Fundamentals of Materials Processing (Part–1)
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Lecture Number 39
Powder Compaction continued…

So, we will continue with this I hope you tried to solve this equation. It is not very difficult, it is point just simple log equation and what you will get over here was should like this.

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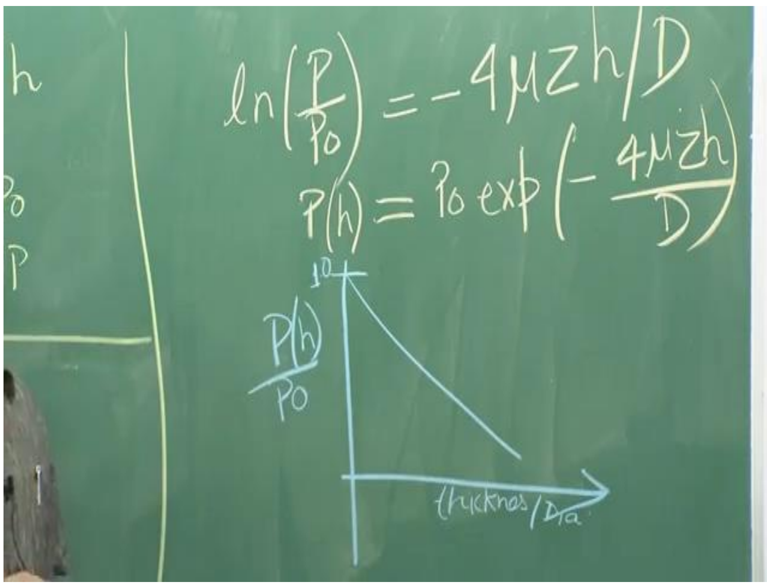

I have already given the limits and therefore, from that limits you should get or in other words p is equal to p as a function of h is equal to p not exp. So, this the form of the pressure as a function of point height h. So, if in a single compact you move from a particular height. So, let us say we would h equal to zero which means you are looking just at the surface. So, this becomes e to the power zero equal to 1. So, it is equal to p not.

So, just at the surface it is equal to p not as you would have expected and when you move away from that surface the point at which the pressure is being applied into the compact then the pressure exponentially decreases and at this point let me show you how the pressure variation looks like.

So, this is p(h) by p not and let say this is point on the x-axis we have thickness by diameter. So, this is nothing but h by D, and over here you have one point ohm meaning p (h) is equal to p not that is the maximum pressure that is being applied is what is you see that you would see at just at the surface, which you will be at this point and as you keep going on what you would expect is that it exponential decreases and this is what you would see something like this.

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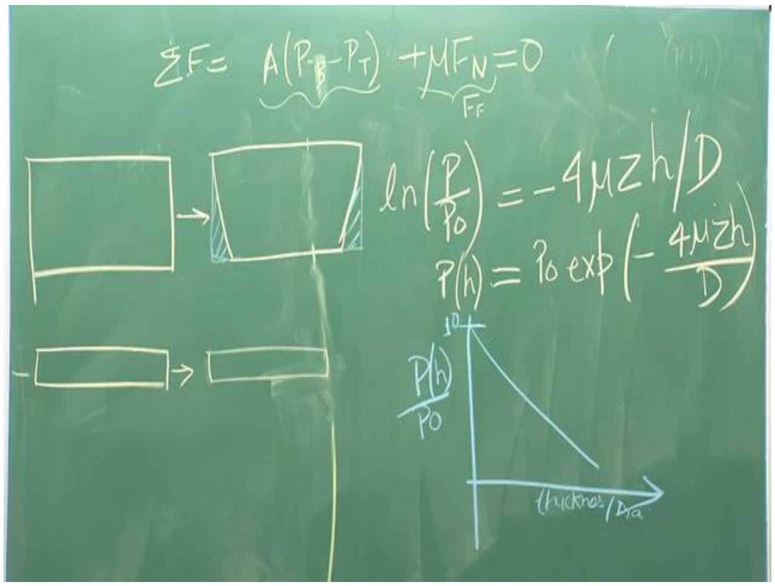

So, your pressure is continuously decreasing. Not only that it also says that if you have a much thicker sample or much thicker material then the pressure difference will be large. So for example; if I were to draw or have two different compacts. Let us say I have one compact which is like this and another compact which is much thinner. So, here the total h (you match) point upper case h is large, here the upper case h is small.

So, the pressure dropped or the pressure change (and the) or the pressure gradient from here to here is very large. Here the total pressure change delta p is much smaller, and what does that imply? What do you mean when pressure change is very large or the pressure drop is very large? It means that the density would also change accordingly. So, here you will get higher density and it will keep decreasing and you will get much lower density in the lower region (say) but here the difference would be a much much smaller.

