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Who does not know that 'Rubber is Elastic'? But did I know all this….?? This experiment on Extension of a Rubber band was an Eyeopener! NAEST 2020

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Problem Statement: *A rubber band does not seem to follow Hooke's law as the extension in the length is not proportional to the load applied to pull it. Moreover, a rubber band can show different extensions for the same load depending on the history of loading. In this experiment, you will explore the behaviour of a rubber band under loading and unloading.*

Get a rubber band of total length not less than 4-5cm. Tie one end at a sufficient height from the floor so that it can be stretched to 10 times its original length. Choose 4-5 such rubber bands and explore.

Will the rubber band really increase ten times in length with small weights?

The problem statement suggested that we need to keep sufficient space for the rubber band to increase ten times. I was rather sceptical initially. But look at the extension that a 13 cm band underwent a weight increase thrice. Can I add more weights and watch it grow? Not now, what if it breaks?

Fig 1. (a) extension 5 cm (b) extension 30 cm (six times)

Again, the strain is huge for a given stress, I understood why the Young's modulus of rubber is so low compared to steel. 'Which is more elastic, rubber or steel?' was a usual conceptual question in the Graduate Examination in Bangalore University.

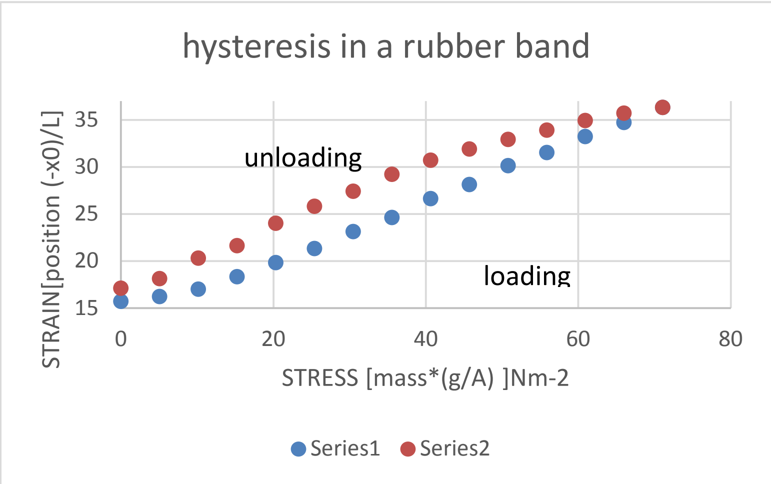
Rubber band I use for my hair, breaks after a couple of use. Then, how many cycles can I do with one band?

Adding weights gradually till I was exhausted with my weights, I decided to decrease the weight in steps and watch the band give a sigh of relief 'relieved of the load, ah!'. But it never came back to its initial position. Load gone, yet there were some peculiar internal changes happening, beyond my imagination. It was always staying longer its former position. It was retaining some of its extension in each step. Every-time the load was removed, it was longer than before! The band is doing more work while loading, but lesser while unloading, why?

No wonder, the extension versus load graph exhibited a hysteresis

curve. The difference in energy is converted into thermal loss, the area of the hysteresis loop signifies this. (Refer Graph 1)

Nevertheless, I repeated the loading unloading process, notwithstanding the fact that the rubber band will give way soon. But no, the same old green tinny-mini rubber band extended and contracted every cycle, like an obedient slave. To quench my curiosity, I plotted the position of the rubber band, end-point with the corresponding load.



Graph 1. Unloading and loading affect the band differently, producing hysteresis. Open loop shows unloading retains some extension.

Watch the spiralling hysteresis here (Schematic Graph 2)

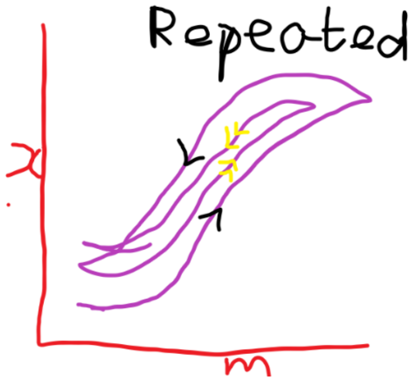


Fig. 2. Schematic

Oh, so the hysteresis loop has lesser area in each cycle! It is spiralling inwards. What internal changes is causing this? Unsolved mystery for me.

There is similarity in the curves, yet some dominating differences.

Extension depends not only on the history, but also the quantum of the load.

