Cooling Technology: Why and How utilized in Food Processing and allied Industries

Prof. Tridib Kumar Goswami
Department of Agriculture Engineering
Indian Institute of Technology, Kharagpur

Module No 02

Lecture 10

Basics of Thermodynamics

Good evening. We have finished in the previous class cooling load. All types of cooling loads we have discussed as far as possible in detail and also we have covered some of the supporting things like how to find out the equivalent thermal conductivity etc, these things we have done. Now, we will move to another very important one, before we go to the generation of cooling or production of cooling, that is the thermodynamics. Some basics of thermodynamics, if we are not able to know, we shall not be able to follow the further proceedings. So, we need to know the thermodynamics and that is the basics of thermodynamics.

So, if we look at the basic definition of thermodynamics, we can say that thermodynamics is a physical science that studies the effects on material bodies and radiation in regions of space of transfer of heat and of work done on or by the bodies or radiation. It interrelates macroscopic variables such as temperature, volume, and pressure, which describe physical properties of material bodies, of course, and radiation, which in this thermodynamical science, are called thermodynamic systems. So, basically the macroscopic variables like temperature, volume, pressure and afterwards, we will see, some more property values are coming up like entropy, like internal energy, which we have already said etc. Of course, out of these temperature, pressure, volume, we know, but entropy we do not know, but we will come why and how entropy is coming, where from.

At least, that is why some basic knowledge on thermodynamics is absolutely required. Now the fundamental of thermodynamic properties are such that we know fluid flow, hopefully, fluid flow, as of now, I have not covered a little, but I will try again as I told you. Now the new thing which comes up, I try to give some, weightage on that. So that it becomes overall complete, not specifically complete, ok. So, from the fluid flow, transfer of heat, work are at the backbone of refrigeration and air conditioning.

A thermodynamic property is an observable property or measurable or calculable and attribute of the system in the state of thermodynamic equilibrium. Now obviously, equilibrium another new word, which has come up, let me tell, if a little possible, that say, you are moving from here to there right, and I am moving from there to here, right, and if there is one observer here, who looks both of us. Now if your going from here to there, and my coming from there to here, are at the same rate, that means, this person will always look both of us at all the places because our rates are same right or if it is not shown in the reverse way, if it is shown on the forward way, then it becomes more visible right. If it is shown both in the same way then it is visible. So then it can be said that we are at equilibrium.

So this person can see us all the time at different places. So we are at equilibrium in terms of our movement. Another example I can set, that will be more clear. Suppose you have one unit which is like one H, this is one H type right, and there is a valve and this is a gas say A and this is a gas say B right. Now, if we open this valve then what will happen? A will move to that, because here A concentration is very high, here low, because of the concentration gradient A will move to this place and similarly B will move to this place due to the same reason, that concentration of B is here very high compared to that.

After sometime, there will be no movement of A or B because, concentration of A and concentration of A in this are same. The same is true with concentration of B of this and this. So, if we even close, we will see that concentration here concentration here is same, no further movement. If there be any movement then the same quantity of A will move from here to there and the same quantity of A will move from there to here right. This means that, both A and B are in equilibrium, both A and B are in equilibrium this is the concept of equilibrium and that concept will be very much required and will be dealing with the entire thing right.

So a thermodynamic property is an observable measurable or calculable attribute of the system in the state of thermodynamic equilibrium. Another example I can set up for equilibrium, sorry, is that in this room if this is a room and say if there is a heater here right and this heater you have put on for say 5 minute, then what will happen? This temperature T 1 will be much higher than T 2 right and T 2 is the temperature here. So, what will happen if this is a gas normally here this will move from there to here this will move from here to there. This movement will go on and this is again in the earlier case we had said that, this is unsteady state right. So this unsteady state will remain till this T 1 and this T 2 becomes one temperature say T 3 and that T 3 will be all around.

So we can say that air at this place, air at this place, they have become under equilibrium condition. This is how equilibrium can be demonstrated or can be explained. So any measurable or calculable quantity which are in equilibrium is under thermodynamic equilibrium. So thermodynamic equilibrium details, or rather, it deals with mechanical, thermal and chemical equilibrium. This signifies that the absence of unbalanced forces, the absence of heat and mass transfer and the absence of chemical reactions prevail in the system at the thermodynamic equilibrium.

So when there is a thermodynamic equilibrium there is no unbalanced forces, there is no mass transfer, there is no heat transfer and there is no chemical reactions. So then we call it to be thermodynamic equilibrium right. So we can say thermodynamics deal with the change in system from one state of equilibrium to another state of equilibrium. So it is that thermodynamics which deals with the change in the system from one state of equilibrium to another state of equilibrium right that is what is thermodynamic equilibrium. Now as I said fluid flow, which we have not touched upon, we have done a little, maybe heat transfer, a little maybe, yeah, heat transfer, and now let us look into a little pipe flow or fluid flow.

