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Theory and Practice of Non Destructive Testing

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Magnetic Particle Testing – 2

Hi, my name is Ranjit Bauri. So, today we are going to continue on this magnetic particle testing, which we have started in the last lecture, as part of this lecture series on NDT.

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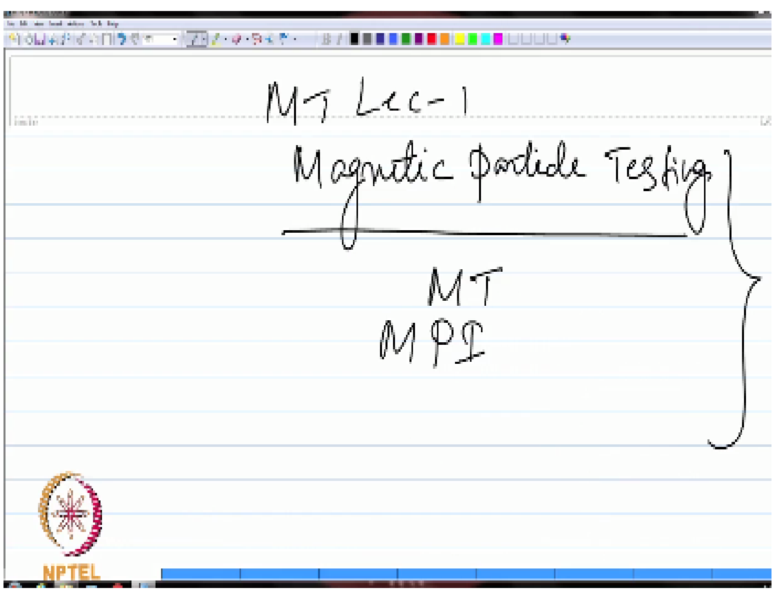

So, before we proceed today, let us have a quick relook, what we did in the last class.

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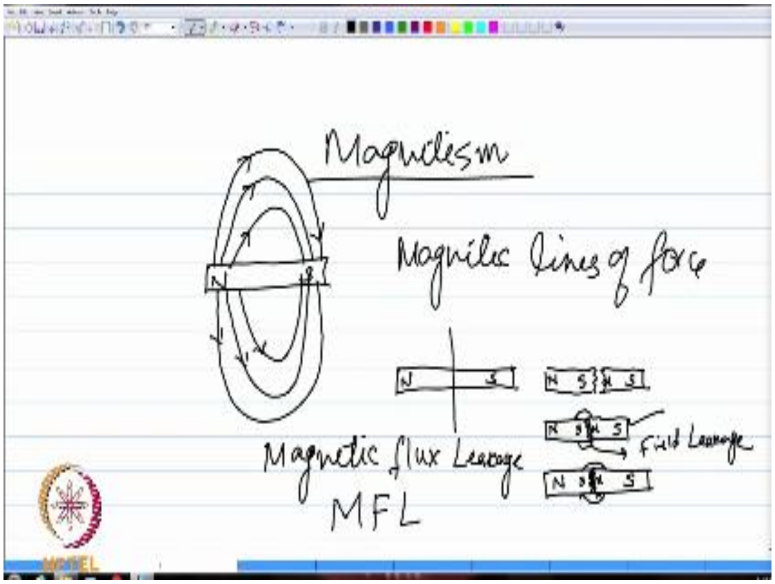

We learned about the basic principle behind this technique and we saw, it is primarily the leakage field, which comes due to the presence of a discontinuity on a magnetized surface. Due to that leakage flux or due to that leakage field, it creates a small magnet along the discontinuity and then, if you apply magnetic particles, they will be attracted to this small magnet being created at the discontinuity and that is how it will be made visible by this magnetic particle testing. So, the main factor here or the main basis for this is the magnetic flux leakage at a discontinuity.

