Fundamentals of Materials Processing (Part–1)
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Introduction to Powder Processing Continued…

So, we will looking at advantages of uhh powder processing.

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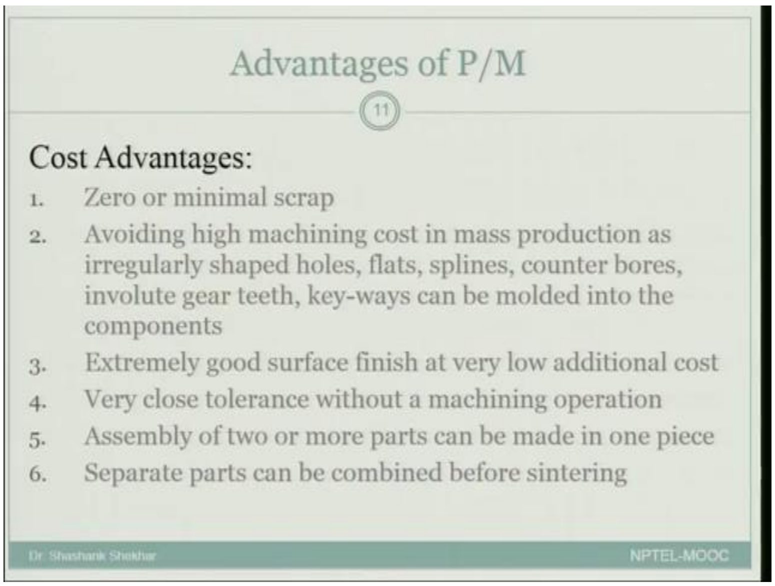

One major advantage of powder processing we looked that was cost advantage and when we say cost advantage one thing you must keep in mind you should want make in that say one or two parts then this is not the advantage we are talking about then you cannot use cost advantage it is only when you have to produce large number of components of the same shape and size then we will get this kind of advantage because once initial there is always a uhh investment cost associated with powder processing as we saw there are huge equipment's involved in in this process.

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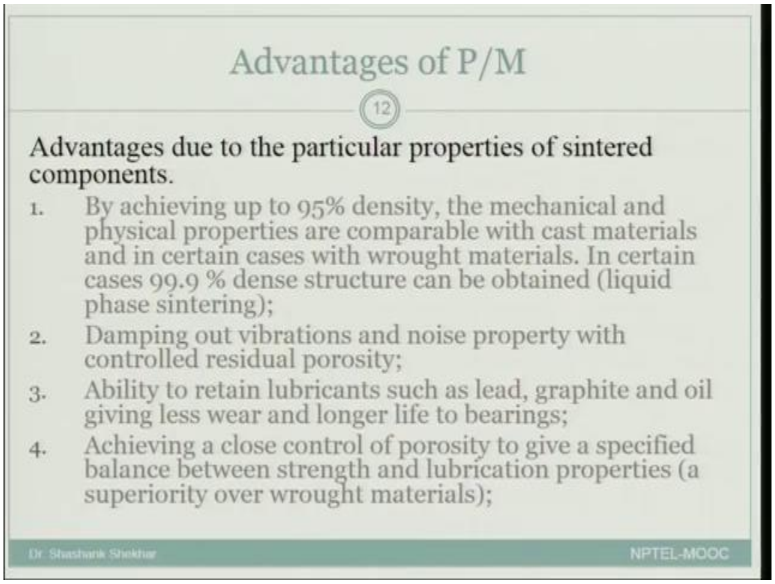

So, the other uhh advantages of powder processing are listed here it will (littlte) these are related to the properties that you can obtain from the sintered components. For. example, by achieving up to 95 percent density by powder processing mechanical and physical properties are comparable with cast materials. So, even with a 95 percent uhh of theoretical density that you will obtain using traditional sintering for powder processing you will start to get properties which are mechanically and physically comparable to the properties that you will obtain for a similar component manufacture by using say casting and in certain cases it may even uhh exceed the proper ties of casting and may be similar to that of wrought materials rock or the processed material for. example, by using rolling or something like that.

So, you may even get properties like that and that is the possible because of several reasons. One is that when you do it by powder processing the powder size are very small. So, the grain sizes you get a very small so, get a high strength extra. Second is that it is much more homogeneous whenever you are doing casting you saw that there is micro segregation and then there are dendrite’s because of that there is anisotropy in the property remain after uhh secondary processing or for the after wrought processing for. example by rolling, how to include rolling anisotropy that is still some amount of an isotropy which is not there when we are getting that component or the material manufactured using powder processing.

