Stretchy "Elastic" Bands

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Prerequisite Knowledge: Have an idea about changes in the load an elastic band holds as it is stretched and unloaded.

Objective: To work as a team member in the collection of data, to make plots for near constant rate loading and unloading of traditional rubber bands, and to show features which are unique to these elastic products.

Equipment:

1. A series of three and one half inch long rubber "elastic" bands of 1/8, 1/4 and 1/2 inch width which are often referred to as number 33, 64, and 84 rubber bands, respectively. Most office supply houses will stock a variety.
2. Yard Stick, or Tape measure or 30 inch long machinist's measure.
3. Two, 2 inch size C - clamps.
4. Mounting board (2 in. by 1 in. by 30 inches) with a six penny nail inserted one inch from one end on the 2 inch by 30 inch face, and to which the machinist's scale can be clamped. The zero of the machinist's scale should be at the nail.
5. Vise to hold the mounting board.
6. Safety Goggles
7. Heavy work gloves
8. Load scale for loads to 50 pounds or 25 kg. A scale with a capacity to 10 pounds or 5 kg. may be helpful, if available.
9. Micrometer or vernier caliper.
10. Data page with 25 lines and nine columns. Measurements are taken at one inch increments starting at a value of four inches listed in the first column. The remaining columns are used in pairs to record load and unload for each of four elastic sizes. Be sure to label columns and include units of measure selected.
11. A Spreadsheet such as EXCEL™. All work performed on the spreadsheet can be done by hand.
12. When the computations are to be done by hand, computation paper and several pieces of linear graph paper with 20 divisions to the inch are needed.

Introduction:

The approach is to stretch each rubber band at a near constant rate and to unstretch it at the same near constant rate while recording the load present at each stretch point. One team member should do the loading and read the load at each position while the second team member should record the data. Try to load and unload the elastic at a constant rate, and about the same rate for each band so that meaningful comparisons between bands can be made. Both team members should work on the data analysis, make observations from the computations and plots, and formulate conclusions.

After the data has been collected and when a spreadsheet is used consider making a column of deformation that starts at four inches, ends at 24 inches, and starts at 24 inches and returns to four inches. Increments of one inch are used. Enter the collected data into the spreadsheet and the make a plot for the entered deformation - load data.

At each deformation position a computation for engineering strain and engineering stress can be made. Engineering strain is the length (L) at any displacement minus a reference displacement (R) divided by the reference displacement (R) or (L-R)/R. Four (4) inches is chosen as the reference dimension (R) for this experiment. Engineering stress or (P/A) is the load (P) divided by the cross section area (A) of the band. Note that the band has two strands carrying load. Compute the strain and stress for the collected data. Make a second plot for the stress and strain found.

Increments for the area under the LOADING line are computed separately from the UNLOADING line. This represents the energy used to stretch and unstretch the band. Now compute the area under the curves with trapezoidal increments. First the upload curve and then the down load curve. A cell should be used to store each trapezoidal area increment. The trapezoidal increment is computed by forming the average of two stresses and multiplying by the change in strain. The total area under a curve can be found by adding the incremental areas in a column, and is the energy related to each curve. The difference between column totals found is the hystersis. A ratio between the difference and the upload curve area when shown in percent finds the portion of energy lost to internal friction or hystersis. Be sure to check UNITS.

An informative comparison for all sizes rubber bands tested can be made by plotting and clearly labeling A. the load deflection data for all elastics on one set of axes and B. the stress - strain data for all elastics on another set of axes. Note how the stress-strain plot curves compare favorably, and the percentage of energy allocated to hystersis is seen to be similar while the load - deflection plot clearly shows the change in load carried by each band.

Preparation:

Prepare the Mounting Board by placing a six penny nail into the 2 inch by 30 inch surface of the board one inch from the three surfaces at one end. Place the board into the vise and clamp the machinist's measure on to the top surface of the board. Clamps at six inches and 20 inches on the scale work well.

Secure several rubber bands for each size to be tested. Measure the thickness and width of the band and record the results. Remember there are two strands of each band carrying load. Now compute

the cross sectional area.
Prepare the data sheet with 25 lines and nine columns. Measurements are to be taken at one inch increments starting at a value of four inches listed in the first column and end at the 24 inch position. The remaining columns are used in pairs to record load and unload for each elastic size. Be sure to label the load columns in pairs (LOADING and UNLOADING) and include units of measure selected. The first LOADING value is made at the four inch position. A position is designated where the hook of the load scale attaches to the rubber band and is sited on the machinist's measure. The last LOADING **value** at 24 inches should be the FIRST UNLOADING **value** at 24 inches because the UNLOADING values are recorded for decreasing positions.

