Fundamentals Of Particle And Fluid Solid Processing

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Lecture - 46
Particle size reduction (Contd.)

Hello everyone and welcome to the another class of Fundamentals of Particle and Fluid Solid Processing.

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So, last week we concluded on the discussion regarding this particle size reduction and we mentioned that we will be now looking at the particle size enlargement. Now before I go into the enlargement let us have a quick summary of what we did on the particle size reduction. What we have seen is that different types of equipment, what is the mechanism of particle fracture, how to introduce particle fracture what are the components or what are the properties that are dominant in dictating the fracture mechanism.

Based on the fracture mechanism we have categorized the comminution equipment's, we have seen a brief overview of several equipments. During this particle breakage or the particle size reduction the amount of energy it consumes we have seen three different laws in chronological order starting from the Kick and Rittinger's law, Kick's law and Bond's law.

With the couple of examples we have seen the utility of this law that how this helps in estimating the primary (Refer time: 02:02) value of the energy requirement although this is not actually that is actual requirement for any equipment it is much more higher than that. But to have an idea of the order of magnitude that energy would be required to come from a certain size to a different or a smaller size range, which law would be more appropriate and why we have discussed this as well. Based on is its genesis or how it is derived we have seen this laws applicability.

We have summarized that the utility of Rittinger's law is when there is a dominant portion of surface area creation is there. For Kick's law when we have the coarser grinding or coarser crushing and this Rittinger's law on the contrary was used for ultra-fine particles and in the intermediate reason between this ultra-fine or fine particles to the coarser grinding we see the applicability of bonds law.

So, these are the things that we have covered and we ended with the discussion on different types of equipment based on the stress mechanism that it applies on a certain particle for its size reduction to a desired ratio.

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Now; by now we have encountered several terminologies and couple of them are say like coarse grinding, fine grinding crushing. So, what are this? What typically this size range means? This size range that term we use the coarse grinding when we talk about in the range of on the order of meters say from 1 m to 0.1 m. This is when so in this size range when the particle size reduction happens we or the industrially it is called the coarse crushing operation. When it goes below or say in the order of point one meter we say the crushing operation is happening, for final crushing the size range go below 1 centimeter.

So, when we handle the product size to a desired value of say 1 centimeter or nearer to that value we call the fine crushing is required or coarse grinding is required. Below this 1 cm to 1 mm range we say this is the intermediate grinding or the milling operation. So, now, I hope you are getting clear idea that why some equipments were called as crusher grinder and some equipments were called as mills, like colloid mills and that kind of an example that we have discussed.

So, what happens, we have coarse grinding, then we have crushing operation say sorry coarse crushing, then crushing operation, then we have coarse grinding. So, grinding is somewhat lower values of the particle or the product size than the crushing operation, then we have intermediate grinding that also sometimes we call as milling operation after that we have fine grinding and ultrafine grinding.

So, fine grinding goes in the range of 100 μm and ultra fine grinding goes in the range of 10 μm. So, these are the typical terminology that are used and now as I said you can possibly relate by the name of the equipment that in which size range it is typically used. Because as I mentioned earlier that not a single equipment would give you the desired size of the product from a very coarse material. It typically goes through a stages of operation. So, at which stage which equipment is to be used that depends on the stages of this size reduction.

So, if we use crushing or grinding operation we have the crushers, jaw crushers and all these type of equipments are there. If we go for the milling operation or that is called the intermediate grinding in the order of millimeter or lower than that we go for different types of milling equipments.

If we go for very fine grinding or ultra fine grinding we go to this 10 μm of the particle sizes then that time we handle with such appropriate equipment called typically say the colloid mills. So, this summary is essential and you have to keep in mind this terminology and I believe by looking at the equipment name you can possibly now judge that what would be the size range.

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Now, more specifically if you see this table say and then specifically look at the names it would be much more clearer to you that say down to three millimeter of the size range we typically use this crushers or the table mills. Ball range has a wide range of applications and it can handle a wide range of particles, from 3 mm to 50 μm of this range several types of ball mills, rod mills, pin mills, tube mills, vibration mills.

