Compliant Mechanisms: Principles and Design
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Lecture – 72
A compliant easy-chair for the elderly

Hello, we are now at the last lecture of the course on compliant mechanisms principles and design, and also the last of the case studies; these are the 6th case study where we are showing how compliant mechanisms can be used in real applications. In our group and also other groups which one work on compliant mechanisms a number of practical applications are explored and I am just taking this opportunity in the last week of the course to introduce to you 6th case studies this is the last of that.

This is a very consumer oriented a device, it is actually a chair - a chair that is all mechanical relies on compliant mechanisms as you will see in order to help elderly as well as arthritics to use the chair with a lot of comfort to minimize discomfort for their knees and other joints as well as weak muscles and so forth.

Let us look at this application that is very down to earth which is this easy chair; compliant easy chair is our last case study and the lecture of the course.

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A number of people here we had faculty from different departments here who are looking at a different aspects of this, professor K V S Hari and Dibakar Sen and also Geriatricians that is an important thing because we are working for a chair for the elderly. So, elderly have difficulty in rising from the chair so that is what it is showing here how you make it easy so that they are knees are not strained too much when they get up. So, it should assist so that they can live by themselves without the dependence on a care giver.

We had analyst students who students analyzed, a number of them were listed here and also lot of engineers who did work on this and also designers who looked at the user friendliness of this. It is a compliant mechanism we are using, but if you put into packed application we need an array of people as it is indicated, we have so many people who are needed to make this work.

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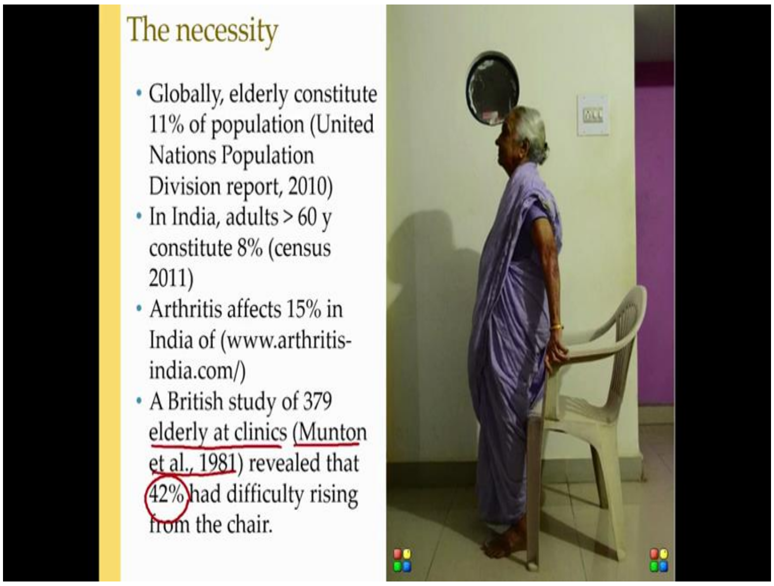

The necessity is very clear. So, elderly people, this grandmother who is able to do it, but many others have problem in getting from the chair and it is a big need. So, globally also elderly population is increasing and arthritic patients number is also increasing and there is a big difficulty. In fact, in one reference here it was stated that as many as 42 percent of the people of the elderly at clinics in UK had difficulty rising from the chair. It is almost like every other elderly person in a British study has difficulty in getting up of the chair they need assistance of somebody. We are not even talking about arthritics, which is also a large population now.

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Let us look at one of our geriatricians what she had to say:

I used to share the basis of (Refer Time: 03:50) easy chair for the elderly and the basis largely comes from mainly experience of the geriatricians and I have seen patients I am in geriatricians for many years now. So, I know that I would like to have an easy chair is designed for elderly not just the sick elder. So, here primarily designing easy chair which is largely going to be a multipurpose chair it is going to serve more than a single purpose.

What that (Refer Time: 04:24) her geriatrician said is that she is looking for an easy chair that is a multipurpose chair that helps people rise from it easily, sit comfortably and while they are sitting they can also do like exercise to keep their muscle and bones in proper condition and also to read eat and other purposes. The main thing that we are focusing on is how to make it easy for them to get up from the chair.

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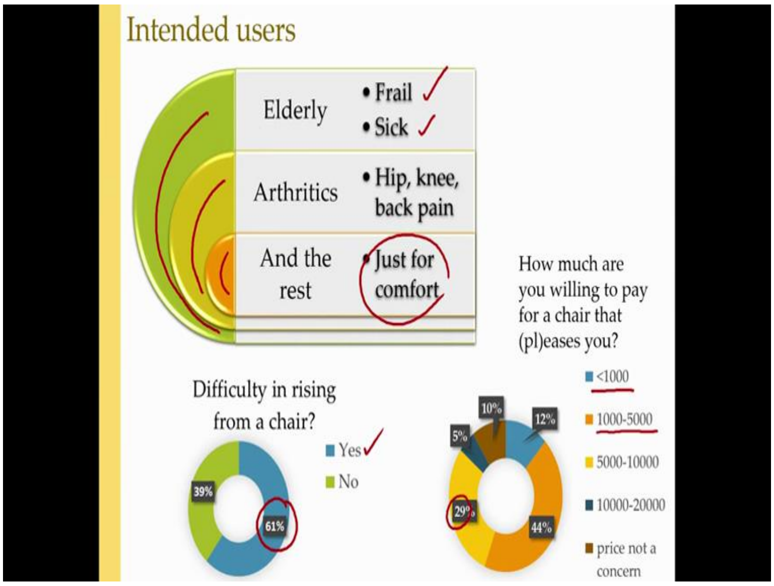

And she also mentioned that elderly of a 2 kinds, one of frail elderly who are very weak other as sick elderly because of some disease or some illness.

Arthritics have pain in the hip, knee, back other things the rest of people also can use this just for better comfort. So, there is a big need for elderly and then little bit on arthritics and then the rest of the people, anybody can use the chair we (Refer Time: 05:23) intended users. So, we also did our own survey our design student take this survey do we have difficulty in rising on the chair 61 percent of the people said yes, the British studies had 42, elderly have difficulty here when we ask people of various ages, most elderly people 60 percent said that they do have a difficulty in rising from a chair that is our everyday experience also and then how much are we willing to pay for such chair.

We are; we wanted to know and here is the range of people. So, less than 1000, there were 5 percent, 1000 to 5000 that is 44 percent and so forth. So, different people actually this is 30 percent and so forth. So, at a people are willing to pay for a chair that makes it easy for them to use this is everyday thing.

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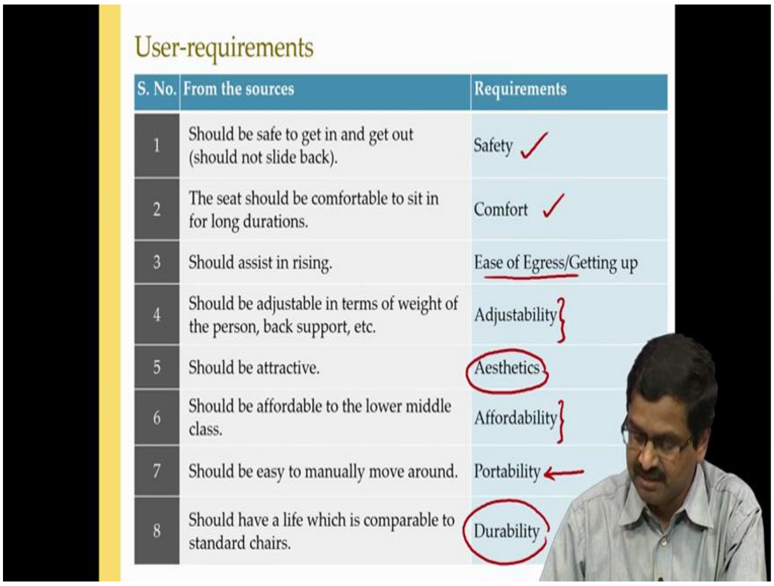

That is at least users are there if you build one; one can build it using motors and sensors and so forth, but our intend was not that we wanted to build an all mechanical chair where there is no external actuation the persons weight itself is an actuation and posses simple hand movements are going to gently get them out of the chair without depending on external anything, not care giver, not external actuation.

