MARINE ENGINEERING

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Lecture36

IC Engines

so good morning today I will start the topic IC engine IC engine means internal combustion engine okay internal combustion means combustion will be happening inside a cylinder so we will have one cylinder and one piston will be there this is called cylinder and this is called piston this shaded one piston when piston is moving up and down the combustion will be happening here combustion combustion or reaction fuel and air you take inside this cylinder combustion will be happening and this will be creating high pressure gas that high pressure gas will be pushing piston down and because of this piston down movement again another Activity will be there like piston will be moving up and down.

So one reciprocating action will be happening continuously in piston. So that will be giving your rotary motion in a shaft. So this will rotate shaft. This will rotate a shaft and shaft will be connected to your propeller. so this the engine whatever power it is producing directly it may not go to your propeller because engine your propeller requirement will be different your engine power production will be different sometime your ship is moving at very high speed sometime it will be standing okay so you need different amount of power for example bike you are driving in traffic you are standing your engine on but your

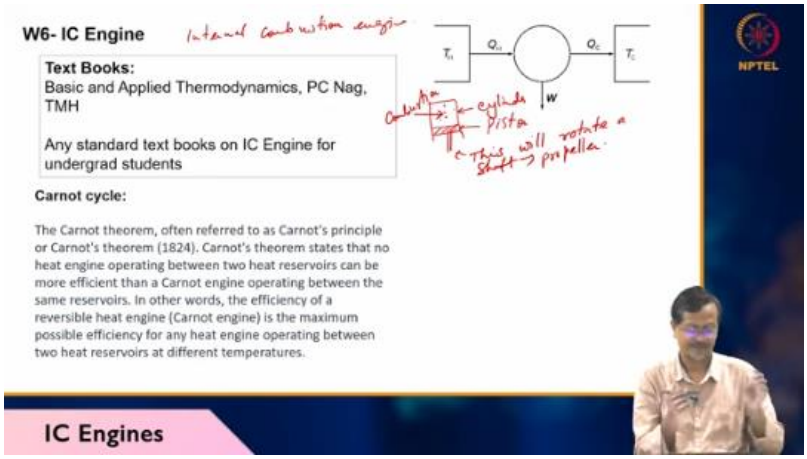
your engine on but you are not moving right your car in traffic or in parking space you started is not moving but engine is on right so that time power requirement will be lower but after you start moving your power requirement will be higher especially initial gear 1 you are giving right so initial power requirement will be higher then you will be moving at cruise speed so that time energy consumption will be lower but still it will be higher than whenever standing the power requirement that will be higher power will be higher when you are moving right so that means whatever power you are producing in engine so same power may not be used in your propeller okay then there will be different mechanism so one mechanism is that yeah we must have one shaft shaft will be transferring torque or

power so engine is rotating this one this in this may be shaft okay at very high speed and propeller will have speed 100 to 100 rpm so that means you have to reduce the speed okay engine is producing maybe 700 rpm or 1000 rpm But your propeller needs 100 to 100 rpm. Sometime lower rpm also possible.

That means you must have certain mechanism to reduce the speed. For example your gear cycle is there. So sometime you speed up. Sometime you just change gear. So there will be certain mechanism to reduce speed of the shaft.

Then engaging disengaging main shaft and propeller shaft. Main shaft means engine is producing power and shaft is continuously rotating. But propeller not rotating. Like bike engine running but you are not moving that means some disconnection happening somewhere ok engine running means shaft is rotating continuously but your wheel is not rotating in bike wheel not your shipping wheel means that steering wheel actually in ship term wheel means steering wheel right but in bike wheel i am saying like bike piya right tire and tube that wheel so engine running shaft rotating

But your wheel, that propeller not rotating. That means some mechanism must be there. Some clutch arrangement must be there. Okay. Some clutch arrangement must be there.



Then you are changing speed I said. Speed changing when happening. So that means there will be certain mechanism called gearing mechanism. In your bicycle also you have gearing mechanism to change speed. So gear mechanism will be there.

Okay. And when shaft is rotating, it will be holding, hold it by something, right? And it is rotating. So, when it is, something is holding it, friction will be there. Lots of friction will be happening.

