Design of Mechatronic Systems
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Lecture 10
Integrated Mechanical-Electronics Philosophy - Part II

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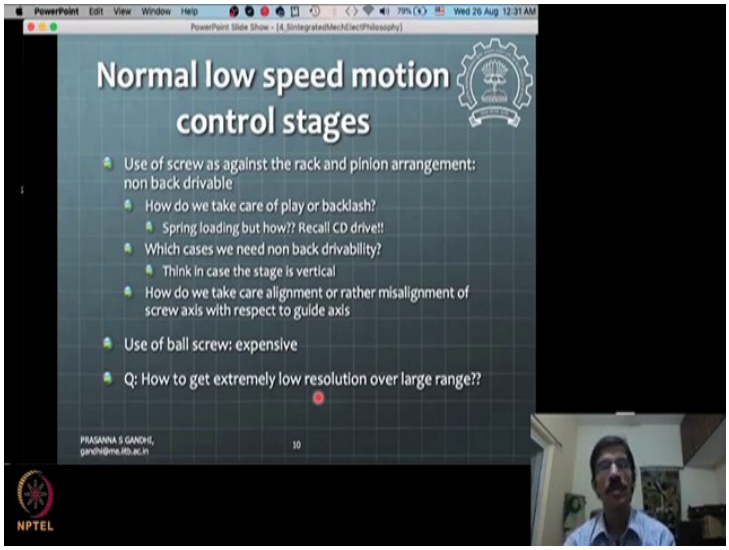

We will talk about normal low speed control motion control stages. Typically some kind of a application so some small motion that let you need in the lab level to adjust some optics or some normal motion stages, I would say microscope we are observing something and you need to move under microscope something. So, those motion stages, you typically will have make use of a screw or rack and pinion kind of arrangement. So, whenever you feel there is a back drivability possibility, then you will go for the screw arrangement.

And rack and pinion or those other drive arrangements can be preferred where there is, back drivability is not a issue. So, we do not want system to back drivable then you use screw, because screws typically when designed properly the screw helix angle for some certain helix angles, that are designed on the screws they will not be back drivable. Otherwise you see that your car jack for example, so you raise, you tighten the screw and the car is raised up.

Now, see if the helix angle or the screw is not properly designed then more, even if you tighten it after sometime the system is going to get back driven by the weight of the car itself and it will start rotating in opposite direction, and you will lose the purpose of the jack.

So screw jacks would be designed to have non-back drivability arrangement. So, you drive and the system stays there. It is not getting back driven by the weight of the car itself. That is a concept of back drivability here.

So, now let us see, how do we can take care of this alignment or rather misalignment with screw axis with the guide axis. So, see some part of this we have seen while doing our CD-ROM example we have seen the guide there one rod is complete guide, another rod is not so completely kind of guiding.

So, that is taken care of some misalignment of the two rods, guiding rods in the system. Now, if you have a screw in addition. So, the screw axis will have some direction for the motion and then with respect to guide axis you need to make sure the screw axis is aligned and guide also needs to have two places it needs to be guided. The system cannot be guided only on one side, for the reasons that it is not fully constrained then.

So, you need to have typically two guiding places for the motion, for the linear motion to happen. And now along with that you have now the screw arrangement that is going to be there. So, how do you think this system can be, what kind of arrangement can be done to take care of this issue. How this misalignment when you are driving with screw is taken care of. So, think about that when we will talk about that in a while now.

And other issue that one can think is how to get low resolution over large range. Again here, when you are using some screw drive to get low resolution means, extremely your resolution, I mean the resolution should be high in actually. Low resolution is not correct word to use here, is the high resolution means you need a very tight motion tolerances here.

You want to move may be say 5 micron or 10 micron and you need to have that over the large range you want to maintain that kind of a high resolution. How do you get that when the screw drive needs there. So, typically when you see the screw car jack kind of a stuff, those screws would it be helpful in here. Or any screw you might have seen, screw and the nut arrangement you imagine, you have a nut and screw arrangement.

And you see how loosely the nut moves on the screw and if you just hold the screw tight and move the nut in a axial direction, then you will find that there is some play that will happen. So, you have a screw and the nut together and then you just move it and you will see that there is a play that can happen there. So, under this scenario, you will again need some backlash prevention. So, this is like a backlash arrangement.

You move in one direction and it touches one side of the screw threats and then the other direction other stand on the screw threats. Now, we have the screw as a complete circular screw there and there nut also is a complete circular nut there. So, how can we think of the, some of the ideas that we had with the CD-ROM screw? In the CD-ROM screw you remember we had these two stuffs which were pressing against the screw.