In certain cases, 99.9 percent denser structure can be obtained and what we can uhh we can also obtain liquid phase sintering meaning the one of the phased is can be in liquid state and then you can get very very denser structure, because then the liquid will be able to impregnate even the smallest of the pores and fill and so, you can see that how much better properties you can obtained in powder processing.

The properties uhh that you obtained in powder processing we saw that there is some amount of porosity. So, even though you have (mechanical) the mechanical properties you are getting 95 percent theoretical density which means 5 percent there is porosity but these porosities need not always be a bad news you can get some good (pro) good properties out of it, one of it is damping out vibration and noise property with residual porosity.

So, because there is porosity then it also this particular material when you manufacture using powder processing is able to damp out vibrations and noise. So, you see it is uhh instead of becoming a drawback it become use it as an advantage. Ability to retain lubricants. So you remember we said for. example, in bearings you can this porosities can be used as uhh places where lubricants can set and therefore, you do not have to worry about to giving uhh extra tolerance or extra space for allowing those lubricants, because there is porosity the oil or the lubricant can set inside that and provide uhh you can say inherent lubrication to components size such as bearings or pistons.

So, ability to retain lubricant such as lead, graphite and oil giving less wear and longer life. So, you will be able to get less wear and longer life because of these porosities. So, uhh keep in mind that uhh porosity in general would be uhh drawback when we talking about mechanical strength extra but you can use it as uhh advantage in some other places and two of those are as vibrations and lubrication. Achieving a close control of porosity to give a specified balance between strength and lubrication properties and so, you can also design now that you know that porosity has some advantages.

You can design so that the strength is only uhh compromise to only basic strength and in exchange for that you are getting some lubrication property or you are getting some vibration or control properties. So, (you are) you can achieve that close or control on the desired property that controlling the porosity which is a superiority over rock materials.

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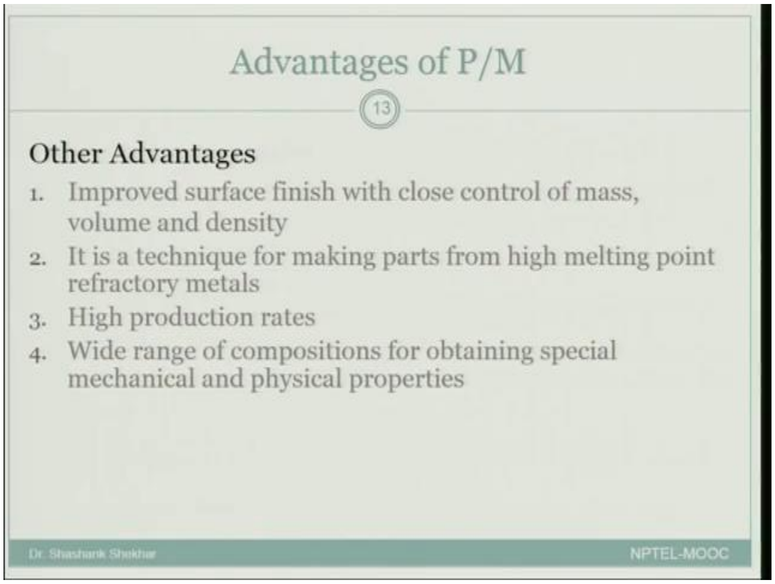

Even the other than these that may be some advantages which for. example, improves surface finish we have already said as we have looked at it that because we are compacting and very high temperature you can get very good surface finish and get the contour sets or the curve, die that we are using uhh with close control of mass, volume and density.

It is a technique for making parts some high melting refractory materials. So, even a material like tungsten which has very high melting point which you will not prefer using casting technique can be manufactured using powder processing. High production rates. So, once you have in the step the cost and we getting those press you can get very high production you can easily manufacture just like we have to keep pressing then sintering and then we have the component ready. Wide range of compositions for obtaining special mechanical and physical properties.

So, it because we are able to use metals as well as non-metals. So, you can get wide range of composition for obtaining special mechanical and physical properties. So, this is another very big advantage uhh which we have been emphasizing again and again about powder processing.

