Hi ! everybody. Welcome to this massive open online course on solid fluid operations. This lecture is about a brief introduction to solid-fluid operations. This solid fluid operation is sometimes called mechanical operation also. As we know, in our daily life, we use several products like cosmetics, different chemicals, oils, even food items, pharmaceuticals, drugs, etc. So all those products basically come from industry after producing with a certain process.

Now those processes include generally different multi-phase systems in terms of chemicals, particles and other different equipment by which we are getting several products in our daily life. Now, whenever the industry they are making these products, they use solid, liquid and gas and also combination of those systems by which after a certain process we are getting this product. Now question is that then why you are going to study these solid fluid operations? Yes, it is required to study the solid fluid operations because all those products those are producing by a certain process and those process involves this solid fluid. Now this solid fluid operation of course, will be based on interaction between solid and fluid.

Now before going to the solid fluid operations, you will see that as a pretreatment of that solid fluid operations, the solids to be processed or pretreated up to certain degree so that the yield of the process involving solid fluid there will be giving a certain degree of yield. So before going to that we have to know these different types of processes of solid and fluid where this solid-solid, solid-liquid interactions are there. So let us see in this lecture what we can learn about this solid fluid operations. First of all we will introduce different solid fluid operations and their respective applications. So you will see that the processes which are based on the interaction of fluid like gas and liquid with the solid particles are called solid-fluid processes and there of course the interaction not only with the solid and fluid there will be interaction between solid and solid also.

So the process whenever it will be performing with those solid and fluid, the processing will be based on what will be the size of the solid, how to transport that solid for that particular process unit and to utilize those sizing solids after transportation what degree of that size to be considered. So that is why sizing of the solid it is very important. So the process of course will be applied with the sizing of the solid. Then chemical synthesis in the presence of catalyst particles you will see that whenever any process to produce any chemical products that you are going to synthesis that chemicals based on certain chemical reactions and for that the enhancement of the reactions or activation of the reactions or you can say that producing that chemical products the catalyst particles will be very very important for that reaction. Then you will see that we need to have some important minerals from the ores that is you know available in nature.

So in that case you have to beneficiate that ores or any other particles or materials from which you are getting the important or valuable minerals. So you have to process that resource materials or ores you can say to get that important minerals. And also you will see that sometimes you need to separate or recover that valuable minerals from the ores as

well as the slurry which is coming naturally. So in that case it is also important to process. So this process basically are involving that interaction of the solid and fluid.

Also you will see that drying of solid there of course you will see that whenever you are going to dry the solid material there will be interaction between gas and solid because hot gas or that some warm gas or warm air to be supplied to the wet material to evaporate the moisture in the solid. So that is why it is called a solid fluid operation. Also you will see that sometimes you need to coat the particles okay with a polymeric substance. So coating of the solid is also a solid fluid operation. Sometimes you need to enhance the reactions or enhance the physical processes like drying or other physical operations there it is important to enhance the mixing of the process, mixing of the solid and liquid.

So their mixing is also called a solid fluid operation. You will see that we have different contaminants in the waste water or in water which are actually being processed for further operation for using our daily life. So in that case some contaminants that is poisonous or unwanted materials which is to be separated. So that separation of that materials from the slurries or waste water or other effluents that is done by membrane. So membrane is a solid material which is porous and through which that contaminants can be separated just passing through it.

So these are actually process which applied in different operations like sizing, like synthesis, like beneficiation, like drying, like coating, like mixing, like separation all those things. So you will see that here how the solid particles are fluidized in a fluidized bed system. So this is actually a catalyst particles, there you will see that catalyst particles enhance the reaction for producing that different types of hydrocarbons. So you will see that here solid particles are being fluidized by air or gaseous medium. So in that case to get the better mixing as well as heat and mass transfer of the gas liquid operations we are processing like this between the solid and liquid and there will be interaction, enhancing the interaction between solid and liquid that is contact between solid and liquid or gas to get this we are actually designing different types of units like one type it is called the fluidized bed reactor or chemical reactor or stirred tank reactor like this.

