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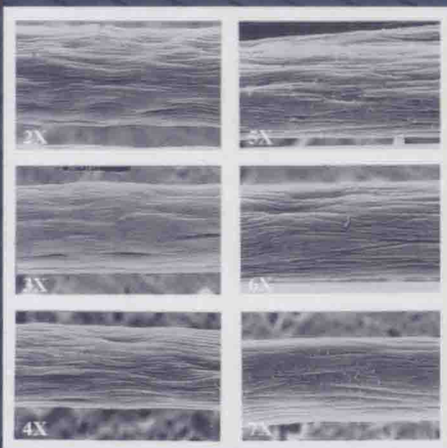

Friction in textile materials

Edited by B. S. Gupta

CRC

The Textile Institute

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Friction in textile materials

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Dedication

To Frank Bowden and David Tabor, their associates, and other scientists, who have pioneered the work in the field of the tribology of fibers.

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Preface

The first major effort in summarizing and comprehensively presenting a work on friction in textile materials was made by Howell, Mieszkis and Tabor in 1959 when they wrote the book, *Friction in Textiles* (Butterworths). Since then much has been published in the field, both at the theoretical and the practical levels, in understanding the mechanisms that apply to fibrous materials and evaluating, modeling and understanding the effects of material, structural and operational variables. Although a number of smaller reviews have appeared, a more comprehensive discussion on the subject has not been published. The project of writing the current monograph was undertaken to put together a more thorough and current treatise on friction in textiles.

The book contains 12 chapters, addressing different aspects of the subject matter (see the 'Introduction,' that follows); they are arranged in a manner that the reader can get a coherent picture of the inter-related concepts of friction in fibers. Except for the first two chapters, which are meant to provide the necessary background information about the structure and properties of textile fibers, and about friction classical laws and concepts known in the 1950s, other chapters provide the current status of the work in the respective areas and future prospects that will stimulate further research. The addition of this monograph to the literature is hoped to provide fundamental scientific and engineering knowledge for those in academia, involved in the teaching of fiber science and in the research on the behavior of assemblies, and in industry, involved in developing automated/high speed processes and in designing fibrous assemblies for new and novel products. The book should also serve as a suitable text for a course on the tribology of textiles at the graduate and senior undergraduate levels.

The chapters have undergone an extensive peer-review process in that each chapter has been reviewed and edited by two to three other authors and, in several cases, also by external experts in the field. Accordingly, the authors feel that the book is an up-to-date treatise on the subject area and will be a useful addition to the literature on textile science and engineering.

With great pleasure I extend my gratitude to the contributing authors for agreeing to develop their chapters and working with me in revising the

contents and serving as peer-reviewers of other contributions. Without their co-operation and support this major undertaking could not have been completed. Several external textile scientists also participated in the review process, notably Professor David Buchanan, North Carolina State University, USA, Professor John Hearle, UMIST, UK, and Professor Stephen Michielsen, North Carolina State University, USA. I thank these and other professional colleagues for reviewing the material and making many useful suggestions. Thanks are also due to the secretarial staff of the Department of Textiles Chemistry, Engineering and Science, for their help with word processing and miscellaneous matters, and the administration of the Department for encouragement and support throughout the project. Two of my graduate students, Mr. Ajit Moghe, Ph.D. in Fiber and Polymer Science, and Mr. Venugopal Boppa, M.S. in Textile Engineering, deserve special recognition and thanks. They spent countless hours in conducting computer searches of the literature, developing soft copies of the figures for many chapters, and formatting and developing the chapters for final submission. Finally, I thank Woodhead Publishing Limited for approaching me to consider this publication. All individuals with whom I have had the opportunity to interact, in particular, Emma Starr, Kathryn Picking, Francis Dodds and Amanda Macfarlane, were most understanding, co-operative, and helpful.

