Engineering Thermodynamics
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Lecture - 32
Applications. Problem Solving: Devices. Schematic/Flow diagrams.

Good morning everyone. This is the beginning of the 4th module. Let me take 6 hours to look at systematic problems solving and applications. You already have a flavour for systemic problem solving in the assignments, in the first three modules. So, I will go over that step by step and do some examples here. If there are any particular problems that you would like to discuss please put it up on the forum and I will pick it up here.

Before I go to solving the problem I am going to take time today to briefly tell about certain common equipment, devices or machines where thermodynamics in the starting point of the understanding. These when we put these things together in a sequence we make cycles. So, today we will spend time looking at the common thermodynamic devices. Look at the processes that happen in them and see what are the major assumptions and the reason why we make those assumptions in solving the problems.

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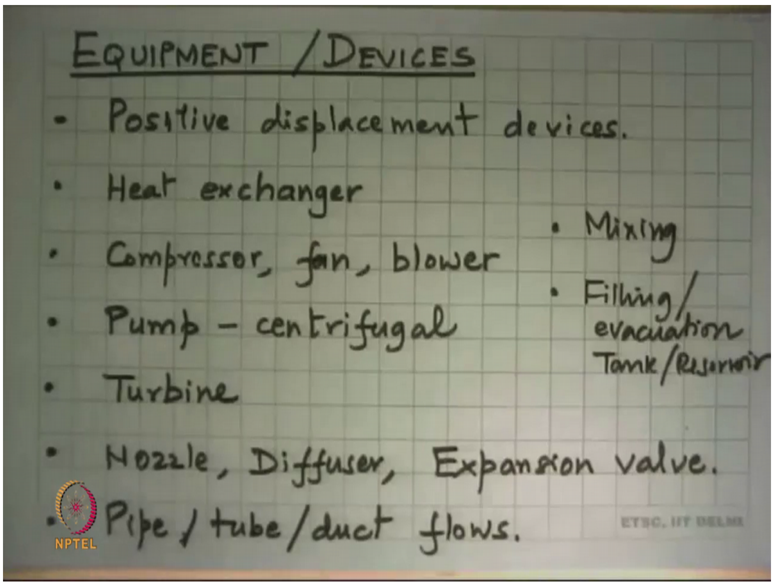

So, we start by looking at a list of some of the common equipment which you will come across in problems. I have listed here a bunch of them we begin with looking at positive displacement devices. So, these are devices that either compressed or pump or the opposite thing they take high pressure high energy fluid and deliver work. Positive displacement that the reason for giving this name and when we look at the construction of these we will know that how these are different from other types of devices. The next we will look at a heat exchanger this is a very, very common device and basically here we hot fluid gives energy to the cold fluid.

So, the temperature of the hot fluid decreases and the temperature of the cold fluid will increases. The next category of equipment will look at is what the study compressors fans and blowers. These are centrifugal devices which as I increase the pressure of a gas or a liquid fluid or a liquid or they do not increase the pressure too much, but deliver large flow rates. The 4th type equipment we will look at is what is known popularly as a pump and in particular and in this thing we will look at centrifugal pumps. Now just to remind you that the most commonly used engineering machinery all over the world were is the electric motor and the second most common machine in use is the centrifugal pump.

So, that is how common these devices are and you look at that. Then we look at turbine. So, this is a device in which we put either steam or gas and expand it and you get work out of it. That work can be used either for propulsion or for generating electricity. Then we look at what is known as a valve in general. I mean in particular we look at a type of valve which is for the expansion valve. In which we expand the fluid without much change in kinetic or potential energy will look at that this is what actually happens when in the pipe you put the restriction it dissipates energy whether pressure drop, but the velocity does not increase too much.

Nozzles and diffusers are devices that have a specific purpose that in the case of nozzle we want to accelerate the fluid to achieve a particular purpose whatever that. And the diffuser we want to decelerate the fluid. So, will see where these 2 get used. And then we will look at something which connects things in a system. It is a refrigeration system or a power plant system or anything like that. So, we pick up some equipment from these and connect them to each other and we produce what is known as the cycle. So, we look at how do we do analysis of pipes tubes or in a in thermodynamics.

You will also come across these and many of these in your fluid mechanics courses also. So, they are not very much different, but in the fundamental sense all of these devices have to obey the laws of thermodynamics. There is no exception to this. We will also add 2 more things to it, one is what I call is a mixing process when we take we in this case take the same fluid at 2 different states ok. Together mix it to produce something else and the third thing we will last thing. We will look at is filling or you may call evacuation of a tank or a reservoir or any such device.