So, here whatever density you get it will not be a much or here it will not be much smaller than the pressure than the density you get over there and that has an implication in the shrinkage during sintering. So, if you were to sinter this it will probably sinter something like this. (Why do you) why have we drawn like this?

So, you will have (I am) of course I am drawing it in exaggerated way and there is no like over here. So, let me remove this. What I am trying to show here is that the shrinkage would be larger in the region where the pressure was smaller or the density was smaller. So, the relative density in this region was smaller. So, it was not packed or compacted to that to point so efficiently and therefore, shrinkage here would be larger.

So, the problem that arises where you do not have proper pressure distribution is that it will leads to non-uniform density distribution and non-uniform density distribution means uneven shrinkage in the sample or distortion in the sample. So, the component may not come out right. So, these are some of the things that you have to be aware when you are using powder processing.

So, now these point now having said this that there will be non-uniform shrinkage and because of this non-uniform pressure distribution the obvious question is how to get rid of it? We have seen that whenever you will have a pressure point whenever you are applying a piston and the pressure on it there will be a pressure gradient and pressure gradient will lead to this density gradient and shrinkage. So, how to get rid of it?

One way is already what I have shown over here. So, you see that if you would have very long in the z direction then it will have larger chance of shrinkage over here. So, shrinkage which we much the smaller. So, if you want to if you want to make this the shrinkage would be so small that it may be within the tolerable limit and that is one reason you see that most of the time in powder processing we use only 2.5 dimensions that is in the third dimension you do not have much larger length or you do not have much height or the component because you want to keep it smaller.

Another thing is if you want to use this kind of system of powder processing let me at this stage draw how a schematic density distribution would look like when you have a system like this.

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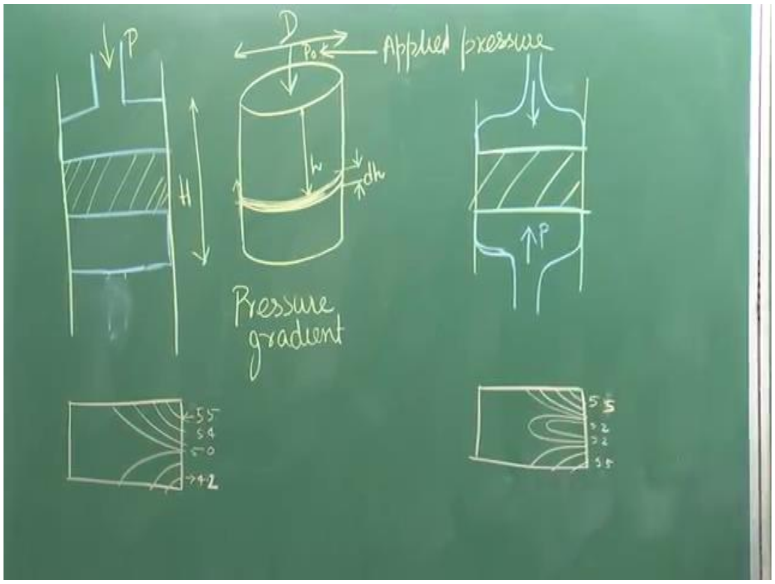

(So, it will be) So, let say we are looking at the compact over here and if you want to look at it because of some other factors like because there is friction also on the surface. The density distribution would look like this. So, for example let us say this will lead very high density, this will be less will keep already you saying and it may reach even something like this.

So, these are some point comparison relative comparison of that variation in density. So, this is very dense and slowly the density has reduced however if you ward to use the get the same dimension and you want less pressure distribution and less density distribution there is one way and that is to use a double ended piston. So, this a single ended piston. (Now, you can have) So, this is the compact that you want to use.

So, you will have this piston moving in, this piston moving in and therefore, the relative motion of the particles over here becomes smaller and therefore, the overall average motion or the average movement of the particle smaller and hence, the friction faced by them would be smaller and if you were to look at point pressure distribution point sorry, the density distribution for this it may look something like this.

So, now here you will have very high density 5.2 let us say because that was point sorry, 5.5. So, it be a 5.5 over here it will also be 5.5 here disymmetry, simple symmetry because you are applying pressure from here and from here. So, the point density would be 5.5 here and let say it gets down to 5.2 over here so by this this will also a 5.2. So, now you see it is the same there using the same dimension compare it over here it drops from 5.5 to 4.2 in this case it drops from 5.5 to just 5.2 and therefore, (your) you have much smaller density distribution. In this case that in this case. So, this is a more preferred way if you want to have much more dimensional accuracy.

