Introduction

R SHISHOO, Shishoo Consulting AB, Sweden

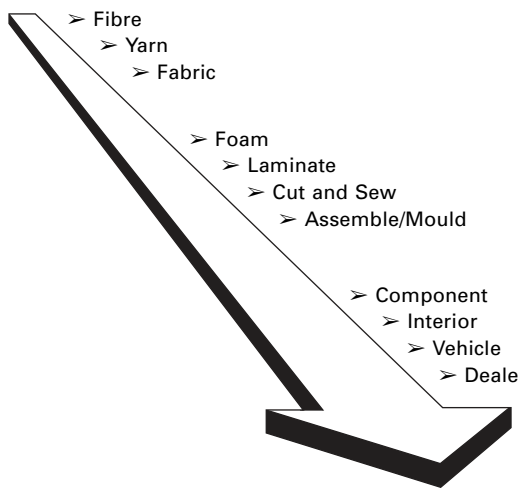
Automotive textiles represent the most valuable world market for technical textiles and within this segment there is a broad spectrum of products comprising novel textile structures with performance properties and attractive design. Total global production of cars and light trucks in 2006 was 67,723,891 units (*Automotive News*, 2007). The EU is the world's largest automotive manufacturer with about 16 million new passenger cars and 1.8 million light commercial vehicles in 2006. The global market for automotive interiors was worth an estimated US$165 billion in 2005 and is expected to grow to an estimated US$210 billion by 2015. The demand and production of vehicles will occur at increasing pace in developing countries – mainly China and India. Quite a large number of different textiles are used in the production of a car.

Textile advances in the automotive industry have been spearheaded by advances in science and technology of fibres and fabric/web forming technologies. These advances have led to the development of textiles and textile-based components for a broad variety of automotive applications which are capable of meeting the industry's tough specifications regarding high performance during use. Automotive textiles represent the most valuable world market for technical textiles and within this segment there is a broad spectrum of products comprising novel textile structures and high quality design. Automotive technical textiles cover a broad range of applications that includes: upholstery and seating, floor covering, trunk liners, headliners, door and side-panel coverings, pillar coverings, sun-visors as well as safety belts, airbags, thermal and sound insulators, filter fabrics, battery separators, hose/belt products, tyres and a variety of textile-reinforced flexible and hard composites. The textiles for interior furnishing are primarily made of woven, weft knitted, warp knitted, tufted and laminated fabrics and nonwovens. The design, aesthetics, feel and comfort are important considerations for automotive textiles. They are designed and developed according to strict technical specifications set up by the industry and must be able to meet many end-use requirements such as: high resistance to different types of mechanical actions under severe external environmental conditions of temperature, humidity,

sunlight and soiling. Since seat covers are not washed, these must show strong soil masking behaviour. The design and performance properties of technical textiles present in automotive interiors are among the most important criteria for consumer satisfaction.

There have been interesting developments taking place in the production of 3D fabrics using all forms of manufacturing technologies *viz*. weaving, knitting, braiding and nonwoven processes. The 3D textile structures have great potential as automotive components in both load-bearing and non-load bearing applications. For example, spacer fabrics can be used as substitutes for polyurethane (PUR) foam in car seats and thereby solve the recycling problems with PUR foam. 3D fabrics are used as reinforcement fibre network in textile composites in both load bearing and non-load bearing automotive components. They are also used as preforms for moulding of components and component parts.

The supply chain for textiles in the production process of a vehicle has a distinctive feature and is unlike textile supply chains in other application sectors (see Fig. I.1). In the automotive supply chain, original equipment manufacturers (OEMs) are the vehicle producers, and the textile component manufacturers do not sell their products directly to OEMs. They have to position their entry in the supply chain depending on the nature of their products and the general specifications passed down and acceptance granted by the OEMs. In the automobile industry, suppliers to OEMs do not have much power and the cost pressures of OEMs have intensified, resulting in long-term contracts being opened for new more competitive bidding from global suppliers.



I.1 Supply chain.

The diversity in textiles for automotive end uses offers plenty of opportunities for growth in the automotive textiles industry because of the ever increasing demands on aesthetics, comfort and safety of passengers as well as the environmental issues such as low weight, lower energy consumption and recycling after a vehicle's life cycle. Many industrial sub-sectors in the automotive textile supply chain are continuously looking for specialised fibre and fabric/web-forming technologies, specialised finishing and coating processes, specialised testing specifications and specialised component-forming technology.

