

World Pultrusion Technology By Inline

In this book, experts on textile technologies convey both general and specific information on various aspects of textile engineering, ready-made technologies, and textile chemistry. They describe the entire process chain from fiber materials to various yarn constructions, 2D and 3D textile constructions, preforms, and interface layer design. In addition, the authors introduce testing methods, shaping and simulation techniques for the characterization of and structural mechanics calculations on anisotropic, pliable high-performance textiles, including specific examples from the fields of fiber plastic composites, textile concrete and textile membranes. Readers will also be familiarized with the potential offered by increasingly employed textile structures, for instance in the fields of composite technology, construction technology, security technology and membrane technology.

Composite materials have aroused a great interest over the last few decades, as proven by the huge number of scientific papers and industrial progress. The increase in the use of composite structures in different engineering practices justify the present international meeting where researches from every part of the globe can share and discuss the recent advancements regarding the use of structural components within advanced applications such as buckling, vibrations, repair, reinforcements, concrete, composite laminated materials and more recent metamaterials. Studies about composite structures are truly multidisciplinary and the given contributions can help other researches and professional engineers in their own field. This Conference is suitable as a reference for engineers and scientists working in the professional field, in the industry and the academia and it gives the possibility to share recent advancements in different engineering practices to the outside world. This book aims to collect selected plenary and key-note lectures of this International Conference. For this reason, the establishment of this 20th edition of International Conference on Composite Structures has appeared appropriate to continue what has been begun during the previous editions. ICCS wants to be an occasion for many researchers from each part of the globe to meet and discuss about the recent advancements regarding the use of composite structures, sandwich panels, nanotechnology, bio-composites, delamination and fracture, experimental methods, manufacturing and other countless topics that have filled many sessions during this conference. As a proof of this event, which has taken place in Paris (France), selected plenary and key-note lectures have been collected in the present book.

To reduce the amount of Rare-earth Elements in high efficient permanent magnet electric motors, the magnetic stray flux has to be reduced. Additionally, a temperature reduction inside the motor reduces the necessary amount of the so called Heavy Rare-earth Elements, which account for the bulk part of the magnet material costs. In this thesis a permanent magnet motor in wet rotor configuration for an automotive application is designed. It was shown that by simple thermal improvements of the electric insulation system the maximum temperature of the stator can be reduced. Extensive measurements on different combinations of insulation material of the stator and the development of a new thermal model for orthocyclic wound stators were performed. Due to the use of fiber cans eddy current losses could be eliminated and the stray flux minimized. In a second stage a magnetizing fixture was build up, which is able to magnetize the buried magnets inside the rotor. The rotor and the magnetizing fixture was developed, so that the magnets can be optimal magnetized. To check the quality of the magnets the magnetizing coil was developed in a way, such that the hysteresis curve of every single magnet during magnetization can be measured. Different magnets were tested and ways to calculate parasitics are given. Um die Menge an Selten Erden in hoch-effizienten permanent erregten Elektromotoren zu reduzieren, muss der magnetische Streufluss verringert werden. Eine Temperaturreduktion im Motor verringert zudem die nötige Menge an so genannten schweren Selten Erden, welche einen Großteil der Kosten der Magnetmaterialien

ausmachen. In dieser Arbeit wird dazu ein permanent erregter Nassläufer für eine automotiv Anwendung ausgelegt. Es konnte gezeigt werden, dass durch einfache Maßnahmen im Bereich der elektrischen Isolation die maximale Temperatur im Stator reduziert werden konnte. Umfangreiche Messungen an verschiedenen Kombinationen von elektrischen Isolationen des Stators und die Entwicklung eines neuen thermischen Modells für orthozyklisch gewickelte Statoren wurden getätigt. Durch Einsatz von Spaltrohren aus Faserverbundwerkstoffen konnten die Wirbelstromverluste beseitigt werden und der Streufluss minimiert werden. In einem zweiten Schritt wurde eine Magnetisiervorrichtung aufgebaut, mit der die zu Anfang unmagnetisierten eingebetteten Magneten im Rotor aufmagnetisiert werden konnten. Der Rotor wurde zudem zusammen mit der Magnetisierungsspule so ausgelegt, dass die Magnete optimal magnetisiert werden können. Um die Qualität der Magnete zu testen wurde die Magnetisierungsspule zudem so ausgelegt, dass eine Messung der Hysteresekurve jedes einzelnen Magneten während der Magnetisierung möglich ist. Verschiedene Magnete wurden vermessen und Möglichkeiten zur Bestimmung von parasitären Effekten gegeben.

