**Applied Thermodynamics**
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**Module - 03**
**Internal Combustion Engines**
**Lecture - 22**
**IC engine – Components, Nomenclature and Classifications**

Welcome to this course Applied Thermodynamics. So, in this course, we are in the module 3 that is Internal Combustion Engine.

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In this module, we are going to cover the following topics: internal combustion engines – components, nomenclature, classifications. 2nd lecture would be basic engine cycle, engine kinematic analysis; engine operating characteristics; thermodynamic analysis of air standard cycles.

Then next we have valve timing diagram and fuel air cycle; thermochemistry and fuel characteristics; combustion phenomena in engines; heat transfer analysis in engines; then finally, we will have exergy analysis, engine pollution and emissions.

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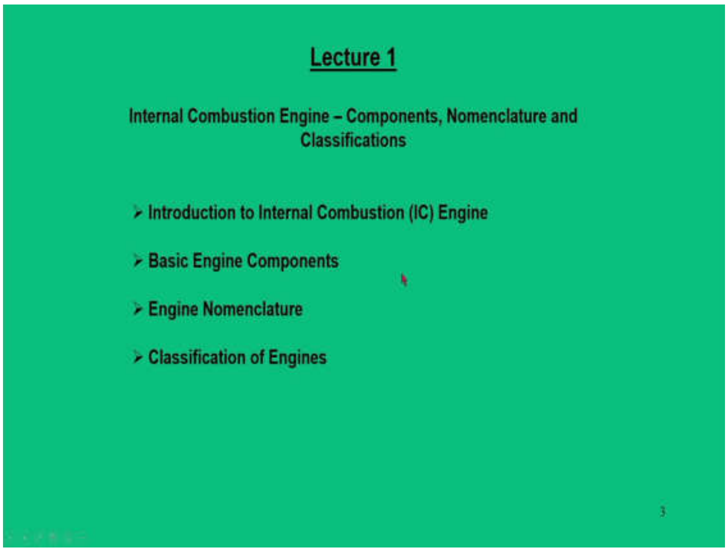


So, let us start the first lecture. In this first lecture, we are going to discuss about engine components, nomenclatures and classifications.

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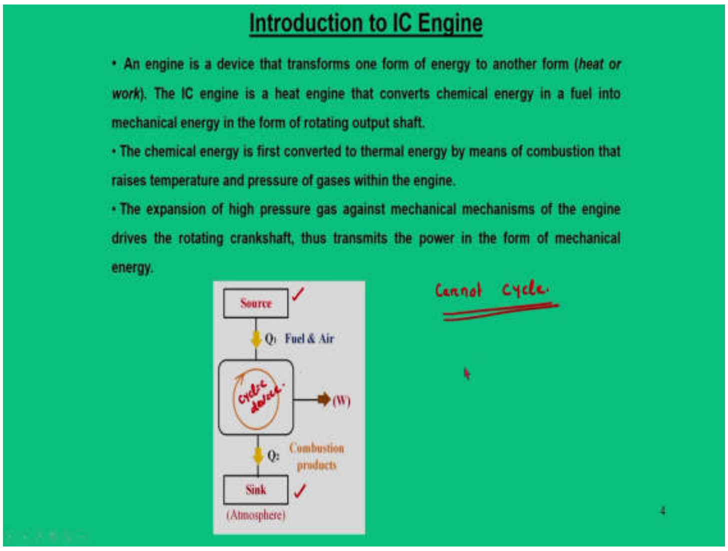


So, let us start what is a engine. In a Layman sense what we can say is that engine is a device that transforms one form of energy into another and in thermodynamics sense, we say that energy is available in the form of heat or work.

Now, when you tell this is a IC engine or internal combustion engines; so, we say it is a heat engines. So, when it is a heat engines, it converts the chemical energy of a fuel into the mechanical energy in the form of rotating outputs shaft. So, in thermodynamic sense we view the output energy as work output in the form of rotating and output shaft.

Now, when you do this change from chemical energy to mechanical energy in the first process what happens the chemical energy is converted to thermal energy; that means, the energy is available in the form of fuel and it converts to thermal energy. And, this happens by the phenomena called as combustions and this combustion rises the temperature and pressure of the gas within the engine.

So, by virtue of this increase pressure and temperatures, when we expand this high pressure gas through some mechanical mechanisms and in this case we call it as a engine, then we can drive a rotating crankshaft. So, in this process we get the power output in the form of work. Now, the concept of engines comes from the fundamental second law of thermodynamics and it is governed through Carnot cycle.

So, in this Carnot cycles, we have a source, we have a sink and between the source and sink there is a cyclic device. So, this particular circular one, we call this as a cyclic device. So, this cyclic device receives the heat from the source and this heat comes from fuel and air mixtures in the form of $Q_1$ and finally, it is combusted in this cyclic device.

And, after combustions we get work output in the form of the rotating crankshaft and the exhaust energy or we call this as waste heat goes to the sink. So, the second law thermodynamics that is Carnot cycle is the governing principle for IC engine operation.

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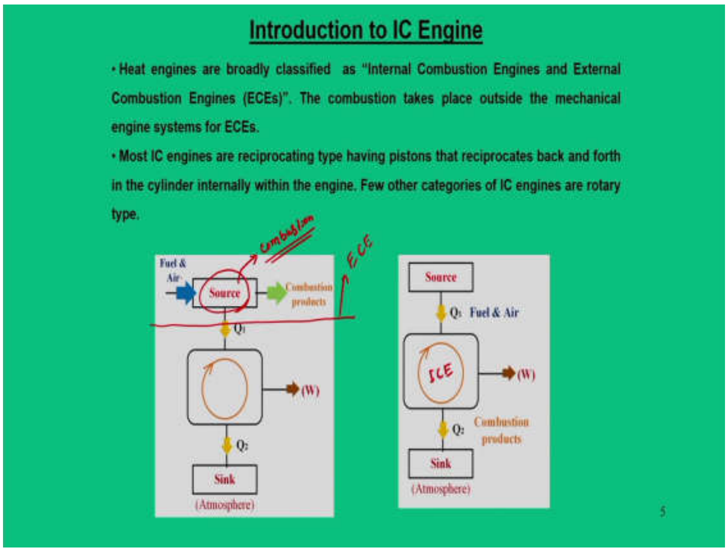


Now, let us see in what sense we can classify these heat engines. So, normally heat engines are classified as internal combustion engines and external combustion engines. So, in an external combustion engine the combustion mostly takes place outside of the mechanical systems.

So, for example, in this Carnot cycle if you just suppress this as one particular part and you say this is source which is a location where we can burn the fuel and air through combustion and this particular part we isolate it from the rest of the thing components, then we can say that the combustion takes place outside the mechanical engineering components.