Okay. When lots of friction is there, energy loss will be there. Because of friction, energy loss will be here. So, how to reduce that energy loss? So, you will have bearing system.

so you will have bearing different types of bearings I will discuss later different types of like gear clutch other mechanism also I will discuss later just I am telling you the name how things will work so shaft is rotating and it must be smooth rotation friction will be lower so there will be bearing mechanism so bearing may be radial bearing thrust bearing thrust bearing what is thrust bearing propeller rotating ok let us say this is shaft here propeller is connected ok propeller rotating when propeller rotating actually it is pushing water when pushing water because of Newton's third law water will be pushing in same with same force but opposite direction right that means shaft will get another force axial force one torque is transmitting but it is getting axial force also okay so but axial force you cannot transmit to your engine engine very much sensitive it is producing power it do not give extra load right so someone is doing some work and you are giving extra load so some that person can fail okay he may not take or the engine may not take the extra load okay so you have to make certain arrangement so that load will not get transferred to the engine propeller is giving extra load axial load so that must not be transferred to engine so then what to do we must have certain bearing arrangement called thrust bearing so thrust bearing will take axial load but it will allow rotational movement okay so we will have bearing radial and thrust okay now ceiling arrangement ceiling arrangement means you have stand tube you may have hard stand tube okay

So propeller is rotating here, bearing is here and bearing must be lubricated. Lubricated means like in your bike or car or bicycle you add sometimes grease or sometimes thick fluid. If you go to cycle shop they will be putting some thick fluid, mobile or lubricating oil they say. Sometimes they will be putting grease, semi-solid, some metal, black color or some yellowish color they will be putting. So this is called lubricating oil or to reduce friction.

okay now when propeller rotating propeller will be passing propeller sharply passing through one bearing okay so bearing must be lubricated to reduce friction now when propeller rotating water splash will go into this lubrication section okay when it is going to lubrication section lubrication will be washed away because of sea water then you have to seal properly both side like i said this is my bearing is holding and seal this end this end So, sealing must be proper. So, sealing will not allow water to enter or inside grease or lubricant whatever is there, it should not go out. So, the sealing is called stern tube sealing.

So, this is my propeller, shaft is going there, shaft is going through one seal section, seal and bearing is called stern tube.

And this lubricating oil or grease, it should not go out. So, you must seal properly. These days, there are new seal arrangement came up, water-based seal and other types of seal. If you are using hydrocarbon-based sealing, sorry, lubricating oil, so what happens in hydrocarbon? If it is going to water, your MARPOL is there, the regulatory authority.

They will be filing a case against you. So, then you must make proper arrangement so that your hydrocarbon based lubricating oil or grease should not go into water, seawater because of pollution issue. Okay. So, sealing must be there. I wrote I think sealing arrangement.

Sealing and bearing. Okay. So, your engine producing power, engine power is transferred to one shaft shaft will have connection of gear mechanism because you want to reduce speed main engine shaft higher speed propeller speed lower you must have gear mechanism to reduce speed you must have some clutching mechanism okay then that shaft will be hold by some bearing bearing must be lubricated to reduce friction okay so all these things i'll be discussing actually in this course okay so first will some lectures are there in first week of my course i have told about with different thermodynamic laws like first law second law third law zeroth law so there are four thermodynamic laws first second third and zeroth law okay so you can recap from your books even in first week lecture also i have given those theories and first law says energy can be converted into heat heat can be converted into water

work but in second law says heat and energy convertible but hundred percent not possible some losses must be there every time okay so that theory says perpetual motion machine so any machine you design it will be running continuously without taking external energy not possible okay so our whatever engine related discussion will do we will consider some losses will be there every time okay if we say some ideal situation so in that case we ignore the losses But normally, when you are converting heat to energy, energy to heat. So, there will be certain amount of losses. So, work can be converted into 100% heat, but heat cannot be converted into work. So, this is given in second law of thermodynamics.

And third law and zeroth law, this is a different story. But basically, all these things should be based on second law. First law and second law, you can say. So first, whenever you discuss about any engine, we discuss with Carnot cycle. So Carnot cycle will have some theorem.

Carnot cycle means this engine, one certain engine, that engine will have maximum efficiency. So any engine you design, that engine efficiency will be lower than this Carnot cycle efficiency. Okay. This Carnot cycle defines the maximum efficiency possible between two temperature. Hot temperature, low temperature you have.

