Mechanical Unit Operations
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Lecture 01
Introduction of Particulate Solids

So, welcome to the mocks course Mechanical Unit Operations. This is the first lecture of the course. Title of this lecture is Introduction of particulates, solids. So mechanical unit operations is a kind of a very important core course for the undergraduate chemical engineering students, right? So we need to understand before going into the course how much it is relevant to the chemical engineering student right. So in order to get into those things first, we see what is in general about chemical engineering and then what chemical engineer would do and then what consist of these chemical plants, et cetera. Those basics we see and then we get into the introduction of particular solids.

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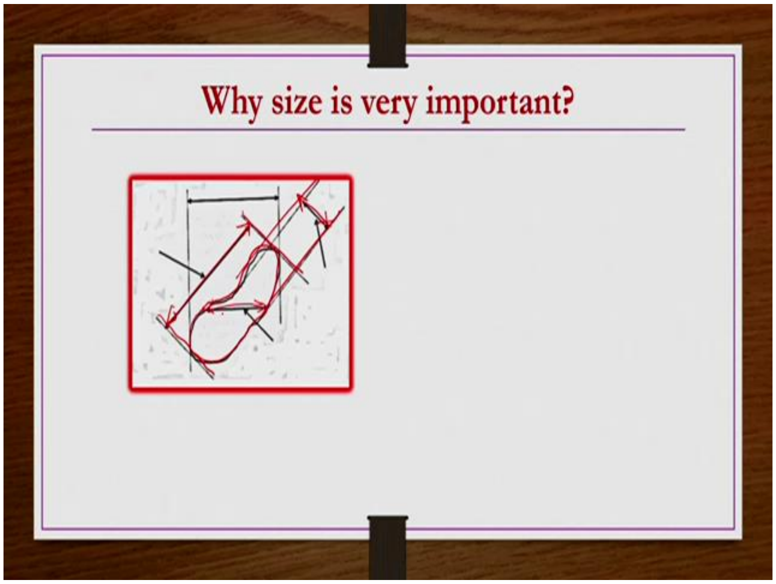

Industrial sector, what does industrial sector doing? Industrial sector usually converts natural resources into primary products of need for the society within the environmental constraints. So that is, what about the industrial sector? Any industrial sector that you take in general, whatever the natural resources are there, they will be converted into the useful products for the benefit of this society, humankind within the constraints of the environmental protection. So that is what industrial sector, so briefly in this stem sector, we may categorize or classify as you know, industrial sector, which is about the manufacturing industry where assembled the goods, automotive industries, etcetera are involved. Then we have a construction industry where building construction, industrial construction etc are involved. Then third and then very important one is related to this course is the material processing industries like you know.

In the under the material processing industries we also have many industries like you know, chemical industry, pharmaceutical industry food industry, metallurgical industry, petroleum industry, textile industry and so on so, so many other kinds of material processing industries are there. So our chemical engineering, whatever is there that is related to the chemical industry.

However at the end of the graduate course you can realize that they, whatever the principles developed or that you learned in chemical engineering, they are also very much important and useful to the other kind of pharmaceutical industry and other kinds of industries such as pharmaceutical industry, food industry, metallurgical industry, right? So whatever the chemical engineering principles that you are going to learn during your UG course, they will also be applied to many of these material processing industries such as pharmaceutical industry, food industry, metallurgical industry, textile industry and so on right.

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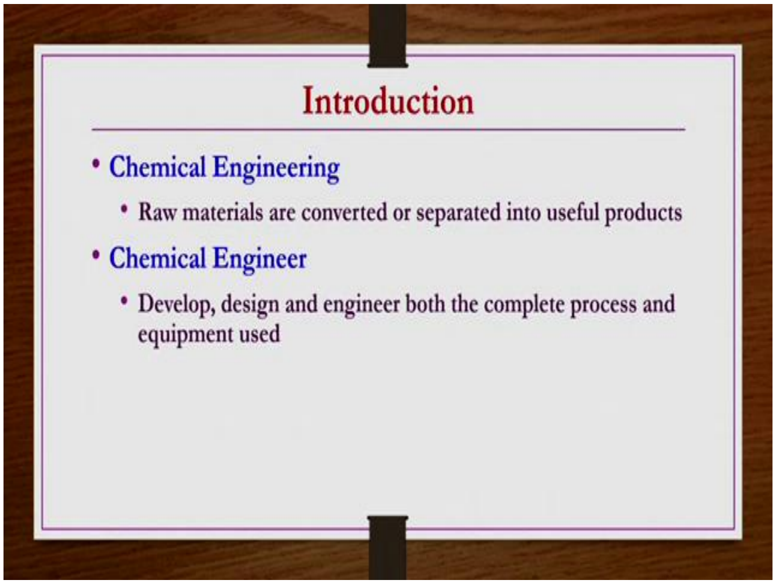

So they, so then what is about the chemical engineering in general? Chemical Engineering, what we expect chemical engineering deals with the conversion or separation of raw materials into useful products. That is what we expect in general chemical engineering. We are not going by the exact definition, but in general perception about the chemical engineering as well as the chemical engineering grads. So then chemical engineers are expected to do what? They are expected to develop design, engineer, both the complete process as well as the individual equipment used in the chemical plant.

So the chemical engineer must have information, knowledge, indeed expertise about the development, design, and then engineering of the entire process, the entire plant as well as the individual equipment used for that, for the production of a required the material from a given raw material. Selection of raw material is also kind of a very much important, crucial kind of thing in order to have a kind of economically better results from the chemical plants.

Then most importantly, operating the plant with safety priority first is the safety, then efficiency, then economically that engineer must be able to operate a chemical plant and then finally check whether the products meet the requirement of the consumer or not. So these are the in general about the chemical engineering and then chemical engineering what we expect, what we know, what we expect from these kinds of things that is what it is.

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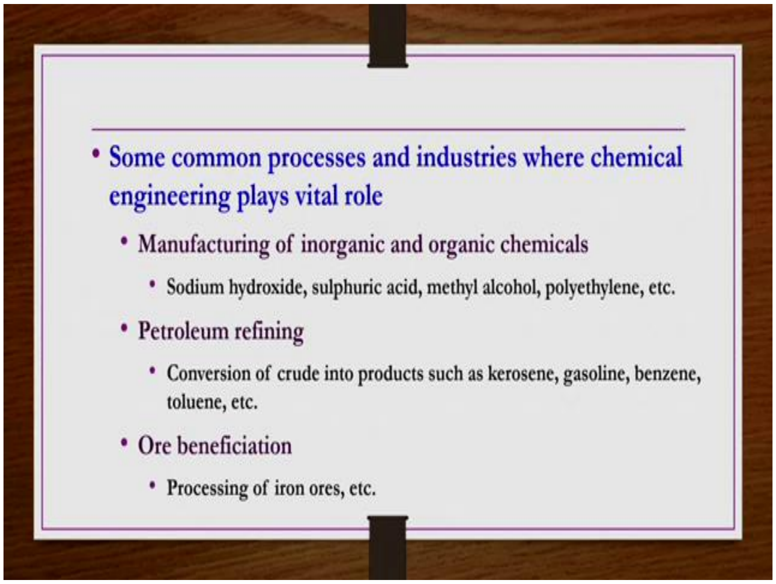

Then as I mentioning that you know, principles of chemical engineering are not only important to the chemical engineering plants, chemical plants, but also other material processing industries, also so many chemical engineering principles are in general used or the applications of chemical engineering are very much important in other processing materials in addition to the purely chemical plants as well.

So we see some of the common processes and industries where chemical engineering plays vital role such as you know, we have the basic chemical plants like where we are all we produce our organic and inorganic chemicals so that is the basic importance the lies in of the chemical engineering in this production of these kinds of plants where we are producing sodium hydroxide, sulphuric acid, methyl alcohol, and then a polyethylene, these kind of chemicals in general we produce.

