Introduction to Mechanical Micro Machining
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Lecture - 39
Components of machine tool (Contd.)

Good morning everybody and welcome to our course on Introduction to Mechanical Micro Machining. In the last class we have seen about air bearing and we have found that this bearings are free from old types of wear as well as friction. So, that can be used for making different type of sliding motion of the micro machining centre.

So, let us continue this topic further and let us understand what are the other components which can be a part of a micro mechanical machining centre which can be used for getting a high precision motion and the very very high accuracy.

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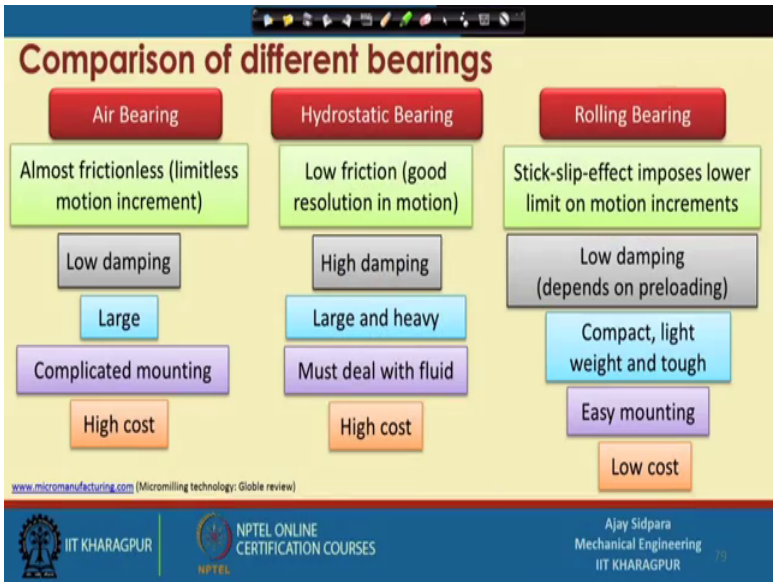

So, in the last class we have seen this comparison between the Air bearing, Hydrostatic bearing and the Rolling bearing. And we have also seen that there are different advantages of all these threes and it disadvantages also. So, we have to found that which way we can get this particular things selected for a particular application. Because everywhere you cannot use a air bearing and everywhere you cannot use a roller bearing. So, you have to find out a suitable application and then you find that how much is the accuracy and precision you required and maintenance is also one of the criteria.

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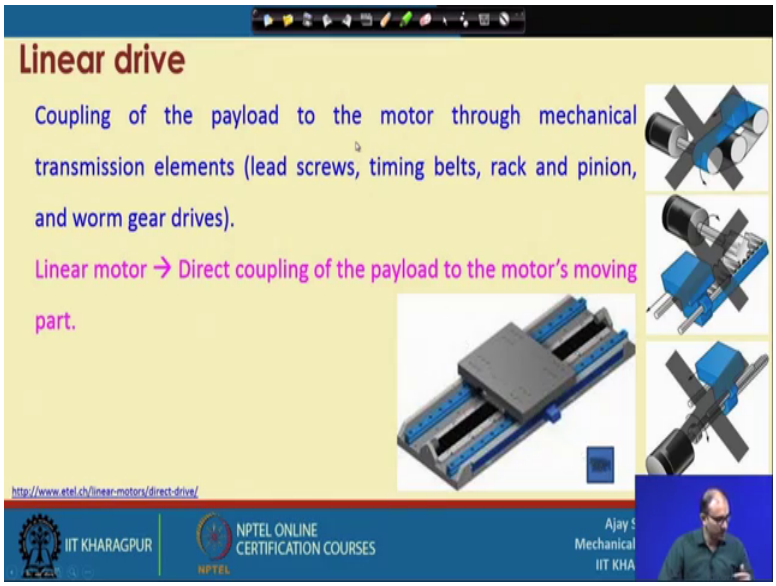

So, let us continue further now coming to the Linear drive. So, whatever we have learnt till now those were related to the bearing related issues. Now suppose you want to move something linearly in one direction to another direction and that is also similar to the air bearing that you do not need any friction between these two; that means, the on there should not be any contact. So, linear drive is one of the things which can be used for making a linear motion that can be used in x direction, y direction as well as in the z direction.

So, what are the differences between the conventional drive and the linear drive? So, mostly what happens if you consider the belt drive, now this is the belt drive where what we do here? That we have a motor and on the motor there is a pulley and on the pulley we put a belt drive. So, we can move suppose this is the one component which we want to move, then you rotate this particular belt drive and because of the rotation of this pulley in clockwise or anticlockwise direction you can transfer this component to another direction.

So, what is that that we have always a coupling of mechanical coupling; that means, coupling of the payload to the motor through a mechanical transmission element. So, here what we are using we are using a belt drive. Suppose this is the coil so it is called rack and pinion kind of thing. So, here suppose you are putting some component and

then you give a motion of this motor and then this rack and pinion will move and because of that you will get one linear motion of this part.

Then there is a re-circulating bolts, screw kind of things. So, here also you can get this thing. So, what is common in all these three applications that everywhere you are using a mechanical transmission element; that means, there is a physical contact between the belt and the pulley and the worm rack and the pinion and the gear and this particular nut.

So, what is problem that wherever we understood from that earlier the roller element and hydrostatic bearing and the aerostatic bearing that wherever there is a mechanical count we are end up with the friction and wear. So, if you want to avoid these things in linear motion also then there is a option that is called linear drive.

So, what is the linear drives? It is a direct coupling of the payload to the motors moving part. So, this is the linear drive. So, what is happening here that this particular top portion it is limited because of the magnetic field and magnetic field will propel this particular movement. So, let us see this video that how this thing will work in the actual condition. So this is this thing we have seen in the last class that we always need some frictionless thing. So let us directly jump to the linear motor. So, what is the linear motor?.

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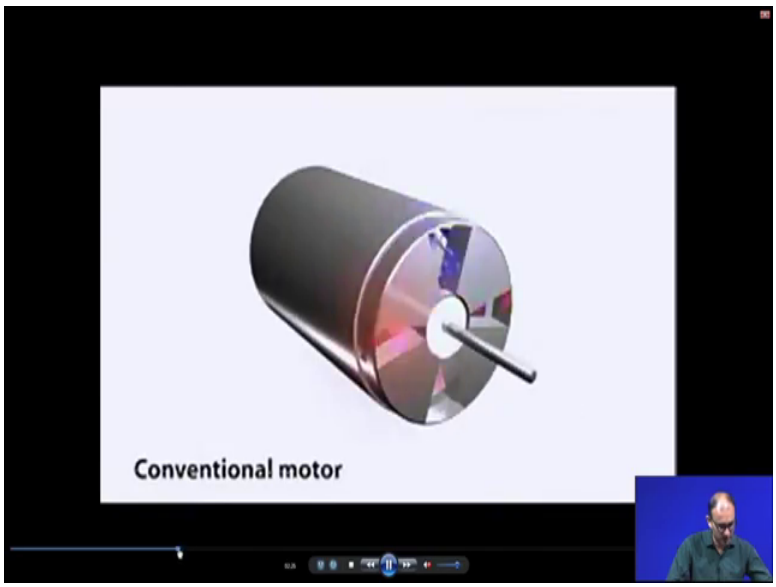

So, now this is a conventional motor correct? Where we have a stator and one is a rotor. So, rotor rotates and stator is around the rotor and because of this connection you are getting a circular motion or the rotational motion in the conventional motor.

