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A18 –SOME COUNTER-INTUITIVE ENGINEERING DESIGN PROBLEMS IN VIBRATION; ON HOW A LITTLE KNOWLEDGE CAN CONFUSE OUR UNDERSTANDING OF COMPLEX PROBLEMS

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Professor C E Inglis noted in his James Forrest Lecture of 1944:
"*In problems relating to vibrations, nature has provided us with a range of mysteries which for their elucidation require the exercise of a certain amount of mathematical dexterity. In many directions of engineering practice, that vague commodity known as common sense will carry one a long way, but no ordinary mortal is endowed with an inborn instinct for vibrations; mechanical vibrations in general are too rapid for the utilization of our sense of sight, and common sense applied to these phenomena is too common to be other than a source of danger.*"

I will give you several every-day examples where our instinct goes wrong. "So what?", you may well ask. The answer is simply this: If we teach vibration analysis at universities then our students have an expectation that they now understand a bit about vibration. What we don't teach is the limit of applicability of what we do teach. Most vibration problems are coupled three-dimensional multi-degree-of-freedom problems, usually with some degree of non-linearity. We use damping treatments to control vibration but damping is notoriously poorly understood. You won't for instance find the damping properties of materials in your average materials data book.

My second concern is that engineers and scientists can easily become "big headed". In fact, I'd challenge anyone reading this to ask themselves honestly "have I ever guessed at an answer to a problem without really knowing what the answer is"? We all do it - and in this talk we'll cover a few examples including, but not limited to, the following:

1. What defines the note that we get when we blow over the top of a glass bottle? Is it the same note that we get when we tap it with a spoon? What if we put some water in the bottle - does the note go up or down? And why? And what about champagne glasses? Do the same principles apply? Whatabout the bubbles?

2. We always use a tuning fork as an example - perhaps the best and simplest example - of a two-degree-of-freedom vibrating system. The handle of then tuning fork is nodal, which is why we can hold on to it there. But if there is no motion, why does it make a difference if the tuning fork is placed on a table? All musicians know that a tuning fork is much louder when it's end is placed on a hard surface. Why? Does our simple 2-dof model work?

3. Further on the subject of nodal points, what can we say about vibrating beams? Does it help to know about nodal points, or is this level of understanding best left to the experts? And what does this have to do with coffee cups and vibration of turbocharger rotors?

4. Vibration damping is a black art. Some materials, like glass, are clearly lightly-damped (just tap on a wine glass) but why do glass windows not ring like a bell? Yet other materials, like rubber, can be made with custom damping, from the light damping of a superball to the heavy damping of a machinery mount. And what about tuned vibration absorbers - how effective are they, and do they really work?

5. Church towers with swinging bells are often found to vibrate at damagingly-large amplitudes when the bells swing, but the period of swing of the bells is around 4 seconds. Can the natural frequency of these towers really be as low as 0.25Hz? The rule of thumb for buildings is that the frequency is 10/(number of floors) and a typical church tower is no more than five storeys high - ie 2Hz. Are we nearly a factor of ten out?

This keynote address will make use of live demonstrations throughout to illustrate the examples given. The objective is simply to encourage the listener to be more aware that our common sense when applied to vibration problems is - as Professor Inglis said - a source of danger.

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