

Atlas of fibre fracture and damage to textiles

Second edition

J W S Hearle, B Lomas, W D Cooke



The Textile Institute



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J.W.S. HEARLE, B. LOMAS, W.D. COOKE

Department of Textiles

University of Manchester Institute of Science and Technology



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PREFACE

In the late 1950s, my research students and I were working on the mechanics of twisted continuous-filament yarns, chiefly employed in tyre cords, with twist inserted in order to improve fatigue resistance in use. We therefore decided that we ought to examine the fatigue behaviour of the twisted yarns, in addition to their tensile properties. Dr Tony Booth was the first to work on the subject, but his work showed us that we really needed to know more about the fatigue properties of single fibres. A sequence of research students continued the studies through the 1960s. During this time, we sometimes used optical microscopy to look at broken fibres, but it was difficult to see the form of the break clearly.

In 1967 came the breakthrough. With a grant from the Science Research Council we bought a Cambridge Stereoscan SII scanning electron microscope, and, for the first time, we could observe fibre breaks clearly. This opened up twenty years of exploration, which is still continuing. We have explored the form of single fibre breaks made on laboratory testers. The classification and characterization of these breaks was the first line of research.

Another breakthrough occurred about the same time. The early fibre fatigue studies, using a slow cumulative extension tester, had not produced very illuminating results: usually the fibre either settled down at a certain level of elongation and did not break or it climbed up the load-elongation curve to break at its normal breaking extension. But then Geoffrey Stevens of the RAE, Farnborough, asked us to look at a problem of loss of strength of the cords of brake parachutes deployed behind fighter aircraft on landing. Frequent failures were occurring. One possible cause was fibre fatigue, because the parachute flutters at 50 Hz, each landing lasts 2 minutes, and the cords were used 35 times — which makes 210 000 cycles of tensile loading. Dr Tony Bunsell built a new fatigue tester, which was load controlled and operated at 50 Hz, and uncovered a new fatigue mechanism in nylon and polyester fibres. This started the second line of research: the development and study of fatigue testing methods.

A third important line of research consisted of case studies of fibre failure in use. Many types of product have been examined — shirts, trousers, knitwear, household linen, carpets, ropes, workwear, military webbings, etc. — and characteristic patterns of breakdown have been recognized. In addition to her responsibility for the detailed microscopy, it is in this area that Brenda Lomas has made the major contribution.

As we progressed in our studies, the files of pictures of fibre breaks grew and in 1972 we decided to start publishing 'An Atlas of Fibre Fracture' in the magazine *Textile Manufacturer*, with the thought that the articles might be collected later into a book. However, the magazine ceased publishing and the series ended, but the idea remained. The main problem was how to make the selection, for our files now contain more than 35 000 negatives.

In 1984 Ian Duerden, from the University of Western Ontario, who had been involved in studies of car seat-belt failures, came to spend a sabbatical year at UMIST learning about our work. This was the ideal opportunity for the files to be surveyed and classified and a selection of pictures started. It provided the impetus to produce this book. I finished the selection in the summer of 1986, and Brenda Lomas and I wrote the text, with some more pictures being taken by Brenda Lomas and Bob Litchfield to fill in some gaps. William Cooke contributed Part VIII, arising from his interest in textile conservation. Christine Gisburne gave some advice on the description of scanning electron microscopy in Chapter 1.

The aim of the book is first to report the academic studies of how fibres break in simple laboratory tests, and then to relate this to case studies of failure in use. To a considerable degree, we have tried to let the pictures speak for themselves, supplemented by the necessary information on how the breaks occurred, but we have included comments and explanations, with which the reader may or may not agree.

During the twenty years of these studies, many people at UMIST, staff and students, have contributed to this research. We owe a great deal to all of them. Their names are given in Appendix 1, and, where there have been publications, also in Appendix 2. I apologize for any omissions. The work has been a team effort, which it has been a privilege to lead. I hope that sharing the information with others through this book will make the efforts of everyone involved even more worthwhile.

One of the reasons for the success of the research has been the high standards of the microscopy and the photography. The credit for this rests with the experimental officers who have run the show at the practical level: first, Pat Cross, and then, for most of the time, Brenda Lomas. They have never been content with a picture which is merely adequate, but have always striven for perfection, both in pictorial quality and information content. They have been ably backed up by a succession of scanning electron microscopy technicians — John Sparrow, Alf Williams, Linda Crosby, Creana Green and Bob Litchfield — and encouraged in their high standards by the departmental photographer, Trevor Jones, who has also made most of the prints for this book. The technical staff in the workshop, particularly David Clark, have made major contributions to the development of fatigue testers.

