Fundamentals of Combustion (Part 2)

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Lecture – 71
Introduction to Solid Fuel Combustion

Let us start this lecture with a thought process creativity can be manifested on the soil of solitude. Unfortunately today the modern people do not understand the efficacy of being staying in solitude and therefore, creativity of individual is being hampered as people are running after the material gains without really thinking. And let us recall that what we are learnt in the last lecture, if you remember that we had basically a discussion about the Liquid Fuel Combustion in that in the beginning we started with the droplet combustion and later on we moved to looking at briefly how to handle the spray combustion. A spray is basically an array of the droplets of various diameter, but we handle earlier for monodisperse droplets.

So, today we will be basically initiating a discussion on the Solid Fuel Combustion, a lot of question might be coming to your mind that why we need to look at solid fuel combustion you keep in mind that the solid fuel combustion is as old as simple our civilization. Indian civilization is the oldest civilization among all people might have seen the natural fires occurred due to the solid fuel particularly in forest and they might have learnt how to handle the fire and how to control the fire and use it for the development of the various kind that will help people to lead a good life.

So, therefore, we always oversee the fire God what we call it [FL]. So, therefore, the most natural combustion one can think of that occurs in nature is the solid fuel combustion particularly from the biomass. And now in present context the solid fuel combustion is very important even today although it is quite complex to initiate the combustion with the solid fuel as I told earlier. And the most easiest way to have a combustion, particularly the clean combustion with the gaseous fuel and of course, then there will be a liquid fuel the most difficult to have a control combustion with the minimum emission, which is the need of the hour is basically solid fuel combustion.

However we do use it profusely even today because of various reasons and as we go along we will discuss, you please ask the question to yourself why we need to use the

solid fuel although it is difficult to handle so, far combustion is concerned. Let us look at a various applications of the solid fuel combustion.

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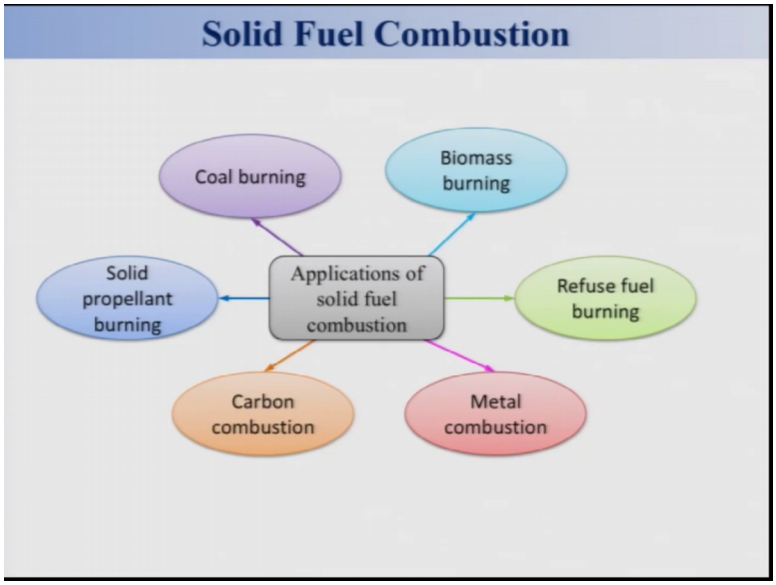

And if you can really scratch your mind and you will find that coal burning is a very important which is being use for various energy devices and power plant even in domestics and other thing.

The burning of coal is very important particularly for us in India because of fact that India is having a very large reservoir of coals, unfortunately Indian coals is having peculiar problems of higher as contents. Now we need to develop the technology for it, unfortunately we just get the technology from outside and then face various problems. So, the coal combustion is a very important and beside this the biomass burning is also one example of the solid fuel combustion and keep in mind that coal is unsustainable because of fact that it is having a fixed reservoir. Whereas the biomass is basically sustainable in nature and according to me that man might of really looked at the biomass combustion and that culminated into a fire which might have really generated lot of interest in the minds the people particularly during forest fire, which has been described very well in our olden scriptures.

