Sensors and Actuators
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Lecture - 40
Introduction and Demonstration of Shape Memory Alloy

Hello welcome to this particular lab module, here what we are looking at is a Actuator and these actuators are based on Smart Memory Alloys is also called SMA and the material that is used is called nitinol. We will have the introduction to this particular nitinol material and we will also see how can you train this particular smart actuators. The examples are many of using these smart actuators. One is that if you have a catheter, let us say is a tube and you want to bend this tube or you want to maneuver this tube, then you have to use this smart actuators in a spring form.

For example, if I want to, if I have a let us say, cylinder and in cylinder, I have this tube right and maneuver this tube in this direction. So, if I open the cylinder, a tube is moving in this direction like this, how can you maneuver it? So, for maneuvering the tube you can use this smart actuator within the cylinder. Now, instead of cylinder, assume that you are talking about human body right, if I put the tube in trachea, if I put the tube in the heart right, this tube is called catheter, technical term is catheter; and how maneuvering is, how to move it, is a movement.

So, you can control the movement with a lot of precision if you use this particular actuator is also called a smart memory alloy. So, we will have a detailed discussion and introduction on this particular subject as a part of the experimental class. Look at it like I said the applications are huge if all the new and novel biomedical research in the area of biomedical robotics uses SMA as a smart actuator. So, it will be really useful, you can have lot of interesting ideas and problems if you understand the working principle of smart actuators, bye.

Hello everyone. Welcome to the course on Sensors and Actuators. Today in this module, we will study something about smart memory alloy, a shape memory alloy. And why does this become important to us? We are talking about actuation, like we have motors where we are using that to actuate the robotic arm for instance; however, when we for us our concern is about micro engineered devices.

And when we are making minute sensors, how do we have an actuation mechanism which is more compatible with the micro engineered devices so that you could reduce the entire size, maybe our requirement could be having it in a smaller size, lighter in weight and all of this integration is possible only when we have different materials which are compatible with our small devices.

Keeping this in mind, today we have an interesting topic called the SMA based actuators. SMA from hear on when I refer, it means shape memory alloy. So, alloy here it is group of metals like the nickel, titanium or it is the copper, aluminum and nickel; these in combination behave like a metal which remembers, it behaves like it has memory and it can be trained. There are multiple alloys which can behave or trained to behave like smart memory-based metal or a smart metal, they are also called as muscle wires.

There are lot of names and terminologies behind this shape memory alloys. However, coming to understanding the mechanism of these, let us see how you can train a shape memory alloy. When I say train, these alloys have two states; either they are in the austenite state or the martensite state. So, these two states are something which they are either in, when it is heated or when they are cooled down to a certain temperature. So, what is the basic phenomenon for this effect, the shape memory effect is; they are thermally sensitive.

So, when the temperature is altered, the crystal structure of these alloys change such that they go back to the state which were they remember, or they were trained to remember one particular state. It is very difficult to even imagine when I am talking to you about having, remembering the state; we will see in practical how you can train this shape memory alloy. For now, for instance here, what we have is a nitinol based SMA. So, it is 100 micron, the dia is 100 micron. So, let us see how you can train this and move between the two phases; that is the austenite and the martensite phase.

And then you can actually have various applications, once you know how you can train your SMA, you can apply them to multiple fields. This is something in the current market because of it is light weight and it can easily replace your hydraulic or the motor-based actuators. Because they are smaller in size and you can integrate them and have your device size reduced and have the entire function or mechanism of actuation in a

very small chip. So, that is the main reason why we are introducing, the smart, the smart alloy here.

Let us see how to train the shape memory alloys. If you are really interested, you could go on and look for applications because there are lot of applications with SMA. Like they are using the shape memory alloys to have different wing morphology in aviation industry, they are used in medical industry; I am sure you have heard of soft robotics, medical robotics or the robotic arm where the entire arm can flex and as you flex the tactile sensing can be achieved with the help of these SMAs.

So, the variance of uses or applications with the help of these SMAs; but today in this session, let us see how we can train the SMA, so that it memorizes and remembers what we have given, what we have trained it to. So, you could train it to work in different shapes and then you can actuate it and it regains its shape which it has learnt. Now, we will see how we can use this in our application.