When you talk to users of course, safety is an important thing, comfort is important, ease of egress and getting up rising from the chair is very important, adjustability because all users are not the same depending their height, weight and their capability their physical condition which will be able to adjust. And aesthetics also was important because it will be living room or somewhere where people visit we wanted to have a chair that does not look like a patients chair should be like a normal chair it should be affordable that finally, balls down to think. It should be easily draggable or portable from room to room or one place to another place and of course, users were able to durability, it is should be as durable as the regular chairs that one has.

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There are lot of thing is that money can buy in terms of this, there are number of them that you see in the market, some of them are passive, some of them are not. This particular one is interestingly passive and this one it looks like passive, but it could be motors with a lot of springs here and there and this is the one that as some strange aesthetic nice aesthetic design strange, something that gives comfort it should be able to the basically move you. This one definitely has some actuators because their whole chair is been tilted; such chairs are there when we have motors, what we are looking for is a completely passive chair.

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And here is a nice video that from Springq Company and this one has no motors. So, similar to what we also want to do which has basically some adjustability as you will see there are some of these rods we can take one and put another one to do this and if a person can sit in this and a rise from it. So, now, this old lady is sitting and then when she wants to get up the chair itself pushes that is a kind of thing that we are looking for.

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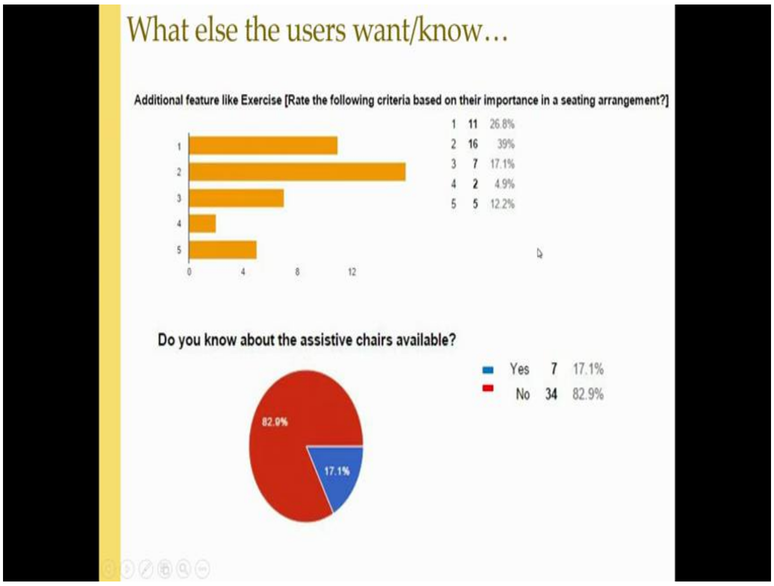

And what else the users want? Additional features we have indicated some of those here that is not relevant to this talk now.

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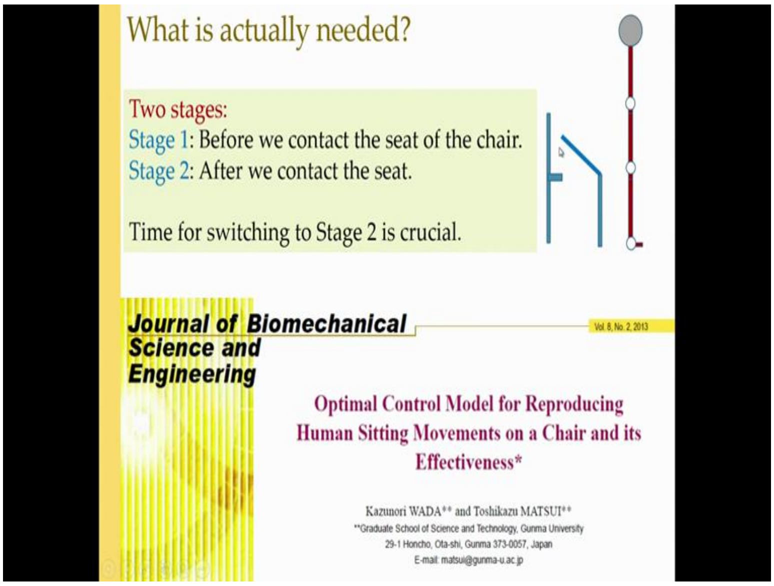

And what you want is that before there are 2 stages when you sit in a chair. Before you touch the seat there is a certain thing that you need to do after I touch contact the seat there is a stage 2 meaning that when the person is here this is the chair let say this is the chair. We want to keep the chair this way, that is it is a low force condition is actually like this there is a imagine there is a spring or some elastic element here chair is always like that, it is no force condition.

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Now, when a person starts sitting first they will contact here we will come down and do this. So, we can see this simulation here this is a chair now that is a condition, now the person is sitting this is the ankle knee and the hip and the head over there. So, the person is sitting until that point there will be some loading on the knees and hip and the ankle after that touch that is where we can come and have stiffness in this such that we can minimize the knee and hip and ankle joint pains. So, this is the thing, there are 2 stages before you touch the seat and after you touch the seat.

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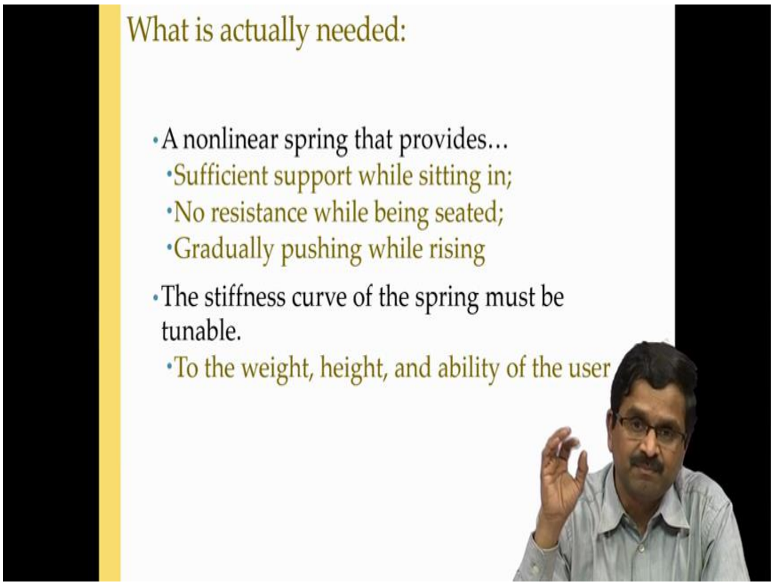

We need a non-linear spring that has sufficient support while sitting in no resistance while being seated, if you put a normal spring when you sit there it will be continuously pushing you we do not want that. We want something that is easy to sit in and no resistance at all while being seated and gradually pushing while you rise. So, that is what we will want and we have to design in the compliant mechanism or spring now to have this stiffness and also should be adjustable for the weight of the person, height of the person and ability of the person this is what is needed in terms of design.

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We went back we have talked about this click clack tin lid which as if you apply force here, it will go down and open and when you press the flaps on the side, it will again switch back.

