# POWER PLANT SYSTEM ENGINEERING

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**Module 2**

## Lec 14: Fuels and Combustion (Part I)

Dear learners, greetings from IIT, Guwahati. We are in the MOOCs course Power Plant System Engineering module 2 Vapor Power System part 3. So, in the lecture we will start a new segments that is fuels and combustions. So, here in steam power plant, the fuel is main source of energy and the type of fuel that you are using here is mainly fossil fuels that is coal. So, basically in this lecture we will try to see the different variety of coals, their grades, coal analysis, and then the method of coal firing. Although there are many methods of creating combustion in the furnace, but one of the best method is the fluidized based combustions. So, we will discuss about that combustion technology in this lecture.

So, let us start the first segment that is fossil fuel that is coal. Now, in the modern steam generator, we require the source of energy to generate steam and for that we need some combustions of fuel and air. So, if you look at this particular figure to get steam from water, we require the heat source from the fuel which is fed at this location. Now, this particular fuel after combustion, generates flue gas and in the entire circuit, the flue gas goes to the atmosphere through the stack.

So, the fossil fuel steam generators mainly deal with the working fluid which is water or steam and this steam production is achieved through flue gases and flue gases are produced by combustions using variety of the fuels. One can think of solid fuel, liquid fuels and gaseous fuels also, but most efficiently in this case we treat the combustion as a solid fuel that is coal. So, in general the fossil fuel is generated in the earth through slow decomposition and chemical conversion of organic materials and they are mainly available in the basic forms either in the solid form, liquid form which is oil and natural gas. The most fundamental way of availability is the solid fuel that is coal and this coal is a classical source of fossil fuel energy, which is responsible for 50% of electric power. We also use this natural gases, they contributes 30% and remaining part comes from the renewable sources that are hydraulic or nuclear.

So, essentially this 50% of electricity generation is achieved through fossil fuels. So, it can be in either solid form or liquid form or natural gas form. But there are new combustion fuels which includes mainly liquid and gases which are derived from the coal, oil shale and tar sands. In fact, there are some byproducts that come out of solid fuels, that is coal and they are called as synthetic fuel. And they are mainly used in the industrial and domestic waste, but that is not part of our analysis when you deal with the modern steam generator power system.

So, let us discuss some history about the coal & its types. So, the coal is the common term that is used in large sense and it caters solid organic materials with wide variety of composition properties and they are rich in, one particular element that is carbon. So, basically carbon is the main constituents. The classification of the coal is based on the physical and chemical properties, its grade, and rank. And the lowest grade is called as lignite, highest grade is called as anthracite. So, first highest grade coal, that is anthracite. It contains highest carbon contents close to 86-98 % by mass and they have very less volatile matter that is difference out of 100, if 86 to 98 goes as a carbon, the rest of the contents is volatile matter which is between 2 -14%.

So, they can be sensed by their colour which is shiny black, they are dense hard and they are very brittle and its heating value is approximately 25 MJ/kg. When you talk about the next grade that is called bituminous coal, which is the largest group that means, its availability in the earth is the largest and they contains mostly 46-86% of carbon, 20-40% of volatile matter and they are used in pulverized form because they contain more volatile matter. Whereas, anthracite can be taken as direct coal that can be burnt easily. But this bituminous coals have heating value in the range of 25.6 - 32.6 MJ/kg. The next category which called as a sub bituminous coal for which the heating value further drops which is a 19.3 - 26.8 MJ/kg and they have relatively high moisture content. Lignite is the lowest grade coal that resembles the laminar structure of wood fiber and they have highest moisture content which is 30%. Heating value is further less that is 14.6 to 19.3 MJ/kg. And Peat is considered as the lowest or the waste form of coal. When the coal formation starts in the earth, its first form is the peat and then it further decomposes with plant matter and inorganic materials with 90 % of moisture content. So, it starts with peat then starts the lignite formation and slowly it goes to the highest quality coal that is anthracite. So, essentially speaking this is the history of coal formations starting from peat which is of course, a non-usable form then lignite then sub-bituminous, bituminous and anthracites. So, this is the how the coal formation takes place in the earth core.

