

Metal and Bone Drilling - The Thermal Aspects

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 Springer

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ISBN 978-3-030-26046-0 ISBN 978-3-030-26047-7 (eBook)
<https://doi.org/10.1007/978-3-030-26047-7>

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*For my lovely wife, Huishan, and children,
Arthur, Brenda, Christopher, and Deanna.*

–Albert Shih

For my lovely wife, Ploy, and son, Dylan.

–Bruce Tai

*For my lovely wife, Xue Zhou, and children,
Chuyu and Yuanbao.*

–Rui Li

Preface

This book summarizes advanced technologies on drilling and demonstrates the evolution of manufacturing from industry to healthcare. Drilling is an art and science. Manufacturing engineers and orthopaedic surgeons understand the importance and challenges of drilling, a seemingly routine process that is often overlooked by people who do not know manufacturing or orthopaedic surgery. Many engineers have dedicated their talent and career to advance the drill design, material, coating, manufacturing, and performance. Every advanced drill is a work of art. New technology is built on these advanced drills, which make high-performance drilling and drilling research possible.

Broad applications of titanium alloys in the aerospace, transportation, sporting equipment, and other industries have driven the research in machining of titanium alloys. Drilling, particularly the high-throughput drilling, is important because it is one of the most widely utilized and technically challenging processes for machining of titanium alloys. The drill tip starts to glow due to high temperature after rapid drilling only a few holes in titanium alloys. Compared to measuring the thrust force and torque using a dynamometer, it is more difficult to measure the drill temperature and even more challenging to find the spatial and temporal temperature distributions of a drill during drilling. Chapters 2 and 3 present our pathway, which is built on the drilling research in the past century, to gain in-depth understanding of drill temperature.

Another evolution in manufacturing is the emphasis on sustainability and the health and safety of workers in manufacturing plant. A group of dedicated and outstanding manufacturing and machine tool engineers worked together and demonstrated that the minimum quantity lubrication system was as productive as the traditional flood cooling with the central cooling system in a plant and could save the overall cost from the life cycle perspective. That was a milestone achievement. New technical challenges of rising workpiece temperature and the resulted thermal expansion during production with the minimum quantity lubrication give great research opportunities. This work will be presented in Chaps. 4 and 5.

We are very fortunate to work with orthopaedic surgeons on the frontier biomedical manufacturing research in bone drilling. We have learned that knowledge

in metal drilling can be applied to study bone drilling. There are many opportunities for innovations in bone drilling. This is a great task for manufacturing engineers and critically important for the future of biomedical manufacturing research to improve the quality and reduce the cost of healthcare. Our bone drilling research is presented in Chaps. 6 to 8.

It takes a village to create and finalize a book. We are greatly indebted to the researchers and collaborators who have guided and helped this team in the past decade on drilling research. We started from the late Professor S.M. Wu who was a giant in drilling research since the 1960s at the University of Wisconsin at Madison. Many of his students, particularly Dr. David Stephenson and Professor Jun Ni, continued his legacy and went to great lengths for drilling research in industry and in the University of Michigan at Ann Arbor. Our work is built on their past achievements. In the automotive industry, Drs. Richard Furness and John Agapiou are professors' professors in advanced drilling. We have learned a lot from them about drilling in high-volume production. Superior drills provided by Kennametal and technical knowledge and support from Dr. Qiang Wu and Parag Hedge made our metal drilling research possible. Outstanding orthopaedic surgeons, particularly Drs. James Holmes, Andrew Palmisano, and Todd Irwin, transformed and guided our bone drilling research. We greatly appreciate the graduate students and visiting scholars who have worked with us in drilling research, including Wenwu Wu, Ali Kazu, Yao Liu, Yiwen Wang, and Barry Belmont. The support from the US National Science Foundation (Program Directors: Drs. George Hazelrigg, Bruce Kramer, and ZJ Pei), US Department of Energy (Program Director: Dr. Raymond Johnson), Ford Motor Company (Dr. William Dowling), Department of Orthopaedic Surgery at the University of Michigan at Ann Arbor, and Springer Nature (Brinda Megasyamalan and Agnes Felema) were critical to make this research and book possible.

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