Inline Fibreglass is the world leader in the development, design, and application of fibreglass pultrusion technology. Inline's success in Canada has triggered its president, George Casselman, to consider internationalizing beyond North America. The case asks students to consider the global strategy for Inline.

This comprehensive book provides guidelines for maximizing plastics processing efficiency in the manufacture of all types of products, using all types of plastics. A practical approach is employed to present fundamental, yet comprehensive, coverage of processing concepts. The information and data presented by the many tables and figures interrelate the different variables that affect injection molding, extrusion, blow molding, thermoforming, compression molding, reinforced plastics molding, rotational molding, reaction injection molding, coining, casting, and other processes. The text presents a great number of problems pertaining to different phases of processing. Solutions are provided that will meet product performance requirements at the lowest cost. Many of the processing variables and their behaviors in the different processes are the same, as they all involve basic conditions of temperature, time, and pressure. The book begins with information applicable to all processes, on topics such as melt softening flow and controls; all processes fit into an overall scheme that requires the interaction and proper control of systems. Individual processes are reviewed to show the effects of changing different variables to meet the goal of zero defects. The content is arranged to provide a natural progression from simple to complex situations, which range from control of a single manual machine to simulation of sophisticated computerized processes that interface with many different processing functions.

Dynamic Response and Failure of Composite Materials and Structures presents an overview of recent developments in a specialized area of research with original contributions from the authors who have been asked to outline needs for further investigations in their chosen topic area. The result is a presentation of the current state-of-the-art in very specialized research areas that cannot be found elsewhere in the literature. For example, Massabò presents a newly developed theory for laminated composite plates that accounts for imperfect bonding between layers with new solutions for problems involving thermal effects. This theory is new and computationally-efficient, and the author describes how it fits in the broader context of composite plate theory. Abrate discusses the design of composite marine propellers and presents a detailed derivation of the equations of motion of a rotating blade, including centrifugal effects and the effects of pre-twisting and other geometric parameters. This book is a major reference resource for academic and industrial researchers and designers working in aerospace, automotives, and the marine engineering industry. Presents recent developments in a research field that has experienced tremendous advances because of improved computational capabilities, new materials, and new testing facilities. Includes contributions from

leading researchers from Europe and the USA who present the current state-of-the-art, including unique and original research Provides extensive experimental results and numerical solutions Appeals to a broad range of professional researchers working in aerospace, automotive, and marine engineering fields

The marine environment presents significant challenges for materials due to the potential for corrosion by salt water, extreme pressures when deeply submerged and high stresses arising from variable weather. Well-designed fibre-reinforced composites can perform effectively in the marine environment and are lightweight alternatives to metal components and more durable than wood. *Marine Applications of Advanced Fibre-Reinforced Composites* examines the technology, application and environmental considerations in choosing a fibre-reinforced composite system for use in marine structures. This book is divided into two parts. The chapters in Part One explore the manufacture, mechanical behavior and structural performance of marine composites, and also look at the testing of these composites and end of life environmental considerations. The chapters in Part Two then investigate the applications of marine composites, specifically for renewable energy devices, offshore oil and gas applications, rigging and sails. Underwater repair of marine composites is also reviewed. *Comprehensively examines all aspects of fibre-reinforced marine composites, including the latest advances in design, manufacturing methods and performance Assesses the environmental impacts of using fibre-reinforced composites in marine environments, including end of life considerations Reviews advanced fibre-reinforced composites for renewable energy devices, rigging, sail textiles, sail shape optimisation and offshore oil and gas applications* Composite materials are used as substitutions of metals/traditional materials in aerospace, automotive, civil, mechanical and other industries. The present book collects the current knowledge and recent developments in the characterization and application of composite materials. To this purpose the volume describes the outstanding properties of this class of advanced material which recommend it for various industrial applications.

Composite materials often demand a unique combination of properties, including high thermal and oxidative stability, toughness, solvent resistance and low dielectric constant. This book, "*Thermoplastic - Composite Materials*", is comprised of seven excellent chapters, written for all specialized scientists and engineers dealing with characterization, thermal, mechanical and technical properties, rheological, morphological and microstructure properties and processing design of composite materials.

