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Theory and Practice of
Non Destructive Testing

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Magnetic Particle Testing - 1

Hello my name is Ranjit Bauri. We are in the second week of this NPTEL course on non-destructive testing. I hope you have gone through the lectures of the first week. Before we proceed today, let me remind you, if you have any question or any doubt for any of the topics that we have been discussing, please feel free to clarify your doubts using either the discussion forum that you have or you can also write back to us, but please make sure that you clarify your doubt. So, today as part of this course, we are going to start a new topic, which will be on magnetic particle inspection or magnetic particle testing.

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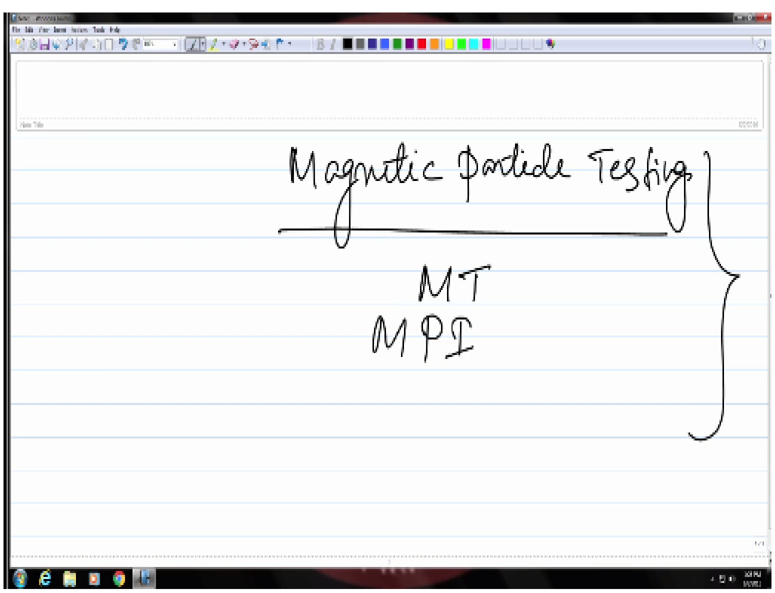

So, this will be our second topic in the series. Magnetic particle testing, or magnetic particle inspection, in short sometimes we will call this as MT and for magnetic particle inspection, sometime in short it is also written as MPI. So, like I said, first we are going to see what is the basic principle behind this and then we will go and see the method and the process details.

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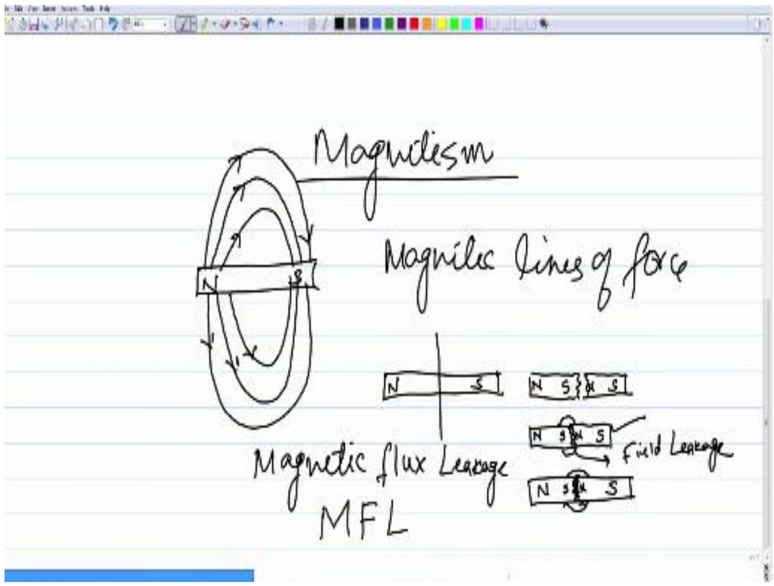

So, as the name suggests, this is based upon magnetism. So, we take the help of magnetism in this case to inspect defect and flaws. So, let us now see, how this magnetism helps in this case to make visible indications of surface defects and surface flaws. So, this is also a surface NDT method and now we are going to see how this works and what is the basic principle? So, as you all know, if you have a magnet, so it will have its poles, north and south poles and the magnetic field will be defined by some imaginary lines, which starts at North Pole and then enters the South Pole on both sides.

