Sensors and Actuators
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Lecture - 41
Applications of Shape Memory Alloy as a light weight actuators

Hi, welcome to this particular module and in this module, we will be looking at the lab class, lab component of this particular lecture and in lab, we will be discussing today applications and properties of Shape Memory Alloy as a light weight actuators and what exactly shape memory alloys are and how we can use it for lightweight actuation. So, what exactly lightweight actuation means. Suppose you understand that if there is a robot right and you want to maneuver the robot; that means, you are to move the robot like this and this for example, in two angle one and two or two direction ok.

Not multi direction robot not rotating one only two directions. How we will maneuver it? Either you have a strings on both the side right like a wires on both the side you pull one wire it will bend here, you then you release that wire it will come stay the polar under wire it will come here. Now, these wires are generally made up of stainless steel. Instead of stainless steel, how about we use smart materials or alloys, which is called nitinol generally, which on cooling it will come to a shape that we want and when heating it will remember it will come back to its original state. So, what exactly we mean by that. So, you can see on the screen.

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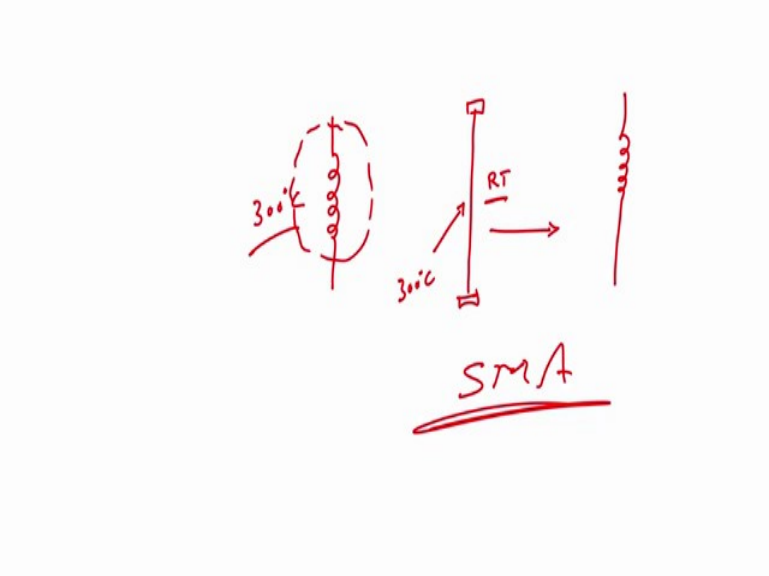

Suppose, I take a nitinol wire and make it a spring like this at 300 degree centigrade; just I am giving a example ok. Now, if I stretch it and put it against let us say 2 clamp at a room temperature, if I stretch it like this; whenever I will heat this at 300 degree centigrade it will try to retain it is original property which was it was trained at 300 degree centigrade this one. This is your smart actuators or smart memory alloys. Now, the advantage of this is, this is lighter than ss and it has much most, in terms of mechanical properties, it is much more better than your stainless steel.

So, can we use these smart actuators as an alternative material for maneuvering the medical robots or you can say catheters alright. So, that is a lab component of this particular class and then what will be looking at is how to use this thing for actuating the catheter. So, I will request my teaching assistant Miss. Alekya to show it to you how to train this particular a shape memory alloy. Thank you and I will see you in the lab next lab class, till then you take care I will request now Alekya to continue.

Hello everyone, welcome to the next module of sensors and actuators. In the previous module, we have seen how shape memory alloys can be used for actuation as a replacement to the conventional the motor actuators or the pneumatic or the hydraulic based actuators. Today, we will see an experiment on how SMA actuator can be used to make a small prototype of a vehicle.

Even before I get into how SMA actuators can be used in a variety of applications, the advantage of using SMA has come into picture mainly because they are light in weight, they can easily replace the working of a bulky motor. And, then again, another advantage its biocompatible; the metal alloy what we are talking about the nitinol for example, is biomaterial. So, the major advantage comes here, that is, the biocompatibility of this material makes it an essential alloy to be used inside the human body.

Various applications we will be seeing through in few minutes. So, for the first application, like you remember, in the previous module, I have told you SMAs behave in 2 phases that is the austenite and the martensite phase. Physically, when you deform the object you, we will in the previous module we have we studied how to train the SMA. Once training is performed, what we do is once you apply heat or the thermal stability the change in the temperature is what activates the SMA to behave like an actuator.