Now, we have say single nut, what we can do? So, you might guess that okay look, you need to have some preload somewhere, some kind of the loading of the screw nut against the screw and should happen somehow. So, if that is happening then I will have this application going good and that is precisely is done. So, if you just use stubs here, stubs thing for the screw then, this may have a load bearing capacity will be reduced.

With a small stubs may not be able to carry very large load if you want to drive daily good load when you move the screw typically. So, imagine in the, again in the car jack you cannot have a stubs which are holding the screw there, that kind of a weight of the car cannot be taken by just so much small some stubs which are out there, if fact they are your screw will have many, many more threads engaged at a time, rather only single thread engage at a time, single or two threads engage at a time.

So, we want this total circular engagement to happen, but still we want to do some preloading of the screw. So, how do we do that?

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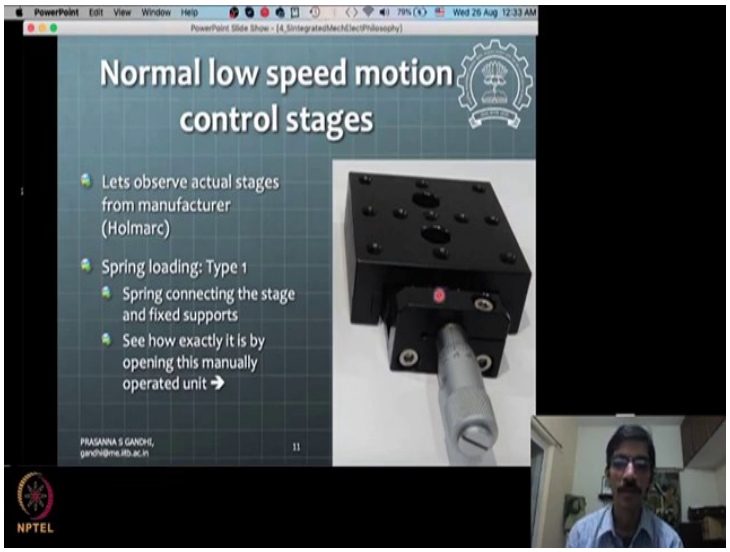

So, let us see some actual motion this stage systems, this is one of the motion stage systems from this company called Holmarc. So if you open up this, so this is a screw we can see this

you have a micrometer screw gauge kind of a screw there and it is pushing this, this stage on which you can mount whatever things that you want to move, and as you have tighten the screw, this will push this stage. But, then this engagement here the screw threads are in this piece and then the stage is just guided in the linear fashion here by some bearings up here and here.

There are two side guides here for the screw as we open up we will see this details, but the screw is in here, so screw is not attached to the stage. So, that is how one can say that, okay, the guides axis and the screw axis is made free. So, this screw axis will just touching up here. So, we can, open up and see here.

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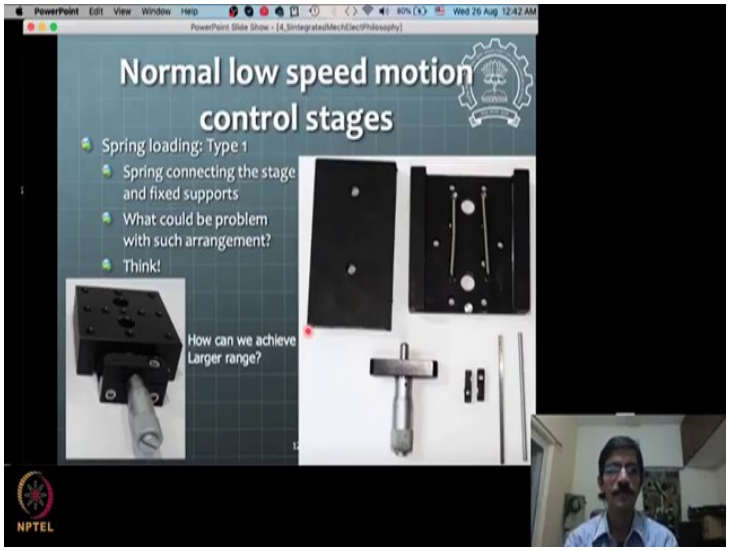

So, this is a screw here, screw has no, the threads are in this piece and then this is a screw and the screw has a small piece that is coming out and touching and pushing this upper stage, this is a upper stage. And you can see these two little springs here, the springs are tensioned and they are attached to this bottom piece, bottom piece is where this screw is assembled on the bottom piece here.

