Scaling Chemical Processes – Practical Guides in Chemical Engineering

by Jonathan Worstell, Oxford: Academic Press/Elsevier, 2016
ISBN: 978-0-12-804635-7, 177 pages.

Reviewed by
David Müller

Jonathan Worstell is a physicist who has specialized himself in applied chemistry. After a thirty-year career in the petrochemical industry he has returned to academia teaching senior level chemical engineering courses. In this book, Dr. Worstell gives practical guides for chemical engineers on how to scale various chemical processes in a very systematic manner.

The book is divided into six chapters, which can roughly be split into three sections. The first section, containing chapter one, gives a general introduction to the topic of scaling chemical processes. Section two, consisting solely of chapter two, discusses units and dimensions. The final section, containing chapters three to six, contains practical scaling applications in different fields of chemical engineering.

Chapter one starts with a general description of the development of chemical engineering as a discipline, using the necessity of continuous production processes as a main motivation. The chapter continues by diving into simple examples of process scaling. Hereby, the author derives a dimensionless Navier-Stokes-Equation to show how a model and its prototype can be designed in a comparable manner. This brief introduction to the topic is followed by a discussion on the concept of similarity in which the four important similarity points for chemical engineers are highlighted: geometrical, mechanical, thermal, and chemical similarity. The author then goes on to discuss the different types of models, which are needed to successfully upscale or downsize a chemical process: true, adequate, distorted, and dissimilar models. This chapter gives a good general description to get an idea of what the different types of models are needed for and how they can be applied, thus successfully laying a foundation for the topic of process scaling as whole.

The second chapter focusses on a dimensional analysis. The topic is initially motivated by introducing the main characteristics and relationships that must be ensured so that a prototype of a chemical process behaves similarly to its model process: geometric, static, kinematic, dynamic, thermal, and chemical. This brief introduction in this chapter is followed by a discussion on the topics of physical concept, physical quantity, and dimension. I am not sure for which group this chapter is designed for, because it goes on to discuss the concept of dimensions and physical units. The author discusses the fundamental and derived dimensions to describe physical concepts. In my opinion a chemical engineering student should already know these before his or her first semester. Next, equations and physical magnitude as well as systems of units are presented. These are extended with basic examples of intensive and extensive units. A short description to the different unit systems is then given. The author devotes several pages discussing the different old unit systems such as the "English dynamic unit system" or the "American engineering unit system". I found this section more confusing than helpful. It mainly showed how engineers can be challenged when working with older literature, in which the applied unit system is not clear.

The third chapter divulges into a discussion on control regimes for various purposes ranging from heat transfer to gas-liquid semi batch processes to regimes for immiscible liquid-liquid processes. Several important and useful statements for chemical engineers are made herein such as the necessity of identifying the rate controlling step and so on. I enjoyed the discussion on the differences between laboratory and production plants. In this discussion points were highlighted showing the errors engineers can be make during the scale-up of a process from a lab or pilot scale to a production-scale plant, simply due to different, sometimes opposing goals and settings in each scale.

In chapter four, scaling fluid flow is of relevance. The chapter starts by performing a dimension analysis to determine the most common engineering descriptions for fluid flow and based thereon determine the number of dimensionless parameters to describe the general characteristics of fluid flow. This theoretical section is followed by several very practical examples, in which the scaling of water flow in a smooth pipe, a circular pipe, a centrifugal pump, and through a packed bed is presented. Several pages are devoted to the packed bed example, in which the validity range of the Ergun equation is discussed. Overall, the performed dimensionless analysis, the derivation of the required equations, and the determination of the relevant dimensionless parameters is done very systematically for each application. Sometimes however, some additional explanations on why specific reformulations of equations are carried out as well as what the limitations of these equations are might be useful for learning chemical engineers.

Chapters five and six focus on the scaling of heat transfer as well as the scaling of chemical reactors. In both, the same systematic procedure as in chapter four is done in which a dimensional analysis and derivation of the relevant dimensionless parameters is carried out. Several useful statements from a practical point of view are made – especially concerning the discussion on necessary similarities between models and prototypes of processes. Hints are given on what points a chemical engineer should focus on with respect to maintaining similarity in order to save time and money in their projects. I found both chapters useful from a practical point of view, because the application of different dimensionless numbers is shown. Overall, I believe that the last three chapters contain excellent advice as well as practical applications for chemical engineers.

The question now arises, for whom is this book adequate? Overall, there are many highly practical and applicable points for professional engineers. I would not recommend this book for complete beginners in chemical engineering. The knowledgebase with units and dimensions, basics of linear algebra, as well as fundamentals of mass- and heat transfer must be set. I also find that experience concerning the application of dimensionless numbers as well as basics on reaction engineering must be present. The derived dimensionless numbers applied in this book often "fall from the sky". The reader is expected to recognize these immediately and understand how they can be applied. Additionally, several matrix operations are performed throughout the chapters. If these mathematical and chemical engineering foundations are not set, reading and more importantly, understanding the content of this book will be more than challenging for students. For professional engineers however, I believe this book contains several useful hints and offers several practical and concise tips when it comes to scaling of processes. Some of these hints could be highlighted more strongly, to make the main message of each chapter clearer to the reader.

The cost of this book lies around $26, which I find more than reasonable. The amount of white pages is low and the overall information content is high. ❒