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Introduction

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The great role friction plays in our life was expressed fully by Bowden and Tabor in their book, *Introduction to Tribology* (Anchor Press, 1973): "from the ticking of clock in the morning, throughout our work and leisure until we clean our teeth at night, we are involved in tribology." Indeed it is difficult to imagine a physical phenomenon in which friction does not play a significant role. We note its works in many different forms: the force we exert in performing mechanical work, the electrical power and fuel we use in running equipment, the wear damage we find on surfaces, the temperature rise we observe in materials and devices during use, and the sound we hear in most industrial and non-industrial operations. Friction is required to be controlled for improving the efficiency of industrial operations, the quality of our products, the performance of transport equipment and devices, and the quality, durability and comfort of materials we wear or use.

Specific to textiles, friction governs the quality of the product made from and the efficiency of staple processing, twisting and winding of yarns, weaving, knitting and braiding of fabrics, and forming and finishing of final products from textiles. Surface physical properties, such as smoothness, roughness or hand, and mechanical properties, such as drape, shear, stiffness, strength and elastic recovery, are all influenced by this property. Friction also affects wear of textiles and guides. The introduction of synthetic fibers with potential for new apparel and non-apparel applications, and increasing interest in high speed automated operations, required that the tribology of fibers be understood.

It is well known that the requirement for friction is not constant; it varies from process to process and application to application, and also within a process from point-to-point and within an application from function-to-function. Usually, different values are desired for optimum performance. As an example, in the use of braided textiles such as sutures for closing wounds, a relatively lower value will be preferred for knot tying and sliding it to the wound, but a higher value will be desired for insuring knot security. Likewise, in use of textiles as apparel, this duality of requirement prevails. A lower value of friction will enhance drape and comfort properties whereas a higher value will contribute to strength and dimensional stability. While one cannot instantly and exactly vary the frictional resistance during a process or application, except by varying pressure which is not always feasible, understanding this property and the effects the material, the processing and the finishing factors produced on it can provide a useful tool for selecting parameters that are optimum for the process or the application.

The project of writing the book was undertaken to put together a current and comprehensive monograph on friction in textiles. Because the field is broad, the treatise is given as a collection of works developed by different authors. Collectively, the chapters include a useful and thorough review of the concepts and models and of the experimental procedures and results. The entire subject area is presented in two parts. The first (Chapters 1 to 5) is devoted to the understanding of the structure of materials, the laws and mechanisms applying to friction in both metals and fibers, the nature of the friction profile generally obtained and the factors affecting it, and the test methods that have been and can be used in examining the property in different types of materials and for different purposes. The second part (Chapters 6 to 12) then deals with the behavior found in specific fiber types, processes and structures.

Included in Chapter 1 is an introduction to fibers, and their structures and properties. The premise being that although friction is a surface phenomenon, it is governed by both the surface and the bulk properties. In order to understand and control friction, an understanding of a fiber's morphology, chemical and physical structures and properties is necessary. Numerous fibers exist and, therefore, the details of the above knowledge will provide the needed foundation for understanding the differences in the friction behavior found in different materials and under different sets of conditions.

The early work in friction was necessarily performed on metals, which were the materials of interest of the time. Studies on these led to the development of the classical laws. A deeper understanding of friction, however, evolved in the twentieth century with the work on non-metals, which were the elastomers, plastics, Teflon®, and fibers. The century referred to can in fact be called the renaissance of the science of tribology. The studies led to the refinement of the concept of friction by recognizing the role actual adhesion between contacting surfaces played in determining friction force. The departures from the classical laws were observed when one or both of the surfaces rubbed were either a rubber or a plastic. The role of the bulk properties of the underlying layers in the sliding or rolling action, when one of the materials was viscoelastic, was recognized. The use of a lubricant in reducing friction, heating and wear in metals, in both the low pressure-high speed and high pressure-low speed operations, was well understood. Chapter 2 gives details of this early work, in large part as discovered on and applied to metals, but also, to smaller degree, of what has been known about the behavior of other materials, i.e. rubbers, plastics and fibers.