Powder Metallurgy
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Lecture – 47
Sintering – 7

Hi everyone, and welcome back. So, we have been discussing about Sintering right now. And, by now you would have already known that the sintering process or the densification which occurs during sintering is synonymous with shrinkage . And, when you talk about shrinkage you will have to look at the dimensional tolerances of the component right, because shrinkage will lead to some reduction in the dimensions right.

So, in this class we are going to look at that particular aspect as to what are the parameters, which control the dimensional tolerances and you know how do you maintain this tolerances in the sintering process?

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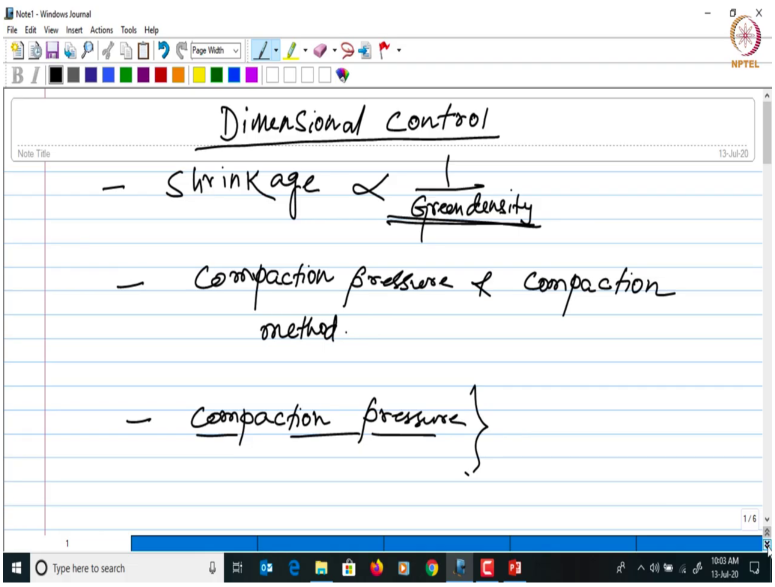

So, as I said this dimensional control is related to shrinkage. And, the shrinkage is related to the green density of the compact, it is in fact, inversely proportional to the green density right. And, this in turn the green density depends on the compaction pressure and the method of compaction. So, while talking about the dimensional control we will have to consider both of this.

So, let us talk about the compaction pressure first and see what is its affect on the dimensional control? So, compaction pressure is related to the dimensional control indirectly through the green density that is what we see here also. The green density is related to shrinkage which intern is related to the dimensional control. So, let us see what way this compaction pressure will affect the green density.

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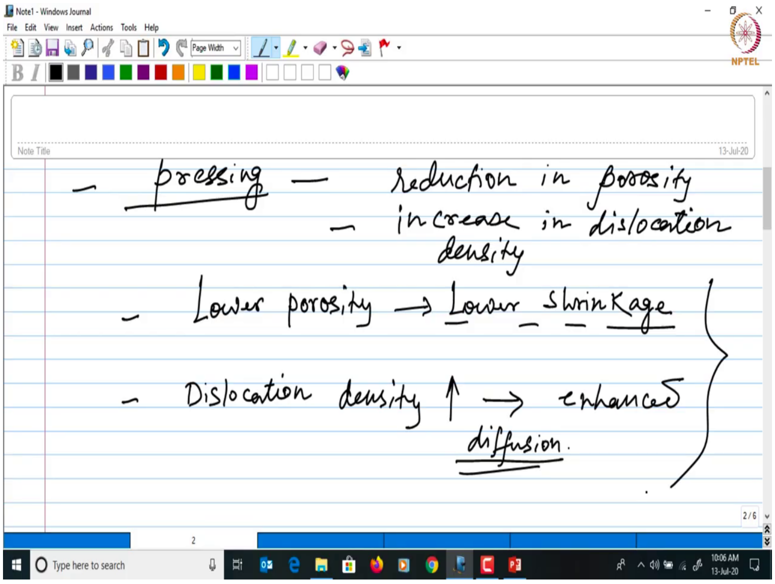

First of all pressing the powder before sintering leads to two thing; which are beneficial for the sintering process, one is reduction in the porosity. And, secondly, increase in the dislocation density. As we have seen before lower the porosity lower will be the shrinkage. And, therefore, it becomes easier to maintain the dimensions of the sintered part.