So definitely their chemical engineering role is very much important. But in addition to manufacturing of these chemicals, chemical engineering principles also applied in petroleum engineering, petroleum refineries where we will doing conversion of crude into products such as kerosene, gasoline, benzene, toluene, etc. The principles of chemical engineering are also applied in metallurgical industries by ore beneficiation, et cetera, where we will be doing processing of, I iron ores, etc.

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Like that if you keep on listing, we may be finding the applications of chemical engineering principles are very much important in so many other kinds of industries also such as kind of a pharmaceutical industry and then food industry, polymer processing industries, textile industry and so on.

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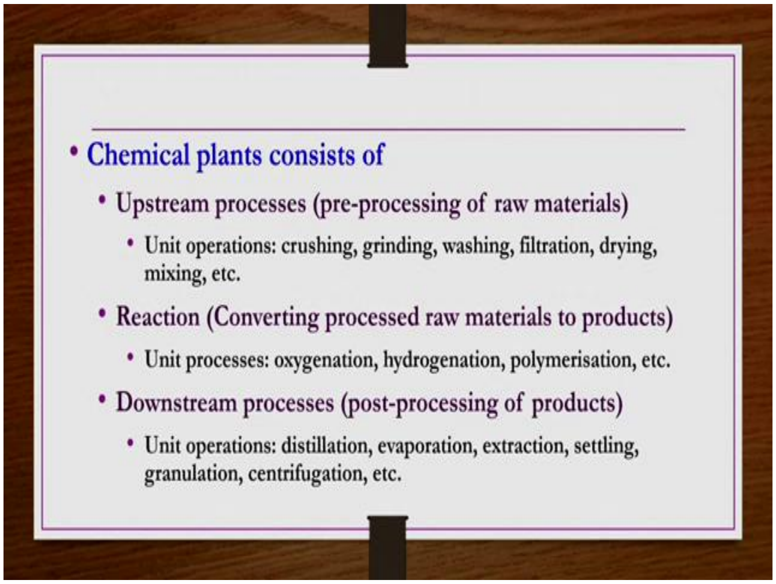

So, so now what is about chemical plants in general? Chemical plants and we may say that it consists of several unit operations and then several unit processes. Indeed we may divide the chemical plants as a kind of primarily the reaction part and then before the reaction part as well as the, after the reaction part, what is happening? Like this three groups, we can have a kind of chemical plants, we can group them like this, right? So first one is the upstream processes, like you know, whatever the in general raw materials we get from the natural resources. And those raw materials may not be in a kind of a required form for the reaction to occur.

Let us say we have a kind of you know, coal combustion, right? If you are operating a kind of a Coal combustion plant, whereby combusting the coal you may be getting the energy that is the basic process, but naturally what you get by underground coal mining or open cast coal mining, you will be getting the coal from the nature right from the earth, right? So that coal is in a kind of very big size. You cannot directly take such a big lumps of the coal into the your combustion reactor. That is not possible. So what you are expected to do? In general, you may be breaking them; you may be breaking them into this smaller size so that is suitable that they can be taken to the reaction Part.

So, and then when you get these raw materials from the natural resources directly, you may be having some kind of impurities also. Let us say in the case of coal, mud, et cetera, those kinds of unwanted materials will be there so you how to wash them out after crushing, after crushing, whatever the impurities are there, you have to wash them out and then after washing those impurities, whatever the fine coal particles out there, you cannot directly take into the a reactor inhibit form., you have to dry it right.

After drying it then you may be taking it to the combustion chamber where you are doing the combustion, so know before come into this combustion section, you have so many other things to do, so all those things, processes, whatever are there, we call them upstream processes or pre processing of raw materials.

In this pre processing of raw materials, we have a unit operation like crushing, grinding, washing, filtration, drying, mixing, etc. Then once you have this pre processed, raw material is ready for the reaction. What you can do, you can take this raw material to the reaction section where the reactor in the reactor, the reaction is taking place so that the conversion of this processed raw materials to products will take place, right? So here, this reaction, whatever this occurring, those in general described by your unit processes in the unit processes we have the reactions as oxygenation, hydrogenation, polymerization, etc right? And then, uh, after the reaction, as we know that a hundred percent conversion is not possible always. So there may be some unreacted reactance along with the products and by products.

So those, unreacted reactants should be taken back to the reactor by recycling. And then from the products one has to do the purification of the products so that those who are purified product, important product can be supply to the consumer, whereas the by products if at all there, so they can be handled according to as per the nature of the those by-products so that is the post processing of the products or we call them as a downstream processes where again we have so many unit operations such as distillation, evaporation, extraction, settling, granulation, centrifugation, et cetera.

So now taking these chemical plants, what we have here? We can have chemical reaction and then separation and then a purification these kinds of operations are taking place. So basically that is unit processes and in unit operations are they, but if you see in a given chemical plant, you may be having a few chemical processes only or you may be having only a few unit processes where a few reactions are taking place. But before that reaction reactions occurring or before the unit processes, there you have to do so many unit operations, after the reaction also you have to do so many unit operations, right? So that means, you know, you may be having couple of unit processes in general, in a small scale plant. If it is a big scale plan, there may be 5-6 number of unit processes. But relatively, the number of unit operations there that are existing in a chemical plant, they are huge number.

They may be in dozens, they may be in dozens right? So that is the reason this unit operations is also kind of a core important course along with the chemical reaction engineering for chemical engineering graduates right. And these and these unit operations are usually based on the different types of mechanism. Like some of them are purely based on the mechanical forces, some of them are based on the kind of a molecular transport mechanism. Some of them are based on both kind of things are there right. So those unit operations also we can separate them kind of in our different ways.

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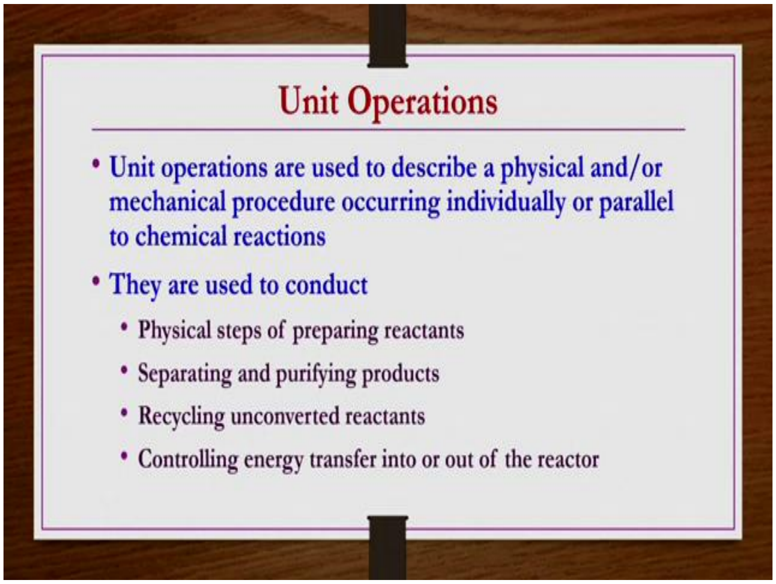

So but however fast we see definition, what is a unit operation kind of thing, unit operation operations. Unit operations are in general used to describe a physical, are mechanical procedure occurring individually are parallel to chemical reactions right. That is what we understand that is in the chemical plant other than whatever the reaction part is there rest everything we may say, almost all the kind of a one or other kind of unit operation is involved that is what basically we can say. So that means these unit operations are in general used to conduct physical steps of preparing the reactants, becoming, making them suitable for the reaction, whatever the raw materials are there making them suitable for the reaction.

