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2.672 Project Laboratory
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3. Heat Exchanger Tube Vibrations

Your firm has been hired as a consultant by a steel fabricator that operates a number of hot-forging presses with water-cooled dies. The cooling water runs through a water-to-air heat exchanger next to each machine, which consists of a number of copper pipes with brazed-on fins. These pipes are in turn brazed to a manifold and support structure, as shown below.

Your client is experiencing catastrophic failure of heat exchanger tubes on some of its presses. They note that these heat exchangers failed when the coolant reached a moderately high temperature, and that the failures were preceded by rattling noises from the heat exchangers. Upon close inspection, the tubes appear to have been vibrating and rubbing against their neighbors before failing. You also observe a noticeable rumble in the floor each time a press closes.

An intern has constructed a simple laboratory model of the problem heat exchanger, which allows the temperature of a tube to be varied while the length of the tube is maintained constant by a large outer pipe at room temperature. The tube is "preloaded" so at room temperature the tube is under tension. You can change the preload by loosening the end screws, heating up the inner tube to move the end plate out and inserting additional spacers between the end plate and the outer pipe. Vibration of the pipe can be measured using a magnetic pickup coil.

Your client wishes to know what conditions are causing the failures, and how they might be able to mitigate the problem. Your job is to develop a theoretical model to calculate the natural vibration frequency of the finned tubes, including the effect of temperature, fin size/mass, and preloading. You should use the experimental results from the apparatus to guide the development of the model and to confirm in detail its accuracy.

Notes:

✓ The signal from the magnetic pick up is low. You should set the A/D internal amplifier gain appropriately.
✓ There is a 2.672 Matlab function "pwrspect" to calculate the power spectrum of the time domain signal.

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Please see any image of a finned tube heat exchanger, such as 4.5.4a in Kreith, Frank, and D. Yogi Goswami. *The CRC Handbook of Mechanical Engineering.* Boca Raton, FL: CRC Press, 2005.

Pipe constrained at the two ends

Water flow to change pipe temperature