Fundamentals Of Particle And Fluid Solid Processing
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Lecture – 23
Fluidization (Contd.)

Welcome back to another class of Fundamentals of Particle and Fluid Solid Processing. In this class we will be continuing with our concept on this Fluidization and relevant particle properties as well as how this influences the fluidization characteristics.

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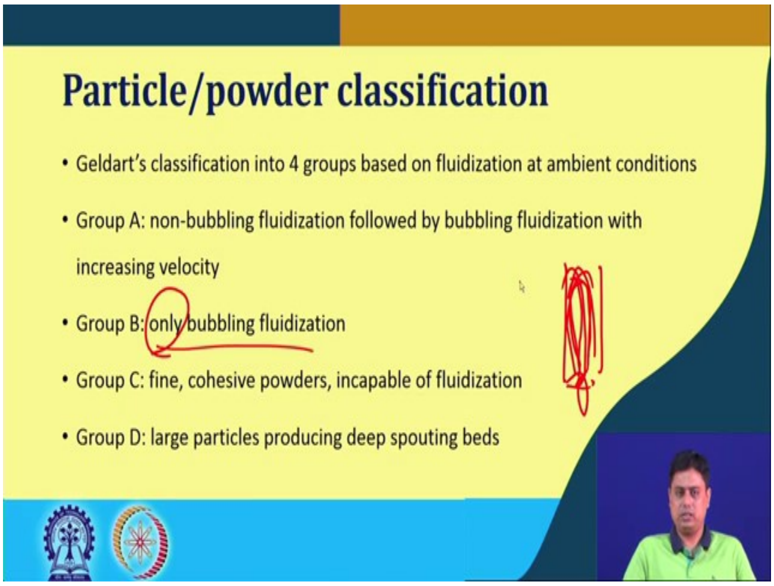

So, we started with the concept of different types of powder or very fine material. So, it was Geldart famous researcher and scientist who initially classified these powdery materials into or these whole particles the segments of different particles; that is used for fluidization into four categories based on its fluidization at ambient conditions. These categories are Geldart's group A, group B, group C and group D particles. Group A particles these are the particles where the non-bubbling fluidization happens followed by bubbling fluidization with increasing velocity.

If you remember the concept of bubbling or the boiling bed ok, the bubbles formation even that the point we mentioned about the analogy between the boiling pool of liquid and when the fluidization happens through solid particles ok. You must now remember or recall the difference between the aggregated fluidization and particulate fluidization. So, the group A basically exhibits this non bubbling fluidization at the lower velocities and as we increase the fluid velocity, superficial velocity the bubbling design starts.

In group B type of particle on the same operating conditions that we discussed for the group A, we have no bubbling fluidization only sorry this is the only bubbling fluidization that no non-bubbling regime that is there for group A ok. Unlike group A in group B there will be no non-bubbling regime or smooth fluidization, there will be only the bubbling fluidization for such particle on the same operating condition as of group A fluidization. Group C are very fine, they are cohesive powders and basically these particles are incapable of fluidization.

So, those particles are very fine, powdery instead, they have cohesive bonds, they are incapable of fluidization, they are categorized as group C particles. And, group D particles are relatively larger sized particles that produces deep spouting beds ok. In spouting bed what happens? You have this fluidization, the flow happens like as if there is a single point of entry and the whole gas bubbles, the gas flows and it flows very vigorously. The particles mixes very vigorously inside that even in fluidization that happens, but it happens as if there is a single point entry ok. Now, we will see these categories in details further ok.

So, once again we have four category of fluidizing material based on their fluidization characteristics at ambient condition, they are categorized in these categories that is group A, group B, group C, group D. Group C particles are typically incapable of fluidization, these are the very fine particles powdery state material. Group D are of relatively large larger sized particles or the materials we have ok.