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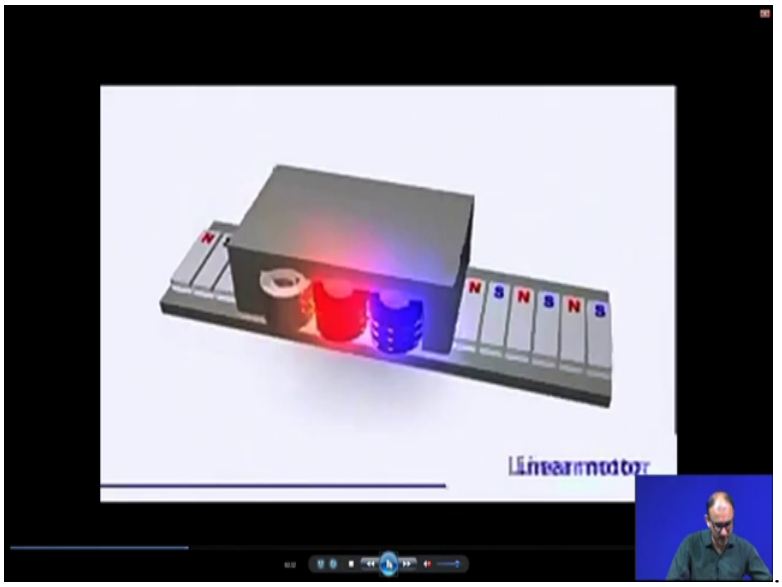

So, it is just a something about this thing. So, now what you are doing that you just undrape this particular stator. So all the North Pole magnets which are earlier in the circular part now it is a flat surface. And the stator is actually play down on this top of that and there this is a rotor which will take the form of this part. And now what is we are doing that we are unwrapping the conventional motor stator and then it is becoming a flat surface. And now this particular movement or where whatever you are putting on the top of that it will move depending on the magnetic switch way. Whatever way you are actually is switching this pole depending on that you will get the movement over this particular magnet. Now you can see this is the magnet. So, this is the way linear motor works. See in earlier case what we have seen that it was a mostly a mechanical contact between the two surfaces, but here what is happening that whatever speed you want to get this thing here and whatever way you want to make it most everything depends on the wall which way you can switch over this particular power supply. So, that you can get the moment in right to left or left to right direction right.

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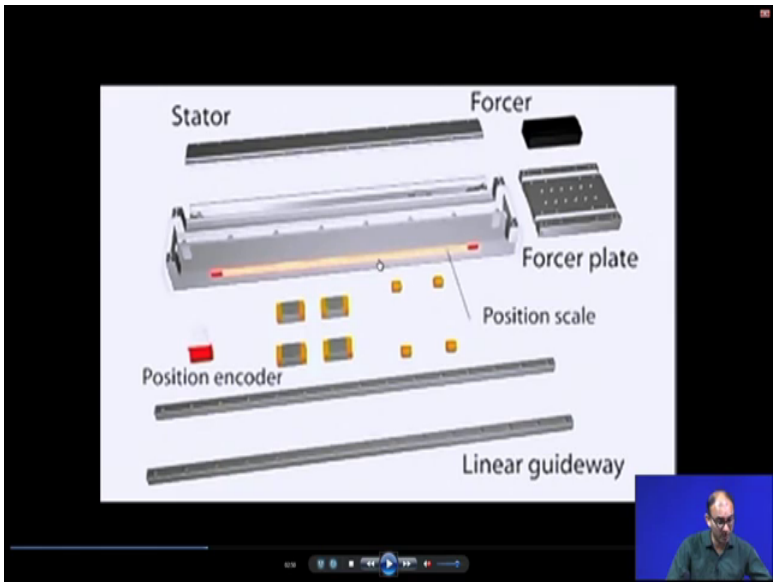

So, these are the different different components of the linear motor. So, this is called forcer. So, forcer is the things which will be put onto the top surface and then forcer that coil will be bounded around this forcer. And this is the plate will be want which will be on the top of the forcer and you put any component. Suppose you want to move a work piece then put the work piece here. If you want to move a tool then put a mount this tool particular here like that and this is the stator because we know that stators are required. So, that you can put the magnets here and because of that magnet you can get this particular motion of this forcer on the top of the stator. And we need a linear guide way because we also want. This is use for just movement and after the movement then you have to also calculate that how much it is travel from one location to another location.

So, this linear guides are very important because the straightness and a linear motion everything depends on the how much is the precision of this linear guides way. So, that is the thing. And this is a position scale because if you want to move with a 1 micron or 0.1 micron, then what you need you need encoder. So, right now we are using here the linear encoder. We will see within few slides after that that what are these encoders, linear encoder, rotor encoder. But for this particular linear drive we are using a linear encoder. Because they have some certain advantages over rotary encoder. So, this is the scale and position encoder assemble, then everything we assemble and finally you are getting this particular thing done.

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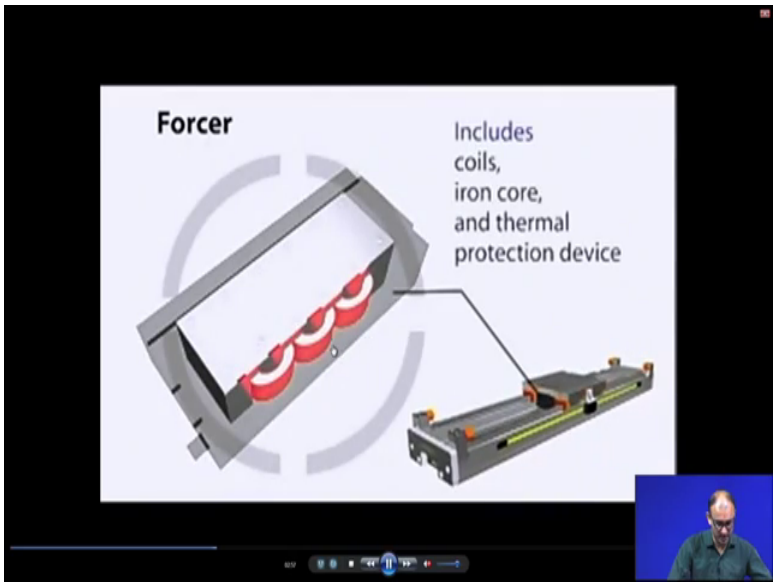

So, this is the complete assembly. So, forcer includes, so this is called forcer this part. So, it includes coil because you have to create a electrical signal here. Iron core is there because it is something like electro magnet kind of things and thermal and protection devices because you have to isolate this thing from the electrical problems

