Engineering Thermodynamics
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Lecture – 30
Properties of a Pure Substance: Process analysis. Summary

So, that is basically bring us to the end of our discussions. We will take questions and then I will summarize what we have done, ok. The first question is, is it possible for polytrophic process to occur naturally? And the answer is yes, in the sense that will you see a air flowing through a building or at some point that the contraction and air goes to it in the velocity goes up, and we know that we assume temperature to be constant we can the thermodynamics of we can approximate that the p v to the power n equal to constant.

If you make that naturally that you give something to itself and it will do it that is also possible. You take shock absorber and you compress it and let it go, I will comes out by itself it could follow that sort of a thing, especially gas filled shock absorber, that will that what it will do. So, it is possible that because those process are irreversible, that is why it is not feeble to be for k equal to constant. Irreversibility it will make an end even if that device all adiabatic, ok.

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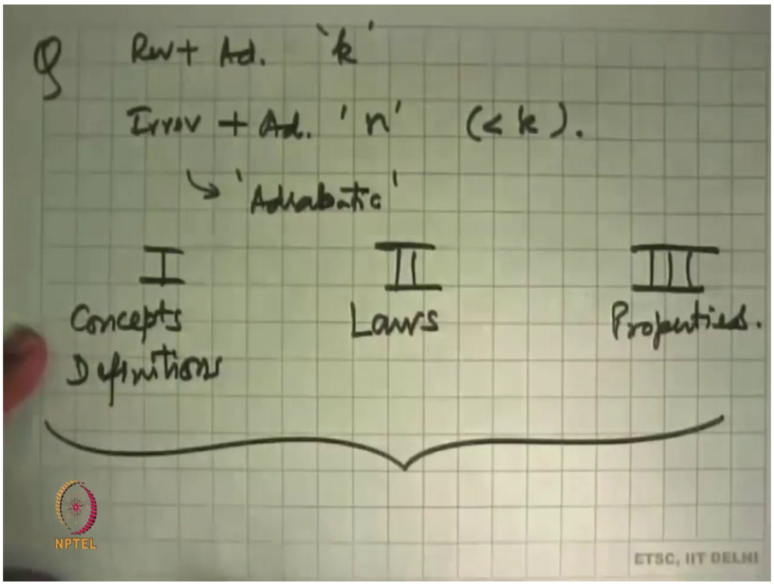

So, even if reversible and adiabatic then the exponent is k, but even if irreversible in terminal irreversibility is in the device and adiabatic then this will be n and typically this will be that be less than k. If you are cooling it then of course, n will come down even more and so all thing that engines and compressor the things like that n is less than k which you should do a complete analysis will show you it is not a good thing because that is not the best efficiency best way to do the compression.

So, people try to make things that you would like to make it as adiabatic as possible. And a lot of work has gone on we will say we cannot make an internal combustion engine where the cylinder piston arrangement will be adiabatic. Right now it is not we will look at a motor cycle engine then what sense on it, so whatever heat was there generated by the burning of the fuel some of that was conducted to be atmosphere through the external energy things and the rest of it you got some work over it.

So, by burning fuel you lost some energy to atmosphere and that one of my best thinking you do. So, I make a adiabatic by putting lot of insulation on it, fine, but then the material will run much hotter, it will get very hot and materials like aluminium or aluminium alloys may not be able to withstand that type of a temperature, they may lose the strength, they have talking or where it they may happen will be lubricating oils methods burnt up or destroy and so that engine may not be weighing a long lasting heat. But that is definitely a thermodynamically basis on the reason why you like to make such a process adiabatic.

Could you please explain the importance of Gibbs energy? Ok, I have generally not gone too much into detail on that, but Gibbs energy basically tells you that will additional chemical reaction we know that we get so much heat out of it. The question is if instead of that chemical reaction happening and instead of taking it on the heat what if it is possible that I work I can get out of it, and that will what Gibbs free energy tells us. So, that is the maximum work that we can get from a particular process. In the case of non-reacting systems, we have gone to straightly different connotation, but it essentially still saying that in the maximum work that you can get without the interaction with the surroundings whereas, very roughly what Gibbs free energy is (Refer Time: 04:09).