So, once we have done that, we have seen how changes in temperature generate some amount of heat and then it returns to its trained state. Now, this mechanism of actuation can be leveraged for various applications. One such application is biomedical application; one, because it is biocompatible; another, the material is really thin as you observed we have we have shown you how the nitinol wire looks like it is a really thin wire.

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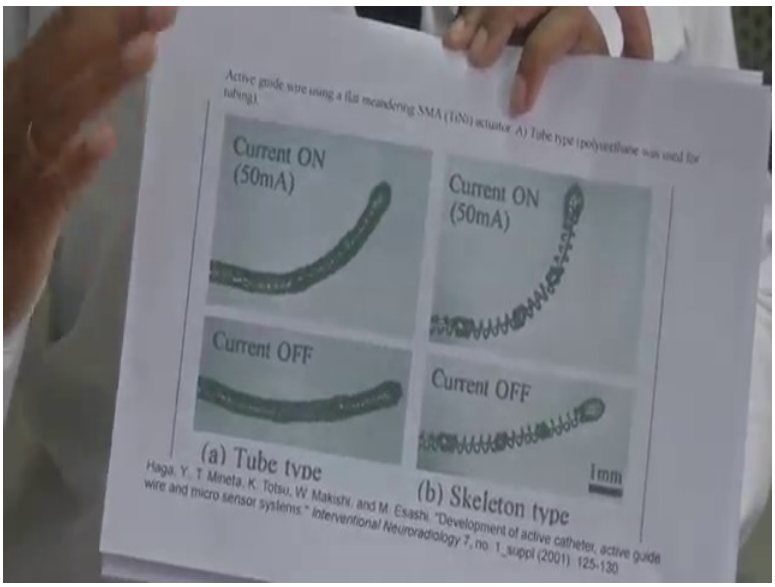

And then it could be shaped into the desired form and then actuated. So, one application here what I like to show you is a catheter. I am sure you have heard of the term catheter. So, the catheters are nothing, but when you are talking about cardiovascular catheters. So, they are mainly used to ablate tissues. So, in heart tissues if there is any sort of lump formation or if there is a blockage, in simple terms, they have to be diluted, churned out.

And, then removed or in case the valve in the heart becomes flaccid or loose and it no more has the mechanical stability to you know to give that strength to your valve so, that it remains open and then there is easy blood flow through it. However, when that blockage happens through the wall blood flow stops and that is when you call it heart attack and there are many other symptoms.

So, one such application here is nothing, but catheter. So, what SMA gives, when you have something called as an SMA inside a catheter or a polyurethane tube, you can maneuver it as per your requirement. So, the veins in our body are really tiny. When we have such small features, we need to actuate your device, or the guide wire; the surgeons use guide wires as you know means to enter into your body either to visually assess what is happening inside or to get a feedback.

So, for that, we have something called as these catheters and this is SMA base in nitinol actuator and here, if you see, current on this actuates. So, it compresses the SMA wire is inside and then there is guide wire through this here. So, if you observe, it actuates when some current flows through it because of the heating effect; this actuation happens and then when you cool, it returns back if you see this is state A and this is state B.

So, when there is no more current is returns. However, it is not in the previous lead state cooled state. So, is. So, if you see if you if there is something called as you know ideal state and then you actuate and then you return back it would not return back to it is original state, perfectly original state that is because SMAs has something called as hysteresis. So, this phenomenon is dominant in SMA and that is why you would see they do not go back exactly to the ideal state.

So, this was one such example. If you see here, the thin line is a guide wire and this is your SMA coil. So, this can be actuated depending on the application. So, for further, you could refer to this reference what I have cited here.

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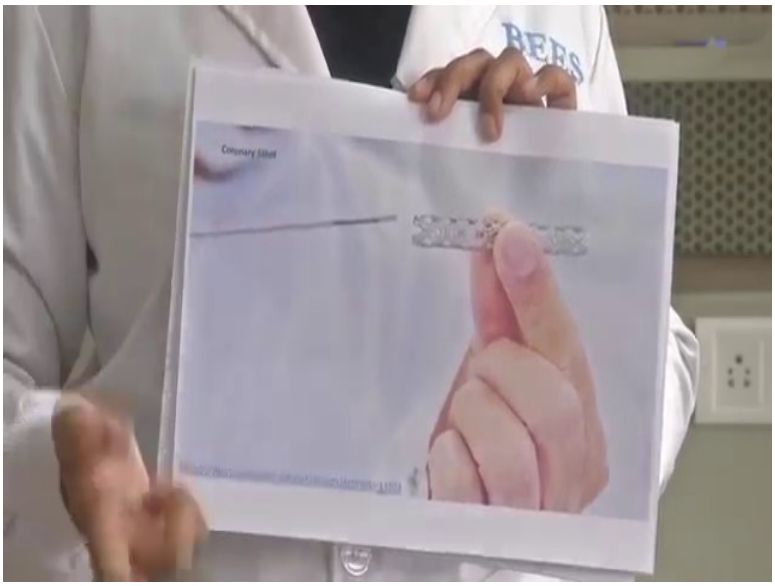