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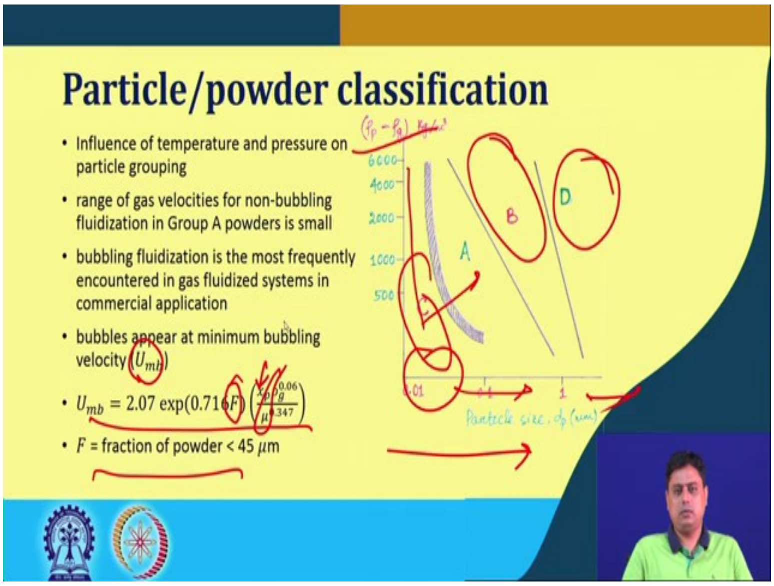

So, what happens this is basically the schematic of that different types of particles that are categorized in group A B C D and their relative density. So, very fine region ok, very fine particle and if it has very higher relative velocity they fall in this narrow region of group C material. Having the similar condition, if the particle size increases they are inter particle forces and all these things becomes less dominant, ok. It inertia forces actually acts more and more on those particles and then this comes to the region A particle; with further larger size and this higher relative density region we have group B particles.

And, further increment with the particle size we have the larger size material which is group D materials. So, the point is that let us say this category at ambient condition ok. Does it mean that group C particle can never be fluidized? It can be but, at a different temperature and pressure. If you can alter the surface properties of these materials the surface forces becomes less dominant ok, the cohesive nature becomes less dominant, the inertia of these particles becomes prominent and then the particles can be fluidized. So, the influence of temperature and pressure on this particles agglomeration, conglomeration particle grouping has tremendous influence.

So, a system that is non-fluidizing at a certain condition can be fluidized at a different operating condition, that operating condition can be changed with the temperature and pressure or some mechanical vibration, some mechanical agitation. I mean this is the additional forces you can provide; a star or a similar kind of external forces that you can provide to make it fluidized. But, this is the broad category at ambient condition based on their fluidization property. So, this window of this non-bubbling fluidization in group A particle is relatively small, ok. In bubbling fluidization ok, this is the most frequently encountered in gas solid system and that is why it is very much frequent in chemical lab, several commercial applications.

Since, this range of gas velocities are lower with group A particle or typically if you have seen the characteristic that particle B or the group B ok; there is no option or let us say the no window of non-bubbling fluidization. Only bubbling fluidization happens there at ambient condition or at general condition, which means in commercial application what happens? You typically have high throughput, you require high throughput and then in the gas phase, if you remember again the aggregative fluidization there immediately the bubbling fluidization starts.

So, the most commercial applications are happening in this bubbling fluidization region. Now, this bubbles appears at minimum bubbling velocity which is different than the minimum fluidization velocity which is designated here as U_{mb}, b stands for the bubble. Minimum bubbling velocity is here designated as U_{mb}, there are several expressions from the literature again. Correlations have been proposed after several experiments with a lot of different types particle, different conditions ok. And, then researchers have proposed such relation, this is one of such relation to know or to determine what is the minimum bubbling velocity which has a parameter F.

It is nothing, but the fraction of powder that has the mean diameter less than 45 micron, x p is the mean size of the particle ok; the other parameters are known for us. So, similarly there are several relations that are available like the minimum fluidization velocity, similar to that we have minimum bubbling velocity. The point where the bubble starts to form non-bubbling region to the bubbling region.