So, therefore, it is very important and today people are talking about biomass combustion, gasification and pyrolysis and it is a very hot topic and earlier also people where using it, And beside this the solid fuel is being used bicycle is the as a refuse fuel

because of fire that there are several material which can be really being thrown out, it can be used like a municipality waste and then some other waste kind of materials can be utilized for burning and so, that we can get a power and heat energy and other things. And metal combustion is very important application particularly in the field of metallurgy for processing industries and that is also important, it is also important in other application like in propulsion if devices and other places. So, they are also solid fuel is being use.

Another application is the Carbon Combustion which is a very important here of course, it is the only pure carbon it is not hydrocarbon as such, but carbon combustion is also very important. So, beside this is the solid propellant combustion, which is being very much used particularly for missile application and space applications and other things and now it is say quite a important thing to have a say in the international arena. So, therefore, the solid fuel combustion is very important.

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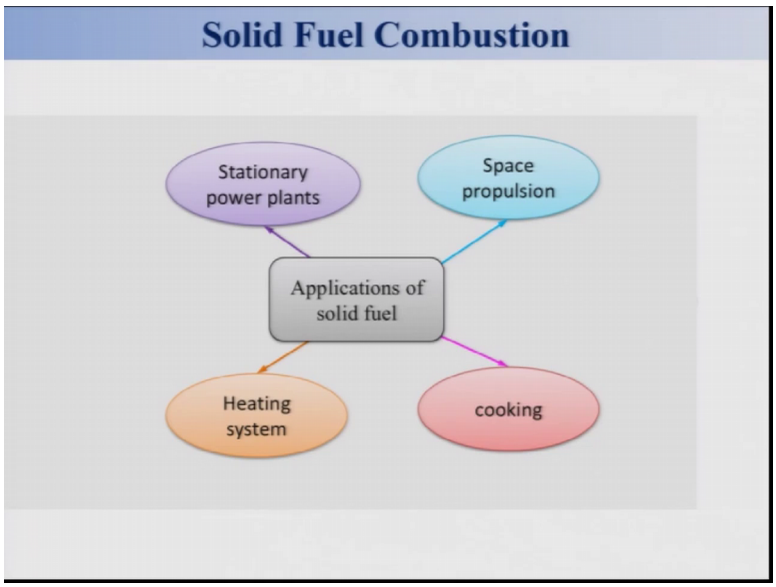

Let us look at like related to all these five aspects, that the solid fuels are being used for generating powers particularly in stationary power plants and there is another great application for the space propulsion as I told in the rockets and the spacecrafts in the missiles and other places.

Of course, the domestic application Cooking is one of the important one beside this the room heating and other places solid fuels are being used profusely, beside this that you

will have to also used for the reheating system even for refrigeration systems one can use the solid fuel and several other application one can think of. Of course, the solid fuel is not really being use very much for the transport applications because of problems of that how to handle the fuel particularly the flow of the fuel into the engine is very important.

And also the some of the particulates which will be coming out unburnt and then they how to handle that and that is the reason why it is not being used and of course, another important reason is that, there are several exotic fuels like your petroleum products like kerosene diesel and other fuels and so, also the gaseous fuel CNG, LPG are available (Refer Time: 09:12) it due to the era of petroleum as we are leaving. So, therefore, it is not really being utilized; however, wherever there is a stationary applications and where is use cool. Then we go for the solid fuel, question arises why we will go for solid fuels, why not liquid or the gases the.