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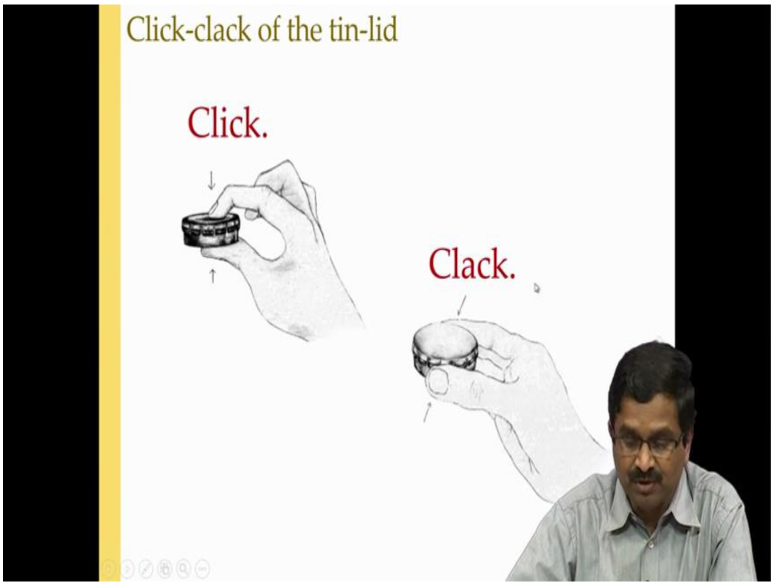

So, what we have said click clack this is one actuation side by side actuation so, this force is much more than clack the side way force. That is what we want to do.

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So, it is click clack thing that we can see, that we have earlier.

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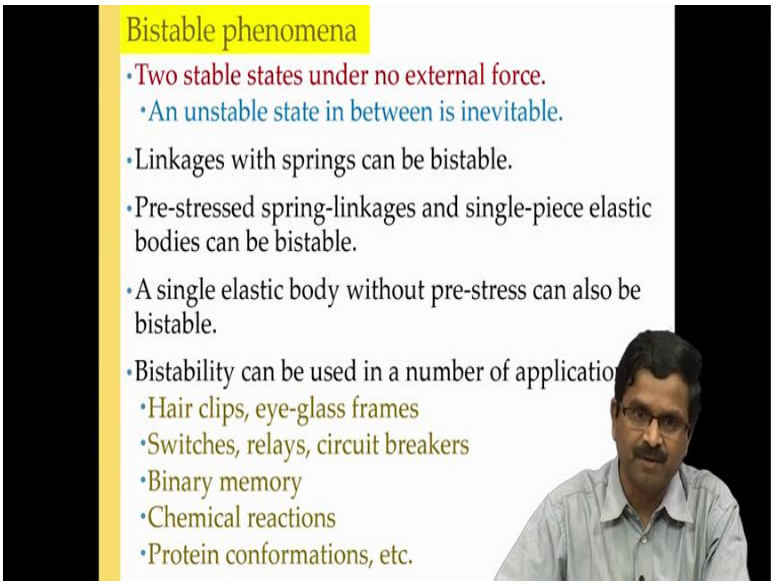

It is a bistable device it also is bimodal. So, here we have a; this is about bistable we have already spent three lectures on it is, so we can read by passing. So, we will not elaborate on this bistable phenomena here.

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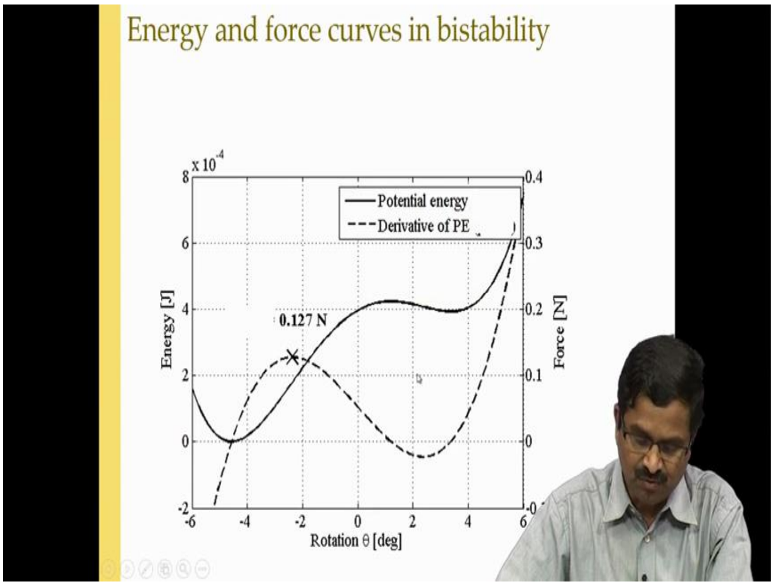

There are lots of them leaves and so forth so, what we say here is that we will go with 2 actuations - port 1 and port 2 actuation, bimodal bistability, this is the weight of the person; think of this as a weight of the person that is bistable.

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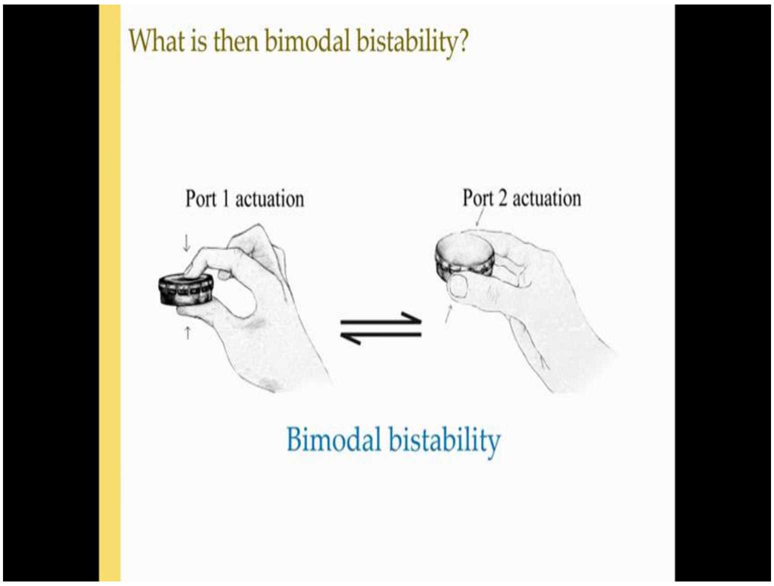

And the side like a handle if we do that will be the second port to move it back, just like this tin if you want to move it the force comes like this when you want to move that way the force comes from the sides. Similarly in a chair when the person is sitting there is this chair like that when the person sits here it goes down, this is stable that is stable that is bistable, but to move from there to here we have the weight of the person. To get up this requires less force that comes from the handles that they were pressed so that is what we were looking at to make this chair.

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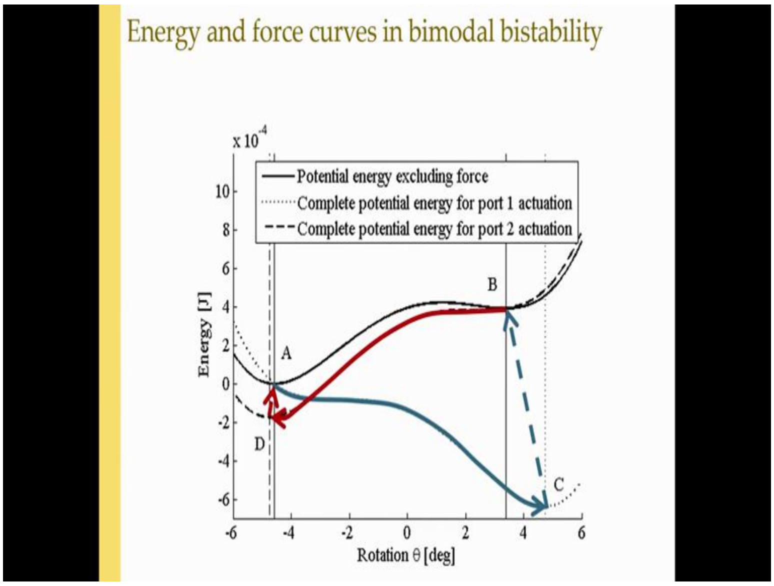

It has one path to go from one state to other state and a different path to come back - blue path while going the red path will coming back. Red path requires much less force than blue path and because the energy is stored in this bistable device. So that is the bimodal bistability and we have discussed all of this in a previous lecture we can pass the slides and look at a there is optimization problem that was solved and all that is analytical 1.

