**Indian Institute of Technology Kanpur**

**National Programme on Technology Enhanced Learning (NPTEL)**

**Course Title**
**Aircraft Maintenance (Engines)**

**Lecture – 02**
**Introduction of Engines Contd…**

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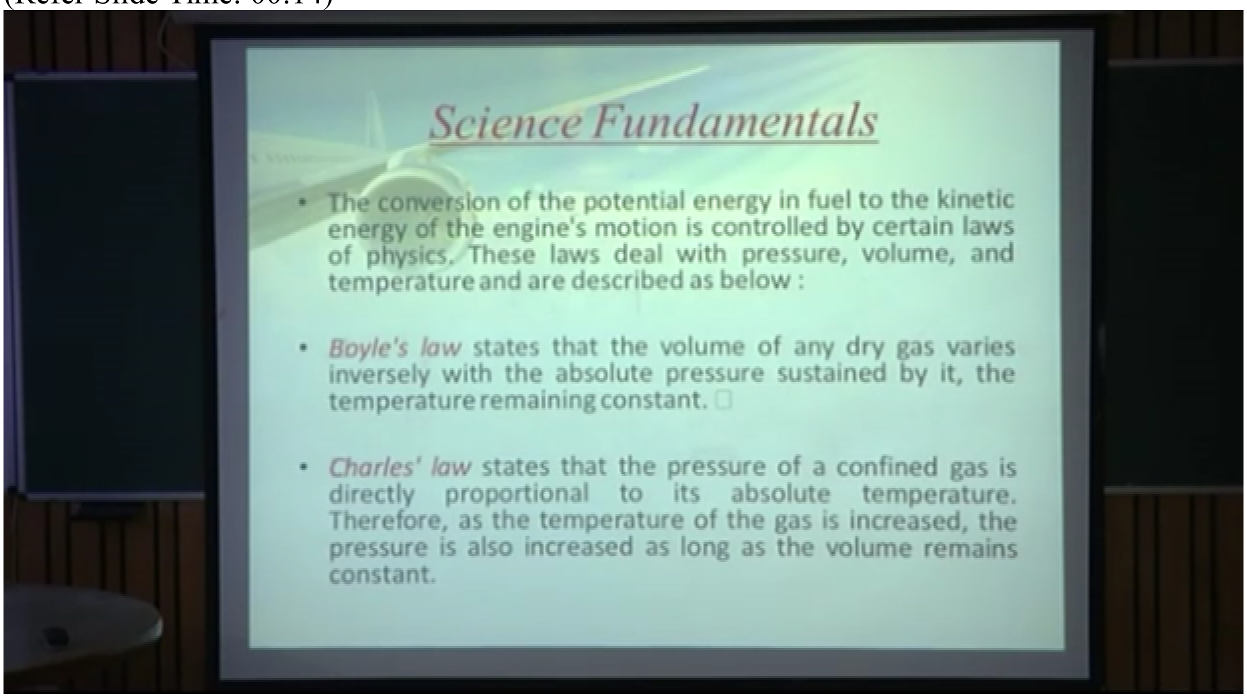


So far we have seen the different types of engines, the inspections to be carried on different engines the requirements and a brief history about the engines.

Now coming to science fundamentals there are few basic fundamentals which we all know, these fundamental laws they are applicable to these engines, the fuel of the engine has some potential energy and the potential energy of this fuel is converted to kinetic energy of the engines motion and this conversion of potential energy of fuel to kinetic energy of motion is controlled by certain laws of physics, these laws are related to pressure, volume and temperature.

The first law is the Boyle's law, we all know about Boyle's law it is volume of any dry gas is inversely proportional to the absolute pressure sustained by it, provided the temperature remains constant.

Second is Charles law which states that the pressure of a confined gas is directly proportional to its absolute temperature provided the volume remains constant, so as the temperature of the gas is increased the pressure is also increased as long as the volume remains constant, so these are the two basic science fundamentals Boyle's law, Charles law which deal with pressure, volume and temperature, these laws are responsible, so these are the basic laws Boyle's law and Charles law which deal with pressure, volume and temperature, and on the basis of these laws we understand that the potential energy of the fuel is converted to kinetic energy of the engine motion.

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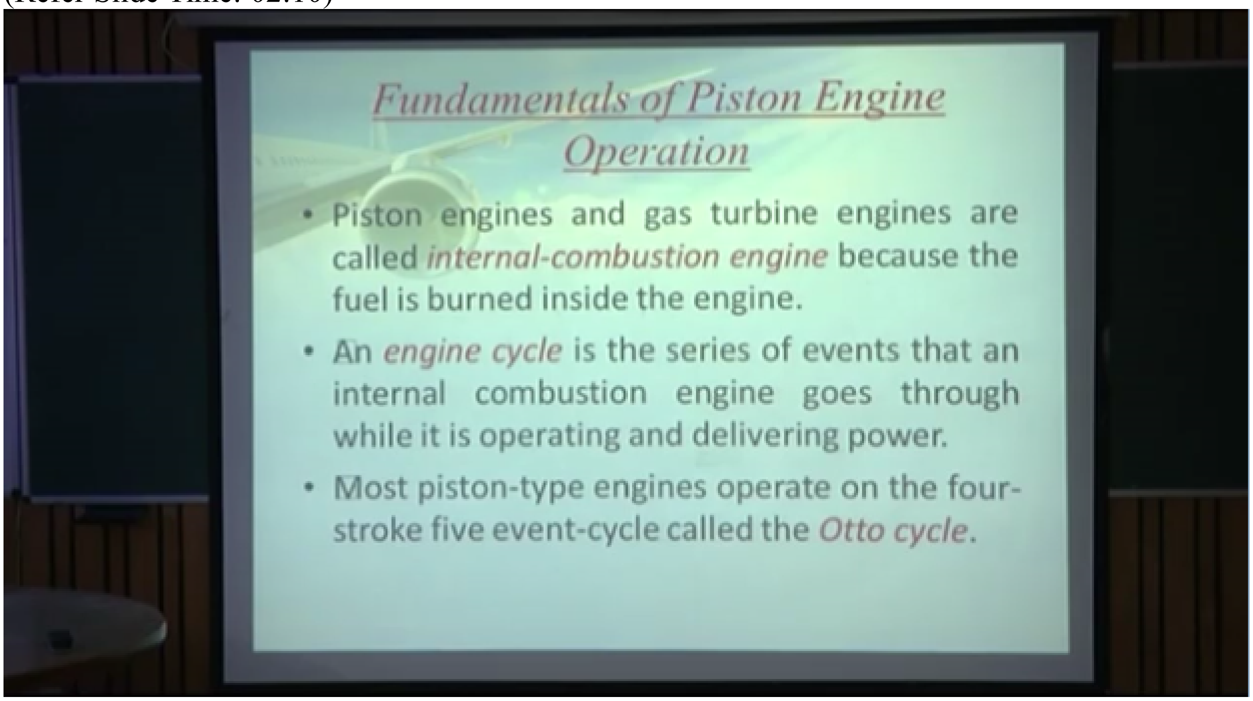


The fundamentals of piston engine operation, piston engines and gas turbine engines both are called internal combustion engine, because the fuel is burned inside the engine, since the fuel is being burned inside the engine therefore it is called an internal combustion engine.

An engine cycle is the series of events that an internal combustion engine goes through while it is operating and delivering power, so when the internal combustion engine is operating it is delivering power, so this sequence, this operation involves series of events, and all these series of events together are called an engine cycle.

Most piston type engines operate on the four-stroke five event cycle called the Otto cycle.
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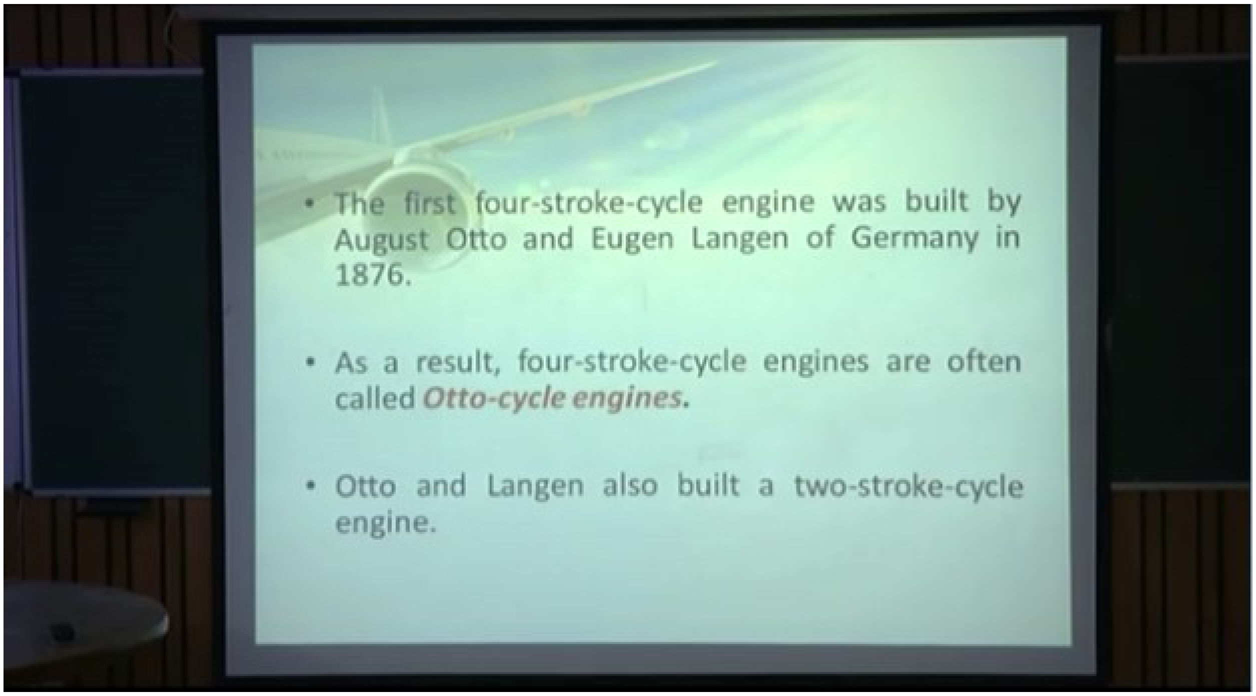


This first four-stroke cycle engine was built by August Otto and Langen of Germany in 1876, as a result, four stroke cycle engines are often called Otto cycle engines, these two scientists Otto and Langen also built a two-stroke cycle engine.

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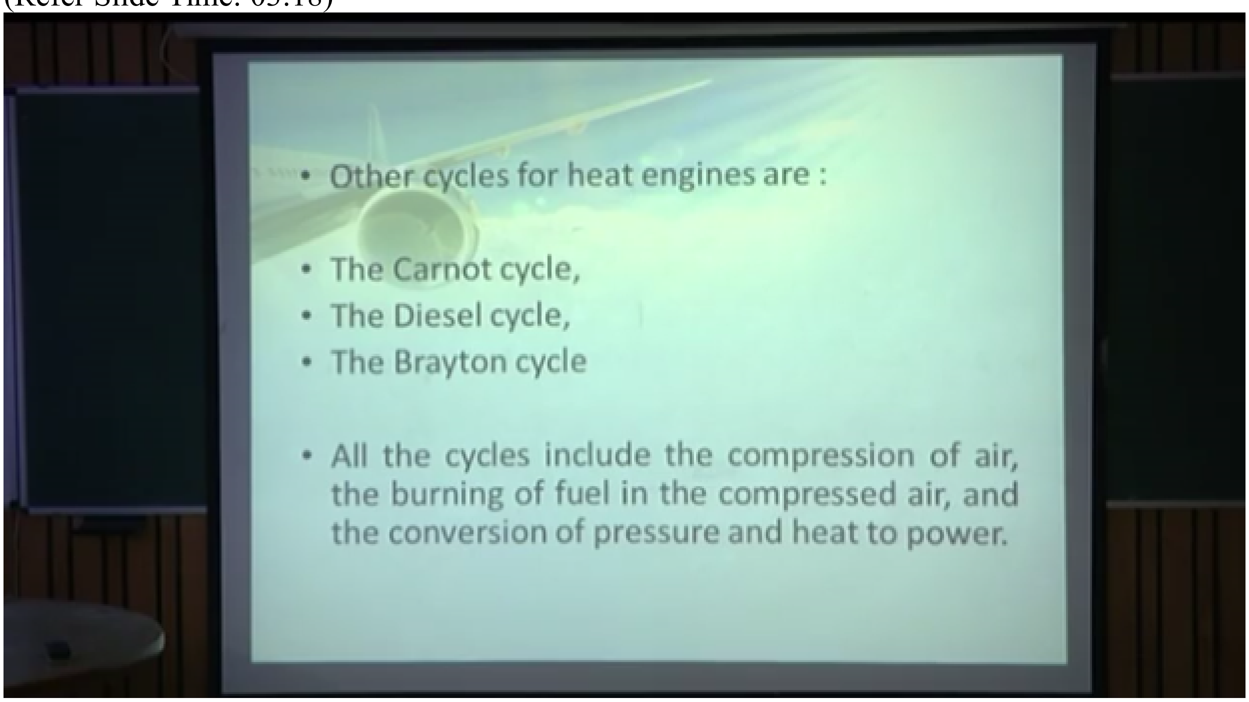


Other cycles for heat engines we all know are the Carnot cycle, the Diesel cycle, the Brayton cycle, and all the cycles include the compression of air, burning of fuel in the compressed air, and the conversion of pressure and heat to power, so the basic of almost all the engine is compression of air, burning of fuel in the compressed air, and conversion of pressure and heat to power.