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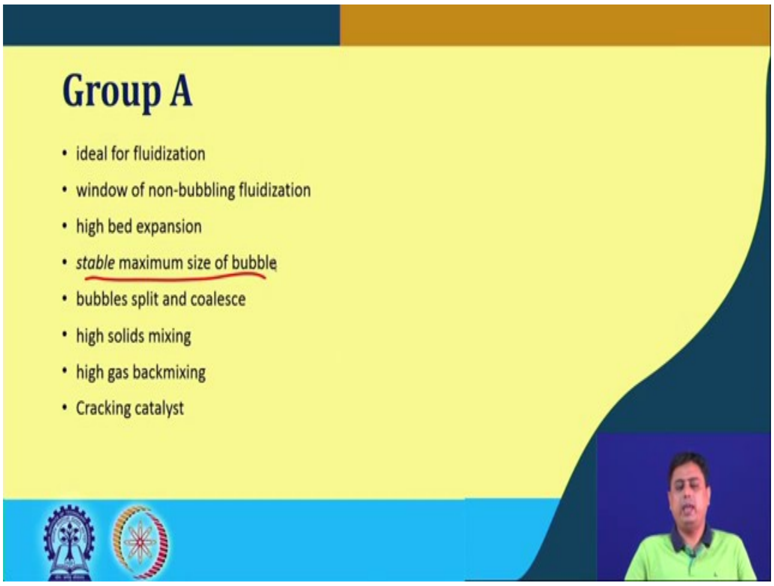

So, group A particles are ideal for fluidization because, it has the complete regime you can say that it can be operated in the non-bubbling regime or in the bubbling regime. Although, the window is relatively smaller, but still you have it in this case unlike the group B particle ok. So, there is the window of non-bubbling fluidization. In this case the bed expansion is very high, we have high solids mixing, high gas back mixing ok. The examples of group A particles are the catalyst, that are used in cracking operations in petrochemical industries.

Now, group A particle has another characteristics where as we have mentioned that there is the onset of bubbles because, there is a window for non-bubbling regime as well as there are the bubbling regimes. Now, at a relatively higher velocity there is the continuous formation of bubbles; it splits, its coalitions happens and that helps us in having a smooth fluidization. In this case you can have the maximum size of a bubble which is stable. In group A particles you can have the stable formation of maximum diameter of a bubble of the biggest size that is possible to form there, that is stable in condition ok. So, these are the characteristics of group A particles.

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In group B particles at minimum fluidization velocity we have onset of bubbling because, there is no window for the non-bubbling fluidization. We have moderate bed expansion relatively lesser than the group A particles, relatively lesser mixing of solids as well as lesser gas mixing than the group A particles. The example of this group B particles are let us say the sand particles, the building sand particles.

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Group C particles as we have already known that these are difficult and these are categorized because, these are incapable of fluidization, these are cohesive in nature ok. If you try to increase the flow superficial velocity ok, there will be no bubble formation, the flow will just channel, ok. It will be channelized at a certain portion ok, like if this is your material that you have the flow can be bypassed kind of a making a fracture through those solid particles or stack of solid particles.

It will bypass through only one section, quite naturally you do not have required mixing of the solids, you do not have gas back mixing. The examples of group C particles we already mentioned are let us say the flours we have wheat, cement this kind of material, ok. So, virtually there is no expansion due to this channelling in effect; very poor solids mixing, very poor mixing if you require in such paid. Naturally poor heat transfer, mass transfer everything is involved in there consequential way.

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Group D particles are coarser materials or the coarser particles ok; as the size increases it there at a particular or at the same operating condition there is low bed expansion; there is low solids mixing, but better than group C particles. We have low gas backpack mixing; the examples are like gravels, coffee beans and something like that which are bigger in size fine.

So, I hope this categorization is now clear to you that what is Geldart's group A, group B, group C and group D. How they will behave in fluidization and which one to choose and why for ideal fluidization.

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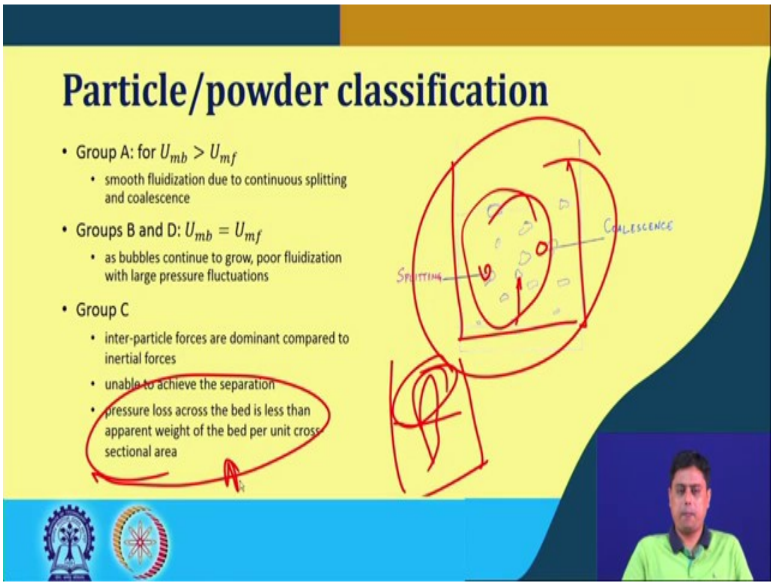