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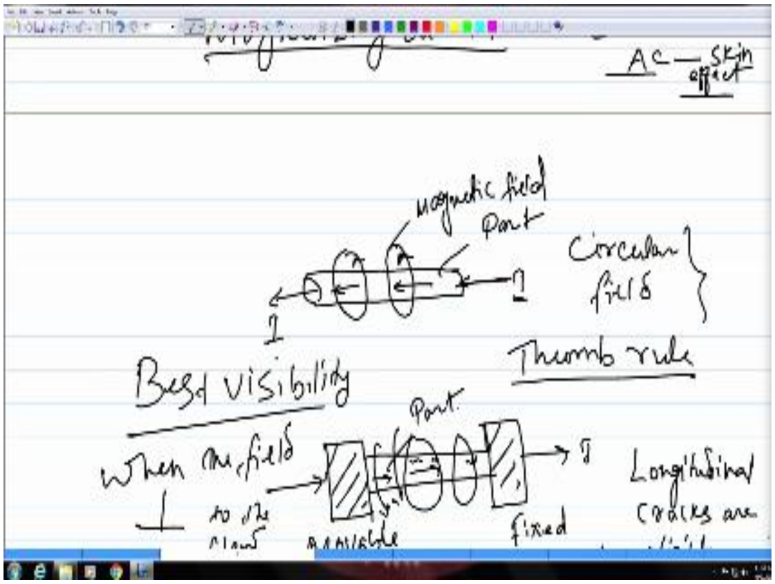

Then, we talked about different methods of magnetization. The first step, in this case, is to magnetize the surface and there are different methods which are available for magnetizing the part and depending on how you pass the current, you can see the magnetic field, how it is created and the direction of the magnetic field can be found by this right-hand thumb rule, as you could see here. So, if on your right hand, if the thumb be the direction of the current, then the fingers will point towards the direction of the magnetic field.

So, these are mutually perpendicular to each other, as you could see in this case, for example, in the first one here. So, if you pass a current like this, through this part, which is being examined. So, the magnetic field will be created in this path. So, these are called circular magnetic field, the direction of which is, perpendicular to the direction of the current. So, this is what we saw and we also saw that the best visibility you have then, the field and the discontinuity are perpendicular to each other. This does not mean that other orientations will not be visible, they will still be visible but the strongest indications will be obtained when the discontinuity is perpendicular to the field.

So, this is what we saw and then we went ahead and saw different methods, few methods by which you can magnetize the part and this was the first one, using two electrodes and clamping the part in between these two electrodes. So, for clamping the part, one of the electrodes is movable and the other one is fixed and then we saw the current requirement also, for this kind of magnetization, the magnetizing current is in this range, depending on the size of the part.

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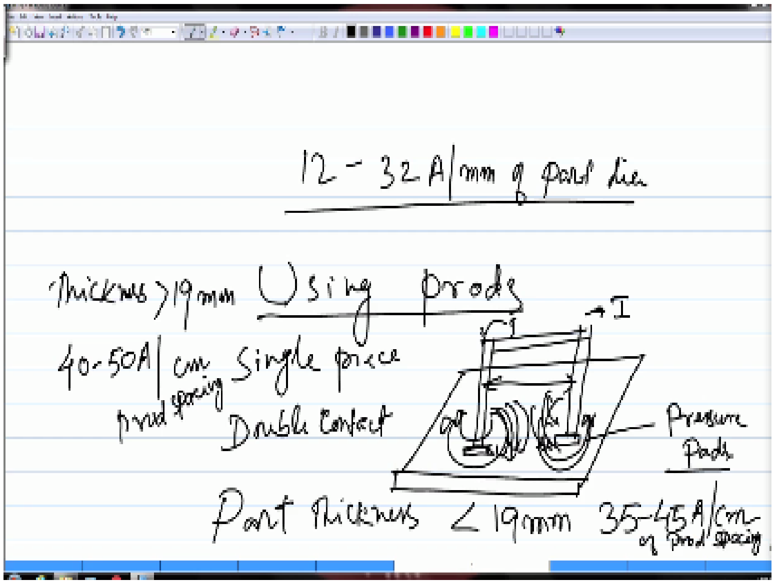

And then we saw another method, which uses this kind of electrodes, which are known as prods. So, you can either use a single prod or a double prod and in this case again, when you pass the current through this part, along this prod, this kind of circular magnetic field will be again generated, like how you see over here and the defects around this magnetic field will be made visible. So, in this case one thing I should mention, here the requirement of the magnetizing current, when you are using prods, it will depend on the thickness of the part.