When the extension exceeds 20 inches for the larger bands you must make a *concentrated* effort to keep the current band under load. DO NOT UNLOAD or LOOSE LOAD on the scale on the upload because the band will be unloaded and the upload data will not be represent near constant rate loading. In case a band breaks when under test, COMPLETELY redo the test.

In preparation for a test run place a designated rubber band over the nail and through the hook of the load scale. Check that a load measurement can be made at the four inch mark on the machinist's measure. Be sure the operator of the load scale has safety glasses on and is wearing the heavy gloves. These Safety Devices will protect the operator if the elastic breaks and the spring scale unloads and the elastic flies around.

Procedure:

1. Tensile load - deflection tests are to be performed on a series of three and one half inch long rubber bands of 1/8, 1/4 and 1/2 inch width which are often referred to as number 33, 64, and 84 rubber bands, respectively. **Place safety glasses and gloves on the spring scale operator, and prepare the recorded for writing the data on the data sheet**. The approach is to stretch a band, and as this is done at a near constant rate, record the load to stretch the rubber band at each added inch. Start at four inches which is one-half an inch past the three and one-half inch length of the rubber band. Continue until the length of the band is 24 inches. Next, unload the band at the same rate as was used to load the band taking load measurements at each inch of reduced length. Remember the load value at the 24 inch position is the same for the LOADING and UNLOADING columns on the data sheet. The recorded data is defined as "raw data" for elastic 33 which is the first elastic tested. Be sure to label the size of the rubber band tested, and measure and record its thickness.

2. The first comparison to be made is for the shape of loading and unloading paths for load/deflection data. Enter the deformation data which starts at four inches and ends at 24 inches. At each deformation level, enter the load. Make an **XY**[1] or **Scatter Plot** of the data. The horizontal axis should be Deformation in inches while the vertical axis is Load in pounds. Label the Load - deflection line as **Elastic 33** .

   Repeat the load-deflection test for each of the remaining three sizes of rubber band, plot the data on the SAME graph as for Elastic 33 and label each curve as Elastic 64, or Elastic 84.

[1] Be sure to make a plot of two variables and NOT a line chart as is the usual default setting on a spreadsheet.

The applied load - deflection plots on the same graph show magnitude changes. The largest load carried by each band should be clearly evident on the right hand end of the deflection axis at 24 inches. Note if a trend appears which shows that the large band carries the larger load.

3. The second comparison is dependent on two modifications made to the raw data. The first modification is to define the engineering strain as the ratio computed by taking the measured band length minus the starting length and dividing this quantity by the initial length. For all samples use four inches as the initial length. This means that the first value of strain is zero with UNITS of inches/inch. The strain is to be plotted on the horizontal axis.

   The second data modification is to divide the load by the cross-sectional area of the original rubber band. This computes the engineering stress in the band which has UNITS of pounds per square inch in the English system and is to be plotted on the vertical axis.

   Again prepare an **XY** or **Scatter Plot** with the modified data. This will be a stress-strain plot for the elastic or rubber band. Label the line on the plot as **Elastic 33**.

   Repeat the strain and stress calculations for elastics 64, and 84, make separate stress-stain plots for each elastic, and add this data to the same stress-strain for Elastic 33 and label each line. Note the similarities between these curves. If the effect of initial elastic length and original cross sectional area are considered, the stain range of 5 times or 500 percent is the same for each rubber band and the stress ranges are comparable.

4. Areas under each of the stress/strain curves are to be found by approximation. An approach is to represent the area between strain values as a trapezoid and to sum the areas of all the trapezoids to obtain the area under the LOADING line. The summing of trapezoids is repeated for the UNLOADING line. Note that the trapezoid has a ‘height’ in stress units of pounds per square inch and that the ‘width’ of the trapezoid has strain units of inches per inch. The product of stress times strain becomes inch-pounds per cubic inch. In summary, the difference between these sums is the residual often referred to as hystersis. The hystersis represents the energy consumed in the deformation process.