So there the solid particles are come in contact with the liquid or gas to produce the different hydrocarbons. You will see that whatever solid-fluid operations that are involved in industry to produce the different products that can be classified broadly into a certain categories like some will be mechanical, some will be electrochemical, some will be chemical processes. So chemical processes may be that the transportation of materials, size reduction and its enlargement sometimes it is required to reduce the size of the particles to get the better interfacial area or more surface area of the catalyst particles or solid particles for that particular processes either in chemical or physical. Then sometimes it is also required to enlarge the solid particles like manufacturing of tablets there you will see that you have to enlarge the solid particles just producing from the different contaminants or different materials and also getting that materials as a tablet just by

enlarging. Also you will see that in urea production you will see that granulation process is important where the molten urea to be granulated in the presence of cold air medium.

So there it is called that size enlargement, you will see that also other operations like mixing, filtration, decantation, sedimentation, flotation and fluidization all are those in the category of mechanical operations. And then electrochemicals like electrostatic separation sometimes very fine particles to separated which is coming out from the equipment when it is processed for producing different products. So they are those particles to be separated before releasing to the atmosphere. So there are sometimes some mechanisms to be followed that is called electrostatic separation and sometimes to separate that magnetic particles from the other mixture of that particles so magnetic separation can be performed there. Sometimes you will see that electrodialysis to be performed to separate that ions from the plasma liquid like this.

Even electroosmosis, electrophoresis, ion exchange, gas permeation, pervaporation all are the operations are under electrochemical processes. Then chemical processes we are having some crystallization, drying, leaching and extraction, adsorption, chromatography, Fischer-Tropsch synthesis even that production of different hydrocarbons so these are under the chemical process. So we can classify those solid-fluid operations into a broad way like mechanical, electrochemical and chemical processes. You see in the pictures here that mechanical processes you will see slurry transport, sometimes you need to transport the slurry from one location to another location. So this is basically a mixture of solid and liquid so it is called slurry.

So transportation of the slurry is also called the operation of solid-fluid. Similarly you will see that solid transport as a bulk of solid you have to transfer from one location to another location for further processing. Then crushing and grinding you need to have that particular size or at a certain size you have to convert the coarser particle to the finer particle by a certain mechanism. So sometimes you will see crushing and grinding will be the main mechanism by which you can get the finer particles. Then mixing, there will be certain mixture by which you can get the mixing of the solid and solid even solid and liquid and then filtration you need to separate that unwanted material from the mixtures so by which you can separate that valuable components.

So for that you need to have that filtration process. So filtration process is also one of the important mechanical process that is under solid-fluid operation. Similarly, fluidization by which you can do the drying operation, you can do the production of various hydrocarbons in presence of catalyst particles. Even some other operations also can be done like coating of the materials, granulation process, even you will see that other segregation of the material by this fluidization process. So fluidization also important mechanical process.

Then decantation, you have to separate the solid particles by gravity, so this is decantation process. Then minerals recovery by froth flotation from the ores, that is also important

operations to get that different valuable minerals from the sources of ores by froth flotation. So basically that get in froth, producing froth and producing the bubbles in presence of surfactants you will see that the air will be distributed through the surfactant solution to produce that bubble and its surfaces and on the surface you will see that there will be attachment of that hydrophobic materials on the surface of the bubbles. Then that hydrophobic materials will be separated from the mixture of hydrophobic and hydrophilic materials and this froth flotation basically the process by which that hydrophobic materials can be separated from the mixture. These hydrophobic materials, this is the valuable minerals that can be separated from the ores.

And then electrochemical processes, you will see that different electrochemical processes like electrostatic separation, magnetic separation, you will see that electro dialysis, electro osmosis and ion exchange. So these are the different electrochemical processes. And then you will see that chemical processes like crystallization, drying, copper extraction, adsorption, even a trickle bed reactor, even a slurry bubble column reactor, these are different processes by which you can get that different hydrocarbons even you will see that separation of the unwanted gas from the gaseous mixture and also you will see that drying operations of the solid material, moist or wetted solid material to be dried in a particular drying equipment, crystallization, copper extraction and also in the production of hydrocarbons or hydro treating in the trickle bed reactor. Even slurry bubble column reactors where the gas-liquid-solid reactions will be there in this reactor by which you can get that different hydrocarbons or cracking of hydrocarbons in the slurry bubble column reactor to produce different hydrocarbons. Then another important operation is called particle separation.