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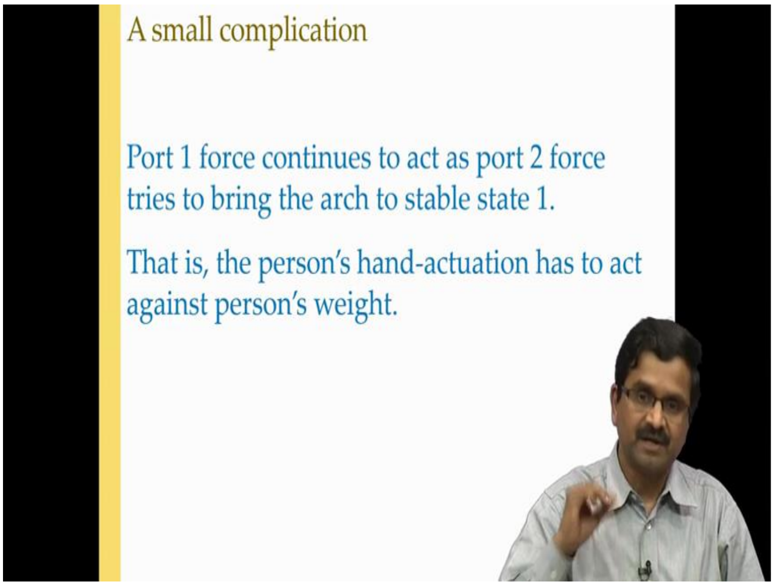

But here what we want is a device that works in practice and then there is a small complication, the port 1 actuation weight continuous to exist unlike in the tin lid where apply the force and apply the sides this force is not there, up down force is not there whereas, here up down forces are weightier than the person itself the person is still sitting in the chair and now person has to get up, so the force required to get up is going to be very high. Both arthritics as well as elderly people will not have that much of force to do this. In fact, if they had they do not need this chair.

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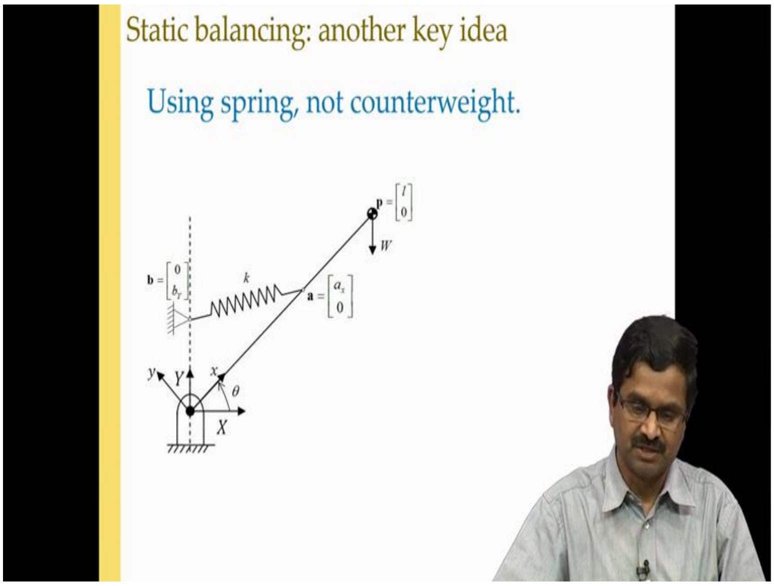

So, we have to come up with something where in the presence of the port one actuation port 2 actuation where a little should be able to get them up. So, we used the principle of static balancing which we have discussed, we discussed bistability as well as static balancing here we are combining both. What does static balance do? Static balance compensate with the weight of the person. So, we want to have a bistable compliant mechanism combined with statically balancing mechanism so that we compare the weight of the person and try to achieve this.

Without using counterweight we are using the things here which we had discussed we do not need to go there.

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Bistability static balancing and a spring are the elements we are going to do to design the energy landscape so that the sitting and staying set and getting up all of them have a particular resistant that the chair has to provide or assistance, resistance or assistance. So, if you see elderly people sitting in they will go there and certainly just all of a sudden they will sit in the chair because they have not have the control, so while sitting in you need some resistance while getting up you need assistance. So, pushing initially you should resist while they want to get up it should push them so that is what we want. So, all of these in one diameter springs something like this would be great and that is what we trying to do here.

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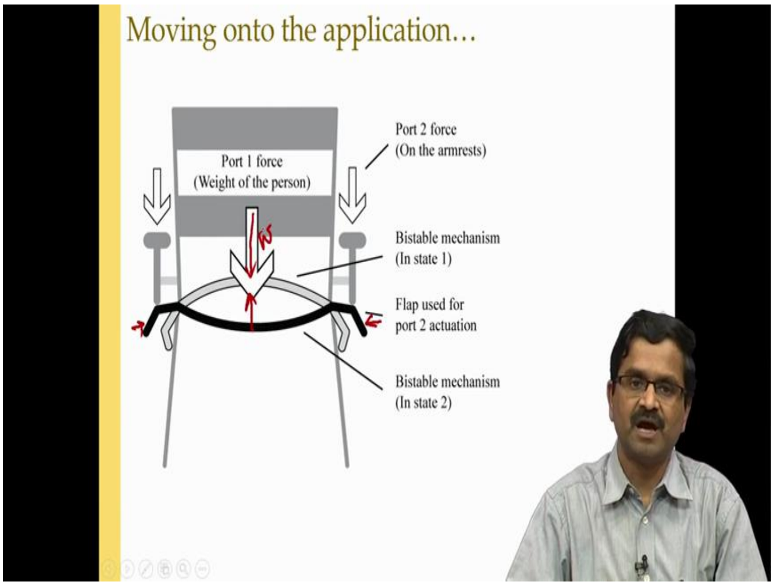

We have the bistable that his up that the weight of the person comes we go to the black one so that is the bistable and then the handles when you do that is port 2 actuation that is a actuation like this it will again switch back to that one, but then the continuously this weight is going to act so for that we have this static balancing.

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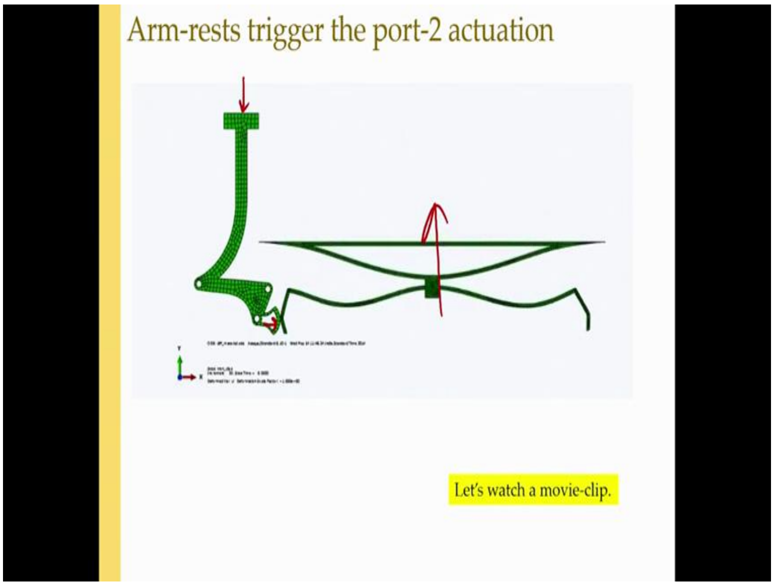

This is what it shows, if this is the seat where you can put a cushion it comes down person sits and then the handle when the force is applied here it would move here and it will switch back so that is the idea. So, bistable bimodal; so, it is 1 stable state, it can be other stable state.

Now, it is there now when the force comes it will switch back. Now of course, it is not going to eject very quickly the gentleness comes in static balancing that we have.

