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Coefficient of Linear Expansion

Experimental Objective

The objective of this experiment is to determine the coefficient of linear expansion for aluminum, copper and steel.

Background

Most substances expand with an increase of temperature. The change in length is proportional to the original length and to the change in temperature. The factor of proportionality called the coefficient of linear expansion depends on the material of which the solid is made. The coefficient of linear expansion α is given by,

$$\alpha = \frac{L_2 - L_1}{L_1 (t_2 - t_1)} = \frac{\Delta L}{L_1 (t_2 - t_1)} \qquad (1)$$

where L_1 is the original length in meters at the temperature t_1 degrees Celsius, L_2 is the length at the temperature t_2 and $\Delta L = L_2 - L_1$ is the observed change in length.

The coefficient of linear expansion apparatus consists of a metal rod placed in a brass jacket through which steam passes through. One end of the rod is fixed and the other end is allowed to move. The micrometer screw is used to measure the change in length. The thermistor sensor is used to measure the temperature. Data Studio is used to display the temperature.

Equipment Needed

Coefficient of linear expansion apparatus	Metal Rods: aluminum, copper, steel
Steam Generator	Paper Towels
Rubber tubing	Thermistor Sensor
Meter Stick	600 cm^3 beaker
Wood Block	50 cm^3 beaker

SAFETY REMINDER

- Follow the directions for using the equipment.
- Rods may be very hot when using the steam generator! Do not handle the rods with your bare hands.

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PART A: Computer and Equipment Setup

1. Plug the Thermistor Sensor into Analog Port D of the 850 box. Turn on the box and double click the Capstone icon on the computer desktop.
2. When the software is running, click on the "Hardware Setup" icon at the left. An image of the 850 should appear. If it doesn't, ask the instructor for assistance.
3. Click on Analog Port D on the 850 image. Choose "Thermistor Temperature Sensor." Click on the "Hardware Setup" icon again to dismiss it.
4. Double click on the graph icon on the right side of the window. A graph should appear. Click <Select Measurement> and choose Temperature.
5. The "Record" button at the bottom of the window should be red, meaning that you can now record data.
6. When the lab is over, kill the Capstone window without saving changes.

PART B: Equipment Setup and Data Acquisition

4. Get about 800 cm^3 of water and pour it into the steam generator. Turn the steam generator on to a setting of 10. Note that it will take the steam generator 10 to 15 minutes to heat the water.
5. Measure the length of the aluminum rod with the meter stick to 0.1 mm at room temperature. Avoid handling the rod with your bare hands so as not to raise its temperature. Use dry paper towels. Record the length in the Data Table.
6. Mount the rod in the brass tube, make sure that one end of the rod is touching the fixed end of the apparatus and the other end is facing the micrometer screw.
7. Carefully attach the thermistor lug to the rod with the thumbscrew. Place the foam insulator sleeve over the rod to cover the thermistor lug completely. This will reduce heat loss in this area. Plug the thermistor sensor leads into the banana plug connectors in the linear expansion apparatus.
8. Place the wood block under the end of the expansion apparatus at which the steam will enter the tube. This will allow the condensed water to drain out of the tube. Place the 50 cm^3 beaker under the lower end to catch the condensate.
9. Turn the outer ring of the dial gauge to align the zero point on the scale with the indicator needle of the dial gauge. Record the setting of the micrometer screw for the rod at room temperature in the Data Table. Press 'Start' to begin data recording. Record the room temperature in the Data Table.
10. Attach the rubber hose from the steam generator to the end of the tube. As the steam begins to flow watch the dial gauge closely as the tube expands. As the tube expands the needle will move in either a clockwise or counterclockwise direction and it can make more than one revolution. Each increment on the dial gauge is equivalent to 0.01 mm.
11. Once expansion is achieved, record the setting of the micrometer screw and the final temperature in the Data Table.

12. Caution! The rod will be very hot. Use paper towels to remove the rod.
13. Repeat steps #4 - #13 for the copper rod. Remember to add water to the steam generator.
14. Repeat steps #4 - #13 for the steel rod. Remember to add water to the steam generator.

Lab Report

Data Table

	Aluminum	Copper	Steel
Room Temperature			
Length of rod at room temperature			
Setting of micrometer screw at room temperature			
Final temperature of rod			
Setting of micrometer screw at final temperature			
Change of length of the rod			
Coefficient of linear expansion			
Given value for coefficient of linear expansion	23.4 x 10-6/ C	17.6 x 10-6/ C	(11.3 to 13.5) x 10-6/ C
Percent error			

Calculations:

1. Compute the change in length of each rod in centimeters from the two readings of the micrometer screw.

2. Using Equation 1 calculate the coefficient of linear expansion of aluminum, copper and steel from your data.

3. Find the percent error by comparing your results with the given values of the coefficient of linear expansion.

Questions:

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1. Why must the increase in length of the rod must be measured so carefully when the length itself can be determined by using a meter stick?

2. What are possible sources of error in your experiment?