So, when you tension the springs and attach it to the bottom piece there is a relative pull between this top and the bottom piece in this direction. And this screw is actually preventing that pull to happen. So, as I tighten the screw I will push this more and more and the pushing force is going to get increased because the springs are getting tensioned more and more.

And as I loosen the screw, I mean push it, then the spring is moving the stage, the screw is just releasing the position of the head, screw head relatively. So, screw head position is

moved relatively and then thus the stage get pushed by their springs which are pre-tensioned here. This is how you create this preload in the system and move the system such that the motion happens in both the directions.

So, the push is active motion by the screw, but pull is happening here because of the springs, that is how the things happen. So, what are the problem for such an arrangement, you can imagine and see that, that if I have a force which is much more than the spring force at any point then in appropriate direction, in the direction say in this case against loosing the contact or in the direction of losing the contact between the screw and where it touches.

So the place where it touches is somewhere on this somewhere here. So, you see this little pin or something here, this is a very hard surface on which this head will be touching. So, this if I apply a force in this direction, then their touch will be lost, by my force. So, there is no active thread engagement which will hold it firmly there.

That okay, this force is applied and it goes against some threads and the threads will take up weight and not allow us to move. That kind of thing will not happen. So, this will allow that motion to happen if that force is much higher. So depending upon application where you want to use you need to think carefully about whether this is okay for your application or not? Take a decision take a call upon that.

What little things that you see here are basically the bearings. There is one, there are these two bearing on each side or will be many more maybe on inside. And then there is this guide which will have these bearings put there and there will be some small adjustment for this guide rods, the guide rods which are placed here in some cavity and those guide rods will have some adjusting grub screws that are put inside this piece.

So, those adjusting grub screws will make sure that both sides are align to each other. So, that there is no jam in the bearings. So that some skilled operations needs to be done initially to engage these two together and make sure that, these bearings are guiding such a way that over entire motion there is no jam that is happening and there is no play that is happening also.

So that kind of a skilled operation needs to be done to begin with because now here we do not have full guide on one side and half guide on the other side. That arrangement would also have been made here possibility is that. But here that has the way load bearing capacity will be lesser in that case, load bearing capacity in such a guides is better typically.

But, then it comes set of cost of doing this additional adjustment of these both the side guides such that there is no jamming that will happen. As you would imagine otherwise if these are not aligned properly then the possibility of jamming that will happen for the stage. So, this is typically the arrangement for the motion stages.

Now, we want to see, so as you see here, as I move more and more, the springs are getting stretched more and more, then the amount of force in the springs will increase as they stretch more and more. So, which is not really desirable, then that means I am restricted to a small range of motions with these kind of stages. I cannot move in a very large motion because my spring is going to apply a very large force at one end and relatively smaller force at the other end of the stage. And that's why force will vary along the length of the stage.

So, for that I will need to do something. So think of what arrangement can we do to get rid of this issue? Even if I move whatever large range I want to move this problem will not bother me. But I still have some arrangement for the misalignment of the axis of the screw, and guide axis.

So, guide axis will be adjusted by these guides in some way, so the guide axis will be defined by the guides. And now in this case if you see the screw axis if it is, even if it is, the guide axis is tilted with respect to the screw axis, is not going to create a major issue. Because there is a relative sidewise motion that will happen at this contact point. So, contact point is so as I tighten the guides suppose go in the one tilted direction and then screw is going in other direction.

So since there is no firm engagement of the screw, there is only pushing contact there. The push can be move slightly on the surface of this thing that is getting pushed. So, there is relative sidewise motion that can be possible between the surface that is getting pushed, the stage that is getting pushed, and the screw motion.

So, that is how this alignment, misalignment problem is taken care of and then backlash problem is taken the care of by the spring, but what problem I invite by using this is, if I have to kind of, if I want to go for larger range I will, the spring force will increase tremendously high, and I will need more effort to move against the larger force of the spring.

And typically if I have a motor to drive this then the motor will have, with series differential load. Depending upon the position of the stage I will have a load that I need to apply because the friction will change at different points.

So, these are the typically drawback, so nothing is free, if you want to take care of the backlash, you put some load, preload then the load on the motor is going to increase. More the preload better system you may get, but that much more torque or friction torque that one has to overcome to drive my system. So these are the issues that come up, and this is the way things could be designed to get them working.

So, you can think like how do you achieve larger designs and if you have some ideas, thoughts, then we can move on from there, we can pause again at this point.