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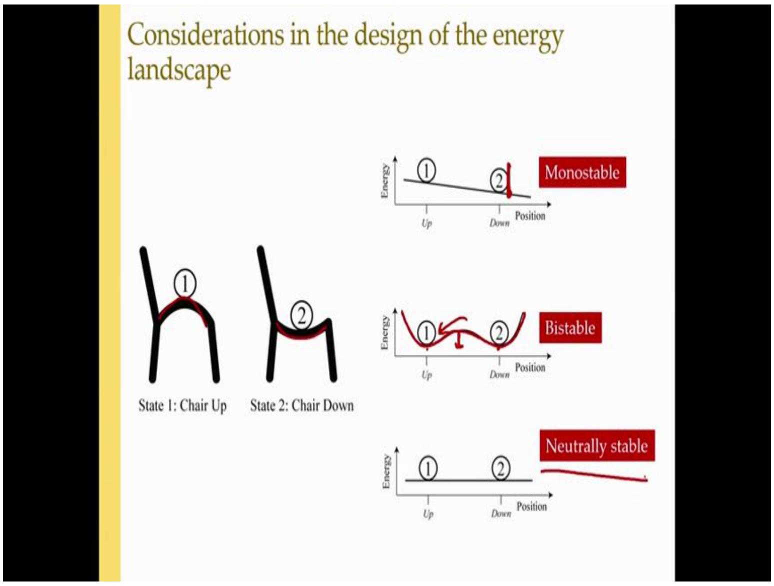

It can be monostable, bistable and neutrally stable, if the energy landscape what we want is this bistability. So, you go from here to here to come back we have this side by actuation so that we do not have to go over the same height of the hill it will be bit much less steeper. And most others will have a spring with a stop that is not going to be comfortable because in this state also that is continuously resistance coming from the spring, spring is always trying to push you up, we do not want, we want in this one becoming here that comfortably sitting in, so there is a stable state. Neutrally stable state will bigger, but it is continually floating operation whereas, here we have the bistability that we want.

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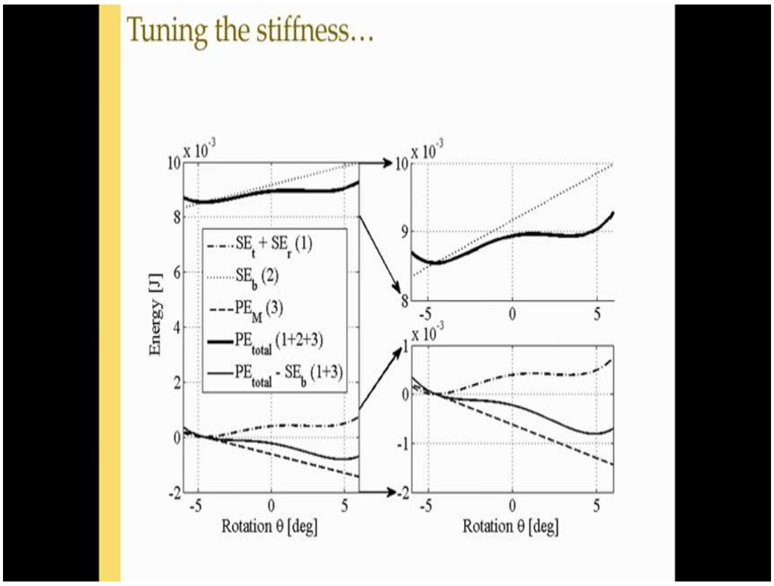

This details also we had discussed how to tune this stiffness. So, I will not go over that.

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So, this small complication is that the weight does not come all at once when you are sitting. So, the chair is here like this when the person sits entire weight of the person does not come. So, we have to do static balancing for variable load here. So, we did some studies on how the weight comes by putting a load cell that is shown here.

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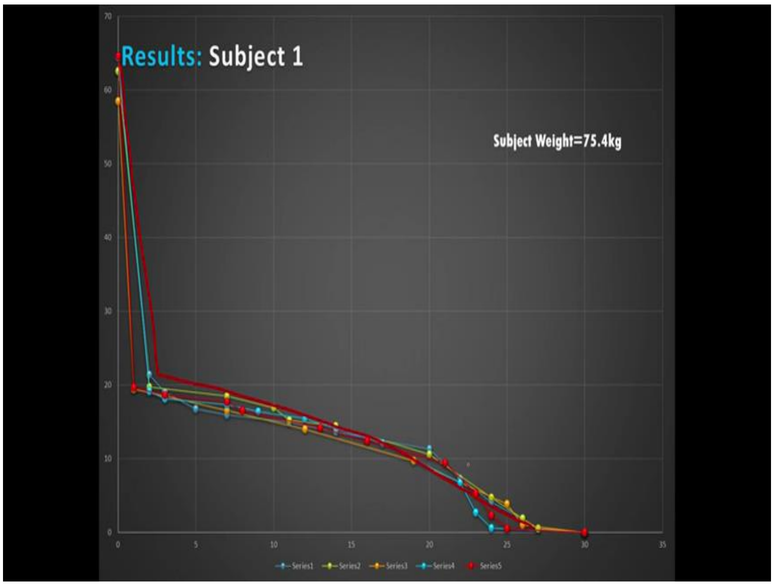

As the angle let us say 30 degrees or 40 degrees, it rises slowly and then rapidly rises to about 90 percent of the weight of the person right in the end. So, it comes like this we are taken into account in making our static balancing for this case. These for different people we did and we observed the strength and accordingly took care of that.

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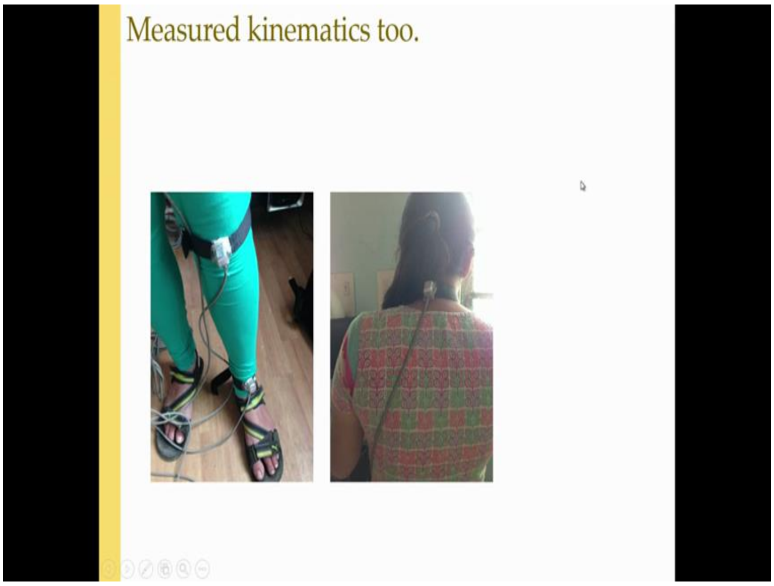

Also measured the kinematics by putting some sensors, even if you want to use a compliant mechanism something you have to do all the design works. So, lot of works was needed to do this.

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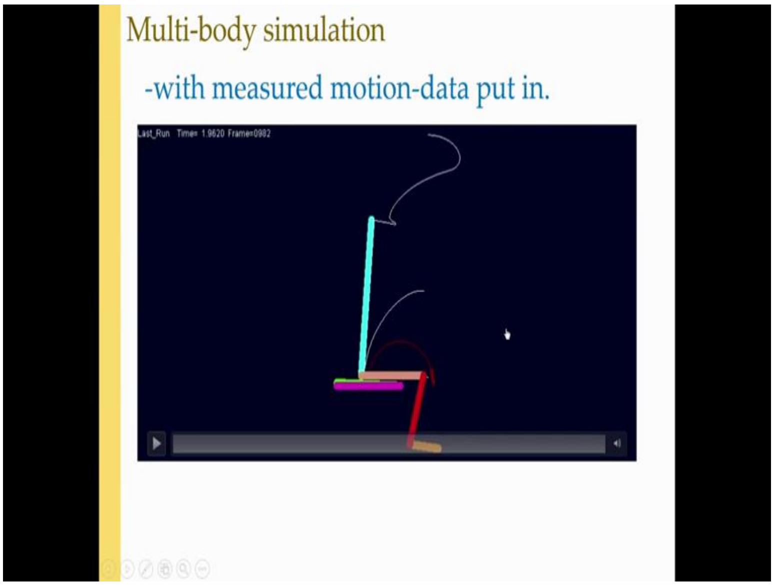

And we also looked at multi body simulation with a measured motion of the data of the person and you can see how their head goes forward when they are sitting with a particular motion and sit there. So, that is how we sit, when we are sitting it bend forwards a little bit and then come here. We can do this for each person based on their anthropomorphic proportions and their weight and so forth.