So, all these mills are specific in nature we have not gone to the details of such all the mills individually it would take huge lot of time. We have gone through the overview we have seen one example in all of the cases which would solve the purpose of having an idea over all idea that how this is used or what kind of stress mechanism it provides for the size reduction.

So, again when we go say near about 50 μm or lesser than that we can still use ball mills, as I mentioned it has it can handle a wide range of particle sizes we can use vibration mills we discussed this while discussing the ball mills. There can be sand mills, colloid mills, fluid energy mills these are the ultra fine grinding equipments. So; that means, what we have seen, we have seen the equipments based on the applied stretching mechanism or applied stress how it is provided to the particle, based on that we have seen several categories.

We have seen three categories that is the impact plus attrition the compaction and that is the crushing plus attrition and the combination of all these mechanisms. And the today we had seen that based on the desired level of size reduction what are the types of equipment or which specific equipment we can use. So, this selection of comminution equipments; obviously, depends on certain parameters and one of them is the material property.

We have seen the earlier points as well that how the stress can be applied or what kind of fracture we need to provide that is one of the strategy that is for sure. But along with that material properties plays an important role in deciding the type of equipment that will be using.

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So, what kind of material properties definitely one of the property is the hardness which is the resistance to abrasion, hard materials are quite and logically difficult to break. Abrasiveness which is closely related to the hardness and is an important factor, very abrasive materials can be handled at a low speed operation for example, ball mills. Because these are the abrasive in nature, their abrasiveness is very high in such cases it is desirable to handle those materials where the RPM or the rotation or say the operations are having low speed. So, as the example here it is mentioned the ball mills, we can see that ball mills operate at a very low speed or the low speed of rotation. So, in that scenario such material can be handled in these mills.

Now, toughness is another important parameter for the material properties, it is the resistance that it provides in order to resist a crack or its propagation. So, the tougher the materials it becomes something similar to the hardness, that it is difficult it becomes difficult to break and toughness is opposite of the brittleness. So, these materials actually exhibits plastic deformation than the propagation of new cracks.

So, the control on this size reduction's is difficult on the tougher materials, and sometimes if we can reduce the temperature while operating or while treating processing this materials it can render some brittleness which helps in terms of energy consumption. If the material is in fibrous in nature then it can be comminuted in shredder or cutter not in usual grinders of crushers.

So, because it has the fibrous nature, if the material exhibits cohesiveness or adhesivity; cohesiveness is the attraction with the same type of particles adhesin is the different types of surface say the equipment surface and the particles. So, the moisture content particle size this basically dictates these properties. So, in such cases when this there is a cohesive or adhesive property, it is actually difficult, it makes the particles or the feed its flow ability becomes very less.

So, the discharge or say the feed inlet all these things becomes difficult scenario while handling these materials. So, a way to grinding in such cases or handling this cohesive or the adhesive materials becomes immensely helpful while having its size reduction. So, that means, we have to look into the equipments which can be operated in wet grinding scenarios as well. We have seen the ball mill can handle dry operation as well as the wet operation it can be carried out inside a ball mill.

So, similar type of equipment or the equipment or the crusher or the grinder that can hand, that can be operated in wet condition or there is a flow of continuous fluid particularly liquid in such scenario the equipment should be efficiently working that kind of equipment we have to choose.

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It has been seen that this removal of generated heat by cold air if we reduce the melting points then it becomes energy efficient to have the size reductions of that particular material. Other different properties that are important sometimes is that if the process is thermally sensitive for the materials then in presence of inert atmosphere or the inert carrier medium that grinding operation can be carried out, because the material is itself is a temperature sensitive material.