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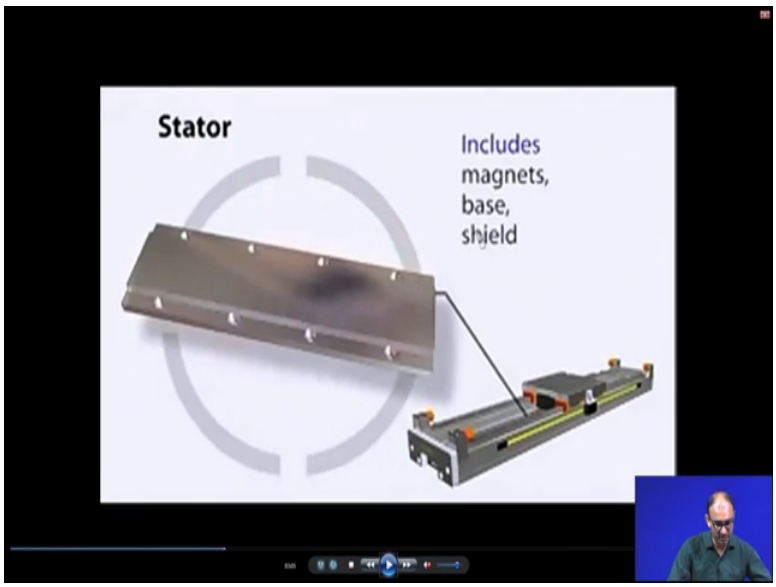

Correct. So, this is the stator. So, it includes magnet base and the shield because we have seen that we have un-wrapping that conventional motor stator and then it was becoming

a flat surface. So, this thing is mounted below the surface. So, these are the magnets and then you have to shield it also. So, that there should not be any type of problem.

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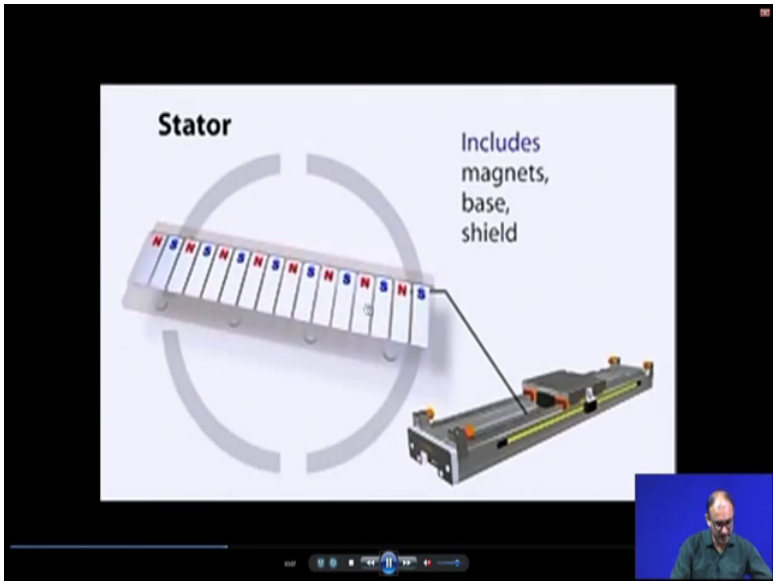

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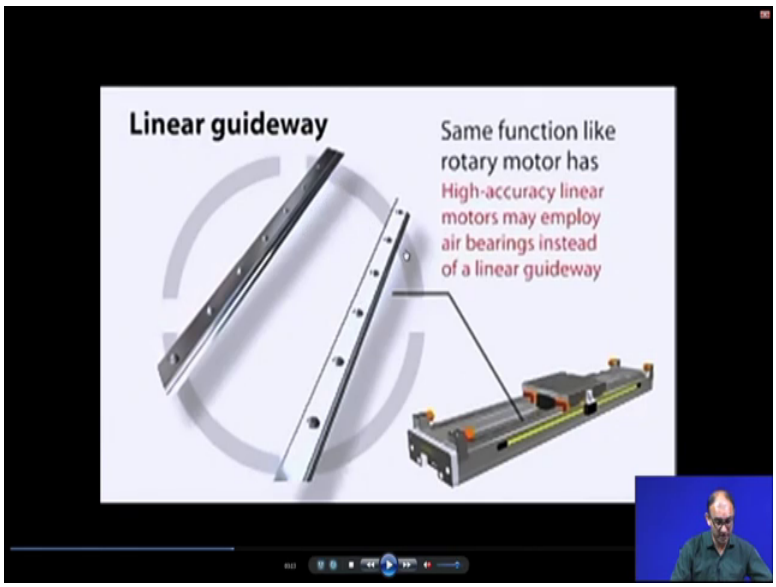

So, these are the linear guidesway. So, it is same function as the rotary motor has the right accuracy linear motor may employ air bearing instead of a linear guideway. So, here we have a different different option before earlier lecture we have seen that we have a linear guidesway, where we are using a different different kind of bearing hydrostatic bearing, air bearing. So, we can use air bearing here. So that you can even get very very

extreme accuracy. So, even 0.1 micron or less than 0.1 micron motion is also possible with a condition that you have a encoder also with a same resolution. So, these are the linear guideway.

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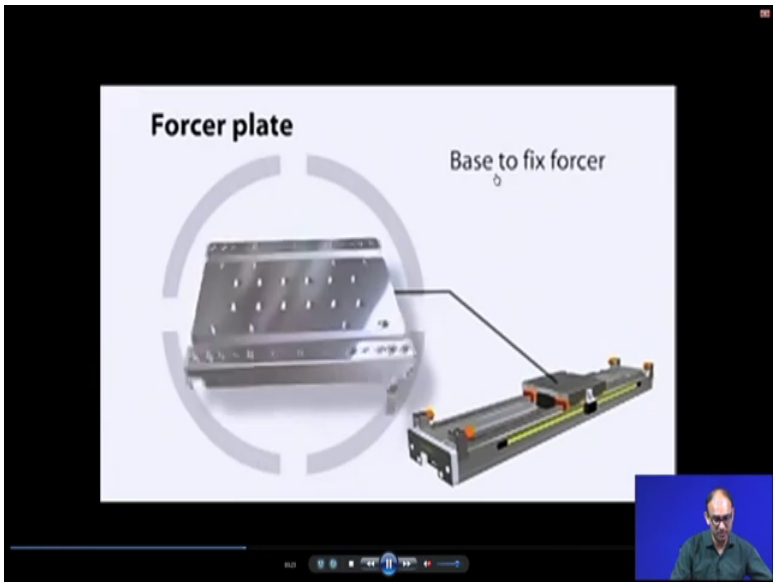

And this is a forcer plate on the top of that. So, it is base to fix the forcer and after that you put something on the top.