So, this particular things we call this as a external combustion engines. Typically one particular example what we can give is that in a boiler. The boiler in a steam power plant receives fuel and air mixture and somewhere outside this boiler the heat takes place and that heat is used to change the state of water to steam. And finally, the combustion products goes out. So, this particular part we say these are ECE, external combustion engine.

But, that is not part of this particular module. We will be mostly concentrate on the internal combustion engine part. So, we view Carnot cycle in this format where heat is added to the engine so, we say IC engine in the form of fuel and air and after the combustion within the engines, we get shaft output in the form of work and rest of the combustion product goes out to the sink and this is atmosphere.

And, our main focus will be on this part. Now the question here is that where this engine can be of reciprocating type or rotary type. So, this IC engine can be of reciprocating type or rotary type and in our analysis we will mostly consider on the reciprocating type engine.

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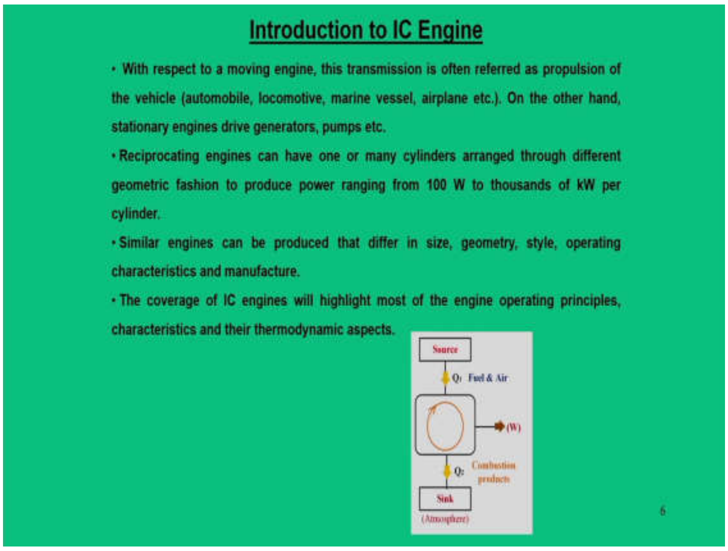


Now, to give some of the more insight to these engines, the process of this Carnot cycle when you take the power output, there are multiple ways that you can use this power output. So, one particular sense that we can take this as a electric power or power output, other way is that you take this work output in the form of creating propulsion or motion of a particular body.

So, that things are mainly used in the transport sector where power is transmitted in moving a vehicle. So, in that sense we use this power as a propulsion device. So, in some sense automobile is also a moving vehicle, locomotives, marine vessels, air planes all these cases it is moving a particular vehicle.

But, there are other usages as well, say we can think of even a stationary engines in the form of generator or pumps that are also used, but they are not in moving any type of vehicular body rather they are used mainly for transmitting power.

Now, when you say reciprocating engines there are possibilities that we can have single cylinder, multi cylinders and they can range from different powers from 100 watt to thousands of kilo watt per cylinders. Now, in this particular things there are many manufacturers that they produce IC engines. So, those engines can vary in size, geometry, style, operating characteristics etcetera.

However, our main focus in this IC engine will be mainly thermodynamics parts. Because the course theme is applied thermodynamics and for IC engines applications, we are try to focus how we can link is a fundamental principle with respect to thermodynamic laws.

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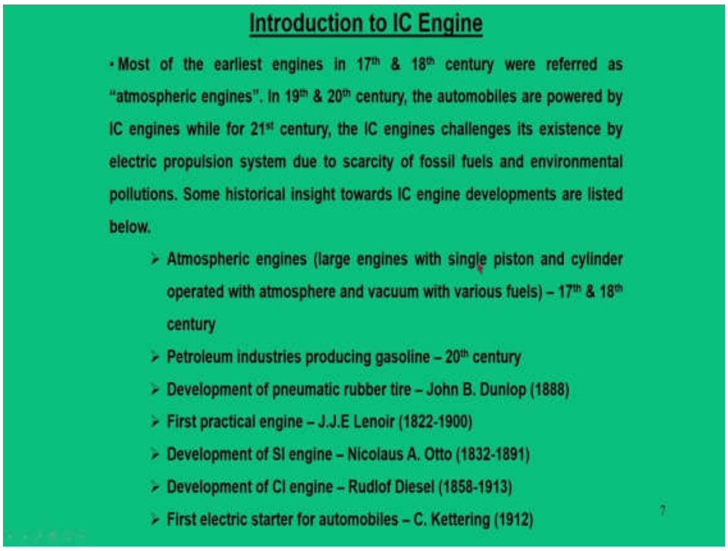


To give certain background to this engine development, I have listed down some of the concepts which were existence since 17th and 18th century. During that time when the engine comes to the existence, it was called as atmospheric engines where atmosphere and vacuum were treated as the two pressure differentials to run that engines.

Slowly in the 20th century the petroleum industries started producing fuel. Because the engine requires some fuel; so, petroleum industries started producing fuels and through this process of developments, we have developed rubber tires for the motion of the vehicle. The first practical engine was realized or maybe you can say commercial version was realized by Lenoir sometimes in the 19th century.

And, those fundamental principle of those developments was based on two concepts one is SI engine concept which is called as spark ignition other was the compression engine concept that is CI engines and in fact, all of us we are familiar that those engine developments were developed to by Nicolaus A Otto. So, based on which we have Otto cycle and R diesel based on which we have diesel cycles.

And, many a times to run this engine or to start the engines we require some initial thrust. So, for which an electrical mechanisms in the form of electrical starter was developed in the year 1912. So, for the starting purpose we require some electric mechanism to start the automobiles.

But, till this point of time IC engines have been used in plenty but, however, in the 21st century the IC engines role is going to be obsolete because of this scarcity of the fuel and what is coming to the market they are named as electric propulsion system or electric vehicles.

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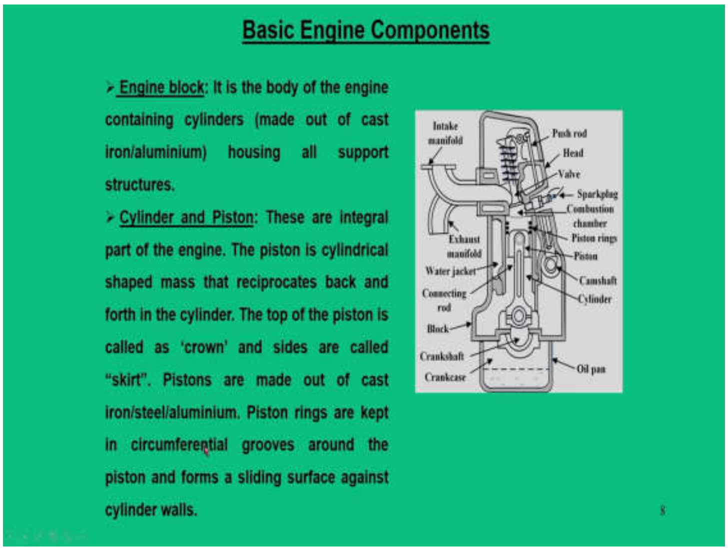


So, now let me start the basic engine components. So, in this basic engine components what I have shown here is a typical cross-section of an engine block or engine arrangement in which there are many components that is integrated to make a complete engine set up.