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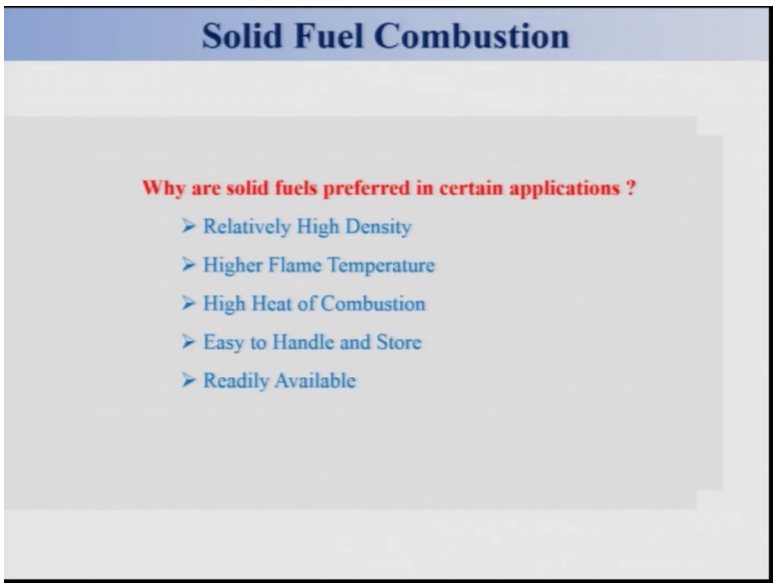

Because of reasons that it has a higher density in comparison to the other fuels, like your gaseous fuel or the some of the liquid fuels as well and it has a higher flame temperature as compared to the other liquid and gaseous fuel. Beside this it has a sometimes of course, higher heat of combustion as compared to other gaseous and liquid fuels and it is easy to handle and store, unlike the gases which is very quiet dangerous because the any leakage from the gas tank or the pipeline can create havoc particularly when the people are living around. And so, also the liquid fuel it vaporizers, it may lead to explosion, it

may lead to fire and other things and it is very easy to store the solid fuel as compared to the gaseous and liquid fuel.

And it is readily available as I told the coal, the biomass are easily available at the cheaper price and it can be transported easily so therefore, it can be used.

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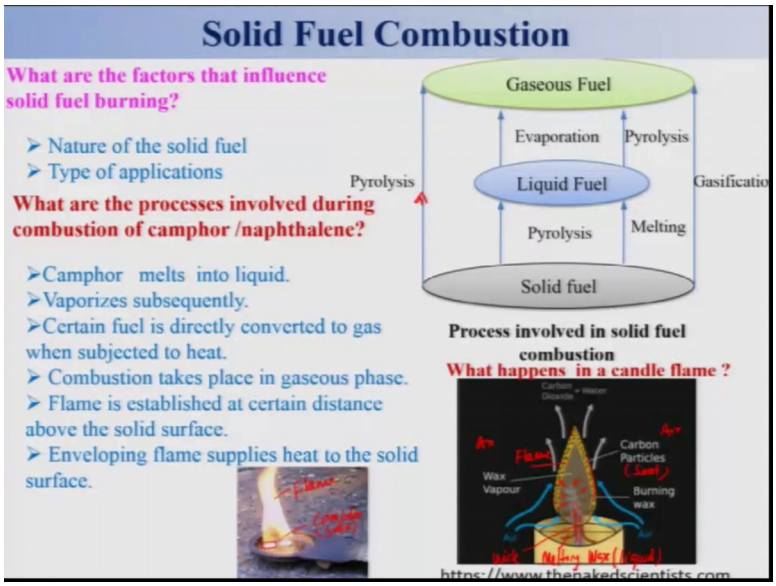

And let us look at what are the factors that influence the solid fuel burning? If you look at really basically it is the nature of the solid fuel as I told earlier the coal. Coal maybe containing large amount of ash as in India the ash content varies from 20 to 40 percent. That means, you are carrying the fuel, which is having large amount of material which cannot be utilize, it is just a ash and beside this biomass also is another fuel where it will be changing because these are all natural fuel, like its constituent will be changing depending on what kind of biomass you are using. And, but of course, you can design your fuel, solid fuel like your propulsion and maybe some kind of coke and other things. So, they are when you design you can densify the fuel and you can have a higher calorific values also.

And also it depends on the type of application one can have for example, you want to apply it for a stationary power plant and you can very easily really transport it and use it particularly making powder so, that the intensity of combustion can really be higher in the boiler, but when you are using domestic you are not bother about intensity of combustion high whatever it is required, but the heat liberated rate; the rate of heat of

combustion is really not that important in domestic application you can use a bigger size. Of course, if it will be too big size then your combustion may not be good and then it lead to the pollutional thing. So, therefore, the kind of applications will dictate the how the solid fuel is getting burnt.