So, these lines which define the extent of the magnetic field of a magnet, these are known as magnetic lines of force. So, anything within this field, if you keep a ferromagnetic material that will be attracted to the magnet. So, this is the magnetic field of a magnet. Now, let us say, if you have a magnet, and if you fracture this into two pieces, so let us say, these are the fractured pieces, then these two pieces will also create two magnets and even if you bring these two piece together, like this, so, let us say, you have fractured it but you again bring it together, then also this magnet which is created due to this fracture is going to remain.

Similarly, if you have a crack on a magnetized surface, so, let us say the surface is magnetized and you have a crack somewhere, so, like in this case, along this fracture the magnet which is created is going to remain and it will have its own field also. So, in a similar manner in this case also, if you have a discontinuity or crack this will also create a tiny magnet around it, like this, what you saw in this case. So, there will be a field leakage due to the presence of a discontinuity on a magnetized surface. So, this discontinuity could be due to a fracture or it could be due to presence of any flaws like cracks.

So, if you have presence of a discontinuity on a magnetized surface, this will create its own magnetic field, it will create a tiny magnet and if you now apply any magnetic particles on this surface, the particles will be attracted to this crack and that is how it will make visible indications of this crack. So, the main principle behind this is the magnetic flux leakage due to the presence of a discontinuity on a magnetized surface, that is why sometimes this particular method is also known as MFL technique, which stands for magnetic flux leakage because this whole thing is based upon this magnetic flux leakage at a discontinuity.

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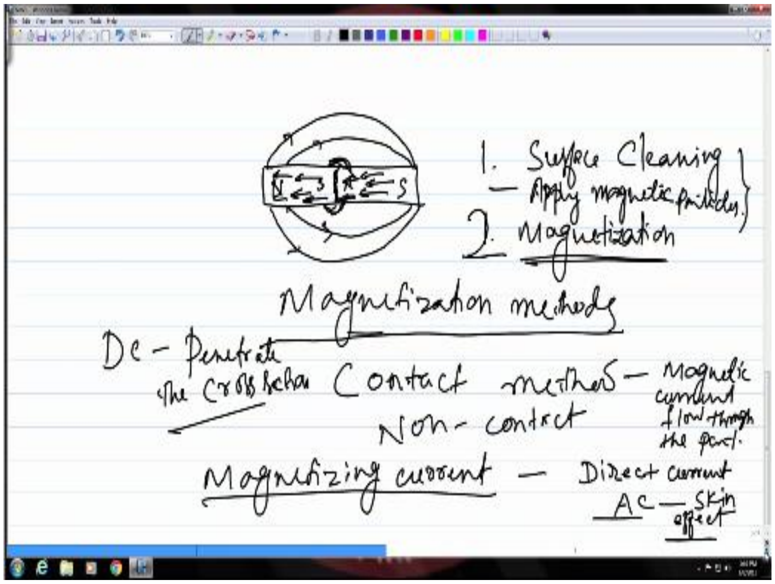

So, now we will see, due to this flux leakage or creation of a small tiny magnet around the discontinuity, what is going to happen and how this will help us in detecting the defect. So, this discontinuity will also have a small magnet and this will also have its own magnetic lines of force in this fashion. So, if the magnetic domains in the parent material are around this discontinuity, they will be perturbed by the magnetic field of this tiny magnet, which is created due to the presence of the discontinuity. So, this is the phenomena of magnetic flux leakage, as I said. So, now if you apply some magnetic particles, like iron, they will be attracted to this discontinuity because now it is magnetized and that is how they will accumulate along this crack and make visible indications.

So, this is as simple as that, due to the flux leakage at the defect, a small tiny magnet is created, which will attract the magnetic particles and make visible indications. So, when you have a part, the part as such is not magnetized, so, the first thing that you need to do in this case is to magnetize the part, but even before you magnetize it, in this case also, you need to clean the surface, like what we saw in the last topic of dye penetrant testing. Surface cleaning was needed here also but in this case, the purpose is different.