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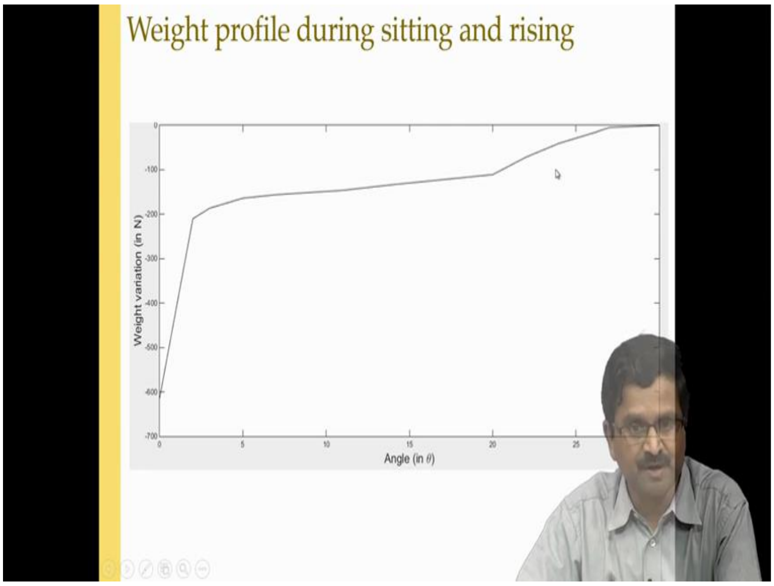

And see how their weight comes in order to chair, this is somewhat similar to what we had observed in the experiment also. This with simulation how weight varies with the angle of the chair, with the experiment we already saw it was similar.

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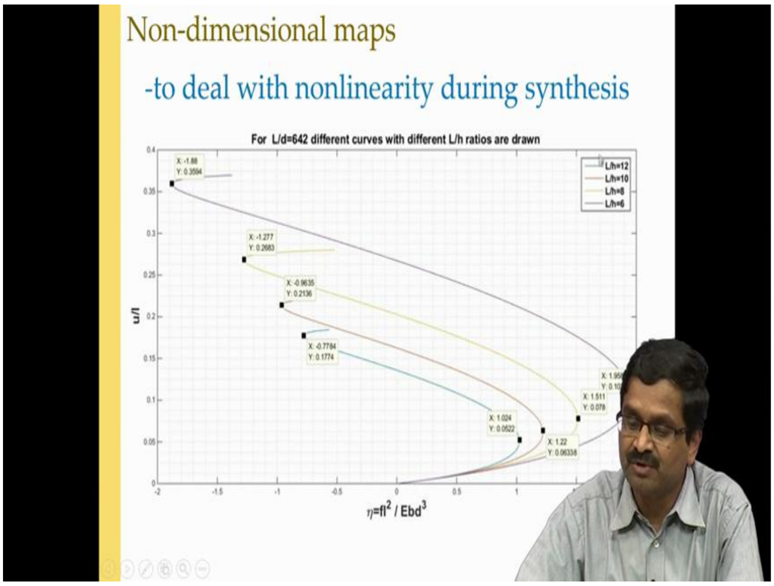

We took all these and then did this non dimensional maps to design the bistable device. So, we have this force versus displacement, the eta, the non dimensional factor, non dimensional displacement to see what slenderness ratio we need to take or l by h ratio we need to take so, we get all those studies.

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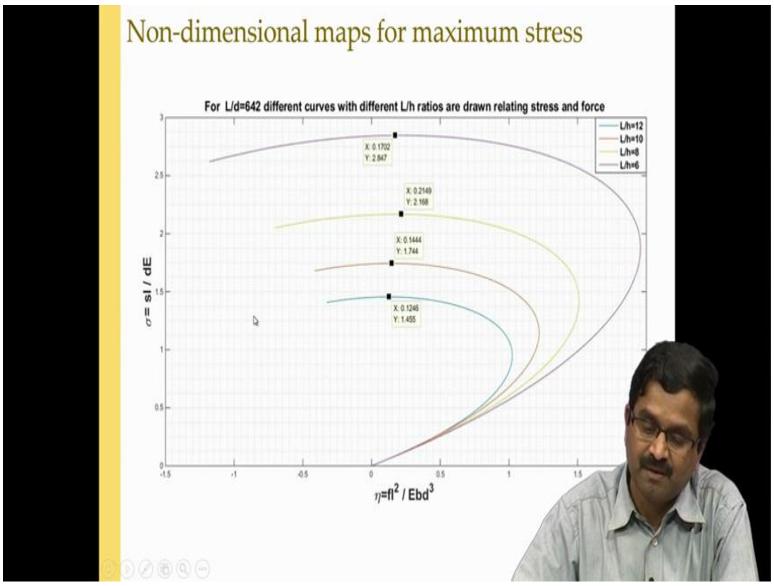

And looked at with maximum stress because we do not want to design a spring that is going to break because elderly arthritic already weak people, we do not want any catastrophic failure any product we looked at the maximum stress also and design some prototypes.

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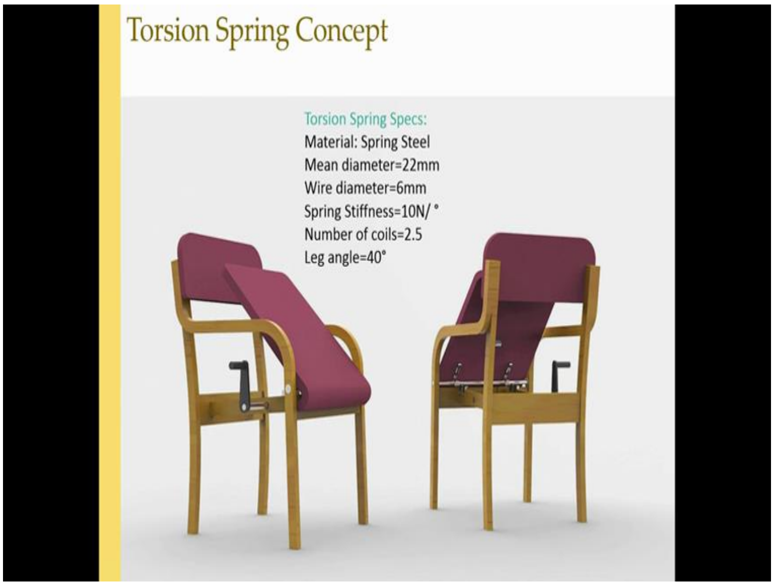

So, if you put a simple torsion spring here this is the prototype there is the simple torsion spring over here when you sit on it; it just comes down, but it will always be applying force on you that is the drawback of this simple chair.

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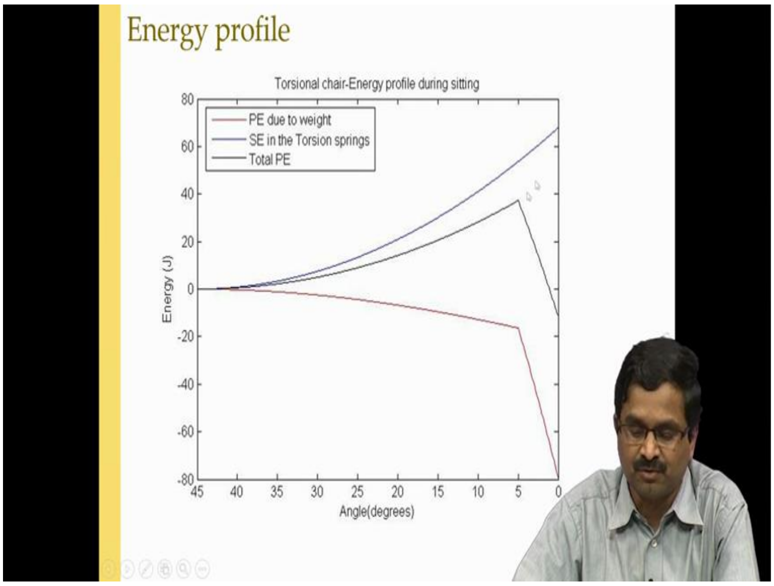

So, that is how energy profile is going to look like it is always is going to apply force here. We are showing total potential energy standard energy in a torsion springs and this, it is going to keep on increasing the total p that we have.

