Shape Memory Alloys

OBJECTIVE:
Through experimentation and/or demonstration, students will be introduced to shape memory alloys (SMAs) and how they are being tested to save energy usage on aircraft. This will introduce them the development and testing NASA is conducting, which is the use of SMAs to make aircraft more sustainable.

ACTIVITY OVERVIEW:
Students will test a piece of nitinol wire (a shape memory alloy) and immerse it in hot water, then compare the outcome to the effect of hot water on a more standard item such as a paperclip. After finding out how NASA and others are using shape memory alloy technology, they will then discuss or develop a way they could use this same technology.

BACKGROUND:
How do you make aviation more sustainable? Some ways to do this include limiting drag on an aircraft when it's not needed, reducing energy consumption, and creating more environmentally friendly fuels.

NASA and Boeing have been collaborating on several projects to test new ideas that will make aviation more sustainable. For these tests they use Boeing's ecoDemonstrator airplane – a large 777-200ER airliner repurposed to conduct aeronautics research experiments. For several years, NASA's aeronautical innovators have been working to create "smart" vortex generators activated with shape-memory alloys. Testing of this new technology will begin on the ecoDemonstrator in late 2022. If this works well, the vortex generators can then be used widely in aviation.

***Image 1**: The Boeing 777 ecoDemonstrator in flight.*

GRADES:
K–12 *hands-on activity recommended for grades 5-12 (for lower grades, the activity is recommended as a demonstration)

MATERIALS:
(per student or group of students):

- Nitinol Wire, 1 mm, 40ºC, approximately 3-4" in length
- Paperclip
- Large Container for water
- Hot (>40ºC) Water
- Tongs or other way to safely place and remove samples from water

NOTE: *Nitinol is readily available in a variety of diameters and require different temperatures to change shape. Wire with a diameter of 1 mm is easy to bend, but other sizes work well too. Using Nitinol that reacts at 40ºC or similar is recommended - it is above normal body temperature but cool enough to be safe for use with students.*

TIME REQUIRED:
10 minutes per student or group of students.

KEY TERMS:
Shape Memory Alloy (SMA)
Nitinol

FLIGHT LOG ENDORSEMENT CODE EDSMA22

***Image 2**: The ecoDemonstrator on display at AirVenture 2022.*

Vortex generators are small, fin-like components on an airplane's exterior to help improve aerodynamic performance by guiding airflow around it. This improved airflow can help an airplane be quieter and more fuel efficient.

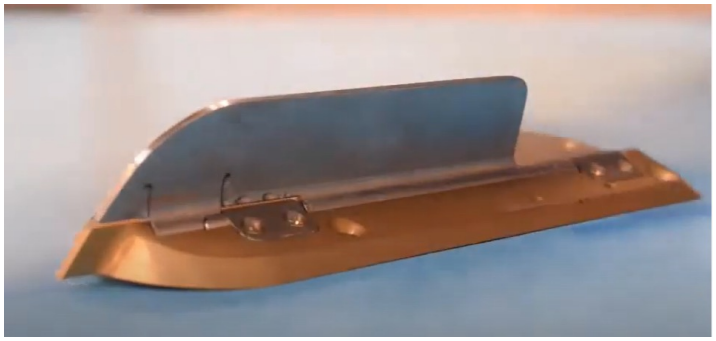


***Image 3**: A close-up image of a vortex generator*

Current vortex generators are fixed in place and do not move. Therefore, the effect they have remains the same in every condition an airplane flies in. If vortex generators could change shape, however, an airplane's performance could be tailored to a variety of flight conditions.

These next-generation vortex generators will be able to change shape at different altitudes, temperatures, and speeds to improve an airplane's performance and help it adapt better in flight.

***Image 4**: Vortex generators on the ecoDemonstrator in the extended and collapsed positions*

That's where shape-memory alloys enter the picture. A shape-memory alloy is a metal with unique properties that allow it to be trained to move on its own. It can be stretched, bent, heated, and cooled and still return its original shape. This quality makes the material popular amongst our scientists, who are researching its use both on and off Earth.

