Teach Deflection Concepts with Hacksaw Blades and Rubber Bands

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TECHNOLOGY and engineering educators can use a simple hacksaw blade to help students learn about deflection, as that which occurs in a beam. Here the beam is fixed at one end and allowed to deflect in a manner that is easy to see and measure—the hacksaw blade represents a cantilever, if you will, an overhanging structure. This simple and very inexpensive experiment uses quarters as a load on the blade. Students can then conduct additional experiments involving loading rubber bands.

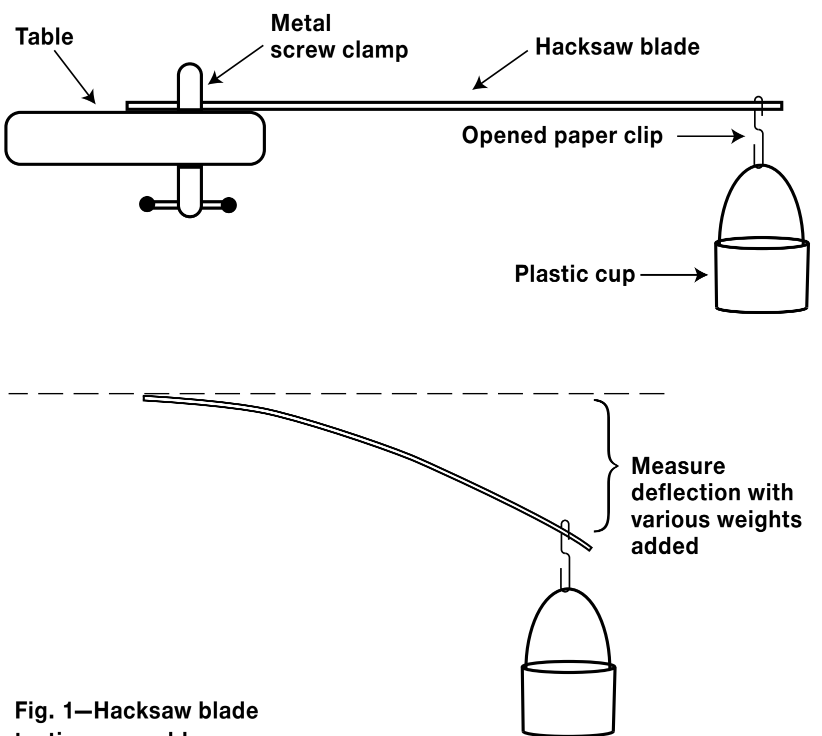

Fig. 1—Hacksaw blade testing assembly

Saw Blade Experiment

Figure 1 shows the testing assembly and the arrangement for securing the blade to a table top using a screw clamp. (Note that while a hacksaw blade has very fine teeth that are unlikely to injure students, you should remind students to be careful when working around sharp edges.)

The cup that holds the quarters is a plastic laundry detergent cup with a wire handle added. (See Fig. 2.) The cup is suspended from the saw blade using an opened paper clip that is hooked through a small hole at one end of the saw blade. (Note that a hole is pre-drilled at both ends of the saw blade.)

Table 1 records my testing of the deflection of the blade for quarter loadings over three blade lengths: 10", 7", and 5". Four quarters are added each time to test deflection. Examining the date in Table 1, we arrive at the following conclusions:

- For each blade length tested, deflection increases for each four quarters added.
- As the blade length shortens, deflection decreases for the same quarter loading (i.e., the elasticity of the blade decreases, or stiffens).

Table 1—Sample Testing Results

Number of quarters	Deflection in inches		
	10"	7"	5"
0	0	0	0
4	0.75	0.5	0.15
8	1.75	0.75	0.25
12	2.5	1	0.45
16	3.25	1.5	0.5
20	3.75	1.75	0.75
24	4.25	2	0.95

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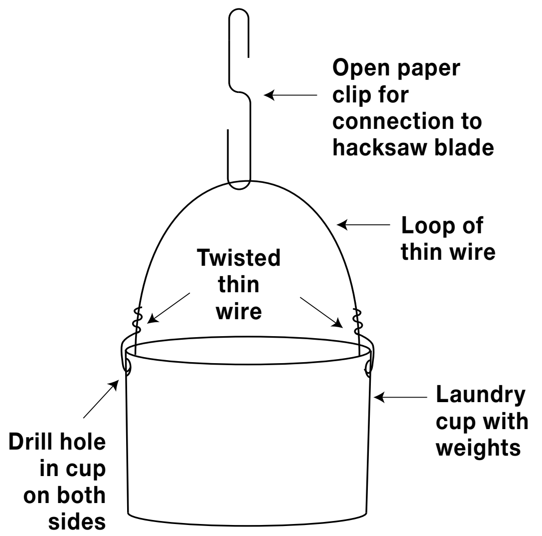