Right, what we have done in this course, we have 3 modules so far and now we have covered all the knowledge that we will be want to solve a problem, we have everything, whichever problem, whatever way it is now that is not an issue for us. We know how to do a first cut analysis of all these type of problems. In the first one we said we have to worry about concepts and definitions. In the second we said what are the laws, and what we learn was universally true there was no it send much it did not depend on the application, it did not depend on the examples. And now we looked at to do calculations of changes in properties we have learn how we can compute and calculate the properties of this substance. So, all of these together now give us the confidence that we can completely solve a problem and answer various questions; so, let us taken couple of examples.

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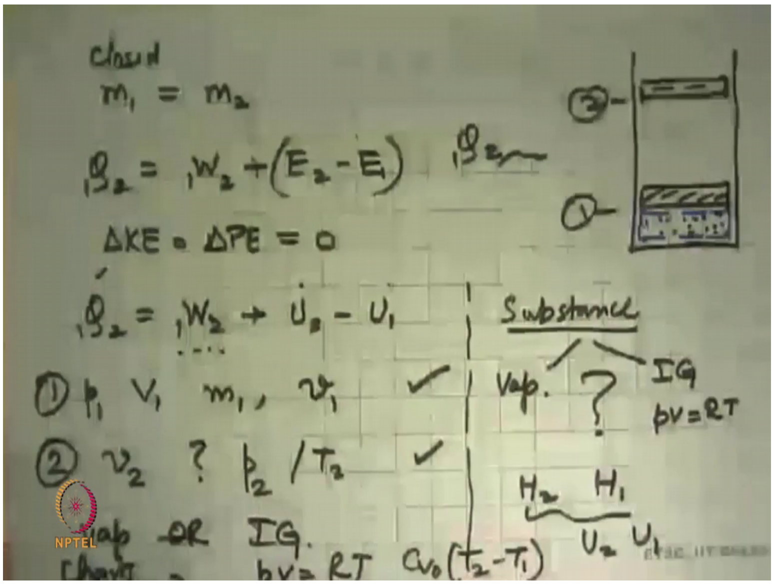

We say that there was similar piston arrangement in which the piston moves from this position to this position these are stage 1 and stage 2, then some material some substance in it. And during this process certain amount of heat was going to it and we want to calculate what is the work done by the device.

So, we know now the start of the way we did in the beginning that we identify the system, the system boundary in what we draw first and say whether it is a open system or close system. And we say this is a close system. So, the way the equation will be that mass of what is there inside this is constant, let be mass in state 1, we go to mass in state 2 conservation of mass and the first law tell us that Q 1 2 is equal to W 1 2 plus E 2 minus E 1, and then we made some assumptions of delta KE delta PE be 0 and that comes that Q 1 2 is equal to W 1 2 plus U 2 minus U 1.

So, we need we need to calculate various things and we did not write down what is it then given in the problem. Say state 1 is fully defined that p 1 is given and v 1 is given and say mass could be given which means that specific volume at the beginning is more. And we said state 1, I have two independent properties I can get enthalpy entropy anything else that I want. And now we define what is in state 2, we know that if it went up there the mass was the same m 1 equal to m 2 the volume increase that is double dot triple dot or triple whatever let us say volume change you know, but say we do not know what is the final pressure.

If you are given the final pressure p 2 then we say that well now I know both thing or say t 2 and we know that state 2 is defined, we can get U 1 U 2 and heat transfer then the process well known, so work for this process can be calculated. And what one does then in that at this point what we have note that so far in our problem solving was say that what is the substance. Have you know the properties of the different substance? Now, we have to make a decision. Should I assume this to be a vapor and go to the tables and charge or should I assume this to be an ideal gas and use p v equal to RT? This is an important decision we have to make and for that we need to look at the problem and say that what is it that is given here.

This could be superheated vapor, in this case we have first idea should be that look I must treat it as the vapor. Let me not assume a priory that this is a gas. At the end I will check again if it is a gas its good enough or if I do not have enough other information I may assume this to be a gas and find out (Refer Time: 09:28). So, this is the first, this is the next decision we make that if I need to get the properties do I have to have a vapor or an ideal gas. And from there we get equation state and from here we go to the charge and get property vapor from there, and then we put it in this go back calculate what is U, if it was from the vapor charge this U will be computed by looking values on the tables.