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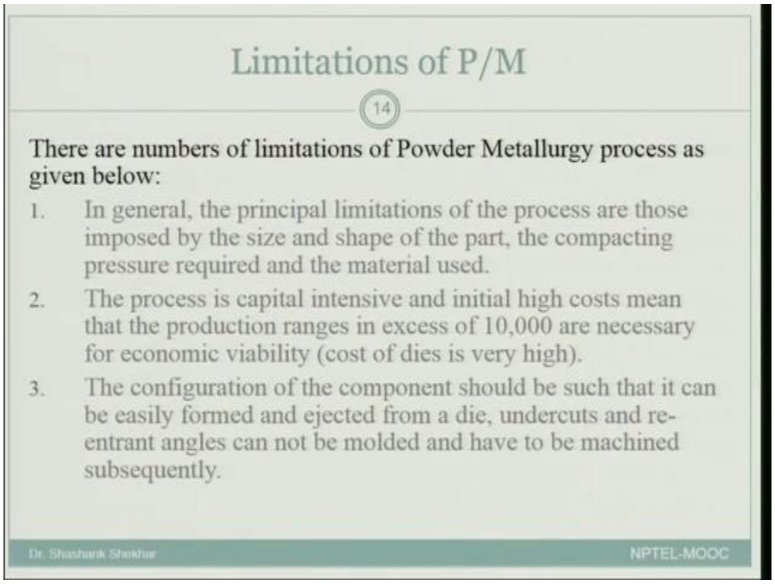

Now, but we have uhh looked that advantages. It is also time that we talked about some limitations. Its note that powder processing can be applying everywhere and for all the kind of materials. So, what are these limitations? In general the principle limitation of the process are those imposed by the size and shape of the part.

The compacting pressure required and the material used. So, like I have already mentioned when we talking about the equipment required. So, usually 100 to 300 tons equipment's are required for those small gears that we manufacture for hydraulic, mechanical parts or automotive parts but if you start to think about manufacturing very large components then it will be you need very very large press and therefore, that becomes a limitation.

In general you will uhh those equipment will cost very high. So, your cost will become uhh larger than other kinds of fracturing techniques and even in the uhh so press you have you may have some material which are very high strength, and in that case you may not be able to compacted using uhh your present abilities of your equipment. So, these are the limitations. So, depending on the size of the press you have on the size and shape of the component that you making and the material that you are using there is only so many components that you can make out off by using powder processing technique.

The processes is capital intensive, remember we have always saying cost advantage but we never said that initial cost there is initial cost advantage. Initially we have to getting a lot of capital to get re-equipment's and there is initial high cost always involved and that means the production range in excess of 10,000 are necessary for economic viability. These are some rough numbers that you can find through internet when we look about powder processing.

So, only if you are planning to make some 10000 of for component that powder processing may become uhh advantageous in terms of or may be become then it may break even. The dies that will be involved are also very expensive it's note the uhh you can just try out several dies to find out which particular component is suitable for you. So, even the dies are not uhh very low cost they involve a lot of high cost. The configuration of the component should be such that it can be easily formed and ejected from a die, under-cuts and re-entrant angles cannot be molded and have to be machined subsequently.

Remember we saw all the components that were manufactured where 2$5 dimensions. They did not have any complexity in the third dimension and that is because of uhh nature of the process you are compacting that is what pressing from bottom and up. So, the die can or the design can have complexity in this plane you can have whatever complexity want in this direction but in the third direction that is the direction which you are applying the load you may not have much complexity.

So, you cannot undercuts, re-entrant angles. So for example, there is some shape like this. So, there is again re-entrant angle or there is under-cut these kind of shapes will not be possible and uhh what you will have to do if you are planning to make such such a component is you will make a much more general component and then you have to machined it. So, in those cases you may have to do the secondary operations but as per as the overall shape and size is concern you do not its near net shape process and you do not need any secondary process.