So, in presence of atmospheric air or say the oxygen it can create some hazard. Similarly if we have to process, toxic or say radioactive material then we have to choose a suitable carrier medium. So, that it does not react or does not explode or does not create any other nuations and it should be operated in a closed circuit; that means, in a closed loop which we will see in the next slide that, what are the different mechanisms to handle this set of operation. And as I mentioned we cannot neglect the importance of the carrier medium apart from the material properties.

So, this carrier medium during this feed inlet or the discharge, typically that these are carrier carried in presence of gas or liquid phase. But again we have to look into the aspect of the surface property of the particles whether it is soluble in liquid or its size changes by mixing it in the liquid, then we have to use the gas phase what its activity or the reactivity with the certain gas phase if that is sensitive to the gas phase we have to use liquid phase. So, such kind of parameters we have to decide or we have to think in deciding this use of appropriate size reducing equipment.

We have to also think of the forces to the particle while it flows with the carrier medium. We have to account for the friction and abrasion while it flows because we will see during a transport in fluidic media the solid particles create a lot of friction and the abrasion it totally changes, the hydrodynamics of the flow. Moreover whether the velocity or say the influence of carrier media on the crack formation, is it makes the solids more brittle or more tougher.

The presence of the carrier media; in presence of the carrier media if the solid particles becomes more brittle or more tougher depending on that scenario, we have to choose the size reducing equipment. And, whether it alters the cohesivity or the adhesivity of the material, that we have discussed that this carrier medium is typically used in order to increase the flow ability of the solid particles.

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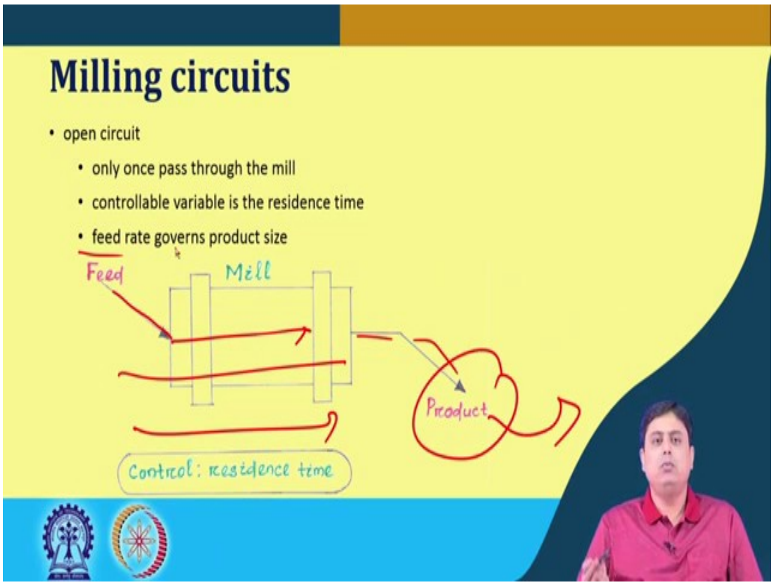

So, this has to be kept in mind, all these parameters are to be considered while selecting appropriate size reducing equipment or the comminution equipment. And these equipments just not only work stand alone in certain cases or in most of the industries these are not just a standalone operation or the standalone equipment it is followed by some other operations. For example, after size reduction drying can happen, in drying industries while it make some cake or say soap and all these stuff.

So, this has to be dried, this is one of the operation; the size after reducing it may be compacted or may be densified. So, such operations are typically followed I mean happens after the size reduction process. So, typically how these instruments are used? It can be operated in open circuit or closed circuit manner open circuit means open loop where only one pass happens through the mill; that means, the feed comes in, goes inside and leaves the mill after the crushing or grinding happens. This is the one time pass of that and then this product is used for further operations. Now in this case the only controllable variable is the residence time.

So, and this residence time is important, we have seen in our previous discussion that how retention of the solid particles in the milling unit or the grinding unit for a longer time how it can help in reducing the size. And since there is no feedback or recycle of this product the efficiency of or say effective operation of that milling operation completely depends on the control of the feed rate. The way you provide the feed rate it dictates the residence time and which instants dictates the product size variation or the product size distribution.