Going to the next example. Now that we have seen SMA can actuate and then move through your body veins to the desired location and then you can get a feedback, this is another nitinol based stent. When I am in stent, these are nothing, but tube like structures these are mechanical structures that is. So, the main purpose of having stents is in order to remove blockage or to give mechanical support to your valves which are which have lost your mechanical stability.

So, in such cases doctors with the help of a guide wire introduce this into the location which is melsec or which has lost mechanical stability. What happens is in the normal, at room at room temperature that is in the outside environment, it is usually covered with a sheet. So, that it prevents any sort any sort of a disturbance or noise we do not want it to expand.

This, in the ideal state should remain compressed, and there is a sheet covering. Once this has been introduced into the human body or the valve which needs to you know have remove where we need to remove the blockage. After introduction because the sheet will be removed gradually dragged and because of the body temperature that is 37-degree celsius this expands. So, as it expands it provides a through the through your vein, when you have this stent passing through and then when it expands it gives mechanical strength to the segment which is lost its mechanical stability.

So, this is one such the major advantage here is it is biocompatible because of its mechanical property and it is biocompatibility and also MR compatible; MR when I say the Magnetic Resonance Imaging, MR compatible. So, that is these are the important properties or parameters which makes it important in various biomedical applications.

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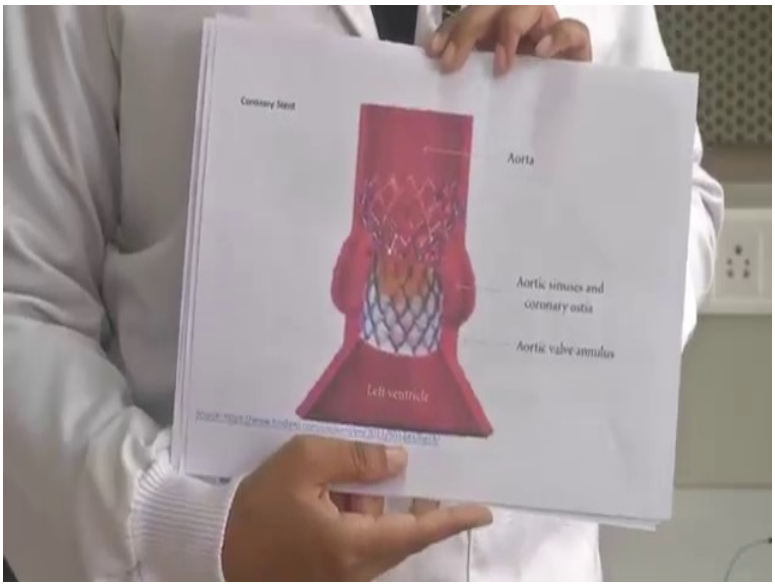

So, now just to give a clear image as to how a stent will be introduced this is a coronary stent or the iota the valve gets blocked and as you see once the sheet material would be removed, this does expanding. The metal here is nothing, but nitinol. So, once it expands for the body temperature, it produces proper mechanical strength to this aortic valve, and it gives support.

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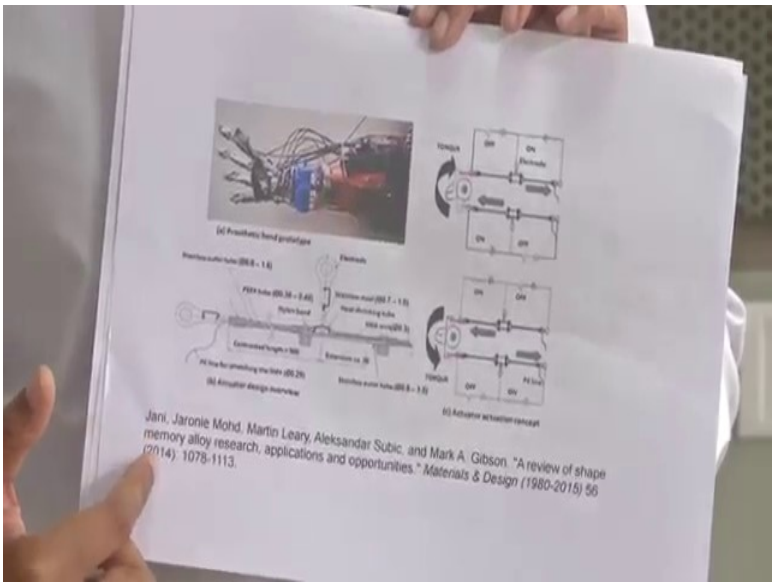