High temperature, low temperature. So, Carnot cycle, the formula will be giving the highest efficiency. Okay. So, we have many other cycle. Diesel cycle, auto cycle, addiction cycle, Brayton cycle.

So, all those cycles will have lower efficiency than Carnot efficiency. Fine. So, Carnot theorem often referred to as Carnot principle or Carnot theorem. 1824, 200 years ago. 200 years ago Carnot's theorem states that no heat engine operate between two heat reservoir can be more efficient than a Carnot engine operating between the same reservoir okay so high temperature th you see top picture th hot temp high temperature tc this is hot i can say this is cold i can say okay and if this is engine so Carnot engine will give the maximum efficiency okay

In other words, the efficiency of a reversible heat engine, reversible and irreversible. Reversible means like we assume entropy constant and system can move from A point to B, B to A possible. When we talk about irreversibility from second law of thermodynamics, irreversible means some energy will be lost every time. So, because of friction or because of heat transfer, because whenever any process will be happening, so there will be certain heat transfer to the environment. So, that you cannot recover.

So, because you cannot recover, so that will be considered as a loss of energy. So, whenever we are talking about reversible heat engines, means we are assuming the 100% heat transfer to work, work transfer to heat is the maximum possible efficiency. For any heat engine operating between two heat reservoir at different temperatures. Two heat reservoir means hot TH and T cold. These are two reservoir we are assuming.

For example, environmental. This room temperature can be considered as a heat reservoir. So, this week 6 lecture basically I have taken from textbook basic and applied thermodynamic PC. PC is not there. PC is not there.

PC Nagaraj. I have written PC but is it PC or PK? PK Nagaraj. So, I have taken this lecture from PK Nag book. I think it should be PK Nag or any standard test book on IC engine you take basic book on IC engine.

There will be lots of books available for IC engine discussion advanced book also. So, we will not discuss advanced part. We will go through only basic part, basic simple calculations. because it is marine engineering course and we have only few lectures allotted for this IC engine so gas powered cycle so gas powered cycle means like we have fuel plus oxygen and we burn it and we get a burn gas okay so this burn gas will be driving your system so this is called gas powered cycle so another cycle is the steam powered cycle In steam powered actually, the coal, especially steam engine, if you see coal or any fuel will be burned.

So that fuel will be giving heat to water. Water will be heated up. So water will be producing steam. So the steam will be running your turbine system. So it is called steam powered system.

But in gas powered cycle, IC engine, you will have gas turbine engine. IC engine means internal combustion engine and gas turbine engine so this is little bit different I will discuss later regarding gas turbine engine that is also gas powered engine so fuel will be burnt so hot gas will be passing through turbine and turbine will be rotating during rotation it will extract energy from hot gas and it will produce torque torque means power actually because power equals T into omega torque into rotational speed Whenever I am talking about torque and it is having rotation that means actually I am talking about power. So engine operates under cyclic or non-cyclic condition. Cyclic operation means like if I say gas turbine engine in that case we assume this is non-cyclic.

Gas turbine engine this is non-cyclic operation. We will discuss later. IC engine, we assume this is cyclic process. What is that cyclic process? If I draw PV diagram, so process will be happening like this in internal combustion engine.

Compression will be happening 1, 2, 3, 4. So, in IC engine, IC engine okay but if i see gas turbine engine so that thing will not happen compression will be happening combustion be happening then so cycle is not complete one two three four okay but cycle is not complete but in ice engine we assume cycle is complete These are assumptions. Actually, whatever gas we produce in IC engine, the same gas will not be circulating.

So, in actual case, it is not cyclic process. But for our simplification, we assume it is a cyclic process. But in gas turbine engine, we do not assume that one is cyclic process. So, this is gas turbine engine. We will discuss later, so we will understand what is this PV diagram.

So, we talked about Carnot cycle. So, in Carnot cycle, when we represent Carnot cycle, we draw TS diagram. So, 1, 2, 3, 4. So, this discussion is already there in week 1 lecture. So, you should go through this.