For example, if the part thickness is less than 19 mm, the current requirement for this case would be 35 to 45 amps per centimeter of prod spacing. So, it depends on the distance between the two legs of the prod. So, it will depend on this distance. So, that means if you have a ten-centimeter distance, for example, then, you would need for a part of thickness less than 19 mm, you need the current in the range of 350 to 450 amps, when the spacing between the prod legs is 10 centimeter.

And for a part thickness of greater than 19 mm, the current requirement would also increase. So, in that case it would be 40 to 50 amps per centimeter of prod spacing. So, this is the requirement of the magnetizing current, for this particular method.

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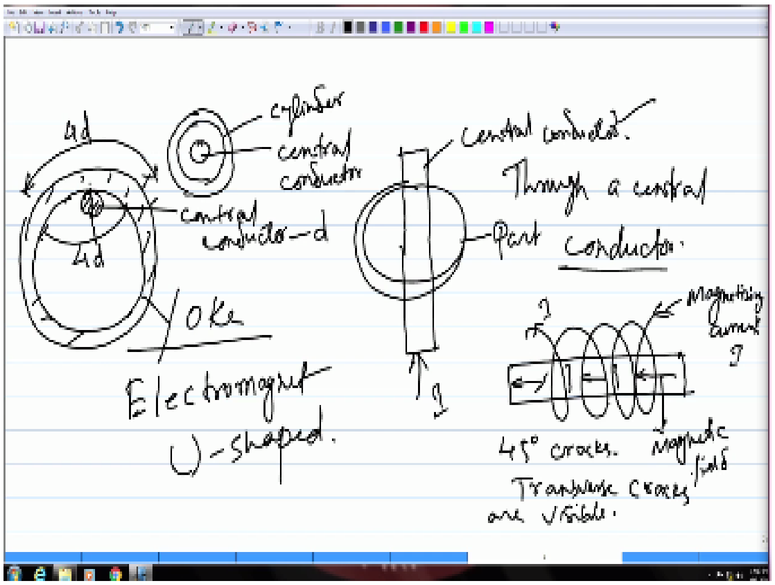

Then, we talked about this also. If you have a part, which is hollow then, in those cases, you can take a conductor and pass it through the central hole. So, with the help of this central conductor when you pass the current through it you can magnetize the part by induction. Similarly, you can use a coil and insert the part through it. So, in that case also, it will magnetize the part and in this case, when you are sending the current through this coil, let us say, this is the direction of the current, as you could see, so, here the magnetic field is not circular, in fact, in this case, it is longitudinal.

So, the cracks which are transverse, that is perpendicular to the axis, will be having the best visibility and cracks like this, which lie along 45 degree, they will also have good visibility. So, when you have a central conductor depending on the size of the part, you have to place it. So, if it is a small cylinder like this, then, you can place it at the center. So, this is the cylindrical part that is being examined and this is the central conductor, which is carrying the magnetizing current. So, if the part is small, you can place the conductor along the center, so that you can have a uniform magnetization on the surface of the cylinder.

But, if you have a bigger part like this, so, in that case, if you place the conductor along the center then the magnetizing will not be uniform across the periphery or across the circumference of this part. So, in that case, the central conductor is placed in contact with the wall of the part in one portion like this. So, this is the central conductor. So, you have to magnetize a particular portion of the part, which is being examined.

So, if the diameter of this central conductor, let us say, if it is d, then in this case, you would be able to cover a distance, along this, which will be equal to 4 d, 4 times the diameter of the central part. So, that will be the effective distance of magnetization. When you use a central conductor, like this, at a part, which is bigger and the conductor is placed in contact with the wall of the part at a particular location, so, this is how it will be, if you see along the circumference. The distance that you can magnetize in this case will be four times the diameter of the central conductor.