And, the second one that is the dislocation density comes into picture because we have seen that the compaction process also leads to plastic deformation as the powder is being pressed. And, as the pressure is increased beyond the yield point of the material, the dislocations are generated and the dislocation density increases. And, this kind of leads to enhanced diffusion, because one of the mechanisms of diffusion that is plastic flow is controlled by the dislocations.

So, when you have higher dislocation density in case of metals we can also expect an enhanced diffusion and that will give rise to a better densification also. So, this is how when you place the compact you know it helps the sintering process in terms of these two factors. So, now if you see the effect of the compaction pressure on the densification and the shrinkage that occurs during sintering, that can be demonstrated with the help of plots like this.

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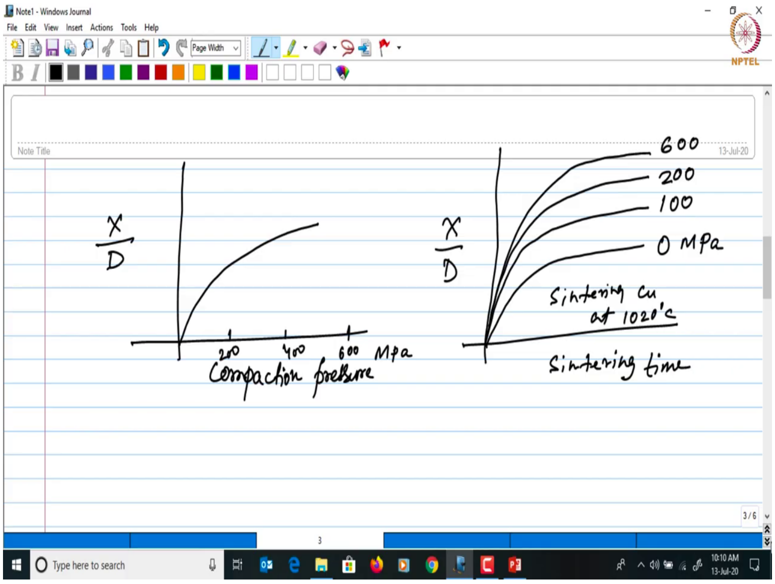

The densification during sintering is represented by the neck size ratio X by D. So, let us see how that varies with the compaction pressure? So, as the compaction pressure is increased the densification will also increase, in this manner . That is one thing and this can also be demonstrated with a similar curve, when you see the densification as the function of the sintering time at different compaction pressures .

So, let us now plot the densification with sintering time and see with different compaction pressure, how this densification varies? The first curve is with no pressure. So, let us say, we are talking about sintering a copper powder at 1020 degree Celsius . And, as you increase the pressure you can see the densification also increases right. So, for a given sintering time you can see higher pressure will give rise to higher densification.

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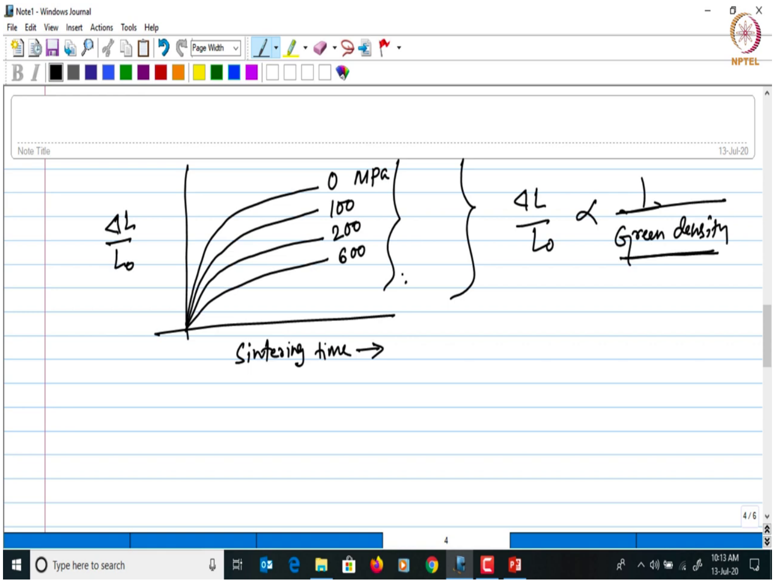