If it is the ideal gas we would put U 2 minus U 1 as CV 0 T 2 minus T 1 or from the charge we directly read off the two values and it values of U was not given you definitely have values of H which we have to given. So, we can get H 2 and H 1 from the charge p 1 v 1, p 2 v 2 are known and from there we can get v 2 and v 1 and substitute in this equation. And then it depends on that equation. So, this is the additional thing we have put and in doing that we have now actually putting numbers on hour, that that we are getting quantitative and getting number. So, we will did not do that at the end of module 2, we just said that I knew the property and we get some arbitrary symbol to the property. Now, what we will do is go back and put numbers on that property, put a title or a name on the substance and solve those problems. That is what we will do now.

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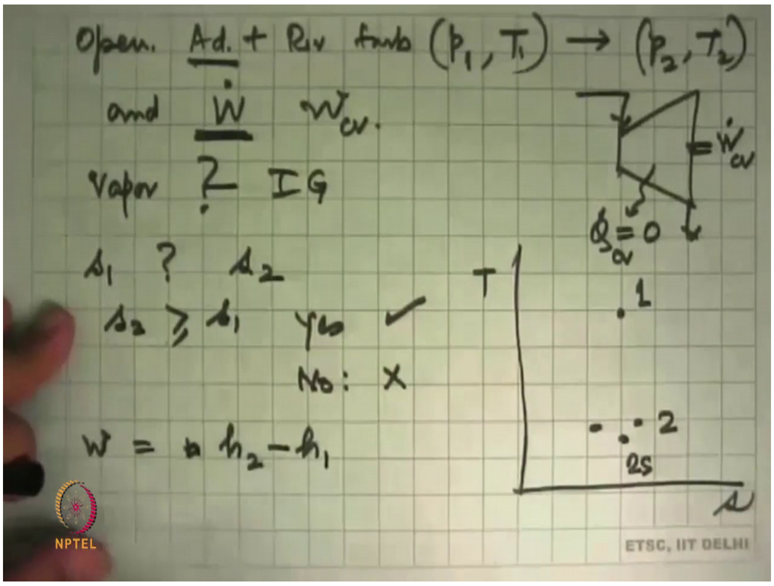

We can also use these properties to do various checks and balances, and say take an open system. And say somebody says that I have make an adiabatic plus reversible turbine that can expand from p 1 T 1 state to p 2 T 2 state and produce this much amount of work or this or W. And the first question we ask is such a machine possible.

So, we do we go back and say that this is a turbine that you are talking off. So, that this picture there is the substance going in the substance coming out and there is some work done. There could be some heat, but it is adiabatic this Q dot this is equal to 0 and all we have left is W dot CV. And now say well the problem would tell you that gas expands in a turbine and that automatically tells you that over gas that you have to you can take it to be an ideal gas or if you say it is steam expansion turbine then by default it assumes it is not an ideal gas.

So, that question we will get answer vapor or ideal gas and then we draw the process on a property charge and say this is state 1, we have given this and this is a state 2 hardly with state 2 will be there or state 2 will be there we do not know. And then we plot it we can very quickly see one thing that if on this plot this exit state. So, this is the isentropic case, if the final state is to the right of this the turbine is possible. If the final state is to the left of this and it is adiabatic the turbine is not possible. So, what we have done is we went and said well I will calculate s 1, we will calculate s 2 and ask if s 2 greater than s 1 or equal to s 1; if yes turbine is possible, if no turbine is not possible.

Then work that is claimed it may be right by the first two analysis that this work would have been m dot or m dotted 1 h 2 minus h 2 minus h 1. And this came from seeing of assumption that we are going. So, this may be true it is getting that much work, but if s 2 is not greater than s 1 then even by satisfying the first (Refer Time: 14:11) now this side is not possible, you cannot make such a thing. We will take one more example and then we will stop. We will look at analysis on cycle.