So, if we go into this further this group A material for a condition that is the minimum bubbling velocity when that is higher than the minimum fluidization velocity $(U_{mb} > U_{mf})$ok. As we have mentioned that this kind of scenario that happens that in a bed this bubbles forms because, we have reached minimum bubbling velocity. And, then there are coalitions splitting everything is happening continuously throughout the bed and this helps in having smooth fluidization, ok.

Or, you can say in other word to understand the scenario more clearly kind of let us say the uniform or homogeneous fluidization. For group B and D these groups, the minimum bubbling velocity is itself the minimum fluidization velocity$(U_{mb} = U_{mf})$. As we reach the minimum fluidization velocity you hardly have any control to operate that in non-bubbling regime, the bubbling regime starts. Now, as the bubble continue to grow, now this poor fluidization occurs with large pressure fluctuations; because the bubble grows and grows and it ultimately may burst at the surface.

So, that is why during the discussion of particle or group 1, I mentioned that the maximum size of the bubble in a stable condition that you can achieve there. Here the bubbling regime starts, but it continues to grow and it collapses at the surface. It burst onto the neighbour atmosphere or the neighbour environment and that leads to huge pressure fluctuations which is detrimental for any commercial application ok; such high pressure fluctuations they cannot afford that. The group C particles, the interparticle forces are dominant compared to the inertial force that is acting on the particles by the fluid material or the fluidizing material or the fluidizing fluid rather. If these are unable to achieve the separation between the particles and that is why this channelling happens.

Because, it sticks to one another due to this inter particle forces and the pressure across the bed is less than the apparent weight of the bed per unit cross sectional area always in such cases, in such group of particles. And, then which means if you cannot visualize a bed that what are the type of this particle that I am fluidizing, if you want to detect that and if you cannot visualize the bed. Then this is one of the criteria that if you plot the pressure loss across the bed ok, you will see or you can detect the scenario that this pressure loss is always lesser than the bed apparent weight of the bed per unit cross sectional area.

If that happens you can sense that this particle is group C type of particle for your operating condition; you must change the particles or you must choose different types of particles for your operating condition to have a fluidized bed. Because, you cannot fluidize group C particles ok, they are non-fluidizing in that particular operating condition. Either you change your operating condition, make it fluidized or if you have to constrain or restrain to that particular operating condition, you must change those particles and, this is an indication that if you cannot visualize what is happening inside the bed.

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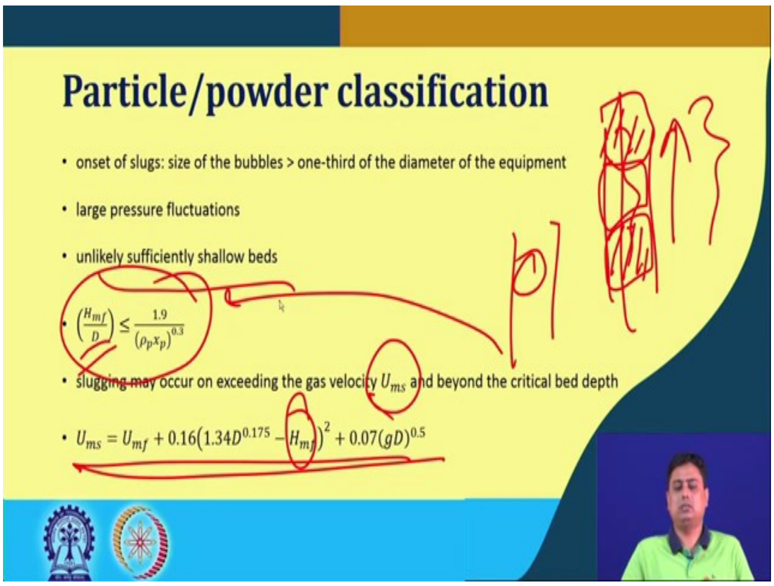

