EVERYDAY EXAMPLES OF ENGINEERING CONCEPTS

S7: Helical springs

This is an extract from 'Real Life Examples in Mechanics of Solids: Lesson plans and solutions' edited by Eann A. Patterson, first published in 2006 (ISBN:978-0-615-20394-2) which can be obtained on-line at www.engineeringexamples.org and contains suggested exemplars within lesson plans for Sophomore Solids Courses. Prepared as part of the NSF-supported project (#0431756) entitled: "Enhancing Diversity in the Undergraduate Mechanical Engineering Population through Curriculum Change".

INTRODUCTION

(from *'Real Life Examples in Mechanics of Solids: Lesson plans and solutions'*)

These notes are designed to enhance the teaching of a sophomore course in mechanics of solids, increase the accessibility of the principles and raise the appeal of the subject to students from a diverse background[1]. The notes have been prepared as skeletal lesson plans using the principle of the 5Es: Engage, Explore, Explain, Elaborate and Evaluate. These are not original and were developed by the Biological Sciences Curriculum Study[2] in the 1980s from work by Atkin and Karplus[3] in 1962. Today they are considered to form part of the constructivist learning theory and a number of websites provide easy to follow explanations of them[4].

These notes are intended to be used by instructors and are written in a style that addresses the instructor, however this is not intended to exclude students who should find the notes and examples interesting, stimulating and hopefully illuminating, particularly when their instructor is not utilizing them. In the interest of brevity and clarity of presentation, standard derivations and definitions are not included since these are readily available in textbooks which these notes are not intended to replace but rather to supplement. Similarly, it is anticipated that these lessons plans can be used to generate lectures/lessons that supplement those covering the fundamentals of each topic.

Acknowledgements

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[1] Patterson, E.A., Campbell, P.B., Busch-Vishniac, I., Guillaume, D.W., 2011, The effect of context on student engagement in engineering, *European J. Engng Education*, 36(3):211-224.
[2] http://www.bscs.org/library/BSCS_5E_Instructional_Approach_July_06.pdf
[3] Atkin, J. M. and Karplus, R. (1962). Discovery of invention? *Science Teacher* 29(5): 45.
[4] e.g. http://www.science.org.au/primaryconnections/constructivist.htm

STRAIN ENERGY

7. Principle: **Helical springs**

Engage

Ride you bike into class again and while braking bounce on the front suspension.

Explore

Discuss why a suspension system is necessary. Discuss what components are needed in a suspension system. Discuss the energy transfers and dissipation.

Explain

Ask the students to consider what would happen if only a spring was employed and hence explain why a damper is necessary. There is a nice graphic and explanation at http://travel.howstuffworks.com/mountain-bike4.htm. This discussion could be extended to cars and handling characteristics http://auto.howstuffworks.com/car-suspension.htm

Elaborate

Consider the design of the front suspension springs. These are hidden inside the front shock absorbers, but physically they must have a coil diameter of about 45mm and it is desirable that they have a deflection of about 10cm. Let us assume that the suspension is designed to absorb the vertical impact of rider plus bike of 120kg from 0.5m, then

Potential Energy lost in fall = Strain Energy absorbed by suspension system

$$mgh = \frac{W\delta}{2}$$

where W is load applied to springs and δ is the spring deflection, so

$$W = \frac{2mgh}{\delta} = \frac{2 \times 120 \times 9.81 \times 0.5}{0.1} = 11772 \text{ N (for both springs)}$$

From formula book, shear stress in spring: $\tau = \dfrac{8WD}{\pi d^3}$

where D is the coil diameter and d is the wire diameter, for Nickel-Chrome steel $\tau_{yield} = 650$ MPa, then

$$d^3 = \frac{8WD}{\pi\tau} = \frac{8 \times 5886 \times 0.025}{\pi \times 650 \times 10^6} \text{ and } d = 8.3\text{mm}$$

Also, deflection of spring, $\delta = \dfrac{8WD^3 n}{Gd^4}$

where n is the number of coils and G is shear modulus respectively.

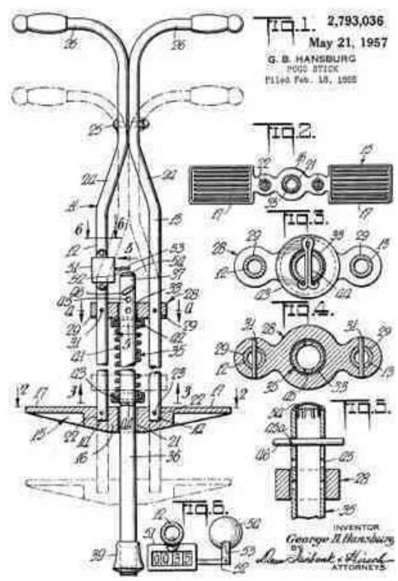
hence $$\delta = \frac{8 \times 5886 \times 0.025^3 n}{(82 \times 10^9)0.0083^4} = 1.87 \times 10^{-3} n \qquad \text{(i)}$$

$$n = \frac{\delta}{1.87 \times 10^{-3}} = \frac{0.1}{1.87 \times 10^{-3}} = 53.5 \text{ coils!}$$

Conclusion: springs alone cannot absorb this amount of energy with this distance of travel. Need energy dissipation in the damper to contribute to the total energy absorption. Actually the front suspension often uses compressed air springs rather than mechanical springs.

Evaluate

Ask students to attempt the following examples:



Example 7.1

A pogo stick[5] contains a Nickel-Chrome steel spring of free length 600mm and mean coil diameter 50mm made from round stock. If the spring is designed to be fully compressed so that the coils just touch each other under a mass of 100kg, then calculate the wire diameter and number of coils required if a factor of safety of 2 is employed.

From formula book, shear stress in spring: $\tau = \dfrac{8WD}{\pi d^3}$

where W is the applied load, D is the coil diameter and d is the wire diameter, so for a factor of safety of 2 and $\tau_{yield} = 650$ MPa, then

$$d^3 = \frac{8WD}{\pi\tau} = \frac{8 \times (100 \times 9.81) \times 0.05}{\pi \times 325 \times 10^6} \text{ and } d = 7.27 \text{ mm}$$

Also, deflection of spring, $\delta = \dfrac{8WD^3 n}{Gd^4}$

where n is the number of coils and G is shear modulus respectively.

hence $$\delta = \frac{8 \times (100 \times 9.81) \times 0.05^3 n}{(82 \times 10^9) \times 0.00727^4} = 4.28 \times 10^{-3} n \qquad \text{(i)}$$

also $$nd + \delta = 0.6 = \text{ free length} \qquad \text{(ii)}$$

substitute (i) in (ii) to give:

[5] *Extract from US Patent #2,793, 036 by G. B. Hansberg*

$$7.27\times10^{-3}n + 4.28\times10^{-3}n = 0.6 \text{ and } n\text{=51.9 coils}$$

So, δ=4.28×10^{-3}×51.9=0.22m and equating potential energy with strain energy stored then $h = \delta/2 = 0.11$m so the spring will be fully compressed for a jump of only 11cm!

Example 7.2

Ask students to look for two other examples in their everyday life and explain how the above principles apply to each example.