What you do, you apply magnetic particles on the magnetized surface, so, these magnetic particles should have enough mobility on the surface, this would be able to freely move on the surface and for that the surface should be clean. So, the purpose of surface cleaning in this case is to provide free mobility to the particles, which are applied on the surface. So, once you clean the surface then in the second step you magnetize the part. So, let us see what are the different methods, which can be used to magnetize the part? Primarily you can classify this, like a contact method and a non-contact.

So, what you do to magnetize the part, is to use a magnetizing current and let this current create the magnetic field to magnetize the part. So, in case of contact method, the magnetic current directly flows through the part and in case of non-contact method, you can use induction. So, you can use a coil or you can use a solenoid kind of thing, through which you can induce the magnetic field into the part.

Now, as far as this magnetic current is concerned, this could be both direct current DC or it could be alternative current or AC. Both can be used for magnetizing a part, but one thing you should remember while selecting either direct current or alternative current is that, in case of AC, it will be the current primarily limited on the surface, which is known as a skin effect.

Since it is primarily on the surface of the part, so, if you are looking to inspect subsurface that means little below the surface, then an AC current is not recommended. On the other hand, if you have DC, then it can penetrate the entire cross section of the part. So, that is the difference between AC current and DC current, but both can be used depending on the requirement to magnetize the part and these are the two main categories, contact method and non-contact method. So, let us now, see how exactly it is done.

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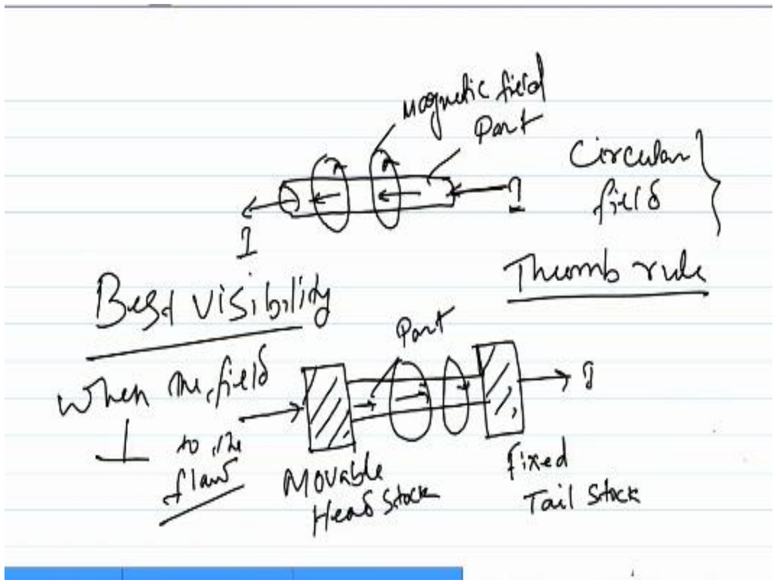

So, let us say, you are using a contact method, so, in that case, the magnetizing current will directly pass through the part. So, that means you need to connect the part in between two electrodes and then switch on the magnetic current and it will magnetize the part. So, let us say, you have a part and this is the current that you are passing through it. So, in this case, if you pass the current in this particular direction, then the magnetic field will be like this.

And the direction of the magnetic field depends on the direction of the current and this you can find out from the thumb rule. That means if your thumb is pointing towards the direction of the current, the fingers will be the direction of the magnetic field, so, this is what you see, if this be the direction of the current flowing through the part and so, this will be the direction of the magnetic field. So, when you flow a current like this on a part, it produces a circular kind of magnetic field, the direction of which will depend on the direction of the current and using this circular field, you can magnetize the part by directly flowing the current through it.

So, this is how you use a contact method. You connect this part between two electrodes and you pass the current. It will create a circular magnetic field, which will magnetize the part. So, there are different ways by which you can connect this part to the electrodes, to flow the current. One of them is to use two draws at either end of the path.

So, this is the part of the sample to be examined and you connect it between two electrodes, at either end, one of them could be movable, so that you can move it and push it against the part and make tight contact and another, on the other side will be fixed. So, you can move this movable part and tighten the part against the electrodes, so that there is no loose contact.

Because when you are flowing electric current loose contact is not desirable. So, the movable part is also sometimes called as head stock and the other electrode, which is fixed, is known as tail stock. So, then you flow the current from this to this. Just Now, we have seen that if you flow the current like this, then it will create a magnetic field around this like this. Now, since the field which is created has a particular direction.