Like different processes are there to separate that particulate materials from the mixtures either from the gaseous mixture or from the slurry or you can say that other effluent systems by there will be separate mechanism to separate that particulate materials like gravity chamber based on the gravity that particles can be separated and cyclones also you will see that the centrifugal force by which you can separate that materials based on its gravity action as well as that size of the particles. And also you will see that there will be back filter which is being used for the separation of the particulate materials by membrane inside this some cloth type of membrane will be used inside this that is called back filter and also electrostatic precipitation where some ionic particles to be produced whenever it will be passed through a some electrode and then whenever it will be ionic then opposite charge particles also or plate will be surrounding it which is to be separated by just attracting this opponent charges. So it is called electrostatic precipitator. So all those processes will be discussed in details in the successive lectures here also. This is just a brief introduction about this the different solid-fluid operations.

Even spray towers as a scrubber you can use and then back filters are used for the separation of the particulate material. Now the process, what are the process that involves the transportation of the materials? Sometimes you will see that conveying, conveying is the

process by which you can transport the material from one position to the another position. In that case, engineer sometimes prefers to transport in the form of liquid solutions or that suspension systems. So in that case the size of the equipment that depends on the necessary capacity, natural shape and size of the material, the distance through which that materials to be transported that also effect on the size of the equipment by which you can transport the material. So you will see that different systems like different equipments like pipelines, pumps, fans, blowers, compressors are used in industry to transport the fluids, finely divided solids in the form of slurry or solution from one point to another point.

And solids that are not finely crushed are transported by railways, trucks, ropeways, ships or conveyors like this. So there are different types of conveyors are available commercially or can be designed to transport that solids from one position to another position. Now what are the processes that involves the size reduction? You need to sometimes reduce the size of the materials to get the better yield for the particular process. Also for the synthesis of the process you will see that the materials as a catalyst to be used, so you have to use that catalyst at a particular size range. So there you need to reduce the particles into a certain size.

So in that case the process of particle size reduction to be performed and that process is called comminution and the primary comminution process are called crushing and grinding. So crushing and grinding, this reduction mainly occurs by compression, impact and attrition mechanism. And crushing you will see that it is the process of breaking material into the desired size to a specified size range you can say where you will see that you may expect that there will be certain range of that particle size with a certain distribution. So sometimes to produce that particle size in such a manner that it will get the, it will give the uniform in size where that narrow particle size distribution will be there. So in that case crushing is one of the important process by which you can get.

And then grinding also it is a process of surface generation it is called by producing micro and nano size particles. You will see there several type of crushing equipment are being used in industry to produce that particular size of that material. In that case it depends on the which mechanism that you would use to reduce that size. Based on compression mechanism you will see that in industry the jaw crusher and cone crushers are being used to produce that particular size. And based on impact mechanism you will see that bar blow crushers, vertical shaft impactors those are being used for that reducing the size.

The most common types of grinders sometimes used to reduce the particle size into a micro or nano size those are you will see that gear grinders, different types of mills such as ball mills, rod mills, pebble mills even you will see that bar stone tower, gap, blade mills these are the different types of mills those are being used in industry to have that particle in a size in micro or nano size region. Then process involving mechanical separation you will see that sometimes you have to separate this particle or segregate the particle into a different sizes. So for that you have to use some mechanism it is called screening, it is

basically the process of segregating that solid particle into multiple grades according to their opening sizes. And the crush you will see that after crushing you will see that some materials will be coming in a mixture so that mixture will have some will be coarser particles some will be you know that finer particles. So coarser materials or coarser particles those are above 250 micrometers is suitable for screening as its efficiency decreases with the decreasing size of the particle.

And also another important process it is called classification by which you can segregate the materials, it is the process for separating mixtures of particles into two or more fractions based on the velocity with which the particles fall through a fluid medium. You will see that finer size below about 250 micron is normally processed by this classification process. Now you will see that important notes to be remember that the different types of screens are generally used in industry as well as laboratory those are called stationary screens, vibratory screen and rotating screen. So all those things will be discussed later on the successive lectures in details with problem and solution. Now filtration process this is also one of the important solid fluid operation based on which you can separate the solid particles from the solid fluid mixture by a filter medium.