The research has been made possible by generous grants from SRC (now SERC), substantial departmental funding in UMIST, and by contributions from industrial sponsors. We have benefited by discussions with many colleagues and friends inside and outside UMIST, and from organizations that have supplied samples for examination. In a few cases, where we could not draw on our own work, we have used pictures from other sources. All these valuable sources are listed in Appendix 1.

A growing area of fibre usage is in rigid composites. However, we have not studied these materials in our scanning electron microscopy work at UMIST; and a complete account of their fractography would fill another book. Nevertheless, it is right to include an introduction to the subject in Chapter 26. I am appreciative of the opportunity to spend a year as a Distinguished Visiting Professor of Mechanical Engineering in the University of Delaware, associated with the Center for Composite Materials, and am grateful to friends and colleagues there, who taught me more about composites.

Finally, we have been greatly helped in the preparation of the manuscript by secretary, Barbara Mottershead. I also wish to express my personal thanks to the Leverhulme Trust for a research grant as an Emeritus Fellow, which has assisted in the completion of this work.

John Hearle

*Mellor, Cheshire
September, 1988.*

PREFACE TO SECOND EDITION

The original edition of this book owed much to the encouragement of the publisher, Ellis Horwood, but, coming out as the company which he had built up changed ownership, it soon became unavailable although a demand for copies still existed. We have now been encouraged by Martin Woodhead, another publisher with a personal touch, to produce a new edition. It has been a particular pleasure to work with Patricia Morrison who joined Woodhead Publishing from Ellis Horwood, as Commissioning Editor, and Amanda Thomas in production.

For this new edition we have added more examples from work at UMIST in the 1990s, but we have also drawn more extensively on research elsewhere. Several authors have written their own additional contributions, and other researchers, listed in Appendix 1, have provided pictures and information. For Parts I to VII, this new material from UMIST and elsewhere continues the themes of the existing chapters, and the new information has been added at the ends of the chapters. Part VIII has been revised and augmented by William Cooke. A major addition to this new edition consists of two new parts — on forensic and medical studies. Finally, we have changed the title — always a source of debate between authors and publishers — in order to make it more descriptive of the book.

John Hearle

Mellor, Stockport

ADDITIONAL CONTRIBUTORS TO THE SECOND EDITION

Dr Franz-Peter Adolf is a forensic scientist at Textilkunde KT 33, Forensic Science Institute, Bundeskriminalamt, Thaerstraße 11, 65193 Wiesbaden, Germany

Dr Ian Duerden is a Professor in the Department of Materials Science, University of Western Ontario, Canada.

Dr Ali Akbar Gharehaghaji, formerly a research student in the Department of Textile Technology, University of New South Wales, Australia, is now a Senior Lecturer in the School of Textile Engineering, Isfahan University of Technology, Iran.

Dr Nigel Johnson, formerly in the Department of Textile Technology, University of New South Wales, Australia, is now Manager of the Physics and Processing Division at the Wool Research Organisation of New Zealand (WRONZ).

Dr Alan McLeod, formerly a UMIST research student, has been Research Manager of Surgicraft Ltd and is now Research & Development Manager, Pearsalls Implants, Taunton, UK.

Dr Neil Mendelson is a Professor in the Department of Molecular and Cellular Biology, University of Arizona, USA.

Dr Michael Pailthorpe is a Professor of Textile Technology at the University of New South Wales, Sydney, NSW, Australia.

Dr Leigh Phoenix is a Professor of Theoretical and Applied Mechanics at Cornell University, Ithaca, NY, USA.

Dr William Pelton is a Professor in the Department of Clothing and Textiles, Faculty of Human Ecology, The University of Manitoba, Winnipeg, Manitoba, Canada.

Dr Petru Petrina is a Senior Research Associate in the Department of Theoretical and Applied Mechanics at Cornell University, Ithaca, NY, USA.

Fran Poole is a Detective Senior Constable in the Forensic Services Group, Parramatta Crime Scene Section, NSW, Australia.

Sigrid Ruetsch is a Senior Scientist/Microscopist at TRI, Princeton, New Jersey, USA.

Dr John Thwaites is a Fellow of Gonville and Caius College and was formerly a Lecturer in the Department of Engineering, University of Cambridge, England.

Dr Janet Webster is a Teaching Fellow at the University of Otago, New Zealand.

Dr Hans-Dietrich Weigmann is a former Vice-President of Research at TRI, Princeton, New Jersey, USA.

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