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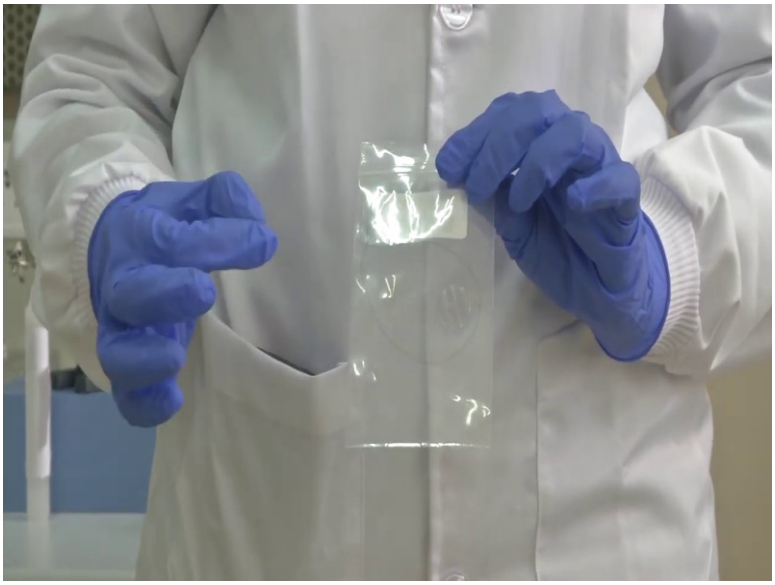

So, here what I have in my hand is the SMA what I was talking about; this is a 100-micron dia, shape memory alloy which I brought it from Flexinol. So, this SMA is nitinol based; this thin wire here is the smart metal and they are available in different dias; this is a 100 micron, there is 300-micron dia and higher dias. So, based on your application, you can have one such nitinol-based shape memory alloy, this is the muscle

wire or the SMA what I was talking about. This is a 100-micron dia nitinol based shape memory alloy, which I brought it from Flexinol.

So, this is the shape memory alloy, in my hand here which I brought it online, this is a 100-micron diameter SMA, also called as Flexinol, which is available in different diameter. So, this is a 100 micron, you could get 300 and higher dias based on your application. As you can see, this is nothing but more or less just flexible thin wire. This, between my hands, is the shape memory alloy and this is nitinol based; nitinol when I say it is the nickel or titanium alloy.

This is a more preferred choice because it has better stability when compared to other SMA's and the alloy is more thermo mechanically stable. Hence this is a preferred choice amongst the other SMA. Now let us see how we can train this nitinol wire and operate between the two phases; that is the austenite and the martensite phase.

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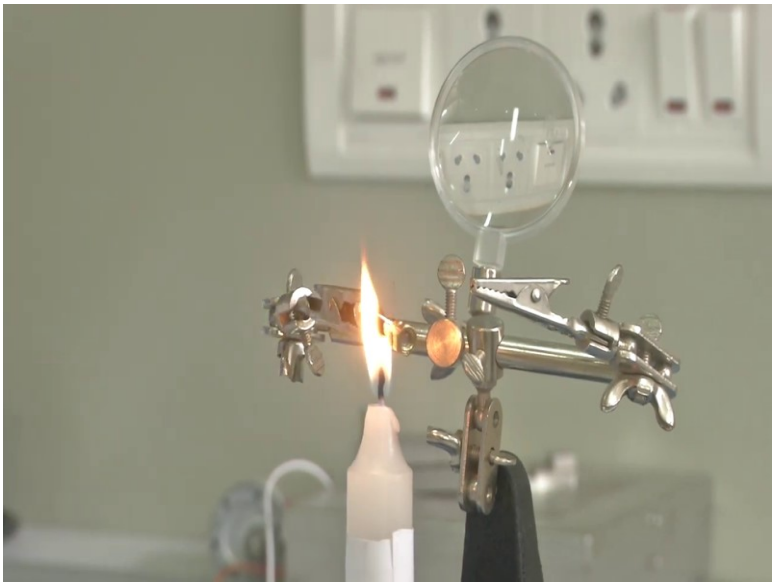

Now, let us see how the temperature induced phase transformation using SMA can be performed using Joule heating; that is nothing, but the actuators are typically actuated electrically by Joule heating. So, the entire mechanism of training will be shown to you with me here is Rabeeh, who will show you how to train shape memory alloy. So, what he has here; to initially you have to fix the SMA into the shape what you require, and then you have to heat it.

