Fundamentals Of Combustion (Part 1)

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Lecture – 06
Thermodynamics of Combustion

In the last few lectures, we basically discussed about what is combustion. And then and combustion plays a very important role in the development whatever we see today. Starting from the beginning of the human civilization. And fire is the key which really helps us to have all the developments in science technology and metalistic life. And so, also the spiritual life of human being.

And we had looked at extensively about the scope of the combustion, and which encompasses a large number of applications, not only in the engineering, but also in other domestic applications, industrial applications and other applications. So, in the process we learnt that the fundamentals of combustion is very important for developing the new systems, and also the reducing emission which is the modern challenge, due to the platent misuse and abuses of the technologies in modern life.

For developing the fundamentals of combustion, we need to look at the various other subjects like thermodynamics, fluid mechanics, chemical kinetics, heat and mass transfer, and what we are going to do is basically today we will be discussing about the thermodynamics, which will be relevant for the combustion, you know work.

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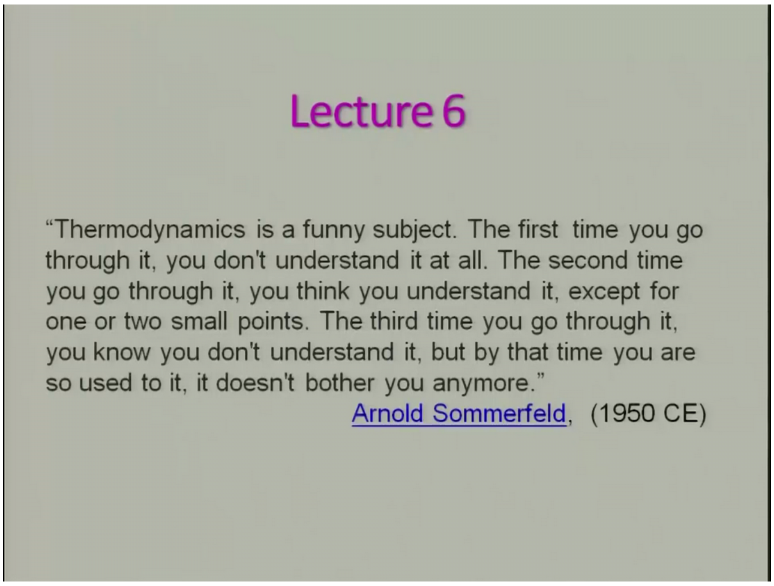

So, let me start this lecture with a quote from Arnold Sommerfeld, who says the thermodynamics is a funny subject. The first time you go through it, you do not understand it at all. The second time you go through it, you think you understand it, except for 1 or 2 small points.

The third time you go through it, you know you do not understand it, but by that time you are so used to it does not bother you anymore, right? Is it not true. I mean all of you have studied earlier thermodynamics. At least starting with a class 2, then thermodynamic subject there is a full place. Then several application in you know other whenever you are des you are talking about other subjects. And now will be removing the whatever the aspects of thermodynamics required for dealing with the combustion problems, right.

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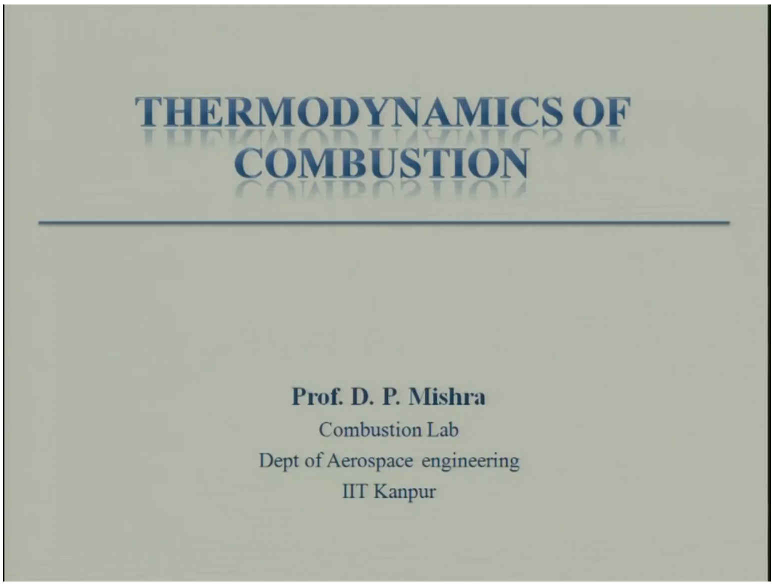