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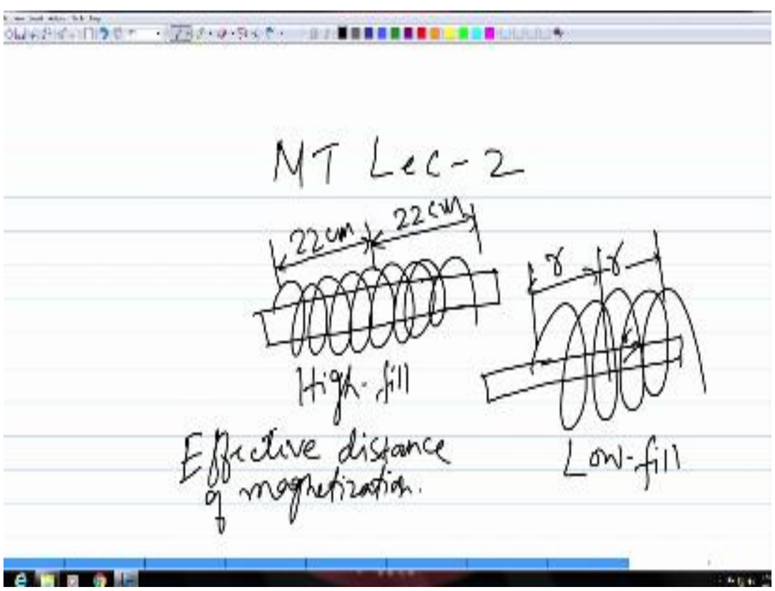

Similarly, when you are using this kind of coil, depending on whether the diameter of this coil is tightly filled by the part or the part diameter is much smaller compared to the diameter of the coil then since this is highly filled, this is known as a high fill and in this case, you could see the filling of the coil is not that much. So, that is why, this is known as low fill. In case of high fill, the effective distance of magnetization from the center of the coil is 22 centimeters, on either side from the center and in this case, the effective distance is r, wherein r is the radius of the coil.

So, in case of high fill, it is 22 centimeter, the effective distance of magnetization and in case of low fill is equal to the radius of the coil. So, this is how it is, in case of a coil or a solenoid.

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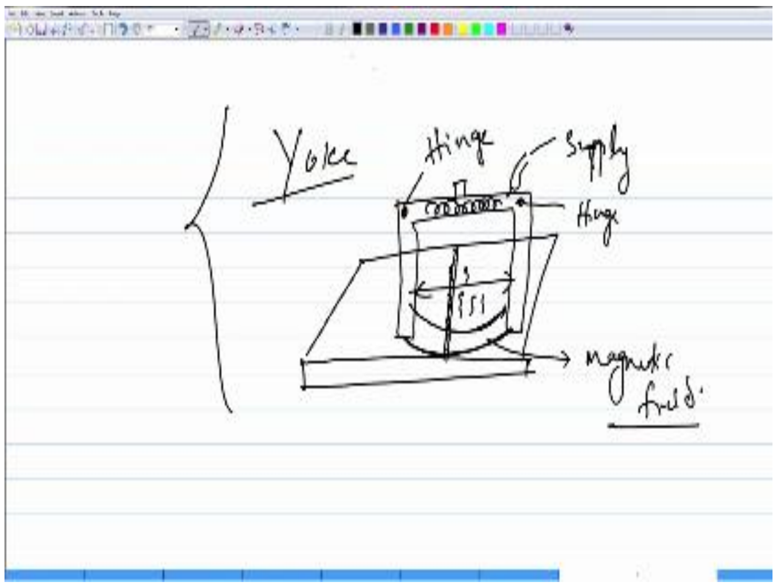

And then, we talked about this also, a U-shaped electromagnet, which is known as a yoke, that can also be used to magnetize the part and in this case, the direction of the magnetic lines, the magnetic lines of force, are across this. If you connect these two legs, so, along this line is the direction of the magnetic field. So, that means cracks, which are lying like this, perpendicular to this field, will have the best visibility.