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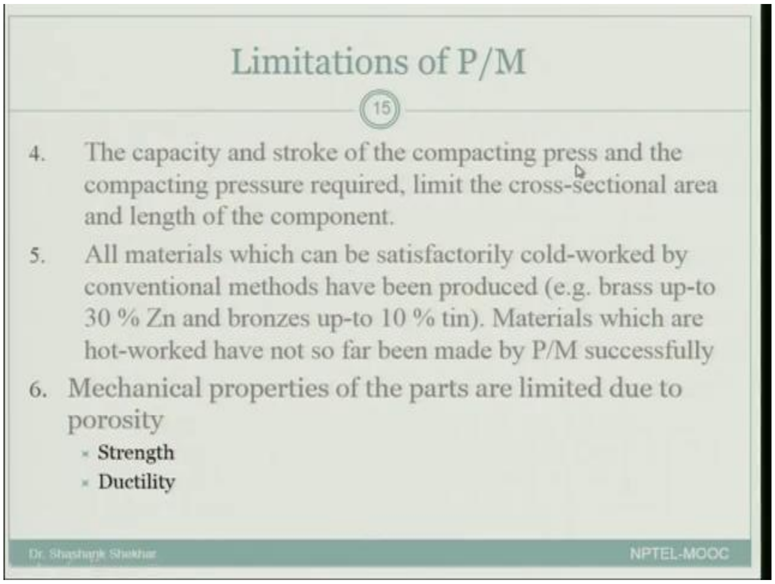

The capacity and stroke of the compacting press and the compacting pressure required limit the cross-sectional area and length of the component. So, for the size is also limited by what is the press size in the we have already seen. What is the total tonnage capacity but it is also limited by the stroke of the compacting press.

So, for example, if you start to think that I can make a pipe out of it. It is 2$5 dimension in the that it has complexity in less dimension and this side it is similar in the shape but if you try to press a die or pipe like this then you will find that the total stroke length that is available in the press may be limited and so, the pipes you that you want to make cannot be made.

So, again the stroke of the compacting press an also limit the uhh size and this can also limit you can also limit the cross-sectional area and so, this is another limitation in terms of shape and size that can be obtained. All materials which can be satisfactorily cold-worked by conventional methods have been produced. So, another disadvantage here is that uhh the material should not have so much high strength that you are not even able to compact it. And the usual rule of thumb is that all the materials which can be cold-worked by conventional methods have can be produced by uhh powder make processing. For example brass different uhh alloys of brass or bronze which are copper alloys but material which have to be hot-worked are not so very successful.

Of course there are very several examples but they are not term most you can say the preferred route should not be powder crossing is not usually the powder processing, because the stresses required would be very large even for a small component. And the last and the most important limitation of powder processing is the mechanical property. So, you saw that when we the talking the porosity that mechanical properties like strength and ductility and toughness are related to porosity higher the density or lower the porosity higher is the strength and toughness.

So, if you are not able to get very good density or if your porosity is high for some region uhh it may be because you are not able to apply the very large stresses or because your die design in such that you cannot compact it beyond that then those cases the strength and ductility will suffer and so, you will not then you may not be able to get some structural components manufacture.

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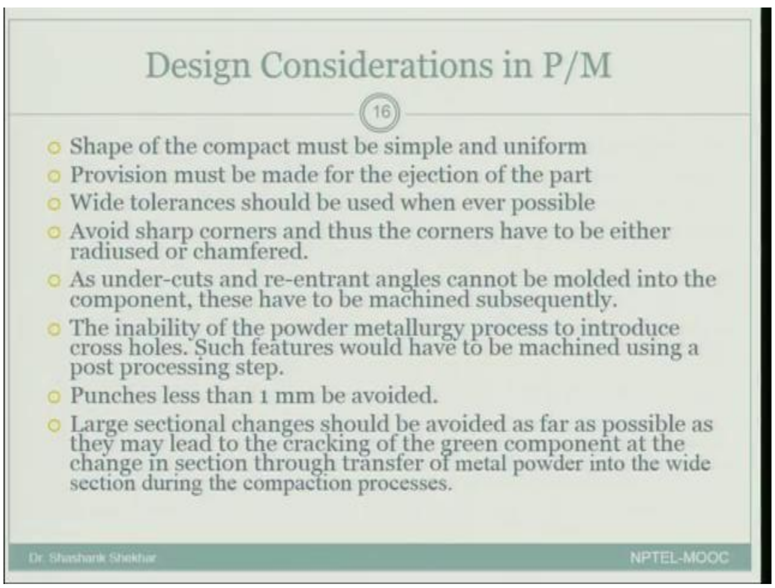

So, design configurations in powder metallurgy. Now, that we have understood all the basics basic introduction of powder processing. It is time we can put together what are the basic design considerations regarding powder processing? Shape of the compact must be simple and uniform, right? The 2$5e dimension rule. So, the shape of the compact that you are trying make must be simple. It can can have some complexity in the plane but not much complexity in the desired direction where you are applying the stresses along the along which the stresses.

