MECHANICS NEED NOT BE BORING TO ENGINEERING STUDENTS

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Summary. Mechanics is the backbone of most engineering disciplines. Yet, many engineering students seem to regard it as a boring old subject with nothing new to offer in the modern high-tech age and do not even give a second thought to conducting research in Mechanics, let alone to pursuing it as a career. This dismissive student attitude towards Mechanics is partly a result of the traditional method of introducing the engineering students to important ideas, often in isolation from interesting examples borrowed from Nature and practice. In this paper we shall describe two examples at the macro and nano scales that may help make the teaching of minimum energy principles and elastic buckling theory interesting and captivating.

The first example borrowed from Nature has intrigued naturalists, physicists, and mathematicians over centuries; why do honeybees construct their combs in a perfect hexagonal configuration. Many esoteric and bizarre explanations were proffered which ignored the fact that the interior of a comb cell begins with a circular and not a hexagonal shape (Figure 1). We will demonstrate that the mechanism whereby the bees construct a closed packed hexagonal honeycomb is the same that transforms a circular plastic straw bundle, tied by a metallic band (Figure 2a) and heated by conduction through a base plate, into a closed packed hexagonal arrangement (Figure 2b). The natural honeycomb is an arrangement that minimizes the surface tension (energy) [1].

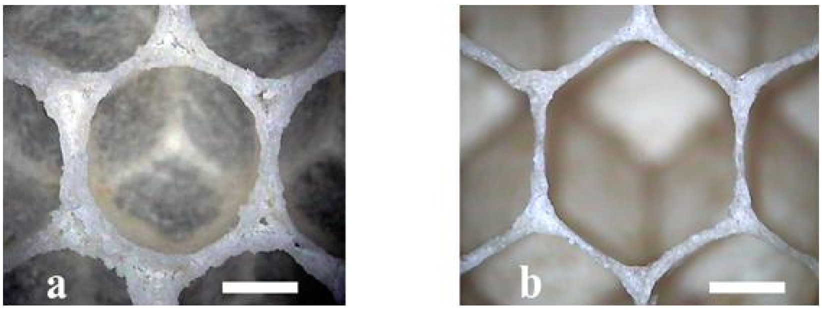

Figure 1. An unfinished fresh cell is circular (a) and transforms into the hexagonal shape (b) in the finished fresh cell. Scale bar is 2 mm

The second example deals with a single-wall nano tube (SWNT) bundle that was first analyzed using the Density Functional Theory under external hydrostatic compression up to a 20% strain applied in two ways. The strain was applied either gradually or suddenly in one step. Under gradual straining, the cross-section of SWNT bundle undergoes several pattern transformations as the relative energy is increased. The circular cross-section under no external pressure gradually changes into a rounded hexagon when the strain has reached 6% (Figure 3b).The deformed shape is further accentuated

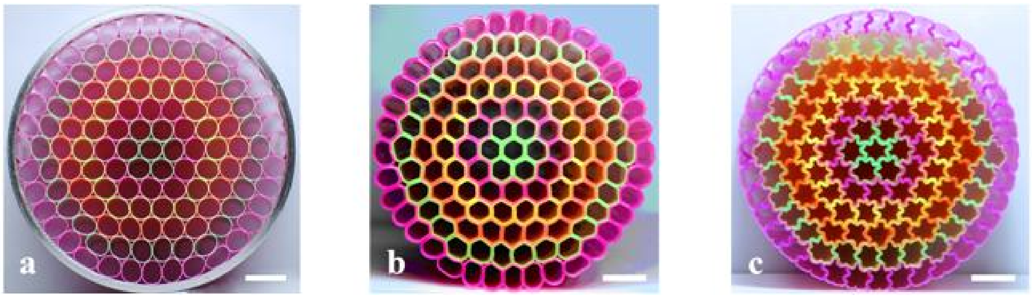

Figure 2 Pattern transformation of plastic tube bundle: a. a bundle of closed-packed circular plastic tubes tied by a metallic band. b. perfect honeycomb on heating by conduction c. hexagram on heating by convection. Scale bar is 10 mm

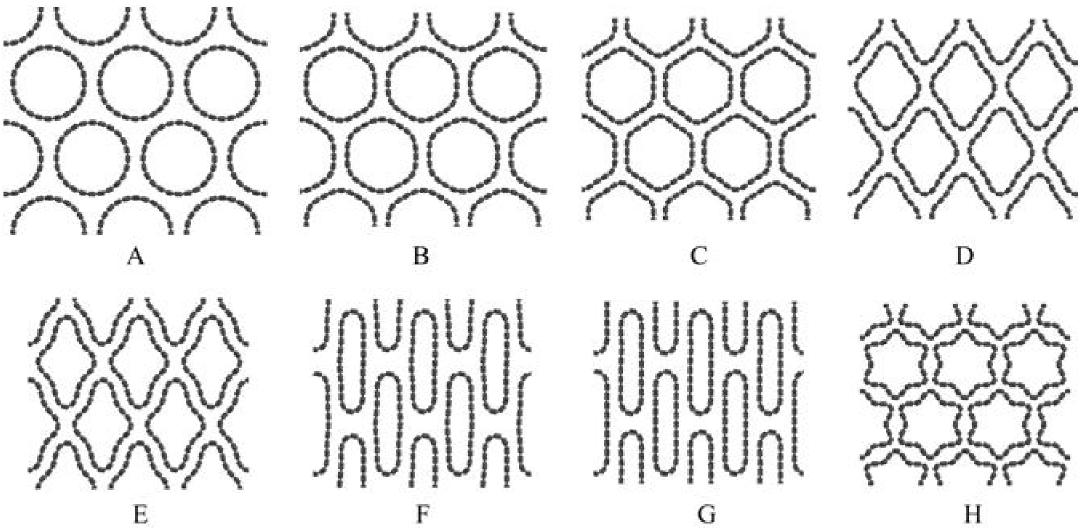

Figure 3 Single-wall carbon nanotube bundle (12, 12) under compression. B. 6% compression applied gradually. G. 20% compression applied gradually. H. 20% compression applied suddenly.

when the strain is increased. As the strain is further gradually increased, the cross-section of the tube goes through a shape transformation for the third time with a decrease of energy; it changes from the rounded tetragonal shape into a flattened structure similar to a 400 m running track (Figure 3g). On the other hand, when the strain of 20% is applied suddenly in one step, an amazing new hexagram pattern is triggered from the circular shape (Figure 3h). The same hexagram configuration is also taken by the abovementioned circular plastic straw bundle when it is heated by convection in a furnace (Figure 2c). We will demonstrate that these pattern transformations can be captured by considering the elastic buckling modes of a circular tube under radial point or distributed loading applied gradually or suddenly [2].

[1] Zhang K, Duan H L, Karihaloo B L and Wang J "Hierarchical, multilayered cell walls reinforced by recycled silk cocoons enhance the structural integrity of honeybee combs", *Proc Natl Acad Sci USA (PNAS)*, **107,** 2010, 9502–9506
[2] Zhang K, Zhao X W, Duan H L, Karihaloo B L and Wang J “Pattern transformations in periodic cellular solids under external stimuli”, *J Applied Physics*, **109**, 2011, 084907