Then after the reaction, separating and purifying the products. Then during this process, whatever the unreacted reactants are, taking them back to the reactor by recycling and then in the reactor or in other kinds of unit operations in general energy is involved energy maybe going in or going out of the unit process or unit operations so whatever the controlling of energy into or out of the reactor or for any given unit operation that should also be taken care of by the unit operation.

So these many important things are there for the unit operation. But then what is mechanical unit operation? As I mentioned, some of the unit operations are based on only mechanical forces where whereas the some other kind of unit operations which are also known as the separation processes, they are based on the molecular transport mechanism, right?

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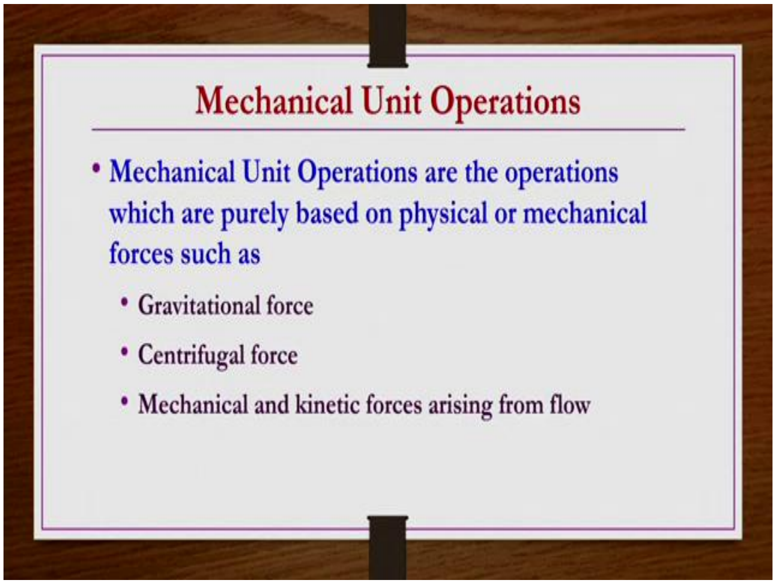

So the unit operations of which are purely based on mechanical or physical forces such as gravitational force, centrifugal force, mechanical or kinetic forces arising from flow, etc cetera, they are known as the kind of mechanical unit operations. How we can differentiate unit operations like you know, rather having a course title as Unit operations, we are having a title as Mechanical unit operations. So what is the difference? So as I mentioned in the previous slide that unit operations, some of them are based on the purely mechanical means, whereas some of them are based on the, based on the molecular transport mechanism.

So whatever the unit operations, which are purely based on the mechanical forces, they are called as a kind of mechanical unit operations. Whereas the unit operations where the separation occurring because of the molecular transport mechanism, et Cetera, they are taken as a kind of separate unit operations and they are studied in general in a kind of different course like mass transfer, et Cetera. So what are the physical and mechanical forces that in general we encounter? We encounter something like gravitational force, centrifugal force or mechanical and kinetic forces are rising from flow.

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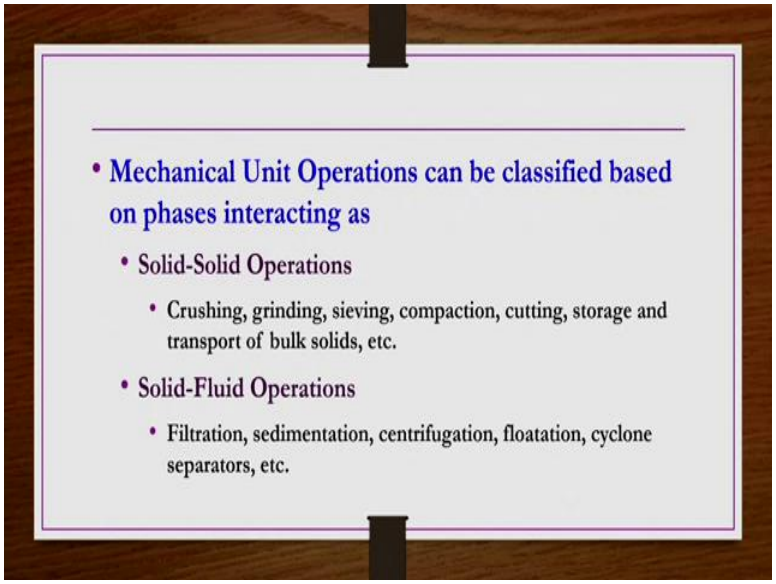

Then this mechanical unit operation can be classified based on the phases interacting. So if the solid-solid phases only interacting, then we have a solid-solid operation. If the solid and fluid phases are interacting, then we can have a kind of operations where you know solid-fluid operations we can have. Under this solid-solid operations we have so many kind of a pre processing of the reactants as a crushing, grinding, sieving, compaction, cutting edge, cutting storage and transport of bulk solids, et cetera. And under the solid-fluid operations, we have a kind of unit operations such as the filtration, sedimentation, centrifugation rotations cyclone separators, etc. In this course, whatever the syllabus is primarily we are going to divide into two parts.

First 5 modules purely based on the operations where these solid-solid phases are interacting. 6th and 7th modules are about the some basic principles about the fluid particle system and then 7th onwards the 7th to 12th modules we will be discussing about the unit operations, principles of unit operations, where the solid-fluid phases are interacting such as filtration, sedimentation, centrifugation, floatation, cyclone separators, etc those things will be discussed in the last five modules.

Now, since this particular lecture is about the particulates solids, so we need to have a kind of a unit operations where involving particulates solids is there, right that is very much essential so that we can get into the course.

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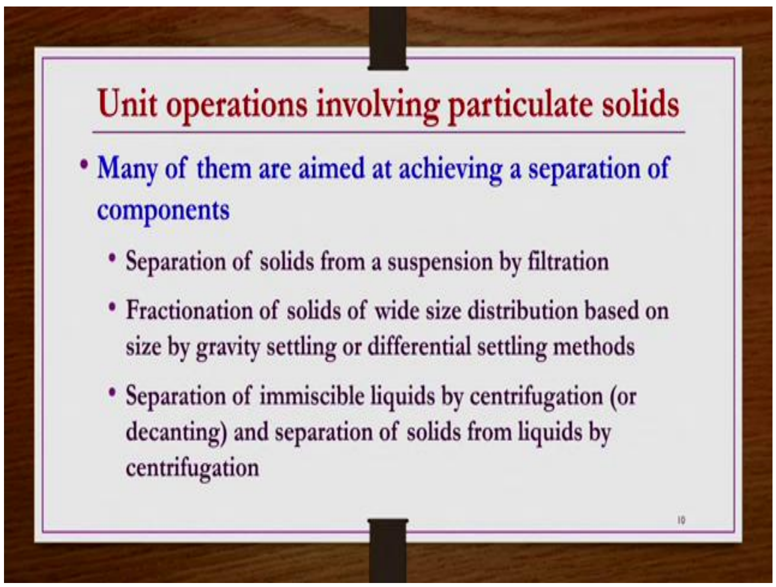

So usually these unit operations where particulate solids are involved, many of them are in general aimed at achieving a kind of separation of a component from a mixture kind of thing right. For example, what you have after the reaction let us say if you have a kind of solid-fluid reaction, a heterogeneous reaction is there and then whatever the product that you are getting that let us assume a kind of a slurry that you are getting so from that slurry only solid is your product let us assume or if only liquid is the kind of your products and what you have to do you have to separate them. You have to separate them as individual phase, so then for that we may use a kind of filtration process. Okay.