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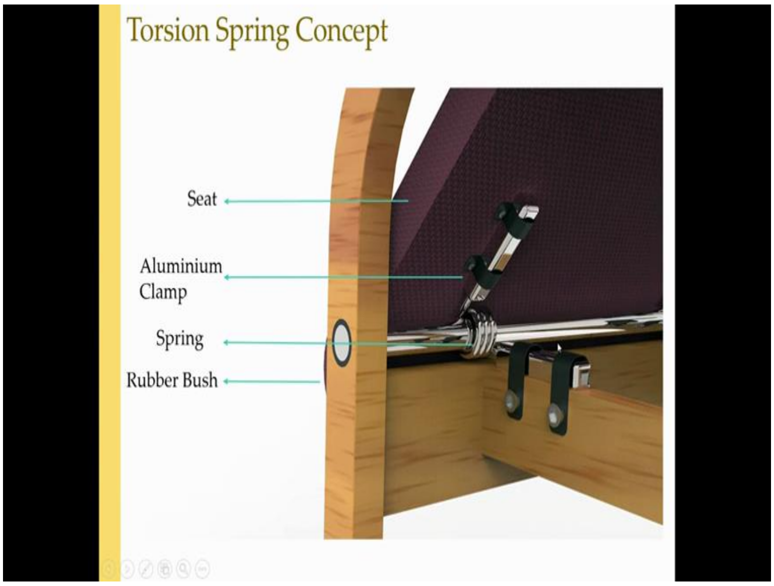

The torsion spring can be put and it is easy that is not an issue.

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And this is a chair where if you sit on it; it will of course, offer resistance while sitting in and when you sit also it will continuously apply the force on you to try to push you up when you are try to get up it will try to assist you for sure, but it will have a force all the time. So, any movement that you do it will try to push you out that we do not want.

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Slider crank - gas spring type of thing which is slightly better. So, this also has a gas spring different weights we can put different springs here so that when person sits according to the weight of the person we provide some assistance since this slider crank has some nonlinearity here there is a little bit. So, while sit there is not that much of a force trying to push you, but it is not 0 forces like in bistable mechanisms.

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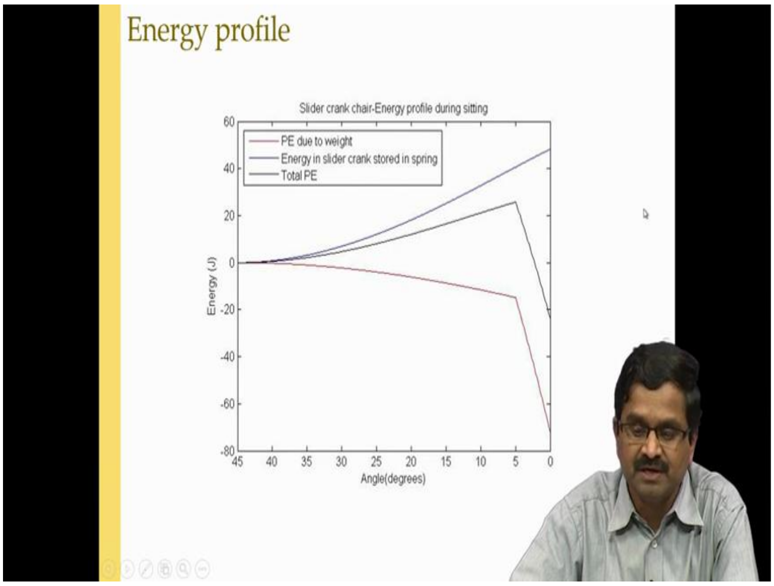

So this energy profile for that, it is all about how you design energy landscape here is that concept closes up and static balancing springs.

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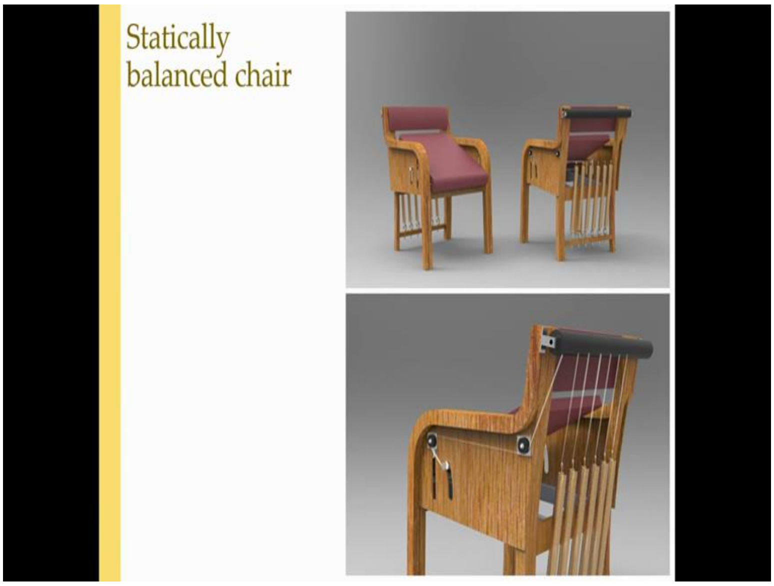

So, we had put this springs at the back of the chair, so that it actually becomes floating that is with the weight everywhere it is perfectly balanced that is what we want to, we want to composite on the weight of the person when we couple it with the bistable mechanism.

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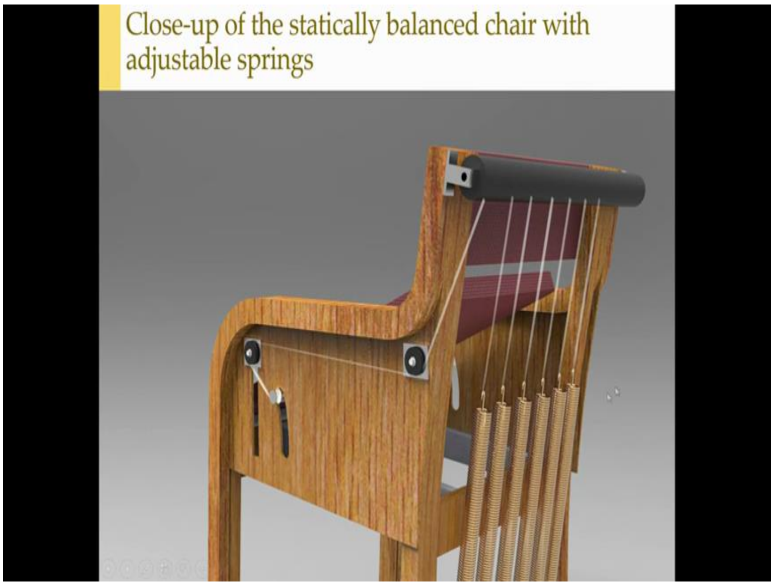

That is a springs there are lots of springs, the number of spring as we remove this springs we can adjust with the weight of the person that is the energy profile for this particular thing.