So, in Carnot cycle we will have two reversible isothermal process, two reversible adiabatic process. And DABD means no heat transfer happening. Isothermal means complete heat transfer happening. You are compressing certain gas with very slow speed. So in that case heat will be transferred to atmosphere and it will be maintaining same temperature continuously.

So this is called isothermal process. But if process is very fast. Suddenly you are compressing something. So in that case heat transfer so quickly not possible. So that is called adiabatic process.

So adiabatic process is also called isentropic process. Entropy will be constant. But in isothermal process heat is getting transferred. So entropy is changing and your temperature is constant. So reversible isothermal process, which one?

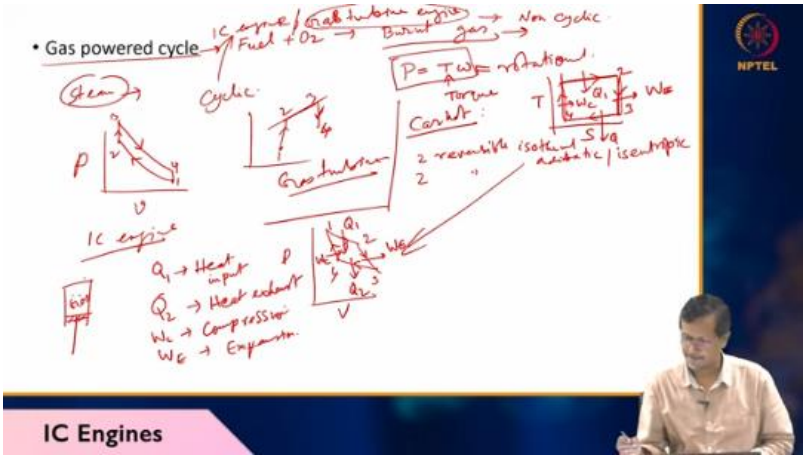
1, 2, 2 is isothermal process. 4, 3, 4 is isothermal process. While 1, 4 is adiabatic process. 2, 3 is adiabatic process. So you should remember the names.

Isothermal means same temperature. Adiabatic process, isentropic process, S is entropic constant. Sometime we use isochoric process where your volume is constant. Isobaric process, pressure is constant. So, those terms you should remember.

Fine. And same thing if I draw in PV diagram, pressure and volume diagram. PV. So, it will be like this. 1, 2, 3, 4. okay here I can assume heat input is happening heat rejection is happening here compression work is happening we are getting power output so here same thing I can replicate TS diagram here actually it is coming like this so compression work is happening expansion work or we are getting work output heat input heat output

So Q is heat, Q1 heat input, Q2 heat output, heat exhaust and WC compression, WE expansion. expansion process so what is this compression expansion process if I take certain amount of volume okay and I have one piston here certain gas is here okay so initially start pushing the piston up when you pushing up compression happening okay so compression happening if it is very slow process it is very slow process then heat will be transferred okay again if you remember the boil slope Boyle's law actually it is isothermal process why that time he did not have any system to make system faster so he made everything slower so slowly compression was happening so PV equals constant he

produced the formula okay when isothermal is there PV equals constant when adiabatic we are saying PV power gamma equals constant right so isothermal where can I write isothermal PV constant adiabatic PV power gamma equals constant. So later stage when people got machinery to compress things very faster so that time they produce this formula PV power gamma equals constant.



okay and yeah so Boyle's law should be very slow process and low pressure application not too high pressure okay that time he did not have a very system with very high compression system okay so very lower compression and slow speed that is used for Boyle's law okay there is a limitation of Boyle's law but if you are thinking about adiabatic process Tb for gamma would be there and system should be fast so heat transfer should not occur okay but if in certain cases later we'll discuss if heat transfer is occurring so that time we say polytrophic process so it is not isothermal not adiabatic in between something happening then we say polytrophic so normally for IC engine discussion internal combustion engine discussion we do not consider this one as polytrophic process we consider this as a adiabatic process okay So, isothermal is not possible in ice engine because piston movement will be at very high speed. So, it is not isothermal. So, it should be adiabatic or polytopic.

But the system moves at very high speed. So, we assume this is an adiabatic process. And it is air. So, our gamma value will be 1.4. Specific heat ratio will be 1.4.

