Scaleup in Chemical Engineering

By Marko Zlokarnik, Wiley-VCH Verlag GmbH, Weinheim, Federal Republic of Germany, 2002, 219 pp., $99.95.

I highly recommend *Scaleup in Chemical Engineering*. All those interested in the area of dimensional analysis and scaleup should have a copy for their libraries. There are few books in these important areas.

In his book, Prof. Marko Zlokarnik presents the main topics of dimensional analysis, pi generation, the scale invariance concept, partial similarity, and a summary of scaleup essentials. He has discussions on the treatment of variable physical properties, and the typical problems and mistakes in the use of dimensional analysis and optimization. He then finishes with selected examples of dimensional analysis applied to mechanical, thermal, and chemical unit operations, and the living world. Overall, the book presents many examples of the application of dimensional analysis. Such information represents a beginning point for scaleup. Prof. Zlokarnik has written other texts in this area, but this text represents the best to date. I also appreciate his historical references to Lord Rayleigh and others.

Having said this, I should also like to point out the shortcomings of the text that relate to scaleup. Scaleup is design, a type of design where a process is enlarged to accomplish specific goals, the most common being the production of large quantities of a new product. Whereas the text contains excellent examples of dimensional analysis, it does not contain information with regard to the important aspects of process design. Examining two examples, atomization and mass transfer in stirred tanks, Prof. Zlokarnik's analysis does not provide much help in the scaleup of these processes. To be sure, Prof. Zlokarnik's discussions are highly sophisticated, but they do fall far short of scaleup. The scaleup information that is provided tends to be over a limited size range. Overall, Prof. Zlokarnik's book is more of a book on dimensional analysis rather than scaleup. The reader is left "hanging" in completing a scaleup.

After an introduction of dimensional analysis (Chapters 1–3), Prof. Zlokarnik proceeds to claim "Scale-Invariance of the Pi Space." He states: "Two processes may be considered completely similar if they take place in a similar geometrical space and if all the dimensionless numbers necessary to describe them have the same numerical value."

This statement is sacred to many and is the basis for Prof. Zlokarnik's book. The concept is stated and restated in many undergraduate textbooks. Such names as Buckingham and Lord Rayleigh come to mind. This is the sacred principle of similarity. However, the statement has never been proved. The few examples available do not make a proof. The term "completely similar" is vague. Prof. Zlokarnik does not give the reader a good explanation of what "completely similar" means. The statement implies that the two processes are mathematically identical. However, the conditions and requirements for mathematical identity are much more strenuous than "completely similar" obtained from this simple statement.

The term "completely similar," is a self-contradiction. "Complete" implies an absolute. "Similar" implies a nonabsolute. An elephant and a giraffe are similar. Both have legs, a head, a nose and a tail. However, they are not completely similar, because "completely similar" has no meaning despite the fact that the phrase is used all the time. To be sure, there have never been two completely identical processes. However, there are a lot of similar processes.

"Similar geometrical space" typically means geometric similarity in the world of scaleup. Geometric similarity is where two geometries differ by a magnification or scaling factor. However, there are many examples in design where maintaining geometric similarity leads to process failure or an impractical result on scaleup. The objective of the scaleup process is to have a successful design. Breaking geometric similarity often leads to success. Maintaining similar geometrical space on scaleup does simplify the design process, but is not a requirement in design unless it is self-imposed. You often want to improve the process as you scale up, so the process may be further developed in the scaleup process and changed too. Changing geometry in the scaleup design process can significantly improve the process and its performance. After all, in a plant environment very few processes are done in test tubes and round bottom flasks with magnetic stirrers.

Limitations of dimensional analysis are well known. The first requirement is the proper selection of the important variables. If this is not done, then dimensional analysis is inadequate. It is easy to overlook important variables. Let's take Example 36 from Prof. Zlokarnik's text: Steady State Heat Transfer in Bubble Columns. To be sure, the example is well done, but not complete. Column tilt often controls the flow patterns in a column and, hence, the heat-transfer coefficient. Column tilt was left out of Example 36. Tilt is measured by an angle, which is a dimensionless quantity already. It is its own pi group. Revolutions, number and angle, all dimensionless, are important engineering quantities that do not participate in dimensional analysis. Many important dimensionless quantities are often left out and ignored when doing dimensional analysis.

It is also well known that many processes have not been scaled up or are nonscaleable although dimensionless groups can be used to describe them. A nonscaleable process is one in which the results of laboratory studies and plant performance do not correlate with each other. Any one-to-one correspondence between the lab and the plant is strictly fortuitous.

Although I do not agree with Prof. Zlokarnik in the area of scaleup, I do welcome his book into the fray to conquer the complexities of dimensional analysis. The book is a good contribution to dimensional analysis, and I encourage the readers of this review to purchase and read his book.

In this era of openness, I wish to point out that I have a new book in press on scaleup. I have also written an earlier text on scaleup.

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