And, now if you look at the shrinkage ΔL by Lo; now, the trend will be completely opposite to the density. That means, for 0 pressure you have high shrinkage and as we increase the pressure it decreases. And, therefore, it is easier to maintain the dimensional control when the compaction is done at high pressure. So, this comes from the fact that shrinkage is inversely proportional to the green density as I said before.

So, when the compaction pressure is increased, the green density also increases and therefore, the shrinkage will decrease as you could see from here right. And, therefore, it is easier to maintain the dimensional control when the powder is pressed at higher pressure. Now, as I said we have to also look at the compaction method, because every method will give rise to a different kind of packing of powders and may lead to a different green density.

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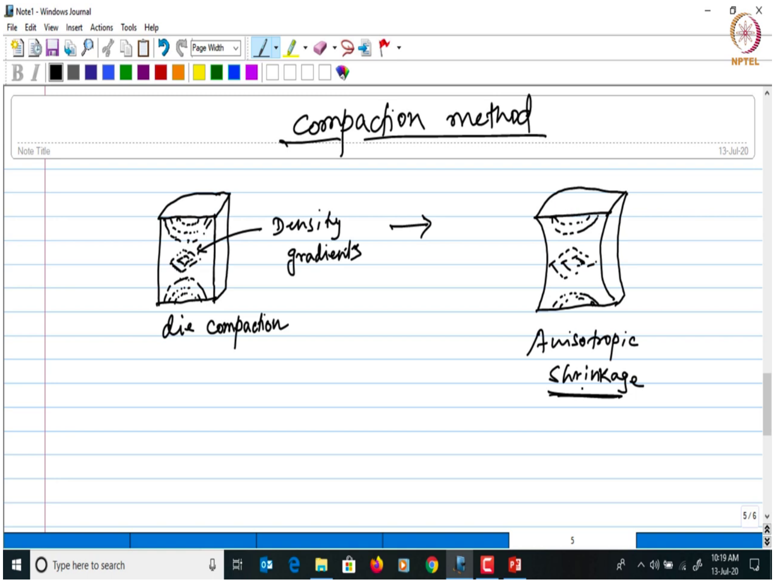

So, let us compare two methods one is the simplest one that is uni axial pressing and we will take another one to compare it with the uni axial pressing. So, in case of uni axial pressing or die compaction we have seen that, there are chances of occurrence of pressure gradient in the compact. During the pressing operation , this will lead to gradients in the density as well .

So, like this you may have gradients in the density in the die compaction process. These density gradients will lead to a gradient in the shrinkage also and therefore, the dimensional changes across the compact will not be uniform. And, as a result of an isotropic shrinkage, the dimensional control will be really difficult to maintain right. So, this density gradient will lead to an isotropic shrinkage which will adversely affect the dimensional tolerances .

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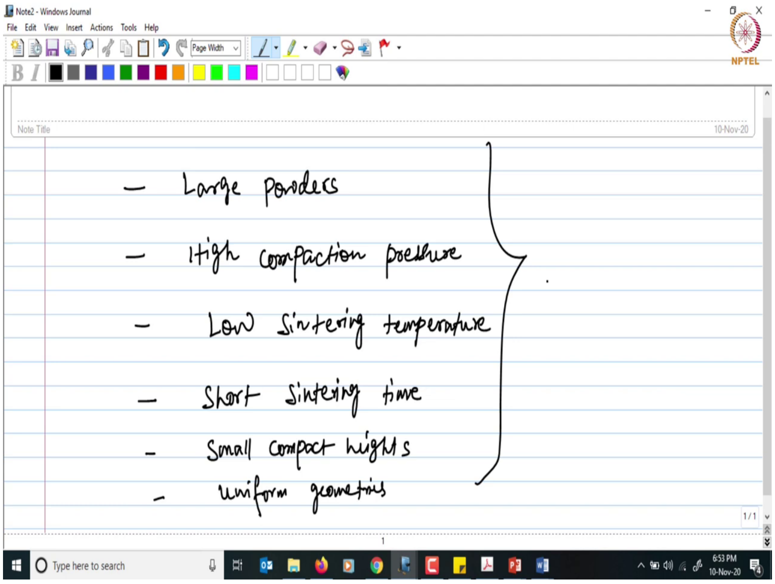