When you use the coal in steam power system, we have to understand that how this coal can be effectively used. One way to use this coal is direct form like as a solid structures, other is in the pulverized form, another category is powder form. So, in order to achieve highest efficiency, the powder form is the best, but again depending on the quality of the coal, whether you are using anthracite or bituminous coal depending on that nature or type of the coal, we start thinking whether to use in powder form or directly in a pulverized form or a solid form. So, to know the quality of the coal, we do two types of analysis which is based on mass percentage. This is just to find the grade and characteristics of coal, when it is used.

The two types of analysis are proximate analysis and ultimate analysis. So, in the proximate analysis gives the ready meaningful information about the coals used in the steam generator. It determines the mass percentage of fixed carbon, volatile matter, moisture and ash. Fixed carbon is the elemental carbon that exist in the coal, which is nothing, but the difference between the original sample and some of the volatile matter, moisture and ash. The volatile matter is the portion of the coal which is driven off when the sample is heated at 950℃ per 10 minutes. That means, in the absence of oxygen if the coal sample is heated to 950℃ per 10 minutes then we can drive off this volatile matter. Then moisture can be determined by a standard procedure in drying in an oven. Ash is another kind of organic salt that is also present in the coal and it is considered as a noncombustible residue. So, that has to be dried off and to do this drying test we must do it at 750℃ in the absence of oxygen for 10 minutes. Sulphur is another culprit because it produces sulphur dioxide after combustions, but it is combustible and this contributes to heating value of the coal. But it forms oxide that combines with water to form acid. So, this is the main cause of corrosion and environmental problem. So, corrosion issues are highly possible in various components of steam power systems. So, the sulphur has to be decomposed during its burning process.

Now next category of this coal analysis is the ultimate analysis. It is based on the scientific evidence or test that provides the chemical elements that comprises of coal together with ash and moisture. So, on a mass basis the elements are obtained as carbon, hydrogen, oxygen, nitrogen, sulphur, moisture and ash.

$C + H + O + N + S + M + A = 100\%$ by mass

The dry and ash free analysis on combustible basics $= 1 - [(M+A)/100]$

So, basically 100% mass by coal contains these components and from our analysis we must find out each of the component. So, dry and ash free analysis of combustion basis, if you just remove this moisture and ash, then basically on combustible basis, this part take the lead during the combustion process. Like moisture and ash are just have to be driven up. So, essentially speaking out of 100% by mass if you take out (M+A) then the rest amount would is the usable form of coal.

Now, another parameter, while using this coal, to be found out is the heating value of the coal. So, it is nothing, but the amount of heat that is transferred when the products of complete combustion of coal samples are formed and subsequently they are cooled to initial temperature of the fuel. So, there are two types of heating value one is higher heating value or gross heating value other is the lower heating value. The main difference between these two is nothing, but the latent heat of vaporization of water. Like during combustion process, if there is a vapor formation then the lower heating value is not taken into account. So, it has to be added with lower calorific value to obtain the higher heating value of the fuel.

Normally why this latent heat of vaporization word is there because at the end of combustions there is formation of water. Normally the gases are not cooled down to deep end temperature of the steam generator because if they are cooled down to deep end temperatures then there will be formation of water vapors. So, dew point temperature is also a critical parameter that has to be estimated during the combustion process of the coal. To obtain the standard heating value of the coal is mainly desired and it is mainly based on the energy balance and efficiency calculations. We will try to see how these values are calculated in the subsequent problem.

