Lec 16: Mixing of Solids: Introduction

Hello everybody. Welcome to this massive open online course on solid fluid operations. In this lecture, we will try to discuss about the mixing of solids, how that mixing of the solids of different types happens? what are the mechanisms? and also what are the basic equipment that are being used for getting that intense mixing of the solid materials? In this module also we will try to discuss about the mixing between solid and fluids in the successive lectures. Here basically what is the introduction of that mixing of solids to be discussed and the next lecture we will try to discuss about the assessment of the mixing, what are the different types of assessing procedure to know that how much mixing happened between the solids or between solid and liquids and also we will try to discuss about that mixing between solid and liquid in a certain mixing devices. In this lecture, we will first cover that what is the mixing, what is the difference between mixing, blending and agitation. In industry, there are different types of mechanisms of this mixing, blending and agitation sometimes this mixing, blending and agitations are used that is without making any difference there but there will be a certain difference that we will discuss and also what is the mechanism of mixing and then what are the different mixing equipment generally being used there.

So what basically that mixing terms, blending and agitation terms are there, you will see that these three terms are very important whenever we are talking about that is there any random motion of the solid materials with one to another and whether it will be called mixing or whether it will be called blending or whether it will be called as agitation. So there these three terms basically will be defining different way like mixing is defined as a process that tends to result in a randomization of dissimilar particles within a system. So in this case, you will see that here basically the randomization or you can say that arbitrary positioning of the materials that may be similar or dissimilar within a particular system and the blending basically it is the terms to represent the mixing smoothly and inseparatively together during which a minimum energy will be required to mix those materials in the bed. So that is called blending and mixing and blending are commonly used interchangeable in the pharmaceutical industry whereas agitation, agitation is also basically that mixing of that solid materials but this agitation terms refers to the induced motion of a material in a specific pattern specially circular patterns.

It may be for single or multiple phases may be solid liquid or liquid-liquid or liquid and solids like that whereas mixing that will give you the random distribution of the solid materials into and through one another especially for multiphases. So this is the basic differences of this agitation with that mixing. So mixing and agitation are not the same technically you can say that those will not be same. So agitation basically is a that randomization of the materials or mixing or you can say that mingleness of the materials in a certain pattern specific pattern or in a fashion whereas it will be also happened only not only that single phase also multiphase also but mixing in that case it will be among the phases you know that multiphase system. Whereas blending in that case single or multiphase both will be there but there will be minimum energy requirement where it will

be there then it will be called as blending that means here very that low kinetic energy dissipation where that blending will happen.

There are different categories of that mixing it is represents like mixing of solids that is solid and solid there will be mixing. Mixing of liquids both miscible and immiscible there and mixing of semi-solids mixing of you will see that some particles will be that very soft so soft particles are mixing there. And why then you have to know that mixing regarding that you will see that in any industry whenever any operation is being happened either with the solid particles or without solid particles there of course that the operations will be the systems or like multiphase systems. So in that case to get the better yield if it is suppose there is a reaction to get the better yield of that reaction you have to mix the solid material as a catalyst inside the bed or you have to randomize the particles in a certain fashion so that will give you that particular pattern of that flow through which that materials will be imparting and then will give you the better yield. Also you will see that mixing of phases like gas liquid and solid both or among the phases you can say gas liquid solid all those phases whenever it will be imparting in a particular chemical reactions especially it happens in Fischer-Tropsch synthesis that we have discussed earlier whenever that conversion of hydrocarbons from the synthesis gases there you have to use the some catalyst particles and their gas and liquid both will be there.

So in presence of catalyst particles gas and liquid will be reacting and then it will give you the hydrocarbons. So there intense mixing of that gas liquid and solid will be inside the fluidized bed or in the slurry bubble column reactor either in that case in particles or powdered forms that catalyst particles will be used which will be very essential part for any that chemical reactions whether chemical engineering processes or that transport process you can say or any other mechanical operations of that suppose that you want to reduce the size of the particles there. So in that case you will see that there will be mixing of the particles there and you want to get that uniform size distribution there. So there should be a certain mixing phenomena inside the unit. So we can say that the mixing is very important in any chemical engineering processes or biochemical processes or pharmaceutical industries or mechanical operations or physical operations there.

