Lect 19: Basic understandings and applications of fluidization

Hello everybody. Welcome to this massive open online course on solid-fluid operations. In this operations we are discussing regarding this solid-fluid operations where that how particles will be flowing through the packed bed and also what will be the particle characteristics and also what are the basic law whenever fluid will be flowing through the particulate beds and what are the basic mechanism of mixing characteristics of solids, even solid-solid and solid-fluids, what are the basic design of mixing equipment that we have discussed in the previous lecture. So today we will start another module it is called fluidization. Under this fluidization module we will discuss about that what is the basic understanding or basic fundamentals of fluidization and its application and also we will discuss about the different flow patterns of the fluidization and also what will be the minimum condition to get that fluidization operation and also we will discuss something about application of this fluidization and also we will discuss in this module the basic fundamentals of flotation where gas-liquid-solid three-phase will be taking part for separation of that particulate materials or beneficiation of the minerals, they are what will be the basic fundamentals. So in this lecture we will try to understand the basic fundamentals of fluidization and its application.

So here this lecture includes that introduction to fluidization, flow patterns and application of this fluidization. Now what is fluidization, why actually we are going to talk about this fluidization? We will see that when solid particles will be converting from a static solid like state to a dynamic fluid like state by means of flow of fluid either by gas or liquid, so it will be called as fluidization. So this is basically that the suspension of the solid particles by the action of flow of fluid or you can say that by the action of kinetic energy by applying the gas or liquid there to fluidize that particles against the gravity of the particles. So as a definition we can say that the process by which a bed of solid particles is converted from a static solid like state to a dynamic fluid like state by means of a flow of fluid either gas or liquid.

So this is the fluidization, so fluidization whenever we are talking about that terms you can easily understand that the suspension of the particles or give the flow of that particles against its gravity and getting it into a suspension state. So it is called fluidization, we will see that in this video that how that solid particles is converting to its that dynamic state from its static bed condition and also you will see that here due to that flow of fluid you will see that solid particles is being uplifted or suspending against its gravity. So this is called fluidization. Now this fluidization terms basically a multiphase operation where multiphase systems in that case there may be the operation with the gas liquid and solid. So whenever that operation will be based on gas or liquid or liquid or solid or solid or gas or solid and solid or you can say that gas liquid solid.

So all three phases will be taking part in a particular operation. So because of this three phase operation or three phase systems or taking part in that operation it will be called as multiphase operation. So fluidization basically a multiphase operation because in this case

the solid particles will be suspending or solid particles will be driven by either gas or liquid or combination of gas and liquids. So in that case this fluidization may be of two phase and three phase. In case of two phase there you can say that it will be gas and solid or liquid and solids that means gas solid operation that means here the solid will be suspending under the action of flow of gas and liquid solid fluidization it is basically the solid particles again will be suspending under the flow of liquid.

So it will be called two phase fluidization whereas in case of three phase flow you will see that the solid particles will be suspending or driven by gas and liquid both flow. So here it will be called as gas liquid solid fluidization. So you are having there are two categories of fluidization one is called two phase another is called three phase fluidization. Gas or liquid acts as a continuous and solid acts will be as a discrete or dispersed phase. So in that case it will be called as multiphase systems and this fluidization engineering or operation will be regarded as a multiphase system or operation.

So why does this fluidized solid bed behave like a fluid? So whenever the solid particles will be suspending against its gravity by the flow of liquid or gas we will see that this fluidized solid will behave like a fluid. In that case you will see that whenever it will be behaving like a fluid it will show some characteristics of the fluid like it seeks its own level that means it will give you the bed height you will see that the objects with a lower density like solids with a lower density then the bed density will float on its surface like that in a liquid or gas you will see if any objects if push down and if it has some that floating capability then you will see that by its buoyancy effect it will go up based on its buoyancy force. In this case also the solid particles when or any object when it will be pushed down in a bed of that solid bed you will see that the objects will be going up because of its buoyancy effect. So this type of phenomena it will be showing by this fluidized condition. So objects with a lower density then the bed density will float on its surface bubbling up and down if pushed downwards.

