combustion chamber as a gaseous mixture. And for that a special device which is known as carburettor which is used to supplier provide the mixture,

rather I can say the stoichiometric mixture that I will discuss above what is stoichiometric mixture? And a throttle valve which controls the quantity of mixture.

But, in case of a CI engine fuel is introduced directly, but in case of a CI engine, fuel is introduced in case of a CI engine fuel is introduced directly into the combustion chamber, directly into the you know combustion chamber. And air is introduced through air manifold and air is introduced air is introduced through air manifold or intake manifold air manifold. So, the air manifold is there through which air is introduced separately while fuels fuel is spread rather introduced directly into the combustion chamber.

Number 3 which is again important that is ignition there is a ignition. So, basic cycle that we have discussed that SI engine in general based on the Otto cycle, CI engine in generally is based on the diesel cycle. Basically would like to map the thermodynamic you know we would like to map the thermodynamic state, as a variation of pressure and temperature during each during every strokes in a in a thermodynamic plane. And that is compared with Otto cycle for SI engine and in case of a CI engine we used diesel cycle to map those.

Now, based on the ignition; the SI engine require an ignition system, because that is what I told that the for SI engine we required an external agent which is known as spark plug. Because, spark without spark plug it cannot ignite the a fuel. So, to initiate combustion in the engine cylinder we should have sparking system.

So, SI engine requires an ignition system. SI engine requires an ignition system culminating in spark plug with the combustion chamber to initiate combustion system, and which is done through carburettor a special device. SI engine requires an ignition system, which is sorry which is normally done through spark plug and with the spark plug within the combustion chamber that is placed. I will discuss while I will draw the you know schematic of an internal combustion engine spark plug with the combustion chamber essentially to initiate combustion. So, this is done to initiate combustion.

So, SI engine requires an ignition system that I am telling you rather I told you that in case of a CI engine we normally use the high pressure temperature at the end of the you know you know compression stroke to ignite the fuel. I mean without having an external

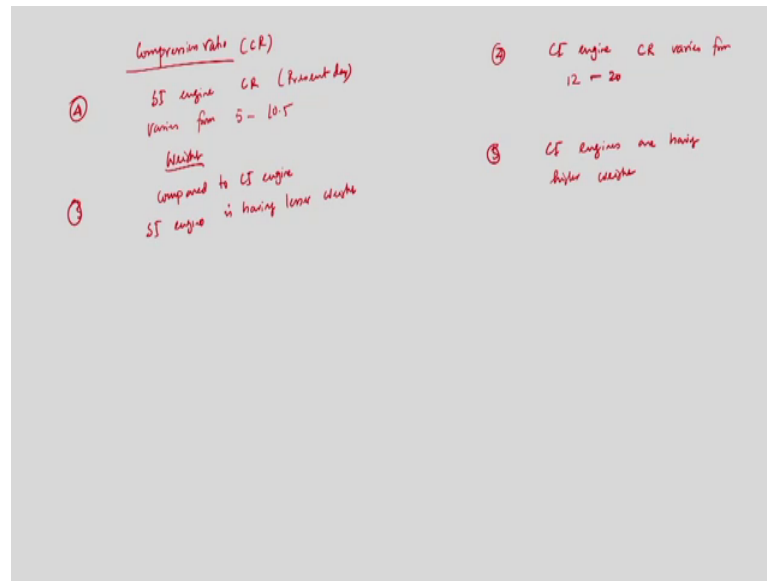
agent without having spark plug we can initiate combustion in case of a CI engine, but in case of a SI engine we cannot start combustion without having spark plug. So, that is we need an external agent, which will ignite the system through a spark plug and that is provided at the top of the combustion chamber and this is done essentially to initiate combustion, but in case of a CI engine.

So, the CI engines utilizes CI engines utilize condition of high pressure and temperature, condition of high pressure and temperature produced by the compression of the air produced by the compression of air in the cylinder.

Because, we take into account if you talk about 4 stroke engine. So, I will discuss. So, during the intake stroke we introduced air in the cylinder during compression stroke we compress the air. And at the end of the compression stroke when air will be having high pressure and temperature then we ignite we safe well. So, we utilize the high pressure temperature of produced by the compression of air in the you know combustion chamber. In the cylinder rather in the combustion chamber or in the cylinder I mean to initiate combustion. Of course, when fuel is injected of course, when fuel is injected?

So, in a CI engine what we do what is done normally? Air is compressed at the end towards the end of the compression stroke whenever air is having high pressure and temperature fuel is introduced or fuel is injected. And the engine itself utilizes the high pressure and temperature of the air during the end of the compression stroke to initiate combustion of course, when fuel is injected. So, this is next is very important compression ratio.

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So, I will discuss about again what are the what is the compression ratio? Compression ratio so, this is four you know the present the range of compression ratio for SI engine, for SI engine compression ratio CR, which present day in today's at present day range compression ratio varies from 5 to 10.5, but in case of a CI engine this compression ratio for CI engine this compression ratio varies from 12 to 20.