What can be presented about the energy differences between the Elastics 33, 64, and 84? A rapid visual comparison is found when the stress/strain plots are super-imposed on one another. This shows the common features such as the LOADING lines as well as differences such as for the UNLOADING lines between the four rubber bands from zero to 500 percent strain. Note that the area term represents ENERGY. When English units are used, the product of pounds per square inch times inches per inch becomes inch-pounds per cubic inch.

What relationship can be found between LOADING energy, UNLOADING energy, and hystersis? A table of rubber band size with columns of LOADING, UNLOADING, an hystersis can show that about half the energy is assigned to hystersis.

Comments:

1. To aid the instructor in the execution of this experiment, a sample for Elastic 33 is shown below. Figure 1 presents the data. Note the starting position for deformation at 4 inches and the load values at 24 inches. In Figure 2 the upload and download curves are seen. Figure 3 is presents the strain values in column one, upload stress, download stress in columns two and three and the trapezoidal areas between strain increments in columns four and five. Figures 4 and 5 show stress-strain and work done, respectively.

   To make a hand calculation for the 6 inch displacement: A. strain [(L-R)/R] is (6-4)/4 = 0.5 and B. the upload stress (P/A) is 0.375 pounds /0.009 in. sq. or 41.67 psi. as seen in Figure 3. In column four of Figure 3 is C. the area under a part of the upload curve as 9.55 in-lb. per cubic inch which is found by averaging 34.72 and 41.67 = (76.39/2 = 38.195) psi. and multiplying 38.195 psi. by 0.25 in./in. which is the change in strain increment. For the incremental download the energy computed is 2.60 in.-lb./cubic inch found by averaging 20.83 and 0.00 and multiplying by 0.25.

   A comparison of the total download energy of 479.17 in.-lb./cubic inches (found by adding all the incremental energies) to the upload value of 975.69 in.-lb./ cubic inch shows a ratio of 0.4911 or 49 percent. The hystersis value is likewise 51 percent which represents the energy consumed.

2. To provide added perspective a 1/16 inch wide or number 19 rubber band can be tried. This size band has not always attained the 500 percent elongation which the number 33, 64, and 84 bands achieve. It breaks! On the other hand, number 19 adds a fourth elastic to the data base and can enhance the experiment.

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Elastic 33 Area = 0.125 0.036 or 0.009 in.sq.

disp in	up load lb	down load lb
4	0.125	0
5	0.3125	0.1875
6	0.375	0.3125
7	0.5	0.375
8	0.625	0.4375
9	0.6875	0.5
10	0.6875	0.5
11	0.875	0.5
12	1	0.5625
13	1.125	0.5625
14	1.25	0.5625
15	1.4375	0.625
16	1.625	0.625
17	1.8125	0.6875
18	2.125	0.6875
19	2.4375	0.75
20	2.8125	0.875
21	3.375	1.125
22	4.125	1.625
23	5	2.875
24	5.75	5.75