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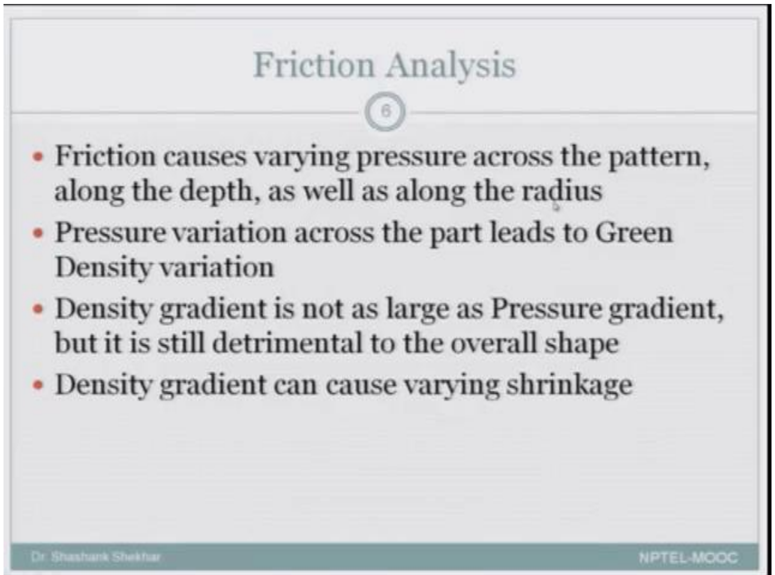

Now, when we are doing point this compaction there is also a phenomena called as end cappin,g but before we that let us come back to our slide and let us see what we have understood about friction analysis. So, friction causes varying pressure across the pattern along the depth as well as along the radius. We have not looked in detail the variation operation is that along the radius but that is also present over there because friction will also be acting over here.

A pressure variation across the part leads to green density variation which is what is more of concern, and the density gradient the although it is not as large as the pressure gradient. So, may be your pressure is varying by 20 percent but the density may change by only few percent but that is still enough to cause differential shrinkage. So but it is still detrimental to the overall shape.

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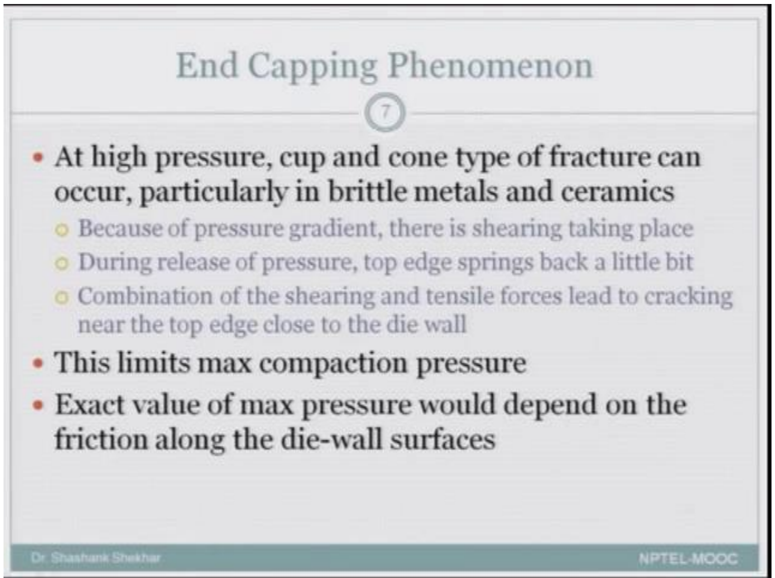

So, density gradient can cause varying shrinkage. So, this is what we have learned so far. Next is when you are doing (chara) when we are doing compaction there is still another important aspect to this which is called end capping phenomena. This is point simple concept and if we were to explain it simply it will come out like this.