For that you need to have some driving force to pass that liquid from one you know part of the separating medium to the another part of the separating medium. There you will see that separating medium it is called filters. So there are different types of filters generally being used those are called cross-pro filters, cake filter, you will see that sometimes series and capsule filters you will see and also membrane. Now all those filters have some advantage and disadvantage based on the particle size which are to be separated and you will see the cross-flow filters is basically the filter designed to concentrate suspensions of fine particles or colloidal type materials. It is generally used for particles in the range of 0.

1 to 5 micrometer and it is generally separated by the porous tube filter and micro straining filters etc. Cake filter generally a cake is act as a filter which is formed by the accumulation of the solids on the septum like filter fresh, shell and leaf filters, rotary vacuum filters etc. Membrane is one of the important separating medium it is called filter medium. So these are the different types of membranes made of different types of material such as silver, cellulose, nylon, ceramic etc. So these are the different types of membrane by which you can separate that you know particulate materials based on the porosity or you can say that pore size of the membrane.

Then you need to separate the particulate material from the atmosphere or from the effluent or gaseous effluent in an industry where you will see several types of very fine micro or nano type particles will be there in the gaseous mixture. You need to separate those poisonous gaseous materials from that you know effluent. So in that case you need to have certain mechanical devices by which you can segregate or separate that particulate matter. Now you will see that sometimes that particulate matter is denoted by a conventional symbol as PMD.

For example, PM2.5 is referred as particulate matter where the diameter of the particles is 2.5 micrometer or less. Particulate matter is a solid particle or liquid droplet that will have certain size like 10 micrometer in range in diameter or less you can say in the suspended particle in the atmosphere which is called as aerosol. And this particulate matter can be separated by various methods like wet scrubbing, cyclones, candle filters or a combination of these, sedimentation, filtration and also you can say biological treatment. Then another important operation it is called settling and sedimentation or thickening you will see that to separate those materials from the slurry.

The settling and sedimentation are the process by which particulates are separated from the fluid either by gravity or by centrifugal force. Gravity settlers, centrifuges are generally used to separate those particulate materials in this operation. Thickening is a gravitational settling of solid particles that are suspended in a liquid whereas classifications imply fractionation of the solid particles based on their rates of flow or settling through fluids. Then flotation process, this is one of the important primary operations in mineral industries based on which the important materials are separating from the ores. There you will see that suspended particles from that that is ore is initially grinding into finer particles and then it will be suspended in a liquid that is suspended particles in the liquid based on the hydrophobic or hydrophilic nature of the particles it is generally separated just by attaching or allow to attach into a bubble surface which is produced from the bottom of a certain devices by gas distributor.

So this flotation is generally a process for separating the suspended particles based on hydrophobic or hydrophilic nature of particles by the introduction of gas bubbles. And you will see that addition of the gas bubbles to the solid particles makes them buoyant and results in separation. So we will discuss about this flotation process later on also in the separate lectures for this flotation processes. And then various flotation processes you will see that will be in this flotation processes like froth flotation, dissolved flotation, induced gas flotation like this. So flotation is done in a flotation machines which are called mechanically agitated tanks, flotation columns, Jameson shells etc.

There are different types of flotation columns available. Then we are going to that another important process for the solid fluid it is called agitation and mixing. Sometimes you need to mix the materials with liquids for producing a certain chemicals or synthesis the chemicals or performing some physical operations. So there it is important. For that the some equipment to be used which are used for mixing depends on the nature of the materials.

So, we will see that this is basically the central feature of many chemical processes like you will see that for catalytic reaction in a reactors, paints and coatings, you will see the production of synthetic rubbers and resin, sealants and adhesives, food processing, making zoos, making candy, biofuels, ethanol and widely used in making pharmaceuticals. So for

those operations you need to have agitation and mixing process. Then some operations with the solid and fluid it will be called as thermochemical processes like drying process is one of the important thermochemical process. It is a process of removing liquid from a solid at a temperature below the boiling point by circulating air or some other carrier gas over the solid. The basic difference from the evaporator is that the evaporator is used to remove water from solution instead of solid.