So, whenever we are talking about gas power cycle so we have two system one is gas turbine system one is IC engine system okay whenever talking about IC engine so we have to go through certain assumptions so first assumption we will assume this is air standard cycle this air as a working fluid and air is an ideal gas practically if you consider then it is not ideal gas but here we are assuming this is an ideal gas gamma value 1.4 done okay PV

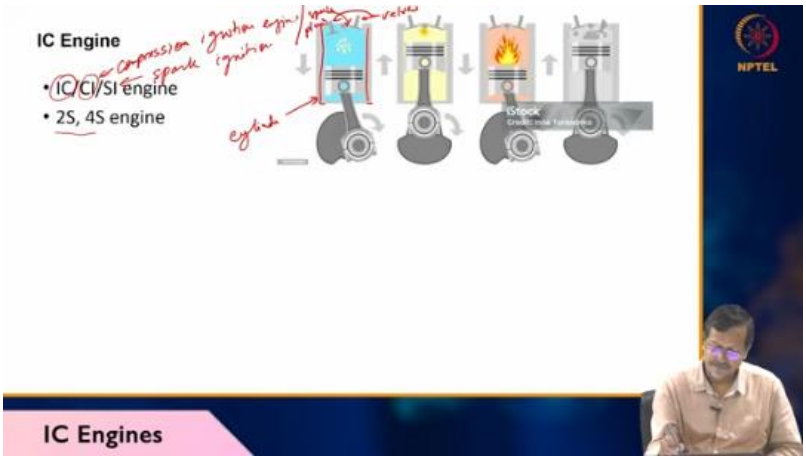
equals NRT formula should be applicable. Constant specific heat, CP, specific when pressure is constant, when volume is constant. These are also constant.

Neglecting mechanical friction, when piston moving up and down, so friction will be there. So, we are assuming there is no losses. We are making it idealized. Heat transfer losses also we are ignoring. I said like this is adiabatic process we are assuming.

instantaneous and complete mixing of air and fuel during combustion entire process as a closed cycle mass flow rate is constant so when system is occurring so mass flow rate is constant we will discuss what is the mass flow rate and all these things later okay just you presently remember these assumptions so whenever you are talking about ic engine so there are several terms actually you should remember ic engine term will be their internal combustion engine another term is their ci called compression ignition engine compression ignition okay si means spark ignition okay normally your bikes cars will be having spark ignition engine okay there will be two stroke four stroke engine also so we'll discuss later What is two stroke? What is four stroke? First try to understand what is IC engine.

So IC engine will have one cylinder. You see this is a cylinder. It will have this is called cylinder. And this will have valves. Okay.

two valves are there another valve is here and this is spark plug spark plug and this is called piston this one ok this is called piston this is called connecting rod there will be one crank actually you cannot see the crank part so crank will be here I will draw another picture same thing I am drawing in 2D format you also can draw if you like Okay, so connecting rod, crank. So this is piston. I will have valve here.



This is cylinder. So whatever I have copied from iStock pictures website, same thing I'm drawing here actually. So this is crank. This is connecting rod. connecting rod this is crank

this is called crank case ok whenever you are discussing about IC engine you should know the terms ok so many time we will be saying ok crank case but if you do not know the term what is crank case then it will be difficult for understanding ok so this is crank case and this is piston this is cylinder c y l i n d e r ok

And valves will be there. Then there will be one spark plug. Your car or bike will have spark plug. So one spark plug will have. Because if it is SI engine.

Spark ignition engine. Then there must be one spark plug. So that is why spark term is there. Spark ignition SI. Another type of engine is there.

CI engine. Compression ignition engine. In that case spark plug will not be there. okay later we'll discuss about CI engine so first we assume this is spark ignition engine okay so we have crankcase crankcase will have lubricating oil actually lots of lubricating oil because if you have bike or car at your home you can see this after certain time you have to remove this oil engine oil they say okay and again you have to fill that engine oil so this is called lubricating oil in scientific or technical term is lubricating oil OIL okay so but normal people will understand this is engine oil okay if you go to any shop they will say engine oil all right so normally it will be like yellowish color oil initially when they'll be putting after two three months or six months you will say it will be it will be almost blackish color so if you do not change the engine oil for maybe one year it will be more thicker okay when it is thicker engine will not start or engine will create a problem

So, time to time you have to change the engine oil. So, later I will discuss about lubricating oil, its property, why you should change. Basically, I am not discussing, I am just explaining the system first. So, if you see the piston in this top picture. So, piston is having certain grooves like this.