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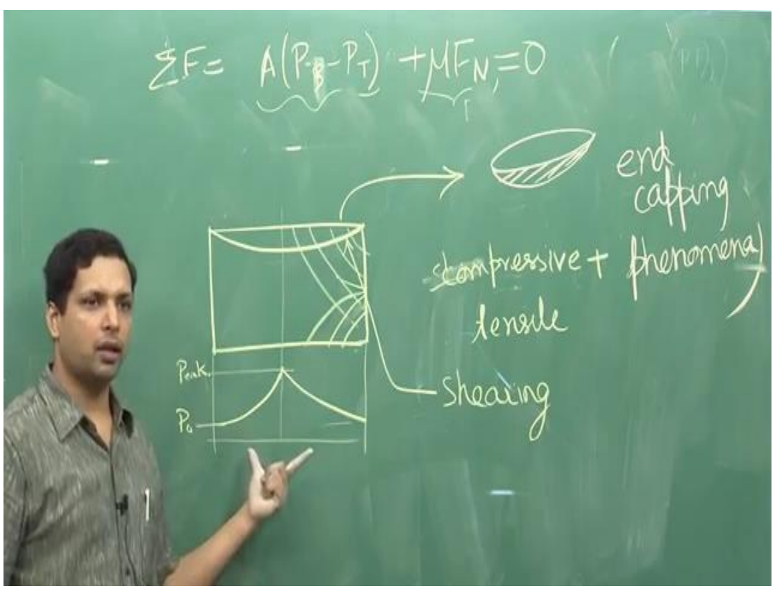

So, let say you have again a compact, there is a pressure variation along this we have already seen like this. So, there is a pressure variation and also along the radius there is a pressure variation. So, if you want to look at pressure variation like this, so on the edges you have applied pressure but toward the center you have a peak pressure. Now, because of this two directional pressures one from the surface and one from the side, there is a variation in the pressure because of this and also because when once you press it and the relaxed a material is called as material tries to come back to its original (spa) point original shape or it relaxes a little bit.

So because of this phenomena and the fact that there is shearing point sorry, compressive plus tensile stresses. So, these two facts the fact that there is pressure variation along point because of friction along the edges and because there is friction along the surface there is another pressure distribution and the fact that after you have compressed and you remove the piston the material or the component tries to relax and hence, there is some amount of tensile forces.

So, the two things add together and lead to a shearing phenomenon. So a (small) small region just near the top, it breaks off. So, it will look like and (I) it is as you can see it is like a cap shape and that is why it is called end capping phenomena. So, this is also important particularly when you are applying vary large forces large compaction pressures. So, this is another reason why we should not apply very large compaction pressure you have to optimize based on point the plot that we saw earlier where you get point saturation in the relative density and also by finding out when the pressure becomes so large that you start to see end capping phenomena.

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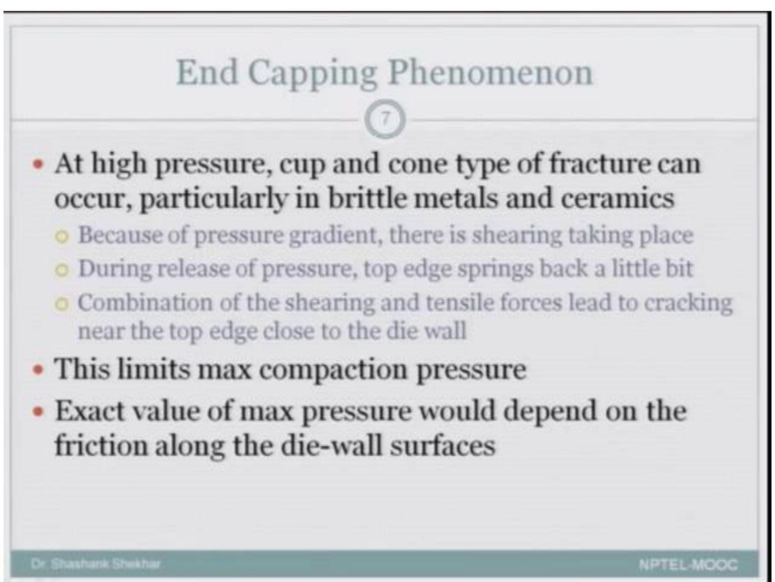

So, let us point get back to the slide. So, at high pressure cup and cone type of fracture can occur particularly in brittle metals and ceramics. So, this is the phenomena that is more common in brittle metals and ceramics not so much in the ductile materials because of pressure gradient there is shearing taking place. So, one of the point reasons to add to this is the pressure gradient as we said point during release of pressure top edge springs back a little bit.

So, there is a shearing and tensile force leading to cracking near the top edge close to the die wall and this is what is called as the end capping phenomena. This limits the maximum compaction pressure that can be used. Exact value of maximum pressure would depend on the friction along the die wall. So, if this you will have to like I said you will have to look at what is the relative density you are able to get and what is the friction condition that leads to this kind of point detrimental phenomena.

So, you that will limit what is the maximum pressure you can apply. Now, having said that there is one another small bit of information that we should look at before we move on from the compaction powder compaction process that is a little point that is about tooling. So far we have assumed a simple shape two dimensional shape or let say that the shape is not two dimensional and it has some you can you say what is called as two levels?