So this mixing will be important there. So mixing is considered as a critical factor specially in case of potent drugs and low dose drugs there where you will see that high amounts of adsubants are generally required to add. So in that case mixing is important because there that distribution of the concentration of that gradient is important. If there are uniform mixing then concentration distribution among that particular you can say that tablet or any other means there, their drug distribution should be uniform just that can be obtained because of that uniform mixing. And also you will see that there are two types of mixing or blending will be there one is called wet mixing another is called dry mixing or dry blending.

So wet mixing is generally considered in the granulation step where you will see that you need to produce the tablets or capsules there. So in that case the wet mixing of that

materials is very important. Dry mixing is done for several ingredients readily used for direct compression as in the tablets. Also dry blending is suitable for powders and capsules, dry seduffs and compounds powders like this. So the production of several doses like fillets, capsules etcetera based on either dry or you know wet mixing in that case you have to know that degree of mixing or you can say that intensity of the mixing of that material or ingredients.

  So that is why mixing is very important you have to assess how much or what is the degree of mixing inside happen. That will be discussed in the next lecture that the procedure of assessing the degree of mixing. Then if you are talking about that mixing what are the basic mechanism of that getting mixed of that solid materials. The solid particles are mixed based on the mechanism like convective mixing, diffusion mixing and shear mixing. These are three main categories of mechanism of this solid mixing.

  In the case of convective mixing you will see that some groups of particles are moved from one position to the other position with a certain fashion or pattern. In that case mixing of two or more groups of solid particles happens so that they are dispersed in each with others. And also another mechanism it is called diffusion mixing in that case solid particles are distributed over a freshly developed interfaces and also you will see that the powdered materials are mixed in a container where the movement of the powder particles occurs by tilting the material beyond the angle of repose. In that case you will see that whenever you are transporting some materials either by   build conveyor or bucket conveyor you will see that whenever you are just you know transporting that materials as a base you have to get it in your bucket or in a   build and in that case the build or bucket will be designed in such a way that what is the interfaces of the solid material above that bucket or on the build. So that actually I will give you the angle of repose that we will discuss later on also what is that angle of repose all those things and this angle of repose that depends on the   position of that solid materials or distribution of the solid materials on the surface of that build or other way.

  So in that case that diffusion of that solid materials on that particular build or other means that actually will give you that particular assessment of that transport phenomena or that the efficiency of the materials handling for the distribution of that materials and by which you can get that energy distribution to transport of that material from one position to the another position. So it depends on that orientation of the materials. So that orientation depends on actually how that solid materials will be mixed with each other this is one another is that that whenever you will see that very fine powder particles will be used in a gas liquid solid reactions in that case gas is actually distributed in the reactor as a dispersed phase of bubbles in a liquid medium where in the liquid you will see that powders will be spreaded over that or you can say distributed in the liquid. Now that powders you will see that it will be attached to the surface of the   bubble where the gas and solid materials will come in contact. So in that case that solid materials how it will be distributed over the surface of that bubble or in the interface of the bubble and liquid that actually will give you

that you know yield of that process.

So here this attachment of the solid materials over the surface of the bubble or interface of the bubble you will see that that will give you degree of or efficiency of the process. This is especially happened when in mineral industry you will see that flotation process. You will see flotation process basically depends on that hydrophobicity or hydrophilicity of that material. You will see that hydrophobic materials it will be separated by that flotation process just by aeration. So in that case whenever aeration will happen there air will be distributed as a dispersed phase of bubbles in that liquid.

So in that case in the liquid the particles which would be hydrophobic nature they will attach to the surface of the bubble. Now it depends on that mixing of the solid material inside that flotation column and what extent of that solid materials can be attached that depends on mixing phenomena of that solid materials inside the bed. So based on that attachment of that solid material on the surface of the that bubble it will be separated by just buoyancy effect of that bubbles and it will carry out at the top of the surface of that flotation column. So then it will be separated. So this is the mechanism so where you will see that at the surface of the bubbles the solid particles will be attaching or depositing.