For the calculation point of view, the two values, lower heating value (LHV) & higher heating value (HHV) are related with respect to the following equation.

$$LHV = HHV - m_w h_{fg}; LHV = HHV - 9m_{H_2} h_{fg}$$

$m_w$:Mass of water vapour in the products of combustion per unit mass of fuel
$m_{H_2}$:Mass of original hydrogen per unit mass(known from ultimate analysis)

$h_{fg}$:Latent heat of vaporization for water

Now, as the Ratio of molecular weight of $H_2O \& H_2 : 9$

So, basically instead of talking about mass of water you can talk in terms of hydrogen means $m_w = 9m_{H_2}$. This is another way of looking at the calculation of lower heating value of the fuel. Estimation of these things we can do in this method as well, because if you look at here the coal also contains hydrogen and this hydrogen takes part in this combustion process to form the water. So, that is the reason instead of taking directly mass of water we take hydrogen into account to calculate this lower heating value of the fuel or coal.

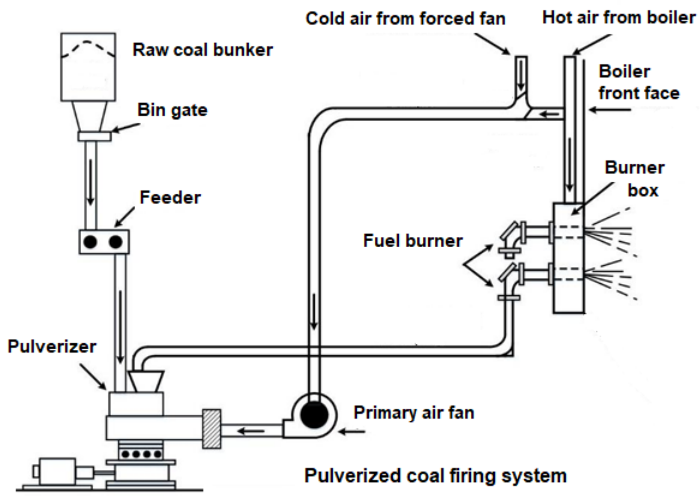
So, there is a standard formula which is called as Dulong formula which gives higher heating value of the fuel, but its unit is Btu per lbm. So, if you want to calculate a higher heating value of the fuel in Btu per lbm then use following equation.

Approximate $HHV$ for Anthracite & Bituminous coal:

Dulong formula, $HHV\left(\frac{\text{Btu}}{\text{lbm}}\right) = 14.6C + 62000\left(H - \frac{O}{8}\right) + 4050S$

$C$:Carbon; $H$:Hydrogen; $O$:Oxygen; $S$:Sulphur

So, this is the standard formula which can be directly used to calculate the higher heating value of the fuel. Once you know higher heating value and the latent heat of vaporization then it will be possible to calculate the lower heating value of the fuel.



Pulverized coal firing system

Once you have this information of quality of the coal then let us see that how we are going to use effectively in a steam power systems. So, if you look at particular figure here, essentially this is a pulverized coal firing system. Here raw coal forms from the bunker and it is fed through the feeder and it goes to this firing system pulverizer. So, in a pulverized form of the fuel, it goes and enters into the fuel burner. So, basically to push this fuel or this coal into the fuel burner, we require a fan that pushes these things here then it enters to the burner box and coal firing starts.

So, combustion takes place here and heat is released on this boiler front face. But again any kind of unwanted things like if there are some particles which are not burnt completely then again it comes back through another route and enters through this primary fan route and goes to the pulverizer unit. So, for the best possible way or efficient utilization of the things, we use in the pulverization form. But if you start looking at the history it starts with with a manual feeding then mechanical stoker that means, manually we can make it to a smaller or medium size coal and these stokers are designed to feed the coal continuously into the furnace by moving it in a grate and remove the ash from the furnace.