So, the first component is the engine block. So, it is the body of the engine containing cylinders made out of cast iron or aluminum and it houses all the supporting structures the next important item is the cylinder and pistons. And, these are two are the integral part of the engines and if you see with piston, piston has one upper part which is called as crown, we have side part which is called as skirt and the piston movement within the cylinder has to be smooth. So, for that reason there are piston rings that are housed in the circumferences. So, this allows the smooth motion of the piston within the cylinders.

So, this is how what I have written here these cylinder and piston are the integral part of the engines. Piston is the cylindrical shaped mass that reciprocates back and forth within the cylinder. The top up part of the piston is called as crown whereas; these sides are called as skirt. Piston is made out of cast iron, steel or aluminum and there are piston rings that are kept in the circumferential grooves around the pistons. And, it forms the sliding surfaces against the cylinder wall.

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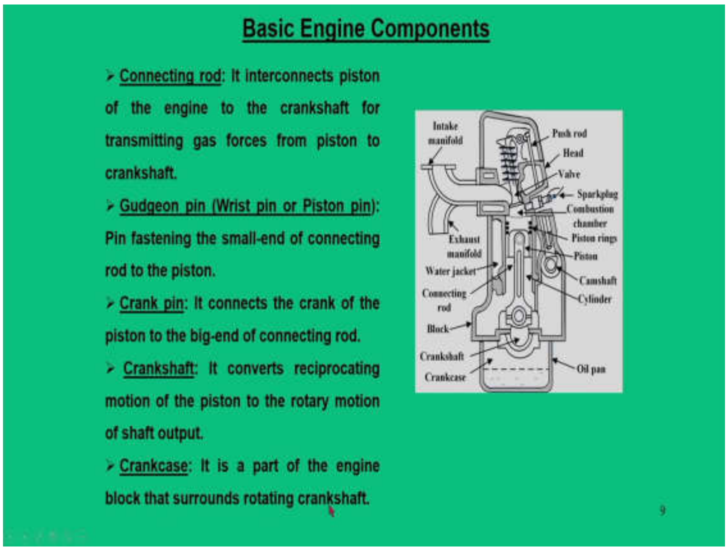


Now, the motion of this piston which is linear in nature has to be converted to rotary motion so that we can get that rotary motion in the form of rotating crank shaft. To do that the piston is connected to the crank shaft through a connecting rod.

So, the connecting rod interconnects the piston of the engine to the crank shaft for transmitting gas force from the piston to the crank shaft in order to connect these two things – one we have a gudgeon pin. Gudgeon pin means this connecting rod has two parts: one is big end and other is small end. The small end is connected to the piston and through a gudgeon pin whereas big end of the connecting rod is connected to the piston through crank pin.

Then we have a crank shaft because this crank pin and the crank shaft is integral part. So, the cranks shaft converts the reciprocating motion of the piston to the rotary motion of the shaft output. So, how it does we will see in the later part of this course. Then we have crank case it is the part of the engine block that surrounds the rotating crank shaft.

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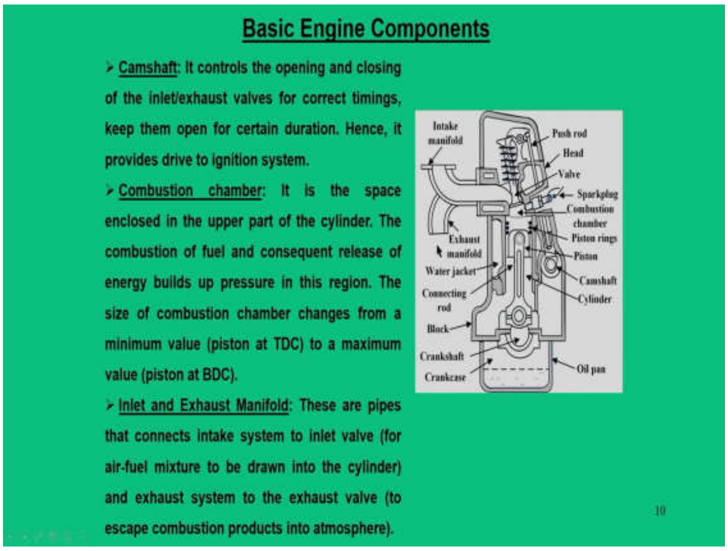


The next important segments of this engine is the cam shaft. What we require is that we require fuel into the engines and also we require air intake system to the engines.

So, all these things come from to the engines through an intake manifold, but what happens is that the engine requires fuel and air in proper timing and for certain durations and also the fuel also been ignited at right time. So, entire things is governed through a shaft what you call as a cam shaft. So, this cam shaft allows or regulates the inlet and exhaust valves for correct timings, and keep them open for certain durations.

So, it provides a drive for the ignition systems. Now, when the air fuel mixture goes into the combustion chamber which is the space enclosed in the upper part of the cylinder, the combustion of fuel and consequent release of energy builds up pressure in this regions.

So, typically the size of the combustion chamber changes from minimum value to the maximum value. The size or space means the amount or slog of mass that gets accumulated within the chamber that changes because of the piston movement. So, the minimum volume is acquired when the piston is at TDC, maximum value is acquired when the piston is at BDC.

Also I explained that there are intake and exhaust manifold. These are the connecting pipes with lot of valves in between that regulates the air and fuel to come into this engine and also at the same time the exhaust manifold will allow the all unwanted combustion products to go out of the engines.