Polymer matrix composites are used extensively across a wide range of industries, making the design and development of effective manufacturing processes of great importance. *Manufacturing techniques for polymer matrix composites (PMCs)* provides an authoritative review of the different technologies employed in the manufacture of this class of composite. Following an introduction to composites and manufacturing processes, part one reviews the manufacturing of short fiber and nanoparticle based polymer matrix composites, with injection and compression molding examined in depth. Thermoplastic processing is the focus of part two. Sheet forming, fabric thermostamping, filament winding and continuous fiber reinforced profiles are investigated. Part three reviews thermoset processing. A survey of resin transfer molding follows, including vacuum-assisted and compression resin transfer molding. The pultrusion process is then

considered, before the book concludes with an investigation into autoclave and out-of-autoclave curing processes in polymer matrix composites. With its distinguished editors and international team of expert contributors, Manufacturing techniques for polymer matrix composites (PMCs) is an essential guide for engineers and scientists working in the field of polymer matrix composites. Provides an authoritative review of the different technologies employed in the manufacture of polymer matrix composites Reviews the manufacturing of short fiber and nanoparticle-based polymer matrix composites, with injection and compression molding examined in depth Examines thermoplastic processing, sheet forming, fabric thermostamping, filament winding and continuous fiber reinforced profiles

Clay–Polymer Nanocomposites is a complete summary of the existing knowledge on this topic, from the basic concepts of synthesis and design to their applications in timely topics such as high-performance composites, environment, and energy issues. This book covers many aspects of synthesis such as in-situ polymerization within the interlamellar spacing of the clays or by reaction of pristine or pre-modified clays with reactive polymers and prepolymers. Indeed, nanocomposites can be prepared at industrial scale by melt mixing. Regardless the synthesis method, much is said in this book about the importance of the clay pre-modification step, which is demonstrated to be effective, on many occasions, in obtaining exfoliated nanocomposites. Clay–Polymer Nanocomposites reports the background to numerous characterization methods including solid state NMR, neutron scattering, diffraction and vibrational techniques as well as surface analytical methods, namely XPS, inverse gas chromatography and nitrogen adsorption to probe surface composition, wetting and textural/structural properties. Although not described in dedicated chapters, numerous X-ray diffraction patterns of clay–polymer nanocomposites and reference materials are displayed to account for the effects of intercalation and exfoliations of layered aluminosilicates. Finally, multiscale molecular simulation protocols are presenting for predicting morphologies and properties of nanostructured polymer systems with industrial relevance. As far as applications are concerned, Clay–Polymer Nanocomposites examines structural composites such as clay–epoxy and clay–biopolymers, the use of clay–polymer nanocomposites as reactive nanocomposite fillers, catalytic clay-(conductive) polymers and similar nanocomposites for the uptake of hazardous compounds or for controlled drug release, antibacterial applications, energy storage, and more. The most comprehensive coverage of the state of the art in clay–polymer nanocomposites, from synthesis and design to opportunities and applications Covers the various methods of characterization of clay–polymer nanocomposites - including spectroscopy, thermal analyses, and X-ray diffraction Includes a discussion of a range of application areas, including biomedicine, energy storage, biofouling resistance, and more

Independent, practical guidance on the structural design of polymer composites

is provided for the first time in this book. Structural designers familiar with design of conventional structural materials such as steel and concrete will be able to use it to design a broad range of polymeric composites for structural applications, using glass fibre reinforced plastic materials, components, connections and assemblies.

This handbook provides a framework for understanding how to characterize plastic manufacturing processes for use in troubleshooting problems. The 21 chapters are authored by well-known and experienced engineers who have specialized knowledge about the processes covered in this practical guide. From the Preface: "In every chapter, the process is described and the most common problems are discussed along with the root causes and potential technical solutions. Numerous case studies are provided that illustrate the troubleshooting process. Mark A. Spalding, The Dow Chemical Company

