Introduction to Mechanical Micro Machining
Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 41
Components of Machine Tool (Contd.)

Good morning everybody, welcome again our course on Introduction to Mechanical Micro Machining. In the last class we have discussed about the encoders. And we have seen that there are two different kinds of encoders: one is a rotary encoder and another is a linear encoder. And we have started discussion about the rotary encoders. And there are rotary also there are two types: one is the a absolute encoder and another is the incremental encoder. And we have also seen that absolute encoder gives you the exact position even if there is a power failure, but that is not the case of a incremental encoder.

So, let us see that further in this particular case how these things are different with each other and then we will continue on the linear encoder.

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So, this was the last slide what we have discussed here, that this is the absolute encoder. In absolute encoder it gives you exact position of the shaft, even there is a power failure, because everything is depending on the binary code; that is very unique for a each and every position right.
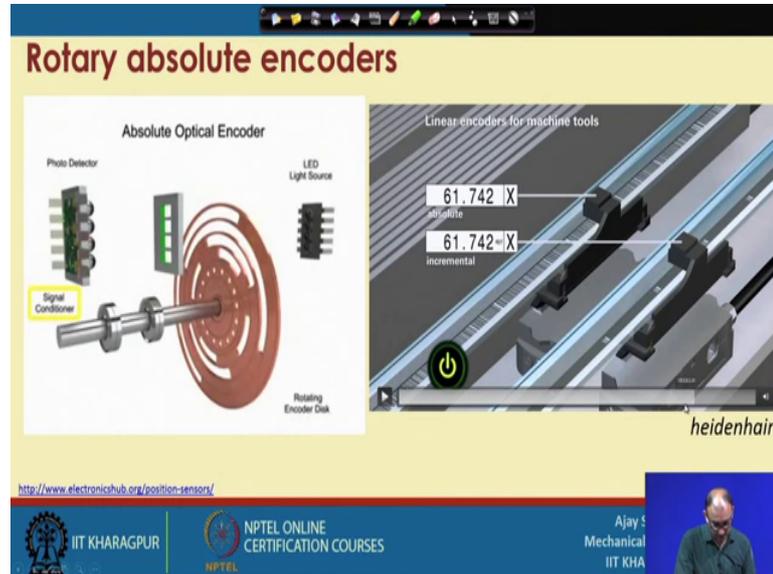
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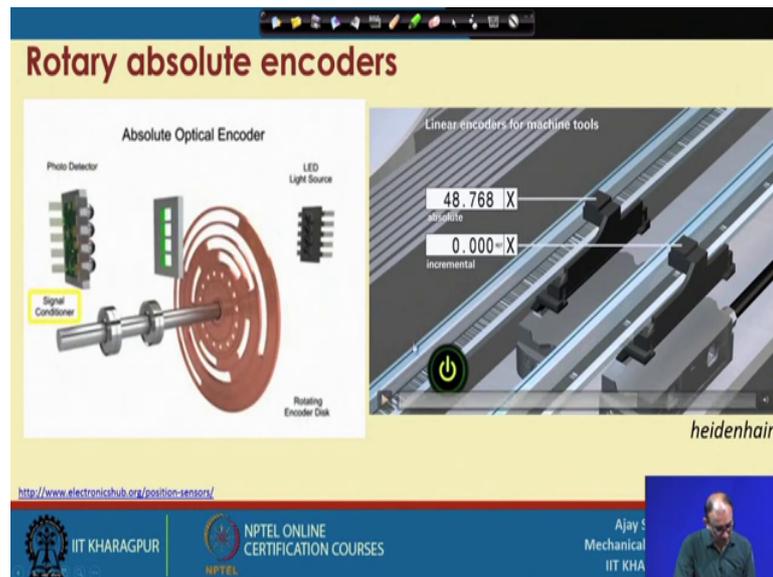
So, this is how it works let us see this particular cart. So, now, in these particular slide what it is showing; that these are the two encoders: one is the rotary encoders and one is one is the; these are the linear encoders, but it is showing how this absolute encoder and the incremental encoder works right.

So, now you can see these particular encoder is the incremental encoder and these encoder is the absolute encoder. When it is starting movement at that time you can see both are giving the same results. Now 11.742 to 11.742 no issue with that because it is at the initial position, now see it is going in power is on right now. So, here you can see the there is a one thing written that is called reference. So, this is the reference line whatever you are getting here, this is the other that whatever the small portion was there; that means, the very very fine grating of the black and white color part. So, now, you sink about this part.