Also you will see that we can have that static bed pressure or static liquid pressure or gas pressure there in case of only liquid or gas whenever we are using. So in this case also when gas liquid a solid liquid or solid gas will be fluidizing you will see that the beds of that fluidized condition will show a static pressure head due to the gravity. Also we can have the two similar fluidized bed will be showing their static pressure heads because of this two similar levels in the fluidized bed surface. So we can say that levels between two similar fluidized beds equalize their static pressure heads. Another characteristics will be shown by this fluidized condition it is called that hydrostatic pressure.

This hydrostatic pressure will be raised by if the depth of the bed will be increased. That means at higher bed of this fluidized bed will give you the higher hydrostatic pressure. So that is why you can say that these are the some characteristics factor based on which you can say that fluidized solid bed will behave like a fluid. Now whenever you are getting solid fluidized in that fluidized bed or solid suspended in that fluidized bed during that

suspension of that solid the characteristics of this suspension or you can say that pattern of the suspension or the flow pattern of that suspension or fluidized bed or flow phenomena will be different and it will be different from its minimum flow condition. At the minimum flow condition you will see that the solid particles will try to get its just suspended and beyond the minimum suspension condition if you increase the gas or liquid velocity in the bed you will see that the flow pattern in this fluidized bed will be different.

So there are several flow patterns you will observe in the fluidized bed. In this slide a diagram is shown here you will see that this diagram in this case it will be these are actually fluidized bed and in this fluidized bed you will see from the bottom there will be supply of gas or liquid and from the top the gas and liquid will be coming out and during that flow of gas and liquid the bed of the solid particle will be getting suspended at a certain gas or liquid velocity. So you will see that if you increase the gas velocity if you consider only that gas you will see that that suspension phenomena suspension pattern will be different. So it is called the flow pattern this flow pattern will be different as gas velocity will be increased. So at the zero gas velocity condition you will see that solid particles will not be suspending so in that case it will be fixed so it is called fixed bed condition.

When if you increase very small proportions of that gas velocity will see that solid particles is try to get just suspended. So there you will see that whenever that particles will be getting just suspending condition at its minimum flow condition there will be no formation of gap between the solid particles only that the particles will be getting suspended and there will be void where there will be no pattern of that void there will be no bubbling of that void in that condition here in this picture you will see that the gas will be flowing upward just by getting that particle suspended. In that case there will be no formation of certain shape of gap of void in this bed. So in that case it will be regarded as homogeneous flow pattern or it will be called as incipient flow pattern or sometimes it will be called as minimum fluidized flow pattern or also it is regarded as particulate flow pattern. So there are several names of at this condition.

So whenever just particles will be getting suspended that flow regimes will be regarded as incipient fluidized condition or particulate flow pattern or you can say that homogeneous flow pattern and beyond this gas velocity if you just increase the gas velocity beyond this minimum flow condition you will see there will be a tendency to form a bubble shape or void inside the bed fluidized bed. So there will be a formation of bubbles and whenever this gas will be passed through that distributor there will be a formation of bubbles from the distributor itself. So here this is the distributor through which that gas will be supplied. So from this distributor you will see that the gas will be passed through that bed as a dispersed phase of bubbles. So it will be called as bubbling flow pattern.

Then if you increase again that gas velocity beyond this bubbling flow condition you will see that the formation of bubbles will be in such a way that the some bubbles will be occupying most of the cross sectional area of the bed. So in that case the bubbles or gap or

void whichever will be formed that occupy almost 90 percent of the cross section of this bed and there will be a big size of void or bubbles will be forming and that will be flowing upward and it will have certain pattern or certain shape and that may be flowing centrally through that bed. So this type of flow phenomena it will be called as slugging flow pattern. So in that case the slugging may will happen that axial as well as flat. So in that case axial means here the void fraction will be flowing upward through the center part of the bed whereas flat bed slug will occupy most of the cross sectional area of the bed and it will be flowing upward as a flat slag.

Then if you increase again the gas velocity you will see that there will be high gas velocity there in that case the bubbles whatever it will be formed it will not be having any particular shape it will be showing as a churning condition inside the bed. So at high gas velocity you will see that there will be arbitrary shape of that bubbles that may be some bubbles will be very small some will be longitudinal some will be that occupying whole axial position in the bed. Here in this shown in this figure it is shown that the churning condition of that gas distribution inside the bed. So it will be called churn turbulent flow pattern and beyond that churn turbulent flow condition again if you increase the gas velocity it may be that more than 20 times of that terminal velocity of the particles. So in that case you will see that it will be called as fast fluidization pattern.

