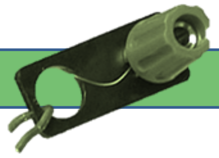

NiTinol 'acoustic microscope'

Equipment

- 2 Nitinol[1] rods (L ~ 22 cm)
- 1 INOX[2] rod (L ~ 22 cm)
- 2 temperature probes
- oven mitten
- software for audio recording and analysis[3] Audacity
- percussion hammer
- glass oven pan (Ø > 22 cm)
- hot plate
- microphone
- computer

Procedure

Qualitative investigation

On the desk you will find two Nitinol rods. At room temperature, due to their different alloy composition, they exhibit different stable phases. Rod A is Martensite, rod B Austenite. Are the two rods perfectly alike? Investigate and make a list of as many different characteristics of the two materials as you may be able to observe.

Characteristic	***Rod A***	***Rod B***

(Classroom discussion follows: groups will share their findings. Afterwards you will be given sheet 2)

[1] At room temperature one is Martensite and the other is Austenite

[2] You may use any other metal , the impobut the rod dimensions should be comparable to the Nitinol ones .

[3] Audacity (http://audacity.sourceforge.net/)

Quantitative investigation

You may have observed that sound transmission in the two rods is quite different. In case throw them down onto the floor and carefully listen to the produced sound.

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You should now investigate how the sound from the rods eventually changes with temperature.

Data collection

1. Take both the Nitinol Martensite rod, (rod A) and the iron one. With a thin line permanent marker make a sign on the rods at one of the nodes (approximately at 1/5 of the total length from the end)

2. Store the rods in a freezer for 15' in order to reach 0°C, or even a lower temperature.

3. As you wait, download and install Audacity *free* software.

4. Connect the microphone and run a few tests to find the best and most silent location Check carefully that you are able to audibly record the typical dull 'thud' of martensite. If you are using a laptop disconnect it from the grid to limit and reduce any "electromagnetic noise". Keep the microphone as near the rod and as far from the laptop as possible.

5. Record 1' of "silence": it will be useful to discern between the frequencies emitted by the rod and the ground noise.

   Rods self-heating process up to room temperature

6. Take the nitinol bar out of the freezer.

7. **N.B**. Try to act quickly: due to the high temperature gradient the rod warms up quite fast

   a. With the temperature probe check and note down the rod temperature.

   b. Start audio recording.

   c. Hit the rod with the percussion hammer 4 times , pausing for 8-10 seconds in between. You should hit the rod either at one end or straight in the middle as you hold it gently but tightly with your two fingers in one of the nodes . Try to hit always exerting the same force and at the same spot.

   d. Stop recording.

e. Check the rod temperature again and note it down (you may afterwards calculate an average between start and end temperature).

f. Export the file in .wav format and save it with a suitable name to remind you of both the material and its temperature (for instance."nitinolo22.wav").

8. As the rod gradually and spontaneously warms up reaching room repeat the whole procedure of step 7 every 5°C .

Nitinol			**Audio file name**
Start Temperature °C	**End temperature °C**	**Average temp °C**	

9. Now take the iron rod from the freezer and repeat the whole procedure (steps 7 and 8).

Forced warming up

10. Once reached room temperature you may force further warming by hot thermal bath immersion. Take the oven glass pan, fill it with water and heat it up on the hot plate. Every 5°C take the two rods out (not simultaneously but in sequence) and repeat step 7. After recording put the bar again in the thermal bath. Stop when you reach 95-98°C approx.

Cooling

11. Take the nitinol rod out of the thermal bath. Repeat step 7 every 5°C during the cooling process from 95-98 °C down to room temperature. Repeat with the iron rod.

Data analysis and class debate

First of all calculate the theoretical rod fundamental frequency with the specific data from your rods. If the rods are not perfectly cylindrical ones the result will be just an approximation but useful enough to identify and delimit the range of the allowed rod. *c* stands for sound speed , *L* for the rod length and *d* for its diameter

$$f = 0.890 \frac{d}{L^2} c$$

f_{inox}_theoretical = ……………………………………………… f_{niti} _ theoretical = …………………………………………………

1. From each audio file extract the sound spectrum and the fundamental frequency of the rods at each specific temperature. In case make an average with the four hits of each temperature .

Fundamental frequency (KHz)		Temperature (°C)
Inox	Nitinol	

2. Plot **fundamental frequency VS temperature** for both Nitinol and inox.

3. Is there any difference in the behavior of the two metals?
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4. Can you find a relationship between temperature and fundamental frequency ?
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5. With regard to fundamental frequency, are the collected data identical in either cooling or warming process? Would you say that temperature and fundamental frequency exhibit a one-to-one relationship?
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6. If the answer to the previous question is 'NO' what's the cause for this in your opinino?
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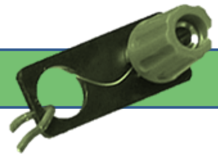
7. From either the collected data or the plot can you extract the transition temperatures of



the rod nitinol alloy? How? Try to explain.

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8. How can the sound produced by the rod upon hitting (macroscopic level) give information on the actual phase of the material (microscopic level)?

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9. Is there any relationship between temperature and sound damping time ?

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10. Have you got any suggestions to improve the experiment?

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