Again as I have said earlier we are giving more emphasis to piston engines at the moment, so the basic power developing parts in a piston engine are the cylinder, piston, connecting rod and crankshaft.

The piston is connected to the crankshaft by means of the connecting rod so that the rotation of the crankshaft causes the piston to move with a reciprocating motion up and down in the cylinder.

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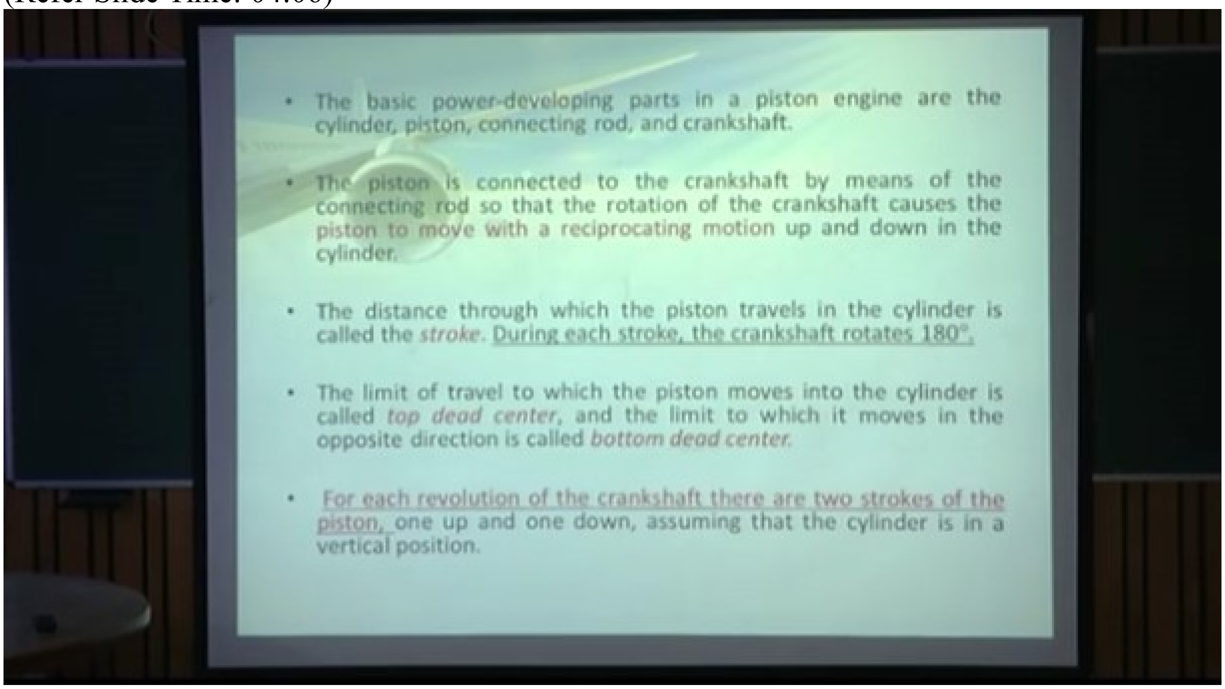


In the next chapter in the construction of an engine we will see all these parts, we will see what a cylinder is, what a piston is, what a connecting rod is, what a crying shaft is, how are they connected to each other. The piston is connected to the crankshaft by means of connecting rod, so the crankshaft and the piston are connected to each other by means of a connecting rod so that the crankshaft rotation is converted to the reciprocating motion of the piston in the cylinder, the distance through which the piston travels in the cylinder is called the stroke, so the movement of the piston within the cylinder is called the stroke, the distance through which that piston moves in the cylinder is called stroke.

And during each stroke the crankshaft rotates 180 degrees, so each stroke of the piston makes the crank shaft to rotate 180 degrees, the limit of travel to which the piston moves into the cylinder is called top dead center, and the limit to which it moves in the opposite direction is called bottom dead center.

So in the cylinder the bottom most position of the piston is called bottom dead center, and the top most position of the piston is called top dead center. For each revolution of the crankshaft there are two strokes of the piston one up and one down assuming that the cylinder is in a vertical position.

As we have seen in the earlier point that during each stroke the crankshaft is rotating 180 degrees, so in one revolution of the crankshaft you have two strokes of the piston, one up and one down, so that means 180 degrees + 180 degrees is 360 degrees, so each revolution of the crankshaft will have two strokes, that means one up and one down.

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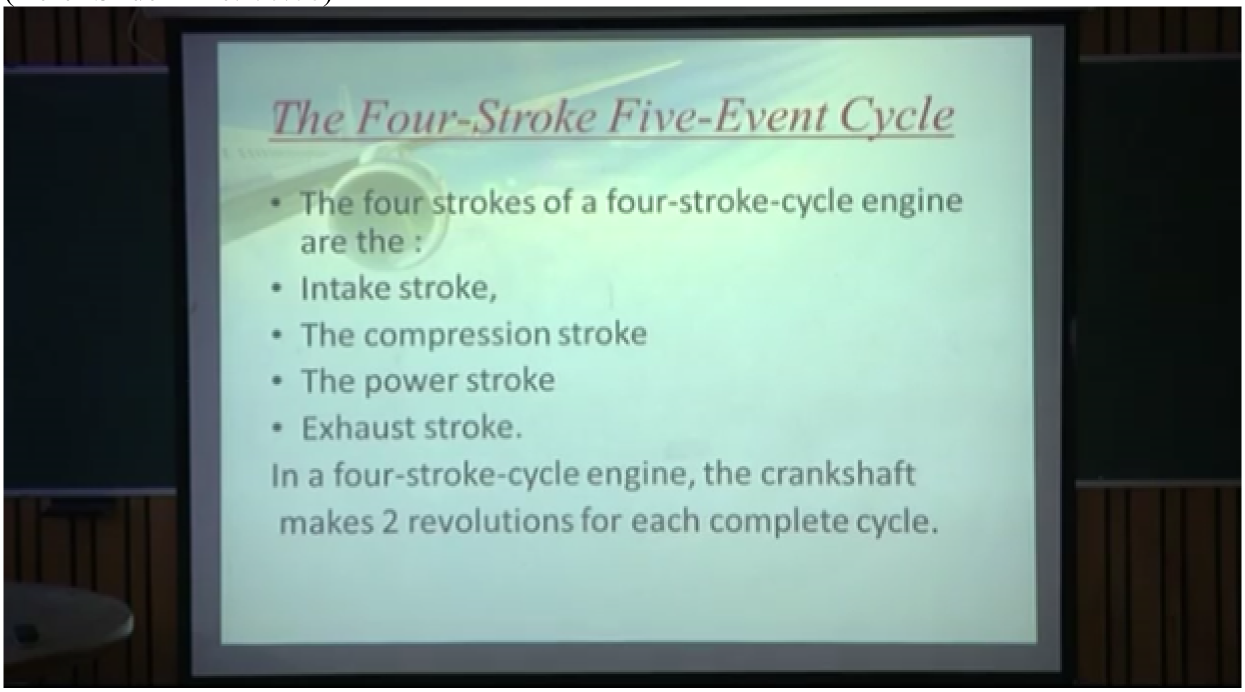


Now coming to the Otto cycle the four stroke five event cycle, in the four stroke five event cycle are the intake stroke, the compression stroke, the power stroke and the exhaust stroke, these are the four strokes intake, compression, power and exhaust, they're also called the events, the intake event, the compression event, after the compression event you have the ignition event then comes your power event and then the exhaust event, so four strokes intake stroke, compression stroke, power stroke and exhaust stroke, and coming to the events that is the intake event, compression event, ignition event, power and exhaust events, so this is how it is a four stroke five event cycle.

And in a four stroke cycle engine the crankshaft makes two revolutions for each complete cycle, as we have seen in the earlier slide your each rotation of the crankshaft involves two strokes so here you have four strokes, so four strokes will require two revolutions of the crankshaft, so the crankshaft makes two revolutions for each complete cycle.

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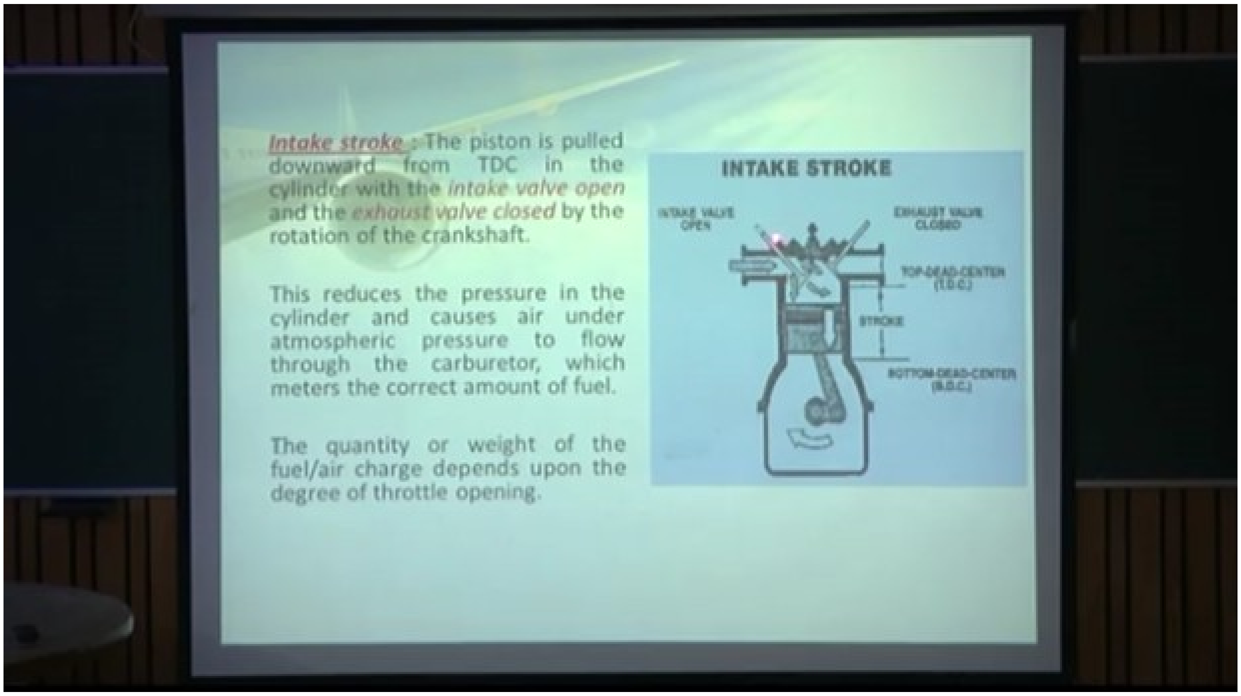


Coming to the first stroke intake stroke, so here you can see in the diagram this is your intake valve, this is your exhaust valve, as I had mentioned earlier this is your top dead center, the topmost position at which the piston can move too, and this is your bottom dead center, the bottom most position at which the piston can move to, so this is your cylinder, within the cylinder this is your piston, this is your intake valve, exhaust valve, top dead center, bottom dead center, and the distance between the bottom dead center and the top dead center to which the piston moves is called the stroke, you can see this is the stroke.

Now this cylinder this passage, this is the intake passage and this is your exhaust passage, and this is your intake valve, and this is your exhaust valve.

During the intake stroke you see that the piston is pulled downwards from the TDC in the cylinder with the intake valve opened and exhaust valve closed by the rotation of the crankshaft, so during the intake stroke the piston is moved from TDC, that is the top dead center position to BDC that is the bottom dead center position, so during the intake stroke the piston moves from TDC to BDC with the intake valve open, and this piston is moving from TDC to BDC your intake valve is open and the exhaust valve is closed, this reduces the pressure in the cylinder and causes the air under atmospheric pressure to flow through the carburetor which meters the correct amount of fuel, so as the piston is moving from TDC to BDC with the intake valve open exhaust valve closed it lowers the pressure within the cylinder and causes the fuel-air mixture to come through the intake passage inside the cylinder, this fuel is coming through the carburetor or the injector which will meter the correct amount of fuel, we will study in the fuel system chapters so at the moment you can just understand that through this passage, intake passage your fuel air mixture is coming.

The quantity or weight of fuel air charge depends upon the degree of throttle opening, so the quantity of fuel and air charge which is coming within the cylinder it all depends on the degree of throttle opening we will study about this in the other chapters also, so this is your intake stroke.