So, the orientation of the cracks and the defects with respect to the direction of the field will affect the visibility of a particular defect. Because of this directionality that you have in this case, so, you will have best visibility, when the field direction is perpendicular to the flaw. So, this is the scenario, where you will have the best visibility. This does not mean that other defects, other cracks, which are not oriented perpendicular to the flow will not be visible.

They will still be visible but the maximum indication, the maximum field, that you will have along a discontinuity, will be perpendicular to the direction of the applied field.

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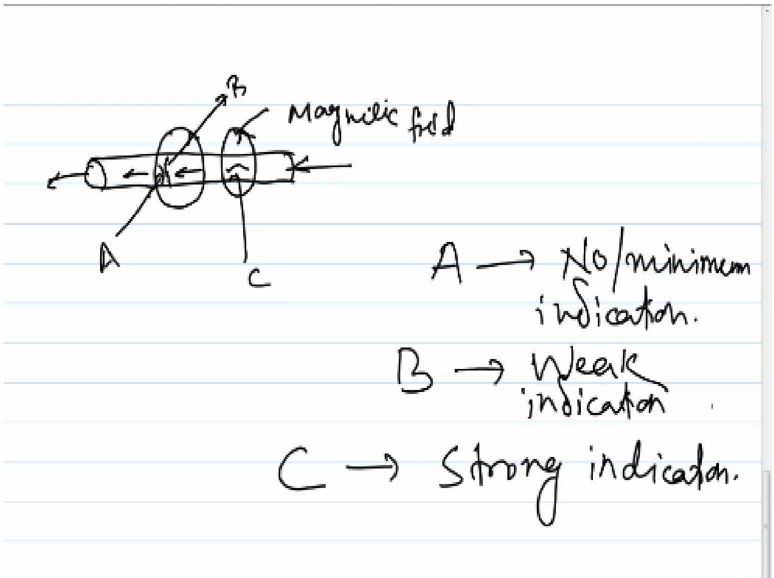

For example, if you have the current and the magnetic field like this and let us say you have a very regular discontinuity like this, which is parallel to the direction of the magnetic field's. So, this is your magnetic field, as I showed in the previous diagram also, and you have another, which is not very regular, the crack is little, you know, uneven. This first one, let us call that as A, this one as B.

And let us say, you have another crack over here, which is perpendicular to the direction of the field. So, since A is a regular crack and it is parallel to the direction of the field, you will have no or very minimum indication. B is parallel but it is not a regular shaped crack, it is kind of little uneven. So, because of that, although it is parallel to the field, it will give some weak indication. So, there are chances that it will still be detected.

On the other hand, flaws and cracks like C, which are perpendicular to the field, will give a strong indication. So, this is how the orientation of the crack with respect to the magnetic field will decide the level of indication for that particular defect.

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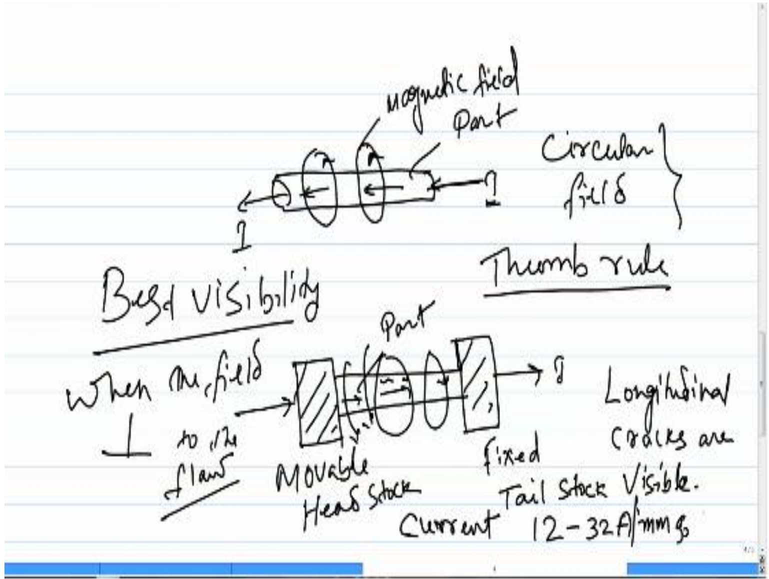

So, in the first case of using this head stock and tail stock, so, you could realize that in this case the best visibility, because this is the direction of the field, so, in this case, your cracks which are longitudinal or perpendicular to the field will have the best visibility. And for this case, the magnetic current levels, that one has to use, it depends on the size of the part, in the range of 12 to 32 amps per millimeter of part diameter.

