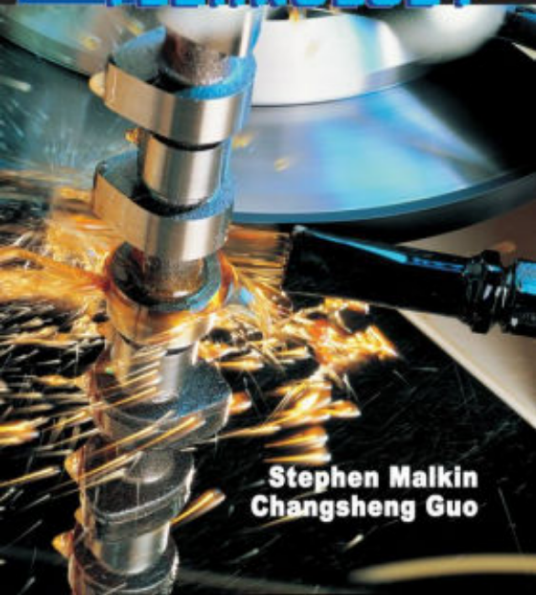
GRINDING TECHNOLOGY

2 Edition



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GRINDING TECHNOLOGY

Theory and Applications of Machining with Abrasives

SECOND EDITION

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Preface

The first edition of this book was intended to provide an integrated scientific foundation for understanding of the grinding process, which can be practically utilized for enhancing and optimizing grinding operations. After 18 years in print, the first edition is still selling and is widely referenced, but many of the newer developments in grinding led us to think that the time had come for a new edition. This second edition builds upon the first edition with greatly expanded coverage of the thermal aspects of grinding, creep-feed grinding, grinding with superabrasives, fluid flow, process simulation, optimization, and intelligent control of grinding machines.

This book is written both for the researcher and the practicing engineer. As with the first edition, it is expected that the second edition will be used as a textbook or supplement for advanced courses on machining and grinding, for industrial short courses, and as a source of fundamental and practical information about the grinding process and its utilization.

Preparation of the second edition of this book was undertaken by the authors as part of their collaborative relationship which began at the University of Massachusetts in 1989. During this time, we have had the good fortune to work with many outstanding graduate students and to benefit from interactions with and support from many colleagues and friends in academia and industry who are too numerous to mention individually.

We dedicate this book to our wives, Maccabit and Ling, who encouraged us to undertake this project and cheerfully endured our excessive indulgence in grinding and abrasive processes.

Stephen Malkin
Amherst, Massachusetts

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Preface to the First Edition

Manufacturing is becoming recognized today as an important commercial activity. Competitiveness in manufacturing, utilizing the most advanced technology, is essential in order to avert serious economic chaos in most industrialized countries. It is evident that the standard of living in countries which have been slow to address this reality is suffering. Aside from mining, agriculture, and foreign tourism, the wealth of industrialized countries is generated mostly by manufacturing.

Numerous initiatives are being undertaken to develop and implement advanced manufacturing technologies. In the United States, considerable resources are being harnessed to promote manufacturing research through such bodies as the National Science Foundation, the Department of Defense, and the newly created National Center for Manufacturing Sciences. An important thrust for this effort is to foster a more scientific or analytical approach to manufacturing. The 'rules of thumb' upon which we relied in the past and continue to depend must progressively give way to analytical engineering methodologies.

The present book is intended to provide a basic analytical approach to grinding as a machining process. Grinding research during the past four decades has established a scientific foundation, thereby providing a rational understanding which can be practically utilized. It seems appropriate at this time to present a comprehensive unified treatment of this subject. As an engineering monograph, this book is written both for the researcher and for the practicing engineer. Graduates of four-year mechanical and production engineering curricula should be able to grasp the technical content. Individual chapters would be suitable reference material in a senior- or graduate-level course in materials processing or machining.

My interest in manufacturing and grinding processes dates from about 25 years ago at the time of my graduate studies. My continued fascination and involvement in grinding research have been nurtured by the challenge of integrating a broad range of diverse technical areas including plasticity, materials, mechanics, tribology, heat transfer, control, and optimization. In this endeavor it has been my good fortune to have been associated with many talented teachers, colleagues, and students in universities where I have studied and taught. My practical experience has been enriched by many engineers I have worked with in the course of technical consulting for machine-tool builders, manufacturers of abrasive products, and

I am pleased to acknowledge the support of the publisher, Mr. Ellis Horwood. For assistance with figure preparation and typing, I am grateful to Ms P. Stephan, Ms B. Craker and Ms T. Mitchell at the University of Massachusetts, and Ms M. Schreier and Ms T. Kalmar at the Technion-Israel Institute of Technology.

This book is dedicated to the memory of my father who encouraged me to undertake this project but did not live to see its completion. The book would never have been completed without the support of my wife, Maccabit, and my children.

Stephen Malkin
Amherst, Massachusetts
December, 1988

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Chapter 1

Introduction

1.1 THE GRINDING PROCESS

Grinding is the common collective name for machining processes which utilize hard abrasive particles as the cutting medium. The grinding process of shaping materials is probably the oldest in existence, dating from the time prehistoric man found that he could sharpen his tools by rubbing them against gritty rocks. Without the capability to shape and sharpen implements by grinding, we might still be living in the Stone Age.

Nowadays, grinding is a major manufacturing process which accounts for about 20–25% of the total expenditures on machining operations in industrialized countries. Society, as we know it, would be quite impossible without grinding. Almost everything that we use has either been machined by grinding at some stage of its production, or has been processed by machines which owe their precision to abrasive operations. How could we sharpen cutting tools for turning, milling, and drilling without grinding? How could we manufacture the rolling bearings for machinery and vehicles? How could we produce disk-drive components for computers?

Within the spectrum of machining processes, the uniqueness of grinding is found in its cutting tool. Grinding wheels and tools are generally composed of two materials – tiny abrasive particles called grains or grits, which do the cutting, and a softer bonding agent to hold the countless abrasive grains together in a solid mass. Prehistoric man's abrasive tool was natural sandstone, which contains grains of sand in a silicate bond matrix. Modern grinding wheels are fabricated by cementing together abrasive grains, usually from man-made materials, with a suitable bonding material. Each abrasive grain is a potential microscopic cutting tool. The grinding process uses thousands of abrasive cutting points simultaneously and millions continually.

Grinding is traditionally regarded as a final machining process in the production of components requiring smooth surfaces and fine tolerances.

There is no process which can compete with grinding for most precision