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# Handbook of Manufacturing Engineering and Technology



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Andrew Y. C. Nee  
Editor

# Handbook of Manufacturing Engineering and Technology

With 2123 Figures and 371 Tables



*Editor*

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## Foreword

This project started in July 2010 when Anil Chandy and Sandra Fabiani from Springer approached me to take on the editorship of a handbook series on manufacturing engineering. The initial thought that came to me was a colossal task involving hundreds of people and taking tens of years to complete. The decision of the topics to be included is equally daunting. We met a couple of times in person and over the Internet to size up the scope and contact a number of potential volume editors. After many attempts and sounding out prominent authors, I managed to convince three section editors to take on this task, which was still a long way from the 12 section editors planned. In May 2011, I approached the Executive Director of SIMTech, Dr Lim Ser Yong, for his help and a joint presentation together with Anil and Sandra was made to his research group leaders on the significance of such a project. He gracefully agreed. Much to our joy, five section editors agreed and were appointed in 2012, followed by another two editors in 2013. The last two overseas editors joined in mid-2013. In April 2014, we finally saw the project through to completion and the handbook is ready to roll out, even though it has been a lengthy journey!



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# Preface

Innovation and manufacturing capabilities are well known to be the wealth creator of any nation which has strong advanced manufacturing technologies for making high-value-added products and is able to compete globally.

Manufacturing is evolving continuously, engulfing more technologies than several decades ago. The rapid development of Internet technology, computer science, materials research, microelectronics, and biosciences has propelled manufacturing activities far beyond mere product fabrication. Manufacturing technology has now entered into the realm of intelligent product creation, and yet at affordable prices, and is highly compatible with environmental concerns.

Manufacturing knowledge has been created by both the academia and industry, but unfortunately a great deal of information is scattered over a myriad of published papers, reports, and books – some are publicly available, while others remain proprietary information and are well guarded by the organizations which created them.

The *raison d'être* of the *Handbook of Manufacturing Engineering and Technology* is to gather the fundamental and evolving technologies in manufacturing engineering from many experts and practitioners in an attempt to cover as many fields as possible in common manufacturing activities. The collated materials will be updated frequently to capture the latest developments. The six volumes of the handbook cover the following topics:

Volume 1 – Forming and Joining

- Materials Forming: Forming of Polymer and Composite Materials
- Metal Forming
- Materials Joining

Volume 2 – Machining and Tolerancing Systems

- Machining
- Tolerancing Systems

Volume 3 – Nanomanufacturing and Non-traditional Machining

- Nanomanufacturing Using Ion Beam Technology
- Non-traditional Machining Processes

Volume 4 – Robotics and Automation

Volume 5 – Additive Manufacturing and Surface Technology

- Additive Manufacturing: Rapid Prototyping, Tooling, and Manufacturing
- Surface Technology

Volume 6 – Product Life Cycle and Manufacturing Simulation

- Product Life Cycle and Green Manufacturing
- Manufacturing Simulation and Optimization

It is hoped that these volumes provide useful assistance for both academia and industry with regard to the needed reference and basic knowledge of each process. What is more important is that the knowledge will be updated continuously to keep abreast with the state-of-the-art developments in the world of manufacturing research and practice.

Andrew Y. C. Nee, DEng, PhD  
Singapore

August 2014



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# Acknowledgments

The *Handbook of Manufacturing Engineering and Technology* is the collective effort of many distinguished researchers and scientists in the field of manufacturing engineering. Much of the hard work also comes from the section editors who painstakingly contacted all the authors as well as edited and proofread their contributions.

The section editors are gratefully acknowledged and are mentioned below along with the names of the respective sections they edited:

- Materials Forming: Forming of Polymer and Composite Materials – Suzhu Yu (SIMTech)
- Metal Forming – Mehrdad Zarinejad (SIMTech)
- Materials Joining – Jun Wei and Wei Zhou (SIMTech)
- Machining – Sathyan Subbiah (SIMTech, now at Indian Institute of Technology (IIT) Madras, Chennai) and Hongyu Zheng (SIMTech)
- Tolerancing Systems – Ping Ji (Hong Kong PolyU)
- Nanomanufacturing Using Ion Beam Technology – Zong Wei Xu and Fengzhou Fang (Tianjin University)
- Non-traditional Machining Processes – Hong Hocheng and Hung-Yin Tsai (National Tsinghua University)
- Robotics and Automation – Guilin Yang (SIMTech, now at Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences)
- Additive Manufacturing: Rapid Prototyping, Tooling, and Manufacturing – David S K Wong (Nanyang Polytechnic)
- Surface Technology – Guojun Qi and Sam Zhang (SIMTech)
- Product Life Cycle and Green Manufacturing – Bin Song (SIMTech)
- Manufacturing Simulation and Optimization – Manoj Kumar Tiwari (IIT Kharagpur)

Special thanks go to all the contributing authors, researchers, and students who have made this handbook possible.

I would like to thank Springer for the great commitment to publish the handbook and, in particular, to the following colleagues from Springer, without whom the project could never be materialized:

- Anil Joseph Chandy
- Sandra Fabiani
- Mansi Seth
- Sunali Mull
- Neha Thapa

Andrew Y. C. Nee  
Editor

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## About the Editor



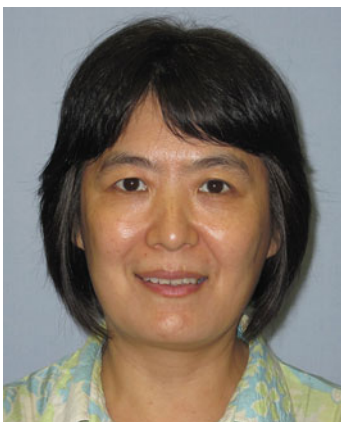
**Andrew Y. C. Nee**, a Full Professor at National University of Singapore (NUS) since 1989, received his PhD and DEng from University of Manchester, Institute of Science and Technology (UMIST). He has contributed to the fundamental and applied research in the design of molds, dies, and fixtures; manufacturing simulation using augmented reality; and sustainable manufacturing. He was appointed Editor in Chief of Springer's long-standing *International Journal of Advanced Manufacturing Technology* in February 2014 and serves on 22 editorial boards. He has published over 500 papers in peer-reviewed international journals and conference proceedings and has authored and edited 12 books and 23 book chapters. He has graduated 40 PhD and 43 master's students by research. Some of the awards he received include the IEEE Kayamori Award in 1999, IJPR Norman A Dudley Award in 2003, and IMechE Joseph Whitworth Prize in 2009. In NUS, he had served as the Head of Mechanical Engineering, Dean of Engineering, and Director of Research Administration.

He was honored with the Engineering Leadership Award by NUS in 2012. Under his leadership, his research team has worked on computer-aided mold design, leading to the setting up of a university spin-off company Manusoft Technologies Pte Ltd and the development of IMOLD. He and his team's effort in the metal-stamping progressive die design had won them the National Technology Award in 2002. He received the National Day Award Public Administration Medal (Silver) in 2007.

He holds honorary professorship from five universities in China: Tianjin, Beijing University of Aeronautics and Astronautics (BUAA), Nanjing University of Aeronautics and Astronautics (NUAA), Shanghai, and Huazhong University of Science and Technology (HUST). He was a recipient of Society of Manufacturing Engineers's (SME's) Outstanding Young Manufacturing Engineer Award in 1982, Fellow of SME (1990), and Fellow of The International Academy for Production Engineering (CIRP) (1990). He is a Founding Fellow of the Academy of Engineering Singapore and served as President of CIRP (2011–2012), the International Academy for Production Engineering. He is the first ethnic Chinese in the world to hold this position since CIRP was established in 1951 in Paris. He received the Gold Medal from the US Society of Manufacturing Engineers in Detroit, June 2014. It is an international recognition of his outstanding service to the field of manufacturing engineering through published literature and education.

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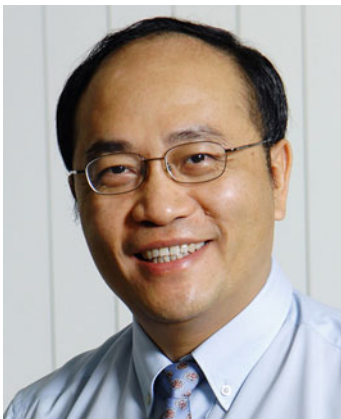
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