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Process Intensification Technologies for Biodiesel Production

Reactive Separation Processes

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Dedicated to my loving wife for her endless support and inspiration,
as well as to the precious memory of my professors and mentors

Preface

This book is among the first ones to address novel process intensification technologies, based on integrated reactive separations, for the production of biodiesel—a mixture of fatty esters. Biodiesel is a biodegradable and renewable fuel, emerging as a viable alternative to petroleum diesel. Conventional biodiesel processes still suffer from problems associated with the use of homogeneous catalysts (e.g. expensive neutralization and separation, salt waste streams) and the limitations imposed by the chemical reaction equilibrium, thus leading to severe economical and environmental penalties.

This book provides a detailed overview illustrated with several industrially relevant examples and case studies of novel reactive separation processes able to tackle the current problems and readily usable in the biodiesel production: reactive distillation, reactive absorption, reactive extraction, as well as membrane reactors and centrifugal contact separators. The integration of reaction and separation into one operating unit overcomes equilibrium limitations and provides key benefits such as reduced investment and operating costs, as well as lower plant footprint. These processes can be further enhanced by heat integration and powered by heterogeneous catalysts, to eliminate all conventional catalyst-related operations, using the raw materials and the reaction volume efficiently, while offering higher conversion and selectivity, and high energy savings compared to conventional biodiesel processes.

The focus of the book is on key aspects of these novel process intensification technologies, ranging from the working principles to conceptual design, process control, and applications. This work includes a number of novel applications relevant to industrial biodiesel and fatty esters processes, as well as results of rigorous steady-state and dynamic process simulations. The readers will have the opportunity to learn about the basic working principles, design and control of such integrated processes, while also getting a modern overview of the process intensification opportunities for biodiesel synthesis. The target audience consists primarily of students and postgraduates, chemical engineers, researchers, project leaders, technology managers, biodiesel manufacturers, and equipment suppliers.

Acknowledgments

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Contents

About the Author

Anton A. Kiss has a Ph.D. in Chemical Engineering and around 15 years of academic research and education experience, supported by a decade of industrial research experience in the area of separation technology, process intensification and process systems engineering. Currently, he works as senior project leader in the Department of Research, Development and Innovation of AkzoNobel—a Global Fortune 500 company, consistently ranked as one of the leaders in sustainability—acting as the key expert in distillation, reactive-separations, and other integrated processes. In his capacity as an award-winning researcher in separation technologies, Dr. Kiss has given many lectures at universities and conferences and has carried out more than 100 research and industrial projects. He has also supervised numerous graduation projects, and has published several textbooks and more than 50 scientific articles in peer-reviewed journals. More details are available on the personal website: http://www.tonykiss.com.

Abstract

Process intensification technologies can drastically reduce the overall costs and improve the sustainability of many industrial processes. In particular, reactive separations offer new and exciting opportunities for manufacturing fatty acid alkyl esters involved in the industrial production of biodiesel and specialty chemicals. Biodiesel is a biodegradable and renewable fuel, emerged as a viable alternative to petroleum diesel. In spite of the recent advances, the existing biodiesel processes still suffer from serious problems associated with the use of homogeneous catalysts and the limitations imposed by the chemical reaction equilibrium, thus leading to severe economical and environmental penalties (e.g. high operating costs, salt waste streams).

This work provides a comprehensive overview illustrated with industrially relevant examples of novel reactive separation processes used in the biodiesel production: reactive distillation, reactive absorption, reactive extraction, membrane reactors or centrifugal contact separators. Remarkably, the integration of reaction and separation into one operating unit overcomes the equilibrium limitations and provides major benefits such as low investment and operating costs. Many of these reactive separation processes can be further enhanced by heat integration and also powered by heterogeneous catalysts, to eliminate all conventional catalyst-related operations, increase the efficiency in using the raw materials and the reaction volume, while offering high conversion and selectivity, and significant energy savings. The readers will learn about the working principles, design and control of integrated processes, while getting a state-of-the-art overview of the process intensification opportunities for biodiesel synthesis.

Keywords Reactive distillation · Absorption · Stripping · Extraction · Membranes · Centrifugal contactors