So, right now all the readings are no problem with that. Now there is a power failure. Now both things are switched off you are not getting any signal out of it right. So, let us continue with that right. So, both are moving power is on ok. Now power is off now you can see now after switch off the power again the power has come back, but now you can see still this absolute encoder is showing the same result here, but here it is not reach to that location, because here it is finding the reference where is the reference.
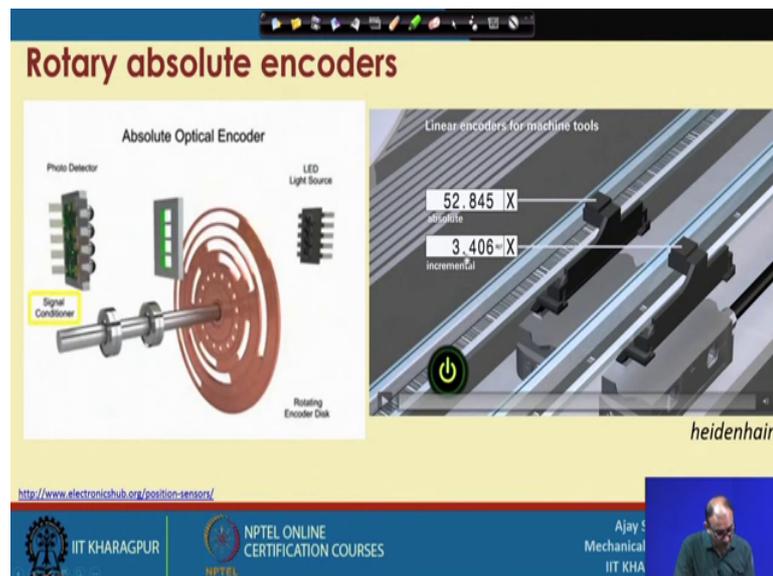
So, if you continue with this operation, then it will take some time now see it is blinking reference is blinking.
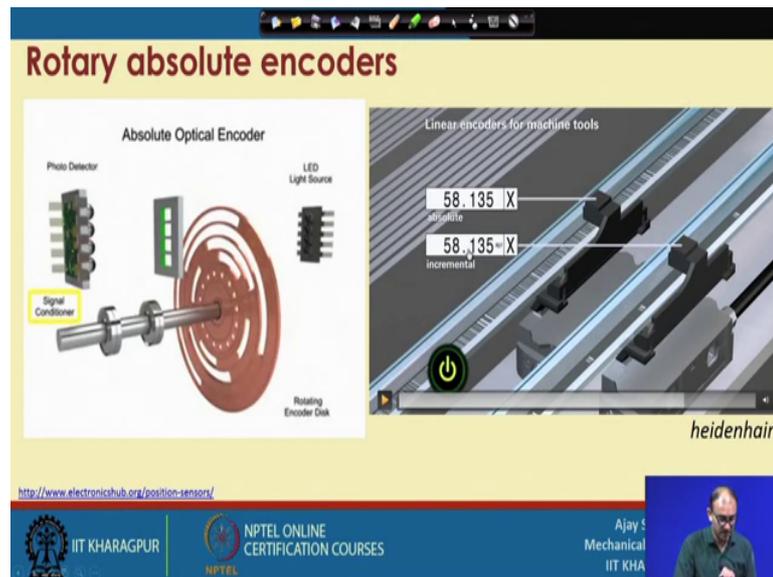
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So, now, it has reached now if you see this part now both things are not same because it has found the reference, but reference will reach to that original position right.

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So, it will take some time to reach then if you continue these things now both things are same.
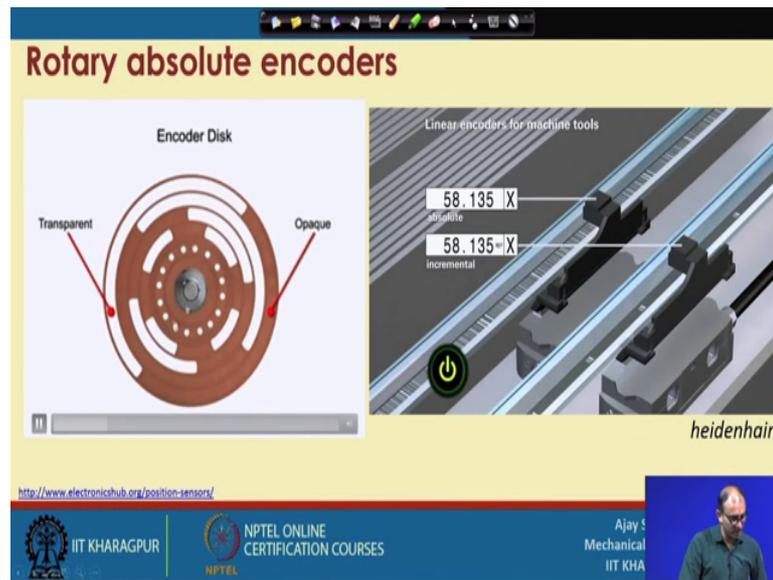
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So, now, you can understand these things, how both encoders works that is called linear encoder absolute encoder and incremental encoder.

We have taken the example of the linear encoder, but this is the same for the rotary encoder also. So, now, you can see that when you are using a incremental encoder you have to go with the reference position first to get the exact position, but in case of absolute encoder even whatever is a situation, because it is creating unique binary code and depending on that you are getting a position.