Now, this is a sectional view of a pipe through which a liquid is flowing. So, in this one thing is required, that is there is no end effect. The basic is that there is no end effect and the flow is steady, a fluid is flowing now that fluid can be gas or liquid anything by the definition of fluid we know that it is either a gas or liquid. So we assume it to be a liquid like water, so what I said is that there is no end effect what do we mean by that? Let us look at here, suppose you have a tap and from that tap water is dropping, there is a source of water right, and now if the source is far away, say from here and if it comes to this, then when you open the valve here, first there will be some gas which is coming or air, whatever, it is coming. I hope you have come across at your home that when there is no water in the tap and when first water was coming then there was more than water some gases or air is coming out with a sound of whatever it be right and after sometime there is a continuous flow of water that we have seen, we have experienced also.

So this is called end effect, this is happening at the beginning of the flow and also happening at the end of the flow when the source is becoming empty, the same thing also happens. So, at the beginning and at the end, that is why it is called end effect. So there is no end effect, the flow is fully developed and steady this is the basic we have to keep in mind right. We have taken a section of the pipe like this we have taken a section of the pipe, this section is vertical section and the thickness of the pipe, some it is there, we have taken a volume element in the pipe this volume element is having delta r as the radius or thickness and delta x as the other dimension. These are the two dimensions.

So third dimension we can assume it to be unit right, the third dimension we can assume it to be unit. So what we are doing, we are applying some pressure at here, that is P at x, right. So we are applying some pressure that is P at x and also we are applying, this flow is flowing from left to right this is the radial direction, this is the flow direction, one is r another is x, we call it to be a shell momentum balance. So if we do shell momentum because it is like a shell. So if we do the shell momentum balance so here P at x and here P at x plus delta x right.

So we can say, one minute, let me erase it off. We can say that during the shell momentum balance inside a pipe which is valid for a fluid which is incompressible. I hope you know incompressible fluid. Incompressible means density of which does not change with pressure, for a reasonable pressure drop or pressure difference, there is no density change for incompressible fluid. If it is compressible, then with the change of pressure the density will change.

So, the fluid is incompressible, there it is a Newtonian fluid, flow is fully developed and it is one dimensional, that too, steady laminar flow and there is no end effect and velocity profile does not vary along the x direction. That means, the velocity profile whatever be the velocity, that velocity profile does not change along the x direction. So, whatever is, here is, here is, here same. That velocity profile is not changing with the direction of the flow. These are some initial conditions for the development of flow through the pipe, this is called pipe flow.

Then we can say the governing equation will be the rate of momentum in minus rate of momentum out plus some of the forces acting on this should be equal to rate of accumulation of momentum. I repeat rate of momentum in minus rate of momentum out plus some of the forces acting on it should be equal to rate of accumulation of momentum. Now, when it is a steady flow, if you again go back to the previous slide, when you have the steady flow right. So whatever fluid is coming with time here, the same fluid is going out at the same time, right. So, that means, this and that has no change.

So we can say that the change in momentum rather momentum in by convection is equal to momentum out by convection . So, momentum in by convection is equal to momentum out by convection that means, ok. One more thing I should say before we proceed further. How the momentum will be transferred? one by convection that is called bulk flow. So this is how it is conveying, this is called bulk flow, BULK, bulk flow right.

So, one is by bulk flow that is the entire molecule, entire thing is moving, this is bulk flow another is called molecular transport right. This we have to understand, molecular transport means, we have said, it to be laminar, that means, all the layers in the pipe they are like this and the fluid is flowing. let me take another I do not know whether it will be possible or not, color it is not coming let it be. So what is happening? This liquid here it is progressing like this. Now when it is progressing like this the molecules inside, you know, as of now the kinetic theory of gases are available that you know I assume that you know that kinetic theory that is the molecules can move freely randomly right.

The same kinetic theory, if we also applied, normally, nowadays, is that, is also done for the liquid, also because it is not developed, so we apply it and find that it is or it can be. So, now what is happening, the molecule of the water, it is going with like this, as a zigzag, in the same plane, but a zigzag right. If we expand with the help of say microscopes, then one molecule is moving like this, like this, like this, like this, like this, like this, the thing is like that first layer is, adjacent layer is there right. So, this molecule is imparting because of the movement of molecule to its adjacent layer by the molecular movement right and this is called momentum transfer by molecular movement, ok. So, if we understand this, then we can find out that, the force, which is applying on it right.

So, perhaps today our time is over, tomorrow, in the next class, we will start, but we will definitely not tell whatever we have told, maybe a preamble a little, but we assume that the bulk flow and the molecular transport we have understood, is it ok. Thank you so much.