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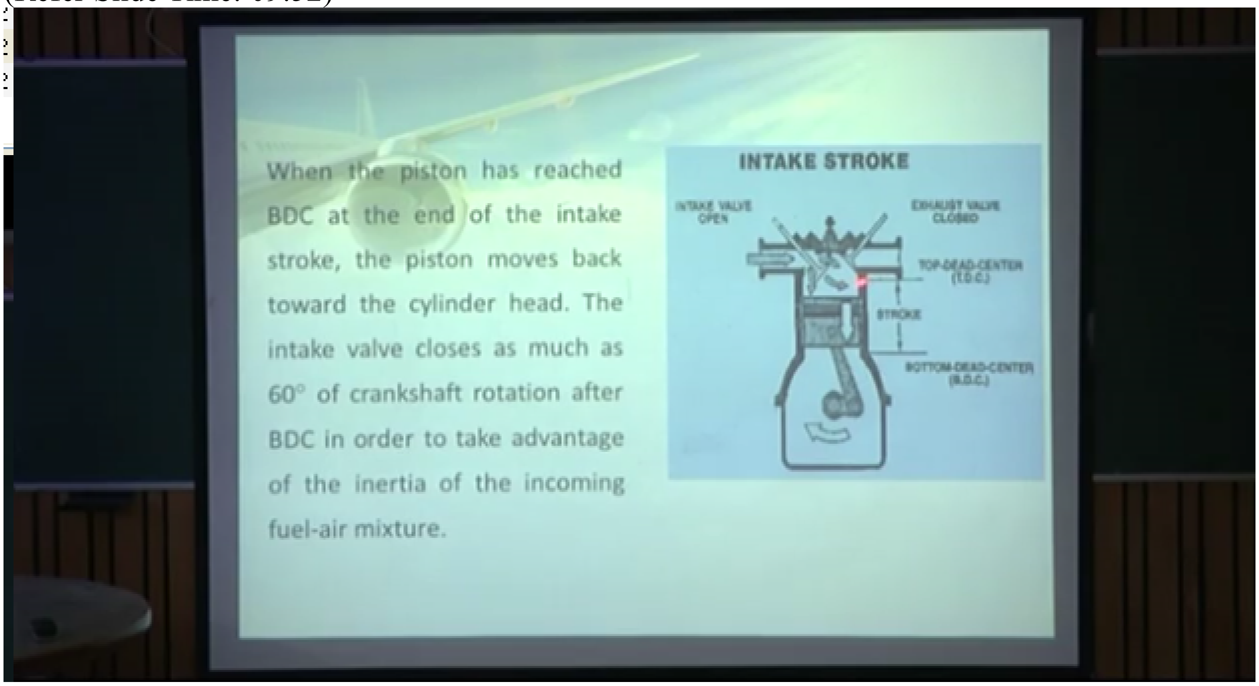


Now when the piston has reached BDC, now piston started from TDC and it has reached BDC at the end of the intake stroke the piston moves back towards the cylinder head, so after moving from TDC to BDC the piston moves back against towards the cylinder head, that means piston has started from TDC it has reached BDC, and from BDC it is again going back to the top of the cylinder head that is towards the TDC, the intake valve closes as much as 60 degrees of crankshaft rotation after BDC in order to take advantage of the inertia of the incoming fuel air mixture, since the fuel air mixture is coming through this intake passage due to the lower pressure in the cylinder, now the piston has moved from top dead center to bottom dead center and again once the piston moves from bottom dead center towards top dead center so after 60 degrees of crankshaft rotation from the bottom dead center the intake valve will close, so when the piston has restarted from TDC position and has reached the BDC position, after reaching BDC it heads back again towards the TDC and after around 60 degrees of crankshaft rotation the intake valve closes, so this late closing of the intake valve, this late closing of the intake valve provides more charge in the cylinder thus it increases the volumetric efficiency which we are going to study about it in the coming slides.

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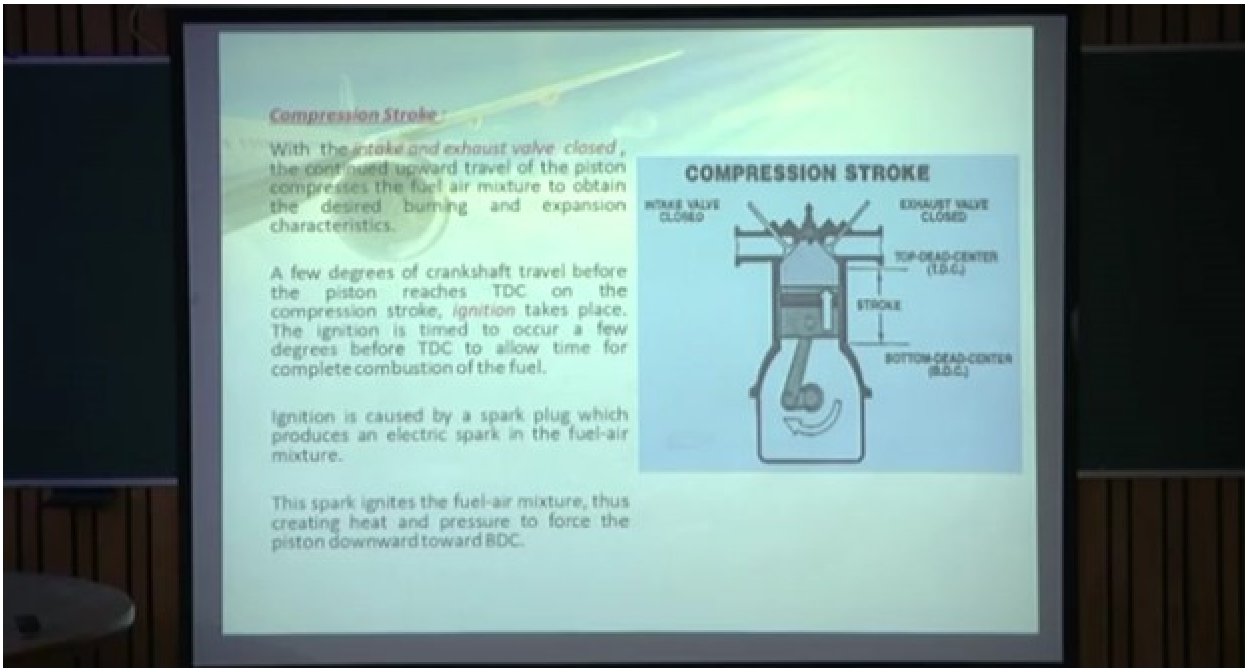


Coming to the next stroke, compression stroke, in the compression stroke the intake and exhaust valves are closed, you can see the intake valve closed and the exhaust valve is also closed. The continued upward travel of the piston compresses the fuel air mixture to obtain the desired burning and expansion characteristics, so we have seen that in the intake stroke the piston moved from TDC to BDC with the intake valve open and the exhaust valve closed, you can see in the previous diagram the intake valve was open and the exhaust valve was closed,

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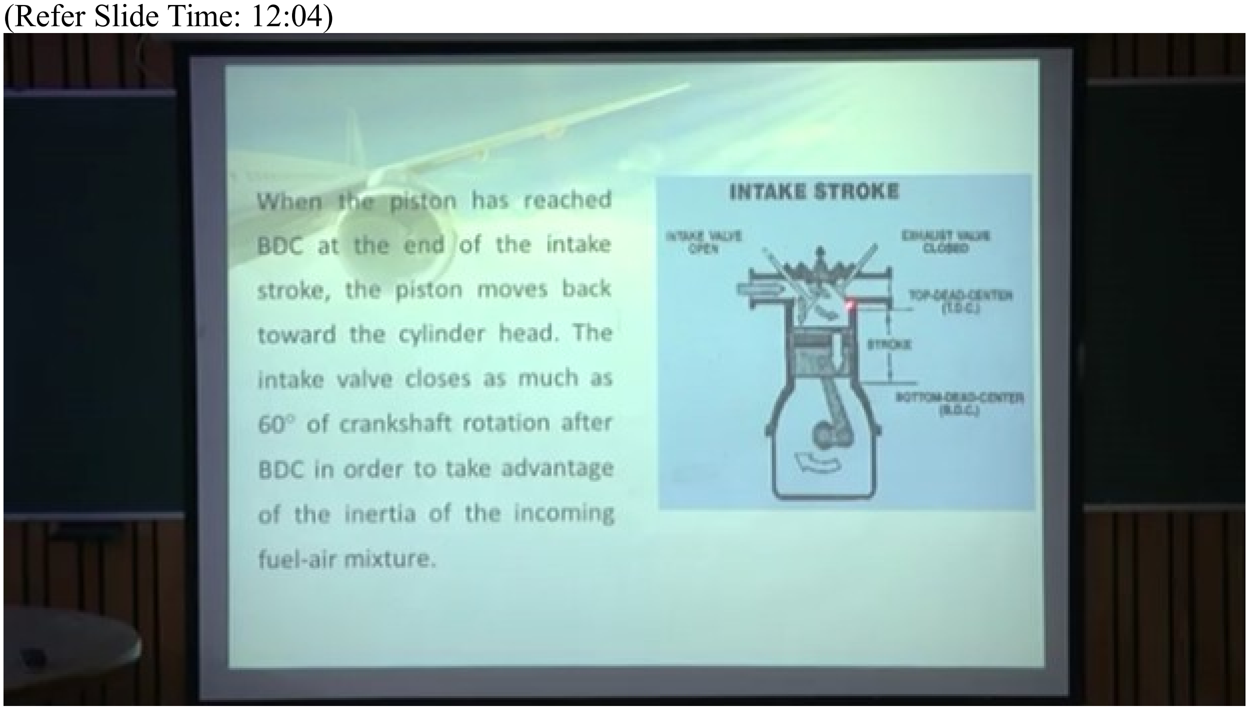


piston was moving from TDC to BDC and started moving back from BDC to TDC, after moving around 60 degrees of crankshaft rotation the intake valve has closed, the exhaust valve has also closed and the piston is moving up towards the TDC position, in the process the piston is compressing the fuel air charge present in the cylinder.

The purpose of compressing the fuel air charge is to obtain the characteristics which are required for burning and expansion, since the piston is compressing the fuel air charge here it is called a compression stroke, a few degrees of crankshaft travel before the piston reaches TDC, so before the piston reaches the top dead center position on the compression stroke ignition takes place, this is the spark plug from where the ignition will take place, the ignition is timed to occur a few degrees before TDC to allow time for complete combustion of fuel, so in the compression stroke the piston is moving from BDC to TDC after the piston has moved from BDC the intake valve has closed, after the intake valve has closed the exhaust valve is also closed and the movement of piston towards TDC compresses the fuel air charge here and this is called the compression stroke.

Just a few degrees before the piston reaches TDC the ignition takes place, it is the ignition event which takes place to allow, earlier timing of the ignition is to allow more time for complete combustion of fuel, ignition is caused by a spark plug which produces an electric spark in the fuel air mixture, this spark ignites the fuel air mixture thus creates heat and pressure to force the piston downwards towards BDC.

Now once the ignition has taken place this will start burning the fuel air mixture here which will create heat and pressure to force the piston downwards towards BDC, so far we have seen that in the intake stroke the intake valve was open the exhaust valve was closed, movement of the piston from TDC to BDC created low pressure in the cylinder, the fuel air charge was brought inside the cylinder after the piston has moved from BDC for about 60 degrees the intake valve closed, with the intake valve and exhaust valve closed and movement of the piston from BDC to TDC the compression stroke happened and before the piston could reach TDC position a few degrees before that the ignition event took place, because of the ignition the fuel air charge inside the cylinder was burnt which caused heat and pressure in the cylinder and forced the piston downwards from the TDC to BDC position.

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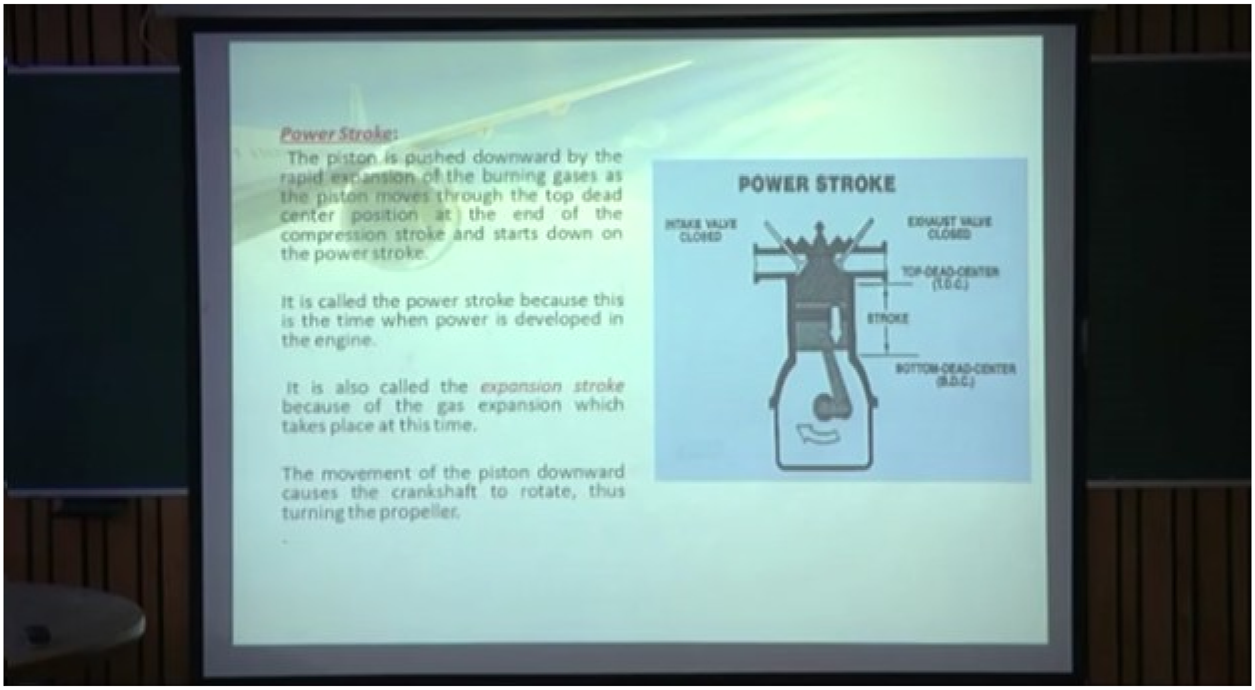


Coming to next stroke power stroke, the piston is pushed downward by the rapid expansion of the burning gases as the piston moves through the top dead center position at the end of the compression stroke and starts down on the power stroke, so now once the ignition has taken place the fuel air charge has burned, heat and pressure is there which makes the piston move downward from the TDC to the BDC this is called power stroke, because this is the time when power is developed in the engine, because of the burning of fuel air mixture, because of heat and pressure, the piston is pushed downward, power is create is developed in the engine, it is also called the expansion stroke because of the gas expansion which takes place at this time, the movement of the piston downward causes the crankshaft to rotate, thus turning the propeller, so this is power stroke that is the third stroke.