You see grooves. So, grooves are called piston. There will be piston rings. So, there will be piston rings. And piston cylinder will have one top dead center TDC called top dead center.

So, center spelling British or American just you can decide C and T are I wrote and you can write C and T are you also if you are following British spelling. And there will be one top dead center bottom dead center. BDC bottom okay so what happens if you rotate the crank you see this connecting rod will be pushing piston up and down okay so if you rotate crank you say a B C okay a a means shaft here crank is here and cranky rotate around this one okay when crank is rotating you see this connecting rod will be moving up and down

bc that bc that rod it's called connecting rod connecting rod will be moving up and down when it is moving up and down piston inside the cylinder will be sliding up and down okay you give crank one rotation piston will be moving one time up one time down So, up and down the maximum distance following is called stroke.

So, how much distance it will move from top dead center to bottom dead center? BDC to TDC stroke. So, piston will have one crank rotation, one complete crank rotation, 360 degree rotation. My piston will be moving up stroke, down stroke. okay crank one 360 degree piston moving up and down okay so piston moves up stroke or piston completes i can write up stroke and when crank

rotates 360 degree fine so when crank is rotating 360 degree my piston will be moving up and down so you increase your crank rotational speed your piston movement will be faster okay in our normal ice engine application car bus truck train train also there these diesel trains are there right because previously it was coal coal based engine now government has replaced all almost all coal based engine only heritage trains are there most probably this uti and darjeeling those trains are there for heritage purpose or tourism purpose they have kept otherwise normally all trains are replaced by your diesel engine or electric engine okay okay so your ic engine will have one crankcase one crank On connecting rod, piston, piston ring, cylinder, valves, spark plug. In some cases, if it is CI engine, CI engine will have a nozzle. Later I will discuss what is the difference between SI and CI.

CI engine will have nozzle and it will be injecting fuel in atomized form. But SI engine, it will be mixing air and fuel, then it will be injecting into the cylinder. now what is happening when piston is moving up okay let's close all the valves maybe I'll okay you see the second picture picture I will put number one two three four okay you see the top pictures so first you take air fuel mixture inside cylinders okay you see the picture one okay inside you take air fuel mixture close all the valves now start pushing piston up when piston moving up compression will be happening when compression happening air temperature will be increasing when air temperature increasing you get you give small spark this is second picture spark is there small spark is happening okay small spark means small fire source you give okay so that will give small reaction so that will be produced that will be exothermic reaction when fuel is burning it will be exothermic reaction fuel plus air plus fire source it will create exothermic reaction so the exothermic reaction will be producing more heat it will be heat will be transferred to another molecule another molecule then whole mass whatever inside cylinder is there air and fuel mixture will be burnt there is a

combustion or reaction is happening so when combustion happening the small air and fuel mixture it will create very large volume

because temperature increased now ok because of charlotte temperature increased temperature increase means pressure increased volume increased ok ah so you see the fire third picture you see lots of fire happening inside cylinder ok so then high pressure piston will be pushed down piston push down means crank will be rotating ok with crank rotated when crank at the bottom portion then open some certain valves okay then you reduce the pressure when again crank is moving up again you compress give fire you pressurize so continuously this sequence will be happening okay take fuel air mixture compress it give fire then it will burn it will create very high pressure piston will be pushed down crank will be rotating at the same time because my connecting rod is connected linked with my connecting rod is linked to crank so when connecting rod is getting pressure from piston connecting rod is rotating half again because of certain mechanism you push it up again compress burn push it down so one time you are giving power another time you are not giving power actually so you are getting one power stroke every time three cv rotation you are getting one power stroke power stroke means one time it is forcing down forcing down means crank will be rotating half another half will be rotated by its own mass so here one mass is here okay this is balancing mass okay when piston is moving down it is getting power when piston wants to move up so that time it needs some power so this mass extra mass is there so that mass will give extra momentum to compress certain amount give spark create pressure so that way things will be rotating okay so lots of YouTube videos are there please try to watch okay how things are working in sequence okay now I'll draw the PV diagram pressure and volume and PS temperature entropy

