Journal of Fluids Engineering

Book Review

Applied Dimensional Analysis and Modeling, by Thomas Szirte, McGraw-Hill, NY, Dec. 1977.

REVIEWED BY SHELDON GREEN[1]

Applied Dimensional Analysis and Modeling is an extended (790 pages!) treatise on dimensional analysis and modeling. Although the intended audience of the book is never explicitly stated, one can reasonably assume, given the hundreds of example problems, that its intended audience is undergraduate students and researchers who have not previously been exposed to the power of dimensional analysis techniques.

The first chapter of the book covers some elementary matrix theory (determinants, matrix inversions, solutions of linear systems of equations, etc.), which is used subsequently in the development of mathematical results concerning dimensions in Chapters 2 through 10. Chapters 11 through 18 include numerous examples of the application of dimensional reasoning, to subjects as diverse as biomechanics, elasticity, electromagnetic radiation, and fluid mechanics.

Chapter 1 of the book (this chapter was written by Professor Rózsa) is a clear recapitulation of matrix theory. Although the chapter would have benefitted from some unworked review problems, the presentation of ideas is clear and at an appropriate pace. In contrast, this reviewer found most of Chapters 2 through 10 to be disappointingly pedantic. For example, surely any first year university student can convert Planck's constant from SI units to Imperial units. Likewise, does one need to explain that it is conventional to leave a gap in the expression "mass = 91 kg" between the "91" and the "kg?" Finally, does one really need a theorem stating that if one multiplies two variables, the result has dimensions equal to the product of the dimensions of the variables?

Chapters 11 to 18 represent a nice improvement from the preceding 9 chapters. In these chapters there are literally hundreds of examples of the application of dimensional analysis to physical problems. The author has found some excellent examples of situations (e.g., a sphere rolling down an inclined ramp) in which dimensional analysis can show that certain variables that one might intuit are important, are in fact physically irrelevant. He also gives nice examples of the application of physical reasoning to determine the form of relations between Π groups. Fluid mechanics specialists will note some unfortunate errors in the text. For example, when discussing the terminal velocity of a falling raindrop, the author neglects that air density could play a role in the process (i.e., he assumes the falling drop is in the Stokes flow regime), and thus deduces that the terminal velocity is proportional to the square of the droplet radius. Unless the rain is a fine mist, droplets will not be in the Stokes flow regime, and therefore do not have a terminal velocity proportional to the square of the droplet radius. As a further example, when discussing the power required to tow a barge, the author claims that model-scale measurements of drag force would be made by holding a model stationary in a moving stream. Although barge drag measurements could be made in this way, it is far more common to use a towing tank for the purpose. One can in fact use a dimensional analysis argument (along with a knowledge of the power requirements of wind tunnels) to show that the power required to operate an open water flume, of a size comparable to a reasonable model ship towing tank, is enormous, which is one of the reasons why towing tanks, not flumes, are used for barge drag measurements.

Without question, dimensional arguments can be very powerful. However, dimensional analysis is only effective if one identifies all physical variables that are important in a problem. The neglect, in the falling raindrop problem, of the role of air density is one example of such an omission. As a second example, the author uses dimensional arguments to conclude that all animals should be capable of leaping from rest to about the same height (of 2 m, according to the author). In fact, only a few select athletes can leap even 1 m vertically; professional high jumpers achieve extra height by converting kinetic energy (produced by a running start) into gravitational potential energy, and by rotating the body such that the lowest part of the body is near the center of mass. Similarly, a cat can leap significantly higher than a small dog owing to the cat's greater flexibility, which allows it to store more energy during the compression phase of a leap than can a dog. These three are very different physical mechanisms from those considered by the author. This example would therefore have been a good place for the author to have explicitly cautioned the reader about the hazards of relying on dimensional analysis when the underlying physics are not understood.

Given these shortcomings of the book, one might ask in what ways it is worthwhile. In view of its many diverse, interesting examples, taken from across the physical sciences, the reviewer believes that it serves a role as a compendium of dimensional analysis problems. As such, it would be a useful addition to the libraries of most universities, although few fluid mechanics specialists would want a copy specifically for a personal library.

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