In this case the heat is supplied to vaporize the liquid and the liquid diffuses through various resistances. And there are different types of dryers are used for this drying processes, some will be adiabatic, some will be non-adiabatic. Adiabatic dryers like spray, flush, rotary, tunnel, tray dryers whereas non-adiabatic dryers vacuum type, purge type, tube type, drum type, even a continuous rotary type, continuous pan type, even radiant type dryers are available. So those are being used for drying processes. Then crystallization process, this is also that solid fluid operation.

In this case the formation of crystals is done by precipitating from a super saturated solution that may contain dissolved solids, melts, vapor at a fixed temperature and the process is driven by a mass transfer of a solute from the liquid solution to a crystalline phase. In this case the first step of this process it is called nucleation and the super saturation can be obtained by cooling, solvent and evaporation. Fractional crystallization is one of the most widely used methods for separating and purifying chemicals. Crystallization equipment is classified according to the method of generating super saturation. So this is the crystallization process which is also involving the interaction between solid and liquid.

Leasing, in this case you will see that the process of separation of solute from a solid by an insoluble solvent, it is called leasing. Solutes are separated based on adsorption or absorption capacity of the solute to the solvent. The material like ore that is naturally available is graded chemically with a solvent by dissolving the active or valuable component into the solvent. Like you will see that some examples you can say that grading of oxide using sodium hydroxide solution at 150 degrees Celsius.

Dissolving aluminium oxide in sodium hydroxide solution. Calculation of silver iron from the ores, example argentine, argentinite, that silver sulphide, silver chloride like this. And also this can be extracted by this sodium cyanide grading of gold containing ore in potassium cyanide are also important examples for this leasing. Then calculation process is also one important solid-fluid operations where you will see that conversion of concentrated ore into oxide happens by heating in absence of air which is called calculation process. This process also helps in separating carbon dioxide, sulphur dioxide, organic impurities and moisture etc.

from the source of a fixed temperature. In roasting process, this is also one of the important process where the solid and gaseous materials will be interacting to each other. And in this

case that converting ore usually sulphide at below its melting temperature into an oxide in presence of excess hot air. It is also known as metallurgical process of gas solid reactions at a temperature for purifying the material in a blast furnace. Roasting is also referred to as frying at a fixed temperature.

It is generally done in fluidized bed. As an example, we can say that roasting of green coffee bean which is being converted into a browned coffee bean, you will see after roasting at a certain temperature, it is generally around 350 degree Fahrenheit to 500 degree Fahrenheit, the green coffee bean is being roasted in presence of hot air at this temperature and it becomes the brownish dried coffee bean. After that it is being grind and then with milk then you are getting the ready coffee. Then reaction process of course, it is a process that leads to the formation of new molecules by the rearrangement or redistribution of the constituent atoms in a particular reactors. The reaction process that depends on temperature and pressure and the components or composition of the reactant mixtures in presence of catalyst and residence time. Reactors are generally four types, chemical reactor, nuclear reactor, fusion reactor and bioreactor.

Then reaction processes like electrostatic separation, magnetic separation by which you can separate the materials from the mixture of its different characteristics materials, those may be non-magnetic, some may be magnetic. So from this magnetic, non-magnetic materials can be separated by this electromagnetic separation or magnetic separation. Then electrodialysis, this is the process by which charged particles migrate by diffusion and convective flow towards a less charged area by electroosmotic effect. And this is done in an electrodialysis cell where the salt ions move over the membranes under applied the electric potential. Also you will see that electroosmosis where the transport process of salt ions through selective semi permeable membrane like cationic, anionic, okay? It is also called ionic exchange membrane under the influence of an electric potential.

So by which you can separate that ions by this ionic exchange membrane. In this case, the motions of electrolytes and solvent are driven by an applied potential across a porous material, capillary cube, membrane or in a microfluidic devices. Then electrophoresis, it is a process of separation to separate biological molecules such as DNA, RNA or protein based on the size and electrical surges. Protein transport towards a positive surge is an example of this process. Then you will see that ionic exchange here separation of the unwanted dissolved ions like nitrate, fluoride, sulphate and arsenic etc.

in water are exchanged with a similar charge by an ionic exchange material like resin or zeolite. So based on which you can separate that different types of nitrate fluoride ions. This is generally done for the processing or treatment of the water or waste water for getting that purified water for drinking. And also you will see that the anions are exchanged with the negatively charged also. So based on that ions for what type of membranes to be used that depends on that ion characteristics.