So in that case again it will not be that particular shape of that bubbles or gap inside that bed you will see there will be huge gap inside the bed there will be dilution state almost you can say and churn turbulent condition will be there but here in this case there will be no particular shape of the churn turbulent condition. Here in this picture it is shown like this the solid particles will try to go up as a small chunk parallely through the bed. So it will be called as fast fluidization condition. Even if you increase the gas velocity beyond this 20 times of terminal velocity you will see that the solid particles will be flowing through the pipe as a pneumatic condition that means there the particles will be as a dilute condition all the particles will be flowing upward no particles will be flowing downward or it will not come back to the bottom. So all the particles will be flowing upward because its terminal velocity very low compared to the gas velocity.

So in that case all the particles will be flowing like a dilute fluid dilute state of that fluid or solid particles will be flowing upward. So it is called pneumatic flow condition. So in this case we are having different flow patterns some will be batch operated some will be transport operated some batch operated up to bubbling or churn turbulent flow condition you can called as a batch operated fluidized bed or fluidization and then fast fluidization and pneumatic transport flow pattern will be regarded as transport operated fluidization. So these are some different flow patterns that will be observed in the fluidized bed. Then some basic elements of the fluidized bed.

Suppose you are considering any fluidized bed so what are those basic elements of that fluidized bed. There will be that some solid feeder through which that particles will be

entering into the bed to get it suspended here and then internal heating of that internal heating condition will be there in the fluidized bed because to carry out some reactions in the fluidized bed at a certain temperature then you have to maintain that temperature inside the bed. So that is why some internal heating provisions to be there. It may be externally also and then there will be that cyclone separator you will see that some particles whenever it will be fluidized very fine particles will be going upward and then it will be coming out from the bed those particles to be separated from the outlet gas system which will be again used for its operation. So that will be separated by a cyclone separator and then to be recycled and also there will be a pump or blower by which you can supply the gas into the fluidized bed and also there will be some provisions where the solids optics to be there that means solids to be taken out and that total fluidized bed will be there as a shell you can see there.

So here these are some basic elements of that fluidized bed and also you will see that different layout of the fluidized bed you can expect some will be circulating fluidized bed there you will see that the solid particles which will be coming out from the outlet of the fluidized bed that can be utilized again or recycled just by separating by cyclone separator. So this will be called as recycle or recycling or circulating fluidized bed. Some fluidized bed you will see that there will be laterally staged bed there here the solid will be entering here and fluid will be laterally allowing so that the solid particles will be laterally flowing whereas fluid or gas or liquid will be flowing upward. So in that case it will be called as laterally staged bed. Some will be vertically staged bed some stage wise that solid particles will be falling downward and fluid will be flowing upward there itself you will see that the solid will be suspending in a stage wise.

And then some riser that means here is a column there will be solid particles which will be suspending by the action of the fluid and then downward also whenever the solid particles will be flowing downward after separating from that cyclone separator it will be recycled into a regenerator section where that solid particles like catalyst to be regenerated so there it will be passed. Some beds will be that floating bed where solid particles will be suspending in a gas liquid system there it will be floating. Some condition will be bubbling bed where bubbles will be forming whenever gas will be fluidized in a solid bed and some will be twin bed condition you will see that some particles which are coming out after reactions on the one bed and that will be going to the another bed for the regeneration. So it will be called a twin bed and then some will be spouted bed there you will see that some particles in the bed will be flowing downward whenever it will be suspending it will be flowing downward along with the wall of that bed whereas at the central line the gas will be flowing upward so it will be called as spouted bed. So these are different layout of the fluidized bed.

Then whenever that solid particles will be coming in contact with that gas or liquid in the fluidized bed there may be that different modes that may be some will be base mode some will be co-current some will be cross current some will be counter current and some will be

inverse. So as per that layout it will be there. Some inverse fluidization also will be there in that case you will see that whenever solid particles will be very lighter compared to the liquid or gas in that case the solid particles will try to go up based on its buoyancy force. So in that case those particles to be fluidized you have to give the flow of liquid against its buoyancy. So that is why the flow of fluid will be downward and based on that downward flow of fluid or momentum the solid particles will be going downward.