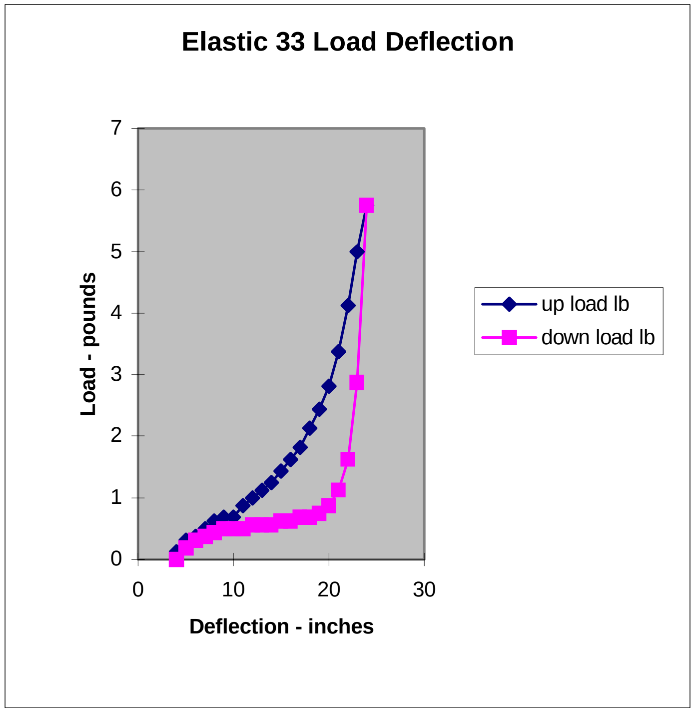

Figure 1 Load-Deflection Data

Figure 2 Load - Deflection Plot

Strain via disp in/in	Stress via up load psi	Stress via down load psi	area up in-lb/in^3	area down in-lb/in^3	Sum area-UP in-lb/in^3	Sum area-Down in-lb/in^3
0	13.89	0			0	0
0.25	34.72	20.83	6.08	2.6	6.08	2.6
0.5	41.67	34.72	9.55	6.94	15.63	9.55
0.75	55.56	41.67	12.15	9.55	27.78	19.1
1	69.44	48.61	15.63	11.28	43.4	30.38
1.25	76.39	55.56	18.23	13.02	61.63	43.4
1.5	76.39	55.56	19.1	13.89	80.73	57.29
1.75	97.22	55.56	21.7	13.89	102.43	71.18
2	111.11	62.5	26.04	14.76	128.47	85.94
2.25	125	62.5	29.51	15.63	157.99	101.56
2.5	138.89	62.5	32.99	15.63	190.97	117.19
2.75	159.72	69.44	37.33	16.49	228.3	133.68
3	180.56	69.44	42.53	17.36	270.83	151.04
3.25	201.39	76.39	47.74	18.23	318.58	169.27
3.5	236.11	76.39	54.69	19.1	373.26	188.37
3.75	270.83	83.33	63.37	19.97	436.63	208.33
4	312.5	97.22	72.92	22.57	509.55	230.9
4.25	375	125	85.94	27.78	595.49	258.68
4.5	458.33	180.56	104.17	38.19	699.65	296.88
4.75	555.56	319.44	126.74	62.5	826.39	359.38
5	638.89	638.89	149.31	119.79	975.69	479.17
Area under Curves:		Total	975.69	479.17		
		Difference		496.53		

Figure 3 Strain - Stress and Work Data

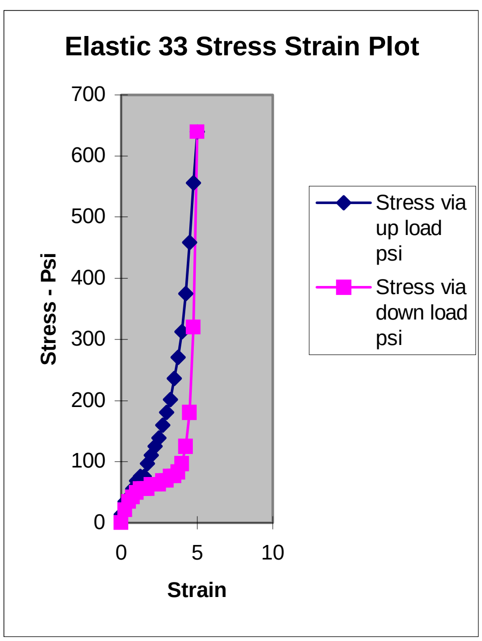

Figure 4 Stress - Strain Plot

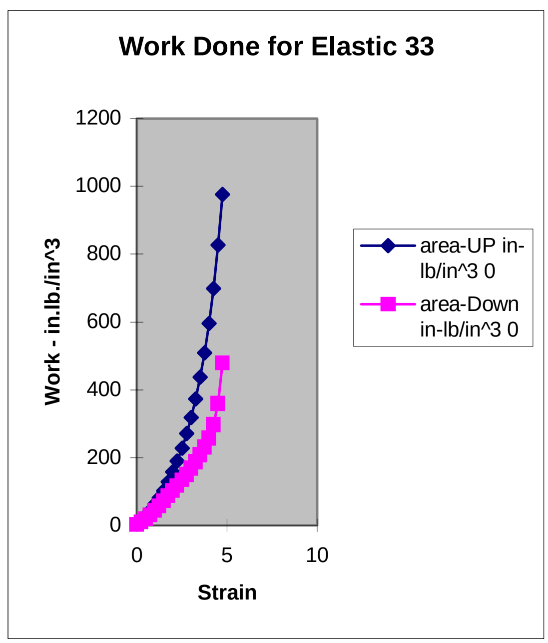

Figure 5 Elastic 33 Work Done