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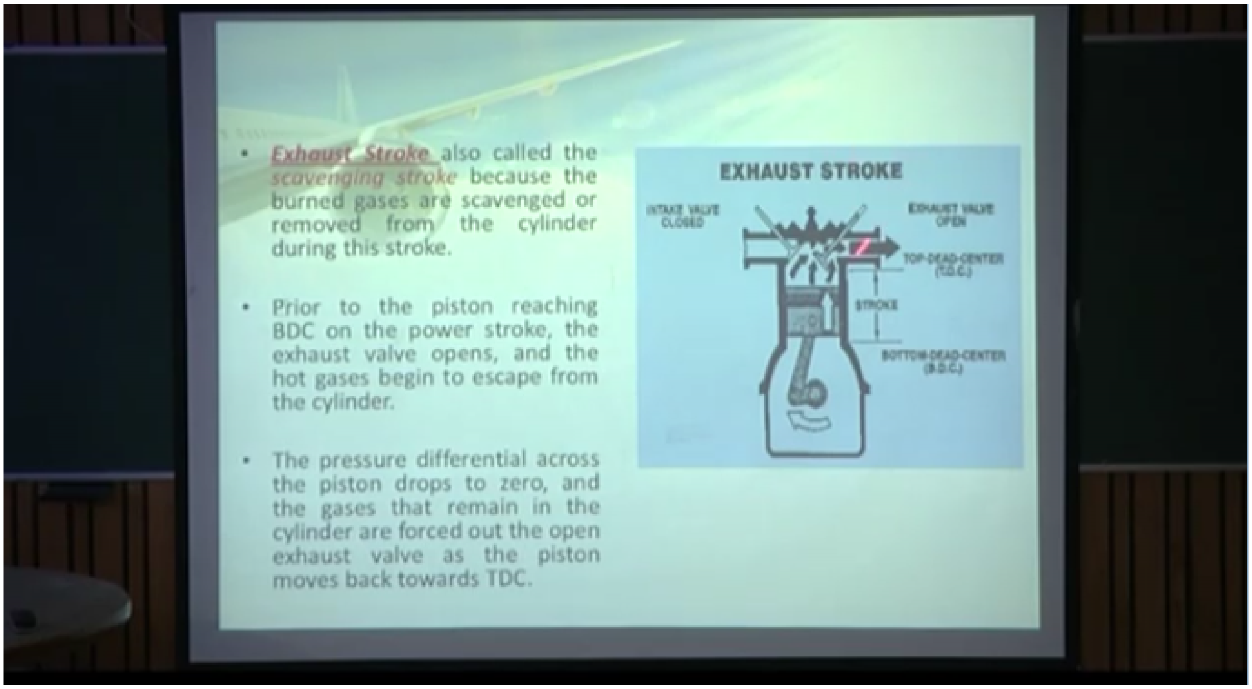


And coming to the last stroke that is the exhaust stroke, so in this exhaust stroke you can see the gases the burnt gases are exhausted out through this exhaust valve, the exhaust valve is open and the burned gases are exhausted outside this passage and so this is called the exhaust stroke, this is also called the scavenging stroke because the burnt gases are scavenged or removed from the cylinder during this stroke.

Prior to the piston reaching BDC on the power stroke, so as we have seen earlier in the power stroke the piston was moving from the TDC to BDC prior to the piston reaching the BDC position on the power stroke the exhaust valve opens and the hot gases begins to escape from the cylinder.

The pressure differential across the piston drops to zero, and the gases that remain in the cylinder are forced out through the open exhaust valve as the piston moves back towards TDC, so as the piston is moved from BDC to TDC during the exhaust stroke, the exhaust gases are scavenged out through this passage out of the cylinder. So we have seen in the exhaust stroke the piston has moved from BDC to TDC, pushing the exhaust gasses out.
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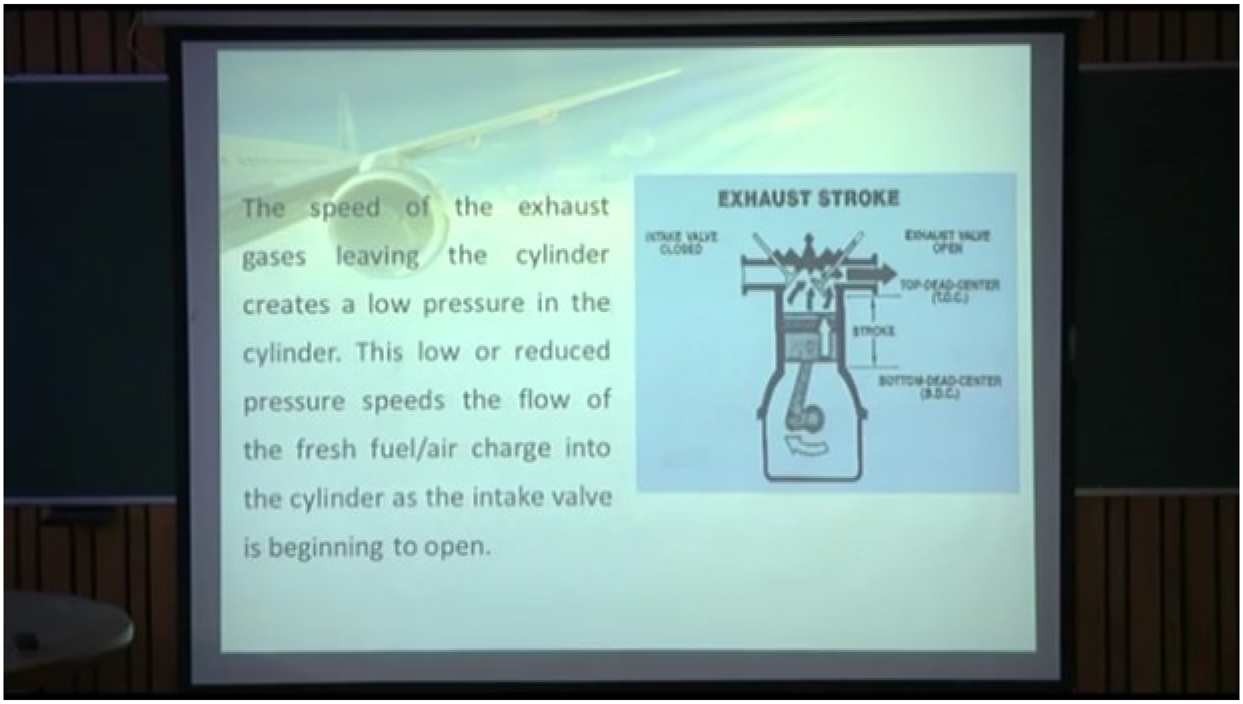


The speed of the exhaust gases leaving the cylinder creates a low pressure in the cylinder, so again the speed of the gases which are rushing out of this passage they create a low pressure in the cylinder, this low or reduced pressure speeds the flow of the fresh fuel air charge into the cylinder as the intake valve is beginning to open, so because of this low or reduced pressure the fresh fuel air charge, because of this low pressure in the cylinder the fresh fuel air charge comes through the intake valve.

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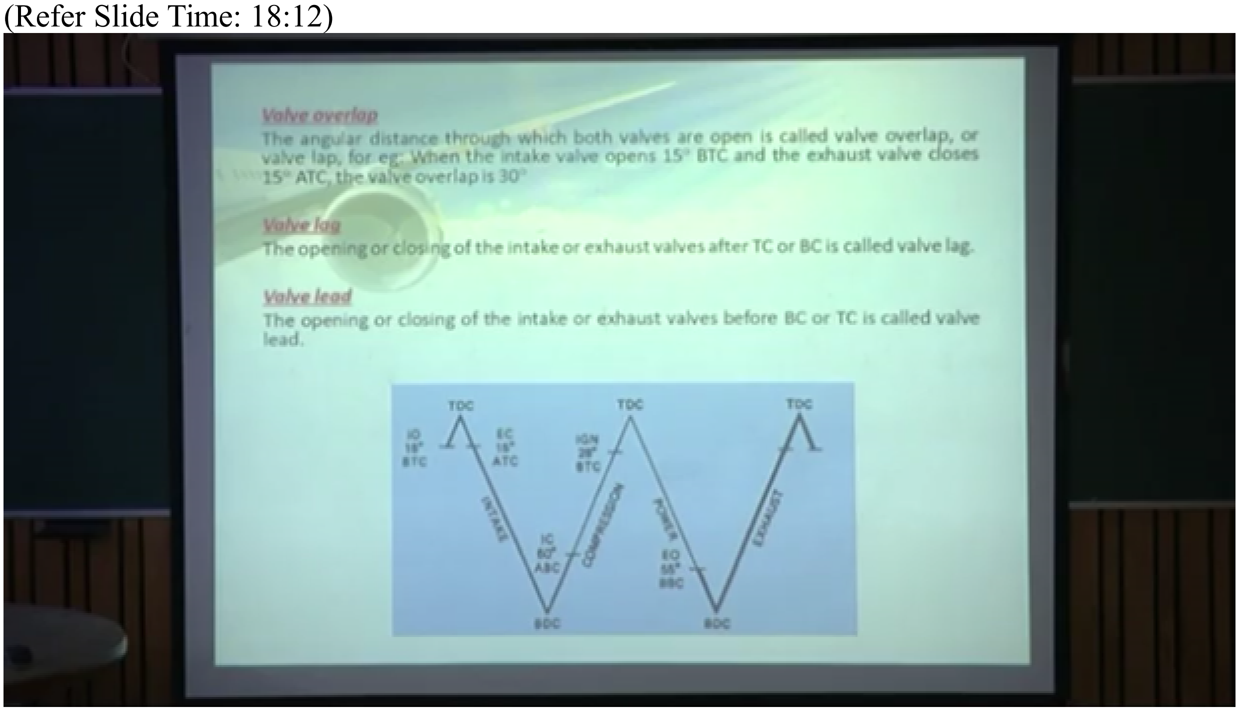

Now all the four strokes and five events they are shown here in the valve timing diagram you can see here, this is a valve timing diagram, this event, this is your intake event, this is your compression stroke, this is your power stroke, and this is your exhaust stroke, so all the four strokes are shown here, and this is your TDC position, the top dead center position TDC and this is your BDC position bottom dead center position, so as we have seen earlier in the intake stroke the intake valve opens and the exhaust valve is closed, you can see here in the intake stroke here this is again the exhaust stroke, this is the exhaust stroke, so during the exhaust stroke before the piston reaches the top dead center position the intake valve opens here, before it reaches the top center position and during the intake stroke, during this time the intake valve is open and then the intake valve closes after the piston has moved from the bottom dead center position the intake valve closes, so you can see that the intake valve opened before the top center position in the exhaust stroke and closed after the bottom center position during the compression stroke. The reason why early opening of the intake valve and late closing of the intake valve is designed to allow more fuel air mixture enter inside the cylinder.

Then in the next stroke compression stroke, here the intake valve is closed, the exhaust valve is also closed and the piston is moving from BDC to TDC position at the fuel air mixture is being compressed with both the valves closed.

Now before the piston could reach the top dead center position here, here the ignition event has happened before top center position that ignition through the spark plug happens, now the early ignition is timed to allow the fuel air charge to burn completely and when the piston starts moving from top dead center position towards bottom dead center position, because of this burning of fuel air mixture heat and pressure is created and it pushes the piston down from top center position to bottom center position, this is called the power stroke because the power is being developed during this stroke.

Before the piston could reach the bottom center position, the bottom dead center position the exhaust valve is opened, this allows the burning gases, the burnt fuel air mixture to be scavenged out of the cylinder from here the exhaust stroke starts, you can see this is your exhaust stroke so exhaust valve is opened before the bottom center position and exhaust valve closes once your intake stroke has started, so you can see here the exhaust valve is opened earlier and closed late, so early opening of the exhaust valve and again late closing of the exhaust valve, this is to allow more thorough scavenging of the exhaust gases.

So this is the valve timing diagram where we have shown where the intake valve is open for the intake stroke where it is closing for the intake stroke, for the exhaust stroke where the exhaust valve is open and where it has closed, so there are a few terms here called valve overlap, the angular distance through which both valves are open is called valve overlap or valve lap, for example when the intake valve opens 15 degrees before top center you can see here intake valve has opened 15 degrees before top center and the exhaust valve closes 15 degrees after top center, exhaust valve has closed 15 degrees after top center, so you can see during this time your both the valves are open, so this is called valve overlaps, so that means 15 + 15 degrees 30 degrees your valve is open, both the valves are open, this is called valve overlap.

Valve lag the opening or closing of the intake or exhaust valves after top center or bottom center is called valve lag, so if the intake valve or the exhaust valve is opening or closing after the top center or bottom center then it is called valve lag. And valve lead the opening or closing of the intake or exhaust valve before bottom center or top center it is called valve lead, so you have seen the three terms valve overlap, valve lag, and valve lead.