In the die compaction process minimum dimensional change can be achieved by large powders, high compaction pressure, low sintering temperature, short sintering time, small compact height, and uniform geometries.

So, all these can minimize the dimensional change or distortion in case of the die compaction process. But, the problem is some of these attributes are also detrimental to the compact strength and some of them can also create problems such as die ware and things like that. Hence, it is difficult to maintain the dimensional tolerances by the die compaction process as I said before.

Now, in comparison to die compaction if you consider one more method, which is kind of more uniform in terms of generating the density, then we can also see you know the shrinkage will be also uniform and therefore, the dimensional tolerances will be much better in that case.

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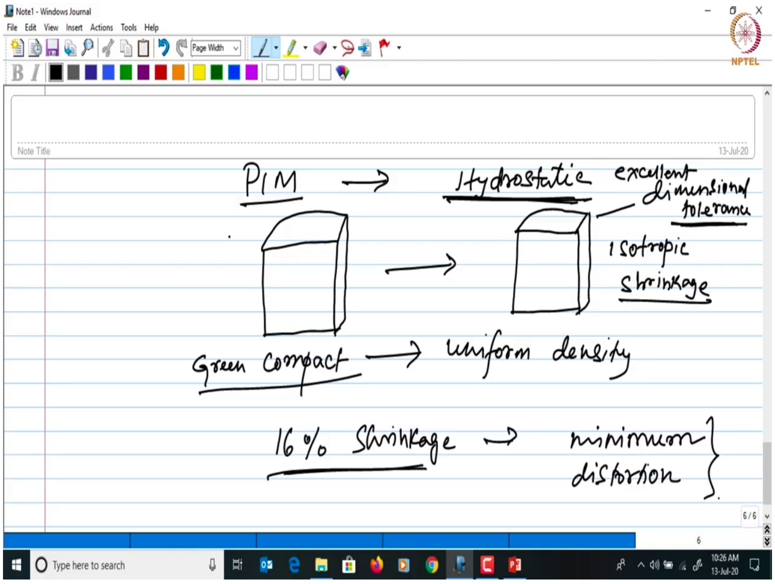

So, let us consider the PIM process, where in the forming which takes places is hydrostatic in nature right. So, here the pressing is uniform and as a result of that, in the green compact if you look at a similar compact, that we had seen for the die compaction, you can obtain a uniform density across the compact.

And, therefore, this will lead to isotropic shrinkage unlike the die compaction method which leads to anisotropic shrinkage. And, therefore, you can see that the dimension is maintained and you can have excellent dimensional tolerances right.

So, this is how the compaction method will also influence the shrinkage and the dimensional tolerance in the sintering process. As much as 16 percent shrinkage can occur during sintering of a compact made by the powder injection molding process. But, inspite of that it provides minimum distortion of the sintered compact this is due to the fact that the density is uniform.

And, therefore, the shrinkage is also uniform and so the dimensional changes are also uniform across the compact and therefore, the distortion is minimum right. So, this is how we can see, how the compaction method will also influence the dimensional control during the sintering process? .