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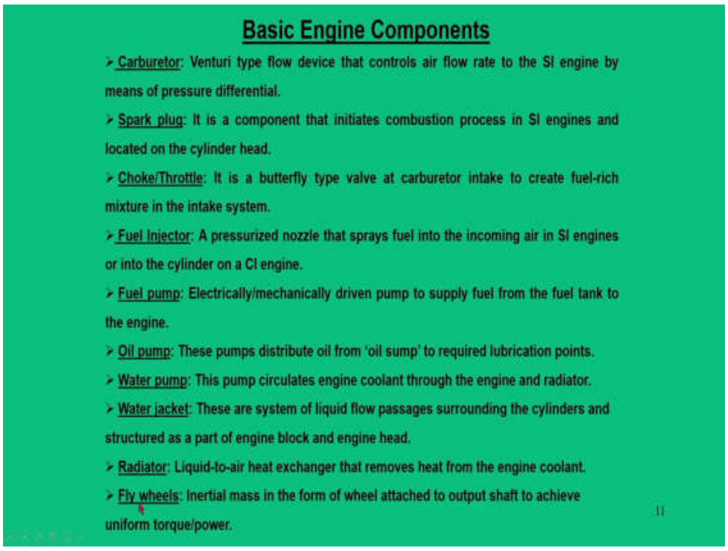


So, apart from these basic components there are many other components. I can just spell out some of them that we have a carburetor. So, it is nothing, but a venturi type flow device that controls the air flow rate to the SI engine. In fact, carburetor is main component for an SI engines and essentially this gives a pressure difference so that the intake air enters into the engine.

Now, in this SI engines there is another mechanism in which the fuel needs to be ignited. So, that combustion process can be initiated. So, that is done forcibly by a spark plug or it through an electric discharge created at a particular time. There is another component which is called a choke or throttle. This particular choke or throttle we used to have very common practices in our day to day life while driving a two-wheelers or any bike.

So, it is nothing, but it is a butterfly valve that creates a fuel rich mixture into the intake systems. It allows more fuel to enter into the engines from the fuel tank and in particular there are other devices like fuel injector. So, these are kind of pressurized nozzles that sprays fuel into the incoming air for SI engines and into the cylinder in a CI engines.

So, directly it is spread into the cylinder for CI engines. So, you have fuel pump. So, it is a electrical or mechanically driven pump to supply fuel from the fuel tank to the engines. Then we will also have oil pump. So, oil pump is something like a lubricating oil. So, it has nothing to do with the fuel system. It has a lubricating oil as I had mentioned that may there are many mechanical components that needs to be lubricated properly.

For example, when the piston moves within the cylinder there are piston rings and there are some space in which the lubricating oils also has to be pumped in because we expect the piston movement is smooth within the cylinders. So, for that reason we call this as a oil pump and in typically we say lubricating oil pump.

It distributes oil from oil sump to the lubricating points there are also water pumps and this water pump is mainly used for CI engines because we require some engine coolant that needs to be circulated to take away heat from the engines. Also if there is no water pump, we can have also radiator and also there are radiators that needs to be also cooled.

There are also we have water jackets; that means, in a big engines we use a some kind of liquid flow passages that surrounds the cylinders and structured as a part of the engine blocks. So, it is like a sweater for the engines and here the idea is that jacket takes away all kind of heat. Water jacket takes away heat from the engine cylinder.

In small engines we have radiators they are in the form of fins. So, it is a liquid to air heat exchanger that removes heat from the engine coolant. Apart from this there we have fly wheels. So, these are inertial mass in the form of wheel attached to the output shaft to achieve uniform torque or power.

So, what happens? Since it is a reciprocating engines there is one particular cycle there is a power, in rest of the cycle there is no power, but ideally the body or vehicle has to move at uniform speeds. This entire thing is governed through a mechanism called as fly wheel.

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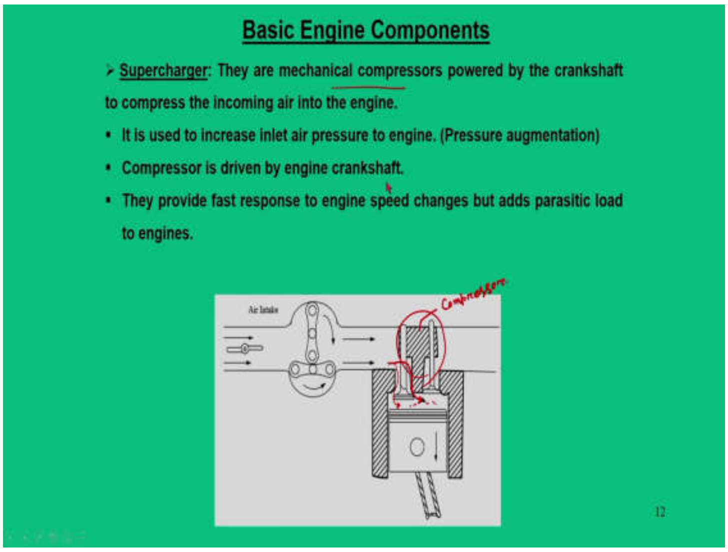


So, these are all the basic components for any normal engines. But in advanced engines people think of additional components and first additional components is a super charger. So, it gives additional increase in the pressure apart from its normal value. So, this is done through a mechanical compressors, and basically speaking if you look at this particular figure we have the air intake system to the engines.

So, this particular part the air fuel has to come to this combustion chamber ideally for a normal engines. But, what happens in a supercharged engines; this particular movement of air is again is controlled through a mechanical compressors which is housed here.

So, instead of directly sending into the engine cylinder, it has to go through this compressors for additional pressure boost. So, this particular compressors gives additional inlet air pressure to the engines. So, normally we refer this as a pressure augmentation.

So, in this process what advantage we get is that whenever the you we change the speed of the engine immediately it responds because we have a super charger, but the main drawback is that it is added as a parasitic load to the engines means that it needs to be powered from the main engine systems. So, the compressor is driven through the engine crank shaft because it takes the power from the main engine itself.

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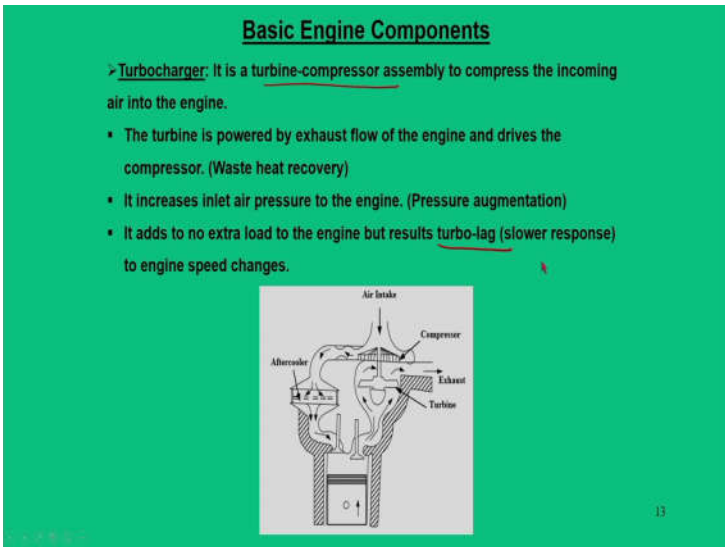


Now, there are other concept as well. So, we have the turbocharger. So, the turbo charger also does the same thing that it gives a pressure augmentations or it increases inlet air pressure of the engines, but through a different technology. What is that? That is called as turbine compressor assembly and through this turbine compressor assembly, it performs one important role in terms of thermodynamic sense that is waste heat recovery.