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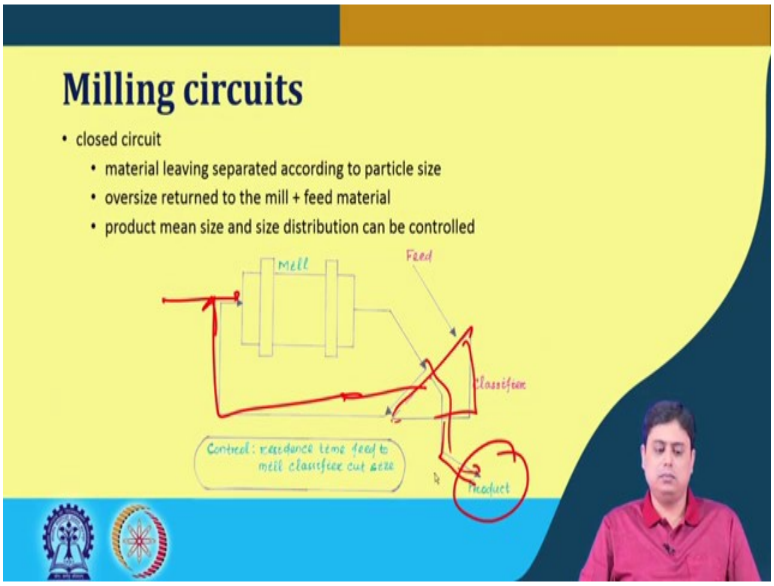

In case of closed circuit operation the materials leaves the milling operation or the grinding operation and then it is separated according to the particle size and over size particles again fed back to the inlet along with the fresh feed. So, it is a kind of a closed loop scenario.

In this case the mean product size and the size distribution can be better controlled than the open circuit operation. So, here what happens? The feed comes in it goes to the mill the product is separated in a separator or a classifier where we receive the final product, which is the finer particles and if those are not suitable the bigger size particle or the oversize particle again feedback which mixes with the feed and goes into the operation. So, it is it continues until and unless we have the sufficiently finer product.

So, in this case; that means, you create the products of certain desired range, this is more controllable than the previous open circuit operation. Closed circuit operation is most popular in the industry because it is efficient; you control the main product size as well as the size range. But in certain cases you cannot avoid instead of using this open circuit operations.

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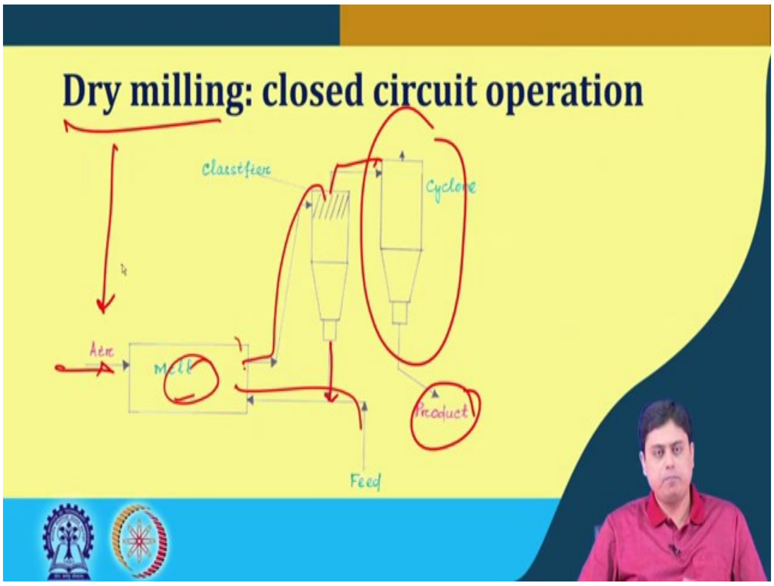

So, the other operations that you mentioned can be of dry or the wet. So, dry milling in absence of any water, most popular liquid phase in the wet operation is the water. So, here what happens in dry milling either air or some other gaseous carrier medium is used it takes the feed to the mill.