So, in order to train here, we have this setup here, where he is got the 100 micron the Flexinol or the nitinol SMA what we purchased online. So, he fixed it on one end of this bolt; now, what he would do is, give it a shape, such that it will memorize that shape what he is giving it now. Now that we have this screw, so he is just going to wind it such that we are going to have a spring mechanism. So, we were talking about the shape memory effect of this nitinol wire, this is mainly because of the temperature induced phase transformation. So, there is deformation because of variation in temperature.

So, let us see how we can train or even memorize the shape using the SMA. Now what Rabeeh has here is a Flexinol or a nitinol SMA, 100-micron dia. What he does is now; step one is to fix the SMA to the shape what you desire. So, that can be trained to any shape, depending on the application; now what he has is just a threaded bolt here and then he is just wire wiring the SMA across it.

Fix it on one end and then you have, because we need a spring like mechanism; so, he is rotating the entire SMA across it. So, step one is to fix the SMA into the shape what you desire; and then we have to train it or memorize it so that it will again deform back. Once it learns one shape, while the transition happens between the two state, it would go back to the memorized shape.

So, like what you have seen, what he has done is; he is fixed it on either ends and then rotated it across the threads. Now what we have to do step two, is to heat it. So, the entire mechanism of learning is because of Joule heating; that is the actuation is because of the temperature transition. Now that he has the SMA shaped according to the requirement, he would now heat it to up to 400 degree Celsius.

So, what happens is, the shape memory alloy; it deforms when it is cold and returns back to its remembered shape when it is heated. So, when we want to heat, all we can do is just apply some voltage across it and drive current through it. Now it will recall its memory. Now what we are doing now, is to train the SMA. So, he has fixed the SMA and now for 4 to 5 minutes just heat it.

So, what happens when you heat is, your training the SMA to behave in one shape. Now that it heats up to around 400 degrees Celsius for a couple of minutes; what it does is, because of the temperature, high temperature it the crystallographic changes happened

between the in the alloy and it remembers this shape. This is a nitinol based SMA. So, now what we do is, once heating is done, we immediately drop it in cold water.

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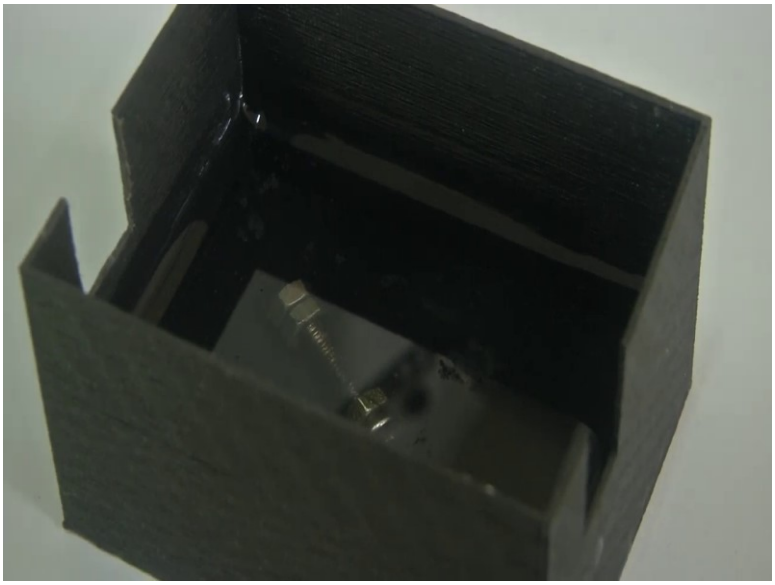

Now, that we have heated it, the next step is to drop it quickly in water. So, we have taken it out from the fixing tool and then dropped it into the water. So, what happens is, once it gets heated, it learns the shape and then when it is cooled, we have transitioned the state changes and what we can do now, this is the entire mechanism is nothing, but training the SMA.