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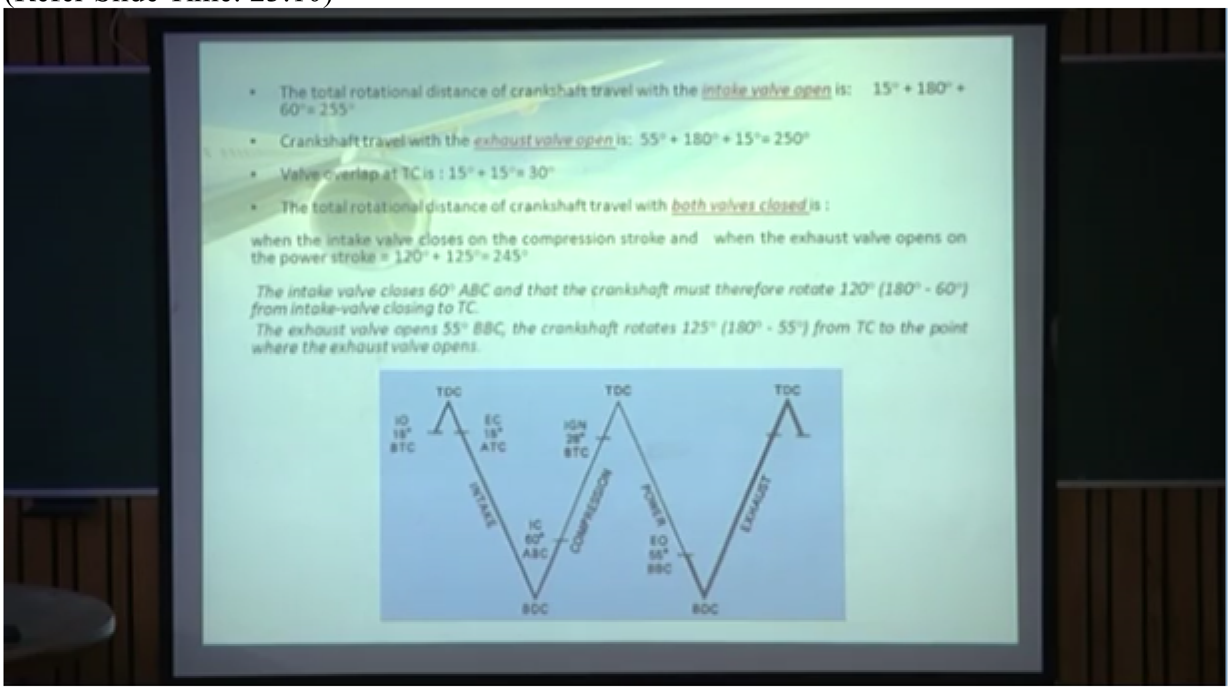


Now if we see that, what is the total crankshaft rotation when both, when the valves are open or closed you see, if we see when for intake valve open so the total rotational distance of crankshaft travel with intake valve open is 15 degrees + 180 degrees + 60 degrees, so here you can see 15 degrees before the top center the intake valve is open, again for 180 degrees this is the complete stroke we have seen earlier for one stroke it is 180 degrees of crankshaft rotation, so this is 15 degrees + 180 degrees + after bottom dead center 60 degrees of crankshaft rotation more than your intake valve closes, so your intake valve is open for 15 degrees + 180 degrees + 60 degrees that is equal to 255 degrees, so for 255 degrees of crankshaft rotation your intake valve is open.

Now crankshaft travel with again you see the exhaust valve it opens 55 degrees before bottom center on the power stroke, this is 55 degrees and again for the complete stroke 180 degrees, 180 degrees here and another 15 degrees here on the intake stroke, so the exhaust valve is opened for 55 degrees on the power stroke, 180 degrees on the exhaust stroke, and 15 degrees on the intake stroke this is equal to 250 degrees, so the crankshaft travel with the exhaust valve open is 250 degrees, with the intake valve open is 255 degrees, and valve overlap as we know that with both the valves open at the top center position is 30 degrees, 15 degrees + 15 degrees that is equal to 30 degrees.

Now coming to the total crankshaft rotation with both valves closed the total rotational distance of the crankshaft travel with both valves closes when the intake valve closes on the compression stroke, so you see here when the intake valve has closed on the compression stroke and when the exhaust valve opens on the power stroke, so during this cycle this time on the compression stroke from here to here your both valves are closed.

Since the intake valve closes 60 degrees after a bottom center so that means this portion from here till here it is 180 degrees - 60 degrees that is equal to 120 degrees, so 120 degrees of this crankshaft rotation and again coming to this thing here your exhaust valve opens before bottom center that means 180 degrees - 55 degrees that is equal to 125 degrees, so 120 degrees + 125 degrees, 120 degrees this thing, and 125 degrees is this thing, this equal to 245 degrees, so 245 degrees of crankshaft rotation gives you both valves closed, so this is the valve timing diagram where we have seen the different strokes, intake stroke, compression stroke, power stroke, exhaust stroke, we have seen the timing of the valves, the intake valves and the exhaust valves, we have also seen the timing of the ignition, so this was about the four-stroke five event cycle.

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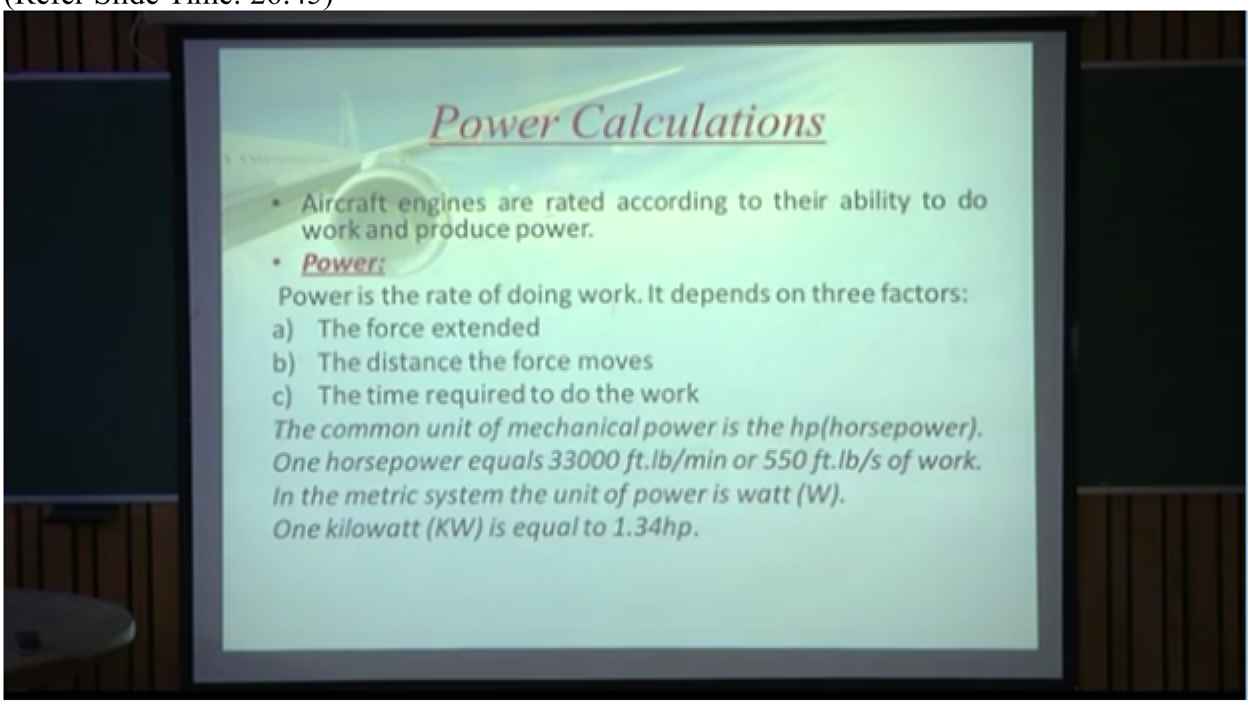


Coming to the power calculations, aircraft engines are rated according to their ability to do work and produce power, so all the engines they have the rating, the rating is according to their ability to do work and produce power.

Now what is power? It is the rate of doing work we all know it, it depends on three factors the force extended, the distance the force moves and the time required to do the work. The common unit of mechanical power is the horsepower, one horse power equals 33,000 feet pound per minute or 550 feet pounds of work, in the metric system the unit of power is watts, and one kilowatt is equal to 1.34 horsepower, so this is just brief information just to brush up, we all know what is power,

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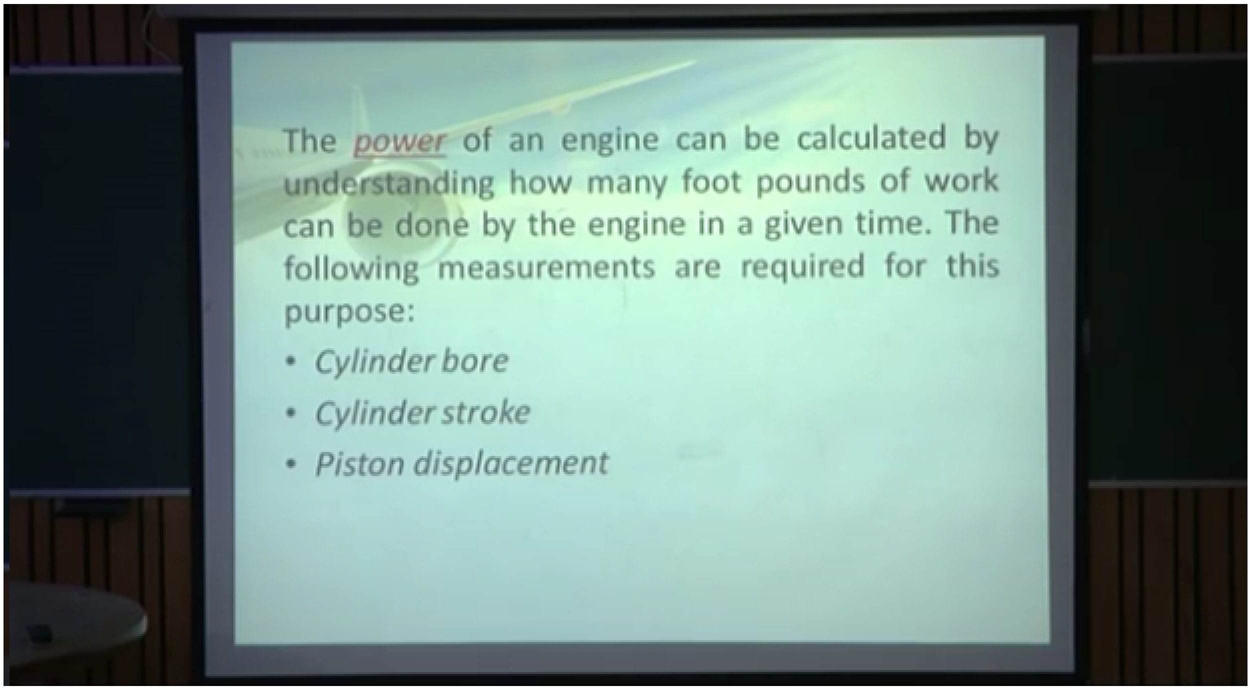


the power of an engine can be calculated by understanding how many foot-pounds of work can be done by the engine in a given time. The following measurements are required for this purpose cylinder bore, cylinder stroke and piston displacement. So we have seen in the earlier diagrams what is the stroke we will also see what is a bore and what is piston displacement.

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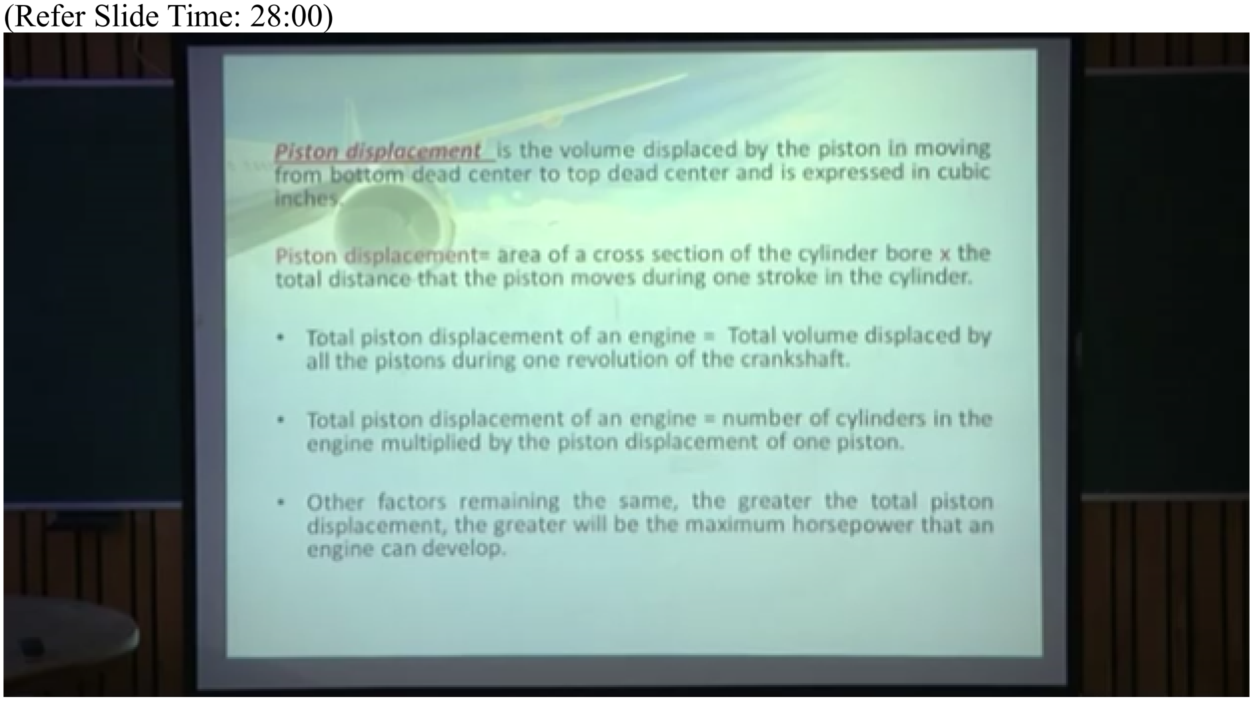


Now piston displacement it is the volume displaced by the piston in moving from bottom dead center to top dead center and is expressed in cubic inches, so the movement of piston from BDC to TDC position and the volume displaced by the piston in moving so is the piston displacement which is expressed in cubic inches. Piston displacement is equal to area of cross-section of the cylinder bore multiplied by the total distance the piston moves during one stroke in the cylinder, so total piston displacement of one cylinder and the piston displacement of the complete engine is the total volume displaced by all the pistons during one revolution of the crankshaft, so total piston displacement of an engine is number of cylinders in the engine multiplied by the piston displacement of one piston.