So this type of flow it will be called as inverse flow. Now question is that why you are going to use this fluidization operation there will be certain advantage over this compared to the packed bed because you have analyzed some example of reactions as well as physical operations which is being carried out in a packed bed condition or fixed bed condition. Now those reactions can also be done in the fluidized bed operation. In this case that solid particles will be suspending instead of getting fixed in a bed. So during that suspension of that solid particles there will be some advantages.

So that is why this fluidized bed operations will be advantageous compared to the packed bed condition. So what are those advantages? In this case this fluidization operation you can easily handle it. There will be a good mixing of the solid particles. There will be high heat transfer.

There will be high mass transfer. There will be more contact efficiency between solid and gas or liquid. There may be that feasible for exothermic reactions also. Here also you can make it large scale operation and you can do continuous operation also here in this fluidized bed. But though here some advantages there will be some disadvantage also. In this case you will see the sometimes some particles whichever used as a very fine particles that make make that agglomeration or clogging to each other because of that Van der Waals force that is cohesiveness nature.

So in that case it will be very difficult to flow those type of particles. So there will be capital investment will be more here in this case. Here one disadvantage is that there will be a chances of back mixing. Sometimes some reactions whenever it will be carried out if there is a back mixing that yield of the reaction will be less. So in this case it may happen that back mixing of this fluidized bed.

And also difficulty in plug flow of course since this is a back mixing happens some solid density will be higher or bigger in size they may come downward whereas fine particles will be moving upward. So if there is a wider size distribution of the particles there will be segregation of this particles inside the bed. And because of which the nature of the plug flow to get it inside the bed is very difficult because some reactions will be giving the prefer yield at this plug flow condition. But those reactions will not be possible to carry it out in this fluidized bed. Also here size problems the fluidized bed to be made in such a way that the column will be very high and also enough space is required.

There will be some entrainment problem in the fluidized bed whenever this mixture of the solid particles there may be a certain size distribution and because of which all the particles may not be suspending some particles will remain in the bottom part. So they are to get all the particle suspension you will see that very high flow rate is required very turbulent condition is required. But whenever you are applying the turbulent condition in this case the very fine particles will be coming out from the bed. So in that case again you have to have some provisions to separate those fine particles. So in that case it will be more investment capital investment even also not feasible.

So in this case some problem will be there. And also erosion problem whenever the solid particles will be flowing inside the bed you will see that there will be interaction of the solid particles with the wall of the bed as well as particle particles. So there will be a sense of that attrition of these particles that means breaking of particles as well as that interaction of the solid particles of wall there will be some breaking or you can say that some erosion problem inside the bed. Also one important point that here disadvantage that some hydrodynamic issue there is a complex hydrodynamic phenomena. You will see that to you have to maintain that certain flow phenomena you have to consider the optimum condition of that geometry as well as other properties of this bed. And also you will see that there are random motion of that solid particles to track all those particles inside the bed.

Also that distribution of the solid particles gas even the void fractions inside the bed that will sometimes affect on the reaction yield or reaction or you can say that operation of performance. So all those complex phenomena of this fluid flow or hydrodynamics it is called that may sometimes assess will be very difficult and also accurate assessment of that efficiency of the process is very difficult. Also you will see that sometimes certain pressure loss inside the bed will be there at high flow rate because of that distribution of the kinetic energy based on its size of the particle. We are talking about that fluidized bed or fluidization phenomena what is that fluidization now where that operation of fluidized phenomena can be applied what are the application of this fluidized bed. You will see the most of the application in industry whatever products we are getting in our daily life you will see all those being done in a fluidized operation.

Especially in the energy sector even other chemical industry where that different chemicals organic or inorganic chemicals are being produced. Then sometimes separation processes where some unwanted materials to be separated those operations is being done in a fluidized bed. In this case you will see that sometimes synthesis of advanced material production of that advanced material the fluidization operation is required like silicon production for semiconductor and solar industry this fluidized bed is being used. You will see that sometimes you need to coat that catalyst particles that is being done in fluidized bed. You have to coat that nanoparticles that is also being done in a fluidized operation.