So, therefore, thermodynamics plays a very important role.

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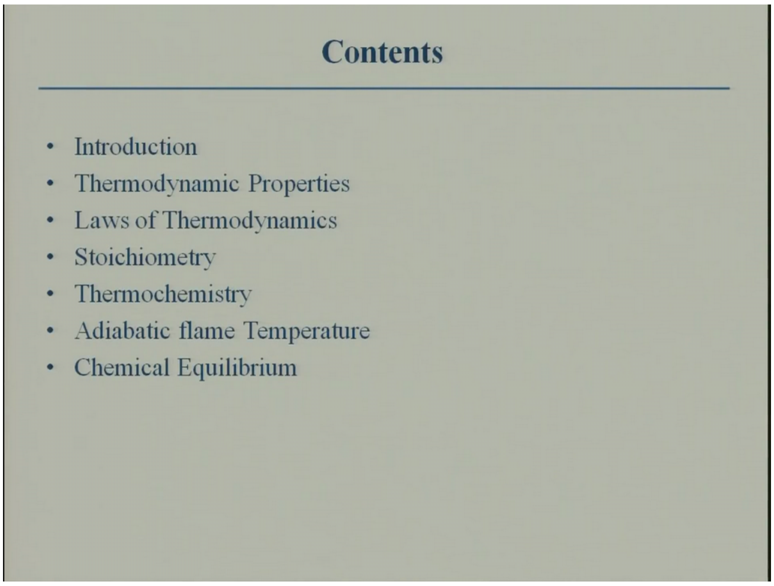

And what will be discussing, I will be trying to start on the very basic. Then will be looking at thermodynamic properties, laws of thermodynamics. And will be looking at thermo, stoichiometry, then thermochemistry. And of course, the we will be learning how to calculate the adiabatic flame temperature. And in the end, I will deal with chemical equilibrium, right. And these are the things which we are going to discuss in few lectures. So, question arises what do you mean by thermodynamics. Can anybody tell me? Because you have studied enough, you know in thermodynamics. So, can anybody tell me what do you mean by thermodynamics.

Student: (Refer Time: 04:07)

Study of heat. So, is it only heat? It is not about work, right. So, it is about basically energy, right? And a question might be arising what is energy, right? So, if you look at thermodynamic word is consists of 2 Latin words. One is thermis, other is dynamics. Thermis means basically, it is the heat, and dynamic is the force.

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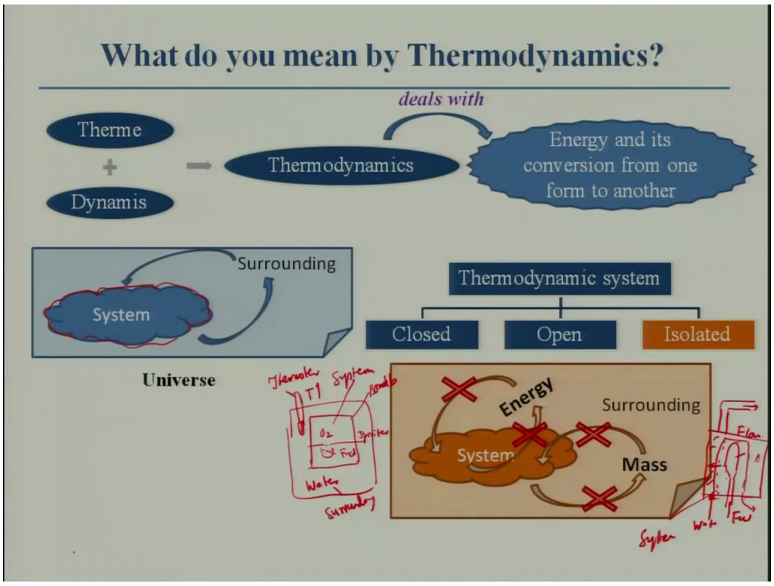