But since this is not an effective way of doing this coal firing. So, the people started thinking of pulverized coal firing methods. So, coals are crushed into fine powders and this method is mainly suitable for high grade coals. The major advantage for this pulverized coal firing method is that

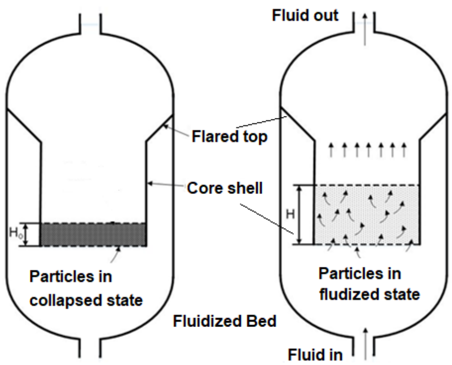
1. They have the ability for usage of any size of the fuel,
2. They have good variable load response,
3. They have lower requirement of excess air for combustions,
4. They require less fan power,
5. They require lower carbon loss that means, if you use pulverized coal firing then there will be lower carbon losses,
6. Lower operation and maintenance cost,
7. Higher combustion temperature and improved thermal efficiency that you get out of the fuel burning.
8. Then there is a possibility of design of multi fuel combustions that means, this pulverized method of coal firing can be integrated with oil, gas as well.

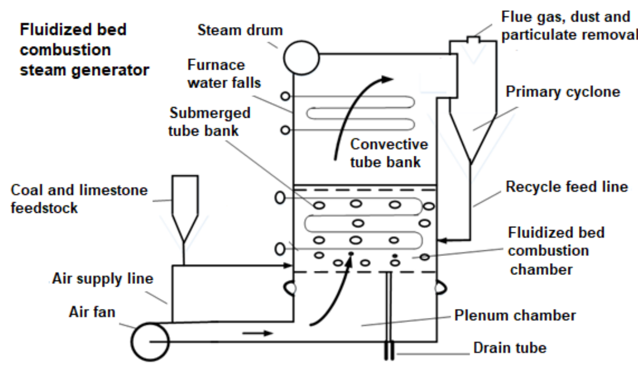
Then moving further there are more developments in the pulverized form of coal firing people start using cyclone furnace. So, this cyclone furnace is nothing, but a similar unit of pulverizer, but the main difference is that the pulverized form coal becomes powder and this cyclone furnace creates a centrifugal motion for this powder form at a very higher speed that means, 80 -100 m/s and when this mixing takes place with air that means, coal plus air mixing takes place at a speed of 80 -100 m/s, it has proved that complete combustion or combustion efficiency can be enhanced. And the additional advantages from it are

1. Reduction in the furnace size,
2. Reduction in the fly ash contents like when you take out the flue gases the fly ash contents less
3. And there is saving in the pulverized equipment.

So, with these continuous development starting from the manual feeding to pulverized coal firing to cyclone furnace, but the most recent technology or current technology of coal is fluidized bed combustions. So, here the main idea is that we are creating an environment such that, although the coal is in a powder form or solid particles it behaves as a fluid during the combustion process. How it behaves as fluid we will come back in the subsequent lectures and subsequent slides.

So, let us see the concept of fluidized based combustions. Till date this is the most recent technology and here we are intended to think that how these coal particles can behave as fluid. So, in this combustion process the crushed coal particles are injected into the fluidized bed so that they spread across the distribution of grid. If you refer this particular figure, we have a furnace and that is called as fluidized bed combustion chamber. So, this is the fluidized bed combustion chamber.




In this fluidized bed combustion chamber we have submerged tube banks that contains the fluid, in this case it is water, which has to take heat from this through this combustion process. So, this submerged tube bank is nothing, but water tubes. Then we have this furnace wall and that is a convective tube bank that is another case that means, another circulation of tubes where the heat transfer from the fuel to the water goes through the convection mode and they are called as convective tube banks. And ultimately we get the saturated steam in the steam drum. But our main intention is not about the formation of steam at this stage rather we will try to link that how we can achieve this fluidized combustions.

So, if you look at this figure, we have the coal and limestone feed stocks. We require limestone because we require the sulfur contents to be minimized or effect of sulfur for the formation of $SO_2$ has to be minimized. So, we have a coal and limestone feed stocks that enters into the supply line and we have air fan. And all this coal and feedstock they goes in the powder form. That means, we use a cyclone furnace to create a powder form of the coal which enters into the combustion chamber.