Also in chemical and petrochemical industries you will see that to crack that heavy hydrocarbons to produce that lighter hydrocarbons for our daily use it is being done in a

fluidized bed. So whatever polymeric substance, polymeric products we are getting here all those polymeric substances are being synthesized in a fluidized bed. So any gas phase polymeric reactions is being carried out in a fluidized bed to get this polyethylene or polymeric substances. And then for combustion and pyrolysis this is one of the important operations in fluidized bed you will see that whatever power we are getting now whatever using this valve or whatever power night or day or any operation we are using those power is coming or you can say that electricity whatever we are using that is coming or that is produced in a thermal power plant. In that case you will see that what is being done there the coal particles are being you burned and producing steam just by combustion of coal and those steam being used in a turbine to produce this electricity.

This is the simple way that I will say. So that coal combustion is being done in a fluidized bed. You will see that whatever ash is coming out just after combustion of the coal those actually ash is coming out from that fluidized bed. So there coal is burning in the fluidized bed to create the steam or to generate steam which is being used in a turbine to produce this electricity. Not only producing that electricity also the coal is being burned in a fluidized bed to produce different valuable gaseous product. So you will see that there will be methane production there will be some other hydrogen, carbon monoxide, nitrogen even other different types of gaseous products can be produced from this coal burning.

Those gaseous products after separation you can get in different ways for different uses. So here we can say that after combustion of coal we can get the steam as well as valuable gaseous product. So combustion or gasification of coal is being done in a fluidized bed. Also you will see that to separate that unwanted material from the ore, that ore is being pyrolyzed in a fluidized bed or sometimes you will see that to separate valuable components of the gaseous component or chemicals in a gaseous form from the natural resources or biomaterials there you will see that pyrolysis is being done.

So that is being done in a fluidized bed. Like that you will see that sometimes you will see that from the biomass like grass or some other biomaterial, bio substances or wood you can say from which you will see that there will be production of ethanol. So ethanol production from this biomass it is being done just by after pyrolysis. So here this pyrolysis is being done in fluidized bed. So this is the fluidization operation. Also some other physical operation like coating of that metal also drying of the solids is being done in fluidized bed.

pady is being dried in a fluidized bed. Roasting of food, different food products after roasting that you are getting that is being done in a fluidized bed. Also you can get that different types of materials or segregate the particles in the fluidized bed based on its size as well as density. Coating of pills, granulation, production of plant and animal cells those are also being done in a fluidized bed. So these are several applications in a fluidized bed. Some commercial applications here solid catalyzed gas phase reactions like fluid catalytic cracking, acrylonitrile and aniline production is being done in a fluidized bed.

Chlorination and bromination of hydrocarbons is being done fluidized bed. Fischer-Tropsch synthesis is being done in a fluidized bed. Polyethylene and polypropylene production is being done in a fluidized bed. Oxidation of NOx and SOx that is being done in a fluidized bed. Thalic and malic anhydride production is being done in a fluidized bed.

Gas solid reactions also you can see that roasting of ores like zinc sulphide, copper nickel sulphides etcetera are being roasted to separate the valuable minerals from the ores. Combustion and incineration that is being done like coal combustion. Also gasification, coking, pyrolysis and carbonization is being done in fluidized bed. These are gas solid reactions, other gas solid reactions like calcination, limestone, phosphates, aluminum hydroxide like this. Reduction of iron oxide is the one of the important that whatever steel you are getting that is being done from the iron ore.

That iron ore is being reduced in a or reduction is being done in a fluidized bed. Also fluid coking catalyst regeneration you will see that fluidized bed catalytic cracking is being done there in a fluidized bed to get that lighter hydrocarbon like gasoline, kerosene, even LPG all those gaseous products you can get it just by cracking in a fluidized bed from the naphtha or other heavy hydrocarbons. Even you will see that fluorination of uranium oxide that is also produced in a plant of that fluidized bed. Here coal combustion that I talked about that how that power or electricity is produced there.