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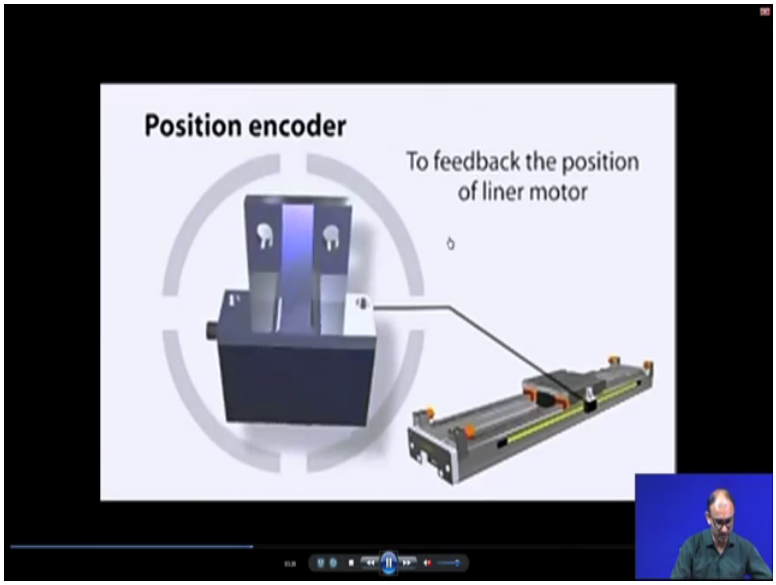

So, this is the position encoder. So, it is feedback to position the linear motor. So, here it will move along this motor. So, that you can get how much is the moment in the linear direction of this motor has performed. So, how this forcer moves?.

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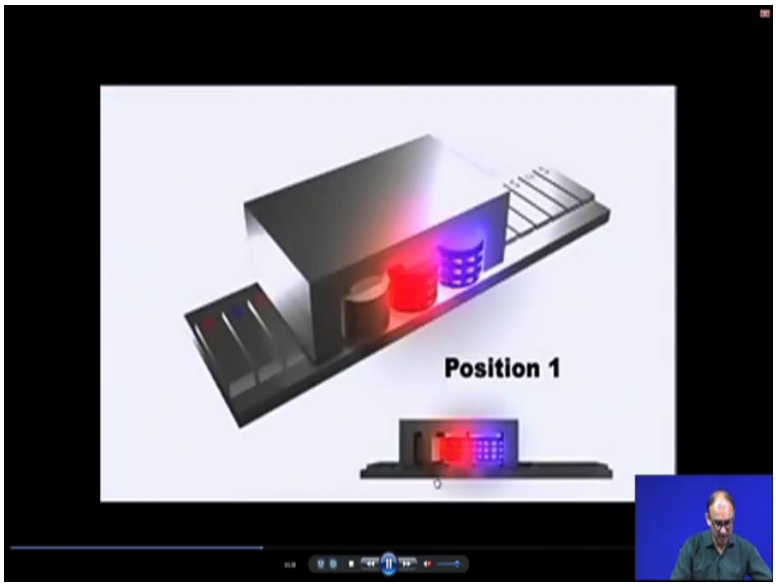

So, here so this is a Position 1. So, we have three coil here. And these two coils are energize and we know the these are the magnets with a alternate pole arrangements. So North Pole, South Pole, North Pole, South Pole like this. So, this is the first position.

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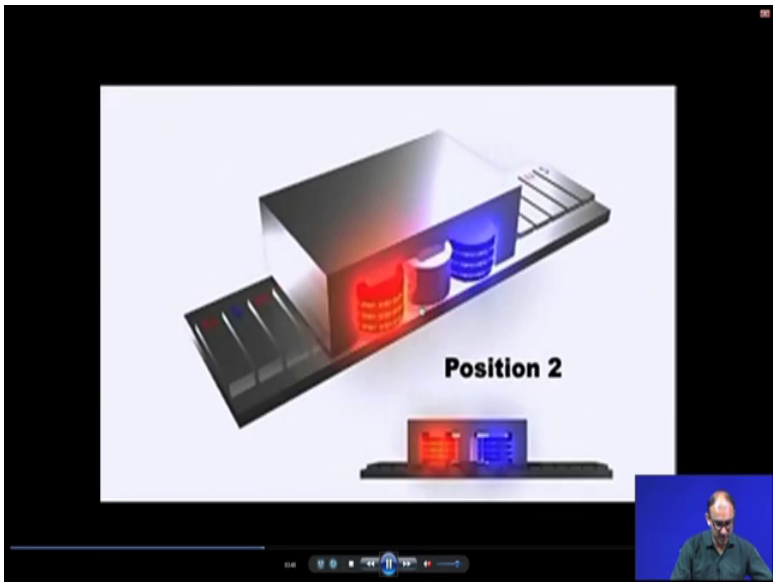

Now you can see that there is a switching over the between the two. So, now middle one is the of end, but this becomes the negative and positive depending on this polarities. So, now it has moved to second position.

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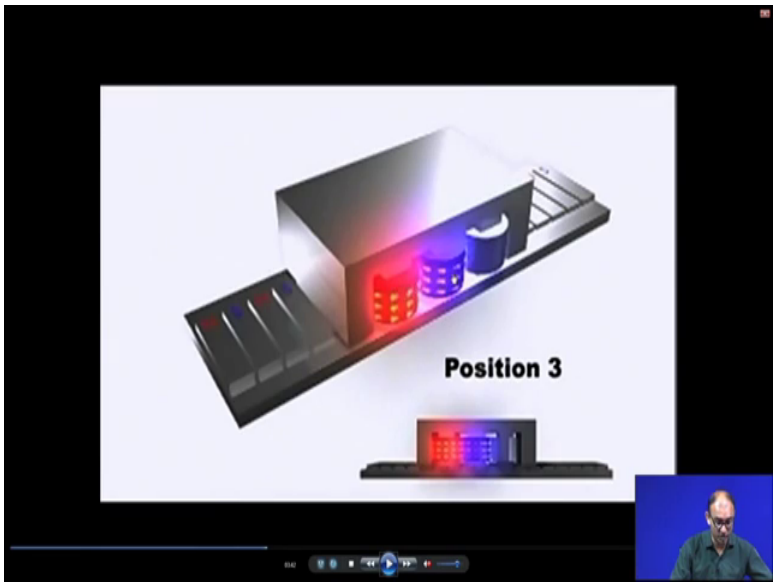

And now it is in the third position. Now see so, it depends on how frequently you are changing this particular position of the poles. So, faster you change this particular thing faster you can get the movement over the linear direction. So, this is the third position.

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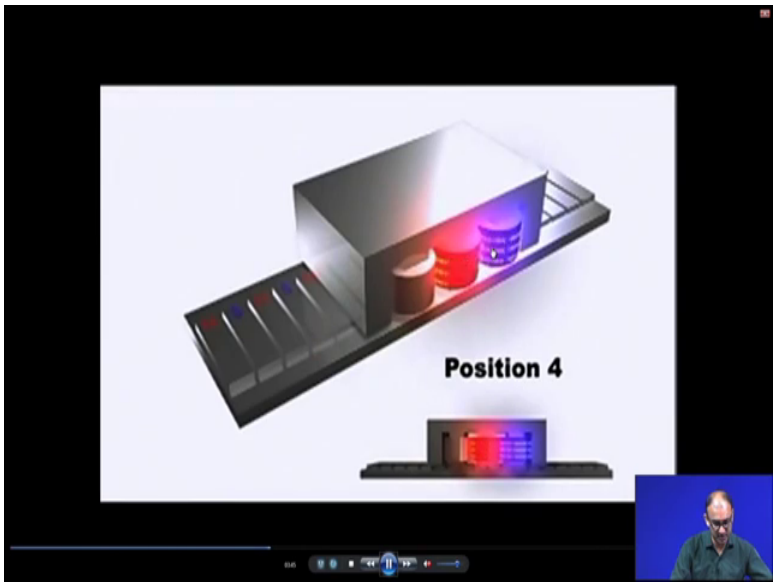

This is the fourth position. Again same thing will rotate. So, first two will energize then first and the last one will energize and then the middle one and the last one will energize correct.