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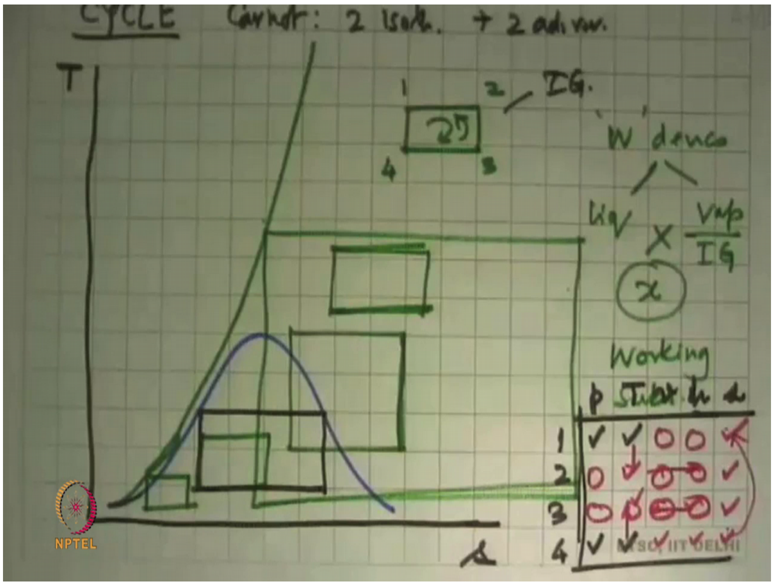

And what we have learnt now, in a Carnot cycle has two isothermal heat transfer and two adiabatic reversible work how received. And now we say work constitutes in the real world for a given substance on this T s diagram how where is the Carnot cycle. So, what we do is you just say that if here is the saturation zone and we know from what we saw from yesterday of T s diagram that even at very high pressure this line goes very close to it and goes like that.

That means, to the left of these states are not possible all the states are to the right of this, and if this is what the Carnot cycle is what it tells us that any square or a rectangle is a Carnot cycle. If it goes this way it is a work producing cycle, if it goes the opposite side it is a heat pump or a refrigerator. So, it has 4 states 1 2 3 4 and we want to know what is the work done per cycle, we need to know what is the different cyclic integral of heat on cyclic integral of work then that will give you the answer.

So, this cycle could there on this property diagram. Now, we have putting numbers, nothing stops us from saying that I have a Carnot cycle sitting over there. But that will be fine. Nobody say that I make a Carnot cycle like this. So, vertically absolutely no problem, practically we start seeing some problems that it is gone to the wet region and as work producing or work consuming devices go, so W [vocalize-noise] type devices turbines compressor or anything then one fundamental principle of engineering that this will either be a liquid or it will be a completely a vapor of ideal gas. It will not be a x.

There are serious engineering issues this. Why? If you want to make like this or like it is a very very difficult task from an engineering perspective. Thermodynamics says perfect is fine. So, we can make a Carnot cycle there, one can even I also make a Carnot cycle there or a Carnot cycle even there, somebody says I will make a Carnot cycle like this. Theoretically all of them are possible, their efficiencies we can see what they are. Practically if we start putting numbers on it after selecting the material, so I select the working substance and start looking at what number start coming out for specific volume enthalpy changes and things like that, then we will see that there is a big problem, something is possible, something is not possible.

A Carnot cycle far away from this dome, like this one that I have drawn. This is completely ideal gas thing, quite nice and easy to look at the cycle which could be like this, this would also be a Carnot cycle somewhat possible, but still it has got problems in it. But this would be a vapor thing this will be only an ideal gas set. So, when we have 4 such states how do we do cycle analysis? And for that we need two independent properties at every point, and let us see what happens in this case. What I will do is make a little matrix, on this side I will put state number 1 2 3 4 and this side properties p e v h and s.

So, how many properties were need to know to the fine the Carnot cycle. One is of course, T 1 and say T 4. So, I say I have specified this and I have specified T 4. And then say under pressure at and the other two states I need something more and that change states that say that we know the pressure in (Refer Time: 19:00). Question is, do I have enough information to complete this table which means that do I have two independent properties at every state. So, let us quickly go through this. Say if state 4 is only define then I can compute v, h and s. And I know from this that s 4 is equal to s 1, so this is known and this is known, the two are the same.

And then when I look at this thing and you say if I know T 1 do I know T 2 the answer is yes this is the same T 2, and from here you know that T 3 is same as this, so this T is also known. So, now, we have got two independent, two property, one property at each of the states. And which are what do I know about 2 and 3 like entropy is the same, soif I get entropy at any one of these which is say if I know one of the properties then this is there, ideally this comes out.

And like that we can complete this table and say that s 1 is equal to s 4. So, at s this is entropy we have already taken, s 2 equal to s 3, T 4 equal to T 3, and T 2 equals to T 1 and while we doing that you can see that if you get two independent properties at any point the rest of the entries in this table we can very quickly complete, where I did the vapor or whether it is a ideal gas. Once we have done that and may be some we may not need all the properties at all points, say specific volume may not even be needed then we can go back and calculate all the other things which the log requires us to do that work is equal to that cyclic integral of it is this property minus that property minus this property like that and we can calculate all of that.