And then it is called pervaporation. This is also one of the important process where solid and fluids are to be interacting. It is the process of separation of binary or multi-component mixtures of liquids based on partial vaporization through a polymeric or ceramic membrane. This concentration gradient you will see that there will be certain concentration gradient to separate these materials by this process. In that case this concentration gradient it is called in terms of partial vapor pressure acts as a driving force for the process. In gas permeation this is the gas diffusion process through polymers include random thermal movement of the gas molecules in the polymer structure.

You will see that the gas mixture based on that permeability to gas according to a dissolution diffusion mechanism through a membrane is happened. The graphene oxide, rubbery polymer, membranes, material, organic frameworks are the some example of promising material for the gas permeation. Then you will see that industry all those operations are being carried out to give you that desired products in our daily lives. In that case so whatever process is being used in industry most of the process you will see that involving this solid and fluid operations. You will see that the industry where the business covers this solid fluid operation like chemicals industry, agriculture industry, pharmaceutical industry, paints, dyes and ceramics around 1 percent of all electricity generated worldwide is used in the reducing particle size.

So, particle size is very important that is solid fluid operation and then impact of particulate products to the US economy was estimated to be 1 trillion dollar US dollar. So, this is see how what amount of energy is being utilized for this solid fluid operation. Around two-thirds of its products involve particulate solids like powders, crystalline solids, granules, flax, disperses or pastures where interaction of solid and fluids are there. So, we can have this solid fluid operations based on that multiphase systems like solid fluid systems where there are two types, there will be two phase systems, gas solid, liquid solid and another is called gas liquid solid that is three phase system. So in gas solid system that we have already discussed the different processes and then we are having some industrial applications for this solid fluid operations like particulate materials, powders or bulk solids are used widely in all areas of the process industries for example like food processing, pharmaceutical, biotechnology, oil and chemical industries, mineral processing, metallurgical, detergent, powder generation, paint plastics and cosmetic industries.

Some solid catalyzed gas phase reactions also being carried out based on this presence of the solid in a liquid phase like fluid catalytic cracking, reforming Fischer-Tropsch synthesis, production of phthalic and maleic anhydride, oxidation of sulphur dioxide to sulphur trioxide or other oxide, chlorination and rumination of hydrocarbons etc. Production of different hydrocarbons based on this fluid catalytic cracking by Fischer-Tropsch synthesis, then you will see some gas solid reactions, there may be some combustion and incineration, you will see that gasification, coking and pyrolysis, carbonization, fluid coking, calcination, fluorination, catalyst regeneration all those operations based on that solid-fluid operation. Commercial applications like natural gas combustion based on which you can produce the

synthesis gas, like fluid bed catalytic cracking based on which you can get the different hydrocarbons, gas, oil, even different fuels by different hydro treating and hydro processing. Then commercial applications like physical processes like particle formation such as crystallization, precipitation, granulation, spray drying, tabulating all those operations, transportation of the processes, mixing and blending, drying, coating processes, gasification, classification, catalyst regeneration, roasting all those operations these are called physical processes. So, particle separation by filtration you will see that in industry the large scale you will see that to separate the particulate material from the slurry, plate and frame filter pressure being used to separate the particulate materials from the slurry.

So those process will be discussed in details later on in the successive lecture. Now let us consider one process that why actually we are going to study the solid-fluid operations, what to be learned, what are the components, why this importance in the particular process. Let us consider one process of producing that hydrocarbons or fuels. Let us consider that liquid biofuels or you can say different types of fuels olefin, gasoline, diesel, wax even other chemicals to be produced. So one process here given from the raw biomass how one can produce that liquid biofuels.

You see that in the beginning that the raw biomass to be used for the production of liquid biofuels. Now what are the different steps to produce these biofuels from the raw biomass? Initially raw biomass from the resource that you have to take suitable raw biomass you know maybe grass or some other things maybe wood can be used as a biomass or coal you can use. So you can use that coal or biomass to produce that biofuel. So before that you have to pretreat that raw biomass to get into a final product. So what is that pretreatment processes to get this final biofuels? So initially you have to do that sizing and separation and then what is that drying process.