And that deposition depends on that intensity of the mixing inside that or collision also that collision depends on the mixing. So that is why this type of mixing phenomena is called the diffusion mixing and then another is called shear mixing. You will see that they are some momentum exchange or some energy to be transported to the powder particles having different velocities and it will be under a shear mixing like it will be you will say that randomly it will be transported in a particular pan and then it will be mixed with other materials with different velocities. In that case this shear mixing can improve semi microscopic mixing and be favorable in both batch and continuous operation. So here you have to remember that during powder mixing all of the above three mechanism takes place together.

Now for that to get that intense mixing of the solid materials among themselves or one solids to the another solids or solids to the liquid there should be certain devices or machine or equipment based on which you can get that intense mixing of the solid materials. Now in that case there are two actually broadly classified equipment we can say one is called active another is called passive equipments. The active type uses certain moving parts to assist in the randomization of the solid materials or the mixer machines moves about physically in the mixing process. So in this case you will see that there will be certain moving parts of the machine and based on which that whenever the machine parts will be moving along with that machine part the solid materials also will be getting movement. So this is the thing like here rebound blenders, tumbler blenders and high shear mixing and multi mechanism blenders are there.

These are the special type of mixing devices by which you can get that active mixing of that

materials by that active mixer or active mixing equipment. Another was passive in this case you will see that the randomization of that solid materials can be achieved by directed flow of the powder streams by baffles. In that case you will see that there will be no moving parts but some baffles will be some mechanical provisions to be provided in that mixing devices. So whenever solid materials will be moving that will start by that baffles or other mechanical means so that its movements will be randomized. So these are the called passive equipments or passive type of mixers.

This is basically that shear mixing happens in this case like baffle and gravity in bed mixing devices these are special type of equipment. Here in the slides you will see that some active and passive blenders mixers are given here one is called rebound blender you see the V2 here and another is called tumbler blender and also you will see that is called baffled blender and also you can get this   gravity-in-bed blender. So here a ribbon blender you will see that how it will be there first of all see that in case of ribbon blender you will see that some ribbon is attached to the shaft and whenever the shaft will be rotating at a certain speed that ribbon you will see that it is aligned in the shaft in such a way that it will be rotating and because of that rotation the solid materials will get the randomization inside it. And tumbler blender you will see that they are here the solid materials will be   just rotating centrifugally at in a certain fashion. And then high shear in this case high shear mixing happens because of this   tumbling action of this impeller.

Whereas baffles you will see that there will be certain mechanical provision in this case you will see that along this side there will be some baffle here. These are the some baffles alongside of the pan   attached to there. And because of this attachment the solid materials whenever it will be moving, it will get stuck and then get the randomization of the solid movement. And then gravity-in-bed blender you will see that the solid materials will be falling downward under gravity and whenever it will be falling downward you will see that it will be you know passing through some baffles or some obstructions or some hindrance in the mechanical devices. And then after stuck on that mechanical provisions they will be getting different directions of falling that materials.

Also you will see that in some mixer grinder there mixer because of that some impeller. They are impeller and also that equipment both will be rotating in a certain fashion and then solid materials accordingly will get mixed. So, here see that ribbon blender how that ribbon blender is acting to randomize that solid materials inside the bed. Then coming to that the best type of blenders we can segregate this type of different types of blenders into that either will be batch or continuous. So, some will be batch type blenders, there are some amount of solid materials to be   fed into the devices and then getting mixed and then again it will be used for particular purposes.

And in this case you will see that tumbling type blenders or it is called mixers you can say these are suitable for gentle blending and also easily cleaned suitable for dense powders and abrasive materials they are not suitable for breaking up agglomerates. And these

blenders can be provided with blades and baffles to break up agglomerates like this here double cone twin shell horizontal drum double cone traveling around long axis with baffles ribbon even vertical orbiting screw base muffler and single rotor turbine these are the specific name of this devices on which you can get that material mixed. So, a base blender or mixer who is continuous to hesitate individual basis of solids for relatively long periods until they are adequately mixed. Ribbon blenders is also a base type in that case the ribbon that will rotates within a static trough you can say or open cylinder and the particles are conveyed by the moving ribbon. And in this case materials ranging from low density finely divided materials that are it rapidly to fibrous or sticky materials that require positively discharge aid can be blended there.