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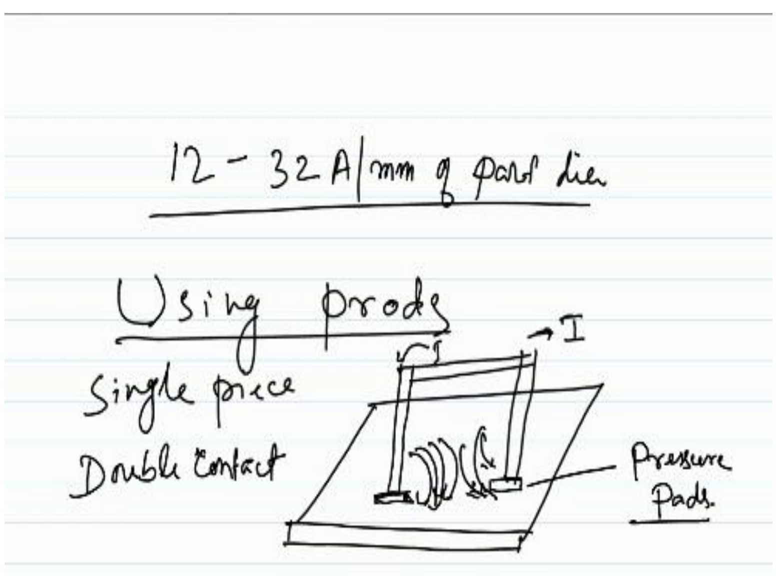

So, if you are using two electrodes as head stock and tail stock then. this is the level of current that you need. Then, you can also use, what is known as prods. So, these are primarily electrodes connected to a power source and when you make a contact of this electrode with the part being examined, it will send the current through the part. So, it could either be a single piece. Let us say, this is the part you have.

So, it could be like this and you can send the current like this. So, if you want, you can use two separate electrodes like this. So, if this is the current, this will come and pass through the sample and go out. So, this will create the circular type of magnetic field, again around this electrode like this and anything within this field, if defects and flaws are there, they will be detected and the best visibility will be for the flaws which are perpendicular to this field direction.

And if you want, in other case, these two can also be connected. So, a prod can be a single piece or double. So, it is carrying the current and it is in contact with the part directly. So, you need to make sure that there is no loose contact. So, it should be pressurized against the part. So, therefore, sometime these kinds of pressure pads are also provided to make intimate contacts, so that there is no loose electrical contact and there are no electrical arcing due to loose contact. So, that is one thing that you need to take care. So that you do not end up with electrical arcing, which is not desirable.

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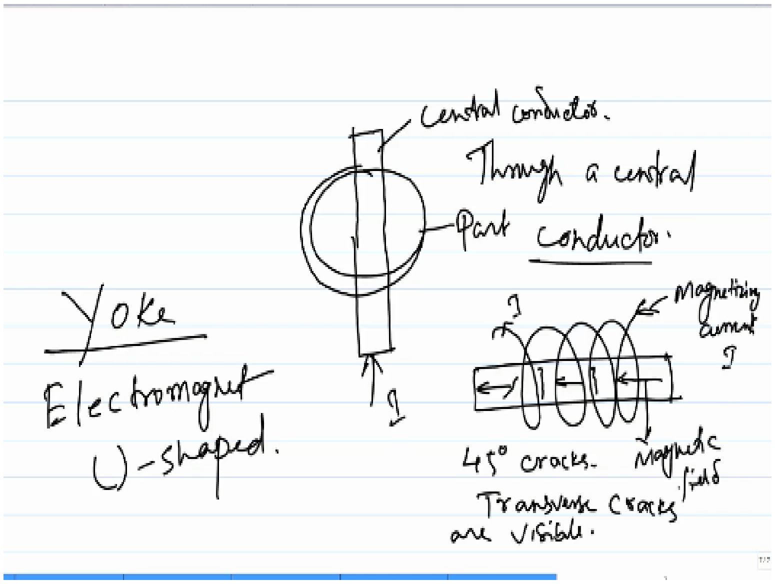

The other method is, to use an induced field, as I mentioned before. So, if you have a circular part and you need to magnetize this to inspect the circumference then, what you can do, you can have a central conductor carrying the current. So, you can pass the current through a central conductor. So, this will carry the current and induce the field in this part, through this central conductor.