So that if it is solid is a product, then you can collect a solid a, if it is liquid is the product, then you can collect the permit as a kind of product and then the remaining one you can use as but as the requirement of the process. Similarly you know fractionation of solids of wide size distribution based on the size by gravity settling our differential settling methods, et cetera. As I mentioned let us say in a coal compression kind of thing, you cannot have a kind of a bigger size of particles like in bulk solid coal particles as a kind of feed to the reactor.

You have to break them and then you how to make into the smallest size, particle size based on the design calculations of the reaction whatever is going to occur based on whatever the number you have achieved so you how to crush them to an appropriate size of that particles. So after crushing those bigger particles into the smaller one, it is not necessarily that you are going to have a kind of a uniform distribution of the products.

So then you may be having different size distribution, so making them into the different fractions, one particular fraction of average size, another particular fraction of the average size bigger than the previous one like that if you how to make a different fractions then again you need to have a kind of these kinds of unit operations and then where we can have a kind of a principles of gravity settling or differential settling methods.

Then sometimes you know, if your reactions are in a kind of in the homogeneous liquid phase, or heterogeneous reaction. But after the reaction catalysts, etcetera, you are taking out the whatever the product is there that is in the liquid form, but in a liquid may not be in kind of in a single phase. It may be there you know two phases and those two phases may not be a miscible into each other right?

So then one of them is product so then what you have to do you by using the decantation, you have to separate out you have to separate out the immiscible liquid phases and then collect the product liquid phase. Sometimes you know what happens, solids has to be collected, not only by filtration, sometimes this separation of the solid from the slurry can also be done by the centrifugation. So here are also some kinds of unit operations are involved, right?

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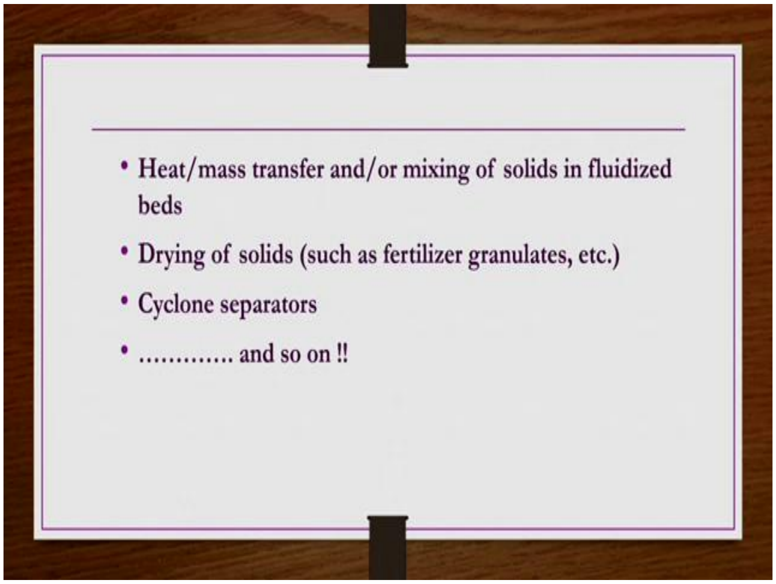

Likewise if you take a fluid as bed where the mixing of solids is taking place so in that mixing of solid in general heat and mass transfer may also be involved. Similarly drying of solids, especially in fertilizer industries, whatever the fertilizers are there in general, you do the granulation. Indeed a granulation is a kind of small scale plant in general. Whatever the fertilizers that you get after the fertilizer industry, again you have a kind of small scale plant where you do the granulation as per the requirements standards, so drying of solids is very much important in those kinds of granulation of the fertilizer kind of plants it is very much important as well as there are so many applications where drying of solids is a kind of variation.

So process, so training is also a kind of unit operation here. Then cyclone separators in general after what happens after the reaction, like if you have a reaction is having involved in the gaseous phase also after the reaction, let us say heterogeneous reaction occurring right gasses are reacting with some kind of a solids or other kind of gases on the surface after catalysts. After the reaction in general, whatever the gas effluents are there, they may also be containing some kind of particles, so particles are in gases, whatever are there, fine particles, those particles you cannot leave into the atmosphere.

So what you do, you apply the cyclone separator and then you try to collect those particles and then remaining effluents if they are environmentally not dangerous so then you can leave into the environment or otherwise those gases separately collected, after separating this particle, those gases should be collected into the bag houses, et cetera and then proper disposal has to be done. Likewise, if you keep on listing these unit operations where particulate solids are involved, so many in numbers of applications we can have, right? So that is the reason, the unit operations of particular solids is a kind of very much essential here as well.

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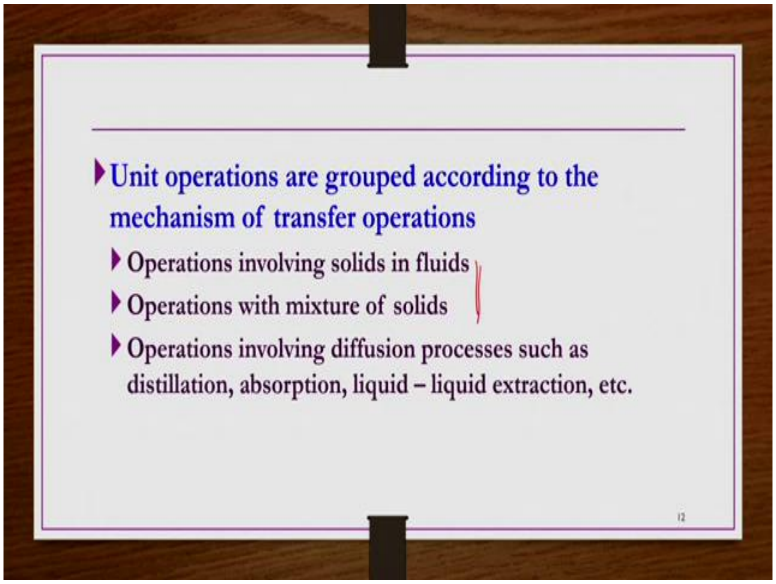

Then unit operations can also be categorized based on the mechanism of transfer operation that is occurring. So one of this, one of the categories that operations involving solids in fluids. Next one is the operations with mixture of solids that we have different types of solids are there. So there, you know, you may be doing this operation based on a certain kind of principles. You may be having the mixture of solids and fluid there. You may be doing this operation based on this different kind of mechanism. Then there may be having the operations involving the diffusion processes such as you know distillation, absorption, liquid extraction later.

So we are not taking this distillation absorption, liquid-liquid extraction, etc because they are taken in general in a kind of mass transfer course. So here in this course we are having these kinds of operations where the involvement of solids and fluids are there or the solid-solid involvement is those kinds of things we are going to take. So this is an one another way of the categorizing the unit operations. So these categorization classifications are not the kind of universal, depending on the application, depending on the point of view requirement they can be classified.