And in this case you could have a hinge also, like this, that will allow you to move these legs and you would be able to adjust the distance between the legs, so that you would be able to vary the effective distance of magnetization in this case. So, these are the different methods of magnetizing the part.

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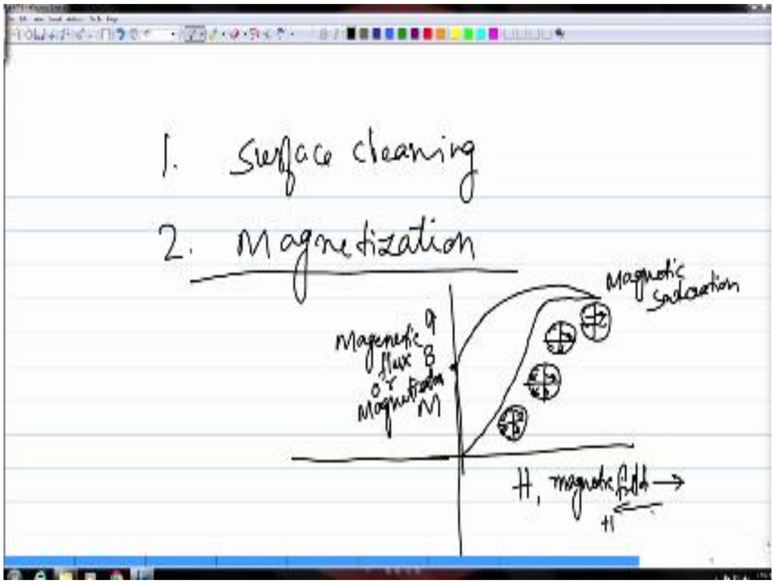

So, let us continue on that, in this lecture. So, first thing that you do, you clean the surface of all dirt, oil, grease and so on and then, you magnetize the part, by using one of these methods, depending on your requirement and the suitability. So, when you magnetize, we know, what are the different methods but when you are magnetizing the part, how do you know what is the level of magnetic field which is optimum or which is good for magnetizing a particular part of given size.

So, if you want to know that, first you need to know a little bit about the theory of magnetization that means we need to go back and discuss a little bit about the basics of magnetism and then you have to see the magnetic properties of the material which is being tested. So, if you refresh your memory on the theory of magnetism, let us say you apply a field, H, in this direction. So, in the part, which is being magnetized, it will create a magnetic flux or it will magnetize it. So, if you plot the magnetic flux or the magnetization on this y-axis, magnetic flux, many a times is denoted by B or you can also use magnetization M along this axis.

So, as you continue to increase the magnetic field, the magnetic flux in the material would increase and finally it will saturate. So, that is the saturation magnetization. So, what basically happens here, you may know that, in a ferromagnetic material, you have, what is called as magnetic domains or magnetic dipole moments. So, in the beginning, when you do not apply any field, when the field is zero, these magnetic dipole moments are randomly oriented like this.

And as you continue to increase the magnetic field in a particular direction, then, some of the dipole moments which are favorably oriented with respect to the direction of the field will grow in size, it is this one, at the expense of the other one. So, the other ones will reduce. So, as you continue to increase, this direction will continue to grow, the favorable direction and it will also tend to a line along the direction of the applied field.

So, at this point, when you reach this saturation point, all the dipole moments which are favorably oriented along this magnetic field will be now aligned and they also grow in size at the expense of the others and they will be almost aligned to the direction of the magnetic field and that is when you reach magnetic saturation. Now, if you reverse the field, if you change the direction of the field, if you do field reversal, then, while coming back, it will not follow this same curve, rather it will follow a curve like this.

So, now at this point although your field is zero, but it is still having some magnetic flux, it is still having some magnetization. So, that means it is retaining some of the magnetization, which was provided in the beginning and that is why this point is known as remanence.