This is the fluidized bed. Here you will see that heat generation is there and due to that heat generation you will see that coal particles will be burnt and then you will see that during which that heat will be generated and those heat will be transferring to the water which will be converting into steam and that steam will be utilized in a steam turbine to generate that electricity. Also other gaseous products which will be coming out after combustion of coal which will be coming out from the top and after separation of that fine particles from that gaseous products it will be again used as a gas turbine here to produce that electricity that is gas generated electricity also steam generated electricity. So gas turbine and steam turbine to run that you need gas and steam which will be produced by the coal combustion in a fluidized bed. Fluorination of uranium oxide this is the plant prototype based on which here this is the fluidized bed in which that fluorination of uranium oxide is burnt. Natural gas combustion also you will see that to combustion of that natural gas which will be giving you that synthesis gas that is carbon monoxide and hydrogen gas can be produced in that just by burning that methane gas.

And then reduction process of iron ore here so you will see that iron ore can be reduced in a fluidized bed these are the fluidized bed it is the continuous operation and based on that carbon monoxide hydrogen. So by reduction of that iron ore by this carbon monoxide and hydrogen you can get that iron there. So from this iron in a blast furnace you can get that steel. Let us have a video just to have a concept of that fluidization operation. Let us see that reduction process of iron ore here you see the plant just see this, this plant this is the Finex company they are using that fluidized bed to produce that iron here this is the

fluidized bed.

Here is the fluidized bed and this is a schematic of this fluidized bed you see a total plant so fine ore particles will be coming from this part in a fluidized bed and after that reduction those will be coming at this third fluidized bed here and the carbon monoxide and hydrogen will be passing through that bottom through the distributor and the particles will be fluidizing and then you will see that some gaseous products will be producing and whose will be recirculating. And then with the help of coke that iron will be burnt to get that that steel there like this here coal particles will be falling downward this coke has a coke can to be falling downward along with that reduced iron oxide and then here that is at in temperature is that iron will be melting and all the carbonaceous product whatever unwanted products will be separated here also the blast furnace and then you will get a certain grade of this iron product there and from which the steel is making as per grade. So this is the benefits of this fluidization operation the direct use of low-cost fine iron ores direct charging of low-cost non-cooking coal generation of clean export gas for a wide range of downstream applications production of hot metal in a quality identical to blast furnace hot metal proven experiment or environmentally friendly hot metal production here. So, you can produce iron eco-friendly based on this fluidization operation. Then another commercial application it is called gas liquid solid reactions there in this case fluid bed catalytic cracking here hydro treating process biochemical process cultivation of microorganisms.

In this case one example here the hydrocarbon production based on that Fischer-Tropsch synthesis in this case carbon monoxide and hydrogen mixture that is called synthesis gas will be used to crack that natural gas to produce that synthesis gas with that help of synthesis gas this heavy hydrocarbons will be cracked into a lighter hydrocarbons in this bed this is three-phase fluidized bed that is called slurry bubble column reactor at a certain temperature and then after getting that product it will be separated into a different graded product. Other fluid bed catalytic cracking this is the complete a process of that fluid bed catalytic cracking here you will see that in the riser this is fluidized bed in this case that heavy hydrocarbons will be cracked in presence of catalyst particles and it will give you that lighter product and it will be separated in a distillation column and then you can get that different type of fuel oil. Whereas the solid particles remains it will be sent back to the regenerator to reuse that solid particles as a catalyst. Now list of Indian company where this fluid catalytic cracking units are used that is that Indian oil Corporation Limited, Guwahati, IOCL Barauni and you will see that Hindustan Petroleum Corporation Limited that is Mumbai, Bharat Petroleum Corporation Limited, Mumbai, Ranchi Refineries Limited, Kochi Refinery, even Bongai Gaon Refinery and Petrochemicals Limited, Bongai Gaon in Assam, New Aligarh Refinery Limited, New Aligarh that is Assam. Those plant in those front they are using this fluidized bed cracking operation.