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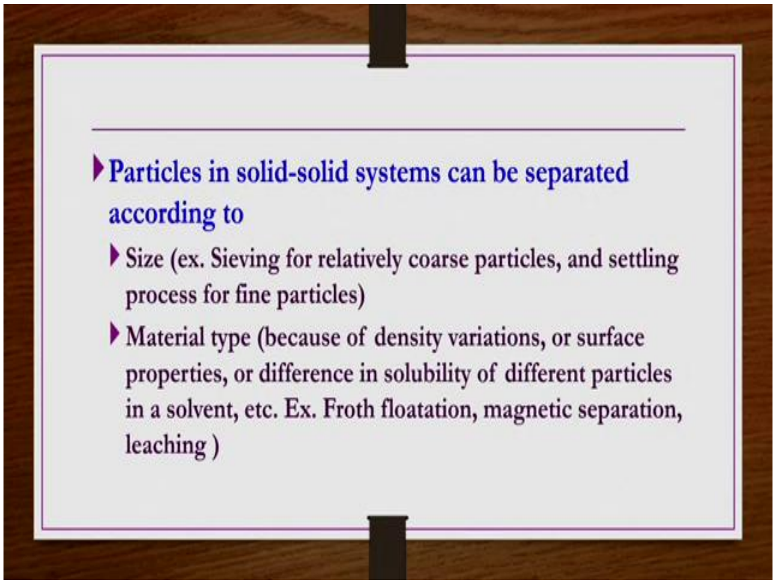

So having seen the importance of the unit operations of particulates solids, because we have seen several cases where the particulate matter is involved, then it is required to do a kind of separation. So how these particles in solid-solid systems can be separated that is the very much important. On what basis we can separate these particles in general? So in general, these particles in solid-solid system can be separated according to size. The simplest and easiest one is the based on the size that is by sieving relatively coarser particle and then settling courses for the fine particles, et cetera, those can be done.

Based on the size sieving action one can do. One can do the settling operation based on the size and they do this separation of these particles right. Then material type material type because density variations or surface properties or differences in solubility of different particles in a solvent, et cetera are going to have a kind of very much important major relevance to the separation process.

So the material type, whatever is there that is again a kind of important way of separating these particles, whatever these solid-solid systems are that you can make a kind of operation. Some examples, like depending on the material type or we have a kind of froth petition, we have a kind of magnetic separation, we have a kind of leaching, etc. These kinds of things are based on the material type that we are using for the kind of a separation of the solid-solid systems ok.

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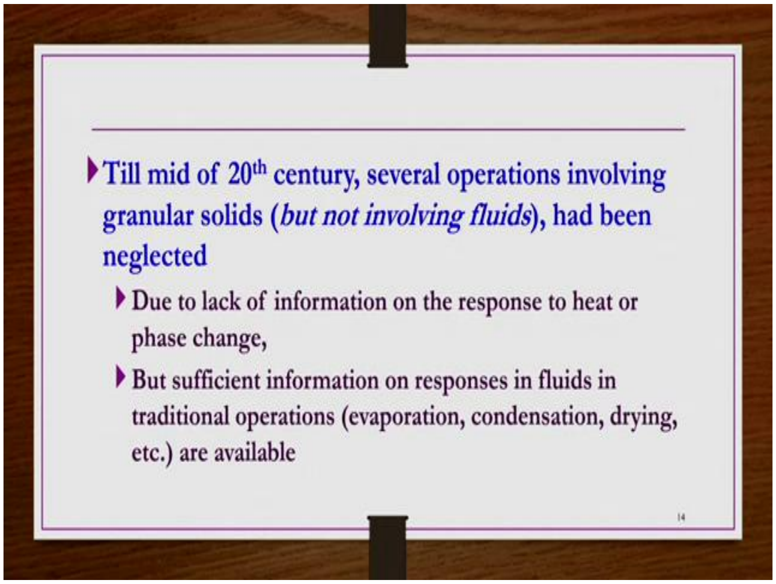

However, having seen these many applications or you know, having a particulate matter involved in this kind of unit operations, despite of this, their importance, their relevance to the chemical industries, especially chemical material processing industries if not alone chemical industry but also including other material processing industries. The unit operations which are involving purely granular solids are neglected till mid of the 20th century right. So whereas the unit operations involving fluids, lot more information is there and then they have been taken properly care because the handling fluids is a kind of easy compared to the handling solids.

Handling solids are transporting solids in plant is a very much difficult compared to the handling of the fluids in a given plant. That is the reason you know why they have not been given kind of important priority because of lack of information on the response to heat are faced in let us say fluid is there. If the fluid is there, when you apply energy to eat, how it is going to response. Those kinds of responses of a material are available for different type of fluids. Indeed, almost all kind of fluids, they are available.

That is the reason fluids are properly handled, but when we apply certain kind of heat to the solids or when we try to make a kind of phase change of the solids you know what happens, the response information is not available. The response information is not available for the case of granular solid that is the reason many operations, many unit operations where granular solids are there, you know have been neglected to the larger extent till mid of the 20th century.

However, nowadays lots of research is going on onto this granular all its case. And then so many kind of, you know, methods are coming up in order to handle these granular solids. But we will be discussing whatever the existing knowledge about these granular solids, anyway. So sufficient information on responses in fluids, in traditional operations like evaporation, condensation, drying, etc are available. But in the case of the solids, their response to heat or phase change are not available that is the reason the unit operations involving granular solids have been neglected until recent past.

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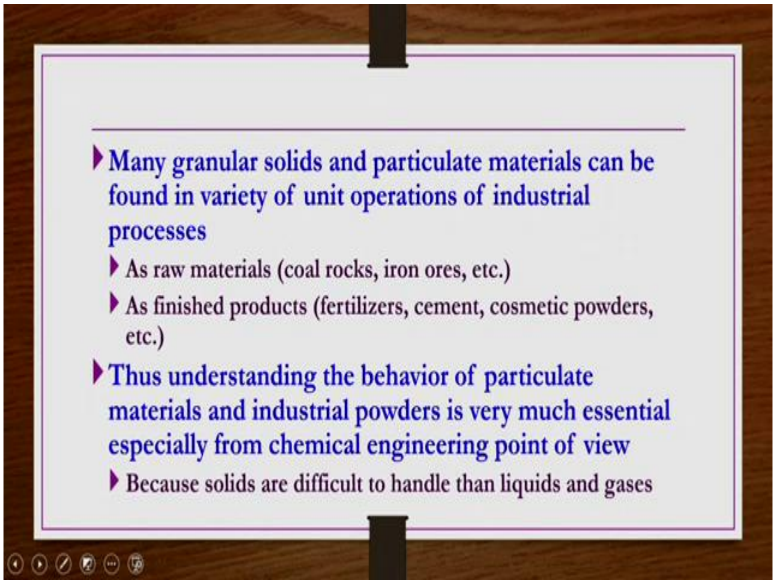

Further many Granular solids and particulate materials can be found in variety of unit operations of industrial processes, material processing industries. They may be appearing as a kind of raw materials, they may be appearing as kind of finished products, as fertilizers, cement, cosmetic powders, et cetera. So because of this reason also we need to study the details of this transport of this granular solids, not only transport, their processing also, we need to see, because they may be occurring in many material processing industries, either as a kind of raw materials, or as a kind of finished product, both way they are involved.

So that is the reason we need to have a kind of basics about this for all these kinds of processes in general. Since they are appearing both as raw materials as finished product, it is very much essential to develop a kind of information or the behaviour, particulate material behaviour and then industrial powder is very much essential, especially from chemical engineering point of view because solids are difficult to handle than liquids and gases in general. So that is the reason we need to have a kind of special attention is required for the kind of unit operations involving these kinds of granular materials.