The other way of inducing current is using a coil or a solenoid, then you will have longitudinal field. So, this is the magnetizing current, in this case, I, which is flowing and this will be the magnetic field, which is not circular, in this case, it is longitudinal. So, in this case, the flaws and defects which are oriented like this will have the best visibility, which are perpendicular to this axis of the part, are perpendicular to this longitudinal direction. So, you will have the best visibility for those and if you have cracks at angles like, let us say, 45 degree angles.

Then also this kind of cracks would be visible. So, 45 degree cracks and transverse cracks, which are perpendicular to this axis, have good visibility in this case, because the magnetic field is longitudinal. So, depending on how you flow the current, the magnetic field direction and the type of the field would vary and as I mentioned before, your best visibility for the flaws would be, when they are perpendicular to the direction of the field, and flaws which are at an angle, not really parallel to the direction of the field, will also have good visibility.

Then, you have one more method which is very useful in magnetizing small parts and that is a part or an electromagnet, which is known as Yoke. So, this is basically U-shaped electromagnet, which can be used to magnetize the part, in this fashion.

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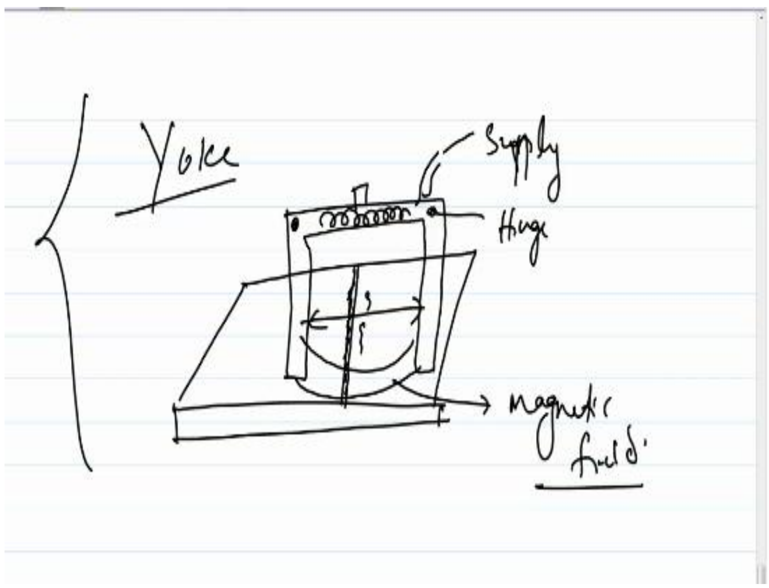

So, inside this, you essentially have a coil, which carries the current and then you can connect it to a power supply and you might have a switch, to switch on the current and the moment you switch on, the current, it will start the magnetic current and create the magnetic field across this. So, let us say you want to inspect this weld. So, these are the two plates, which are welded.

So, the field in this case will be along these imaginary lines, if you connect these two poles, these two ends. So, that is how the field will be in this case, when you are using yoke. So, this will be the field direction. So, that means in this case, the best visibility will be for cracks which are oriented to this magnetic field, which is generated by this Yoke. And this is very convenient to use in a laboratory or to magnetize on localized parts or small parts. If you want, you can also provide the hinge, some kind of hinges at this location, so that this distance can be varied, that will again help you out in magnetizing at different distances. So, that is another advantage that you have, these two legs can be movable, so that you can adjust the distance between them and then your magnetizing distance will also vary, you can vary the magnetizing distance on the part. So, these are the different methods, the most commonly used methods, by which you know, you can magnetize a part and once the part is magnetized, then comes the other steps that we are going to discuss in the next lecture. So, this is all I have for today, see you next time.

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