Provisions must be made for the ejection of the parts. So, remember we could not make re-entrant angles or complex step like that and it was because it will not be you cannot eject it from the piston after compaction. So, the provision must be made for ejection of the part so when we designing you must see that you can eject out the component after taking away when you have first apply the stress to the piston and then the piston goes back. So, after that you should be able to eject your component out of that die. It you are not able to eject it means it has some re-entrant angle or some complex parts which is uhh which is interfering with the ejection mechanism and probably you need to simplify the design.

Wide tolerances should be used whenever possible. So, usually you will get very tight tolerances but if you wherever possible you should be able to use wide tolerances. Avoid sharp corner and thus the corners have to be either radiused or chamfered. Now, you can imagine that if you have a very very sharp 90 degree angle like this if you press it and then try to eject it this edge what will happen to the edge.

Edge will be very fragile because particularly at the stage of green compact where it has not really bonded at the microstructure level. So, this can be fragile and can break away. So, you have to be uhh it will be best if you can make radius out of it or make a chamfere out of it. That way this will no more be your week your week point or it may not break during making of the green compact. As under-cuts and re-entrant angles cannot be molded into the component these have machined subsequently.

So, you cannot uhh think of any die design where you can have undercuts and re-entrant angles. These must be machined subsequently. The inability of powder metallurgy process to introduce cross holes. So, if you for example, a looking for a 2 dimensional shape like this but cross angle or cross will perpendicular to the direction of the applied phase that is not possible. You can always have uhh holes like this but making holes like this is not possible and such features will have to be machined using a post process step.

Punches less than 1mm must be avoided because using very large stresses in the punches that you are using it may be because of the die design that you have if it is in very small say less than 1 millimeter then it is very easy to buckle and break. Punches less than one millimeter must be avoided. Large sectional changes should be avoided as far as possible and we will see at one stage the there is a pressure gradient whenever even though you are applying uniform pressure but inside the material there is a pressure gradient.

So, some of the surfaces do not receive as much pressure as the top surface and because of that if there is a gradient in the shape then it will that gets exaggerated, you will have much more pressure gradient and therefore, for some parts some of the cross sections may not be compacted to the same extent as the surfaces as the components on the uhh top surface and therefore, you should avoid large sectional changes.

So, as it may lead to cracking on the green component have the change in the section through the transfer of metals. So, one is a large gradient and the other is sudden cross section change even a sudden cross sectional change (should bi) should be avoided because it can lead to cracking of the green component at the change in the cross section. So, uhh at remember at one stage you have to eject out the component and if there is very large cross sectional change for. rxample you it start with a 10 inch and suddenly go to 2 millimeter then there is very large cross sectional change. So, one even when you are applying pressure it will not be uniform. For this two millimeters diameter and for the 10 inch diameter.

Second when you are trying to eject it the green mold may break and that is mainly because the pressure not uniform. So, these are some of the important uhh design considerations that we need to be aware of when we are talking about the powder processing. So, now we have looked at some brief introduction about uhh powder processing, it is time that we move on to the second on powder processing which is powder characterization. So, remember this is our overall layout of the powder processing module. So, we have talked about introduction. Now, let us get to powder characterization.

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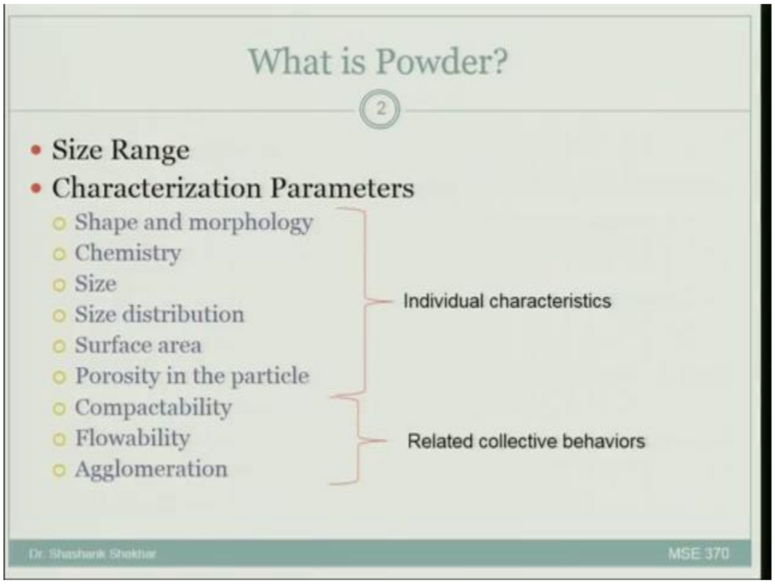