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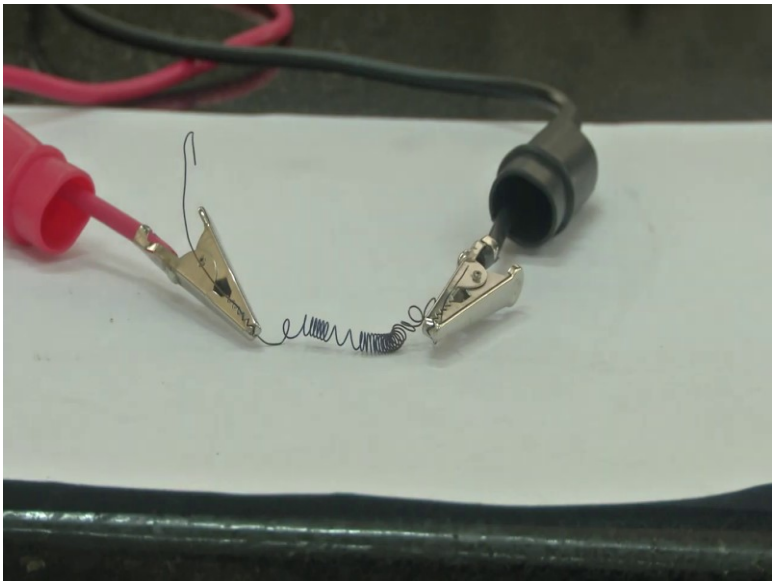

So, here we have removed it, once we have heated it up to 400 degree Celsius, next what we do is, we have it here; the SMA is removed from the test bench or the table where we had you initially just heated it. And after uncoiling, we have connected to the supply. So, slowly just like sub give some 2 volts and then 0.5 Amps slowly increase current.

And let us see how it regains it is shape; that is, it moves from martensite, which is nothing, but the cold state. The transition happens from phase 1 to phase 2; that is phase 2 is nothing but the austenite state, where it has learnt or memorized the shape for which we had trained. Now, if you can focus closely, the SMA will start, like you see that is what we had trained it for. So, as you increase, slowly increase the current, it is literally dragging the probe towards it.

So, that is the actuation mechanism which is leveraged and has been replacing all the conventional actuators; that is the hydraulic, pneumatic or the motor-based actuators are now being replaced with this lightweight solid-state alternative, that is the shape memory alloy. So, as you see, it slowly the entire length of the wire regains it is learned state.

So, this is the austenite phase. So, the phase transition because of temperature is what you are seeing. Now, this, what we are seeing here, is the nickel, titanium alloy; however, there are many other alloys copper based or iron-based alloys which are, again, commercially available.

However, nitinol based are preferable for applications, because of their stability and practical applicability and their thermo mechanical performance is good compared to the others. So, this here in my hand is a trained nitinol wire, which we have seen how it can be actuated by just doing the phase transition; that is, between the two phases the austenite and the martensite phase. In further let us see how this principle, the actuation mechanism can be used to build other and how we can experiment using this. In the next session, we will learn one of such applications using the SMA.

So, this is how you can train your, the super metal to have and leverage the memory effect. So, now, we know how we can train the shape memory alloy, we can have different diameters; this is the 100-micron thin nitinol wire and their different alloys. So, you can choose based on your application; the dia and the type of alloy. And how to train the mechanism for this is; step one you have to require; get the desired shape depending

on the requirement and then heat it at around 400 degree Celsius and then immediately cool it.

So, once that is done, it memorizes; that is the shape is coded into the alloy and every time you heat it, it goes back to the shape which we had learnt, we had trained the alloy to work in that mechanism. So, now, we simply have a spring mechanism here, the SMA based spring; and let us see how we can use this for actuating for our purpose. That is it for the today session. In the next session let us see a few experiment on how SMA can be used and replaced as a lightweight actuator in micro engineered devices.

Thank you.