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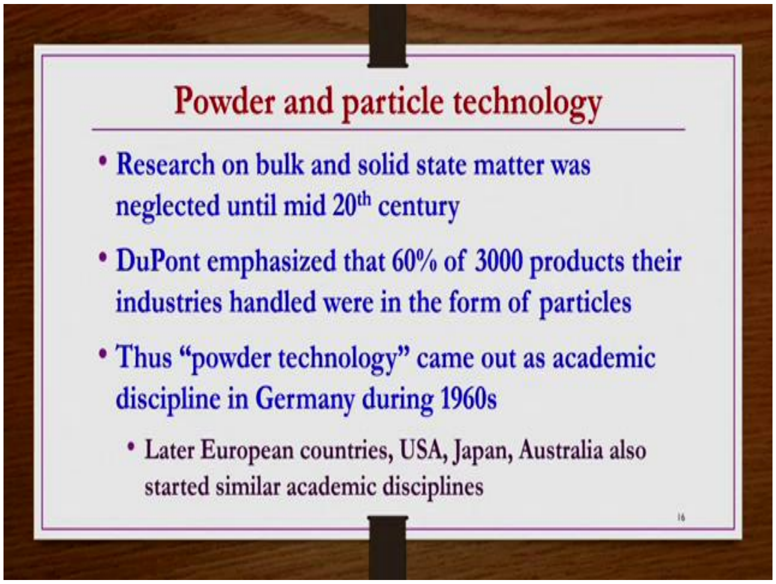

Then how to define a powder in general that is important or what is the basis for powder and particle technology? As I mentioned already, the research on bulk and solid state matter was neglected until recent past, especially from Chemical Engineering prospective especially from a unit operations prospective right, but DuPont company, what they emphasize, they have a more than 3000 products and out of those more than 3000 products, more than 60% not less. I mean like more than 60% of their products are handled in the form of particles, right? Not 1 or 2%, 10%. It is now you can realize the importance of these particles DuPont to emphasize that 60% of 3000 products that their industries handle in the form of particles.

Not only kind of products either as a kind of raw materials or any other kind of products, whatever they form there, but 60% of them are handled as a kind of particles. Thus powder technology has come out as a kind of engineering discipline in Germany during 1960s and then after that other countries like, you know, European countries, USA, Japan, Australia have also started similar kind of academic disciplines

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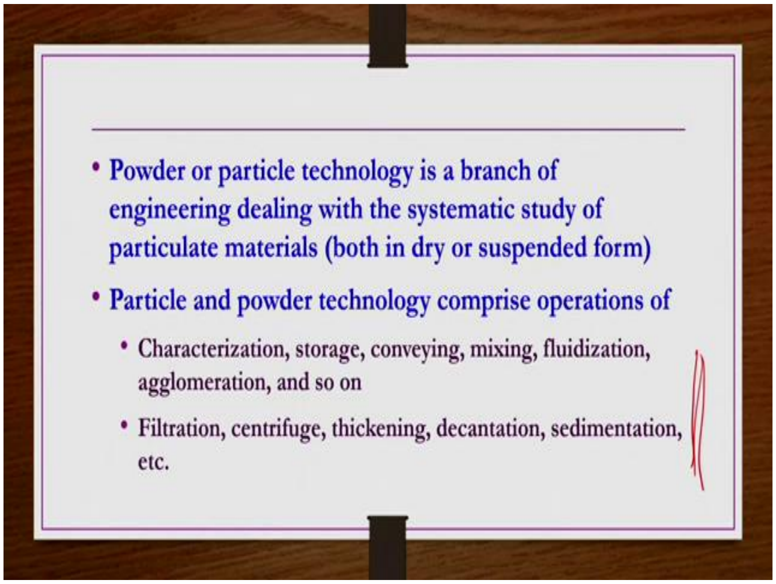

Powder or Particle technology is a branch of engineering dealing with the systematic study of particulate materials both in dry or suspended form. This is how you can define what is a powder or particle technology, this you can define it as the powder or particle technology as a kind of branch of engineering dealing with the systematic study of particulate materials both in dry or suspended form. So particle and powder technology in general comprises operations of some kind of operations like characterization, storage, conveying, mixing, fluidization, agglomeration and so on. They also have a kind of operations like filtration, centrifugation, thickening, decantation, sedimentation.

Indeed we are going to study all of these kinds of operations, uh, working principles and then, uh, related equipment, their operation, operating methodology, et cetera, all those kinds of things we are going to study in this course.

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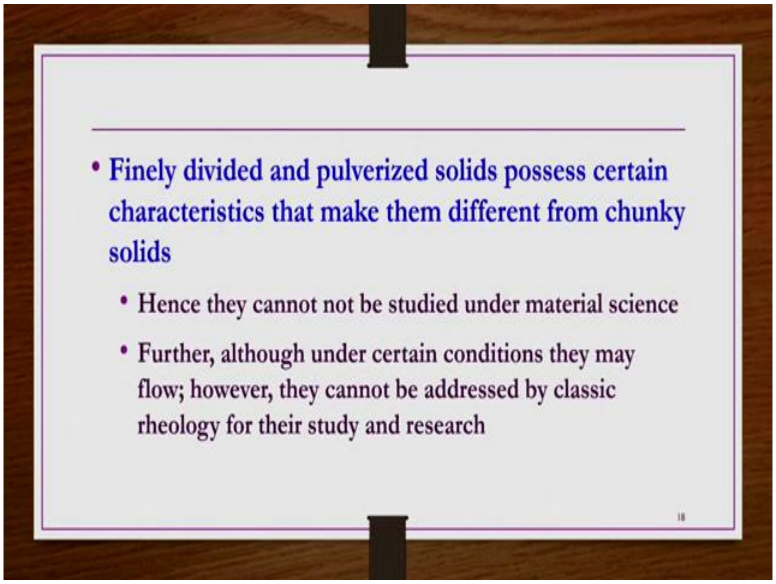

And then further, finely divided in pulverized solids possess characteristics that make different from chunky solids. So because of this, whatever the finely divided solids are, there, they behave very much different from the chunky solids. So then we cannot club them together and then cannot be studied under the material science category further. Further although some of this material, this powder, they flow under certain conditions, but they cannot be addressed by classical rheology for their study and research. So, neither they can be taken under the material science category nor they can be taken a kind of rheology kind of category. So we need to give a special attention for these kinds of particulate matters.

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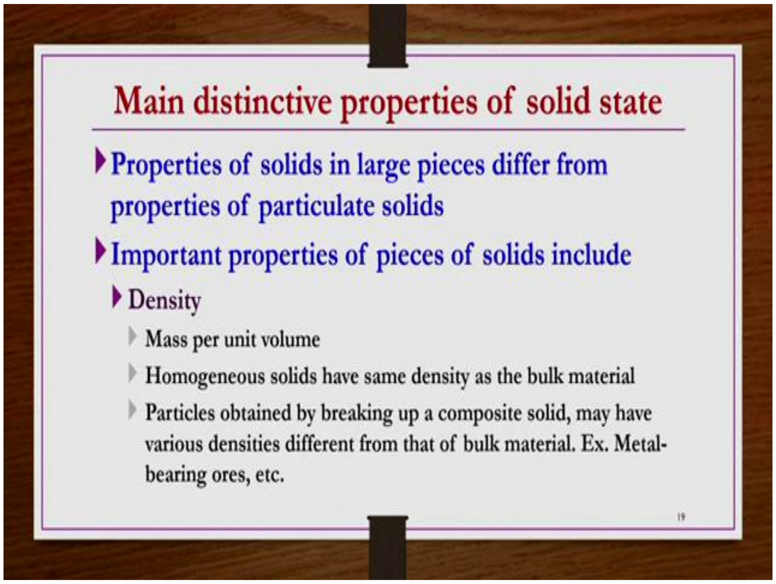

So what makes distant two properties of solid state in general that is what we are going to see right. Properties of solids in large pieces in general different from properties of particulates solids in like in a particular, small particles. When you make a kind of granular solid, you know their properties are very much different from the large bulk pieces of the same material right. And then some of the important properties of the pieces of solids that include the density where it is mass per unit volume.

In general if it is homogeneous solids, then they may have the same density as the bulk material. The small pieces of solids may have the same density as the kind of bulk material if the solids are homogeneous, then particles obtained by breaking up composite solid. Then we may have the various densities different from that of the bulk densities because whatever the solid was composite solid made up of the different elements. So then when you break them out, obviously it is possible that you are going to have a kind of a different densities different densities and they are different from that of bulk material example, metal bearing ores, etc.