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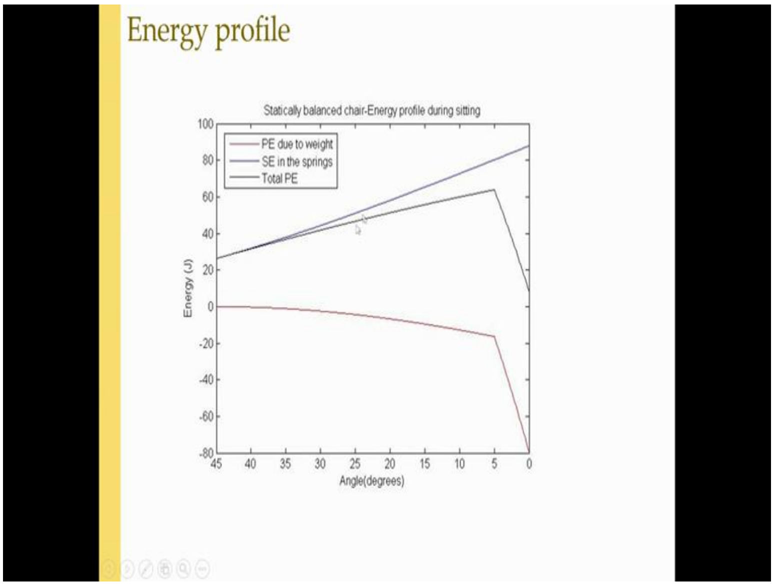

And here is a prototype of that.

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There are a lot of springs at the back and person can sit until always (Refer Time: 21:56) with the weight of the person.

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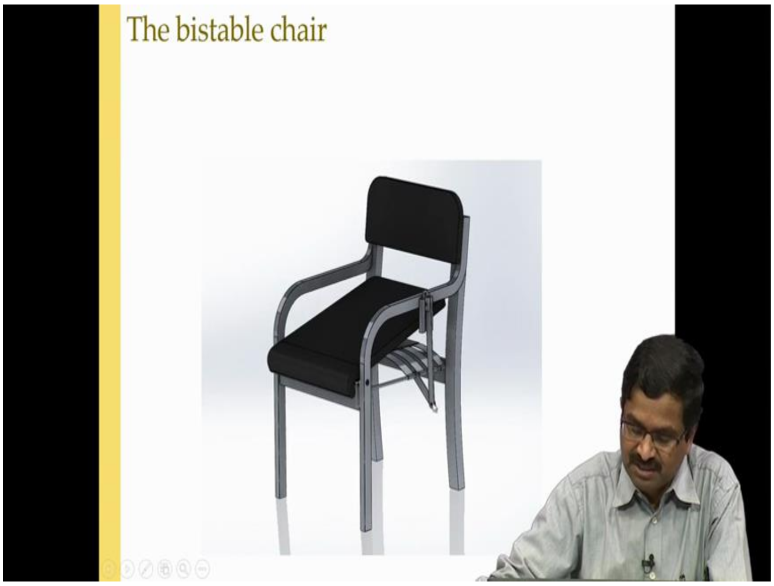

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Now, cause the bistable one, so, bistable one have this strips that we have. So, which are really bistable there were unkneeled and put there and again depending on number of the thing the weight of the person will change.

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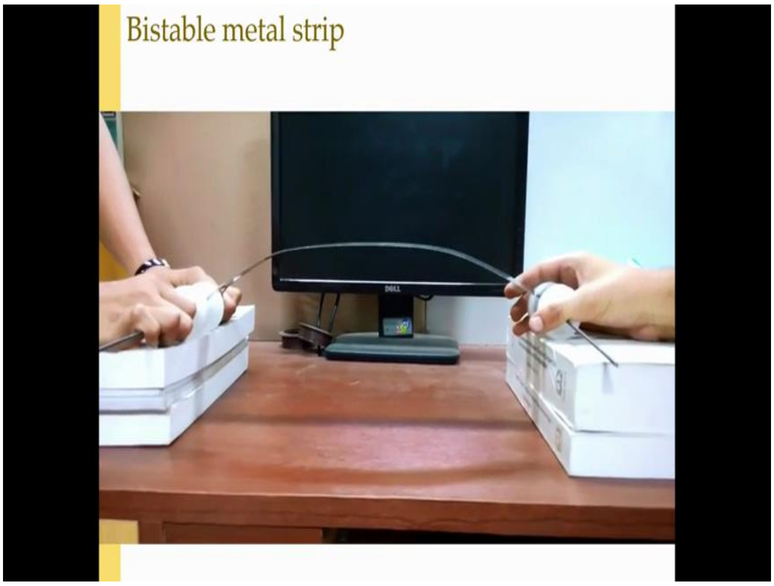

This particular video shows that it is indeed bistable. So, we have the strip here we will apply the force as you will see. So, if we apply the force it will go from one state to the other state this is being adjusted now, when apply the force will go from there to the other when you set it is going to go like that. Now it looks like slightly drastic action going back and forth.

Again let us play this here it goes this way let play this one goes that way and goes this way, but if you couple it with static balancing mechanism it will be smooth. And that is how we want to do it.

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So, this is the prototype and this is the one where there is the handle also which will gently go. So, we have static balancing and this combined will get you this. Putting it all together this is the bistable one static balancing lot of mechanical details, now trying to get it all with much simpler design, but still having the same concept of bistability combined with static balancing.

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Now, we can see the compliant mechanism coming in ways it is not a simple gripper or a gripping mechanism and so forth being put to real use.

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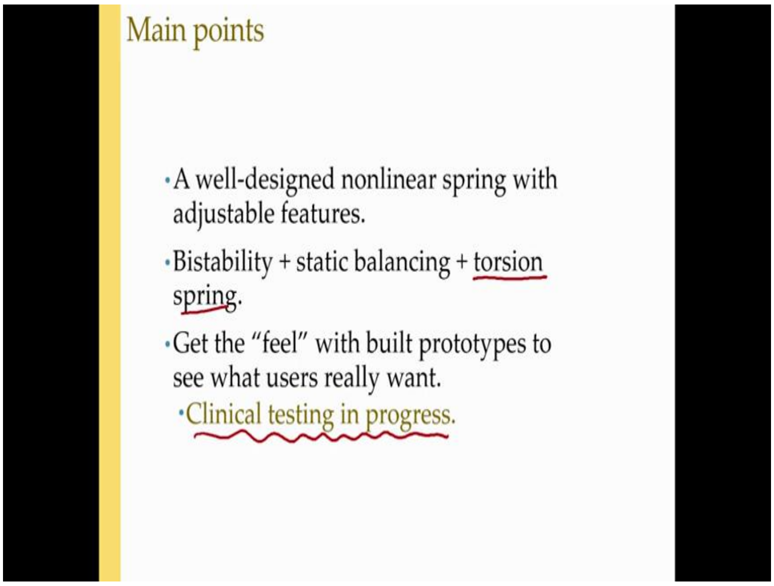

The main points here - we have a well-designed non-linear spring with adjustable features that combined by stability and static balancing and also if one wants a torsion spring because it is simple to do, it is should get the right feel by the users. Right now we are using this chair in nearby a hospital with Doctor Medha Rao with geriatrician who is with all human ethic clearance is testing it in the clinic to see it what the patients say -

you have four different chairs with the different features in them and then see which one of them to work.

A compliant mechanism has the potential for real consumer or goods where as simple as a chair can be built that will access people to get up and use it with a lot of comfort. So, this concludes the last case study.

So, whatever we have discussed in the course in terms of the theory, designed techniques and principles in order to put them to use, one has to do a lot more which was the intend in all these 6th case studies a lot of details might not have been discussed because each lectures only 30 minutes, but I have given references of the papers the research papers where one can see. So, one has to remember that compliant mechanism is just a idea to begin with in order to make it work we have to work a lot.

And again it is still look like compliant mechanism, but whatever designed techniques we discussed are not necessary, but not sufficient to make a practical application work so that is something we have to remember, it is not a text book example of doing some little devices. Those devices are important, their profiles are important, their shapes are important we have to put them all together with a lot of other input as you see in 6 case studies from micro accelerometers and this chair today and the tissue cutting device and a robotic crawler and a few other case studies we have discussed and several example it is in the course all them need a lot more work to make it work. So, compliant mechanisms idea might a powerful idea with which you can make good use in many applications.

Thank you.