The environmental requirements are putting pressure on the automotive industry to reduce a vehicle's fuel consumption and thereby reduce the CO_2 emission. One way to achieve this goal is by reducing the weight of the vehicle. Textiles can play a big part in this if structural textile composites can be developed to replace the heavy metal-based load-bearing components. Besides, strong requirements do exist in the European automotive sector due to the European Directive on end-of-life vehicles. This necessitates some design changes upstream in order to develop new textile products which are 100% recyclable. Nowadays, many automotive textile products are composed of two or more types of raw materials, which are difficult to separate, and are only partially recyclable.

Airbags and seat belts constitute a major tool for consumer safety. The airbag market has had strong growth over the last decade as a result of increasing market penetration not only by the frontal airbag system but also by the side impact and side curtain airbags. Seat belt development has reached maturity and these are now an integral part of all cars and trucks.

Leather interiors have been perceived in the market place as a luxury level option. Leather and its substitutes are used in the automotive industry as upholstery material for seats, headrests, as covering material for dash boards, back shelves and door linings, for centre consoles, gear shifts, steering wheels and ceilings as well as for accessories. Coated textile substrates – summarised under the name artificial leather – compete with 'real leather' in the many applications in car interiors. Whereas leather consists of a meshwork of collagen fibres, artificial leathers are compound materials made of textile substrates and polymeric layer/s.

Tyres constitute the largest application for textiles in automotive applications. Tyre markets differ from those for other automotive components in that end users consume as much as two-thirds of total supply. Only one-third of tyres are supplied to OEMs.

About the book

The objective of this book is to give the reader a comprehensive description of the advances made in textile materials and technologies from the point of

view of their application in the automotive industry. The contents of the book have been planned to cover many topics of interest ranging from: technical requirements and specification of automotive textiles; mapping of the automotive supply chain; design management for performance and style in automotive textiles; advances in woven, knitted and nonwoven materials for varied automotive applications, and requirements of safety, comfort, noise reduction and recycling. This book comprises four parts: Part I: General, Chapters 1–5; Part II: Automotive interiors, Chapters 6–11; Part III: Safety applications of automotive textiles, Chapters 12–13; and Part IV: Use of textiles in automotive bodywork, Chapters 14–15.

The contributors to this book represent a team of international experts and specialists from both academic and industrial worlds.

In Chapter 1, Erik Söderbaum writes about the requirements for automotive textiles from a car producer's perspective. He describes Volvo Car Corporation's criteria for selection of technical textiles which include the technical requirements, the design requirements, the purchase requirements and the purchase engineering requirements. Volvo purchases upholstery material which includes textiles for seats. Other textiles in the interior are purchased by system suppliers but developed by Volvo. Volvo has some specific technical demands – design prerequisites, master samples, drawings, technical regulations, etc., where they also specify testing methods. There are some unique and extra tough demands for textiles including light-fastness, ageing, fogging/emissions, dirt resistance/cleanability. Volvo's development work needs early involvement by textile suppliers. The suppliers must have a creative design/styling department of their own and a flexible production capacity. The normal lead time is 12–24 months to develop a new textile. As Volvo has warranty periods up to four years in some markets, the textile supplier will also be involved in regress issues – continuous improvement is a must.

In Chapter 2, Nancy Powell, Robert Barnhardt and Robert Handfield map the automotive textile supply chain and write about the market drivers, trends in automotive textiles, quick response and just in time concepts, effect of globalisation and future trends. The sourcing of textile products for vehicles is typical of the complex supplier network for the large-scale global automotive industry. The demand for rapid prototyping, cost effectiveness and streamlining of supply systems is critical in all component parts, but particularly in automotive textile materials. In the tiered structure of the automotive supply chain the original equipment manufacturer (OEM) is responsible for initial overall design, assembly and marketing of the complete vehicle and brand through dealerships to the consumer. A complete system component such as an interior compartment would be supplied directly to the OEM by a Tier One supplier. A Tier Two company would supply subassemblies to the interior system. The individual parts of these subassemblies would be sourced to a

Tier Three supplier, and the materials would be provided by a Tier Four company. Some companies function in roles across tier levels. A textile company may be considered a supplier at the third or fourth tier. In order to improve performance in the automotive supply chain and create a truly integrated value system, a number of tactical and strategic changes will be required throughout the automotive textile supply chain.