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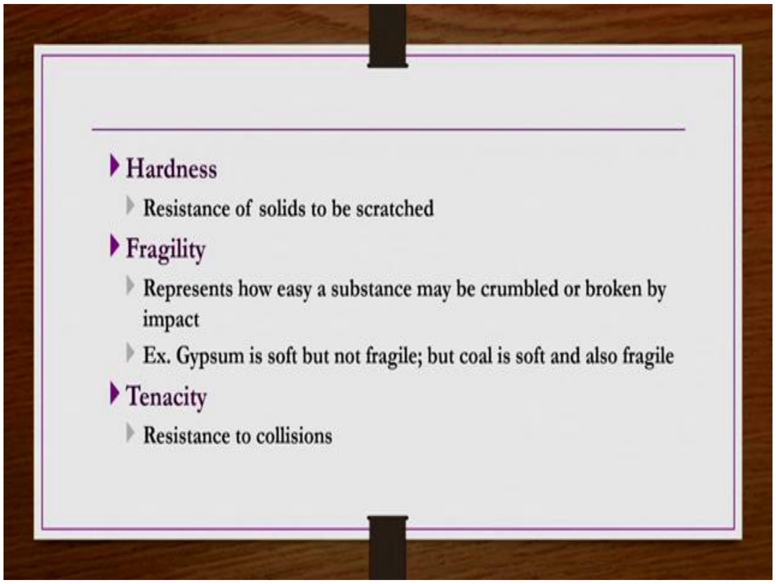

The next property hardness, resistance of solids to be scratched is again different for small pieces of solids compared to the bulk solid materials. Similarly fragility, the fragility that represents how easy a substance maybe crumbled or broken down by impact that is also different for the bulk material as well as the small pieces as granular material of the same material. Example, gypsum is a soft but not fragile whereas the coal is soft as well as the different material. Then tenacity is a kind of characteristics where it tells about the resistance to collision. This is also different for the kind of bulk material as well as the kind of a particulate material, particulate matter of the same solid.

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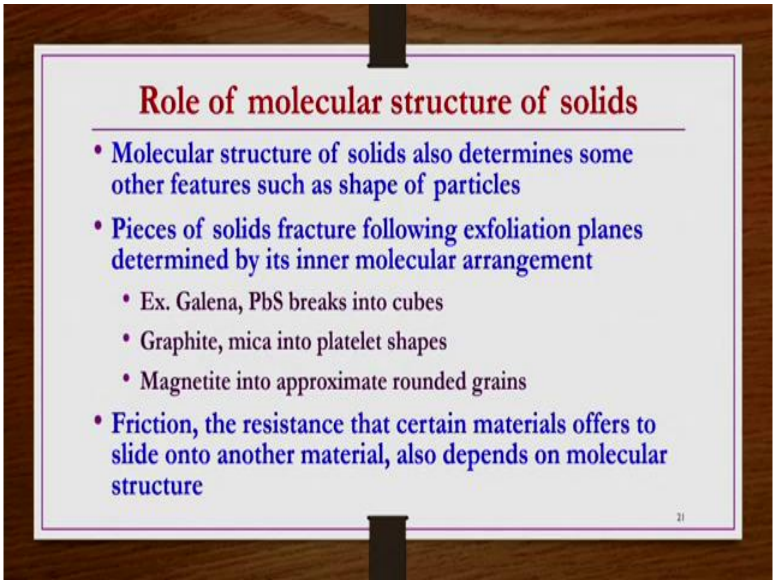

Then sometimes if you see when you break the big lumps of the solution to the smaller fraction. So then in general if you observe, you can find that some of them are breaking into a nearly round shape, some of them are breaking into kind of platelet shapes, et cetera. So why that is happening why all of the material are not breaking into a kind of almost rounded shape or almost like a platelet chips, why it is not possible because the molecular structure of the solid is also playing role, right because of the molecular structure of the solids or depending on the molecular structure of the solid, this the broken material will take a kind of different forms.

So pieces of solids fracture following explosion planes determined by its inner molecular arrangement. So example, you know, Galena, PbS, mostly breaks down into cubicle form, whereas the graphite, Mica, in general breakdown into platelets shapes and then magnetite, etc in general, breaks down into approximately rounded grains, etc. Because of their difference in the molecular structure these materials also breaks down into different shapes. Further the friction that is the resistant that certain materials offers, offers to slide down to the other material in the solid phase solid form is also depends on the molecular structure.

You can see some of the materials can easily slide onto the other, whereas other kind of a solid materials, they may not able to comfortably slide on to the others. Let us say if you have a kind of almost a rounded grain, so they may be comfortably sliding onto other, but if you have a kind of platelet kind of a particles, then it will, the friction is more and then particles may not be able to slide onto other or they may not able to flow comfortably that is also because of the molecular structure.

So then having seen these things, we indeed required to study about the particulate matters. So in order to study about the particulate matters, we should know the characteristics of the particles. What are the important characteristics of the particles, how many of them very much important to be considered as a kind of a part of the curriculum? How many of them are the kind of having smaller in influence, those things we have to have.

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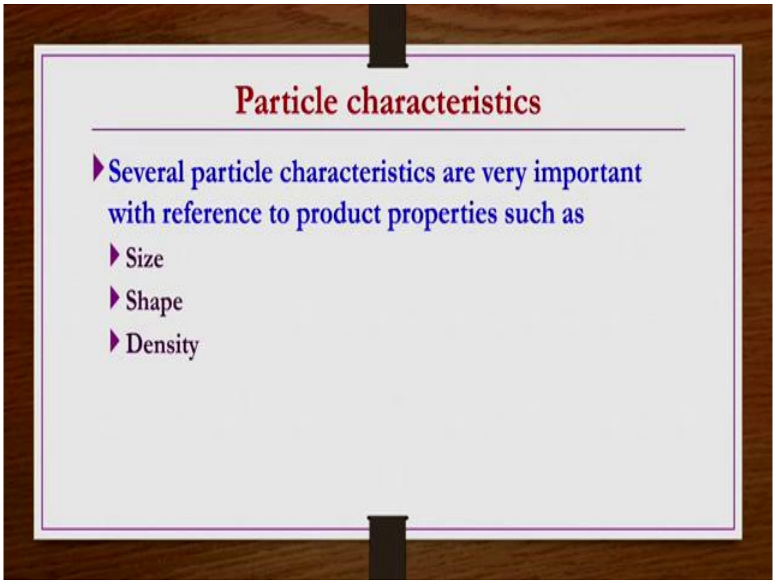

So primarily the several particle characteristics are very important especially with reference to the product properties and then some of these properties are like, you know, size is very much important based on the size only you are going to decide each involvement in unit operations or unit processes, then shape is also very much important then density. These three are the kind of very much essential kind of particle characteristics, especially related to the granular part, particulate solids, transport and their processing in unit operations.

