

Integrated design and manufacture *using* fibre-reinforced polymeric composites

Edited by
M J Owen, V Middleton and I A Jones



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This book is dedicated to the hundreds of people who have been involved over the last 37 years with the composites programme in the Mechanical Engineering Department at the University of Nottingham

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This book is about fibre-reinforced polymers (FRPs) excluding rubber matrix materials. Although some contributors refer to 'composites', 'composite materials' or 'fibre-reinforced composite materials' the restriction to fibre-reinforced thermoplastic and thermosetting polymers still applies and rubber, metal and ceramic matrix composites are excluded. The overall intention is to show that material selection, manufacturing feasibility and material properties are strongly inter-related factors that have to be considered at an early stage in the design process in order to achieve cost-effective products. Often this can be done without recourse to elaborate calculations.

Following an introductory chapter that is intended to set the scene, there are three main parts to the book. Part I describes the main material constituents and the main manufacturing processes. Part II is based on case studies of some recent successful applications. The authors explain their development approach for both product and manufacturing process. Part II also includes chapters on adhesive technology and the growing importance of closed mould processes. Part III is an introduction to design methods with due regard to manufacturing feasibility. Three substantial appendices cover laminate analysis, sample material properties and a glossary of terms.

The provenance of the book lies in courses offered regularly by the Department of Mechanical Engineering, University of Nottingham, over the past 20 years. These comprise short intensive continuing professional development (CPD) courses and final year undergraduate and master's degree modules. CPD courses have also been presented at the premises of individual firms and trade associations both in the UK and around the world including South Africa, Singapore and other countries. The editors intend the book to be useful for similar courses and particularly to individual engineers, scientists and managers in industry who might be considering new products for which FRPs are unfamiliar candidate materials.

The editors have only acknowledged by name friends and colleagues who have made direct contributions to the book. However, over the years there have been hundreds of industrial collaborators, academic colleagues, research assistants and research students who have participated in sponsored research programmes, who have also helped with courses and who have made indirect contributions without which the present outcome would not have been possible.

About the contributors

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Dr Richard Brooks is a Senior Lecturer in the School of Mechanical, Materials, Manufacturing Engineering and Management at the University of Nottingham. Following a period in industry working for Courtaulds he gained a PhD in Engineering from the University of Cambridge in 1982 and joined the University of Nottingham in 1984 as a Lecturer in Polymer Applications. Since that time he has worked on the development of design procedures and high-volume manufacturing methods for thermoplastic composites. He has published extensively and has supervised a number of large collaborative research projects. Current research interests include orientation in short fibre composites and design with these materials, glass mat thermoplastics, co-mingled composites for structural automotive applications and the use of composites in sports equipment.

Mr P Bryant

Peter Bryant, now retired, was formerly Managing Director of Adams Hydraulics Ltd, York, manufacturers of sewage treatment equipment and purpose-designed composites products. Most recently he was Director responsible for Quality, R&D, and Project Manager for several DTI-sponsored development projects for highly stressed equipment constructed in composites. Prior to that, after training with C A Parsons & Co Ltd, Newcastle upon Tyne, manufacturers of turbo-generators, he worked for many years in Engineering and Production Management positions within the Baker Perkins group, becoming Managing Director of Baker Perkins (latterly APV) Chemical Machinery Ltd, Stoke on Trent, manufacturers of mixing, compounding and extrusion equipment for the plastics and chemical industries.

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Dr G Eckold

Geoff Eckold was educated at University of Manchester Institute of Science and Technology. After completing a PhD thesis concerned with the design of filament wound structures he joined Plastics Design & Engineering (PDE) as a Design Engineer. His responsibilities covered the design, manufacture and installation of composite process plant. While at PDE he became involved in the development of design codes and standards for composite design. In 1984 he joined the Harwell Laboratory of AEA Technology and became involved in the design and prototype study of composite components for automotive, offshore, aerospace, process and engineering industries. He also was concerned with process modelling and the integration of CAD techniques for composite manufacture. Geoff Eckold is currently a Senior Manager within the engineering business of AEA Technology with overall responsibility for a wide range of materials and engineering projects within the industrial sector.

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Bill Lees obtained both his BSc and PhD degrees in organic chemistry from Manchester University and after a brief period in the paint industry spent his working life in the field of engineering adhesives. He was instrumental in developing products for civil, mechanical, structural, electrical and electronic applications. As a founder member of the PermaBond Division of NSC Ltd – now an ICI Group Company – and its Technical Director for more than 20 years he was responsible for the initial UK manufacture of both the cyanoacrylate and anaerobic adhesives. He also assisted in the establishment and exploitation of the now ubiquitous toughened adhesives. He is both author and editor and prepared the logic for both the PAL and EASel software – acknowledged expert systems for the selection of engineering adhesives. Dr Lees has served on a number of BS committees. Now recently retired, he is an independent consultant currently engaged in CEN on the preparation of Euro standards for structural adhesives. He is also a member of the DTI's Industrial Advisory Group.

Prof V Middleton

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Dr J A Nixon

After graduation in Metallurgy and Materials Science at Nottingham University in 1980 John Nixon conducted research into the flow and cure behaviour of sheet moulding compounds which led to a PhD in 1984. Following a further period of research into moulding and NDT techniques for thermoplastic composites at Bath University he joined Vosper Thornycroft (UK) Ltd to work on composite ship construction and the application of composites in the offshore oil and gas industry. He joined the Scott Bader Co Ltd in 1993 to work on fabrication process development where he now manages the Applications and Testing Group.

Prof M J Owen

Mike Owen was Professor of Reinforced Plastics in the Mechanical Engineering Department of the University of Nottingham until his recent retirement. After National Service he obtained a BSc in Mechanical Engineering from the University of Birmingham before spending three years in North America. After returning to Nottingham he was awarded a PhD degree for fatigue studies of gas turbine compressor disks and he was appointed to a lectureship. For over 30 years he was involved with FRP research projects in collaboration with industry, especially Ford Motor Company. He was the