Now here this fluidization combustion takes place. When there is no combustion, we have a stock of bed which is called as a coal bed which are in the collapsed state and it has certain height. That means, the powder form of the coal is contained in this for a height $h_0$, that is initial height. Now this bed has to be made like a fluidized bed form. For that you allow this air at a very high velocity, so that entire stock becomes fluidized. That means, it pushes the coal particles or collapsed state of this coal powder form to a fluidized form and it goes out. So, basically a beginning state it is a collapsed state and during fluidized states it becomes particle form.

So, essentially there are three densities involved, one is density of the bed, then density of the fluidized form and the fluid that is air density which pushes these things up. So, basically due to the density difference of air and this fluidized bed and the gas particles, the necessary pressure difference is created. So, to have more efficient way of this burning, combustion air is blown through some grids with and it has some upward velocity coefficient that causes the coal particles to become fluidized. Fluidized means this fuel coal does not become fluid, but it behaves as a fluidized form. The unburned carbon leaving the bed is collected in a cyclone separator and returned back to the main unit again.

So, the main advantage of this fluidized combustion is the ability to desulfurize the fuel by adding limestone directly into the combustion bed during the combustion to meet the air quality standard for oxide formations. Now, more specifically when you look at the fluidized bed, here we use the crushed coals of certain diameters which is 6-20 mm. And other thing is that we also require a plenum chamber or we call as air plenum which is in the bed and that gives necessary fluid velocity. Now, for the mixing, we require swirling mixing for fluid and air to mix very properly in order to enhance the combustion efficiency.

And ultimately at the end of this combustion, the heat that is released through this coal and air combustion has to enter into the boiler water tubes. So, the boiler water tubes located in the furnace receives heat released due to this combustion. So, essentially this submerged water tube bank and also this convective tube banks receive heat from this combustion. And finally, the products of combustion leaving the bed contains large portions of unburned carbon particles and they are again collected back through a cyclone separator. The unburned particles return back to the fluidized bed to complete the combustion process.

So, main difference between this fluidized bed and cyclone furnace is that in a single method one can use to remove sulphur, which means, when you use a conventional cyclone furnace there are difficulties in separating sulphur, but in this mechanism of fluidized based combustions, there is a possibility that sulphur can be removed during this combustion process. And that is the reason this fluidized bed combustion technology is gaining more importance. And moreover for environmental viewpoint, this method gives lower production of NOx. Now, let’s check during a fluidized bed combustions how this sulphur contents gets removed. When you use this calcium carbonate $CaCO_3$ with sulphur oxide and oxygen and when this combustion process happens we get calcium sulphate and $CO_2$.

$$CaCO_3 + SO_2 + (1/2)\ O_2 \rightarrow CaSO_4 + CO_2$$

So, $CO_2$ anyway goes out to the atmosphere this calcium sulphate is collected as a dry waste. So, this is how the limestone helps in getting this sulphur or this $SO_2$ formation does not happen in the end here. So, had this equation not been there, probably you would have $SO_2$ in the products which goes to the atmosphere. Now, this $SO_2$ when interacts with limestone it forms $CaSO_4$ and it can be collected as a dry waste. So, this is the advantage, that the fluidized based combustion gives us by removing sulphur from the coal.

Reduction of sulphur oxide can be achieved up to 90% in a fluidized bed plant and here maximum temperature can go up to 750 - 950℃.

Now, let us see some theoretical modeling of this fluidized bed combustions. So, there are two important information that we need to share. First thing the theoretical model for fluidized bed involves the required pressure drop, so that the coal has gained sufficient momentum to become the fluidized form and we also require minimum velocity for the fluidization to happen. That means, initial state the coal particles they are in collapsed state.