And a broad ribbon can be used for lifting as well as for conveying while a narrow one will cut through the material while conveying it. So, here one you will see that ribbon blender is shown here see here already we have shown earlier also that ribbon blender how it is working there. And then vertical orbiting screw blender you will see that this type of blender consists of a conical vessel with a rotating screw who slips powders from the base of the conical vessel to the powder surface while at the same time orbiting around the vessel wall. Here as shown the video. An advantage of this or writing screw design is that mixing is rapid and the powder consumption to produce a uniform blend is thus considerably reduced.

So, how this vertical orbiting screw can be used for getting that intense mixed of that solid materials. Then another type it is called a molar mixer this is also batch type you will see that in this case it is also called a pan mixer. It consists of flat bottomed cylindrical pan shaped vessel that is equipped with agitators here as shown in the video. This vessel is equipped with large rotating wheels and a set of scrappers called the molar turret. And also in this case you will see that the wheels which is used in this molar compress materials against the pan bottom.

This is basically the action similar to that of mortar and vessel known as you know muling. And also in this case you will see that when these wheels compress materials against the pan bottom the scrappers move the materials from the pan side and center to flow under the wheels. And because of this shearing action the particles are being mixed to each other. It is useful for mixing problems that requires certain types of aggregate breakdown, frictional anchorage of particles to one another and densification of the final mix. It is also used for mixing solids with liquids to produce paste.

So here see that molar mixer how it works to mix that solid material. Then coming to another type it is called drum type blenders. This is also works on base type you can say that how it will be working. Drum type blenders with the axis of rotation it may be that horizontal to the center of the drum are in common use in this case. Similarly they are provided with internal baffles or helical plates to improve the cross flow of the solids.

The drum itself is rotating randomly in either direction horizontal or   that vertical that is in the randomly random direction you can say. So there you will see that whenever this drum will be rotating inside that drum whatever materials so there will be a mixing. So here basically this also 3D swing motion it is called because of which you that randomly the solid particles will be distributing and getting mixed. So it may happen either smooth running or 3D random running. So sometimes it will be quite operation there where is laminar flow will be there so that the particles can get mixed in a certain fashion.

And then you will see that other type is called single rotor blender or mixer. This type of blender consists of a single shaft with paddles inside of a cylindrical shell and these blenders usually operate at high tip speeds generally 6000 to 9000 speed per minute. And turbine blender or mixers consists of a circular trough with a housing in the center around which revolves a spider or a series of legs with plough-shares or you can say moldboards on each leg here as shown in the picture. The plough-shares spin around and through the circular trough which causes the material to circulate rapidly from the center to the walls then upwards and down to the center like this. You will see that here how it is rotating there.

Here see in this case how that principle are being used and getting that mixed in the solid material here like this. So another type it is called the in-beam blenders. These blenders are essentially silos with various means of moving the stored solids to achieve that blending and that blending may happens by falling the solids by gravity through a perforated pipe or multiple pipes you can say here as shown in the picture. It may happen by aerating the mass in the bin. Also it can be done by introducing pulsed air, that pulsed air which creates intense turbulence and causes intermittent fluidization and movement of the materials in the bed.

So there we are having three different types of in-beam blenders and in that case that three types of that blending or three ways of blending happens. One is that falling the solid by gravity that is here you will see that through a perforated pipe or multiple pipes and another one is by aerating and then also by aerating by air but with a particular pulse. So in that case in all cases you will see that the solid materials will get that intermittent mixing or movement of the materials inside the vessel. Then it is called continuous type blenders. A continuous blender or mixers agitates and moves material through the equipment and their mixing happens in quick pass.