Fig. 2—Laundry cup and hanger details

The metal blade acts like a springy material over the range of additional weights. The shorter length of blade can be thought of as a tight spring. Have your students plot their findings on graph paper. Plotting will reveal a series of graphs that slope upward in an almost linear fashion, but the slope of the lines grows smaller with a shortening of the blade length—indicating a "stiffness factor."

Ask your students to visualize what would happen if multiple blades were stacked one on top of another and the loading experiment was repeated. Could multiple blades of 10" or 7" in length produce as little deflection as a short 5" blade length? Have your students run that experiment.

What do the results mean for someone building a structure with an overhang?

Have students predict how many overlapping blades of 10" and 7" lengths would be needed to equal the 5" overhang deflection, then have them run that experiment.

At some point, continued loading of the blade would cause the metal to bend permanently, or fail. At this point, the graph of the loading would probably indicate a change in the slope of the line, a slowing down of deflection (an inflection point) as a prelude to failure. The slope would tail off on the upper right, and then a failure would occur. Failure would take place because the elasticity of the blade would be exceeded—much the same as happens when you stretch a rubber band to the point at which it breaks. The more you stretch, the less deflection occurs with each discrete load, and then suddenly the band snaps.

Rubber Band Experiments

Have your students replace the saw blades with a variety of rubber bands, both thin and thick, to see how these correlate to the long and short hacksaw blade lengths. The loading of the rubber bands will require hanging the bands vertically. See Fig. 3 for a simple rubber band testing apparatus that I constructed, or have your students create one of their own design.

Instruct students to subject five rubber bands that are the same size to a load of four quarters. The results may well show slight differences in the rates of deflection. What might differences in the deflection among data takings indicate? It could mean that each rubber band is very slightly different from the others in molecular composition, length, or width—fabrication of rubber bands is not a high tech, high reliability proposition.

And here is one final, interesting experiment option: Put several rubber bands in a refrigerator for an hour before doing the deflection test. How do these runs compare with rubber bands at room temperature? Why? Here, consider how normally pliable substances like plastics and automobile tires react to cold by becoming stiff. After sitting all night in extreme cold, car tires can feel stiff and out of shape when they start rolling. The same can happen to rubber bands after exposure to cold—they might not stretch as far as they would when temperatures were higher. (This also happens to rubber bands as they age, dry out, and lose their natural plasticity.)

Have students research what happens in a large steel-framed building that is subjected to a prolonged fire. What happens to the stiffness of the steel frame? Here, the plasticity of steel at high temperatures can lead to the collapse of the structure. Structural steels can lose a significant amount of their load-bearing capability with exposure to heat from a fire. Exactly how much of a loss in strength would depend on the characteristics of the steels used (and their carbon content). At 1,000° F, common structural steel would have only about 40% to 50% of its load-bearing capability. (Check out the yellow graph line at www.engineeringtoolbox.com/metal-temperature-strength-d_1353.html.)

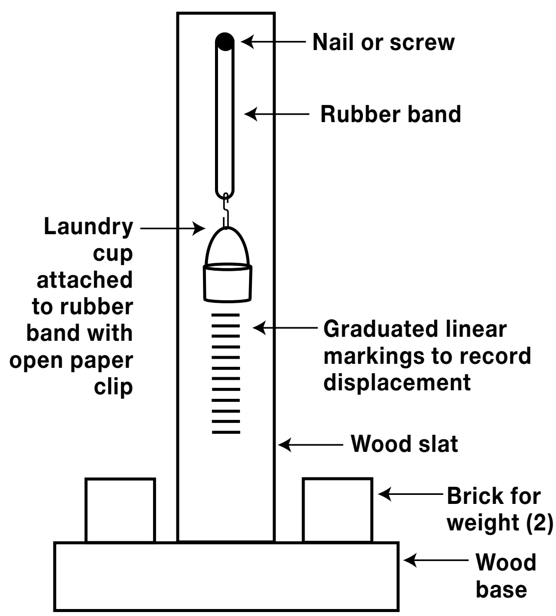

Fig. 3—Rubber band testing apparatus