So, there is no issue with that particular part. So, if you see this particular any machine now here what is? So, is optical absolute optical encoder this is the photo detector and this is the led source. So, light will pass from here it will be sig getting here then there is a signal conditioner, because whatever light you are getting here it has to be converted into signal and then you are getting the motion things out of it.
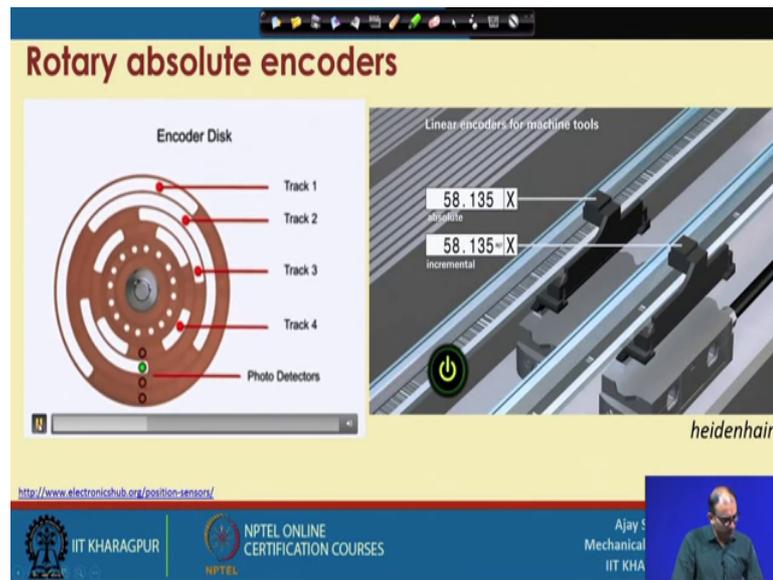
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So, this is the encoder disk and it has two region opaque region and transparent region and it has a four different track right now here 1, 2, 3, and 4 tracks.
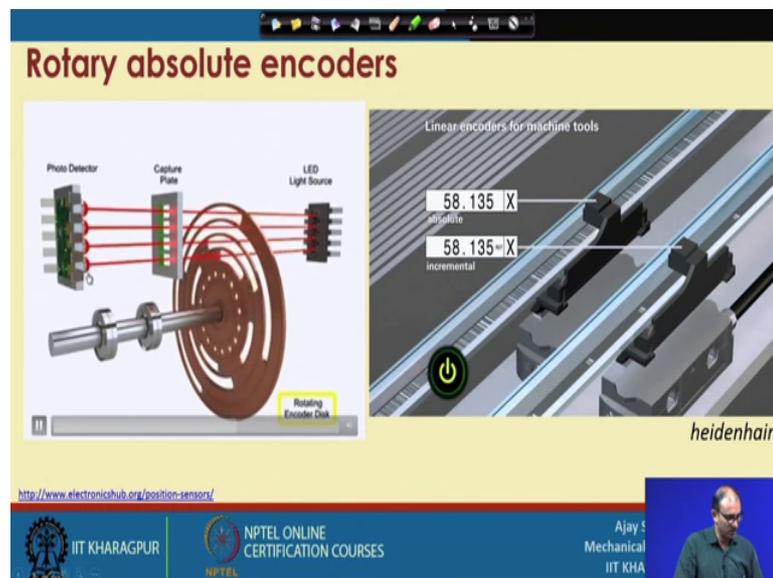
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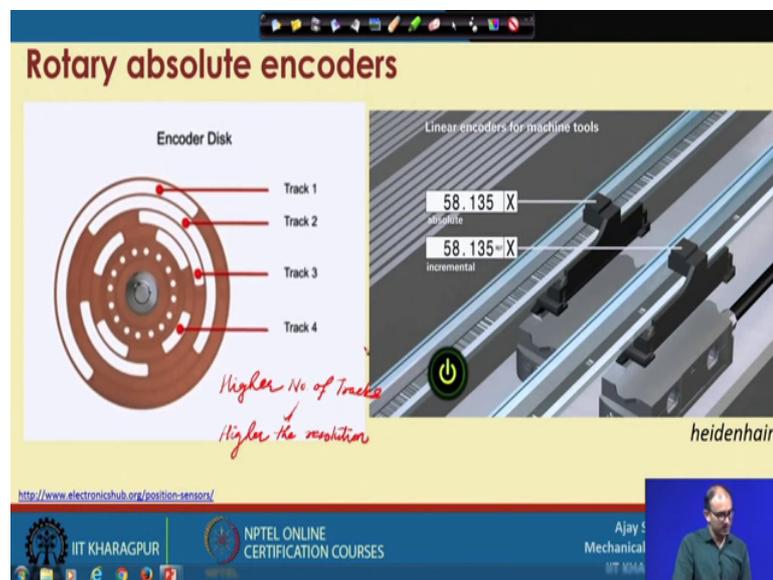
So, now if you want to increase the resolution, what you have to do you have to increase the number of tracks right. So, that is higher the higher number of tracks higher the resolution correct. So, that is what is the disk are.

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So, this are the four photo detectors right.

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So, when it rotates at that time it will generate a unique signal out of see wherever it is opaque region you will not get the signal and whenever there is a light signal you will get the signal out of it. So, these will generate one unique code and that unique code will help you to find the absolute position of the shaft.