so I'll be drawing one piston cylinder arrangement here again I'm not drawing all the connecting rod and casing thing just I'm turning vertical piston to horizontal so that I can draw in PV diagram properly okay and piston will not move up to the end it will keep certain gap because of mechanical reason mechanical reason okay so this is called top dead center okay piston will be moving maximum this one so this is BDC so piston is moving from top dead center to bottom dead center top dead center is not the end of the cylinder because certain gap we have to keep otherwise this piston will be coming and it will be touching continuously this top section it will break okay so we don't want to touch every time piston and this cylinder okay so that's why we should give certain amount of small amount of gap okay so that maximum piston traveling that is called tdc top dead center minimum bottom dead center okay now pv diagram this assume okay assume initially my

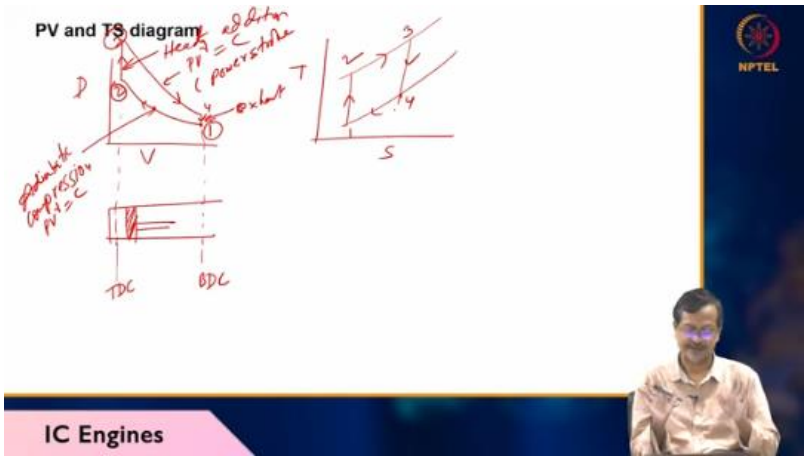
piston is here okay piston at the furthest end at the bottom dead center okay now your cylinder is filled with lots of air now you start compressing you close all the valves and start compressing what will happen compression will be happening okay what type of compression i said adiabatic compression okay adiabatic compression and dbt compression means we are assuming there is no heat transfer just you compressed now after that after compression what will happen i said like a spark you give some spark and burning will be happening so give a spark and burning is happening okay so one two three two to three burning happened burning happened means you got lots of heat so what will after that what will happen that high pressure gas piston will push backward

TDC to BDC piston is moving backward TDC to BDC so again the formula adiabatic compression adiabatic expansion piston moved down so adiabatic expansion happening then for So, you have to put arrow also whenever you are if I ask you to draw the PV diagram. So, you should put properly arrow direction. If you are putting wrong direction I may not give marks. And once it reaches to 4, 4 means this bottom dead center all gas should go out.

So, we are assuming instantaneously gas went out. And 2 to 3 if you see piston is the top dead center and instantaneously you are giving all the energy practically is not possible when piston is moving very high speed moving going up down up down so when it is reaching a top dead center it is not having enough time to get heat actually but to approximate we are assuming this is ideal case and instantaneously it is getting all heat so process 2 to 3 instantaneously happening And 4 to 1 also, we are assuming instantaneously all gas is out. And all intake also happened.

And 1 to 2, again compression happening. 2 to 3, heat addition. So, 2 to 3 process is heat addition. 4 to 1, exhaust. So, when we are getting power, 3 to 4, this is power stop.

so when piston is moving TDC to BDC at very high pressure because of high pressure gap we are getting power so this is called power stroke and if I draw the same thing in TS diagram TS diagram will have like this 1 to 2 1 to 2 adiabatic process so I am assuming this isentropic no heat transfer happening 2 to 3 heat addition, heat addition means my temperature increasing 3 to 4 expansion happening, I am getting lots of power 4 to 1 exhaust happening so this, if I ask you to draw PV-TH diagram with your 1 pistons in arrangement so you should give proper nomenclature name 1, 2, 3, mismatching of number or error direction wrong, I will not give marks


PV and TS diagram
Heat
P
V
TDC
BDC
T
S
NPTEL
IC Engines