In Chapter 3, Thomas Stegmaier, and his co-authors write about the advances made in woven, weft-knitted and warp-knitted fabrics used as textile components in automotive interiors. Owing to their function in the application, automotive textiles have to fulfil comprehensive lists of requirements regarding properties for aesthetics, comfort, security and fastnesses. So they have to pass corresponding test procedures to determine the relevant mechanical, physical and chemical properties. The finishing of textile plays an important role for the mechanical and surface-related properties, and for the final product a textile material often has to pass processes such as lamination, coating, deep drawing and make up. The authors describe various types of textile components in car interiors followed by description of advances in woven and knitted fabrics and their finishing, lamination and other processing resulting in composite structures. They then describe different test procedures and standards which are specific to automotive textiles. In the future, new fibre developments will extend the resources and application areas, and new numerical simulation tools will be used in construction, processing and application for vehicles.

In Chapter 4, Stephen Russell and Matthew Tipper write about the advances made in nonwoven materials for a number of applications in automobiles.This chapter considers the utilisation of nonwoven fabrics in OEM automotive interiors and in automotive filtration. The importance of nonwovens in the automotive industry continues to be fuelled by the ability of such fabrics to be customised and engineered to meet the requirements of modern vehicle assembly operations and technical performance in use. According to the authors, nonwovens are particularly attractive in the automotive industry because of their ability to:

(i) be integrated into multi-layer, modular components with other materials including foam,
(ii) be incorporated into light-weight and low-density modules,
(iii) meet stringent cost-performance targets in what is a highly price-sensitive industry,
(iv) be deep draw moulded into complex shapes at relatively low temperature,
(v) contain recycled raw materials and still meet performance requirements, and
(vi) be compatible with emerging recycling processes.

In Chapter 5, X Normand writes about recycling of automotive textiles.

He describes the legislative considerations with regard to the disposability of used vehicles; shortcomings in textile materials used today; examples of recyclable automotive textiles and their performance properties. The author then presents the results of an experimental study where the principal aims were: (i) to replace the classical engine air filter manufactured in several raw materials, which are difficult to separate, and partially recyclable, by a filter composed of a thermoplastic (recyclable or not) mono material. The recycling of this mono material was studied for automotive applications or for other fields; and (ii) to replace classical acoustic insulation products manufactured in several raw materials, which are difficult to separate, and partially recyclable, by textile structures (nonwovens) composed of a thermoplastic (recyclable or not) mono material. The recycling of this mono material was studied for automotive applications or for other fields.

In Chapter 6, Nancy Powell writes about design management for performance and style in automotive interior textiles. This chapter considers the challenges for designers across the automotive supply chain for textile products, where art meets engineering through the design process. The range of basic textile characteristics developed within high performance and low cost parameters to be considered are fibre characteristics, fabric constructions, pattern, colour, hand, lustre, and recyclability. The author describes contributing factors such as cost pressures, speed to markets, quality, sustainable products, design strategy, trim selection process, impact of seat design requirements, communicating value and design, service and innovative materials. Furthermore, the influences of consumer lifestyles and fashion trends continue to grow in the differentiation of brands in the wide choice of vehicle offerings.

In Chapter 7, Holger Erth and Bernd Gulich write about the progress made in developing 3D textiles and nonwoven structures for PUR foam substitution in car seats. They describe some key technologies for replacing PUR foams in car seats and explain the resulting environmental advantages. Some selected and summarised requirements for seat cover composite and cushioning layers are described, followed by a discussion of the substitution of PUR foam in upholstery components by polyester nonwovens. The properties and performance requirements are set and evaluated for both the complete composite of seat cover fabric and the cushioning layer. These requirements, including passenger comfort, manufacturer's guidelines, environmental regulations and total cost, must be met by a complete seat containing a textile substituted foam cushion.

In Chapter 8, Volkmar Bartels writes about the developments in physiologically optimised car seats. He describes in detail the topics of thermophysiological comfort of car seats and the methodology of seat comfort evaluation. In this chapter it is demonstrated how the described physiological test methods can be used to improve the comfort of car seats. Some of the recent experiments and results in this area are described. The advantages of

modern technical textiles in comparison to traditional materials are discussed. Using a number of examples, it is demonstrated how the physiological seat comfort of vehicle seats can be improved by using modern technical textiles. Only if the material and design of a seat are optimally coordinated will the driver enjoy optimum seat comfort. Otherwise, heat and moisture can accumulate, which feels unpleasant and which can have a negative physical effect on the driver, thereby limiting driving capability and concentration.