So, what we are doing is in this case putting fluid before it in chamber or drawing fluid out of it and not being able to maintain the state inside. So, that is why it will be filling or evacuation. So, with this we largely cover all the equipment that are there from which we can create thermodynamic systems. Or if we get a thermodynamic system we should be able to identify which of the equipment in in which category and today we will see what are the salient features of that. And tomorrow I will show you some more pictures of these devices what they look like in the real world.

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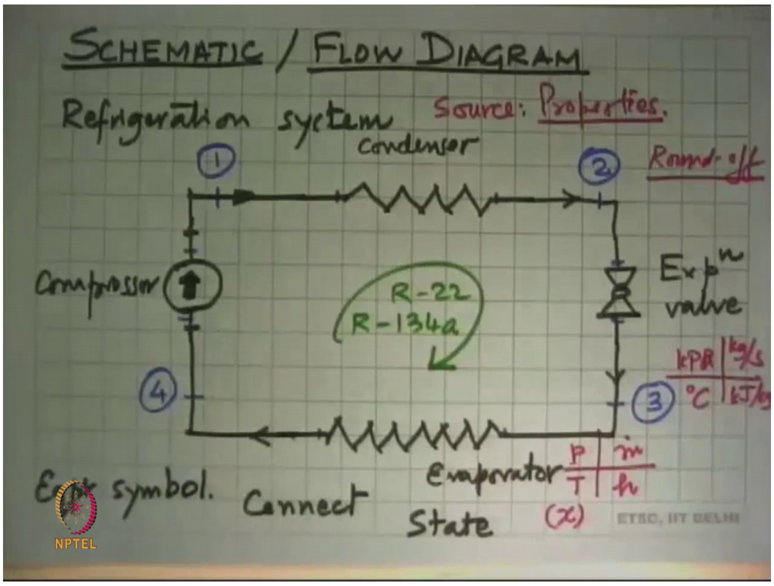

So, let us begin it by first looking at a simple example. And the one that I have chosen here is the refrigeration system. So, a refrigerator or an air conditioner whether it is the domestic one which is a small little device. Or could be a big one which is like a centralized air conditioning systems where the equipment is big. They all have 4 basic equipment. One is the compressor and as the name suggests it takes in low pressure vapour and produces high pressure vapour high pressure in the process the temperature also goes up.

The second device we have is the condenser. Where we condensed vapour for saturated liquid or slightly the sub cooled liquid. The third device is the expansion valve where the saturated or sub cooled liquid goes in, throttle it changes face and the temperature drops. And if this dropping temperature and the cold fluid that we get which we send into the evaporator. And the name suggests what we had was a mixture at low temperature or vapour and liquid this takes heat and the liquid evaporates to become vapour in the process it draws heat out from the surroundings there this is and gets heated up.

So, we have 4 major equipment with thermodynamics we know what how do you are going to analyse. And to complete the cycle we say that this will be connected to this, in this manner outlet of the condenser will be connected into the expansion valve. The outlet of the expansion valve will lead to the evaporator and from the evaporator be complete we send it back to the compressor. So, we have 4 equipment and what these are a tubes or pipes. And the diameter the length the material they are design requirements they could be different in the 4 sections. The fact is that we assume that we have also connected them with pipe.

From the outlet of this to be inlet of this and like that therefore, and the next thing we do is we said I want to do analysis of this. So, I have 4 equipment and then 4 pipes. So, there are 8 components that complete this system. And we can say that the flow in this is like that. So, we can even put a arrow like that and say that well the material flows like this and to that we can insert this we can also add what is the material that is in there. So, you can put there they are 122 or 134 a and it tells you what the working substance that is flowing through this and will.

Now, go through the individual items and see what is it how is how can I do the analysis of this. And then we will say that how do I do the analysis of the tubes or the pipes and finally, what is it that I get together and say I want to design something to do so much cooling or I have a system and I want to make measurements and understand how well it is performed either of those could be our objectives. So, one is the performance objective the other is a design objective. So, what other things we do in the beginning here is that we say that in the pipes and dollar tubes.

We assume that there is very little pressure drop or heat transfer; that means, the state of the fluid coming out here in the same as the state going in there. So, in despite the state of the fluid is not changing. So, we can say that this entire length, we can denote it by state one. The same assumption tells that we assume that in this pipe there is no pressure drop low heat transfer there is just an ideal flow. And so, there is no pressure drop from the outlet of the condenser to the inlet of the expansion valve no matter how long despite it may be. And all of this is the same state and this we will denote as 2. The same thing we do in this pipe we say that from here to here there is no change in properties. And so, this we will call as state 3 and the last one is from there from there and this we will say is state 4.