Physical operations like drying of solids, coating of catalyst tablet, granulation, heat treatment like annealing, quenching, blending or classification of the solid particles,

adsorption, roasting all those operations are being done in a fluidized bed. Here you can see this video of that coffee bean roasting. You will see that the green coffee bean will be roasted in a fluidized bed at a certain temperature and pressure just by fluidizing that green coffee bean. At a temperature you will see that this green coffee bean will be converting into a brown coffee bean after just fluidized at a certain temperature that is hot air will be supplied at that temperature and it will be roasted or fluidized and then green coffee bean will be converting into a brown coffee bean after roasting and then it will be ground to mix with the milk to get your final cup of coffee. So here in this case roasting of coffee bean is being done in a fluidized bed.

Here see this is one fluidized bed in the video. Here see this coffee bean, this is green coffee bean, raw coffee bean is being fluidized. The gas is supplied from the bottom of this fluidized bed at a certain flow rate that means above the minimum fluidization velocity and start of roast at 3 minute at 350 Fahrenheit degree Celsius and after that again that after 6 minutes that temperature will raise to 370 degree Fahrenheit and then you will see that green coffee bean will be converting into a brown coffee bean after roasting. So this is being done basically that in the fluidized, see you see that final stage 4 minutes at 425 degree Fahrenheit and 3 minutes at 455 degree Fahrenheit coffee is being getting ready. So after final product of this coffee bean will be coming like this. This is the conversion of this brown coffee bean from its green coffee bean and then it will be ground in a mixer grinder then it will be making into a that powder form which is being used for your cup of tea.

So this is basically the fluidized bed operation. And then another operation is called granulation and coating process. Here also you can get some smell of that fluidization operation how that fluidized bed can be used for this granulation and coating process. So in this case I want to thank to this GLAAD SP process this is the code say of this GLAAD process here I acknowledge them I have used their video here from the YouTube. So in this case this is fluidization. So here see that fluidized bed and from the bottom gas is coming out and the solid particles is being fluidized.

Now granulation to be done that means this fine solid particles will becoming a bigger solid particles. Now for that you need some binder. So the binder will be sprayed from the bottom here from the spray nozzle that is spraying it done and then spraying basically the binder the solvent that we have discussed in the granulation operation in the earlier lectures. Here after binding of those that solid particles will be making a granular forms that means agglomeration it is called the granule. So after that it will be drying and then also this fluidized bed can be used for that coating of that solid particles.

So for coating you need some polymeric substance over that solid particles that coating of that polymeric substance will happen and for this you need that fluidization operation to get that uniform coating over the solid surface and that is why you are doing this fluidization. You will see that some red color that polymeric substance is coated on this particle over the solid surface and then particle is being coated here. So this is called

granulation and coating operation in a fluidized bed operation. Now question is that that we have some idea about that fluidization operation we have seen video as well as that we have discussed what is the basic concept of that fluidization operation, what is the advantage, what is the disadvantage, where that fluidization operation can be utilized or applied all those things. But what you have to know except this application and this phenomena where you can apply this.

So for that you have to know some fundamental or basic more about this fluidization operation. In that case you have to know what is the hydrodynamics behind this fluidized bed, what will be the flow regime, flow pattern, what is the distribution of that phases, what is the mechanism of that distribution, what is the entrainment characteristics of the solid particles inside that fluidized bed, how that solid particle size distribution can affect on that mixing of that solid particles inside the bed. Also what is the attrition characteristics of that bed, what will be the minimum fluidization condition that you have to keep based on which you can get that particulate fluidized fabric for a particular operation, is there any other force that can be applied to get this particle suspended or not, what will be the heat transfer characteristics, what will be the mass transfer characteristics for that particular separation operation or other reaction systems, how can you simulate or can model to assess this fluidization operation, how can you scale up this process, all those things you have to know. But in your course all those things cannot be possible to discuss, so in this case only as per your course structure we will be discussing what will be the minimum fluidization condition as an under-fluid. For more details you can get more about this fluidization operation or fluidization engineering, so you can follow this NPTEL course, this MOOCs course again here in the fluidization operation that is fluidization engineering course that you can follow.

So in the next class, we will try to discuss or try to learn about that minimum fluidization condition, what will be the criteria to get that minimum fluidization, what will be the velocity, how can I find out that minimum fluidization velocity based on which you can get that particle will get just suspended or you can maintain the incipient fluidization condition. So what will be the minimum velocity required to get the fluidization operation, so that will be discussed in the next classes. So I think you understood the concept of fluidization, so thank you for your attention, have a nice day.