Now other factors remaining the same, if other factors are constant the greater the total piston displacement, the greater will be the maximum horsepower that an engine can develop.

Here you can see in this diagram you can see the stroke and the bore, we have seen that this is the stroke this is top dead center position, this is the bottom dead center position,
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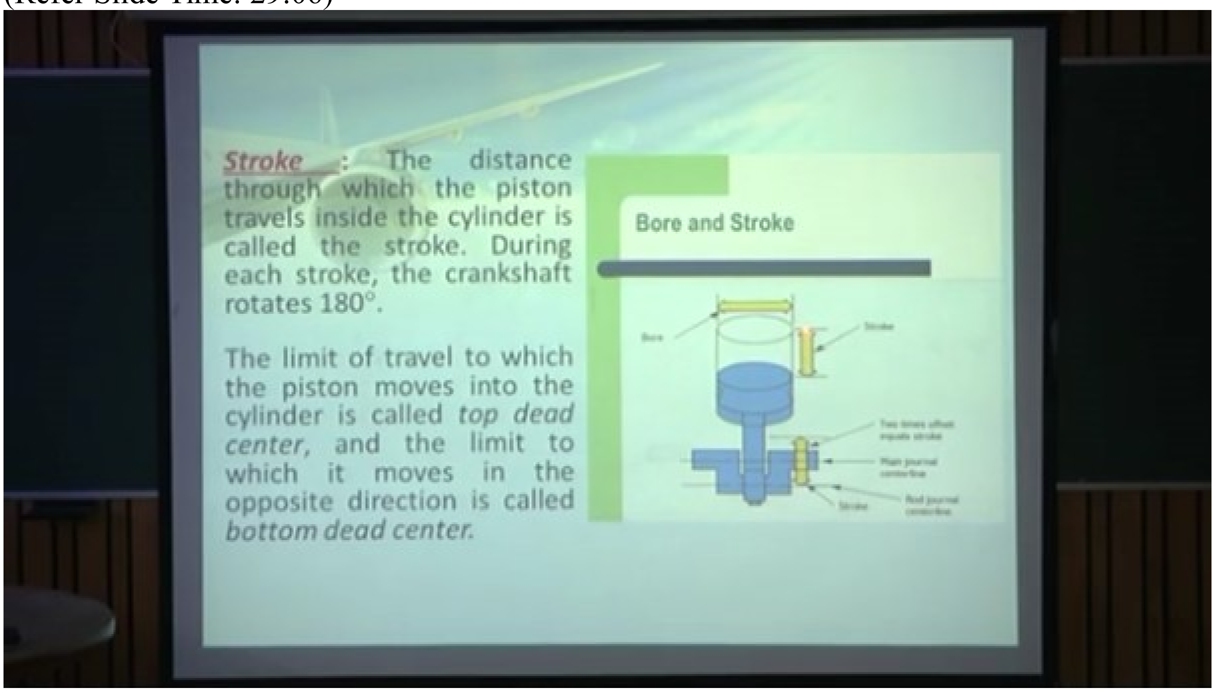


so the distance between the TDC and BDC this is called the stroke, the piston moves from TDC to BDC and BDC to TDC this is the stroke, and this distance this is called your bore, so you can see this is your bore and this is your stroke. Stroke the distance through which the piston travels inside the cylinder is called a stroke during each stroke the crankshaft rotates 180 degrees, so we have seen earlier also during each stroke the crankshaft rotation is 180 degrees, the limit of travel to which the piston moves into the cylinder is called top dead center, and the limit to which it moves in opposite direction is called bottom dead center, so we have seen this also earlier, this is your top dead center position, this is your bottom dead center position.

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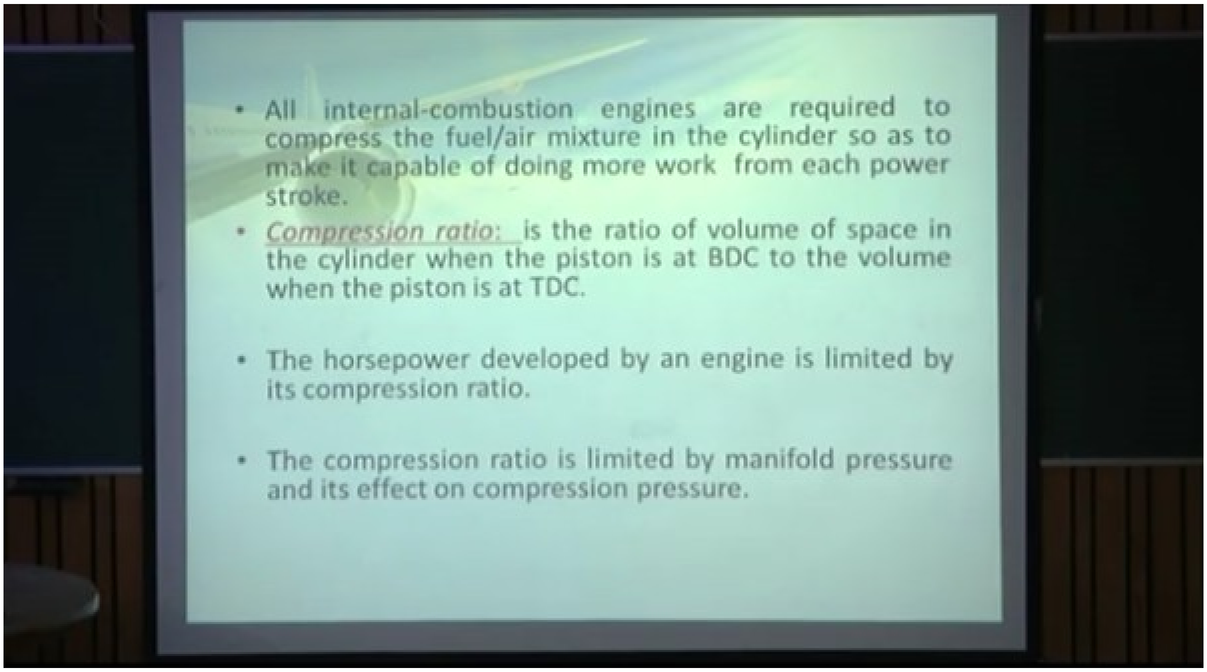


All internal combustion engines they are required to compress the fuel air mixture in the cylinder so as to make it capable of doing more work from each power stroke.

Now what is compression ratio? It is the ratio of volume of space in the cylinder when the piston is at BDC to the volume and the piston is at TDC, so it is the ratio, compression ratio it is the ratio of volume of space when the piston is at bottom dead center to the volume when the piston is at top dead center.

The horsepower developed by an engine is dependent on the compression ratio of that engine, and the compression ratio is limited by manifold pressure and its effect on compression pressure, so here you can see the manifold pressure this is an important parameter which affects your compression ratio, and in turn the power being developed by the engine.

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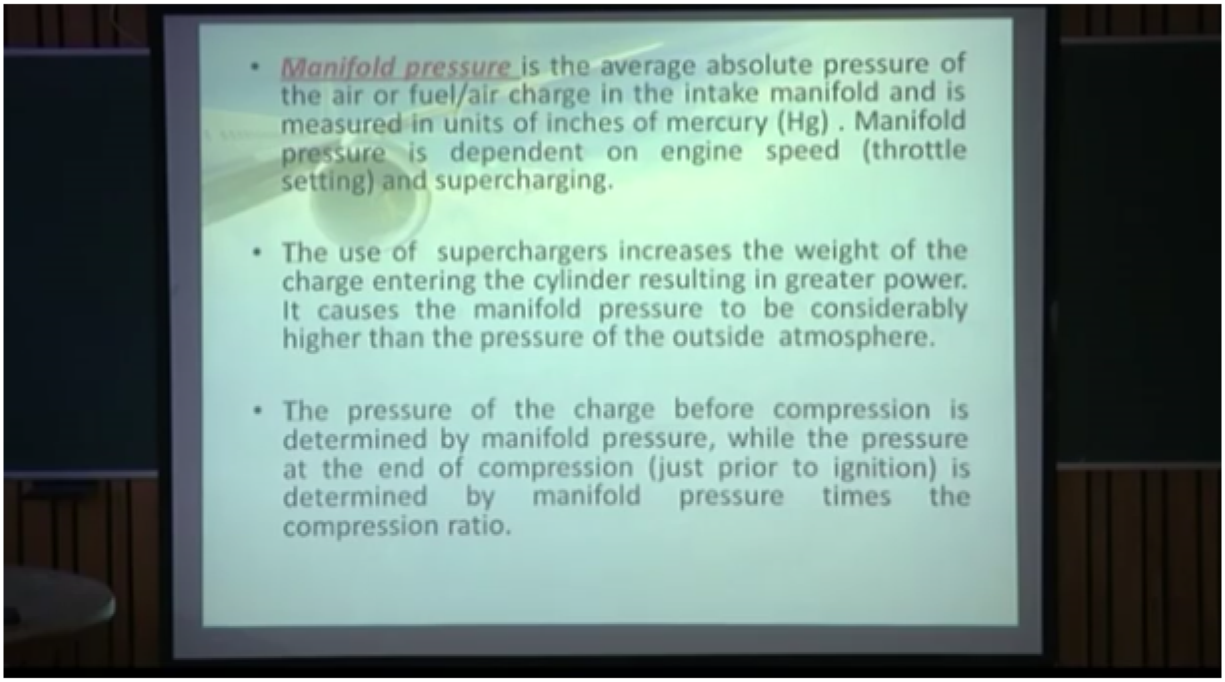


Now what is manifold pressure? Manifold pressure is the average absolute pressure of the air or fuel air charge in the intake manifold and is measured in inches of mercury, manifold pressure is dependent on engine speed that is your throttle setting and supercharging, so basically manifold pressure it is the average absolute pressure of the fuel air charge in the intake manifold which is measured in inches of mercury, the manifold pressure depends on your throttle opening, the amount of throttle which you have opened or the supercharge.

The use of superchargers increases the weight of charge entering the cylinder resulting in greater power, now if your engine is equipped with superchargers, the job of the superchargers is to increase the weight of the charge which is entering the cylinder which results in greater power, it causes the manifold pressure to be considerably higher than the pressure of the outside atmosphere, so the job of your supercharger is to increase the weight of the charge entering the cylinder which causes the manifold pressure to increase, and it increases the pressure of the manifold pressure, the supercharger will increase the pressure of the manifold pressure as compared to the outside atmosphere.

The pressure of the charge before compression is determined by manifold pressure, while the pressure at the end of compression just prior to ignition is determined by manifold pressure times the compression ratio, so in case if your engine doesn't have a supercharger then the pressure of charge before the compression is your manifold pressure, whereas in case if your engine is equipped with a supercharger then the pressure just prior to ignition is your manifold pressure multiplied by your compression ratio on the edge.

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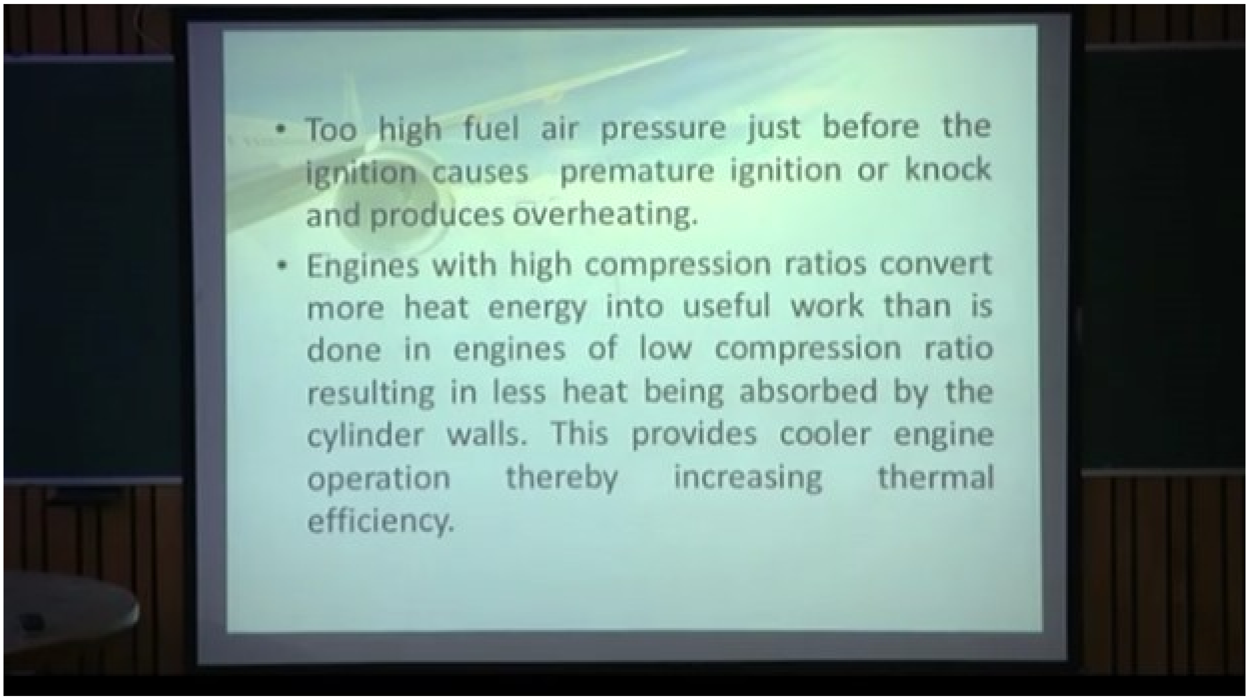


Too high a fuel air pressure just before the ignition causes premature ignition or knock and produces overheating, we will read about this in the future slides just to understand that too high fuel air pressure is also not a very good thing.