So, let me show you one more video here that is the extension of this video only.
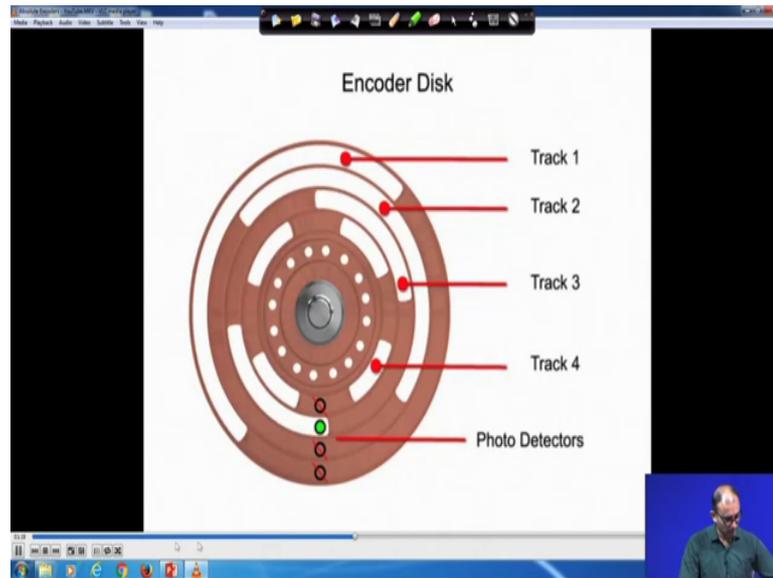
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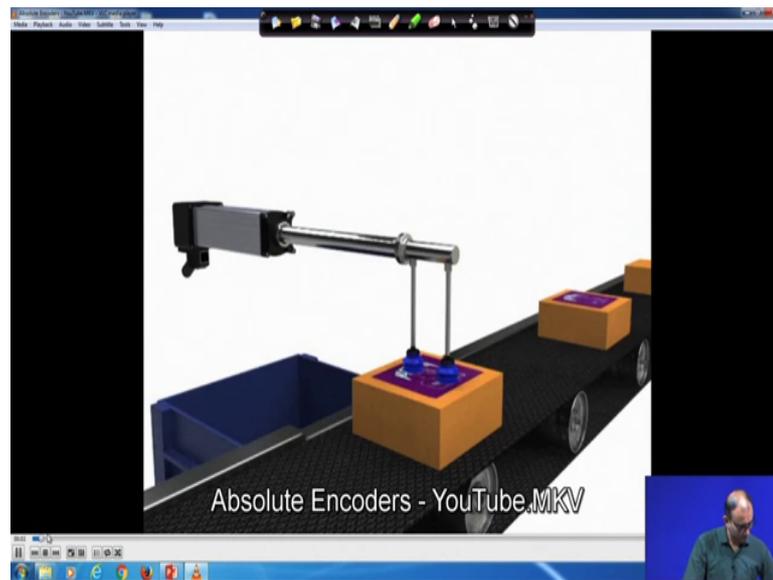
(Refer Time: 06:02) So, I have used in many applications that require speed. So, this is one of the application, what is happening here that your robotic arm is there robotic arm is instructed to pick up the part where you are not getting these particular wrapper on the top of that.
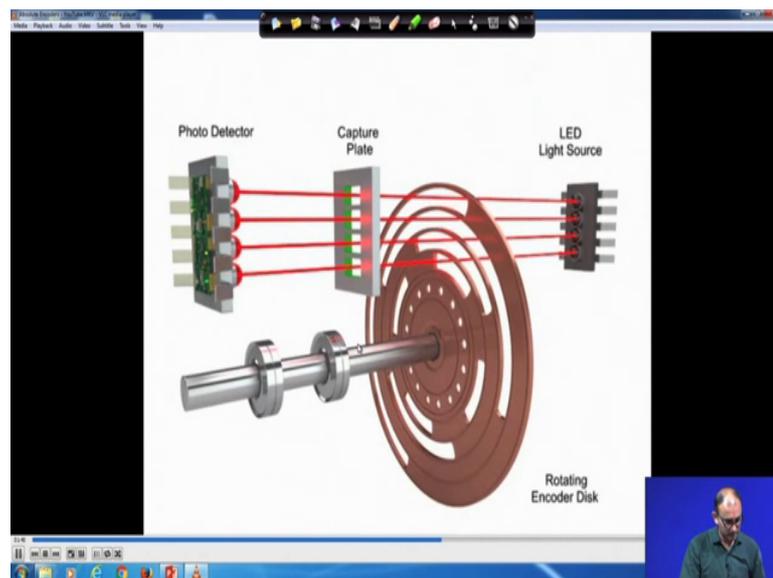
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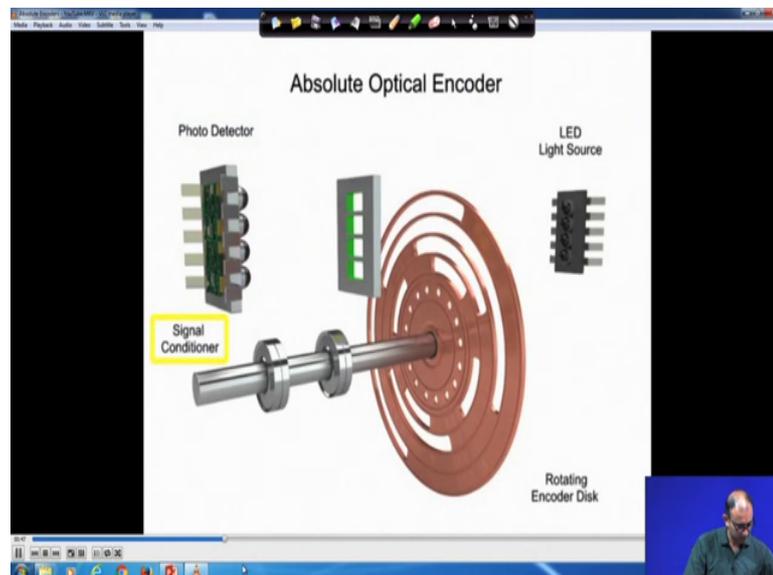
So, that is the application yes. So, this we have already seen this particular part. So, let us not go through that again. So, these are the track what we have seen in the previous slide.
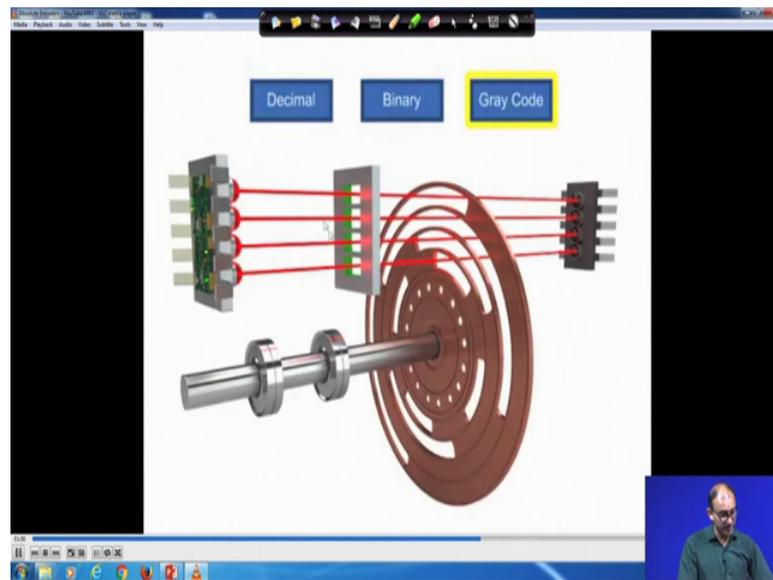
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So, this is how it will capture all the signals correct. So, now, there are three set one is decimal system.

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Another one is a binary system and another is the gray scale. So, from these three you have to find out the, which one is best suitable for it, because it will get the signal based on all these three system. So, let us that how these things.