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So, this way you can get the linear movement. So, now if you increase that frequency change then it you can get the very very high speed. So, this is the computation that is called how frequently you are changing this particular current direction. So, what are the parameters and definition we can think of.

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So, it is a continuous current. So, we have to apply the continuous current. So, that you can get this particular moment possible and we know that if you increase the current what is going to happen that we have a temperature rises so, with a (Refer Time: 11:10) and so we have to maintain that how much is the continuous current we can provide. So, that your whole system will work within the desired or the limited temperature zone.

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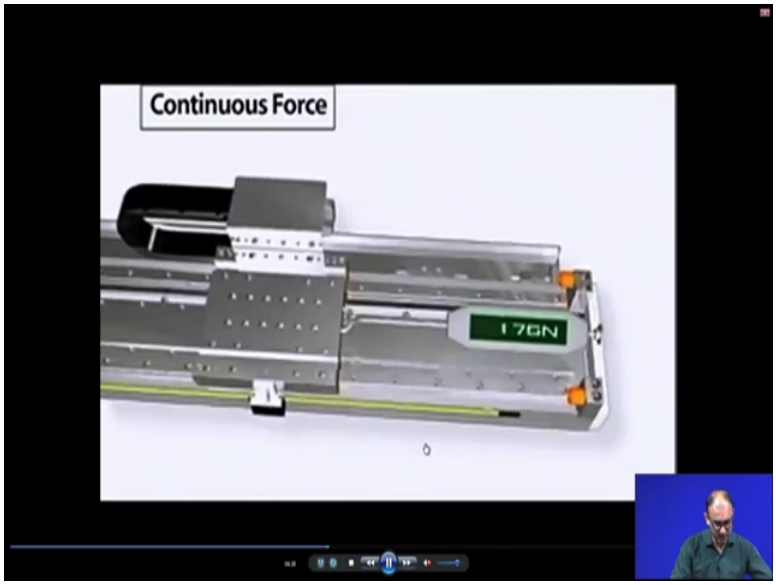

As on stator is the continuous force? Because now if you apply a force here, so how much is the force when you apply continuous current how much is the force you can get when you are moving this particular platform? So that is called forcer.

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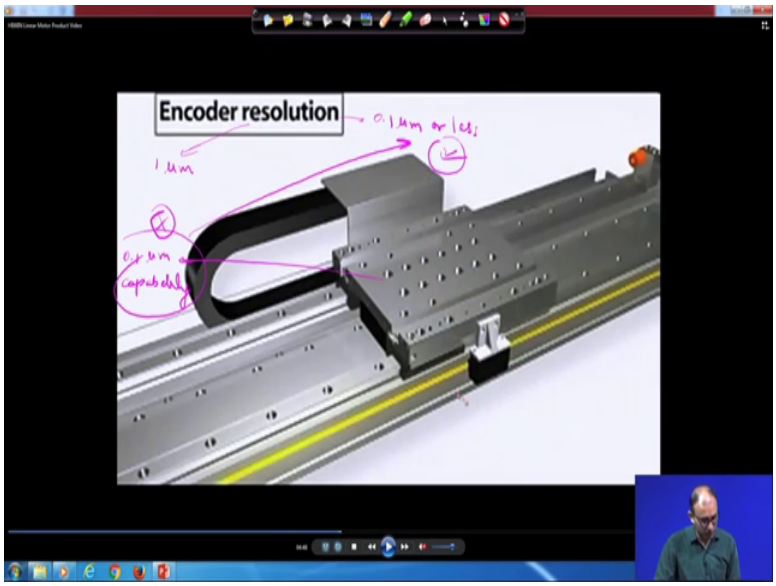

And this is the encoder resolution because everything depends on this encoder resolution Even if you have very very high precision motion of this linear motor, but you have not installed a sufficiently high resolution encoder then what is going to happen that you are not extracting the complete capability of this particular linear motors. That we have discuss I think few lectures there, that if your motor has a resolution of 0.1 micron and if you install a encoder with a 1 micron then whatever you are getting a motion it is a in a multiple of a 1 micron not with a 0.1 micron.

So, that is the problem. So, whatever things you get this thing. So, this is the encoder resolution. If it is a 1 micron and your motor has a 0.1 micron capacity or capability. So, this combination is not correct combination. What you have to do you have to find out this one is also 0.1 micron or less and then you get this particular thing here. So, this is the right combination because whatever thing you are getting at least you have to select encoder in such a way that it has a much higher resolution than the system then you can get the required thing done. Right. So, this is the position scale attached with this thing.

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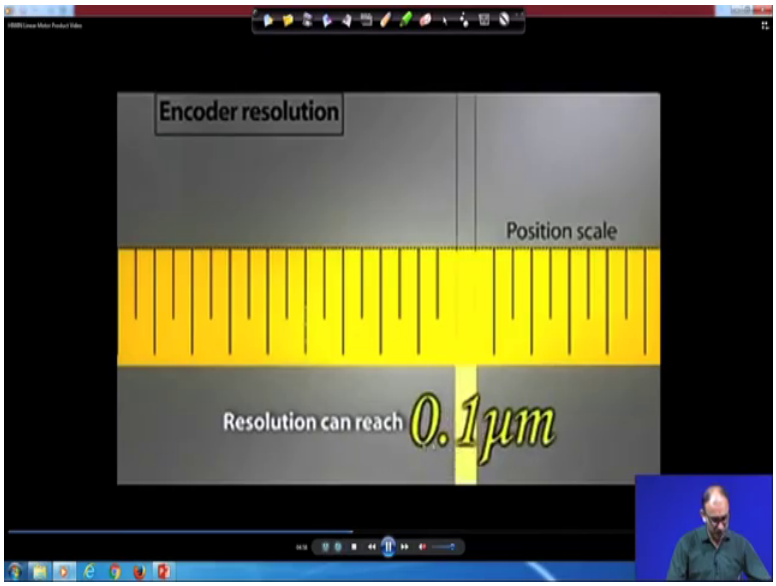

So, there are different different marking that is called position scale and each one you can get with a 0.1 micron.

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And then when you build the system what you have to do? You have to supply the current also. You have to finalize that what is the straightness, what is the velocity of the current when it is in under operation, heating of that particular system all the things you can think by this particular analysis that is called finite element analysis.