In that case as short as one tenth the time required in a batch blender you can say. And also this continuous type of blender is usually long, narrow and enclosed and this special design will ensure the materials that are get mixed together in the time it takes the material to enter the blenders inlet and pass through the blender and discharge from the outlet. And basic continuous blender types are pug mills, twin screw blenders, ribbon blenders, twin mixers, static mixers and free fall impeller mixers. Specialized designs include the zig-zag blender, the poly kneader and the continuous muller.

A pug mill consists of a drum or trough. It is a special vessel it is called the trough shaped vessel that is equipped with a double shafted or less of a single shafted agitator you can say with paddles that will be mounted on each shaft here. And the paddles are usually adjustable so that they are forward and backward motion can be varied during mixing. Also you can see that this pug mill can handle very large volumes and is often used for very crude solids blending such as preparing clay for brick formation. Here one continuous type of blenders it is called twin rotor blenders. Here you will see that it is manufactured to more exact tolerance and has a very sophisticated twin screw agitator design.

It is also called a twin screw blender. This is basically a pug mill you can say. So, it consists of two shafts here with either screw or paddles that is attached and encased in a cylindrical vessel. The vessel is designed like a closed figure and is maintained to fit very closely around the screw agitators here as shown in the video and also picture. The screw agitators can be overlapping or tangential and co-rotating or counter rotating you can say that depending on the application. So, here see the video that how that twin rotor blenders can be acting to mix the solid materials.

And then static mixture is also another important mixture here you will see that it is also called motionless mixture which consists of a cylindrical chamber in which chaos in inducting elements that are located along the axis of the mixture. And in this case the solids pass through the mixture by gravity flow and the elements cause the particles to move in different directions. They are suitable for blending such as solids, grain and plastic chips. And then another also that fall impeller blender which is also run continuously. This type of blender or mixture consists of a vertical cylinder with blades that will be mounted on a central shaft as the materials fall through the cylinder by gravity here as shown in the picture.

The higher speed rotation of the blades causes that blending here and the typical uses are for the blending of detergents, fat or flour mixtures and animal feed stuffs. Another important continuous mixture it is called zigzag blender. This is a special designed mixers. It is based on the design of a tumbling twin shell V shaped blender it is called here as shown in the picture.

You will see that V shaped here like this. This consists of a number of V shaped blenders called legs joined together. It operates strictly on tumbling action without internal scrappers, stirring devices, screens, vanes or paddles. In this case the motion produced is a rolling one you will see that so that particles are not crushed and you can say smeared or subjected to excessive mechanical work. So you have to operate in such a gentle flow rate so that there will be no crushing of that materials. And then another type of continuous blender, it is called muller type.

Here already we have shown earlier in the base operation. This blender is a series of two

or more base pan mular. The pan mulars are arranged so that some material in the first mular flows to the second, some materials from the second mular flows to the third and so on until the finished mixture disserts from last pan mular. Here the series of pan mular will be there. The continuous mular is used for mixing solids with liquids to form damp solids or pastes like this. So here see how that sticky materials can be that mixed here also and it will be continuously and one pan will be transferred to the another pan so that to get that degree of mixing will be more higher.

Then another base type is domestically also it is being used is called kneader. This blender consists of a closed cylindrical vessel equipped with stationary pins that project from the housing. The agitator is an interrupted flight screw. The screws edge have gaps or openings in them and then during mixing the shaft rotates and reciprocates so that the screw moves around the housings stationary pins which blends the material. Also you will see that the like the twin screw blender it is used primarily for mixing solids with liquids to produce pastes.

Here it is shown in the video how that kneader is working. We have discussed that different types of blender or mixer and how that mixer or blender will be working and their mechanism and also what is the basis of analysis that mixing, intensity of the mixing that is done by this   different mixers. So in the next lecture we will try to learn about the degree of mixing and its assessment. So till now whatever we have learned in this lecture that different type of equipment which are being used for mixing of solids what are the basic mechanism of that mixing and also what are the different types of mixing either solid-solid or solid-liquid or semi-solids and what are the importance of the solids that we have learned here. In the next lecture we will try to learn about the intensity of the mixing and what extent of mixing will be happened.

So thank you for giving your attention. So have a nice day. Thank you.