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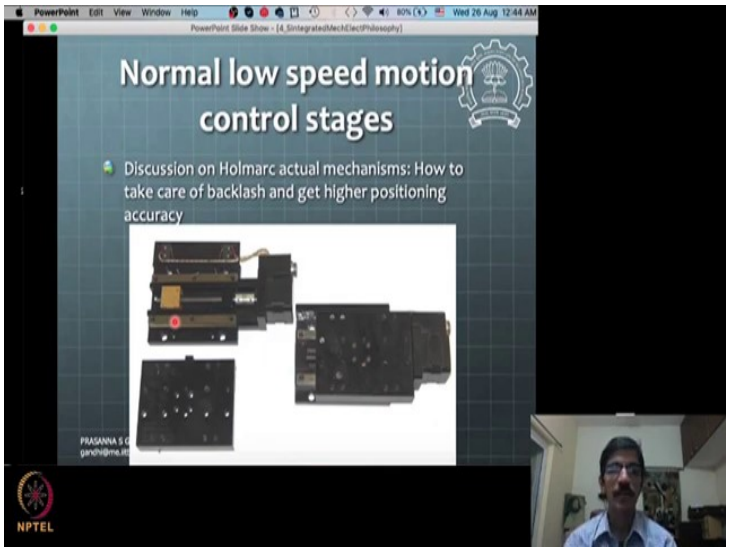

And then, let us move on, so this is an arrangement for the larger range positioning without having now these two big spring there. So, you see in this arrangement again this is open up stage, what you observe here is this is a nut cage here. So this is not single nut I will show you what is there inside in a minute, but this is some arrangement here.

So, imagine that this had been only the nut, there is no some arrangement this is just a nut here and then the top there are 4 screws, which are attached to this stage that moves on the surface.

And then there are these guide rod here and guide reel here. These are two guide reels here and here and they will have a some limits which is that they have put here for in the limits of the things. So, that you can turn off the motor. So this is already motor mounted here, this motor driven stuff there is over you can see here this is flexible coupling and then all these arrangement is there.

So, when it is assembled it looks like this, when it is opened the top stage, these bearings are open then you get this view. And then there is screws typically the screws are with very fine threads. So, the fine threads mean they will not be back drivable and for a large motion of the rotation, you will get very small motion of the screw so that it will have a very high positioning accuracy can be possible.

So, for one step of the motor you will get a very tiny motion that will happening for the stage, given that like we do not have a backlash issues and given that we do not have a misalignment issue. So, see this axis of this screw and the guide axis again there might be possibility that, okay, they may get small misalignment and then you will see that screw will get jammed in no time if there is no special arrangement that is done inside this.

So, think about what kind of arrangement can be there inside this to take care of these two problems. One is like a backlash, another is your misalignment of the guide axis and the screw axis.

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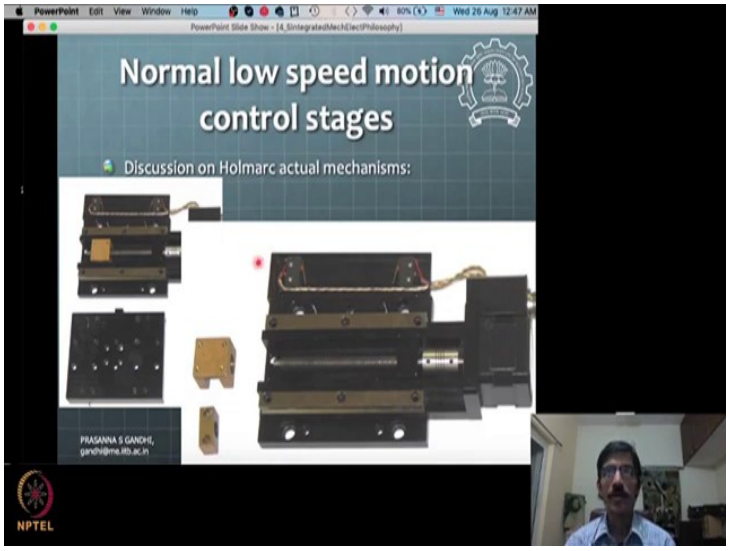

And if you open up further, you will get this upper thing. Now, so you see this is part here and then this is the part here opened up inside that this is a nut. So, this is only the nut and then this is some kind of a cage around the nut. So, this cage has this typical construction, this is a C kind of a cage and inside there is a hole here, and there is a hole on the other side and nut is slight inside and now you can imagine. So, now you can imagine if this axis of the screw and axis of the guide has small misalignment.

So, a small tilt, then the screw is going to move inside the cage, but the cage is attached to the top thing which is guided. So, the cage is guided by these two side rails, which is attached to this piece here which is a stage, motion stage which is guided by these 2 side rails.