So, from the engine exhaust, we can say that a lot of unwanted energies are still available, but we can use them with proper arrangement. So, a mechanism is thought of in which the turbine is used and it is powered through the exhaust flow of the engines and these turbines drives the compressor in a sense that the turbine does not take any extra power from the main engine block rather it taps the heat or energy from the exhaust gas and that drives the compressors.

So, it does not add extra power to the engines. So, that is main difference between a turbo charger or supercharger, but when we run this turbo charge engines? There is a kind of a lag. So, when the user changes the engine speed, there is a lag what we call as turbo lag or slower response but it adds pressure argumentation, but at a relatively slower response. So, we call this as a turbo lag.

So, that is the main difference between a turbo charger and supercharger.

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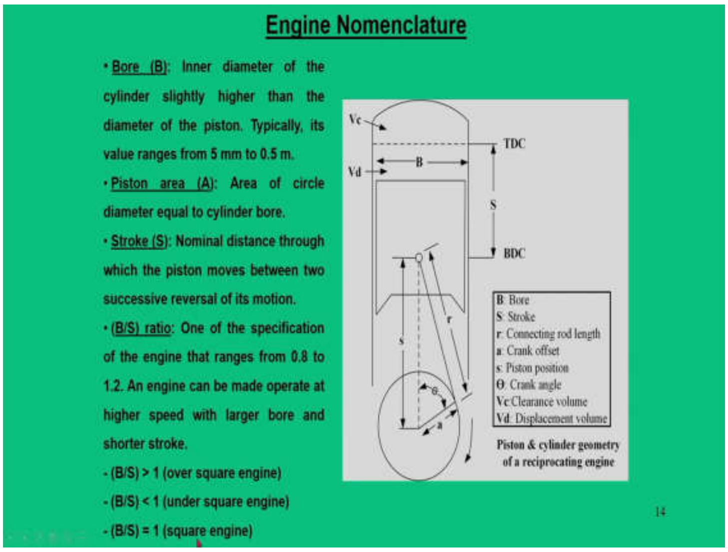


Then we will move to the next segment of this particular lecture that is engine nomenclatures. So, I have mentioned that cylinder and pistons these are two important segments of any IC engine and here it is represented in a very schematic manner. And in fact, what we have shown is that the complicated structure of an engine can be represented in this simple geometric dimensions.

We have a piston and this is the crank shaft and this part we say it is a connecting rod and the piston is connected to this crank shaft through this connecting rod, but at this point of time we will discuss is that some important terms with respect to engines.

First important term is engine bore. So, engine bore is nothing, but the inner diameter of the cylinder which is slightly higher than that of piston. So, basically the piston and cylinder dimension are adjusted with a very little bit tolerance so that piston can move smoothly within the cylinders. Typically, the bore diameter is in the range of point 5 mm 0.5 meter. So, once we have engine bore and the cross section is circular. So, we can have the piston area that is the area of circle diameter equal to the cylinder bore.

Then we have stroke that is nominal distance through which the piston moves between two successive reversal of its motions. So, what it means is that that piston moves the cylinder back and forth; there is a upper position which is called a TDC top dead centre that is the upper limit in which piston can go within the cylinder.

The bottom limit the piston can move is up to is BDC. So, distance between the TDC and BDC we call this as a stroke and in fact, from TDC the piston reverses its path. So, we call this as a reversal of its motion and same thing happens at BDC the piston reverses its path from bottom to top.

And, we have also another term which is called as B/S ratio that is bore to stroke ratio. So, it is one of the specification of the engines and for any normal engines it is value is in the range of 0.8 to 1.2. In this terminology, we can have a larger bore, shorter stroke or shorter stoke, larger bore.

So, based on that B/S ratio tells you that whether an engine is over square or that is B/S greater than 1, whether it is a under square B/S less than 1 and it is equal to 1 that is square engine.

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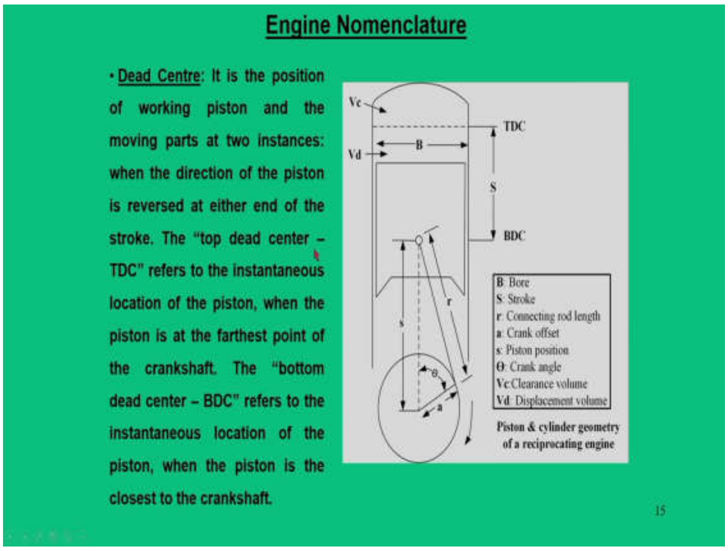


Also I mentioned the word dead centres and it is the position of the working piston and the moving part at two instances when there is a reversal in the piston directions. So, one we call is as a top dead centre TDC, other you call as bottom dead centre BDC. So, these are the terminology which we will be using frequently.

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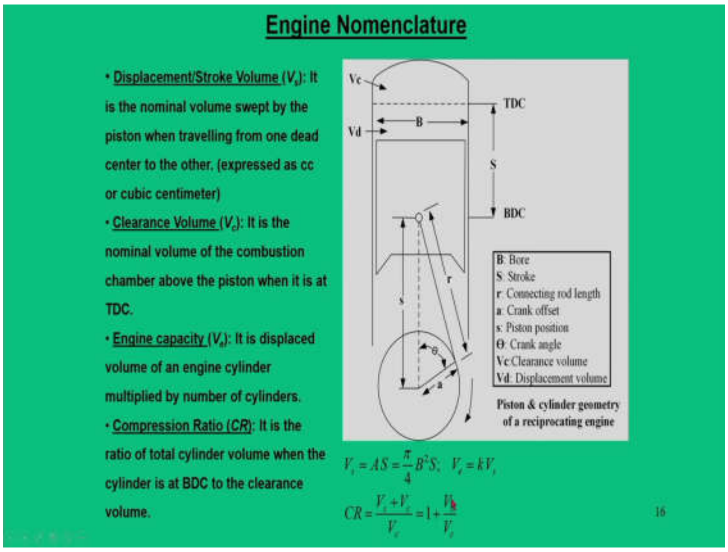


The next important term what we are going to use is the displacement or stroke volume. So, once we have all the dimensions of bore and stroke, then we can express them in the form of volume because the slug of mass is contained within a certain space. So, the displacement or stroke volume is defined as the nominal volume swept by the piston when it travels from one dead centre to other dead centre.