So, this is one way we can tackle cycles that making a matrix and asking ourselves that in the problem not sending in the numbers, but in the words do I have enough information that I can calculate two properties at every state. The answer is yes then in it possible to solve the problem, then we go ahead and solve it, ok. What is the question between nozzle and diffuser? So I will take that, ok.

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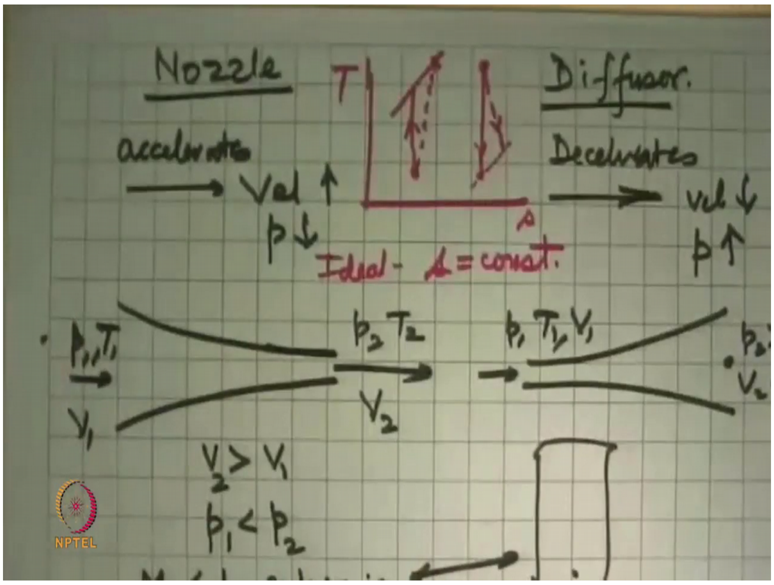

So, there are two devices, a nozzle and a diffuser. Now, this is the device which accelerates a flow that mean in the direction of flow the velocity increases pressure decreases. The diffuser is exactly be opposite which decelerate the flow; that means, in the direction of flow velocity will decrease and pressure will increase.

So, if you look at say air going through a passage like this, there the pressure is p 1 T 1 and it goes to this and comes out with the higher velocity the pressure here has become p 2 T 2 the velocity here v 2 is much greater or say greater than 1 and p 1 is less than p 2. So, this is a nozzle. With a one little caution, that those of you have gone in to compressible flow study visualize, that this is true if everywhere in this the mark number is less than 1 in the subsonic.

Now, if you just reverse everything, we get a diffuser, directly you send it here at p 1 T 1 and some velocity V 1 and what you get here is p 2 which is greater than p 1, V 2 is less than V 1. And where do you see these type things? It was on, recall the rocket that I showed p s l v v 1 (Refer Time: 23:13), and the bottom of the rocket we could have seen a structure like this from which there were gasses coming out. This is the diffuser. So, we produce high temperature gas then we accelerated it to make it high velocity by dropping the temperature and then we got it out here so that the pressure increases and then pressure acting on this which pushes the rocket up. So, diffusers are required in every rockets.

And like before this is also few case here that this will happen with the flow everywhere is subsonic. And the reason for putting this is that if the flow were in the other extent that mark number is greater than one with the supersonic wave, then exactly the opposite will happen in this passage and opposite will happen in this passage. This will decelerate the flow, this will accelerate the flow, but that for a different type and a different course, right now we are not going into that so, but just for a completion of the description of what is a nozzle and diffuser I am showing this.

In both cases if there is no other dissipation and there is no heat transfer ideally, both would mean isentropic s equal to constant. If there were irreversibilities, yes exit entropy will be more than inlet entropy and on the property diagram say T s diagram the nozzle will look like this ideal nozzle and the same pressure a real nozzle will do this. And the diffuser from here in the ideal diffuser it will go over there, the real diffuser this will go there and this will be in exit state, ok.

So, we will conclude at that point that we have now got all the theory, and the property and the laws cleared up. We have already attempted 7 systematic way of solving problems, and in the last module we will come with applications and we will solve some problems during the lectures. If you want some particular problems to be addressed please post it on the forum, I will address that in the last module.

So, with that we stop and thank you.