So, when at one stage in the one of the previous lecture when I was talking when I was started talking about powder I said you must be start thinking about what should be called as powder range? Powder or particulate matter. What is that range that should be called as uhh powder and not let say we cannot call few inches as powder like that will be called as rock. If you go a little smaller uhh then you will call them pebbles and if you go even small you call it granules.

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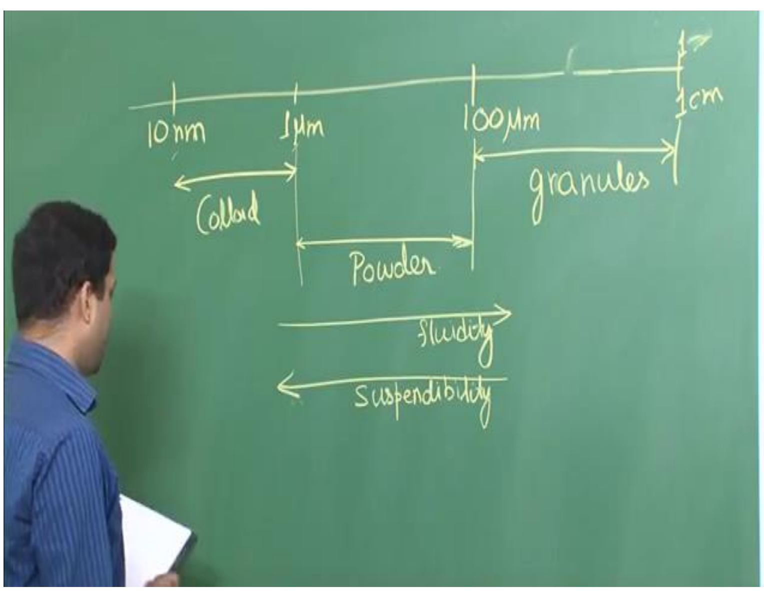

So, at what size do you think we should called powder? So, let us take a look over here on the board and uhh let us say I have a ranges like this, if I make a scale and I say 10 nanometer is it powder? Then I ask one micrometer is it powder or I say 100micrometer is it powder or if I go let us say 1 inch not even 1 inch, we are talking about meter, so let me say 1 centimeter. Is it all powder? Let us say we have uhh we have not even talked about shape yet.

Let us say all of them have similar shape. Let us say all of them are spherical. So, can we call this as a powder? Can you call this as powder or what will be called as powder that is something we should ask? And if you go through the literature you will see that this range is usually defined as colloid? These are very fine particulates and not usually grouped together with powder and when you go to this range this is usually called as granules or granular material.

It is this range that is usually classified as powder. So, now that we have the range of the powder. Let us look at some specific uhh quantities that we that we may have always be interested in. For example fluidity, what is fluidity? The ability of the powder particles to flow. So, if you keep increasing the size of the powder particles then it is becomes easier to flow, you can imagine the sand particulars or sand particles or sand granules and you just take in your hand and uhh tilt to your hand the sand particles start to fall down and that is that looks like flow and sand start to flow you always say that sands has to flow. So, that is the term we are referring to as fluidity.

So, the larger the particle fluidity will be larger if it is very very small it will not flow. For, example, uhh think about uhh the talcum powder. So, if you put it like this it will not fall on its own because the powder size is very small. Then comes suspendibility in some liquid medium. For example, it can be water or it can even be air. How easily it can suspend or stay in air balanced?

So, the smaller the particle higher will be itself suspendibility, you will be able to or it will be able to hold on its own in the air. So, even in uhh here over here there may be lots of these chalk powders which may be floating around in the air. So, they are suspended, they neither falling there nor the neither flowing up. So, that is the suspendibility, If it was a very large in size it would have settled down at some corner, if it is very small the smaller in the size it is still floating somewhere in the air.