So you have to first dry that raw biomass and then you have to cut it into pieces that is sizing and then separate that unwanted materials. So these are the operations sizing, separation, drying all those things to be done. After drying of that biomass you have to pretreat and you have to grind it and then pretreat a biomass to be gasified in a gasifier to produce the different gases. Now after that you have to separate that unwanted gases and getting that used gas that is called synthesis gas. So that is gasification will give you that synthesis gas after gasification at a certain temperature.

This is around 1600 Kelvin and then after that you have to water quench and then less than 1200 Kelvin temperature that is in gas to be adjust in a reactor to get that hydrogen adjustment to produce that synthesis gas. So synthesis gas is basically the mixture of carbon monoxide and hydrogen here and then this gas to be cleaned by a chemical wash and after that you have to synthesis by the Fischer-Tropsch synthesis you can say. And then you will see that you will get the different hydrocarbons and then you have to treat it, hydro treat in presence of catalyst particles that is carbon monoxide and hydrogen gas at a certain temperature and pressure in presence of catalyst you can get different type of products like

gasoline, diesel, wax, oxygenated olefins, lower olefins even other liquid biofuels also. So then you have to fraction it as per boiling point range and also that carbon number ranges you will get different products by separation.

And then you will get the liquid biofuels along with the other fuels also. So this is the simple operation by which you can get the liquid biofuels from the raw biomass. Now to get these biofuels what are the operations actually required, what are the processes required? All those operations are basically based on the solid and fluid operations. You will see the raw biomass you have to size it that is sizing operation you have to separate it, you have to separate the unwanted material that is separation process, drying, you have to dry it and then grind it to make it finer particles and then gasify it you have to use that particular size of that particle raw mass and then you have to pyrolyze it and then you will see that gases will be produced and then gas maybe after that in presence of again catalyst particles that interaction of that synthesis gas and catalyst particles at a certain temperature and pressure you will see the different hydrocarbons will be produced. So all the operations involve the solid fluid interactions. So that is why you have to learn the different solid fluid processes or operations to get a final product in a particular system in a particular operations in industry to get your final valuable products.

So in this case you will see that list of Indian company where FCC units that is fluidized catalytic cracking are used like you will see that where you can produce different hydrocarbons like Indian oil corporations. You will see in Guwahati also there is a plant Hindustan Petroleum Corporation Limited, Mumbai Bharat Petroleum Corporation Limited, Mumbai, KOSI Refiner is limited that KOSI Bangainga Refinery of Petrochemicals Limited, Ashram, Nimaligar Refinery Limited, Nimaligar Ashram. So these companies are producing that fuels just by hydro treating. So for that hydro treating it requires solid, there will be interaction between solid and that feedstocks, maybe crude petroleum oil, maybe that synthesis gas with the that solid fluid that catalyst particles. So here that for that you need to size the particle, you need to maintain that certain drying operation, the temperature or drying operation by used you can have the dried product of the solid particles and then pretreat it and then other solid fluid operations to be done, mixing also required for that.

So this to get the finer products behind there are several solid fluid operation. Now question is that what to learn for this courses, why this course is important? So whenever you are going to produce something in a big scale, there are several solid fluid operations, processes will be there, so you need to know that process, what is the mechanism of that process and to know what will be the synthesis mechanism of that solid catalyst particles, how to characterize that solid particles, what is the surface area and also what are the different types of materials which will be suitable for that operations and also how to separate that particles, how to mixing that particles, how to interact that or how to enhance the interaction of solid particles with the fluids, how to separate that particles by filtration or other mechanism, is there any other mechanism to separate that particles and for that reactions what will be the heat is required, heat transfer characteristics that you have to

learn, how that mass transfer happens whenever that reactions happens there, so their mass transfer operations important for physical operations like drying or releasing or extraction, how that mass transfer happens from one fluid mixture to the solid material or solid mixtures that you have to know the mechanism, how to model, how to predict that process output, how to scale up that process all those things to be known. So, that is why this solid fluid operations are important to learn and I welcome all of you to learn this courses, so in the successive lectures we will discuss all the process whatever we have discussed here one by one in details will be elaborated and also explained in the successive lecture. So thank you, in the next lecture we will try to discuss about the particle characterization. Thank you.