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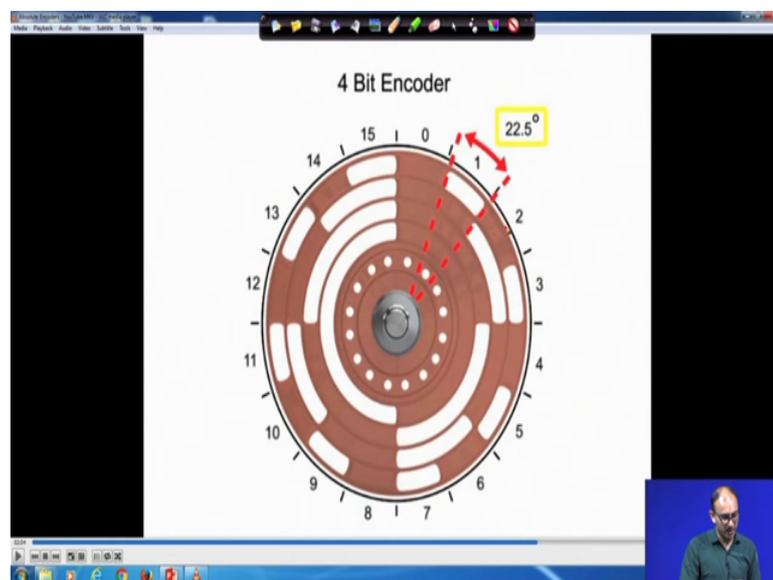
So, this is the 4 bit encoder. So, 4 bit; that means, it has a four track. So, based on the four track you are getting a signal output and for each and every this it is divided into total 16 division. Now, if you see here 0, 1, 2, 3 up to 15; 15 plus 0, that is also 1 signal right. So, 36 degree is divided into 16 part. So, each one has a one particular angle here.

So, after every 22.5 degree signal rotation you will get one unique combination of that. So, if you see this thing after 220 if it is moving to this location. Now see this becomes the opaque and these becomes a transparent, and if you continue this particular part these particular thing is changing now. So, this is the third position is changing, if you continue these two become opaque and this is a transparent, that is the second track starting from the centre.

So, after every 220.5 degree rotation you will get one unique signal and, that is where you can get the power output right.

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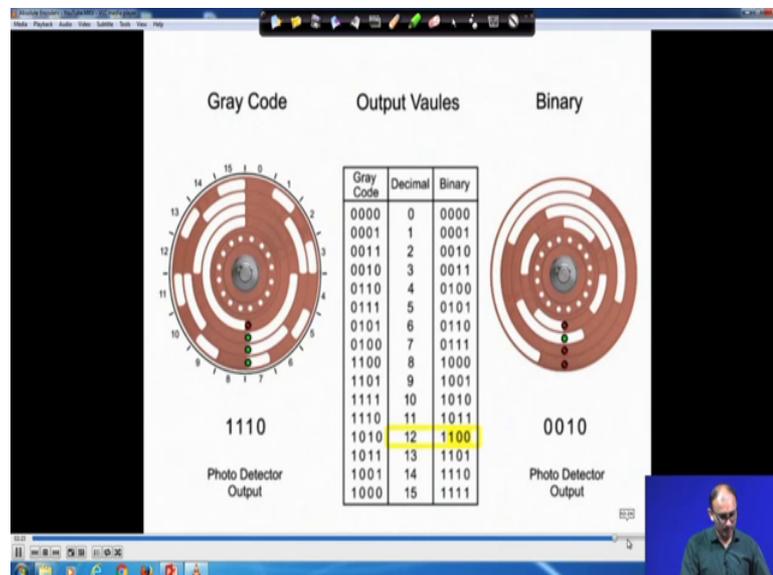
So, these are the all three kinds of things, now this is called the gray scale this is the decimal scale and this is the binary scale, how it is different in gray scale; what is going to happen; that you will always get a only one output; that means, when it is rotating only one signal will change not all the three or not more than one signal. So, for each and every rotation or every movement you will get movement or change in the only one signal, but if you consider binary there are more than one signal also will be change with a 22.5 degree change.

Now, see when it is moving from here to here, in this particular case more than one signal will also change. So, that is the problem here in this case, because accuracy will not be that much high. So, if you want to use with a extremely high precision or the resolution motion it is better to go with the gray scale code instead of the binary code,

because it is getting a only one loc only one change in the signal compare to the other two cases. So, that is the advantage of the gray code compare to the binary code.

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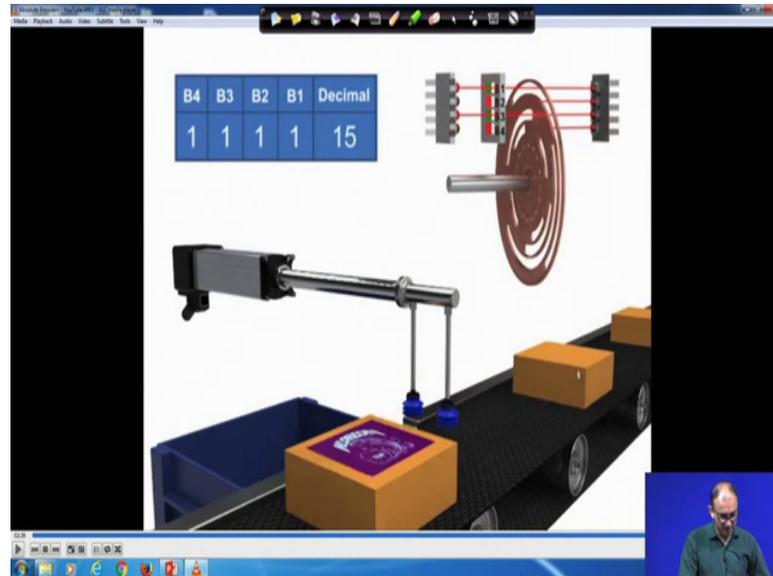
So, how we can use these particular things so, again the same things are here that you have a four different code and you will get the decimal out of it and whenever it will match that particular signal; that means, it is not only this robotic arm there is another sensor available which will tell you that; when this particular belt is moving in this creation when your encoder has to activate this particular robotic arm and then it will pick up the component right.

So, this is rotating right now depending on this particular part. So, now, now you can see that this wrapper is there, but this wrapper is not here. So, when this particular part will come, because now distance between these two are also fixed and then when it is moving at that time your encoder will give a signal to this particular actuator that when this particular part without wrapper is coming. So, your ro robotic arm will pick up this part and put into this beam correct. So, this is how it will work in different-different applications.