Engines with high compression ratios convert more heat energy into useful work than is done in engines of low compression ratio resulting in less heat being absorbed by the cylinder valves, this provides cooler engine operation thereby increasing thermal efficiency, so your engines which have high compression ratio they will convert more heat energy into useful work which results in less heat being absorbed by our cylinder valves, this provides more cooler engine operation and resulting an increased thermal efficiency.

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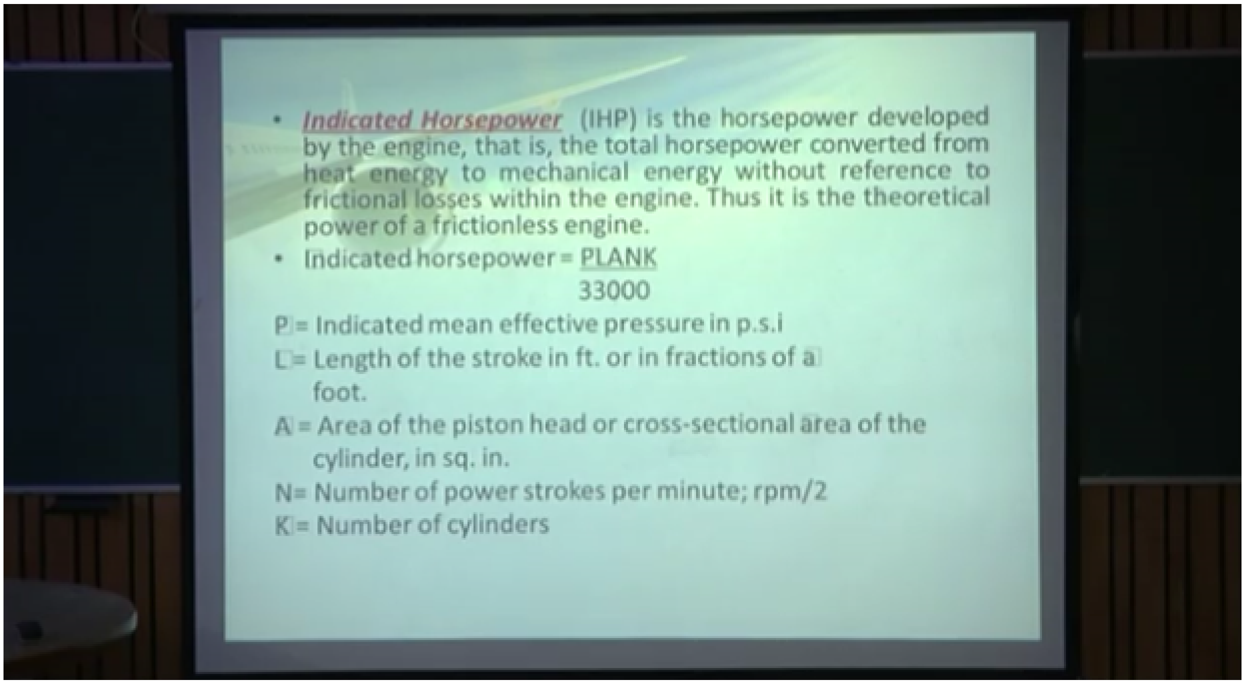


So coming to various powers, first is your indicated horsepower which is the horsepower developed by the engine, that is the total horsepower converted from heat energy to mechanical energy without references to frictional losses within the engine, thus it is the theoretical power of a frictionless engine, so if we don't consider the frictional losses within the engine then it is the total horsepower which is converted from heat energy to mechanical energy without considering your frictional losses then it is called the indicated horsepower.

So indicated horsepower is given by a formula PLANK/33,000 in which P is your indicated mean effective pressure, we will see what does indicated mean effective pressure in the slides to come, L is the length of the stroke in feet, A is the area of the piston head or the cross-sectional area of the cylinder in square inches, N is the number of power strokes per minute that is RPM/2 and K is the number of cylinders, so this is your formula which is indicated horsepower is PLANK/33,000.

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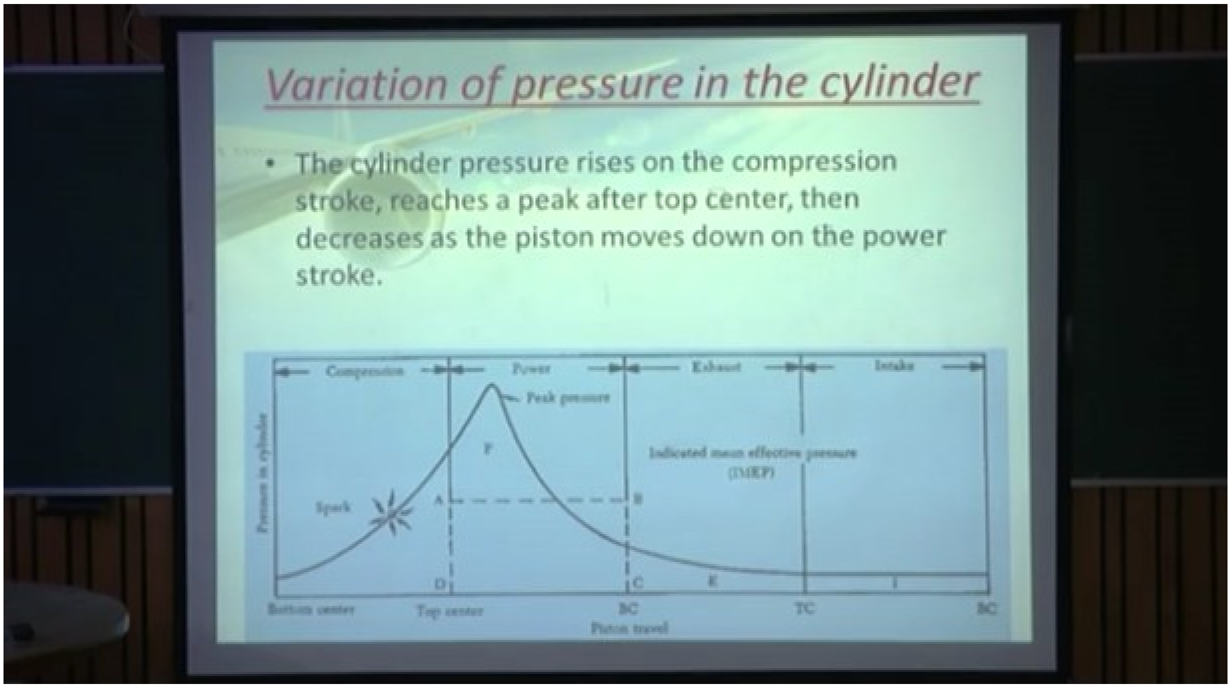


Now in this diagram you can see we have shown the variation of pressure in the cylinder during the various strokes, in this diagram you can see this is your compression stroke, this is your power stroke, this is your exhaust stroke, this is your intake stroke, this side Y axis is showing you pressure in the cylinders, and this X axis is showing you the piston travel, this is your bottom center, this is your top center, again bottom center, top center, again the bottom center.

Now as we had seen earlier in the compression stroke the piston moves from the bottom center towards the top center, so now piston is moving from bottom center to top center you can see there, the piston is moving from bottom center to top center, as the piston is moving from bottom center to top center your pressure is increasing, this piston is compressing your fuel air charge in the cylinder and your pressure is increasing, you can see the pressure here, this is the pressure in the cylinder on the Y-axis, you can see the pressure increasing as the piston is moving from BDC to TDC, just before the piston reaches the top center position your ignition event takes place, here you have a spark, ignition happening, because of this ignition your fuel air mixture is ignited, is burnt, heat is created and pressure is created, because of heat and pressure your power stroke happens.

Now early ignition timing allows complete combustion of the fuel air charge and here is your power stroke, during the power stroke the piston moves from top center to the bottom center, the piston is pushed because of heat and pressure from the top center to the bottom center. As the piston is moving down from top center to bottom center you can see the pressure is decreasing, you can see here the pressure this was the peak pressure here, this was the peak pressure, and now the piston has moved from top center to bottom center in the power stroke and the pressure is decreasing.

And again during the exhaust stroke the piston moves from bottom center to top center, the pressure is further increasing because your exhaust valve also opens, and now the pressure is continuously decreasing so the cylinder pressure rises on the compression stroke reaches a peak after top center, you can see the cylinder pressure rises on the compression stroke reaches a peak after top center, after top center it reaches a peak and then decreases, that decreases as the piston moves down on the power stroke, as the piston is moving down on the power stroke your pressure is decreasing.

Now since the cylinder pressure varies during the operating cycle, you have seen that the cylinder pressure is continuously varying first it is increasing then decreasing, because the cylinder pressure is varying during the operating cycle and average pressure line AB is computed, so this is your average pressure line AB is computed, this average pressure if applied steadily during the time of the power stroke or do the same amount of work as the varying pressure during the same period, and this average pressure is known as your indicated mean effective pressure.

So we had seen in the diagram of indicated horsepower in our earlier slide you can see this was your indicated horsepower formula PLANK/33,000, and P this was your indicated mean effective pressure in PSI, here you can see in the diagram this is your indicated mean effective pressure,

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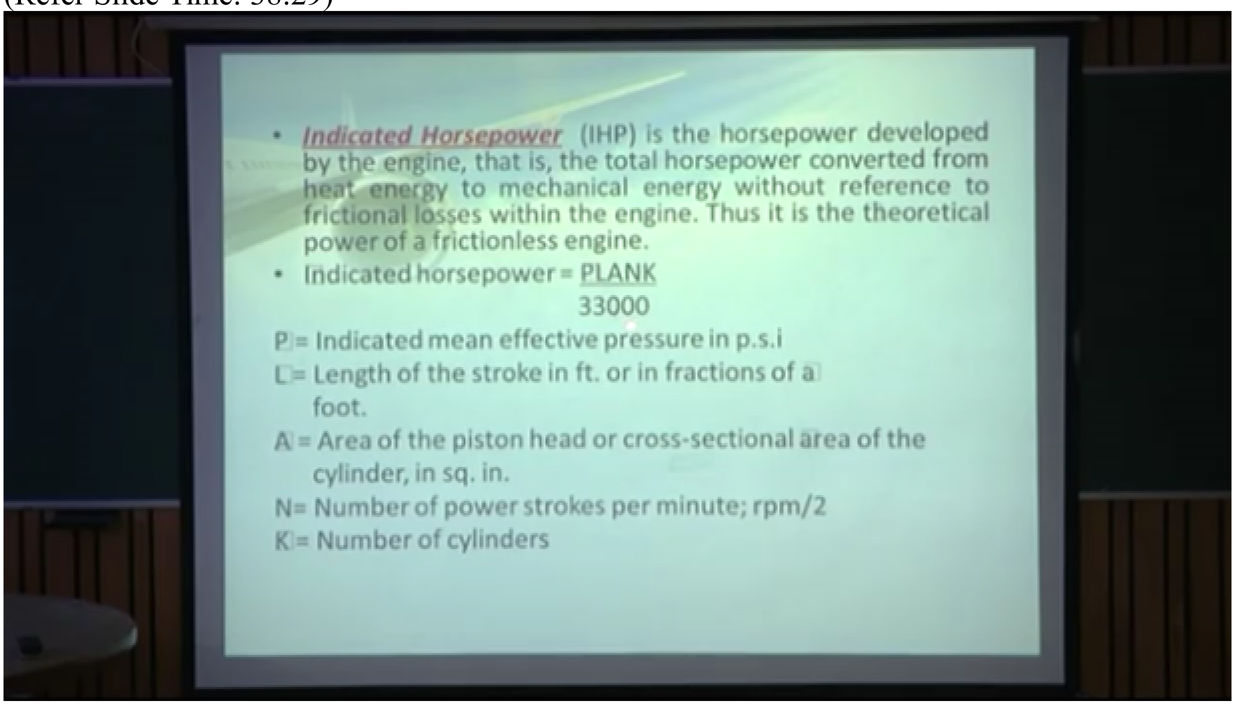


this is line AB, this is your average pressure known as your indicated mean effective pressure, which is also called IMEP.