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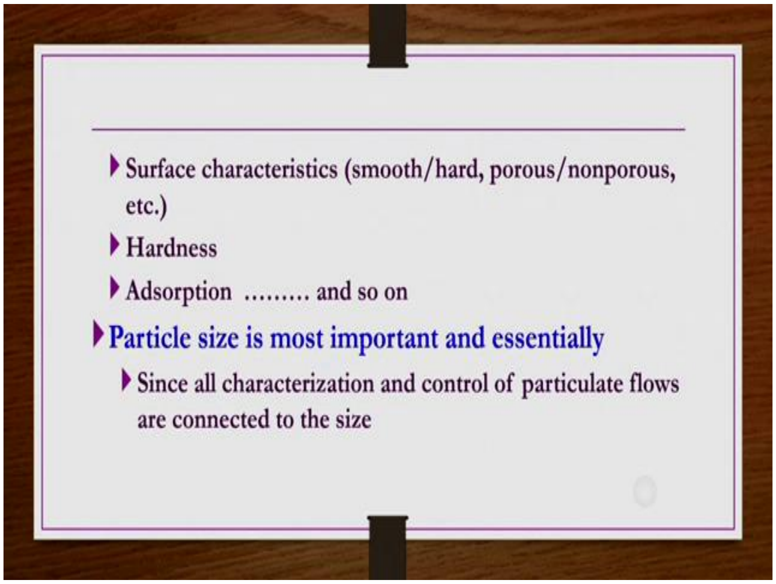

But however, in addition to these things, there are also kind of other characteristic like surface characteristics, smooth, hard, porous, non porous, etc are also important hardness, adsorption and so on so like that, if you keep on listing out, there are so many kinds of properties, but primarily we will be studying the size, shape and then density of the particulate matter in this particular module. Then we will go into the remaining, unit operations related to this particulate matters.

Particle size is most important essential because since all characterization and control of particulate flows are connected to the size. The design or operations are one way or other way, they are connected to the size of the particulate matter that we are going to handle in a given unit operation. So that is the reason size is a kind of very much essential.

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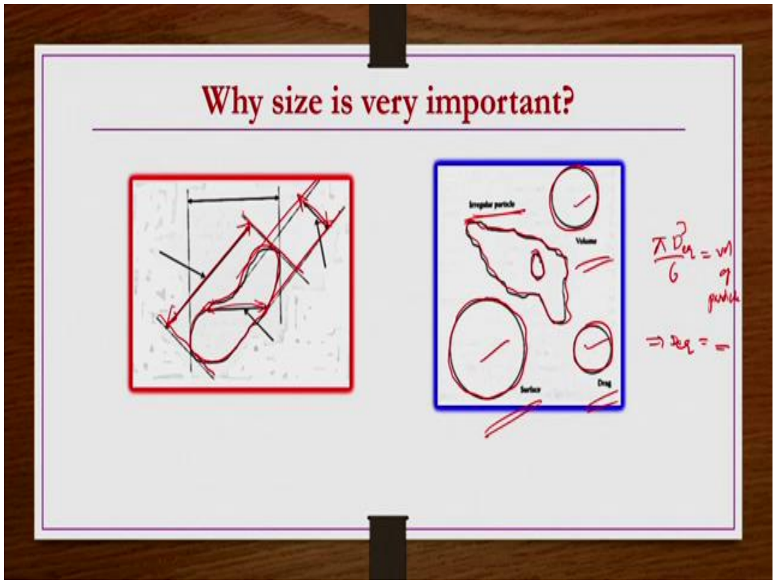

So why size is very essential in general, which size should be taken. That is again the important question. Let us say if you have big rocks of like coal bulk coal material you have in the kind of bigger size of the diameter, let us say a few meters approximately size of few meters. When you crumbled or break them down into the smallest mar fraction, it is not necessary that all of them will be having the same shape. It is not necessarily that all of them are having a kind of uniform size it is not possible. When you break them in general in reality, you have a kind of very unstructured material.

Indeed, one particle will never be same as kind of any other particle given in the system. That is almost all particles will have a different size, different shape, etcetera. You will never have two particles exactly same in any given process in general, especially in industrial applications like this right. So then so then under such conditions which size should be taken, let us say after crushing the particles, grinding them, smaller ones let us say if you have a kind of particle size of this particular shape let us say then you have this many dimensions.

This is the one dimension, larger dimension of the particle. So in your design calculations, should you take this, uh, this size of the particle, there is a kind of a minimum size of the minimum dimension of the particles so that is this size. So that is this minimum size of this particle. Should you take this one or should you take the maximum one? If you take this along this cross-section so this is no here, this is a kind of intermediate one neither so large neither so small but it is in between of these two. So should you take this one, which particle size should you need to consider for your engineering calculation. So that is very much important.

So in general we are going to have different types of representing the particle size anyway for a given system, but again for individual particle there is a kind of a equivalent representation that is also we are going to study in the next lecture. Equivalent representation let us say now we have a kind of particle here of this particular shape as shown here with the kind of hallow holes, something like this right. And this is the regular particles same as like this one more irregular particle that we have. No, if you wanted to have a kind of engineering applications, if you wanted to kind of represent in a kind of equivalent diameter.

So different types of equivalent diameters are the, it is not possible to have say that this particular equivalent diameter is going to be more reliable and the other one is a kind of less reliable it is very difficult. Why? Because let us say, if you wanted to define a size for this particle, for this particle based on the volume equivalent sphere diameter, that means whatever the volume of this particle is there that you equate to the volume of the spherical particle $\frac{\pi D^3}{6}$ And then that D_{eq} that you take. So that is $\frac{\pi D^3}{6}$, D_{eq} we say, right, this is the equivalent volume of this sphere , and then this equal to volume of particle, whatever this volume on this particle is there from here, whatever the equivalent you get, you will get some value.

So that value if you pictorially represent, so that is this one. Let us say, if you take surface equivalent or sphere diameter, that means, so whatever the surface of this particle is there that you measure and then that value you equate to the surface of a spear and then from there you get the equal in diameter. So that surface equivalent sphere diameter if you take that is having a bigger size like this compared to the previous case volume equivalent sphere diameter. So likewise there are many other kinds of uh, equivalent diameters are there, settling velocity and all those things. One such kind of representation is the drag equivalent diameter that is, you know, you take this particle and then settle it in a kind of Newtonian fluid. What is the drag of this particle? The drag you equal to the drag of a sphere of equivalent diameter from there, whatever the diameter you get let us say that is drag equivalent sphere diameter given by distinct.

Even by different equivalent representations also you are getting different sizes, different numbers.

Not all these D_{eq} are same. This D_{eq} is different here. This D_{eq} is different. This D_{eq} is different here so which one should we choose? So that is the reason this size is very much important factor. That is what we are going to see in the next lecture, the size of the particles. We are going to represent the size of the particles. And then how to do the calculations and all those things we are going to see in the next lecture.

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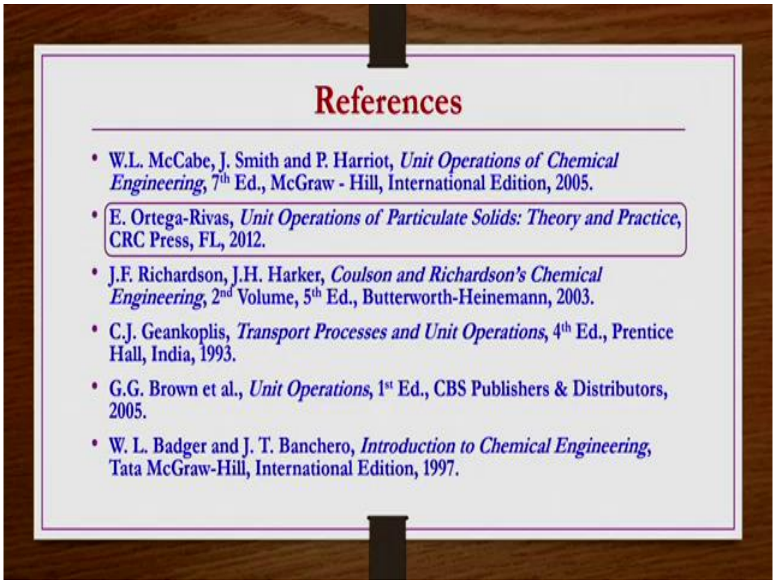

So the references for this lecture are, you know, given here. So I have not used all of them. Um, primarily the source for this lecture is taken from the second reference Unit Operations of Particulate Solids Theory and Practice by Ortega Rivas. Thank you.