Determination of Coefficient of Linear Expansion of a Metal Rod

Introduction: To determine experimentally the coefficient of linear expansion ($\alpha$) of a metal, an object made of the metal must be subjected to a measurable temperature change ($\Delta T$) and the corresponding change in length ($\Delta L = L_f - L_i$) noted. If the original length of the object ($L_i$) is known, the coefficient can be determined since it is defined as the fractional change in length per degree temperature change: 

$$\alpha = \frac{\Delta L}{L_i \Delta T}$$

Our apparatus for determining the coefficient of linear expansion consists of a cylindrical metal tube, which is shown below and which can be clamped to a supporting frame. A cylindrical rod made of the metal of interest is placed inside the tube and is held at the center of the tube in the axial direction by passing through a hole in the center of a rubber stopper at each end of the tube. One end of the rod is held fixed by making contact with a stop on the supporting frame, the other end makes contact with a device that measures the change in length of the rod as it expands. (The operation of the device--a micrometer screw with a contact point that completes an electrical circuit with a light emitting diode when it is in contact with the rod-- shall be explained in lab.)

To change the temperature of the rod, cold water is first run through the tube and then steam is passed through it. In addition to openings in the tube for water or steam inlets and outlets, there is an opening for a digital thermometer probe to be inserted for measuring the temperature of the metal rod.

Objectives: Determine the coefficient of linear expansion for one metal.

Apparatus: Coefficient of linear expansion apparatus, two metal rods, meter stick, power supply, connecting wires, plastic tubing, hot plate, steam generator, digital thermometer.

Procedure and Instructions:

A. Measure the length ($L$) of the metal rod and record this value with its possible error (± 0.5 mm and no less than this) on the spreadsheet data sheet.

B. Mount the tube in the frame with the micrometer screw "backed off" from the end of the rod and with the thermometer probe inserted. Connect plastic tubing so water is passing through the apparatus entering through the lower inlet and leaving through the upper outlet. Wait until equilibrium is achieved and the temperature of the water is not changing and then give the screw at
the fixed end of the rod a slight turn to assure that it is firmly against the rod. Record the equilibrium temperature and its possible error (±0.1°C).

C. Tighten the micrometer screw until the light emitting diode glows. Record the micrometer reading. Back off and then tighten the micrometer screw four more times recording the position when the LED glows. Using spreadsheet calculations, determine the mean and mean deviation of these five values. (This mean deviation will be used in error calculations as the possible error in the micrometer reading if it is greater than the plus or minus value to which the values have been read.)

D. Back off the micrometer screw and, being careful not to move the tube or the rod with respect to the frame, connect the tubing so steam is passing through the apparatus entering through the upper inlet and leaving, along with condensed steam, through the lower outlet. Wait for equilibrium and take five-micrometer readings at steam temperature. Record the micrometer readings and determine their mean and mean deviation. Also record the new equilibrium temperature with its possible error.

E. Repeat the process for a second rod. (To remove rods from the apparatus without burning fingers, it is recommended that water be run back through the apparatus briefly after the steam readings are completed. The water should enter through the lower opening and exit through the upper opening.)

F. Do spreadsheet calculations to determine the coefficient of linear expansion for the metal rod.

G. Save a copy of the spreadsheet data sheet for each lab partner.

H. Calculate absolute possible error for α

I. Discuss your results completely and draw conclusion(s) by comparing the value you obtained for the thermal coefficient of linear expansion and the value quoted in the textbook or any other source. What is the % difference between your value and expected value.

Experimental Setup shown below.
Experimental setup by Alex Stameroff

Figure 2, the setup to measure the initial temperature.

Figure 3, the setup to obtain the final temperature.