And, typically most of the engine cylinders are specified in the form of cc – 100 cc, 1000 cc, 800 cc. So, these cc we refer as cubic centimeter. So, all these numbers what we call as a stroke volume. Next we have the clearance volume. So, what happens is that when the piston is a TDC, there is some kind of a volume which is remains as a clearance volume and this is required. Because this has a very significant impact in the combustion chamber because entire volume has to be squeezed in a particular space during the engine operations.

So, we call this as a clearance volume. So, it is the nominal volume of the combustion chamber above the piston when it is at TDC. So, when the piston is at TDC, the volume which is enclosed in this combustion chamber, we call this as a clearance volume. So, here it is represented as a $V_c$.

Then we have engine capacity. So, in this case we have one cylinder, one piston, in particular engine you can have a multiple cylinders, multiple number of pistons. So, engine capacity is nothing, but it is the displaced volume of an engine cylinders multiplied by number of engine cylinders. Then another important word that we mainly use in this IC engine terminology is called as compression ratio.

So, it is the ratio of the total cylinder volume when the piston is at BDC to the clearance volume. So, whatever I have explained here mathematically we can represent $V_s$ is nothing, but the stroke volume that is nothing, but area of the piston into stroke that is nothing, but $\frac{\pi}{4}B^2S$. So, if there are k number of cylinders, then total engine capacity would be $V_e = kV_s$.

Now, based on the definition of compression ratio we can write the compression ratio is the total volume to the clearance volume. Total volume constitutes two parts one is stroke volume plus clearance volume divided by clearance volume and finally, compression ratio mathematically is represented as $CR = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c}$.

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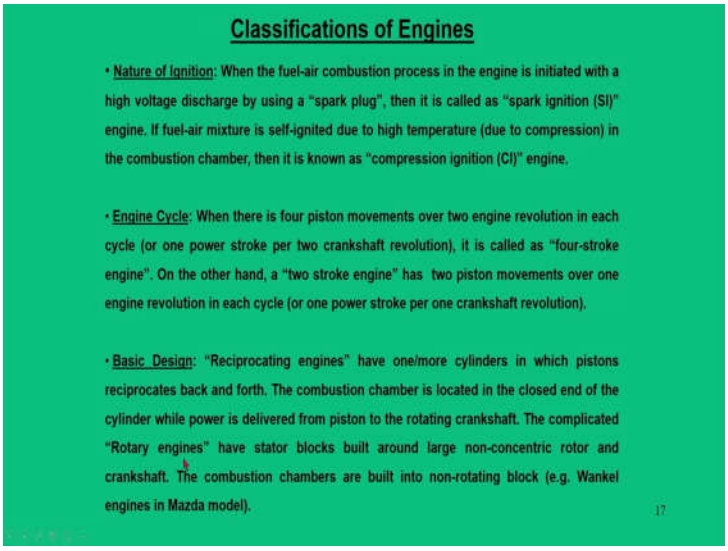


Then we talk about something about classification of the engines. So, in the classification of the engines we are going to discuss is the nature of ignitions. So, nature of ignition means that when the combustion has to be initiated within the engine cylinders. There are two ways one can do – one is manually create an ignitions, other way is that we allow the charge to ignite spontaneously on its own. So, based on that, we call this as a spark ignition engines or ignition engines.

So, when the fuel and air combustion process in the engine is initiated with a very high voltage discharge by using a spark plug. So, we call this as a spark ignition engines, when this fuel air mixture is self ignited due to high temperatures or due to compression on its own, then we call this as a compression ignition engines.

In the form of engine cycle, one can differentiate the engines as a two-stroke engine cycle or four-stroke engine cycles. So, when there is a four piston movement for two engine revolution in each cycles or in other words we obtain one power strokes per two crank revolution then we call this as a four-stroke engines.

One power stroke is obtained per two crank shaft revolutions, but in a two-stroke engines there are two piston movements over one engine revolution cycles. So, we get one power stroke per crack shaft revolutions. So, in the bottom line we say the one power stroke per two crank shaft revolution in a four-stroke engine and one power stroke per crank shaft revolution in a two stroke engines. I will be explaining in details in subsequent lectures.

And, in the basic designs that the engine can be of reciprocating nature or in we can of rotating in nature. So, in a reciprocating nature we have seen that the piston moves back and forth and there could be in one or multiple number of cylinders. So, the nature of the motion is reciprocating in nature.

We typically use rotary engines in the turbo machines and aircraft engines, where they have stator blocks and with non concentric rotor. So, those rotary engines are used mainly for aircraft applications. But, however, a commercial application for a rotary engine which was built we call this as a Wankel engine. Wankel engine a very common engine in a Mazda model. So, their design in automobile sector comes under rotary engine category.

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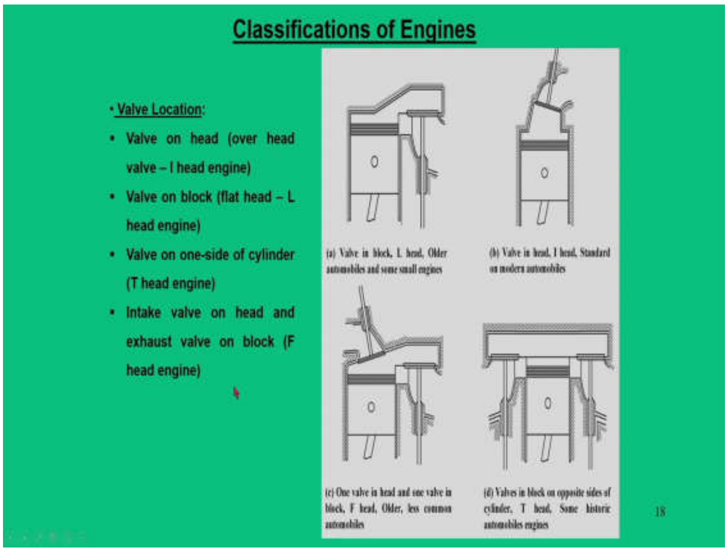


The other classification goes in the form of engine geometry depending on the location of the valve. So, based on the engine geometry, many manufacturers try to optimize their engine shape, designs in such a way they can improve the engines with a larger run or operations.