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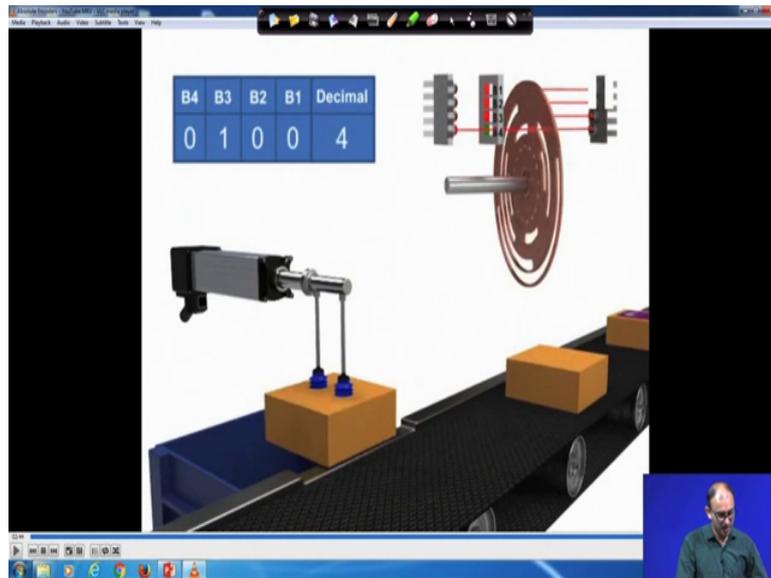
So, now you can see here that it is not only the encoder, but there are many sensor which are used for making this system working. Now, if you see that this is one is that vision system, which is probably finding that whether wrapping is there are not on the box another thing is the, what is the location of that particular box.

So, that is why you can find out the use of this encoders after the there is actuator and other signal processing, which will tell you that when it this particular box is coming just below the robotic arm. So, you actually create the vacuum of this particular part and then takes out this part out of this belt and put into the beam.

So, many sensors are used for any automation or automatic system or the automatic transfer of the parts. So, let us go again back to the slides right. So, this is what we have seen about the rotary encoders and the, abs absolute encoder and the incremental encoder.

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So, now what is the problem with the rotary encoder, that we have seen in earlier thing the rotary encoders only determines the distance of the or the speed of travel distance speed of travel; that means, if it is rotating at a some rpm then we will definitely get the, because every rot instance of rotation you are getting one signal.

So, how fast you are rotating the faster you are getting the signal. So, rpm you can easily get it will also find the distance by which we have seen that if you know the lead pitch of the led screw, then pitch of the led screw you have to find out that what is the rpm; that means, how much is the rotation of that particular shaft if one rotation is there and fiv5e is the 5 millimeter lea pitch of the led screw, then it will move 5 millimeter in the translation direction.

But, what is the problem; that suppose your led screw as a backlash or wear or thermal changes of the ball screw, then it will not ac account this particular thing, because these are the mechanical parts and your rotary encoder does not have any type of signal or any type of feedback device which will end account this particular problem. So, if you think about this thing. So, any such ball screw geometrical changes will cause error in the calculation of the actual position.

So, let us see this things that if you are using a rotary encoder for getting a motion of a linear motion with a condition, that there is a backlash or thermal changes, then what is going to happen with the position accuracy right.

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So, right now what we are doing?

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That, this is one of the operations.

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 Now see this is the one drive it is re circulating ball screw kind of drive and we are adding one rotary encoder at the end, because we know that we have to mount the encoders at this location only correct. So, this is the; one full system and rotary encoders is located at this location.

Now, you know that this is the semi closed loop, because the rotary encoder measures the rotary motion of the spindle. In this particular case, now how we calculate these things? We have seen that from rotary motion and the screw piece the control calculates the position of the axis, because you have to find first the what is the pitch of that particular screw and whatever the rotation and based on that calculation you will it will find the what is the exact linear position of the axis right.

So, it is moving hundreds of timings here and there and, what is happening; when it is moving even though it is re circulating ball screw kind of things.

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So, this is called the linear guide way that we have seen long time before that is screw that balls are here, which are re circulated around this particular system and then you have a point contact or line contact or mini balls. So, it will reduce the friction between these two, but still if you find that if you are moving this thing 100 or 1000 times and then there is; obviously, heat generation and that heat generation is enough to get some backlash here.

So, what is the axis drift that axis drift is, because the spindle becomes warmer and expands slightly? So, because we know there is a coefficient of thermal expansion of each and every material. So, if you heat that particular component beyond a certain limits then there is a expansion of those particular materials. So, shaft will expand slightly. So, now, it is a heating and now you can see the temperature is increasing.

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Now, it is motor is also heated and this particular ball screw or the led screw is also heated.

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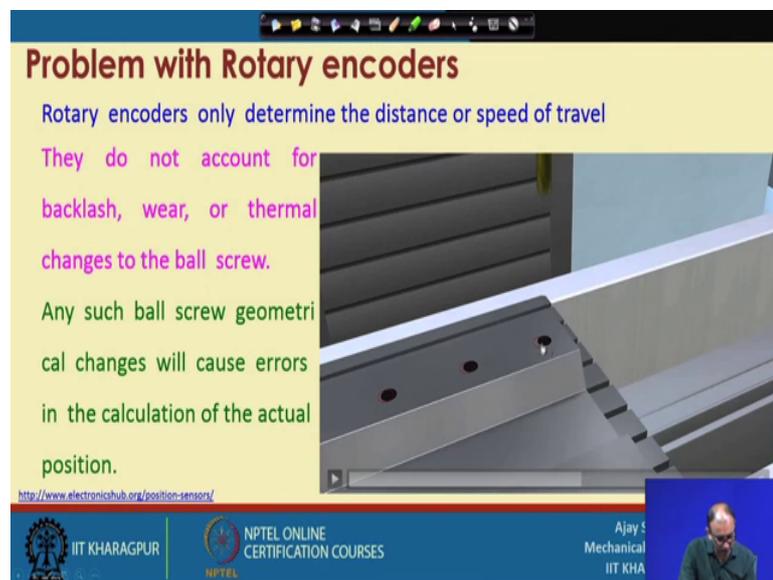
Now, consider right. So, now, you want to drill holes. So, these are the points.