So, therefore, if you look at and heat energy is or you sometimes we call it as a thermal energy is basically will be converted to various forms. Like electrical, mechanical, magnetic and other forms, various forms. Therefore, the thermodynamic, will be dealing with subject, about energy and it is conversion from one form to another. So, therefore, you can say thermodynamic is the physical science, that deals with the energy and it is conversion from one form to another. As I had asked questions what do you mean by energy. It is a very commonly used word, right? We use every day. But when we define it will little awkward, you know. Because we know. So, therefore, to say something is very difficult, but; however, you if you recall the definition what we are exposed to; that is, it is energy is basically a capacity to do the work, right? Or it is ability to cause any fact, isn't it?

You call that energy, am I right? According to me energy is an enticing entity that governs all the activities of the entire universe. Without energy can you think of anything, right? For example, you are sitting and listening to my lecture. Attentively or without attention you know whatever it may be, right. But still you are doing a suppose a pen is there will it listen to my lecture, and understand or would not understand or try to understand no, nah because it is not having what you call energy, is it so? It is having energy.

But it is not having consciousness, right. And of course, in our scriptures people have defined this energy, and then comp consciousness and all those things you know related. And which we call it as a brahman. So, if you want to really learn about it, then you will have to read the Bhagavad-Gita which is very important scriptures to learn a lot of things about our tradition. Now whenever we talk about this energy, and it is interactions you know we do.

Therefore, we need to understand what is happening. When you do that how to analyze basically will be using a system. What do you mean by system? Is a domain physical domain, or it can be virtual, it can be you know physical domain, right? Whichever it maybe it may be fixed boundary, it may be variable boundary right. So, in which you will be you know basically focusing your attention, and then trying to find out how is interacting. So, whenever there is a system.

So, if you look at, this is a system here, right? And this is basically system here, right? And then rest of the thing is your surrounding. And the system plus surrounding is basically universe, right? For example, if there is a let us say this is a candle flame, right? Let us say this is a candle and this is your flame. Now if you look at if I want to see how much heat is coming out of this flame, right? What will happen? Like the surrounding will outside, right? This will be my boundary system right.

So, therefore, I will be you know looking at how much heat is transferred, how much mass is transferred, or not you know all those things I will be looking at it to having some interest to know what is happening. But if I look at if I take outside of my room, that has a system, what will happen? No changes will occur; that means, it is very important to identify the proper boundary of a system, are you getting? So, therefore, and whenever you are saying that you will have to depend on what do you want, accordingly you will choose your boundary. There is no fixed, you know rule that look I will do this way for all the problem, no. You will have to look at what you want, and accordingly you will have to define your system. And it is boundary and outside the system it will be basically surrounding, right. And system means surrounding together.

We call it as basically universe. Now as I told, that the system whenever the system is interacting surrounding, there will be you know some change will be occurring. What are what are those changes? Means, there will be heat interaction, there will be work interaction, there will be also mass interaction, right? Now depending on that we can divide the system into 3 categories.

What are those? One is closed system, other is your open system, other is your isolated system. That all of you know, right? And when I say this closed system what you mean by that? Basically, there would not be any mass exchange between the system and surrounding. But; however, there will be energy interaction which will be taking place. Like for example, if this is your system, there is no mass interaction between system and it is surrounding, but; however, there will be heat exchange which is taking place, between the system and the surrounding. If would you recall the last to last lectures, you know, we had discussed about 2 calorie meters, are you getting? Now which one will come under this closed system if I want to analyze.