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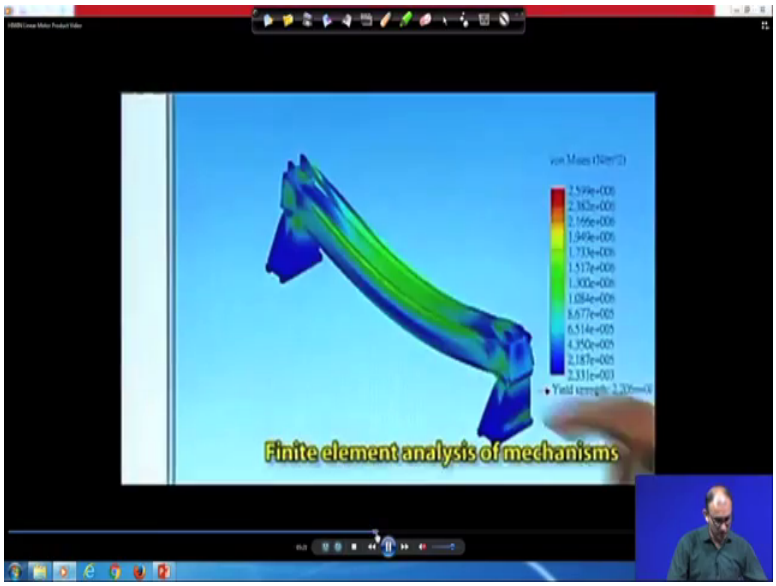

You can also do the some frequency mode analysis. So, that if it is under motion then how much is the bending of this particular rail.

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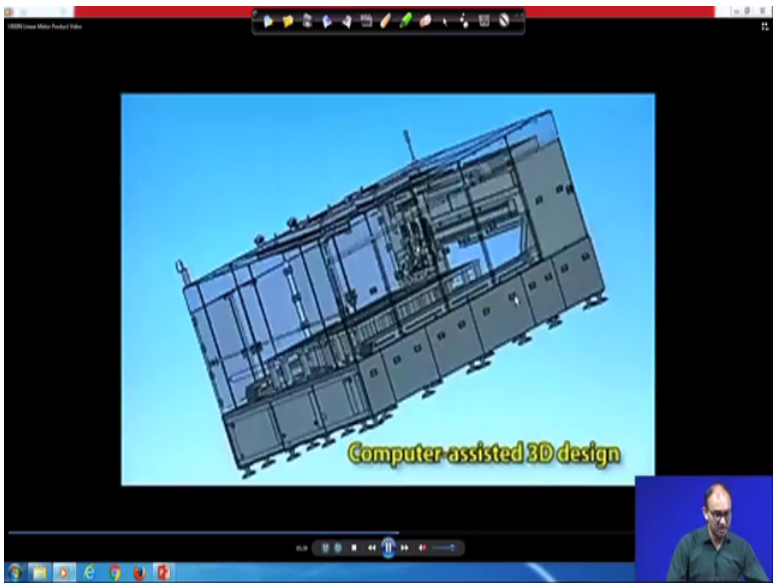

If you are heating this particular thing; that means, when you are supplying current what is the heating of this whole component? Where is the heat is concentrated or not? So, those things can be analysed by this particular softwares.

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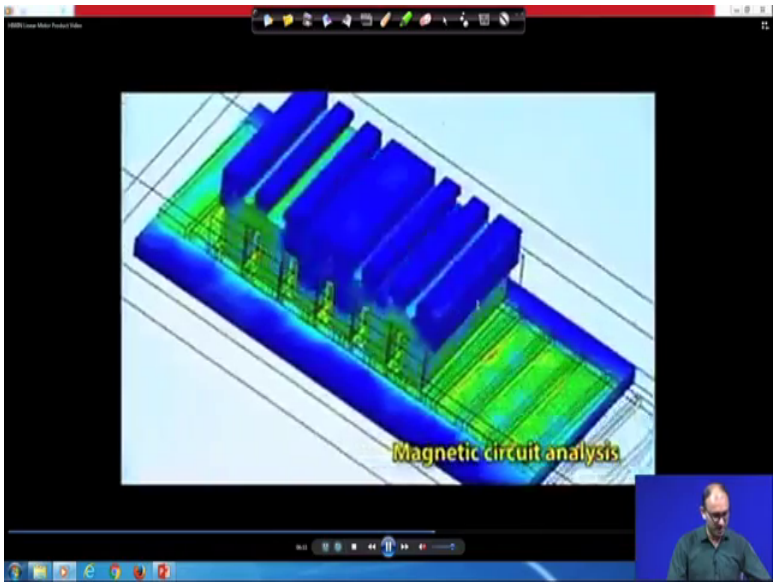

So, this is all the things about the magnetic circuit. So, let us not discuss this thing more right now. Because these things are used for the simulation and analysis before design purpose only. So, this is all about the umm linear motor. Right?.

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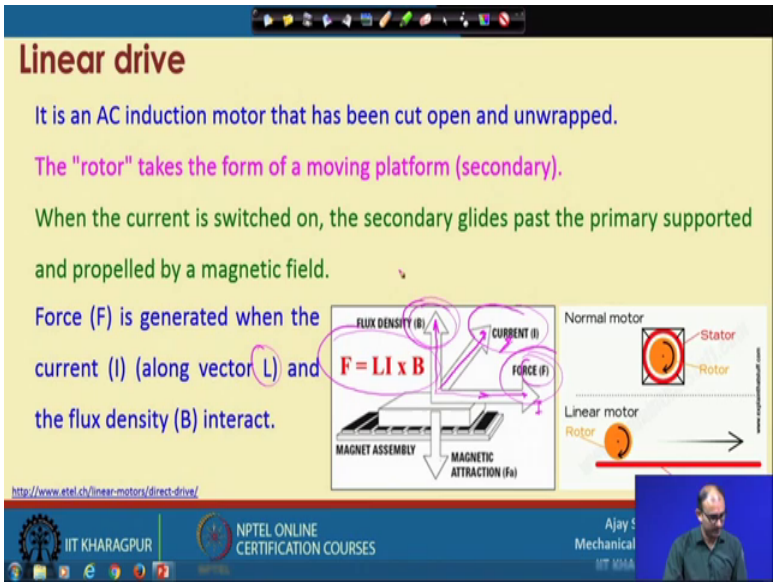

So, this we have seen that this is our normal motor with a stator and rotor is arrive in between these two it will rotate. So if you flatten this particular stator and move this linear rotor on the top of that you can get the linear drive. So, this is called the rotor takes it is called the secondary part and this is called the primary parts. So, that is the linear

motor. And how it will work? That suppose this is called the low and slow. So, what is happening here? Let me get these thing. So, this is the current you are applying so, that is called the magnetic field. So, this is the magnetic field you are applying in this direction that is in vertical direction and if you supply a current in 90 degree to that thing then it will generate a force which is perpendicular to both of these things. So, that is called Lawrence force. So force F is generated when the current I and the flux density interact. So, along the length so that is the length of this particular direction in which you are applying the current whatever the component you are adding.

So, this is the formula F equal to L into I into B so whichever way you want to give direction. So, suppose you want to get direction movement in this particular direction then what you can do that you change the direction of this current, either in this direction or this direction. So, at time this force will change. If you want to move this force here then you have to change the current in this direction current or the magnetic flux density. So, depending on this whatever direction you are getting putting this magnetic flux density and current you are you will get a force exactly perpendicular to both of those direction. So, we have to design this particular system in such a way that you get the motion in the required direction not into the other direction. So, this is all the things is given a magnetic assembly is given that is the attraction force. Because magnets are located bottom and we will see that some of these components are made of iron. So, iron will attract this particular thing and then you can actually move in the different different steps or the very very high resolution.