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So, which is actually the location where you want to drill. So, you start drilling with the first hole second hole and third hole let us see that; what is the problem of location accuracy; because of this thermal error. Now, you can see that now here is it is actually matching the desired dimension of the red color circle, but as you moving from here to here you can see there is a shifting of the red circle with the drill hole. Now this is the; what is problem here right.

So, if you see the last hole you can see the, how much is the difference between the desired position and this position right. Now, what we have taken the example it is related to thermal change only, but it may be because of backlash also wear also because whatever is the mechanical system you will get the wear not today, but after two more or after one year also. So, that is the position problem here.

So, now you can see the how much is the different between that two part. Now you can see that if you want to avoid these things, what you have to do that instead of a rotary encoder you have to put a linear encoder. So, this is the linear encoder more is measures the position directly on to the axis slide right. Now, we are not putting the encoder at the motor side we are putting one strip here that strip will help you into finding the linear position. So, this is the encoder it is along the axis of this particular travel right.

So, whatever is that is a problem even if, there is a backlash then either is a thermal change, but it always finds that particular position. So, spindle temperature is no effect

because of the position is directly measured on to the axis right. So, now, it will exactly find; where are the positions? So, you do not get the exact or the deviation in the drill hole and the desired location. So, we understood that rotary encoder is good for the rotational measurement only not the displacement; that means, how much distance travel it is sometimes very very tricky, if the system is not exactly as per the required dimension, because of this backlash wear and the thermal changes right.

So, now let us go to the linear encoders and what are the linear encoders to ensure the most precise axis position micro milling applications requires glass scales. So, that is called linear encoders to be placed close to the guide ways in order to provide additional feedback to the controller right; see micro milling it mostly necessitate use of 0.1 micron glass scale rather than commonly used 0.5 micron version.

Because, we know that we our many system that suppose we are using a linear drive, then your system itself as a very very high resolution. So, it is better to go with a 0.1 micron compared to the commonly used 0.5 micron, because if you are going with 0.1 micron or 0.5 micron, you are not actually getting all the benefits of your very costly system.

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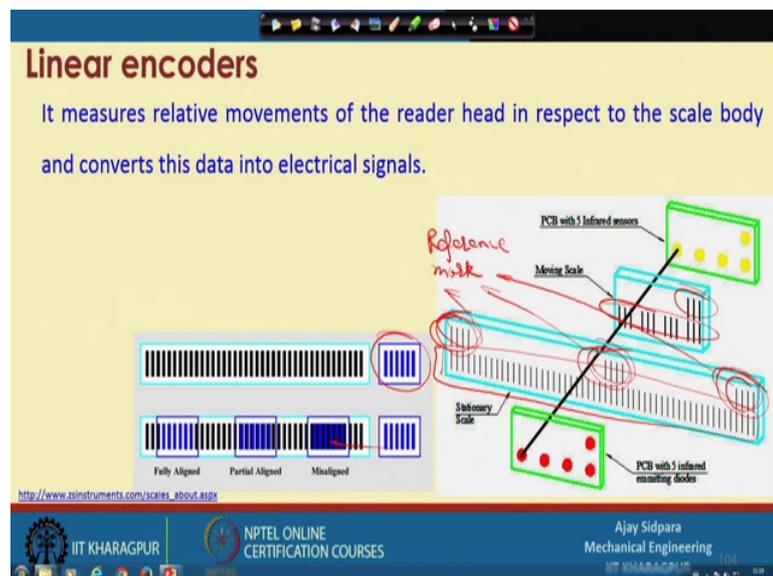
So, better to go with the 0.1 micron so, how it will work that it measures the relative motion between the; reader head in respect to the scale body and converts this data into the electrical signal. So, this is the similar to what we have seen in the rotary encoder

only difference is that; now everything is flatten away not in the rotational part. So, again same thing that you have a source here which is passing through this light and these are the glass scale. So, earlier case it was in a circular pattern, but it is not circular pattern now it is in the linear part.

Then this is the moving scale with respect to that and this is the infrared sensor, where it is receiving the signal. So, here also we are talking about the incremental part here. So, if you are talking incremental part then every time it will give you. So, this is the case. So, similar to that part, what is happening here that this are the actual scale and this are the reference scale right.

In that case also there was a z scale and this is also considered as a z scale reference mark and see that reference mark is aligned with this one only while this remaining part is aligned with these four part correct. So, if it is end position you can find the reference if it somewhere in the middle you can get and there is one more you can get at the starting position, this is what happening here. So, this is your actual scale which is on this part and this is your moving scale right.

So, when your scale is moving at that time it is in this particular case it is not misaligned and it is misaligned comp completely, because it is not aligned with this blue color and red color what a white color, then it is facing with that then it continue, then it is partial aligned, then it is the completely aligned. So, when it is completely aligned, what is going to happen; your light will pass through it and when it is light will pass through it you will get a signal and you know that; what is the position of that part, but here also we are seeing you have to have a reference mark here. So, that even if some power failure or some type of other problem you can reference it is to the actual position right.

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So, made from a strip of high quality glass with evenly etched the very small mark here so how to create this mark correct. So, that is also very important, because we are discussing that distance should be the distance between the two marks should be 0.1 micron or something. So, what we are talking here that the; this particular distance between these two whatever the distance similar way you will get the signal out of it right. So, these are the distance between these two.

So, if you think about 0.1 micron 0.1 micron to 1 micron. So, first thing how to make this particular thing? So, what; how this there are lithographic process available etching available. So, what you have to do that you have to create one particular mask out of different process there are electronic lithography available mask generator, then what you have to do that you have to create one glass plate here and on the top of that you to put one layer that is these particular black layer the black color whatever is there or the opaque layer; that is let us write black color right.