Interest in sustainable, green building practices is greater than ever. Whether concerned about allergies, energy costs, old-growth forests, or durability and long-term value, homeowners and builders are looking for ways to ensure that their homes are healthy, safe, beautiful, and efficient. In these pages are descriptions and manufacturer contact information for more than 1,400 environmentally preferable products and materials. All phases of residential construction, from sitework to flooring to renewable energy, are covered. Products are grouped by function, and each chapter begins with a discussion of key environmental considerations and what to look for in a green product. Over 40 percent revised, this updated edition includes over 120 new products. Categories of products include: Sitework and landscaping Outdoor structures Decking Foundations, footers, and slabs Structural systems and components Sheathing Exterior finish and trim Roofing Doors and windows Insulation Flooring and floor coverings Interior finish and trim Caulks and adhesives Paints and coatings Mechanical systems/HVAC Plumbing, electrical, and lighting Appliances Furniture and furnishings Renewable energy Distributors and retailers An index of products and manufacturers makes for easy navigation. There is no more comprehensive resource for both the engaged homeowner and those who design and build homes. Editor Alex Wilson is president of BuildingGreen, an authoritative source for information on environmentally responsible design and construction, which also publishes Environmental Building News. Co-editor Mark Piepkorn has extensive experience with natural and traditional building methods.

Sheet forming is the most common process used in metal forming and is therefore constantly being adapted or modified to suit the needs of forming composite sheets. Due to the increasing availability of various types of fibre reinforced polymeric sheets, especially with thermoplastic matrices, the scope of use of such materials is rapidly expanding in the automobile, building, sports and other manufacturing industries beyond the traditional areas of aerospace and aircraft applications. This book contains twelve chapters and attempts to cover different aspects of sheet forming including both thermoplastic and thermosetting

materials. In view of the expanded role of fibre reinforced composite sheets in the industry, the book also describes some non-traditional applications, processes and analytical techniques involving such materials. The first chapter is a brief introduction to the principles of sheet metal forming. The next two chapters introduce the various forms of materials, manufacturing techniques and the fundamentals of computer simulation. Chapter 4 describes the different aspects of thermoforming of continuous fibre reinforced thermoplastics and the following chapter studies the shear and frictional behaviour of composite sheets during forming. Chapter 6 explores the possibility of applying the grid strain analysis method in continuous fibre reinforced polymeric sheets. The next two chapters address fundamental concepts and recent developments in finite element modelling and rheology. Chapter 9 introduces the theory of bending of thermoplastic composite sheets and shows a novel way of determining both longitudinal and transverse viscosities through vee-bend tests. A significant expansion in the usage of composite materials is taking place in biomedical areas. Chapter 10 discusses the thermoforming of knitted fabric reinforced thermoplastics for load bearing and anisotropic bio-implants. The final chapter introduces roll forming, a commonly used rapid manufacturing process for sheet metals, and discusses the possibility of applying it economically for continuous reinforced thermoplastic sheets.

Inline Fibreglass

Over the past two decades concrete has enjoyed a renewed level of research and testing, resulting in the development of many new types of concrete. Through the use of various additives, production techniques and chemical processes, there is now a great degree of control over the properties of specific concretes for a wide range of applications. New theories, models and testing techniques have also been developed to push the envelope of concrete as a building material. There is no current textbook which brings all of these advancements together in a single volume. This book aims to bridge the gap between the traditional concrete technologies and the emerging state-of-the-art technologies which are gaining wider use.

The Plastics Handbook provides everything important there is to know about plastics, comprehensively compiled in a compact and well-organized format. From material properties to machines, processing, and applications, the user will find detailed information that allows the successful implementation of new materials and technologies. This concise, competent, modern reference not only explains the basic facts and interrelationships, but also serves as a practical guide for engineers to help them succeed in today's challenging, global industrial world. Searching for specific materials, properties, or any other information is particularly easy, because the reader also has free access to the electronic version of the book. The 5th edition is comprehensively updated throughout, with a new clearer layout. Also now in full color! Contents: - Common Acronyms in Plastics Technology - Introduction (Economic Significance, Classification,

Composition, Effects of Processing on Properties, Modifications of Plastic Materials) - Material Properties and Testing Methods - Plastic Processing Technologies - Plastic Materials - Additives, Fillers, and Fibers - Material Properties Overview