And what are the processes involved during the combustion of a camphor and naphthalene of course, I have taking a example of camphor. Camphor is a part and parcel of our culture because we use the camphor for our rituals and every day (Refer Time: 13:35) we use that. And you might have seen particularly a camphor fire what I have shown here. These are the camphors right and there is a basically a flame we could see and naphthalene of course, is a petroleum product which is being used vapor various purposes in modern life.

And if you look at you just to ignite this a camphor initiate a fire and this and then it is looks to be very nice fire and with a yellow flame and of course, it is little bit suity in nature and, but what are the processes involved in that? If you look at basically the camphor can melt into a liquid initially you might have observe and therefore, getting the heated by like your matchstick or some other kind of naked flame for initiating the combustion of camphor.

And once it is liquid is being formed and that liquid subsequently is converted into its vapor and undergoes basically vaporization process and once its vapors are formed it mixed with the certain oxidizer, which present in the air in the atmosphere and then of course, the combustion flame will be occurring, but and there are certain fuel, which is directly converted into gas when subjected to heat. And combustion as I told earlier the combustion takes place in gaseous phase mostly therefore, the flame you could see this is a flame.

And really what happens in that, the flame is generally established at certain distance above the solid surface if you look at this is the solid camphor and as a result the heat will be transfer from this flame to the solid camphor. Such that it will be melted with the gas is being produced and then you can really get a flame whenever this gaseous fuel is mixed with the oxidizer due to the diffusion process.

So, let us look at what happens in a candle flame, which is basically petroleum wax, what we use and day to day life we use that, here it happen similar things like let us say

this is your wick, which is being this portion is your wick which carries basically the fuel along with due to the capillary action provided that is a melting wax. So, this is your melting wax right, this portion is your melting wax or a in a liquid form this is in a liquid form.

You might have observe this and this basically then what happens this is liquid being generated due to the flame and a flame is formed, but in the beginning as I told earlier that you will have to use a naked flame or burning this wick and that wick will be giving some heat to this wax or the candle and which is converted into liquid and this liquid will be going up with the help of wick due to the capillary reaction, Then that will be converted into the gaseous this liquid fuel be converted into gaseous undergoing the paralysis process and the fuel will be going towards the oxidizer in the air, this is your air in atmosphere right.

And then the air also will be getting into the flame, which is here and then the mix together and the flame is formed. So, this is your flame which is being formed and this contains a certain amount of carbon particle what we call soot particles and beside this there will be carbon dioxide and water which have been formed due to the combustion of hydrocarbons with the oxygen and then it will be going. So, if you look at this is basically the process is quite complex as compared to the gaseous fuel here the process of vaporization and also the pyrolysis and some of the gasification will be taking place.

So, let us now summarize what are the process involved in the solid fuel? So, as I told earlier, that the solid fuel whenever it will be subjected to the heat and the it will be can be solid can be converted directly into gaseous fuel undergoing basically the pyrolysis process or the solid fuel will be melted into the such that the liquid fuel is being formed and it can go directly gasify into the gaseous fuel. And once this liquid is formed it can be evaporated or which can also be undergoes pyrolysis process and converted into gaseous fuel.

So, there is the various ways the solid fuel can be converted into gaseous fuel and it will be mixed with the oxidizer and then only the combustion can take place. Keep in mind that the pyrolysis is basically a process by which the fuel is decombust whenever it is subjected to the heat.