So, for that there are many designs are possible one can think of L heads. So, L heads means that is the inlet or exhaust valve is kept in the engine block.

So, we say it is a flat head or L head engines. This valve can be directly kept on the head itself. So, it is a I head engine. So, when there are inlet and exit valve, one can think of one valve on the head and other valve on the block. So, this can be a possible combinations; that means, we can think of one as inlet valve other may be exit valve.

So, this particular design we call this as a F head engine. There are other possibilities that we have engine cylinders, we have head and the valves are located on either side of the cylinders. So, it represents a shape of T. So, it is a T head engines. So, in that way there are multiple number of designs that are possible.

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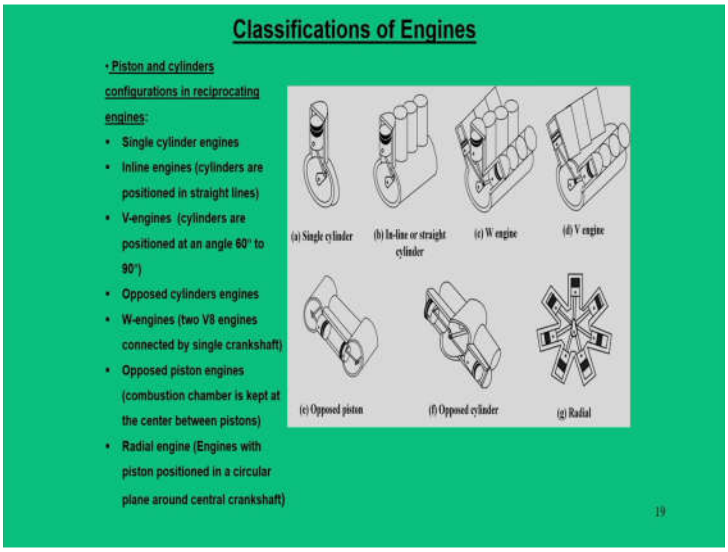


Another way of looking the classification is that how the pistons and cylinders are oriented. So, in a single cylinder engines we have one cylinder and one pistons or we can have one single straight cylinder, there may be multiple number of pistons.

We can have a V engines where there are multiple cylinders and multiple piston. Each cylinder has its own pistons. But they have made some angle which is in the range of 60 to 90 degrees and when two such V engines are joined together we get a W – engines or two V8 engines are connected to a single crank shaft.

Then, we have a concept of opposed piston engine; that means, where the combustion chamber is kept at the center between the pistons. Then, we have opposed cylinder engines also we have also can have radial engines. So, these are the engines with piston positioned in a circular plane around the central crank shaft. We have a central crank shaft, but the pistons are uniformly distributed radially. So, these are called radial engines. So, based on these kind of arrangements the automobile manufacturers use their concept for improving the performance of the engines.

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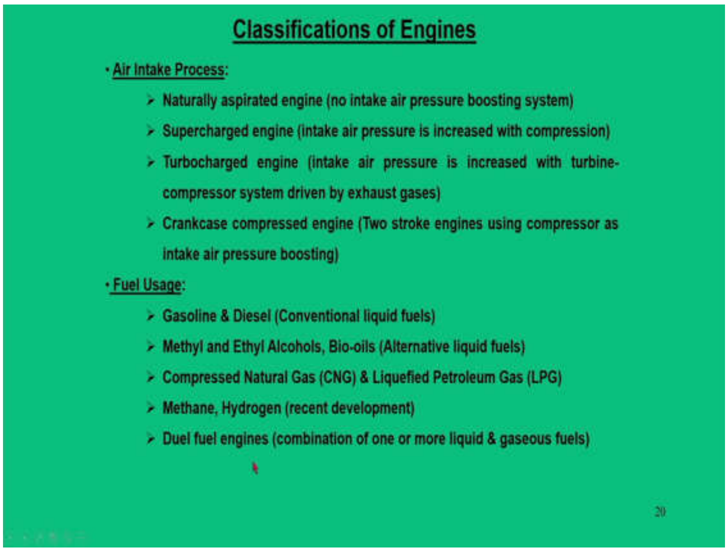


Then the classification goes in other direction as well in air intake process. So, engine requires fuel and air and now if you talk the engine with respect to air intake, how air enters into cylinder, there are possible ways. In a normal aspirated engines where there is no boosting of air, it comes on its own air intake or air manifold.

So, it is a naturally aspirated engines. I also mentioned the supercharge engine and turbocharge engines in which intake air pressure is increased with compressions. So, these are the two integral parts in which the intake air pressure boost up and typically these are the part of the four stoke engines and this super charge or turbo charge engines are modular in nature So, they can be integrated to any naturally aspirated engines.

But, there is a concept of crankcase compressed engines. So, this particular engines were used for two-stroke cycles in which they use compressors for intake air boosting. So, by default in a two-stroke engine cycle there was a compressor within the cranks case. So, we say crankcase compressed engines. So, in fact, since there is no two-stroke engines in the market. So, this concept is now obsolete.

Now, based on the fuel usage, engines can use mostly liquid fuels or you run the engine with solid fuel as well. So, accordingly we have a gasoline or diesel engines which are conventional liquid fuels. We have methyl and ethyl alcohols, bio oils – these are alternative liquid fuels. We can have compressed natural gas and liquefied petroleum gas, and in the advanced developments people are thinking of using methane and hydrogen as the fuel usage.

And, there are other research concept that goes as a duel fuel engines in which both liquid as well as gaseous fuels can be used simultaneously in an engine. So, those engines are called as duel fuel engines.

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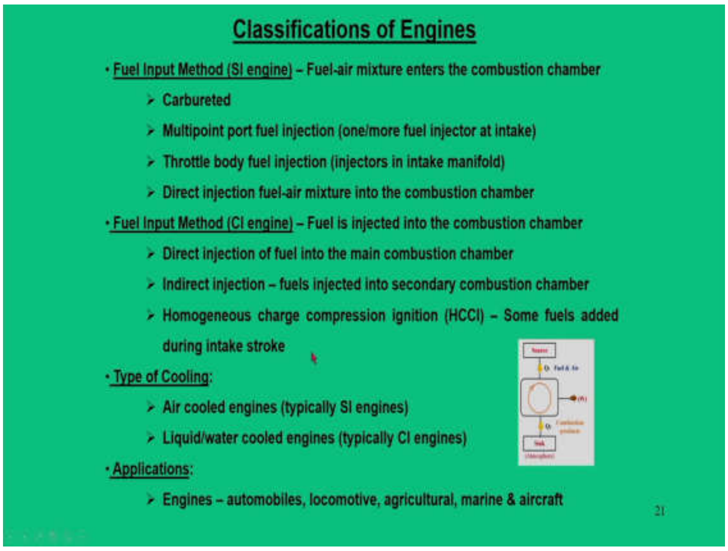


And, the last few concept is that fuel input method. So, now we will say how fuel comes to the engines. So, basically there could be two possibilities one we can use for SI engines, other could be used for CI engines. So, a basic difference is that in a SI engines fuel and air mixture enters into the combustion chamber as a whole.