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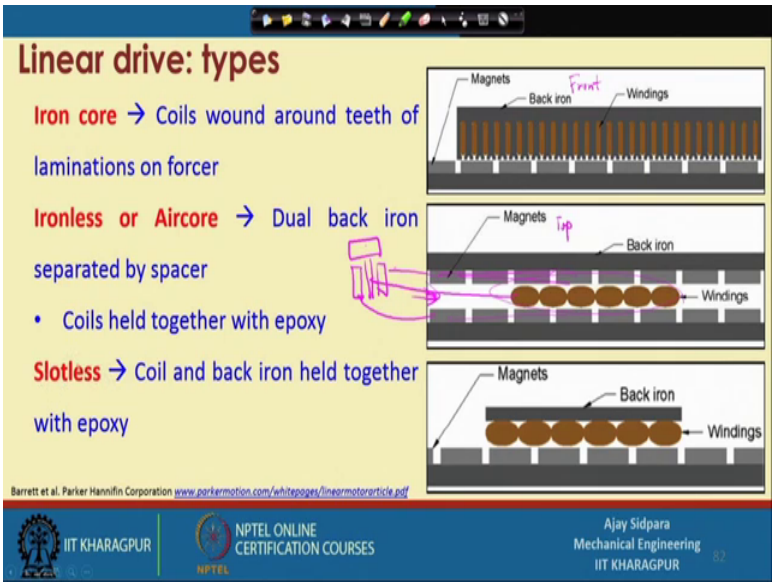

So, what are the different types? There are three different types of linear drive. One is the Iron core motor. So, what is this Iron core motors? So, these are is the particular forcer or the back iron and these are that yellow colour showing it is the coil and these are the magnets located here. So, that is called winding coil or winding both the things. So, coil wound around the teeth of the lamination of the forcers. So, this is the forcer lamination and then you put the epoxy and then repeat and make it complete.

Second one is called the Ironless or the Aircore because why it is called ironless because we are not using iron here. So, dual back iron separated by the spacer. So, this is the same thing, but this is this is the front view, this is the front view and this one is the top view. So, we are looking from the top we will see this thing more detail in the next few slide. So, what are the differences here? That now here the magnets are magnets have two rails. So, these are the magnets when you are looking from the top and this winding is at the centre and on the top of that you are putting something. So, this is the something that these are the magnets and this is the winding and on the top of these parts. So, we are we are looking from this direction. So these are the magnets and what are these things it is these small part. And on the top of that you put plates so that you can mount something from the top.

So, this is about the ironless or the core iron and coils held together with epoxy and another last one is the Slotless. So, this is actually the getting advantage of iron core and

the iron less one. So, it is all the things it is in between these two. If you are getting some disadvantages of this both the things will be here as well as disadvantages of both the things also here. So, how this thing is there that now some of the features are recreated here because this is something which is similar to this ironless, but you are putting this particular rail also similar to the iron core. So, this is in between that is called slotless and coil and back iron held together with the epoxy here in this particular case. So, let us discuss this each one with a separate advantages and disadvantages.

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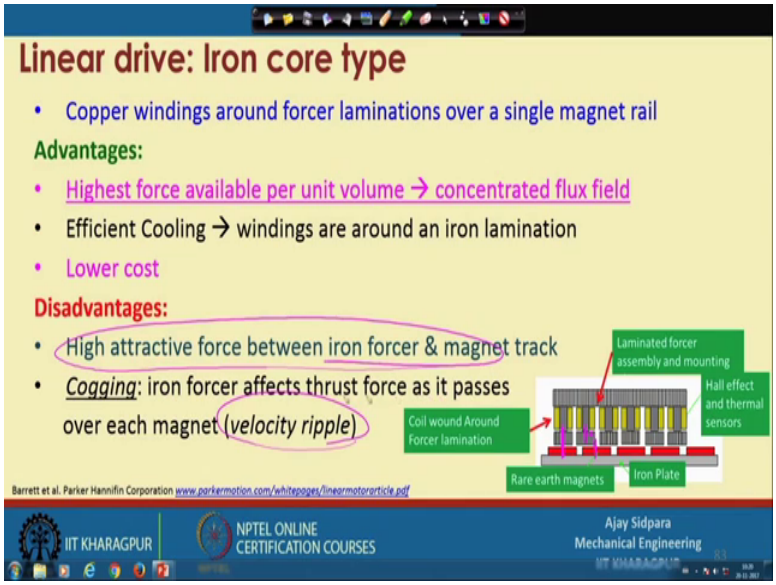

Right? So, first one is the iron core. So, this is the schematic diagram of that earlier things whatever we have seen in the last part. So, this was the laminated forcer this particular part and this is the coil around the forcer laminations. So, these coils are bounded like this way correct? And this are the rare earth magnets this is the iron plate available and these are some sensors are used for position sensing or current sensing that is called Hall effect and the thermal sensor. Thermal sensor we required because we know that by applying this very high electrical current then you may get the heating effect also. So, we have to reduce that heating effect for continuous and smooth motion.

Right? So, copper winding around the forcer lamination over a single magnet rail. So, we have only one rail of the magnet. So, this is called rail magnet. So, what are the advantages here? Because here the highest force available per unit volume because here what you will get you will get a concentrated flux field. So, that is magnetic flux field is

very concentrated. So, compared to all the three rails compared to not other completely has different system, but here you will get more force. Efficient cooling because windings are around the iron lamination. So, what is happening that whole system is actually open. Now you can see that this whole part because this is moving in this direction or this direction, but this when it is moving at that time you have air circulation in all around the parts. So, that is the advantage that here efficient cooling is there. So, temperature effect will be little bit less compare to the other two types.

Lower cost because it is simply the extension of this convention motor you just un-wrap this stator and then use with a few sensors only. So, the cost is also less compared to other two categories. But what are the disadvantages here because here one disadvantage is the high attractive force between the iron force and in the magnet track. So, what is that? Because this is a magnet. These are the series of magnets attached here and our forcer which is made of iron. So, that is a big problem. As if it is iron and this is very close to this particular magnet.

So, what is happening here that there is high attractive force between these two because we know that wherever you are putting magnet and there is some iron compo iron available nearby place then it will be attracted by the magnet. So, same thing happens here also. So, because magnetic track will attracted by the iron forcer and because of that there is one problem happens. So, that problem is called Cogging. So, this is called the cogging. So, what is the cogging? That right now it both things are situated here. Now consider so, this is at the alignment position right. So, now you have to switch over the supply. So, that this is off position and this become the on position. So, this line and this line will be moved in this direction.

So, when you are moving from one magnet to another magnet what is happening here that because we know there is attractive force and because of this attractive force you will get a velocity ripple right. So, it is difficult to get a smooth motion from one magnet to the another magnet. You can you will get a very very quick motion from shifting from one to here. That quick in the sense that it is extremely small, but when you are talking a motion with a micron of a or the lees than one micron this velocity ripple will create a problem at the micro scale. But if you see at the micro scale when you are talking about the hundreds of micron it may not make any difference at that location. So, iron force affect the thrust force as it passes over the each magnet. So, whenever it is shifting the

position it will get the velocity ripple. So, that is the problem of this particular type of motor.