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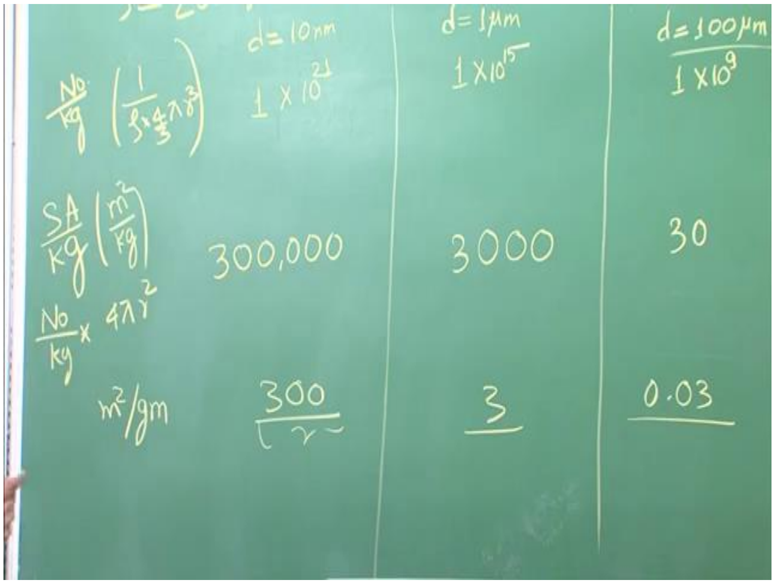

So, that is the suspendibility. Now, when we are talking about powder let us get a field of the numbers a little bit of numbers so over here. So, let us say we are talking about powder with a density two times that of water. So, it is 2000 kg per meter cube. So, it is not a very dense material uhh it is low density material 2000 kg per meter cube and let us look at three different sizes although nanometer 10 millimeter is not powder but still we will consider it for our calculation just to give you feel of the number that we are talking about.

So, these are our three different powder size. Now, what uhh the number feel that I am going to give you is number per kg. How many particles of this size are there in 1 kg? So. you take a 1 kg 10 nanometer particle. How many particles would there be? So, it is not very difficult to calculate (you can) you can say that it will be one over rho into 4 by 3 pi r cube. One by rho is the uhh number total volume and total volume per kg and divided by 4 by 3 r cube is the number of particles per unit kg.

So, can you imagine how much it will be of the order I am not going into exact details. So, you will get 1 into 10 to the power 21 particles of this size that is a huge number and if this particle size are little bit larger about uhh 2 magnitude higher that that then we are getting 10 to the power 15 and if you go toward its magnitude still higher you get this size and (these) this is the range we have describe our powder.

So, even if you look at the largest particles size we are still looking at a very very large number of powder particles and therefore, you will see that is stastical understanding of the size characterization because very important because we cannot identify or individually characterized each and every particle. Each and every particle cannot be even for a 1 kg particle we have so many millions of particles and if so you will have to have a average understanding or average realization or the characterization.

This is one number that you should be aware of or should be get a feel of another number that you should be aware of or get a feel of its surface area per unit kg. Now, if you take a very large scale or one particle which is of one kg let us say it has diameter is uhh r. So, its surface area comes out the 4 pi r square. So, how much it will be few tens of meter square? At the most but when we are talking about particles of this size 10 nanometer, 100 nanometer we will see how much it comes out to and will use the units meters per per kg to begin with and this will be nothing but number per kg times 4 pi r square.

So, we already know the number. We have to just multiply by 4 pie r square to the get the surface area in terms of meter square per kg and meter square per kg 300 thousand meter square per kg. It is not very small; it is always comparably little bit smaller. It is 3 thousand meter square per kg. And when we get to equal to 100 micrometer which is our largest uhh range that we have allowed for our powder size then this comes down to 30 meter square per kg.

So, this one you can see is also very large humongous numbers for one particle of 1 kg few tens of centimeter square actually, earlier I said meter square it will be few tens of centimeter square if you have just one particle which will be point zero zero one meter square per kg. But when the particle size are of the order of 100 micrometer we are talking about 30 meter square per kg. So, it is a huge number and therefore, so there is numbers are very large the proper unit to use would be meter square per gram.