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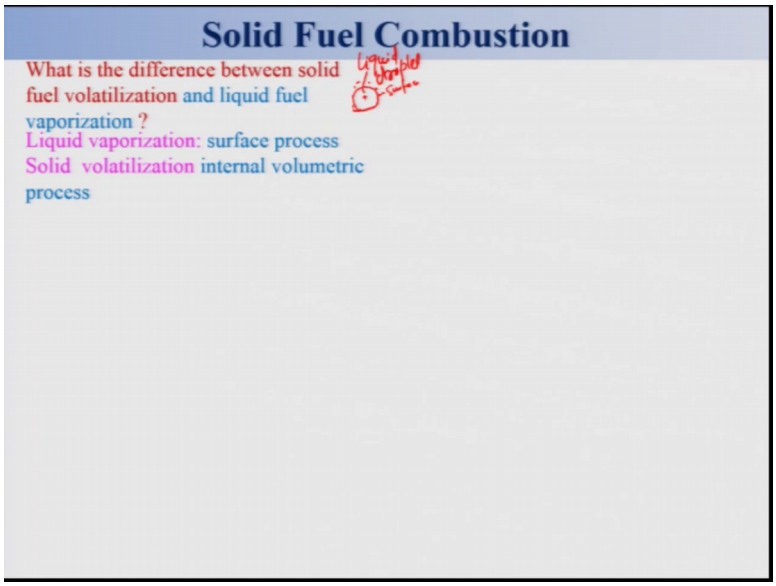

So, therefore, what will be looking at now, what are the process you know difference between solid fuel volatilization because whenever the solid fuel is there it has to converted into liquid, it can converted into the gaseous way. And whenever it will converted into gaseous we call the volatilization because the solid fuels which will be containing lot of volatile, which can really converted into gas at a little higher temperature and the liquid fuel of course, will have to vaporize it will be converted into gaseous phase.

Now, what is the difference between both the process which looks to be similar in nature? The liquid vaporization is basically a surface phenomenon; that means, it will be occurring at the surface of the liquid droplet, if there is this is the liquid droplet and it will be occurring at the surface like this is the surface right. So, this is basically a surface phenomena whereas, if it is a let us say a carbon sphere, which is having a undergoes volatilization or the gasification, then what will happen? It will be occurring at the inside it suppose this is a carbon right, particle which is a solid.

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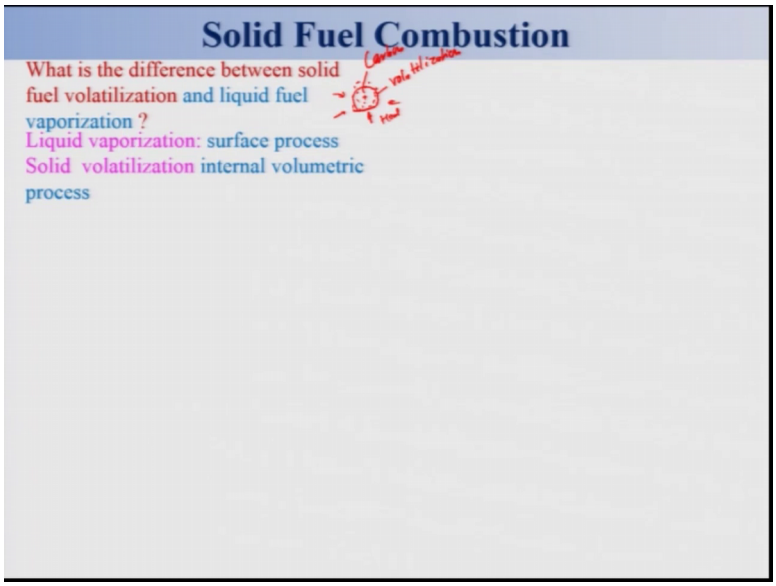

Now, it would not get into suppose if the heat is subjected to heat here coming from this side heat the naturally in this zone there will be some devolatilization will be taking place or volatilization will be taking place. So and this is a basically volumetric process so, that is very important one has to keep in mind.