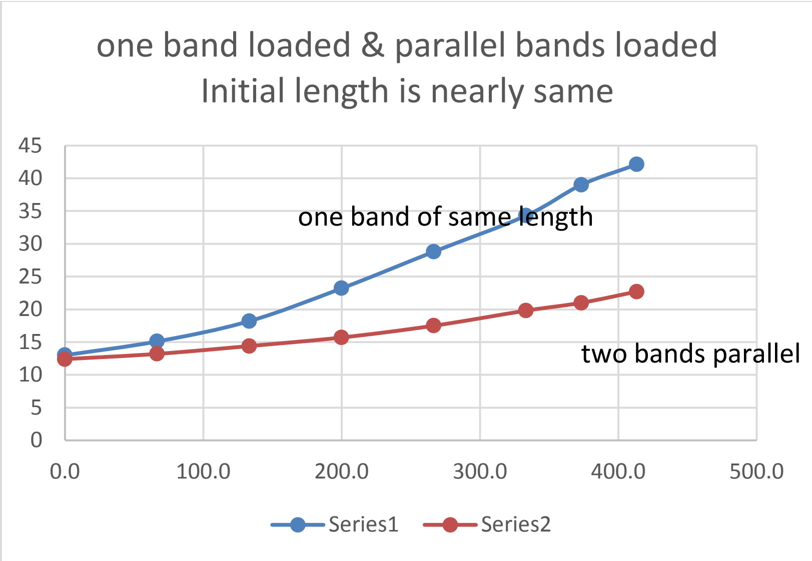
A sample area of the hysteresis loop is here, when load was changed in steps of 5 g, the area was 208 g cm while when the load was changed in steps of 10 g (double) the area decreased to 138 g cm.

Does the rubber band have ‘springiness’?

In parallel springs, the spring constant of the parallel springs is the sum of the spring constant of the individual spring. Will this also hold for a rubber band? I had proved it in a slinky spring very elegantly. Now, I wish to do that here, but can I??

Parallel bands suspended at one point and loaded at the other together, while ***One band*** of the same length, loaded in the same way showed a great change, refer Graph 3

The extension *vs* load graph shows at about 400 g (load) the extension in the parallel band is less than half of the single band!



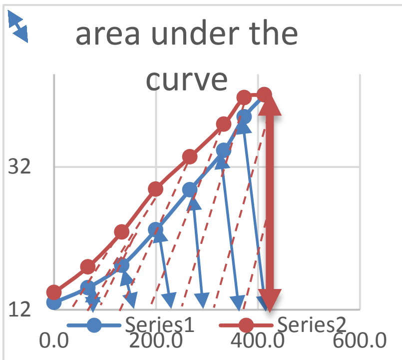
Graph 3. Huge difference in single and double bands.

Can I correlate the two?? Not sure.

Hysteresis loop of a rubber band is an open loop!

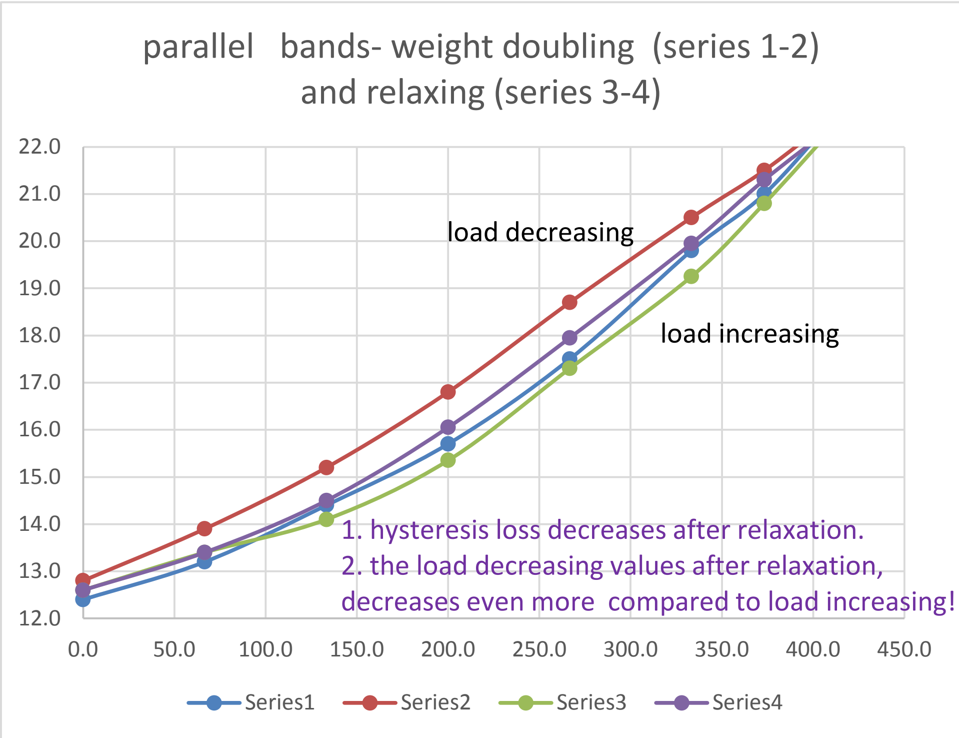
I had plotted hysteresis of soft iron in an alternating magnetic field and measured the hysteresis loss from a closed loop using Origin (software). '*Integration*' of the curve was possible for a closed loop. But how do I calculate the area of the open loop in hysteresis of a rubber band? The technique of area under the curve, the two boundary ordinates and the x-axis came to my rescue.

$$area = \int_{x_0}^{x} e_{loading}\, dm - \int_{x0}^{x} e_{unloading}\, dm$$



Graph 4. Hysteresis loss equals difference in area under loading and unloading curves.

It is like relaxing when you are tired, your output increases tremendously!



Graph 5. Relaxing makes a difference!

Many questions have remained unanswered. I need to take up this exercise seriously and more intently soon.