So, when they enter they had to mix properly. So, we say it is a carbureted engines and these air fuel mixtures can go as a multi point port fuel injection mode ; that means, there are one or more fuel injector at the intake or we can take the entire slug to go as a single entity. So, we call this as a throttle body fuel injection; in that case we have to use the injector in the intake manifold.

The other option or most efficient option could be we can use this as a direct injection mode into the combustion chamber directly. So, this is how we can inject the fuel in an SI engines.

In a CI engines the concept goes in a different way. Air is compressed in the cylinder; fuel is injected into the cylinder directly. So, the possibilities could be that we have to use fuel nozzles to for direct injection of the fuel into the main combustion chamber.

Other possibility is that if there are big engines and there are provisions then we can think of a secondary combustion chambers; that means, we can have a main combustion chamber, we can have a secondary combustion chamber so, where indirect injection is also possible.

And, in advance technology people think of homogeneous charge compression ignition engines. That means, fuels are added during intake stroke ideally in the intake stroke we only compress the air, but here during intake stroke itself one can think of injecting the fuel into the cylinder. And, based on the type of cooling. So, we have seen that the engine exhaust it is in the form of combustion products.

So, most of the heat goes as a waste and in fact, the engine gets hot and hot as and when it operates. So, based on that we can have a air cooled engines typically SI engines where the engine is cooled by means of a circulating air other option is that we can think of liquid water cooled engines or we can think of water jackets. So, that is mainly used for CI engines.

And, lastly with respect to application point of view, we can use this engines either in the automobile sector, locomotive sector, agricultural sector, marines and aircrafts. So, these are the classifications of engine in variety segments.

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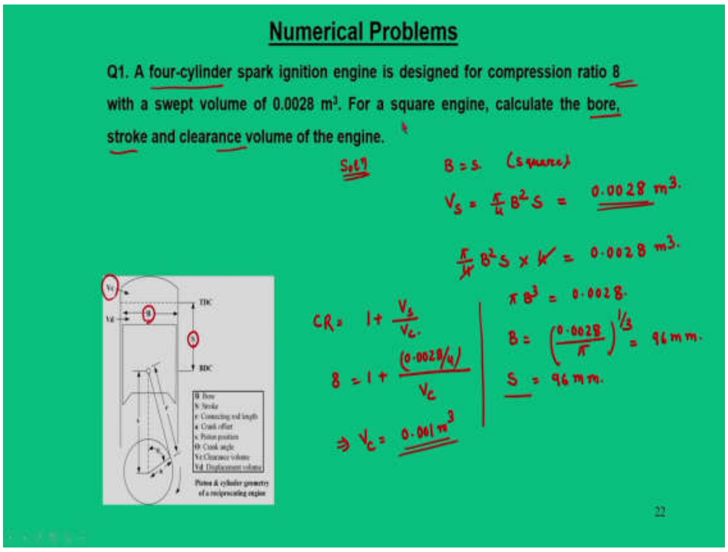


So, with this, I conclude this first lecture, but before I make the final things let us see what we have studied so far. Just to refresh some of the our study or analysis we try to solve some numerical problems, the first problem which is given to us is that there is a four-cylinder SI engines and it is designed for a compression ratio of 8 and given that it has a swept volume of 0.0028 m$^3$ and it is a square engines. So, we have to calculate the bore, stroke and clearance volume of the engines.

So, it is a square engines. So, we can say B=S; swept volume is given as $V_s = \frac{\pi}{4}B^2S = 0.0028\text{m}^3$. And, this swept volume is for four-cylinders.

For 4-cylinder means $\frac{\pi}{4}B^2S \times 4 = 0.0028\text{m}^3$. As B=S, $\pi B^3 = 0.0028\text{m}^3 \Rightarrow B = 96\text{mm}$. So, B=S=96mm.

So, once you know B and S and to get its clearance volume we require compression ratio. So, compression ratio $CR = 1 + \frac{V_s}{V_c} \Rightarrow 8 = 1 + \frac{\left(0.0028/4\right)}{V_c} \Rightarrow V_c = 0.001\text{m}^3$.

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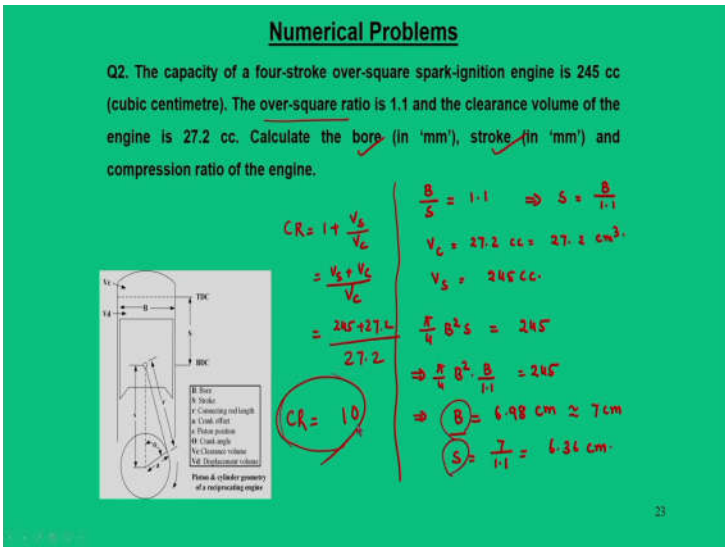


There is another similar problem in this direction that is over square engines where there is a definite ratio between B/S. So, for an over square engine, B/S=1.1. We have also given $V_c$ as 27.2 cc that is 27.2 $cm^3$ and $V_s$ should be 245 cc.

Then we can write $V_s = \frac{\pi}{4} B^2 S = 245 \Rightarrow \frac{\pi}{4} B^2 \frac{B}{1.1} = 245 \Rightarrow B = 6.98\text{cm} \approx 7\text{cm}$. So, S would be 6.36cm.

So, we got bore, we got stroke. So, by definition of compression ratio we can write $CR = 1 + \frac{V_s}{V_c} = \frac{V_s + V_c}{V_c} = \frac{245 + 27.2}{27.2} = 10$. So, these are the two small problems which we will refresh our concepts. So, with this, I conclude my talk for this lectures.

Thank you for your attention.