So, the axis of this is so, this cage is moving around one axis and then this is moving around another axis and then there is a relative motion that is created between these two. Because, this is a sliding inside this. So this is a arrangement that is made to make sure that your misalignment of this axis is taken care of. And then you see now little holes here, these holes if you see carefully I mean they are not there here, but you can imagine that these holes one can puts springs there.

When you have put springs in these holes here, they are pressed against this top. So, I have to really push this and put a springs in pre-compression to align the hole of the nut, the hole of this cage to get the screw inside the nut. So, that will make sure I have some preloading of the screw done, so nut with respect to screw is getting preloaded on the surface.

And whether the nut is here, or here, or here, or here any position I put this cage, the spring load is not going to change. So, this is how one takes care of, solving the problem of misalignment also and having now we have remove those big springs that were causing the increase of the force. So, this is how the things are done here. So, maybe it is a good point we can pause here and.

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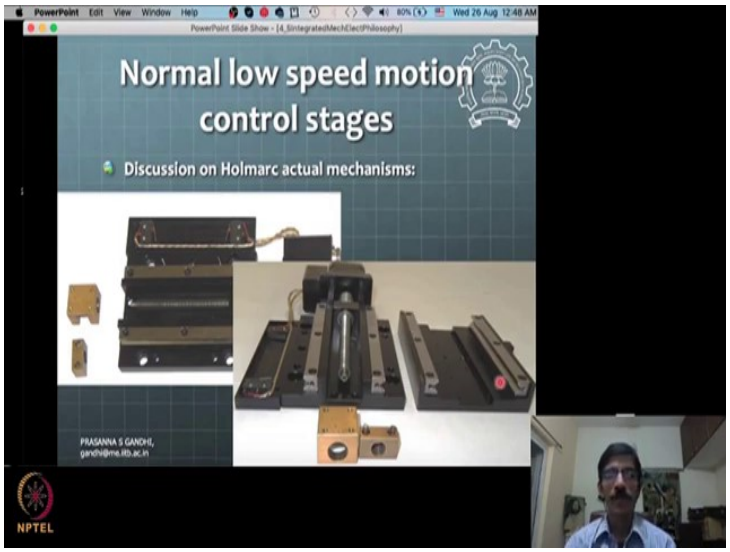

We have, so these are more kind of a pictures that you can see, what this arrangement of the guide. So, we can see that here a 45 degree cuts made in the guides and then the small little

bearings that are actually the cylindrical rollers which have put inside this to make sure that is guided and then there are some adjustment screws that are provided at the back here for the alignment of both the guides to be done.

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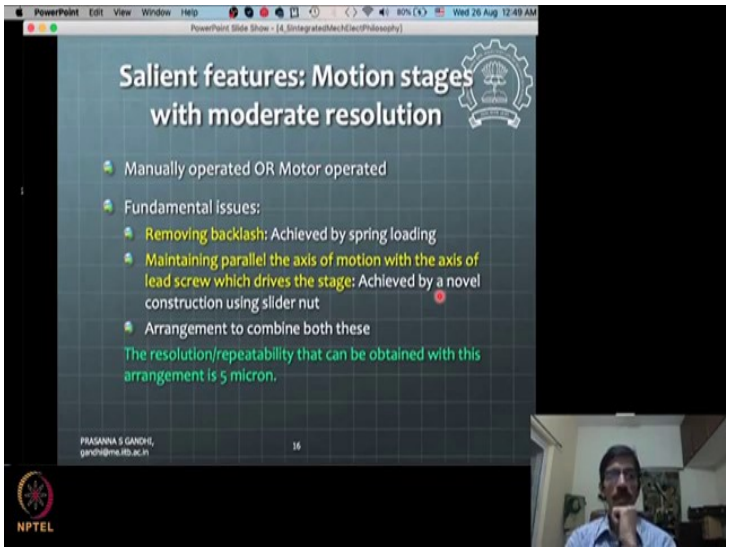

So, we can pause here for the discussion and then we will move discuss little more in the other class. So, these are some silent features or summary of things that are, that we have learned today. So, for removing backlash you do some arrangement, for removing maintaining the parallel axis motion with the misalignment problem is taken care of by some kind of arrangement. So, one can do this kind of designs, thinking and affect the design in such a way that you do not have to do a lot of drudgery in control domain.

So, these are all these kind of things are done to make sure the like you have no pains in motion actually having their motion and also you will have a little bit of a ease in driving the systems in the electronics domain. And I would like to think, like you to think about now, what is a cost that we are paying for putting the spring loading things in, on electronic side, so think about that.