So, we have 4 states to work with. And in either case whether it is design of a problem or analysis of an existing system essentially our looking in information about these 4 states from which we can calculate the performance of these 4 devices based on what thermodynamic relations happen in the processes. This is the starting point of all things whether there is a cycle. And there are many things when even if it is not a thermodynamic cycle in the sense that we have learned here. Even if it is the flow system we would begin by looking at an analysis like this one.

In such cases what we can we can also do is we can say that I want to have one picture which gives me a complete information about everything that is happening here. And so what we can do is we say then at this point I put a line and put this thing here and you say that here I will write the pressure P, that temperature T and here I can write the mass flow rate and this specific enthalpy. In case there is a wet state, we make a small change. Because pressure and temperature are the same they can give either pressure or temperature and that will have to be mention the dryness fraction. So, what we are basically done by putting this type of an information here and this would actually be those numbers real numbers that are there we specify what the units are and we can say that ok.

This is in kilo Pascal the mass flow rate in kg per second the temperature is between Celsius and specific enthalpy is in kilo Joules per kg. So, each takes that completely defined on this diagram. And if you look up such diagrams from any manufacturer say of a power plants. They will write one more very important piece of information which says that for this substance I am telling you that these are the properties, but how did I get these. And so, they will always write what is the source of the properties. And as I put out the solutions for the third module, what happens is there are many places from which one can get properties of any working substance including many on online websites. And if you use one or the other you will see slight differences from one source to the other source.

In some cases, the differences will be very small in some cases the differences could be large in large part because the reference state at which they have taken s equal to 0 or h equal to 0 that is like different temperatures. So, the absolute values could change in that case, but what happens is that as long as we are consistent in using the same property force, we do not have a problem. Because in almost all these cases wherever we are looking at changes in property across the device we invariably come across difference or two property h 1 minus h 2 or s 1 minus s 2 and that difference is largely independent of the source from where this properties are taken.

So, if the designer of the system used a particular source and we are checking that calculation based on property source some other source this could be a book or a table or a website, we could find some differences in the values that will get over here, but largely the differences will be small, but in the end there will be some deviation from what has been given because of the source and the second deviation will also come because of round off. The property tables that you would have come across in some cases they are up to 4 places of decimal some 5 places of decimal in some cases only 2 places of decimal.

And that is given because it means that both of the significant places over which the designer of those proper confident at there is no error in that the next place of decimal is in doubt. So, if you are doing calculations and giving answers we must not add too many more decimal places after that because your source did not have that much accuracy to begin with. So, please keep that in mind when you report answers to a calculation. The calculator may give you 8 9 decimal places, but in the end the goodness of your property is how good your final result will be you cannot do anything more than that please keep that in mind the round off is an important feature.

So, there will be cases where we have done round off in the solutions also somewhere one decimal place somewhere 2 decimal place. You could find that there could be a small difference within what you get and what is there in the solution in case there are doubt please do post it on the forum, I will cross check and clear those doubts there, but should important point is source of the properties in the round off build cost differences in numerical answers, but the formulation of the equations if that is correct most of the things we have done right the next step can be easily checked out ok. So, this is how we will put together things for a cycle, but there are many cases that we will not be studying a cycle, with the application we are only going to look at one component.

So, in that case we will just take one portion of the same only this part and give the inlet outlet states here and there and do all the analysis from that part. So, the same process we will follow for single process. A device like this is a flow system and a picture like this is called a schematic diagram or flow diagram which I hope you have learnt in one of your engineering drawing courses. Almost every system design begins with this. It could be something like the fuel system of a car, but the first picture that the design that will make it what are the equipment that I am going to put how I am going to connect them and decide what are the equipment that was there and they may go about doing the engineering of the device the sensor in a post plant or power generation plant or a combined cycle power plant and same thing is the this is the beginning thing to design that process.

Once we have done the thermodynamics of this we get lot of information we tells you what is the mechanical design of the followings. For instance, this tube if we know what the properties here what the flow rate, then we can decide that what should be the diameter what should be the thickness. So, that it can withstand that pressure and what should be the design pressure based on the thermodynamic pressure that I have been told from towards from this side the evaporator for instance we know that we need to go from this state, to this state.

And so, much mass flow rate is then then we can calculate and see how many tubes are required how many filter to be put what is the physical shape and size of it what should be the pressure for which the tube should be designed. So, they do not rupture all those designs follow this fundamental information. So, in the design of all of this this particular type of a system is hugely important, I think is important we get it right ok. So, this is the idea of a schematic or a flow diagram.