Student: (Refer Time: 11:06)

Bomb calorie meter, why? Because in that case what happens, there is a bomb here, you know where there is a fuel, right? And there is a system here, right? And this is oxygen, right? Oxygen is reacting with that we are having ignition you know, this is your igniters. And surrounding of course, we are having water, right; that means, this is my system, right? This is your bomb, right? This is your bomb, which is not bomb, which is nothing but your system. And this water is your surrounding, right? And this we can call it as a basically closed system, right? Is that clear? Because there will be no mass, like fuel and oxidizer when it react with that, it will be converted into product. If it is hydrocarbon fuel naturally product will be carbon dioxide and water, right? And this product will be remaining there after the combustion takes place, but; however, the heat temperature if you look at if I put a thermometer here, right? Thermometer, right? What will happen to this temperature? Temperature will go up of the water right. So, naturally what is happening? This system is basically is the closed system.

Now if you look at open system, what is happening? Both the energy and mass transfer will be taking place between system, and it is surrounding, right? For example, there is a burner, right? And you are supplying the fuel and air; like in case of fuel lpg burner, there will be some combustion taking place, and product will be formed; that means, the mass is coming in, mass is going out, basically products, and there will be also heat interaction.

So, if you take the example of the calorie meter, the junker calorie meter. You remember the junker calorie meter, right? Junker calorie meter you remember? That if I draw here, or maybe I will draw here there is a flame, right? And keep in mind that this is the fuel this is your flame, right? And of course, there is a water what we are transferring, right? This is the fuel, right? And this is your flame, and what is happening? This is your what you call there will be also a chamber, that include each water you are passing through. These are basically water you know which is going out this is water is going out.

So, therefore, if I take this as a system you know, right? If you take this as a your what you call system, right? Boundary and what is happening then your fuel is going out, right? And then of course, the mass flow will be going out of this gases will be going out here products. And this is my system boundary, right? And this is your water is your surrounding, right? Of course, water is also flowing, but we are not bother about it right.

So, there will be exchange of heat, or energy transfer will be there, and mass also being transferred in this system. So, therefore, that is an open system, right? And in case of closed isolated system, neither the mass nor the energy which will be transferred, or in taking place between the system and surrounding. In other words, there would not be any exchange of mass, and the energy between system and surrounding. Question arises when will you use it. We mostly use open and closed systems, right? Do we use isolated system? Any idea? Where?

Student: (Refer Time: 16:05).

Thermas, thermo flask you are talking about.

Student: (Refer Time: 16:12).

But what will do? We do not use that as the system. If I want to find out.

What is energy transfer or what are the this thing? Then what will I will take it as a open or closed system and then manage. But isolated system where do we use? We do not use nah, right? Or we do use.

Student: (Refer Time: 16:35).

No even cryogenic also we would not be using. Basically, when you want to calculate the entropy Gibbs free energy and other things, we use that using that principle are you getting. Except that in our day to day life, we do not use it. Except those places were you know we need to calculate their entropy, and then find a because entropy of the you know system is increasing then will take a both the systems surrounding then will see then calculate back, and then find it out you know that way we do.

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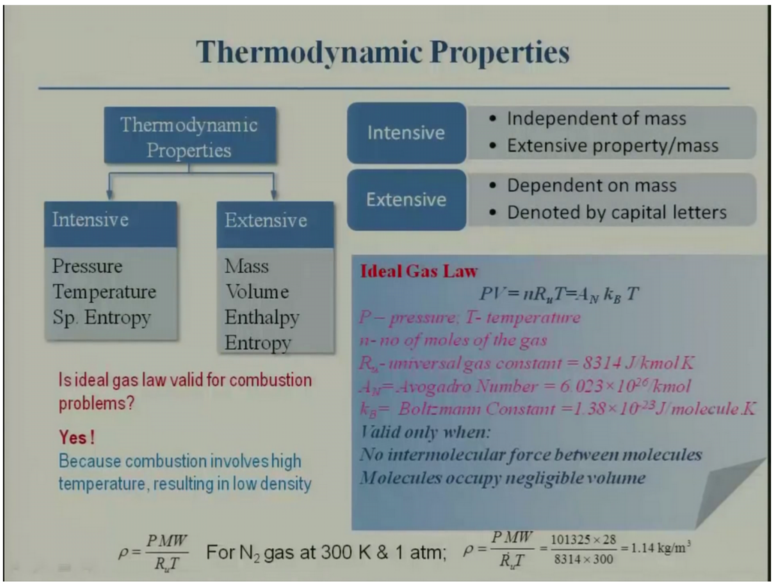