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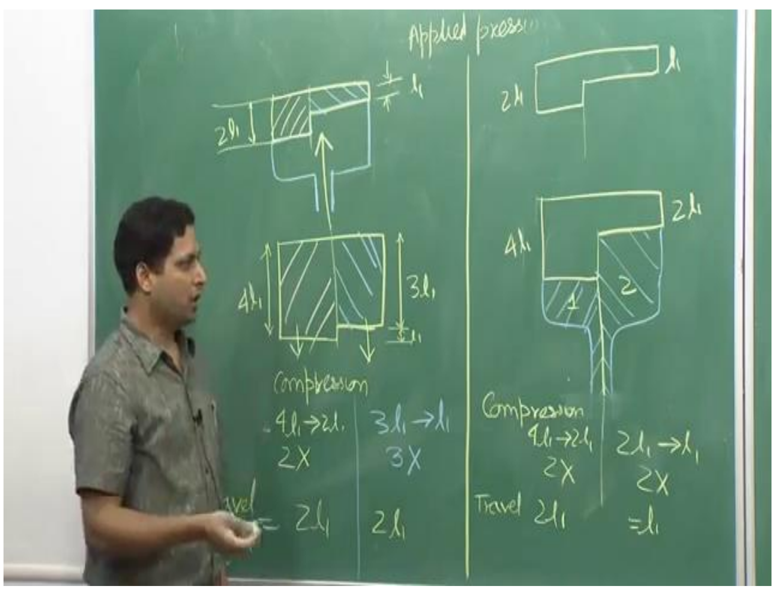

So, to begin with let say this is a shape. So, it is called a two level shape because it has two levels. Now, for sake of simplicity I will assume that this is l1 and this is 2l1. Now, if I want to make a component like this two level shape. So, if I and assign using a simple geometry for powder processing that is just single piston point from both sides that is double ended but single piston on each side, then I will have to start with a material shape like this.

So, let us say I start with 4l1. Now, the piston that I will have will in end will also have to have a difference similar to that what is in the final component which is 2l1 minus 1l that is a difference of l1. So, to begin with the piston must have a difference of l1. So, if this is l1 then this distance must be 3l1.

Now, from here it gets compressed to this. So, now let us look at the two regions separately. (So, what is the) So, this is one region and this is our second region. What is the compression that you get in over here? Let us compare with the compression that you get over here. Over here you are getting 4l1 to 2l1 implies two times of compression. Here you are getting compression from let me write in different color to ensure that we do not mixed up.

So, here we are getting from 3l1 to l1 means 3 times compression. So, you see for a simple shape although it is very simple in many sense we are getting differential compression over here which would again mean different density in this region and different density in this region, and that is because we are using a single piston on each side. So, let us say this is our point piston. Since the piston it is very simple like this which will have a constant travel length. What is the travel length over here?

So, it point starts from here. So, therefore, it comes all the way 4l1 to 2l1. So, the total travel length is 2l1, you can look at over here or over here. So, it goes from 3l1 to 1l. So, the distance that it travels is 2l1. So, in both the cases to travel length is 2l1. So, in the both the cases to travel length is 2l1 because this limitation where that you have to have similar traverse length we get different compression ratio.

Now, if you want to improve way what is the way? It is that you design your tool that is your pistons in a way that they can travel different lengths. So, what you can do? Let us again draw a shape that we were looking at. Now, here let us say we start with like this. So, here we have a piston which has two parts. So, these two parts let say are able to move independently. Okay.

Now, again I will give a distance so we already have said this is 2l1, this is l1 and if we want the same compression ratio. So, if it is going from 4l1 to 2l1 this should go from 2l1 to l1 that is the total length that we are talking about. So, to begin with the powder compact is 4l1 length and it gets compressed to 2l1. Here, it is 2l1 and getting compress to l1. So, if we talk about compression 4l1 to 2l1 on this side and over here 2l1 to l1 that is 2x.

So, now we are safe we have equal amount of compression on both side. What is different? Here is the total travel here it travelled 4l1 minus 2l1 which is equal to 2l1. So, this is travel. How much the piston has to travel 2l1? Here, it has to travel from 2l1 to l1 which is equal to l1. So, the two sides of the pistons these two parts. These are one part this is one part this is another part. They have will have to travel different lengths.

So, this is the kind of point technology or ideas or innovation that you will have to apply depending upon your component that you are trying to create, even for a simple geometry where we have just two levels you can see that we have to think about what should be the travel length? What should be the compression ratio so that you can get very good dimensional accuracy.

So, that is all we will point look at in this aspect of point powder compaction. There are of course lot more things if you point if you want in more detail you can always visit the book. Thanks.