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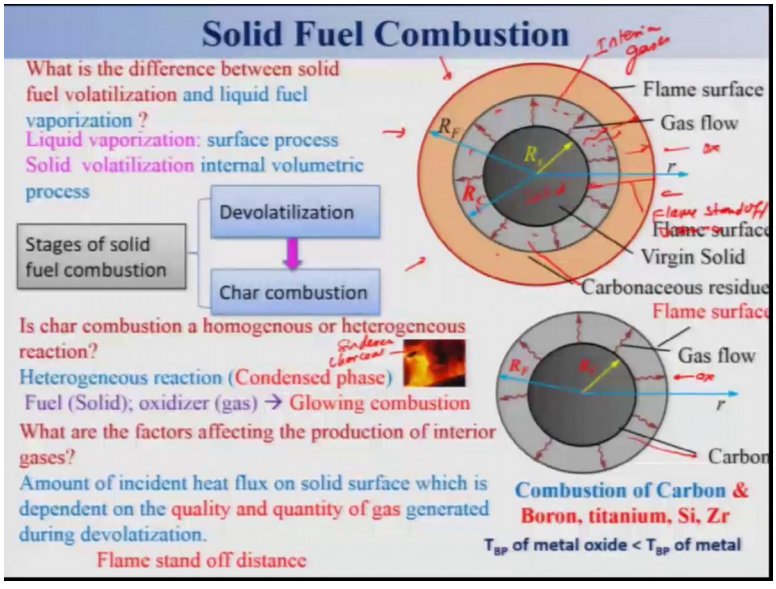

So, as I told earlier the Stages of solid fuel combustion basically it can be divided in to two fast is there it get volatilize; that means, some of the solid will be converted into gas and then after that whatever it will be remaining, that will be undergoes a char

combustion of course, there are certain kind of solid fuel which will not undergo any volatilization and directly undergoes the combustion. So, that is kind of fuel which will be particularly the carbon, if you are a only pure carbon that you want to going and in such kind of fuel solid fuel, which will be undergoing the volatilization that is known as pyrolysing solid fuel.

And is the char combustion homogeneous and heterogeneous in reaction? Actually when you talk about char combustion char combustion is basically the heterogeneous reaction and undergoing in which the chemical reaction undergoes in the condensed phase. For example, fuel in the solid and a gas will be getting into the solid and then will be getting this solid phase or the condense phase combustion will be taking place.

As a result there will be glowing combustion, will see particularly if you see the sintered carbon right charcoal right charcoal are carbon you will find the similar kind of image which is a growing in nature. So, therefore, you will be getting that it is basically the what you call pyrolise char combustions right, and let us look at as I told earlier let us say there is a solid fuel here of course, the whole thing is solid fuel and it is subjected to the heat from various reasons right. And in the beginning it maybe a solid only and then after that what happens it will be undergoing the volatile you know the gases will be going out as it is being formed in this region this gases and that became basically carboneous residue; this is the carboneous residue which will be remaining.

And of course, this one what I have shown is basically the virgin solid, which is not subjected to any kind of combustion or no changes occurs in this because that is why it is virgin and gas flow will be taking place and this gases which will get into here and it will be mixed with the oxygen or oxidizer and then a flame is formed. And the flame will be giving heat and so, that process is going on such kind of process you called it basically the pyrolising solid fuel combustion.

Then the question might be arising in your mind what are the factors affecting the production of interior gases? These are interior gases which are produce and that basically depends on the amount of heat is being transfer amount of heat transfer is basically depend on how far the flame standoff distance. So, if you look at this is the flame standoff distance; that means, how far it is from the solid surface and also that it depends on amount of incident heat flux and the solid for surface, which is dependent on

the quality and quantity of the gas which is being generated. This gas which is being generated here right, this will be getting into transferred to the flame and therefore, the flame standoff distance depends on the amount of gas generated and also the quality of the gas therefore, that is very important.

So, and there is the another kind of combustion which will be the thing which will be taking place basically for the carbon, this is your carbon where the solid fuel wont undergo any pyrolysing process and but; however, it will produce on the surface the gas and then it will be gas will mixed with the oxidizer in the atmosphere and then flame is being formed. And this is possible only for certain fuels like a carbon, boron, titanium, silicon and zirconium these are the metals and this is of course, for other metals the pyrolysing combustion will be taking place what I have shown here.

And this is possible only when the boiling point temperature metal oxide is less than the boiling point of metal and that is basically when non pyrolysing combustion will be taking place. Pyrolysing combustion sorry will be taking place when the boiling point temperature of metal oxide greater than the boiling point temperature of metal. So, with this I will stop over, thank you very much and we will be discussing more about in the next lecture.

Thank you very much.