So, to bring it if to a fluidized state, we require a velocity which is called as minimum velocity for fluidization and this can be calculated by equating drag force of the particle due to motion of fluid to weight of the particle. So, if you look at this core shell of this collapsed state and fluidized state, so essentially the weight of the fluid particles that can be $(U\rho_s)g$, where $\rho_s$ is nothing, but density of the solid particles. So, $U\rho_s$ becomes weight and final equation is mass times gravity, then we can get drag coefficients by this expression. The fundamental expression of drag coefficient is given below. So, here $U$ stands for the fluidization velocity and here we assume these particles to be of spherical shape for which we can find its volume $\left(\frac{4}{3}\right)\left(\pi r_p^3\right)$ and cross sectional area of the particle is $\pi r_p^2$.

Drag coefficient, $C_D = \frac{F}{\left(\frac{1}{2}\right)\rho_b A_c U^2}$; Weight of the fluid particles, $F = (U\rho_s)g$

Volume of particles (spherical), $V_p = \left(\frac{4}{3}\right)\left(\pi r_p^3\right)$; Cross-sectional area of the particles, $A_p = \pi r_p^2$

So, equating these two we can find derive a fluidization velocity $U$ in terms of density ratio and a particle diameter.

Fluidization velocity, $U = \sqrt{\left(\frac{8}{3C_D}\right)\left(\frac{\rho_s}{\rho_b}\right)(r_p g)}$; $g$: Acceleration due to gravity

$\rho_s$:Density of solid particles; $\rho_b$:Bulk density of bed; $r_p$:Radius of spherical particle

This is the main theory and of course, we require the pressure difference. So, the total pressure that occurs in a fluidized bed consists of three components; pressure drop due to friction, pressure drop due to static weight of the solids in the bed and pressure drop due to hydrostatic head in the bed. So, in normal circumstances these two components we normally neglect the pressure drops due to friction and hydrostatic head. So, the total pressure contains only the pressure drop due to the static weight of solids in the bed. But here we have to introduce a parameter that is called as a porosity or void that is $\alpha$.

The total pressure drop in fluidized bed, $\Delta p = \Delta p_w + \Delta p_s + \Delta p_f$

$\Rightarrow \Delta p = \Delta p_s = (1-\alpha)\rho_s g H$;

$\Delta p_w$:Pressure drop due to friction; $\Delta p_w$ & $\Delta p_f$ are usually small

$\Delta p_f$:Pressure drop due to static weight of fluids in bed (hydrostatic head)

$\Delta p_s$:Pressure drop due to static weight of solids in bed

So, $\alpha$ is the average porosity or void fraction of the bed in the fluidized state. That means, in fluidized states, you can find that the entire unit or entire area is not filled with the coal particles, there are voids in between. That means, when the coal in powder form goes up in this dome, then what happens you will not find that entire area or entire unit is covered with all the particle of the coal, but it contains coals as well as some voids. That means, in the void, there is no coal. So, those void part also has to be taken into account while calculating this H which is the height of the fluidized bed. So, in collapsed states we call this porosity as $\alpha_0$, this is in the order of 0.4. When they are in the fluidized state this value also goes up.

So, one fundamental linear relation we can obtain that is

$$\frac{1-\alpha}{1-\alpha_0}=\frac{H_0}{H}$$

$H$:Height of the bed in fluidized state; $\alpha_0$:Porosity in collapsed state($\sim$0.4)

$H_0$:Height of the bed in collapsed state i.e. all solids are randomly packed at bottom

$\alpha$:Average porosity or void fraction of bed in fluidized state(Fraction not occupied by solids)

So, this will give you necessary pressure drop. So, you can find out $\Delta p/H$ by normalizing this equations. So, this is how the working equation is all about. Now, to calculate the minimum fluidization velocity we need to introduce the term called as a non-dimensional number which is called as Archimedes number and for a fluidized bed if you want to calculate what is the voidage, for a working range of fluid particles that has to be involved and third thing what is the minimum fluidization velocity all these things can be calculated by a simple expression which is called as Archimedes number.