So, on the top of that what you have to provide that you have to provide one mask here on the top of it right. So, this is called the mask with this much precision, whatever we are talking here there are some open position available. So, that open position will directly come into; that means, whatever you are putting from the top that is called etch. So now, let me draw that also that this whole thing are etchant this is called etchant right. So, whatever this opening position is there; so this opening position. So, whatever this

position is there. So, this the same dimension what we are talking that is a 0.1 to 1 micron correct.

So, now what is happening the; this etchant will come in to contact with these it is contacting all the surface, but some portion is actually a mask a actually insulated by this mask. So, those portion is will not be etched away. So, now, if you te give some time and temperature particular temperature, then what is going to happen these particular part will be removed from these particular layer right. So, this is the portion will be removed. So, once it is over then what you have to do that you have to apply one mask on this mask removal process or you have to apply another etching process. So, you can get this thing done without creating any problem so this is called etching process the way you are getting these particular mask.

So, this is the way of operation of a linear encoder.

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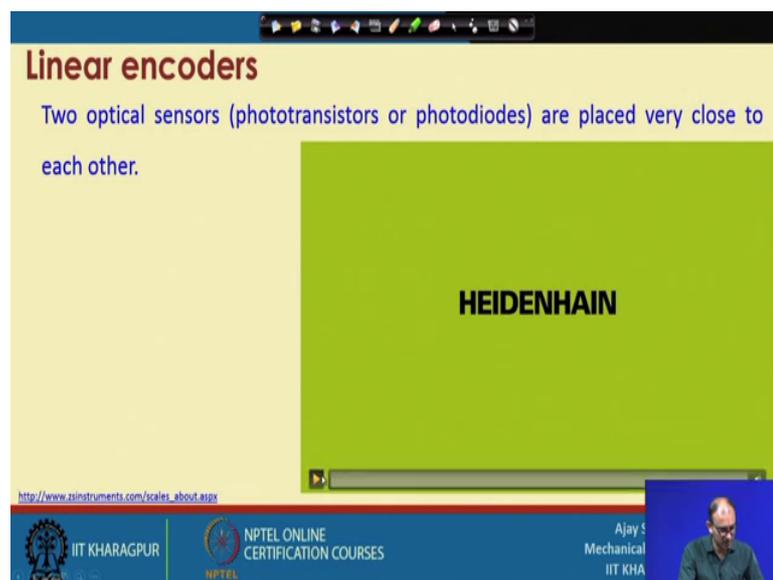
So, two optical sensors are placed very close to the each other.
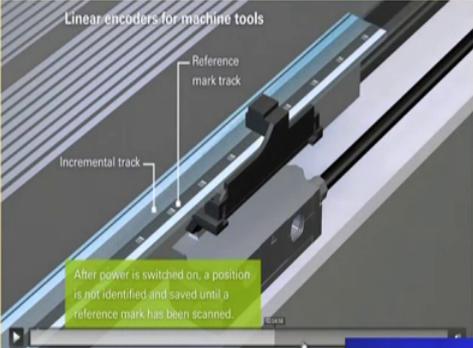
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So, let us see this thing also and so this is called the encoder.
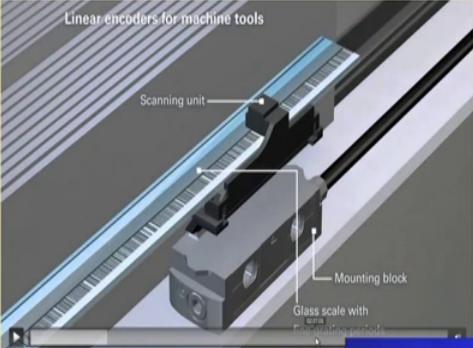
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So, encoder is located here. So, you can actually get the direct position of this particular part. So, this is the mark that we have seen there also. So, there are two ways of doing that thing let me see if it is visible.

So, this is the scanning unit; whatever is available this is mounting block, because you have to mount these things.

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And you have to make sure that when you are machining because you are using a coolant also many chip is also coming which are very very hot. So, it is a due to protect these things that everything will be completely covered by some metallic cover. So, that nothing from outside will create any problem with the measurement unit.

So, this is the glass scale with a very very fine grating on the top of it.

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These we have seen already right.

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So, there are different ways you can you are getting the signal.

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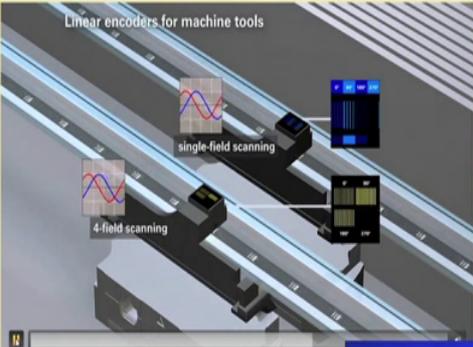
So, these are the way the; so suppose you are getting you have 4 signal, then 1 is 0, 90, 119, 270 degree so, you will get a signal out of it.

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So, there is a single fields scanning this is a four field scanning. So, similar to that you have a four different aligner 0, 90 degree 180, 270 you will get another way out of it.

So, in that case you can get the signal, but problem is that; in these particular case in four filed scanning it will actually create a problem, if you see this signal strength, then here you will get little bit of contamination in the part. Now see you can get these things; now you can see the signals are not same. So, here you will get some contamination quality because of the signal problem. So, it is better to go with the single field scanning and you can get the required result done. So, here also you have to find the way it is moving correct. So, in earlier case we were using in the rotary encoder a and b slip. So, depending upon a and b sled it was giving the results.

So, here also we are using the similar way, but it is on the side by side, but it is in the linear scale. So, again which way it is moving from right to left or left to right still you can find the direction of the motion as well as the how much it is moving in the different directions so, that is ok.

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Now this one is enough for this part.

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Now, coming to the spindle so how is this thing works? So, it is better to let me see that this thing we will cover in the next class, because this is very big topic we will start from the next class.

Thank you very much.