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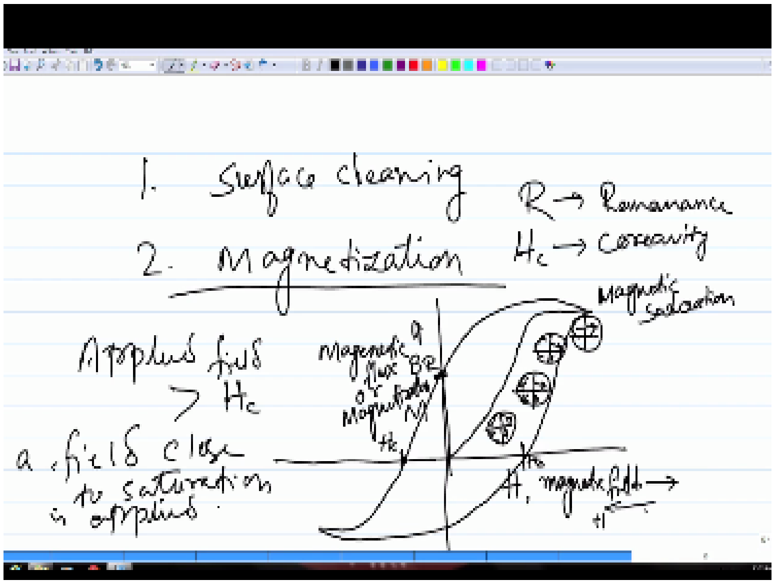

So, if we denote that as R and then, if you continue to reverse the field, then it will finally saturate on the reverse direction also and now at this point, the magnetization is becoming 0. So, to take it back to the zero magnetization, you have to apply a field in the opposite direction and this particular point, the field H, corresponding to the point, when the magnetic flex is becoming 0, is known as the coercivity. So again, this is a property of the material and now, if you increase again on the same direction then this hysteresis loop develops.

So, this is the magnetic hysteresis that we all know. So, now coming back to this, as to what should be the level of the magnetic field that we apply to magnetize the part, so, as you could see, in any case, the applied field has to be greater than the coercive field. So, it must be greater than the coercive field so that the magnetization is not zero, it is some positive value, it is more than zero. In most cases, a field close to saturation is applied, so that when you remove the field, you have enough magnetic flex remaining.

So, theoretically this tells you what should be the level of the magnetic field that you apply to magnetize the part but when you actually do it, this theory is fine because this gives you the idea as to how much you should apply, but when you are practically do it and as you apply the field, you do not know what is the exact magnitude of the field, which is being applied. So, that means during doing it practically, you need a reference, or something which would at least indicate, if not tells you the exact value of the magnetic field, at least indicate that the field, which is being applied is good enough to magnetize that particular part. So, that is where these field indicators come into picture.

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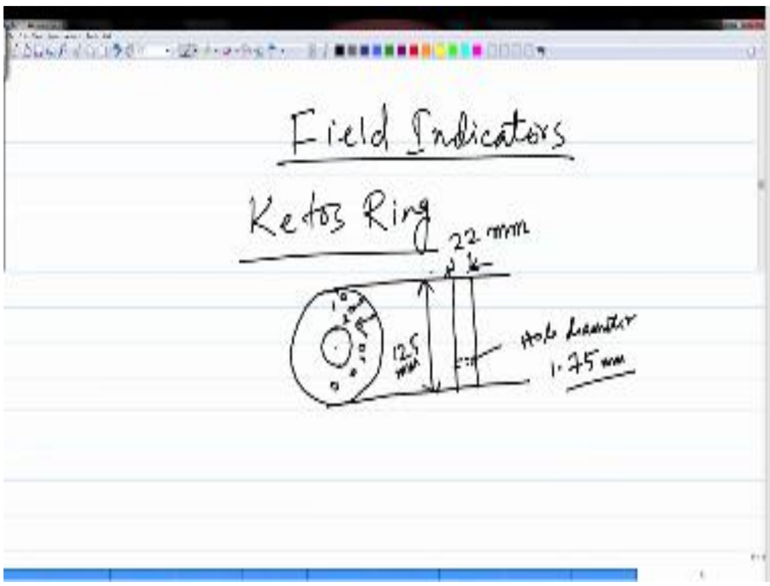

As the name suggests, this will indicate the level of the magnetic field, of course, in a qualitative manner, whether it is optimum or whether it is enough to magnetize the part or not. So, there are different types of field indicators, depending on what kind of part you have, which can be used to indicate the level of the magnetic field being applied and one of them is known as ketos ring. This is basically a ring like this, with a hole at the center and then along the periphery you have some smaller holes at different distances from the edge like this. So, as you go on this distance from the edge increases.