Advances in Technical Nonwovens presents the latest information on the nonwovens industry, a dynamic and fast-growing industry with recent technological innovations that are leading to the development of novel end-use applications. The book reviews key developments in technical nonwoven manufacturing, specialist materials, and applications, with Part One covering important developments in materials and manufacturing technologies, including chapters devoted to fibers for technical nonwovens, the use of green recycled and biopolymer materials, and the application of nanofibres. The testing of nonwoven properties and the specialist area of composite nonwovens are also reviewed, with Part Two offering a detailed and wide-ranging overview of the many applications of technical nonwovens that includes chapters on automotive textiles, filtration, energy applications, geo- and agrotextiles, construction, furnishing, packaging and medical and hygiene products. Provides systematic coverage of trends, developments, and new technology in the field of technical nonwovens Focuses on the needs of the nonwovens industry with a clear emphasis on applied technology Contains contributions from an international team of authors edited by an expert in the field Offers a detailed and wide-ranging overview of the many applications of technical nonwovens that includes chapters on automotive textiles, filtration, energy applications, geo- and agrotextiles, and more

This book deals with all aspects of advanced composite materials; what they are, where they are used, how they are made, their properties, how they are designed and analyzed, and how they perform in-service. It covers both continuous and discontinuous fiber composites fabricated from polymer, metal, and ceramic matrices, with an emphasis on continuous fiber polymer matrix composites. This book contains advanced-level research material in the area of lubrication theory and related aspects, presented by eminent researchers during the International Conference on Advances in Tribology and Engineering Systems (ICATES 2013) held at Gujarat Technological University, Ahmedabad, India during October 15–17, 2013. The material in this book represents the advanced field of tribology and reflects the work of many eminent researchers from both India and abroad. The treatment of the presentations is the result of the contributions of several professionals working in the industry and academia. This book will be useful for students, researchers, academicians, and professionals working in the area of tribology, in general, and bearing performance characteristics, in particular, especially from the point-of-view of design. This book will also appeal to researchers and professionals working in fluid-film lubrication and other practical applications of tribology. A wide range of topics has been included despite space and time constraints. Basic concepts and

fundamentals techniques have been emphasized upon, while also including highly specialized topics and methods (such as nanotribology, bio-nanotribology). Care has been taken to generate interest for a wide range of readers, considering the interdisciplinary nature of the subject.

Presented here are 130 refereed papers given at the 36th MATADOR Conference held at The University of Manchester in July 2010. The MATADOR series of conferences covers the topics of Manufacturing Automation and Systems Technology, Applications, Design, Organisation and Management, and Research. The proceedings of this Conference contain original papers contributed by researchers from many countries on different continents. The papers cover the principles, techniques and applications in aerospace, automotive, biomedical, energy, consumable goods and process industries. The papers in this volume reflect: • the importance of manufacturing to international wealth creation; • the emerging fields of micro- and nano-manufacture; • the increasing trend towards the fabrication of parts using lasers; • the growing demand for precision engineering and part inspection techniques; and • the changing trends in manufacturing within a global environment.

This text teaches readers how to analyse and design with fiber reinforced polymers (FRP) for civil engineering applications. It demystifies FRP composites and demonstrates applications where their properties make them ideal materials to consider off-shore and waterfront structures, factories, and storage tanks.

The book offers an in-depth review of the materials design and manufacturing processes employed in the development of multi-component or multiphase polymer material systems. This field has seen rapid growth in both academic and industrial research, as multiphase materials are increasingly replacing traditional single-component materials in commercial applications. Many obstacles can be overcome by processing and using multiphase materials in automobile, construction, aerospace, food processing, and other chemical industry applications. The comprehensive description of the processing, characterization, and application of multiphase materials presented in this book offers a world of new ideas and potential technological advantages for academics, researchers, students, and industrial manufacturers from diverse fields including rubber engineering, polymer chemistry, materials processing and chemical science. From the commercial point of view it will be of great value to those involved in processing, optimizing and manufacturing new materials for novel end-use applications. The book takes a detailed approach to the description of process parameters, process optimization, mold design, and other core manufacturing information. Details of injection, extrusion, and compression molding processes have been provided based on the most recent advances in the field. Over two comprehensive sections the book covers the entire field of multiphase polymer materials, from a detailed description of material design and processing to the cutting-edge applications of such multiphase materials. It provides both precise guidelines and general concepts for the present and future leaders in academic and industrial sectors.