Going to the next example, like I mentioned, SMA actuators are used in robotic arms. When it comes to biomedical application, they are smart catheters which are steerable, maneuverable at different degrees of freedom and all that is done using your shape memory alloys and there are stents which are introduced through the help of guide wires. Next application here, if you see, this is nothing, but a robotic arm. In order to get tactile perception for this robotic arm, we would have tactile sensors at the surface of this arm; however, if you have seen your hand, there are these are called tendons.

So, if you have to bend your hand and then; this muscle movement can actually be imitated using your SMA that is why it is also called as a muscle wire. All of these SMA wires here to the robotic arm can give mechanical actuation just like the human hand. For more, if you are more interested, you could go to the source below and study more about how a robotic arm mainly uses SMA wires for actuation.

So, they are also called as tendons which come along with your SMA for support and they give a sort of actuation. So, this was about the application of SMA wires in robotics.

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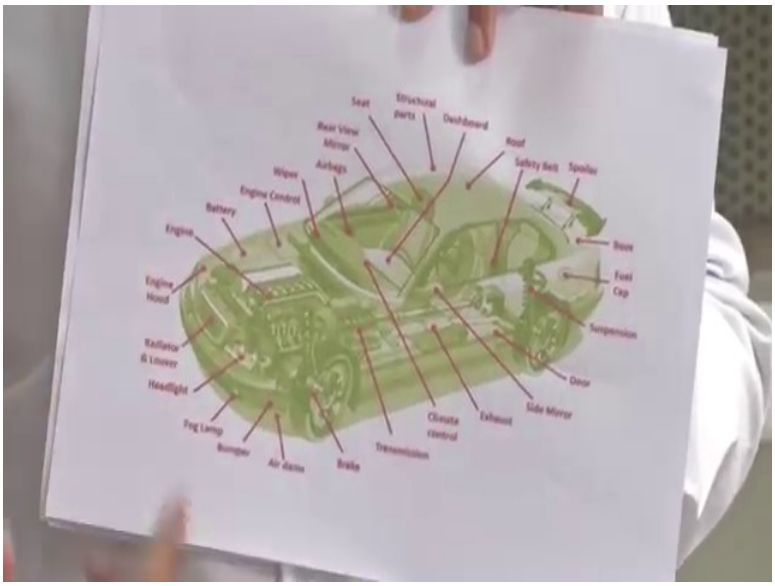

Now, coming to the next application. Like I mentioned, it is a smart replacement of the conventional actuators such as your hydraulic or pneumatic or the other motors which are present now in your industry. So, since these are really light in weight, smaller in size and can easily replicate and replace the conventional actuators. So, this is where it finds a place. So, the different parts of your or the automotive; the automobile can be replaced with your SMA. This is one such major application of using actuator which is the nitinol-based actuator.

As you can see, there are multiple parts in or. So, this plays a major role even in automotive industry; how it can be replaced. Very much similar analogy is what we can show you; simple actuation mechanism in just a couple of minutes. So, this was about the different vast application of shape memory alloys in automobile industry or it could be in the biomedical or robotic applications this was an introduction.

So, that you could understand how you can use such materials the smart materials or a combination of such alloys; so, it is not just nitinol, nitinol when I say it is a nickel or titanium. So, it is not just nitinol based, SMAs can be of variant combination of alloys; you could check for them online and each of them behave differently at different temperatures and each of them should be characterized because they have something called as hysteresis.

So, the behavior has major factors the amount of cooling. So, there are few actuators which require very high temperature, lot of heat to be generated for it to actuate. So, when you are using such SMAs then you need something called as cooling. The cooling component can come in the either when you use you can pump in air or you can pump in fluid or oil. So, all of these additional components would be required when you are using SMA and again it depends on what type of SMA you are using.

Now that we have understood some basics about the shape memory alloys and its applications in catheters and biomedical application, let us just see small example of how the actuation can be used with a simple Arduino and then you can actuate yeah with just simple car prototype is what we have shown here.