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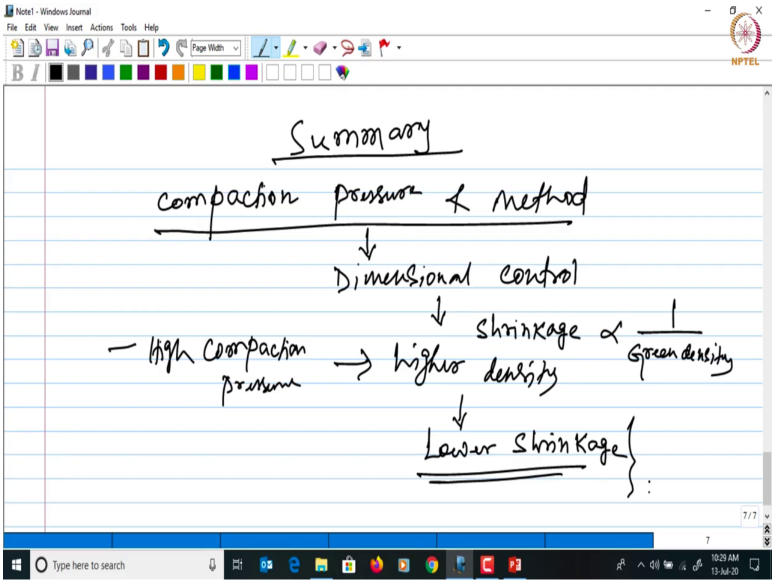

So, before we finish let us take a moment to summarize this lecture. So, to summarize we can say that, the compaction pressure and the compaction method both have an influence on the dimensional control during the sintering process. And, this dimensional control is basically related to the shrinkage, which is inturn related to the green density of the compact, higher the green density, lower will be the shrinkage and therefore, better will be the dimensional control right.

We know that higher compaction pressure leads to higher density and therefore, lower shrinkage right. So, in order to maintain dimensional control a high pressure compaction is recommended .

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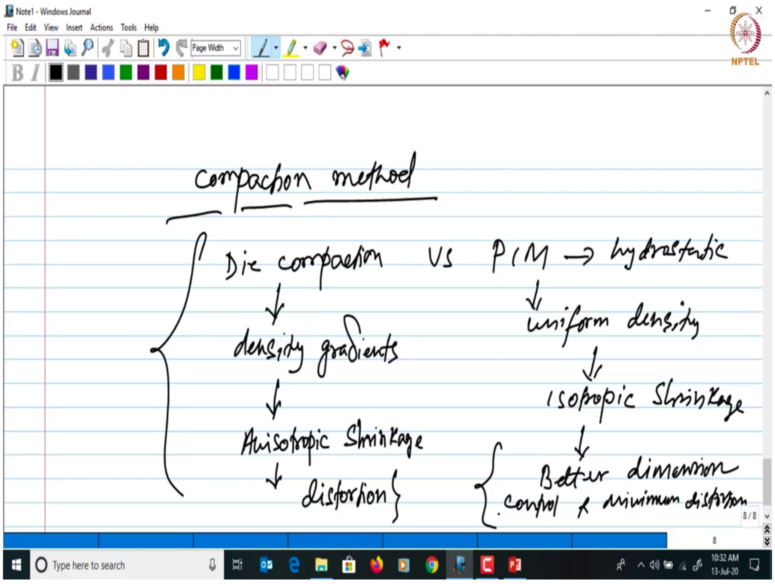

On the other hand when you compare the compaction methods used for pressing the powder one method, may be better than the other in terms of giving a better dimensional control. For example, if you compare the die compaction process with the powder injection molding., then, here you have density gradients, which will give rise to non uniform or anisotropic shrinkage, which will lead to some distortion in the sintered part.

And, therefore, dimensional control becomes difficult for compacts made by the die compaction method. PIM on the other hand is hydrostatic in nature and gives rise to uniform density and this will lead to isotropic shrinkage. And, hence a better dimension control with minimum distortion of the part can be achieved right. So, the objective will be always to have a uniform part and no distortion.

And, therefore, depending on the part shape size and the complexity an appropriate compaction method should be chosen. So, that at the end of the sintering process a part with the desired shape and size can be obtained. And, with that we come to the end of this particular lecture.

Thank you, for your attention.