Wood-polymer composites (WPC) are materials in which wood is impregnated with monomers that are then polymerised in the wood to tailor the material for special applications. The resulting properties of these materials, from lightness and enhanced mechanical properties to greater sustainability, has meant a growing number of applications in such areas as building, construction and automotive engineering. This important book reviews the manufacture of wood-polymer composites, how their properties can be assessed and improved and their range of uses. After an introductory chapter, the book reviews key aspects of manufacture, including raw materials, manufacturing technologies and interactions between wood and synthetic polymers. Building on this foundation, the following group of chapters discusses mechanical and other properties such as durability, creep behaviour and processing

performance. The book concludes by looking at orientated wood-polymer composites, wood-polymer composite foams, at ways of assessing performance and at the range of current and future applications. With its distinguished editors and international team of contributors, Wood-polymer composites is a valuable reference for all those using and studying these important materials. Provides a comprehensive survey of major new developments in wood-polymer composites Reviews the key aspects of manufacture, including raw materials and manufacturing technologies Discusses properties such as durability, creep behaviour and processing performance

This basic source for identification of U.S. manufacturers is arranged by product in a large multi-volume set. Includes: Products & services, Company profiles and Catalog file.

The potential application areas for polymer composites are vast. While techniques and methodologies for composites design are relatively well established, the knowledge and understanding of post-design issues lag far behind. This leads to designs and eventually composites with disappointing properties and unnecessarily high cost, thus impeding a wider industrial acceptance of polymer composites. Manufacturing of Polymer Composites completely covers pre- and post-design issues. While the book enables students to become fully comfortable with composites as a possible materials choice, it also provides sufficient knowledge about manufacturing-related issues to permit them to avoid common pitfalls and unmanufacturable designs. The book is a fully comprehensive text covering all commercially significant materials and manufacturing techniques while at the same time discussing areas of research and development that are nearing commercial reality.

Vols. for 1970-71 includes manufacturers' catalogs.

- One of very few books available to cover this subject area.
- A practical book with a wealth of detail. This book covers the major manufacturing processes for polymer matrix composites with an emphasis on continuous fibre-reinforced composites. It covers the major fabrication processes in detail. Very few books cover the details of fabrication and assembly processes for composites. This book is intended for the engineer who wants to learn more about composite processing: any one with some experience in composites should be able to read it. The author, who has 34 years experience in the aerospace industry, has intentionally left out mathematical models for processes so the book will be readable by the general engineer. It differs from other books on composites manufacturing in focussing almost solely on manufacturing processes, while not attempting to cover materials, test methods, mechanical properties and other areas of composites.

Pultrusion for engineers is a comprehensive overview of the latest developments and applications for this growing and increasingly important area of the fibre reinforced plastics industry. Trevor Starr is well known as a specialist consultant with many year's experience in the FRP world. He has assembled an international panel of distinguished experts to provide the widest possible coverage of the state-of-the-art in novel pultrusion applications and development including many leading US researchers such as Brandt Goldworthy, regarded by many as the father of modern pultrusion. Because this book is one of very few to cover pultrusion, it is essential reading for industrial producers of pultruded profiles, chemical companies producing resins and composite materials specialists eager to reach the new markets in, for example, civil engineering that

are rapidly being opened up to design solutions involving pultrusions. The legacy of Leo Hendrik Baekeland and his development of phenol formaldehyde resins are recognized as the cornerstone of the Plastics Industry in the early twentieth century, and phenolic resins continue to flourish after a century of robust growth. On July 13, 1907, Baekeland filed his "heat and pressure" patent related to the processing of phenol formaldehyde resins and identified their unique utility in a plethora of applications. The year 2010 marks the Centennial Year of the production of phenolic resins by Leo Baekeland. In 1910, Baekeland formed Bakelite GmbH and launched the manufacture of phenolic resins in Erkner in May 1910. In October 1910, General Bakelite began producing resins in Perth Amboy, New Jersey. Lastly, Baekeland collaborated with Dr. Takamine to manufacture phenolic resins in Japan in 1911. These events were instrumental in establishing the Plastics Industry and in tracing the identity to the brilliance of Dr. Leo Baekeland. Phenolic resins remain as a versatile resin system featuring either a stable, thermoplastic novolak composition that cures with a latent source of formaldehyde (hexa) or a heat reactive and perishable resole composition that cures thermally or under acidic or special basic conditions. Phenolic resins are a very large volume resin system with a worldwide volume in excess of 5 million tons/year, and its growth is related to the gross national product (GNP) growth rate globally.

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