Now, as you increase the gas velocity or let us say the fluid velocity in such particles or any kind of let us say particles there will be onset of slugs. Slug means I mentioned last time that there is a kind of pockets of solid materials and pockets of gas and this kind of flows will happen sequentially. So, this onset of slugs are typically determined by the size of bubbles when they are greater than the one-third of the diameter of the equipment. So, it basically occupies most of the spaces in the equipment or in the vessel where you are having that fluidization or you are doing that fluidization.

So, the size of this bubbles when they are greater than the one-third of this diameter of this equipment that is you can consider that the onset of slugs. And, then this kind of scenario will have significant pressure fluctuations which are typically to be avoided. But, this slugs are unlikely to be developed in sufficiently shallow beds; the bed of depth lesser than a critical value. How do you determine what is that critical value? Again the research results are here, the correlations or the expressions are there where H mf is that critical height, ok that relates with the diameter of the bed.

So, if we strictly maintain this condition we can avoid this onset of slug in the vessel that we are operating for fluidization. Now, this slugging phenomena can occur on exceeding the gas velocity U_{ms} and beyond this critical bed depth where U_{ms} is defined in terms of minimum fluidization velocity and this critical length, critical depth.

$$U_{ms}=U_{mf}+0.16\left(1.34\,D^{0.175}-H_{mf}\right)^2+0.07\left(gD\right)^{0.5}$$

So, these are the strict conditions that if we maintain we can avoid the slugging operation which is detrimental for the whole operational safety because, there is larger pressure fluctuations.

So, operational safety can be compromised, if such pressure fluctuations happens, to avoid that which means we have some conditions, some expressions, some restrictions if we follow we can avoid this onset of slugs in fluidization. So, the point is that you need to remember this we discussed also that, in shallow beds you can avoid the slugging operation or this onset of slugs or the formation of slugs.

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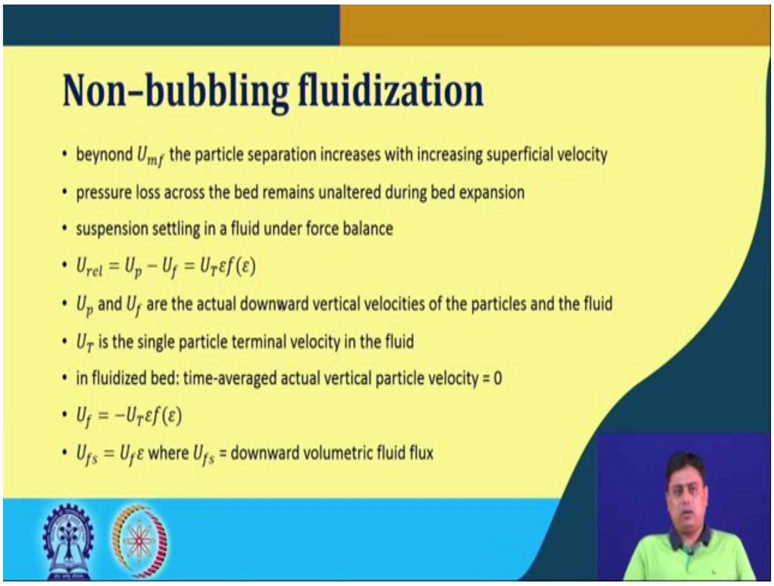

So, I will stop here for the moment and we will be seeing with you in the next class with the types of fluidization ok. The different types of fluidization that we will go into the details like the non-bubbling fluidization what happens there in details and the bubbling fluidization how do we estimate, what would be the depth or what would be the height, what would be the voidage of the certain point of time. This kind of discussions we will be having in the next class and also some problems in the forthcoming class of these sections ok. I hope you have understood till this much whatever we have discussed on fluidization and I will see you with the next class shortly.

Till then thank you for your attention.