So, compression ratio is high for the CI engine we will discuss again this issue while will be discussing about the you know operational principle of the engines where the whether it is SI and CI. So, SI engine is for SI engine compression is a varies from 5 to 10.5, but for CI engine it varies from 12 to 20. And number 5 this very obvious because this is called weight compression ratio weight is directly related to the compression ratio.

So, since compression ratio for SI engine is a less. So, weight compared to CI engine compared to CI engine SI engine is having lesser weight, it is obvious because compression ratio is less again I am telling compression is roughly I am telling compression ratio high means cylinder which needs to withstand high pressure.

So, when we talk about a cylinder. So, of course, pressure inside the cylinder. So, this is this acts like a pressure vessel. So, compression ratio high means the cylinder which needs to withstand high pressure. So, if we think about that the cylinder itself just like a pressure vessel. So, to withstand that high pressure engine cylinder valve should be much more you know will be thicker as compared to that of the SI engine. Since, the engine

valve should be thicker essentially to it is an high pressure it should be it should have a higher weight. So, that is why for CI engines are normally have are having higher weight.

So, this is the you know think that is very important that so, this 5 words the fundamental differences. So, what again I am repeating although there have you know many more you know more features which are common for both the engines, but still there are some fundamental differences and fundamental differences are based on you know let us say basic cycle. As, I have discussed that basic cycle SI engine based on the Otto cycle and CI engine is in generally based on the diesel cycle.

I mean we compare the thermodynamic states during each and every stroke rather at the end of the each and every stroke in a thermodynamic plane and that is what is this we talk about cycle? Although, we are calling it a Otto cycle diesel cycle, but those cycles are not thermodynamic cycle that again I will discuss, because although the mapping thermodynamic states in a rather states in a thermodynamic plane, but those are not thermodynamic cycle rather we will call it mechanical cycle we will discuss.

Introduction of fuel that is very important because in most of the SI engine fuel and air are introducing the cylinder, because no I mean to precise fuel and air should be you know in a gaseous mixture. They are introduced in a as a gaseous mixture and I mean, whenever we are supplying fuel air mixture to a cylinder we should rather engine should take the stoichiometric air fuel ratio at essentially to have you know very efficient combustion. I mean if we supply more air or less air then either combustion will be mixture will be to lean or to rich in that case combustion should not be efficient.

So, essentially to have efficient combustion we should we should supply stoichiometric air fuel ratio and that is done through a special arrangement which is known as carburettor, because carburettor allows to supply you know gaseous you know stoichiometric air fuel ratio. And it allow the fuel air to be mixed in a that is in a in a more homogeneous form. And we have a throttle valve that controls the quantity or mixture that is introduced, but in case of a CI engine fuel is introduced directly into the engine cylinder while air is taken through air manifold.

Ignition again is very important that is what because to initiate combustion in a SI engine we need to have a we need to have an external agent that is spark plug. So, spark plug is

provided which is placed at the top of the cylinder. So, at the end of the compression stroke we need to initiate we need to you know initiate the spark plug which will allow the ignition rather essentially to allows to create a spark which will allow the combustion to starts I mean initiate the combustion. But, in case of a CI engine that is very important that air is compressed and whenever air is compressed during rather towards the end of the compression stroke, air will have a pressure temperature the condition of that state will allow combustion to initiate when fuel is injected without having an external agent.

Fuel is SI engine compression ratio; compression ratio is something that I told you that compression ratio indicates the you know pressure that is with that we need to build during the end of the compression stroke. So, in case of a SI engine since we are having external agent for that is spark plug to initiate combustion. So, we do not require that the pressure and temperature of the air fuel mixture to be that high. I mean and for that compression ratio is generally low and since compression ratio is generally low; that means, engine does not require to is in the high pressure and for that weight will be less, because engine wall of the engine cylinder is not need not to be very thick.

In case of a CI engine, because we are utilizing that the condition of high pressure and temperature to initiate combustion without having an external agent. So, of course, we need to have high pressure and temperature at the end of the compression stroke. Since, we need to withstand that is since we need to develop that high pressure cylinder has to withstand that pressure and for that if you think about that cylinder is acting like a pressure vessel. So, if cylinder would like to cylinder is withstanding that pressure. So, of course, the wall of the cylinder has to be thicker.

And for that CI engines are normally having higher weight. So, with these I discuss I stop my discussion today and I will continue a discussion next class, where we will discuss about the schematic diagram of an SI engine and then we will discuss about different strokes rather 4 stroke and 2 stroke engine. And when you are talk about 4 stroke engine what are the different strokes and as I said you that in a 4 stroke engine we should have 2 revolution in a per of the crank in per 1 cycle, while for 2 stroke engine we should have wall revolution of the crank per 1 cycle. So, of course, we will have certain advantage and disadvantages rather advantages and disadvantages when we talk about 4 stroke and 2 stroke engine and we will discuss in details.

And of course, we will discuss about the schematic of SI engine. So, maybe we need not to draw the schematic of CI engine again, because SI engine and CI engines are schematically they are different that in a CI engine we should not have spark plug we should not have carburettor. Rather we should have fuel injector to supply fuel into the engine cylinder directly and air will take through the air manifold. So, those issues we will discuss in the next class.

Thank you very much.