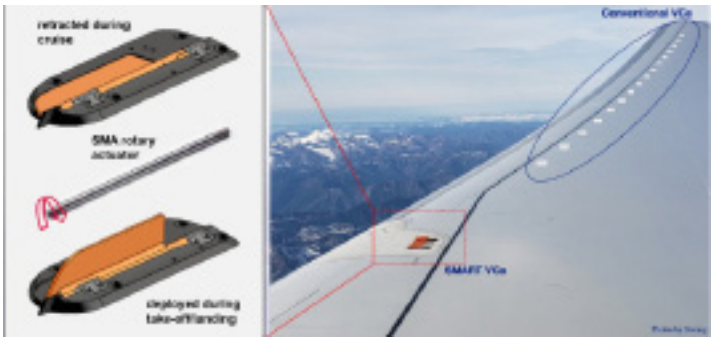


***Image 5**: explanation of how the smart memory alloy will work on a vortex generator*

The shape-memory alloys used in this research are created in a NASA laboratory by mixing specific types of metals together using special machinery. Once completed, researchers "train" the metal by forming it into a desired shape at a certain temperature. Each time the metal returns to that temperature, it also returns to that shape.

A short video demonstration of the shape memory alloy and the vortex generator can be seen here.

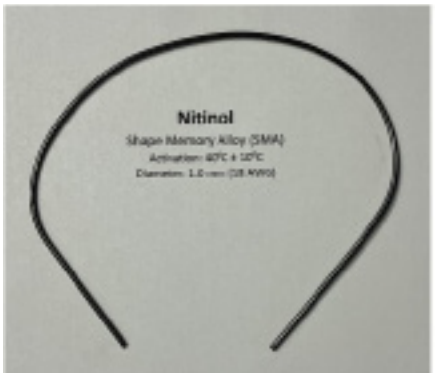
Activity

1. Fill the container about two-thirds full of hot water. Water from the hot faucet is sufficiently hot for many nitinol samples (please refer to nitinol sample specifications for minimum temperature needed)
   – FOR STUDENT SAFETY DO NOT USE BOILING WATER.

2. Walk students through making predictions about what changes, if any, they expect to see when the paperclip is placed in hot water. Have them record their predictions on their student worksheets.

3. Ask students to place the paperclip in the water and observe what changes, if any, occur. Again, have students record their observations on their student worksheets.

4. Students can bend (deform) the nitinol into any shape they like.



5. Based on the information about nitinol on the student worksheet, have students make predictions about what changes, if any, they expect to see when they place the deformed nitinol wire in the water. Have students record your predictions on the student worksheets.

6. Using tongs to place the deformed nitinol in the water and observe what changes, if any, occur. Have students record their observations on their student worksheets.

7. Students will then respond to the reflection questions.

IDEAS FOR GOING FURTHER

This example about how NASA is using existing technology to develop uses of their own can be taken further by asking students to research more about existing uses for nitinol and other shape memory alloys, then more fully developing their own ideas for usage.

ADDITIONAL RESOURCES:

"Memory Metals are Sharing the Evolution of Aviation"
https://www.nasa.gov/feature/glenn/2019/memory-metals-are-shaping-the-evolution-of-aviation

Shape Memory Alloy

STUDENT WORKSHEET

What is a shape memory alloy?
Alloys are made by combining two or more metallic elements. When different metallic elements are combined, the resulting alloy can have effects that differ from the individual metals that make it up. Nitinol, for example, is an alloy made of nickel and titanium that exhibits the shape memory effect. Materials that exhibit this effect can "remember" their original shape even after they are deformed. In the case of nitinol, if it is deformed and then heated above a certain temperature, it will regain its original shape.

Data and Observations:
What changes, if any, do you think will occur when the paperclip is put in the hot water?

Record your observations after placing the paperclip in the water. You can draw or write about your observations:

Shape Memory Alloy

STUDENT WORKSHEET CONTINUED

Carefully bend the piece of nitinol wire into a different shape, then place the wire into the hot water. Be careful when working with hot water! Record your observations after placing the deformed nitinol in the water.

Reflection:

1. Read through the background information about how NASA uses shape memory alloys with properties like nitinol. Explain why shape memory allows are well-suited to create SMART vortex generators.

2. NASA is testing shape memory alloys to help specific aircraft parts stick up on an airplane wing during takeoff and landing but lay flat when higher in the air. It is also used to make watch springs and even in braces for your teeth. Using this alloy doesn't require electricity or other moving parts. That saves energy and can help reduce drag, which will also reduce fuel consumption. What are some other ways you can think of that nitinol or another shape memory alloy could be used?