So, therefore, whenever we looking at the system, basically what we do? See suppose the system is interacting with the surrounding, what will happen, right? For a properties for example, this is your what you call a candle, right? Or no let me say this is your candle, and this is your flame. And then if there is a heat is going you know to the surrounding, what is happening? The properties will change, what properties temperature, right? What else? Pressure if it is a closed system the pressure will increase otherwise, it would not because atmosphere is there. Therefore, it will be not really changing the pressure. Because it is a very big you know, it is like a even though the gas is expanding due to the temperature in the flame, but it would not affect the atmospheric air that much.

So, pressure will be remaining constant, right. So, therefore, you know like what happen to other properties, densities, some other things right. So, it will be changing; that means, when we are talking about this interaction, basically will be looking at properties, then only will estimate you know various interaction what is happening, how much energy being transferred how much mass being transferred all those thing will do out otherwise we cannot do without properties can I do talk about anything no we cannot.

In the similar manner what we do? If you look at if you want to connect to your life. You know, for example, like you people are youth, right? Isn't it? Now whether you are a youth or myself a youth is a one question comes. Then how will I identify I will have to look at properties. Otherwise, you and me are same. Isn't it? So, but if I ask this question, what are the properties of the youth?

Student: Age.

Age is not, because your age and my age different right.

Student: (Refer Time: 19:27) hair colour.

Hair colour, how does? I can make colour see now a days colours are available, right? Even the young people are having now brown colour hairs, right? Or some people blondy you know like we are following American. Some people are putting blonde colour you know. Or may be streap one colour is different you can do that that is not a big thing. So, properties you need to understand is very important, but unfortunately, we do not know.

Neither the students nor the youth, they know what are the properties? How they will develop? Whether they are having those properties or not. And also, the people who had dealing with the youth, they do not also know are you getting, anyway. So, if you want to know that if you can read my book wings of youth am I have identified 16 properties. There might be more than properties by which youth can be identified. So, therefore, properties very important to identify and then find out what is happening interaction otherwise it is very difficult.

So, when you talk about this properties thermodynamic properties, what are those? Pressure, temperature, right? Volume, density, entropy enthalpy, right? Internal energy. These are the properties. If these are the properties, the natural you will have to divide into 2 categories generally. One is intensive properties, right? Like pressure temperature specific entropy these are intensive properties. And extensive properties mass volume enthalpy and entropy. So, what is preference between these intensive and extensive, we need to know.

Student: (Refer Time: 21:16).

Yes, intensive is independent of mass volume, right? And others. So, whereas, extensive will be dependent on the mass and the volume, right? For example, like if you look at this milk man who supplies milk you know. He is very much aware that if will add one you know liter of milk with another half-liter of water, then it will be milky water, but; however, he will tell you, that look this is milk and sell. And you will get some money out of it gain. So, is he aware about this extensive property, but he knows what it is, you may not be knowing this is extensive property.

So, therefore, that is the extensive property is your what to call volume, right? The enthalpy entropy, right? Mass these are the things. And which is dependent on mass and also it dependent on the volume, right? And intensive property is independent of mass, and generally extensive property per unit mass or unit mole, sometimes we call intensive property, but; however, I would like to say it is specific property like specific entropy, right? And your mm specific volume, right?