Archimedes number, $A_r=\frac{\rho_a(\rho_s-\rho_a)gd_p^3}{\mu_a^2}$;

$\rho_a$&$\mu_a$:Density and viscosity of air, respectively; $d_p$:Particle diameter

$\rho_s$&$\rho_b$:Density of solid and bulk density of bed, respectively

So, first thing that we need to calculate is the void fraction which can be correlated with respect to density.

Void fraction, $\alpha=1-\frac{\rho_b}{\rho_s}$;

Because we have two densities, when the entire coal products sits on the bed we have certain density and, each coal particle also has own density that is density of the solid. So, then fluid drag can be estimated by this equation

Fluid drag, $F=(\Delta p)A=AH(1-\alpha)(\rho_s-\rho_a)g\Rightarrow\frac{\Delta p}{H}=(1-\alpha)(\rho_s-\rho_a)g$

$\Delta p$:Pressure drop across the bed;$H$:Height of the bed in fluidized state;

Then also we can introduce Reynolds number. This Archimedes number is related to find this minimum superficial velocity. So, essentially when superficial velocity that is the gas flowing through the fixed bed reaches the minimum value means, when you are pushing this air into this bed this air velocity reaches to a minimum value in order to achieve the fluidization state and that velocity is called as fluidized velocity. And this can be related through this Reynolds number.

Reynolds number, $\text{Re} = \frac{\rho_a d_p U_m}{\mu}$; $U_m$:Minimum superficial velocity

So, this Re and Archimedes number for the fluidized states can be represented by this equations.

Reynolds number, $\text{Re} = (C_1^2 + C_2 A_r)^{0.5} - C_1; C_1 = 27.2 \& C_2 = 0.0408$

And this relation helps us to find out the fluidization velocity or minimum superficial velocity which is required to obtain this fluidized state. So, this is all about the fluidized bed combustions, its terms & technology. I have not gone deep into this particular segments, but I have just given the summarized view of the coal combustions through fluidized bed technology in an efficient way for a modern steam power unit.

And finally, before I conclude I will just give some summary of this fluidized bed combustions. There are many advantage of this fluidized bed combustors due to its low temperatures.

1. That means, through this fluidized bed technology inferior grades of coals can be handled because we are bringing them into fluidization state.
2. Carbon and ash carryovers on the flue gas do not cause any kind of harmful effect or fall in the heat transfer process.
3. And there is a substantial reduction of emission of oxides of emission that is NOx reduces drastically.

4. The construction becomes economical due to cheaper alloy materials and requirements and there is an absence of pulverized equipment that adds further economics.

So, basically these four advantage has necessitated the fluidized bed technology in a large sense. The fluidized bed combustions can be designed to incorporate boiler within the bed and through this fluidized bed technology the volumetric heat transfer rate can be increased about 10 -15 times and at the same time surface heat transfer rates is also higher by 2- 3 times as compared to conventional boiler technology. And more advantage is that they can be integrated with combined cycle steam power plant. Normally fluidized bed combustors used Rankine cycle for steam power generations and they can be linked to combined power cycle systems that involves Brayton- Rankine cycle. And more specifically it also caters the need of this steam power systems which works up to 170 bar and 550℃ and it can handle the fuel flow rate of 40 kg/s.

Hence the fluidized bed technology becomes an attractive alternatives for power plant applications. So, this is about fluidized bed combustions. So, based on our discussion we will try to solve some numerical problems.

**Q1. The ultimate analysis of medium volatility bituminous coal shows mass percent as, carbon: 80.7%; hydrogen: 4.5%; sulphur: 1.8%; oxygen: 2.4%; nitrogen: 1.1%; water: 3.3%. Assume stoichiometric, chemically correct combustion air and write down combustion equation. Calculate HHV, LHV and dew point temperature.**

So, the first problem is based on the ultimate analysis for the coal. So, the ultimate analysis of the coal that means, we are using a bituminous type of coal and this ultimate analysis gives different compositions carbon as 80.7%, hydrogen 4.5%, sulfur 1.8 %, oxygen 2.4 %, nitrogen 1.1 % and water 3.3 %. So, we are asked to write the combustion equations, calculate HSV, LHV and dew point temperature.