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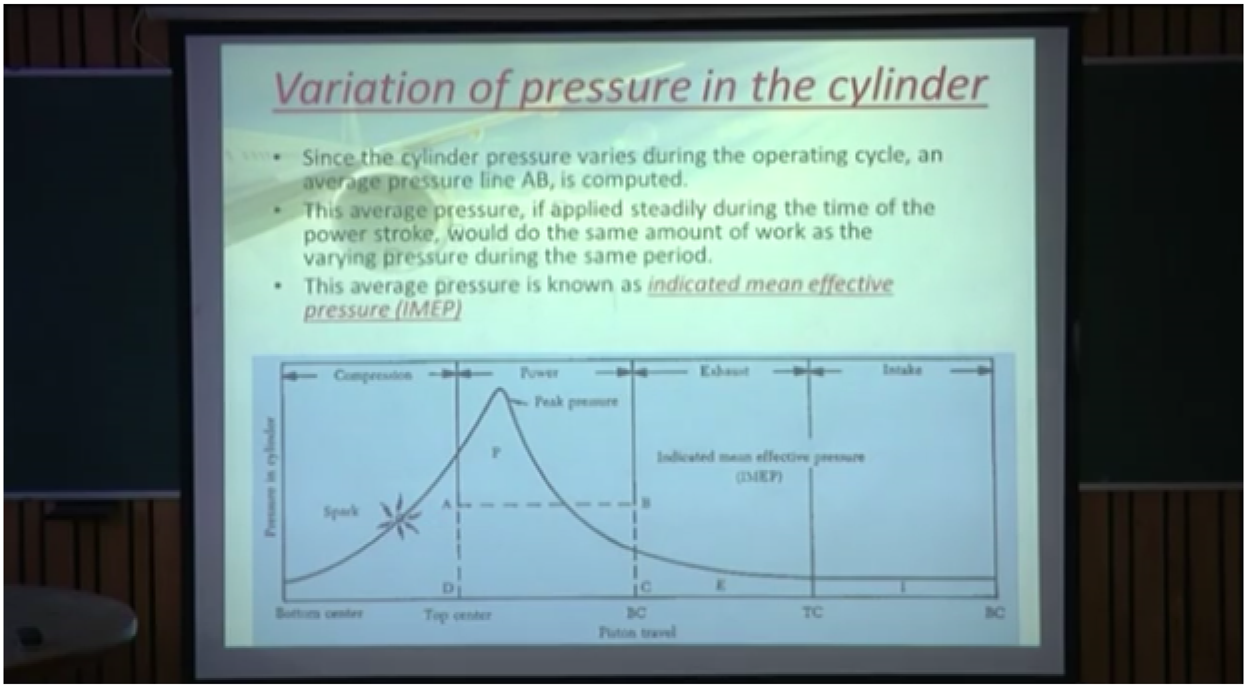


Coming to another horsepower which is your brake horsepower, the power delivered to the propeller for useful work is known as brake horsepower called BHP it is the indicated

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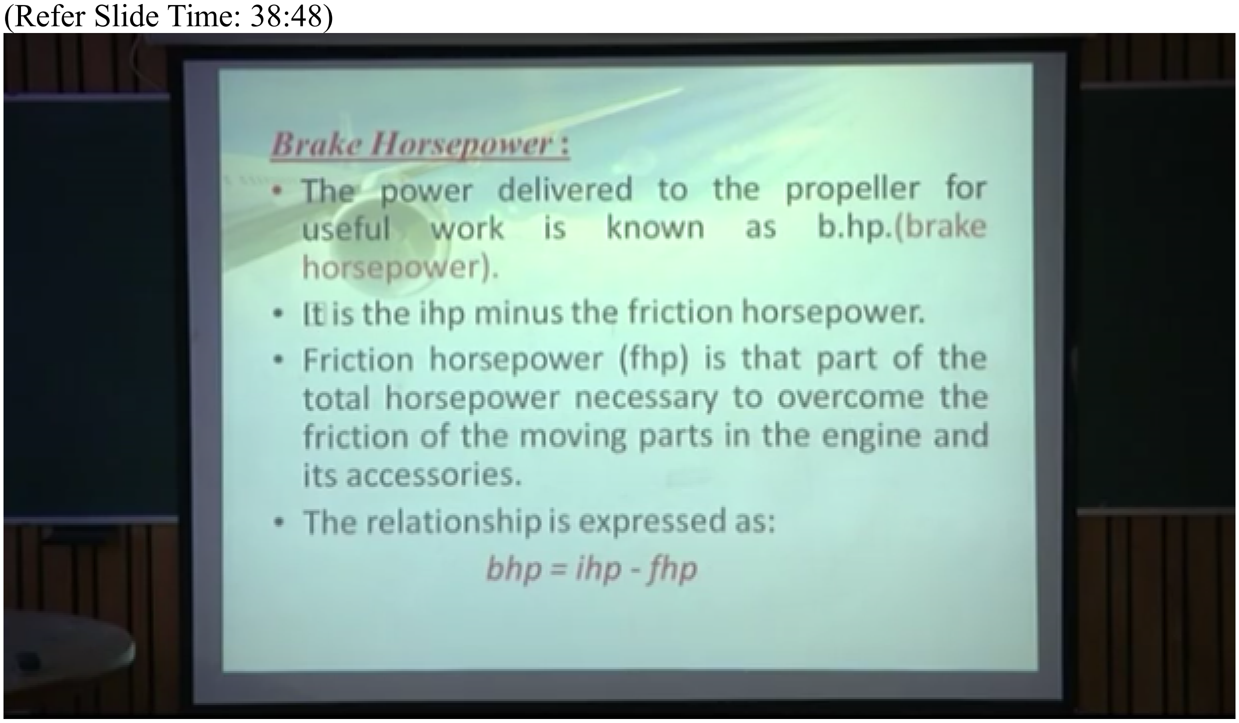


horsepower minus the frictional horsepower, we've seen earlier that indicated horsepower was the horsepower was the power without considering frictional losses, in this brake horsepower this is indicated horsepower minus the frictional horsepower, friction horsepower is that part of the total horsepower necessary to overcome the friction of the moving parts of the engine and its accessories, so the relation is expressed as brake horsepower is BHP = IHP – FHP, indicated horsepower - frictional horsepower.

Coming to thrust horsepower, the power resulting from a combination of engine and propeller working together is known as thrust horsepower, so if we consider the engine and propeller working together it is called thrust horsepower. Thrust horsepower is equal to brake horsepower, if the propeller is designed as 100% efficient.

Now if you consider your propeller as 100% efficient, then your thrust horsepower is equal to brake horsepower,
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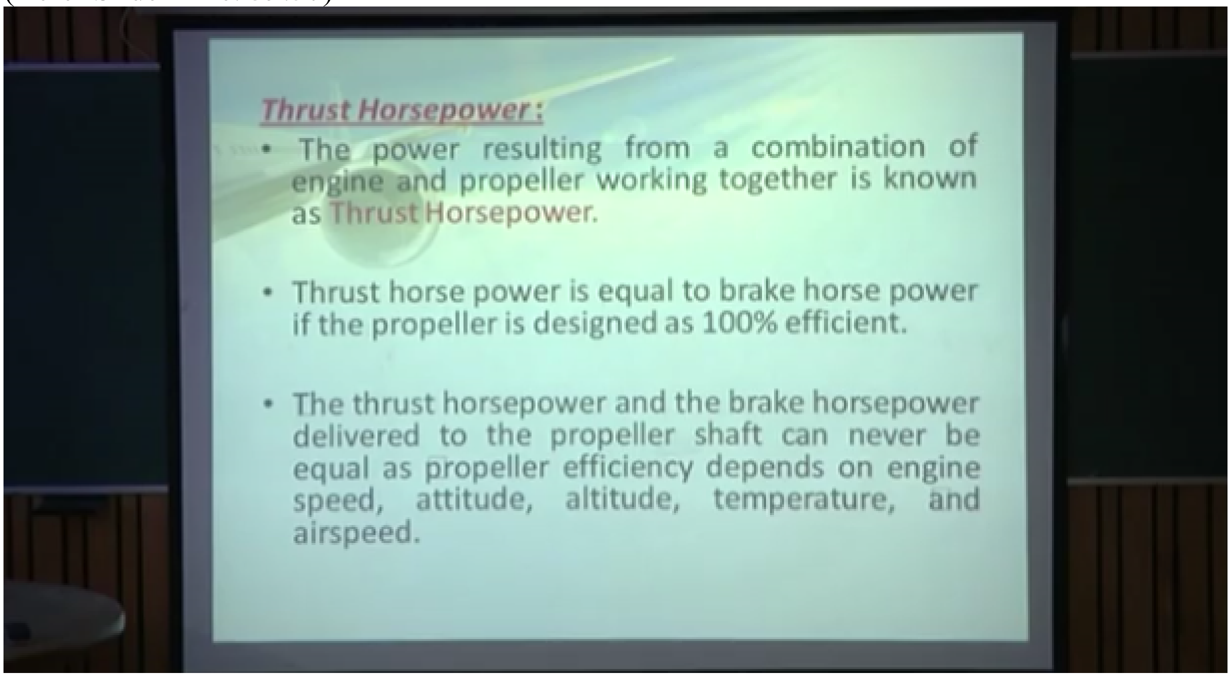


but in practical conditions the propeller cannot be designed as 100% efficient, the thrust horsepower and brake horsepower delivered to the propeller shaft can never be equal as propeller efficiency depends on engines speed, attitude, altitude, temperature, and airspeed. Now because your propeller efficiency is dependent on so many factors attitude, altitude, temperature and airspeed so your thrust horsepower can never be equal to brake horsepower because your propeller cannot be designed as 100% efficient, so we had seen the different powers indicated horsepower, brake horsepower,
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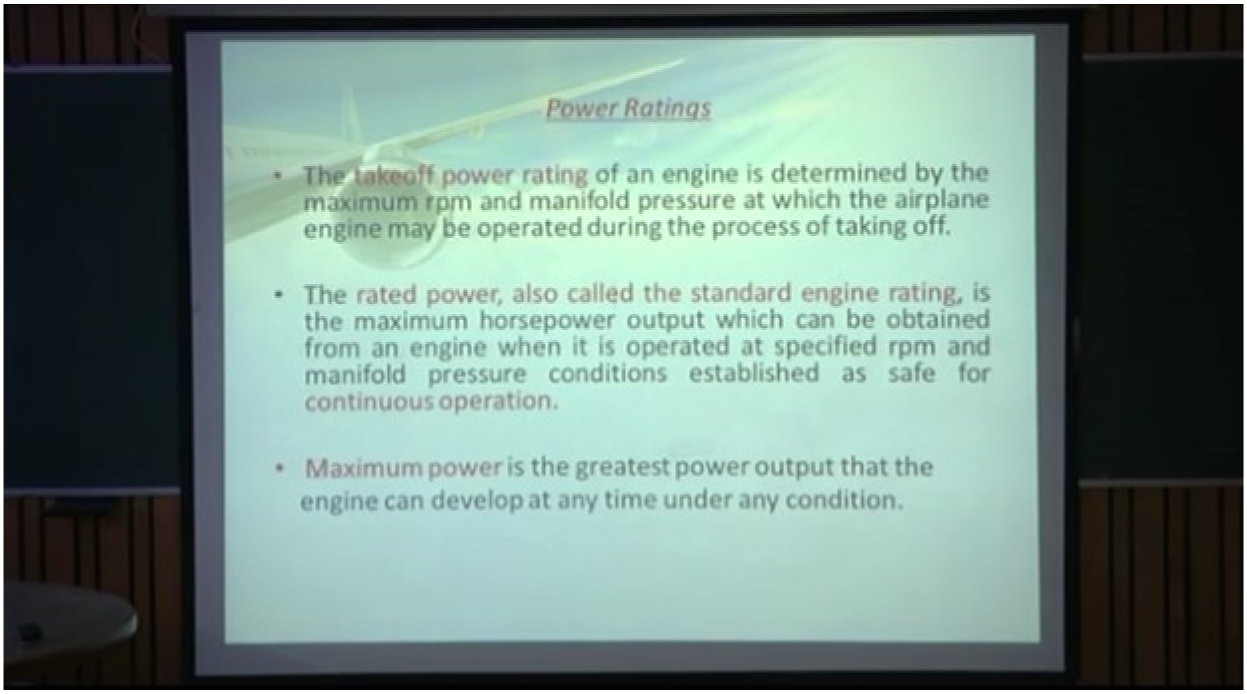


thrust horsepower coming to power ratings the engine has different power ratings, the takeoff power rating of an engine is determined by the maximum RPM and manifold pressure and which the airplane engine may be operated during the process of taking off, so the maximum rpm and manifold pressure at which your engine can be operated during the process of taking off is called your takeoff power rating.

Now another power rating is your rated power which is also called your standard in generating it is the maximum horsepower output which can be obtained from an engine when it is operated at specified RPM and manifold pressure conditions established as safe for continuous operation, so your specified RPM and manifold pressure conditions which are considered as safe for continuous operation, the power that is obtained from an engine when it is operated at specified RPM and manifold pressure conditions for continuous operation is called your rated power, that is the maximum horsepower output which is obtained when an engine is operated at specified RPM and manifold pressure conditions which is considered as safe for continuous operation.

Now coming to maximum power it is the greatest power output that an engine can develop at any time under any condition, so at any time under any condition the power that can be developed is your maximum power, rated power is the maximum horsepower output which can be obtained from an engine if then it is considered safe for continuous operation, so your rated power it is your standard engine rating which is the maximum horsepower output which can be obtained from an engine if it is operated at specified RPM and manifold pressure which is considered safe for continuous operation, and your takeoff power rating is the maximum RPM and manifold pressure at which the engine may be operated during the process of taking off, so this was all about the power ratings, the basic history behind the engine some science fundamentals involved and the four stroke five events cycle and different powers developed by the engine, the different ratings of the engine. In the next chapter we will see how an engine is constructed, what are the different parts of an engine.

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