It is then grinded in the milling or crusher, then it goes to the classifier; where in the classified; again, we have the oversized material that comes and mixes with the feed once again and the finer products or the desired size or the let us say smaller product again are classified in gas cyclone where we get the desired product. So, this is a kind of closed loop or the closed cycles of a circuit operation that happens where we have these mills followed by a closed loop of classifier and the subsequent classification of the finer products. Now in this case, this is the dry milling operation which means the carrier medium is here without humidity dry air.

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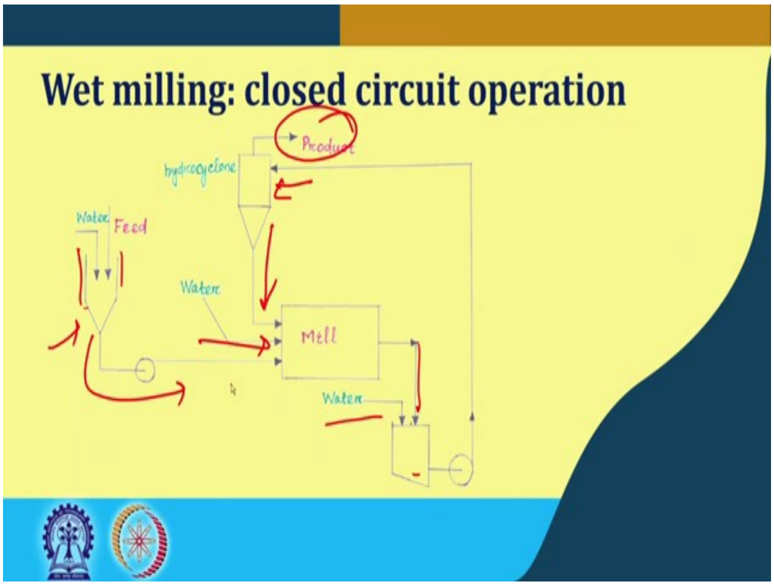

In case of wet milling and again closed-circuit operation because as I mention closed circuit operation is more popular because of its efficiency.

So, what happens here? Here we have water and feed that this water carries the feed, goes into the mills and then we have a certain desired product which is further the fresh water is added here, this goes for the classification in hydro cyclone where the finer particles are collected at the top and the bigger particles again comes back to the mill with the fresh feed; where water is supplied everywhere, in order to facilitate the flow ability of the material. So; that means, this dry milling and wet milling and how this close circuit operation works, how the open loop works or the open circuit operation works. We have seen these variations.

And these sums up this whole size reduction, summary that I wanted to convey that starting from the size reduction of the particle knowing the stress mechanism, categorization of the equipment based on the stressing mechanism, the energy consumption the selection of the equipment based on the different stages of crushing grinding or milling operation. How the material properties influences the choice of comminution equipment? How this system works in an industry, in a very sketchy way that it can be operated in open loop or open circuit operation or closed loop or closed circuit operation.

In open loop cases; then open loop cases you have control only on the residence time that is the feed rate which controls the residence time and this in turn results in the size variation of the product. But in closed circuit operation the oversized products always goes back to the loop and mixes with the feed fresh feed.

So, you have a better control on the feed size, the mean size of the product and the size distribution of the product as well as this close loop operation, we have seen in terms of wet milling and the dry milling operation. In wet case we have water as a carrier medium, in dry milling case we have dry air as the carrier medium both has its pros and cons, based on these we have to choose a appropriate size reducing equipment.

So, with this I conclude today’s talk. And from next day we will start the discussion on the size enlargement part. So, this is the overview of size reducing equipment although the all equipment’s that I have mentioned the names are not covered in details, but those are interested can look into the different handbook, say Perry’s handbook or (Refer time: 28:28) encyclopedia regarding this details of this size reducing equipment and its design.

With this I thank you for your attention and will see you in the next class.