To solve these problems first let us start with relative mole fraction.

$$\frac{80.7}{12}\ C + \frac{4.5}{2}\ H_2 + \frac{1.8}{32}\ S + \frac{2.4}{32}\ O_2 + \frac{1.1}{28}\ N_2 + \frac{3.3}{18}\ H_2O$$

$$\Rightarrow [0.725\ C + 2.25\ H_2 + 0.05625\ S + 0.075\ O_2 + 0.03929\ N_2 + 0.1833\ H_2O\ ] + (\ )Air\ [N_2 + O_2] \rightarrow (\ )CO_2 + (\ )H_2O + (\ )SO_2 + (\ )N_2$$

But for a stoichiometric combustions, we get the above equation. This fuel has to be mixed with $Air\ [N_2 + O_2]$ to give rise to this, but we do not know the composition of $[N_2 + O_2]$ requirement. So, for that we need to do this $H_2$ balance.

For $H_2$balance if you see, the left side of equation has $H_2$ of 2.25 mole and water 0.1833 mole, which will give water in the right side.

So, $H_2$Balance, $\quad 2.25 + 0.1833 = 2.433$

Now Sulfur balance, Sulfur in the left side will give$SO_2$. So, in sulfur balance same sulfur is being used this that means, sulfur will have in the product as like is 0.05625.

Sulphur Balance, $\quad 0.05625$

Then we have oxygen balance. So, oxygen has two parts one in products and other in reactants.

$$\mathrm{O_2}\ \text{Balance, Product componet} \rightarrow\ 0.725 + \frac{2.25}{2} + 0.05625$$

$$\mathrm{O_2}\ \text{Balance, Reactant componet} \rightarrow\ -0.075$$

So, the balance amount that will come from oxygen here would be 1.83125.

So, for $N_2$ Balance, If you look at air it gives 3.76 moles of $N_2$ per mole of $O_2$.

So, $N_2$ Balance $\rightarrow\ 3.76 \times 1.83125 = 6.8855$

So, doing these balancing we can write this equation as

$$[0.725\ C + 2.25\ H_2 + 0.05625\ S + 0.075\ O_2 + 0.03929\ N_2 + 0.1833\ H_2O\ ] + 6.8855\ N_2 + 1.83125\ O_2 \rightarrow 0.725\ CO_2 + 2.433\ H_2O + 0.05625\ SO_2 + 6.92479\ N_2$$

So, this is the combustion equation.

Then we can recall,

Dulong formula, $HHV\left(\frac{\text{Btu}}{\text{lbm}}\right) = 14.6C + 62000\left(H - \frac{O}{8}\right) + 4050S$

By looking at this percentage numbers we can get $HHV = 33.6$ MJ/kg

Now, we also require LHV and dew point. So, to do that we need to find out the partial pressure of water. So, to get this partial pressure of water first you have to find out the mole fractions.

$$\text{So, the mole fraction of } H_2O \rightarrow \frac{2.4333}{0.725 + 0.033 + 0.05625 + 6.92} \times 1.01325$$

$$= 0.24 \text{ bar}$$

Where atmospheric pressure=1.01325

So, at this pressure use saturated pressure table. So, this will give you

$T_{sat} = 64.58$℃ ; $h_{fg} = 2347.2$ kJ/kg

With this enthalpy value, we can find out LHV.

$LHV = HHV - h_{fg} = 33600 - 2347.2 = 31.3$ MJ/kg

And since we require dew point temperature corresponding to the saturation temperature we can call the saturation temperature as DPT. So, dew point temperature is 64.58℃. So, with this I conclude. Thank you for your attention.