So, you just divided by 1000 and this becomes 300, this become 3 and this become 0$03. So, even for 1 gram of particle of this size you can see, you have 300 meter square. You have 3 meter square of particles of this size surface area and 0$03meter square of this particle size. So, if you were to do some reaction at the surface this is the type of surface area available to you per unit gram huge numbers.

So, this is uhh very very large number and therefore, important that when you are dealing the powders you be aware of it. It also means that if the powder is the reactive, it will be very (high) it becomes highly active and it can actually is very uhh (can be den) or dangerous if it starts to burn, because surface area so much surface area is available and all of it will start to burn and react. So, (there will be) uhh there can be explosion only if it is a reactive material. The powders can be a little dangerous to in that sense however let us (this is) this is the kind of number that you should be aware of when we are talking about powder particles.

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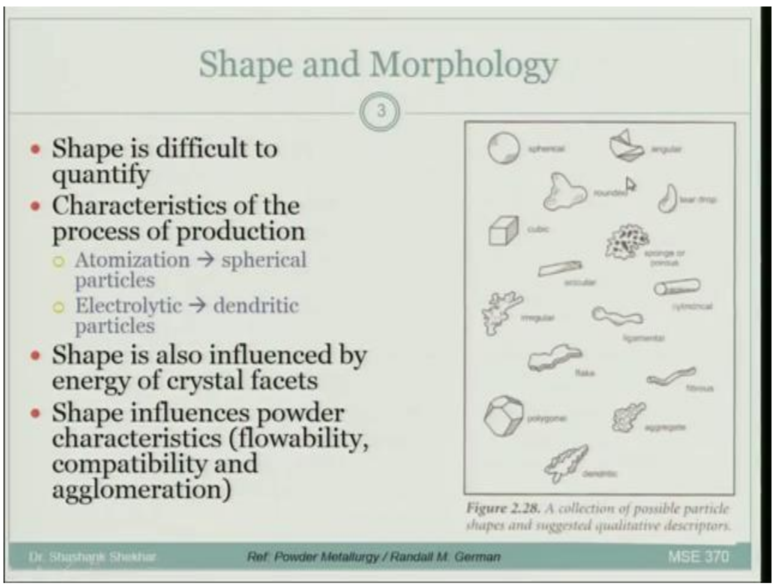

Some of the other parameters that, uhh when we talked about powder that you should be aware of are for. example, shape and morphology, chemistry, size, size distribution, surface area and even something like compactibility, flowability, agglomeration.

Now, the first of these characteristics as you can see in the slide. The first uhh sixth of these characteristics are the characteristics of a individual powder particles. On the other hand the last three have been clubbed together as a relative collective behavior. Sorry, relative collective behavior. For. example, compactability does not have anything to do with individual particle only when you have uhh lots of (())(28:15) put together then you can talk about compactability.

When you talk about flowability then is again it is one particular, if you just take one particular and try to make it flow, it does not flow. Only when you have lots of these sand particles that you may say (So) it is flowing or not if you just put one sand particle and say a tilt my hand, is it showing, I do not know(I will) you will not have any answer. It is not a individual behavior and similarly, agglomeration etcetera.

So, let us a just take a quick look at some of the some other shape and morphology and will come back to this in our next lecture. Of course most of the time we are assuming a spherical particle which is like this but that is not always the case you can get all wide variety, all different kinds of particle shape angular. So, these are angular like faceted like this then rounded.

So, these are uhh small particulates but they are rounded they do not have sharp edges that can even be cubic. For example, think about uhh sugar particles although they are not still in the size range of the uhh powder but still you can get something like this. Tear drop just you can get something like this, sponge or porous, this is very common particularly if you are using electrolytic process.

Acicular, it is long needle like shapes, irregular shapes. So, basically if you cannot define it any way, it is irregular, ligamental Swhich are long shaped but uhh not really cylindrical. So, cylindrical is also a long but (it does not) it is not squeezed at any point. Ligamental they are like look some cylindrical that is squeezed at several points, then it can be flake, fibrous, polygonal. aggregate or dendritic.

So, these are the different kinds of uhh shape and morphology of powder particles that you can obtained during different kinds of process, manufacturing process of powder. And you should also be aware that depending on what shape you are getting what is the size will you have getting your compactability your, flowability everything will depend and that is why it becomes important to understand the shape and morphology of the particles, So, we will get back to this same slide in our next lecture to discuss it further. Thank you.