You know specific volume volume divided by mass or volume divided by mole, right? So, when we deal with these we will be also trying to relate this properties, right? For example, pressure, I need to relate to the temperature. Pressure I need to relate to the volume. And this is you know is being used particularly the gas, and other also and this is known as the equation of the state, right? And we use the gas very much in our combustion. Because the gaseous combustion is very easy. And also, easy to handle, easy to control. And the most of the combustion will be taking place in gaseous form except very certain things which will you mean the condense phase condense means liquid phase or solid phase, right?

Some combustion do take place, but those are very limited, but even if it is taking place in the solid state solid phase of the liquid phase, but still the majority of this combustion will be in the gaseous phase. So, therefore, we will be dealing with mostly the gaseous towards the end may be I will be talking about little bit solid fuel combustion. And also, the liquid fuel combustion will be looking at in the droplet combustion whenever we looking at. But mostly will be dealing with gaseous fuel combustion. So, when you do that the equation of state, a you know that is very much what you call, you are aware that is very basically governed by the ideal gas law.

Now, that means, the gas should be ideal, right? Of course, this formula you know PV is equal to basically nR uT. P is the pressure. V is the volume. N is the number of moles. Ru is the universal gas constant. And of course, an is avocados number. And kb is your Boltzmann constant. And these values given here which you people are very much aware. That avocado number is 6.023 into 10 power 26 per kilo mole kb the Boltzmann constant is equal to 1.38 into 10 power minus 23 joule per kelvin per molecule. And question arises, when this gas will be you know valid, when this gas ideal gas law you can apply, any idea?

Student: (Refer Time: 25:53).

Low pressure I can apply, right? And high temperature I can apply, the ideal gas you will follow. But what is the basic for that? What is the fundamental for?

Student: (Refer Time: 26:10).

So, basically what will happen? The volume occupied by the molecules in a container is very, very small as compared to volume of the container or containers volume, right? And the intermolecular forces between the molecules will be very, very low, right? Then only we will can use this kind of ideal gas. But question arises how do I know? Whether I can apply it or not; that means, how actual gas is deviating from the ideal gas. Because under this condition, we can call it as an ideal gas, right? For example, like if I take this room here, this a one atmospheric pressure, right? The temperature will be maybe you know let us say 25 degree Celsius. Because ac is here. So, therefore, 298 kelvin, right?

And whether can I apply say that it is an ideal gas. How I will know, right? For that I need to look at compressibility chat; which will be discussing in the next lecture. And question arises whether we can use the ideal gas law for the combustion or not, right? That question we need to ask, right? And if you look at let us say this room.

If I take or something like that, and atmospheric pressure and this thing I want to find out what will be the density, right? So, by this we can basically look at if I take, then I am sorry like if we take this room that contains nitrogen gas at 300 kelvin, and one atmospheric pressure, right? I can find out what will be the density? Density will be basically p into molecular weight, right? Divided by rut and we will substitute this values, right? Pressure is 101325 pascal into 28. 28 is a molecular weight nitrogen. And the gas constant 8314 into 300 kelvins, if I take, right?

It will be 1.14 kg per meter cube. So, by this we can find out the density, right? And of course, we can also find out other properties if I know like a pressure, and we can use this ideal gas law for combustion or not that we need to ask. And actually, you can apply basically or we can use the ideal gas law for the combustion problem, because the temperature is very high. And even the pressure is moderate, right? Is even high, right? Because if pressure is high can I apply this ideal gas law, I cannot right.

So, what you are telling basically low pressure or not low pressure. You can apply, but ideal, because high pressure you cannot really apply. Because the molecules will be coming closer, density will be very high, right? And the intermolecular forces will be high. So, as a result you cannot, but in combustion temperature being very high, we can apply very easily the ideal gas law, density being very low, right?

As the result the molecule number volume occupied by the molecules will be very less as compared to the total volume of the containers or the system whatever you are considering. So, with these we will stop over we will take of this about compressibility factors or the chart in the next class.

Thank you very much.