So, you have different holes like this at different distances from the edge and these holes are given numbers like this, 1, 2, 3, 4 and so on. As the distance from the edge increases, this number also increases and if you see the typical dimensions of this particular indicator; the diameter is 125 mm and its thickness is 22 mm and this series of holes have the diameter around 1.75 millimeter.

So, through this central hole, you can put a central conductor and pass the magnetizing current. Then, as you pass the current, this will be magnetized. Now, depending on how many holes are visible, or how many holes are being indicated by the magnetic particles, so, you first magnetize this ring and then you apply the magnetic particles and then see how many holes are being indicated by the magnetic particles clearly.

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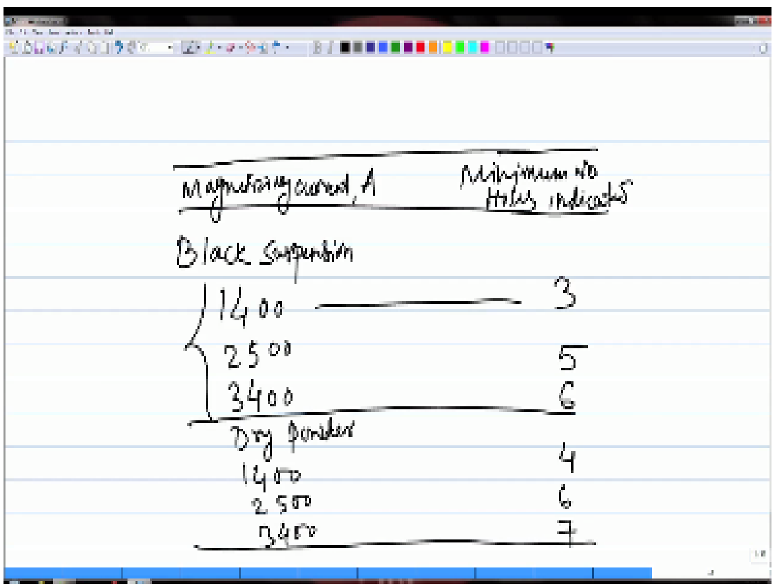

So, it will depend on what is the level of current you are using and what kind of magnetic particles are being used. So, if you see this table, for example, which is the magnetizing current, which is being applied to magnetize the part and the minimum number of holes indicated by the magnetic particles. So, these magnetic particles can either be used in a suspension, in a low viscosity liquid that we'll talk about later in little more detail or they can also be applied as dry particles.

So, let us say you are using a black suspension and in that case the number of minimum holes that should be indicated that would depend on, what is the magnetizing current, which is used. So, let us say, for this black suspension, these are the levels of current, then for each of these currents, the minimum number of hole that should be indicated; for 1400 amperes, it should be 3; then for 2,500 amperes, it should be 5; and then for 3400 amperes, it should be 6.

So, this is how this ketos ring would indicate that the magnitude of the magnetizing current, which is being applied, whether it is good enough or not. So, if you are applying, for example, 1400 amperes and then if you see three holes are clearly indicated, when you apply the magnetic particles, then for that particular current, for that particular scenario, this much current is enough. So, this is how it will be for black suspension and if you use dry powder for the same level of current, this number should be 4, 6 and 7, little high.

So, this is how depending on what kind of magnetic particles are being used and how many holes are being indicated by them, the optimum level of the magnetizing current can be found. So, this is how these ketos rings is going to indicate whether the magnetic field or the magnetizing current, which is being applied, whether it is optimum or not. So, this is one of the methods, one of the indicators, by which you can do it. There are two or three more methods, which we are going to discuss little later.

But I think we can take that in the next lecture because today this is all I have. So, I will stop here today. Thank you for your attention and I will see you next time.

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