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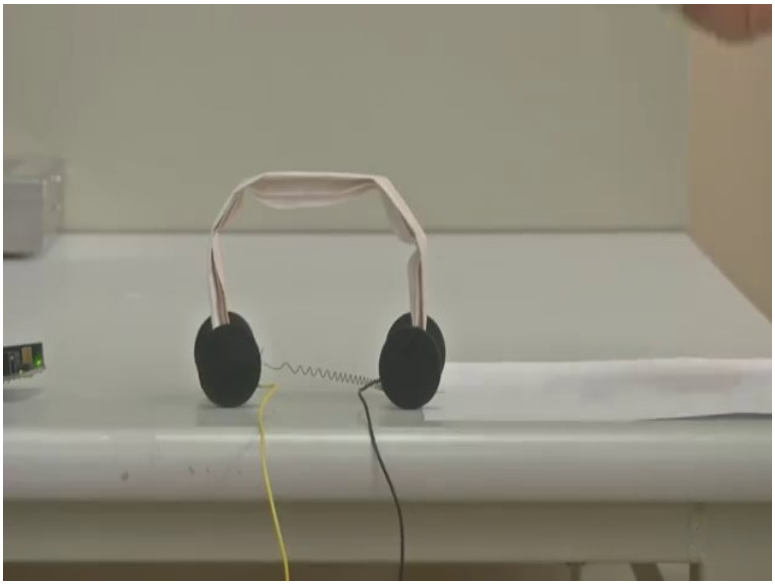

So, now here Robby is here with me he is just made this prototype in like 10 minutes, that is, he is just taken an SMA wire train the SMA wire like we have shown in the previous video. So, that is a trained SMA and what we have here is just prototype 3d printed prototype of wheel structure. Now, he is using an, he is using his, he is using a source supplying small voltage to the shape memory alloy. So now, if you see, what happens is, what happens as you supply the voltage to the actuator you see the actuation mechanism it is literally dragging through the wheel.

This is nothing, but the trained state. We had a previously in the previous module we had trained the SMA by winding it. So, this is nothing, but the as you see it is expanding. So,

the austenite and the martensite upon cooling this is nothing, but the martensite phase it goes back to it is original shape. Now, when I, when I told you there is a point called hysteresis, let us see how that affects these SMAs. Now, let us say the let us say the starting point of the wheel is here. So, now, this is point A now when we heat this is nothing, but the cooled state, the martensite phase. Now what happens when we run current through the shape memory alloy.

So, as you see it drags itself, the actuation mechanism pulls the 2 strings to the center. Now this is nothing, but the austenite phase. Once it is released, it takes time 1, 2, 3 3 seconds and then it starts actuating. So, it is come back it is moving back to the original that is the deformed after the deformation because of the heating.

Now, you will see we started from this point A; however, it stops at this point B, the new point, this is nothing, but hysteresis. So, when I showed you how a maneuverable catheter does not move back to it is original state, this is another a simple example why it cannot return back to it return back to it is a original state.

However, the advantage is we know how it actuates, but then irrespective of the amount of deformation and the number of times we repeat this, you can see n number of times. I repeat the same principle; however, it is really robust in nature. So, in spite of the mechanical deformation what I gave, the mechanical load, it again behaves in a proper fashion. So, this is the major advantage of the SMA and how it is very good replacement for the actuators in today's studies.

So, this was a demonstration as to how the smart alloys or the shape memory alloys, also called as the muscle wires, can be used in various applications and when it comes to us, the biomedical application, when we and then our major focus is on making bio chip or a micro fabricated chip. So, each of these are very tiny nature and when you want to use actuations, such as if you want to pump fluids in a micro channel, use a micro valve or a micro actuation mechanism that is when you can use something called as the SMAs. And, then integrate them into these tiny sensor devices and have the entire mechanism.

So, this is an application. I hope you have got it was just brief introduction as to how their different properties the of these alloys. There you can go ahead and look at the different variants, the different combination of alloys which are available. Make sure that you understand what is the working temperature because the nitinol wire what we have

used here, that is not get heated much. So, it is just few 200 milliamps with what we have shown the actuation mechanism. So, the heating is not really high. So, when it comes to stents again they can operate a 37 degree celsius, but there are alloys which require 100 200 degree celsius.

So, considering and keeping all of this in mind, the hysteresis, the working temperature and the different alloy combination which can suit your application, the bio compatibility, the mechanical strength, again, this was just the 100 micron wire you, if you require higher strength mechanical strength you could use 300 micron wire. These are again used for measuring your weights or in case of automobile applications, like I have shown you, the applications are vast. So, this gives brief introduction about how SMAs can be used in various applications; that is it for today.

Thank you.