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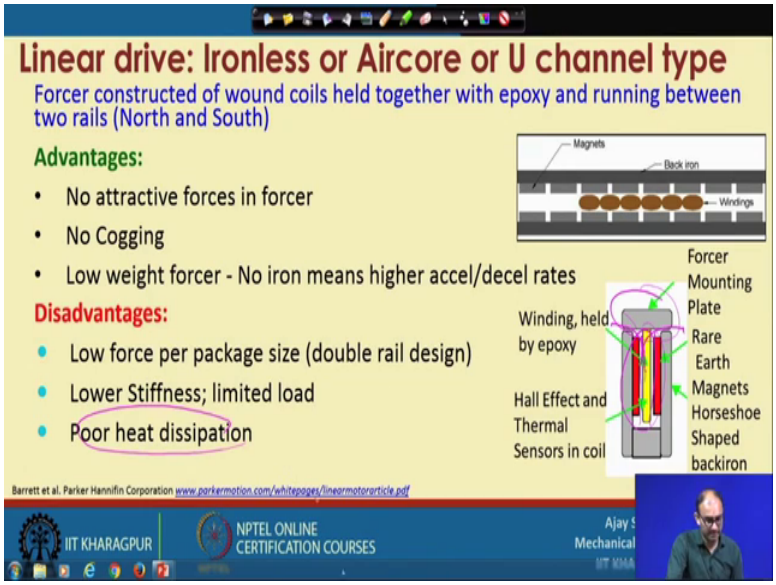

Second one is the ironless so the iron cores. So, this is the same thing here, but now we have seen this cross section here. Now you can see. So, this is the first thing. So, this particular thing is here and these two are the red colour part whatever we are looking from this. So these are the magnets and on the top of that you are putting a forcer mounting plate. So, you put any object here or the tool here then it will move with a such a high precision. Now, difference between the first and to the rail earlier case we are using only single magnet rail, but now we are using two magnet rail. So, that is the another thing you put the same Hall effects and Thermal sensor everything in the coil and then this is the Horseshoe back iron plate. So that you can contain this all the things in a small volume right. So how this thing is different than another. The forcer constructed of wound coils held together with epoxy and running between the two rails both the North and South in this particular case.

So, it is moving in this an earlier case what was the thing that this whole thing was a from top to down and only single rail was there. So, that is the distinguished feature between the earlier case. What are the advantages here because now we are writing ironless so we are not using iron. So, once iron is absent what is happened that you will not get the cogging motion or the no attractive force between the two parts right? Low

weight forcer because no iron means higher acceleration and the deceleration is possible here. So, this is the one motor which can be used for a very very highly precise motion where you need a very very high acceleration and sudden deceleration so that you will not get any type of motion error. So, that is very very good motor fall, but it has a low weight forcer.

What are the disadvantage? The low force per package size because it has a double rail design here. Because here whatever the system you are using it is very very heavy. So, if you consider the package size you will not get say that say amount of force air. So, here force is very less, but if you want to use with a very very highly precise moves on or where you are not getting a force in a few microns of Newton then this is the better choice compared to the other two motors. Lower Stiffness and limited load here because what is happening here that whole thing is mounted on the top of this part. This is the forcer and you are putting everything here and these we know then everything is actually epoxy and what say the other way we are putting with epoxy.

So, this is not actually the mostly compared to the metallic joint. So, if you are putting more weight on the top of that what is happening then you have to sacrifice. So, you have to compromise the stiffness of that. So, load what whatever you are putting it has limitation because of the stiffness of this particular motor. So, you cannot use a very very heavy object on the top of that right? Poor heat dissipation because in earlier case we have seen that we had a proper heat motion from one location another location. But right now here what is happening? That whole thing is actually moved or it is a very very highly couple fix within the system.

So, movement of the air is very very difficult here and these are the motors which are located here. These are the magnets and this is the coil. So, if you want to dissipate heat from this particular part then what you required that you have to have air circulation through that and once air is circulated then it does not have the escape root also here from this part. So, for reaching to this particular location it has to travel to such a large distance and then only heat dissipation is possible. So, that is way the poor heat dissipation is there.

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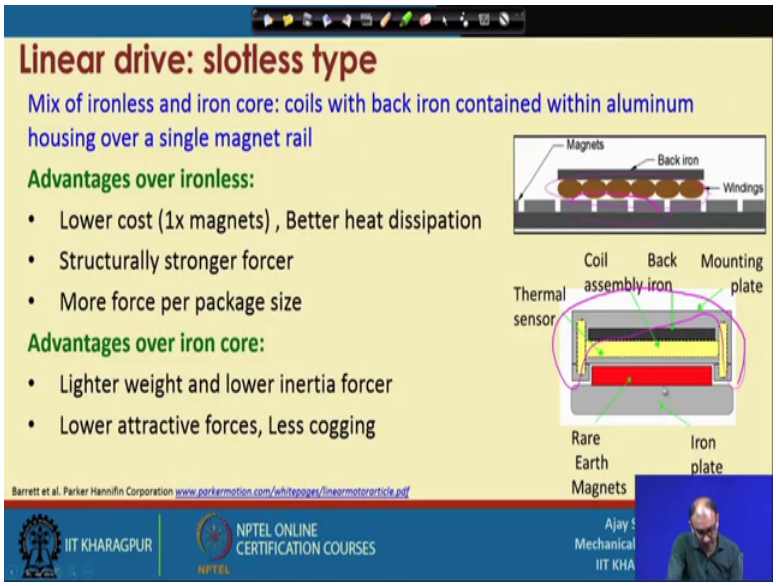

Then the last one is the slot slotless way. So, this is actually the mixture of the ironless and iron core. Whatever you are getting in earlier two cases you will get both everything here. So, how this thing the coil with a back iron contains within the aluminium housing over a single magnet rail. So, here the one thing is that you are using a single rail. So, that is similar as the first cases and then you are winding is similar to the second case. That is called the ironless or the air core type of thing. And all thing is actually fix within the aluminium housing. So, you can actually secure for a later case much better way to avoid some other problems.

So, what are the advantages over the ironless? So, it is lower case cost because we are using single magnet here. An earlier case the magnets were two. And it has a better heat dissipation compared to the first one only not to the second one. Structurally stronger forcer here available because in first one cases that was not the case. More first for force per package size because the size is compact, but still you can get the advantages of the first one. So, that is the better way.

Now, what are the advantages over iron core that is the first one. So, this ironless was the second one whatever we have discuss and advantage iron core that is first one the light weight and the lower inertia forcer. Lighter weight means this light weight is bit comparison with the first one, the iron core. Not with this one because this is the lightest compared to all the three cases. And we know that there is no cogging available even

though we are using iron plate here, but the distance between the forcer and the iron plate is large now. So, this is the completely you can avoid the coarse that cogging in the ironless kind of thing, but here you will get the cogging, but that cogging is very very less compared to that particular first kind of thing.

So, these are the advantages of this slotless with respect to ironless and the iron core. So, this are the different type of things. So, we will discuss about the advantages and disadvantages of this linear drive in the next class.

Thank you very much.