In Chapter 9, Francois Boussu and his co-authors write about the advances made in the development of smart textiles in automotive interiors. They describe, in general, the textile structures in car interiors and, in particular, the technical elements enabling the production of smart textiles. Different building blocks, i.e. textile sensors and textile actuators, have been presented in order to show development and integration possibilities of smart textile structures designed for car interiors. Furthermore, they describe the design of textile heating elements and shape memory alloys for use in car seats. Sensors based on conductive composites may be used to detect fabric lengthening, passenger presence or to evaluate safety belt ageing

In Chapter 10, Yan Chen writes about advances made in reduction of interior noise in vehicles. This chapter introduces noise reduction issues involved in the design and production of vehicle interior parts. The focus is on the principles of noise control and engineering approaches for vehicle noise reduction using acoustic textile materials. The issues of vehicle noise sources and noise propagation are discussed and two major noise paths, airborne noise path and structure-borne noise path, are addressed in particular. The concept of a noise-path-receiver model in vehicle noise systems is also described. The author then lays down some theoretical fundamentals that help understand why textile materials can be used as acoustic materials for noise absorption and noise insulation in vehicle interiors. The main effects of textile structure, fibre type, and physical parameter on the material acoustic performance are explained. Major standard methods (ISO, ASTM and SAE) for testing noise absorption and noise transmission loss of acoustic materials are described. Some typical cases of material approaches for controlling interior noise absorption and insulation are exhibited. Finally future trends in the new surface vehicle design and production are discussed and new material requirements for vehicle interiors are reviewed. New developments in acoustic interior manufacture are highlighted, including applications of new textile materials, new design of interior parts in both substrate and surface structure, and new computing tools for interior noise mapping and simulation.

In Chapter 11, Michael Meyer, Haiko Schulz and Michael Stoll write about advances made in leather and coated textiles in car interiors. They describe the market value of leather upholstery and the latest developments in producing leather upholstery and coated textiles as well as the design of

car seats with leather and leather/textile face fabrics. They describe the technologies of making leather and leather substitutes, their specialities, and requirements to be performed when used as automotive interior materials. The technological trends for the production of automotive leather are described. There is a tendency to eliminate toxic, mutagenic and other health hazardous chemicals from the tanning processes. Furthermore, automotive leather will be optimised as regards its utilisation properties such as abrasion resistance and non-soiling behaviour as well as water vapour permeability. The authors then describe various technologies for producing coated textiles and artificial leather for automotive interiors. Testing of physical and chemical requirements of leather and coated textiles for automotives is now carried out according to recently developed EN/ISO methods.

In Chapter 12, Samir Mukhopadhyay writes about technical developments and market trends of automotive airbags. The fabric used in making airbags needs to be strong, tough, hard wearing with low and controlled in air/gas permeability behaviour. He describes the characteristics of various polymers for airbag yarns, airbag deployment and performance criteria as well as airbag key technical parameters and contributing factors. In the event of an accident, the critical performance factors of an airbag in saving an occupant's life and injuries are described. The author gives an example of what an airbag supply chain looks like and mentions some of the leading players in this chain. He then describes some future market trends and technological challenges and lists some of the technical areas on which the industry is expected to put more emphasis.

In Chapter 13, Kevin Westgate and James Gillick write about the key technology developments in textiles for use in automotive tyres. They describe in detail the properties and performance requirements of automotive tyres, tyre designs in use today and how the various reinforcement materials and components contribute to tyre performance. They then review recent developments in fibre/textile reinforcements used in tyre manufacturing including the new, novel, advanced fibre reinforcement technology. They also describe the important issue of fibre-rubber adhesion in tyres and recent advances in tyre designs. The authors also take a look at trends in the automotive world and write about how they may impact future tyre development and hence fibre reinforcement opportunities.

In Chapter 14, Thomas Gries, Jan Stueve, Tim Grundmann and Dieter Veit write about development of textile structures for load-bearing applications in vehicles. They describe the role of high performance textiles in automotive engineering and the latest developments in technologies for producing 2D and 3D textile load-bearing structures for automotive applications. Complex textile reinforcement structures in near-net-shape form (textile preforms) can be produced in one-step or multi-step processes, using one-step preforming technologies such as 3D braiding, 3D weaving, contour warp knitting or net-

shape weft knitting. Usually, at least sub-preforms are manufactured that are processed in further preforming steps. In many cases 2D textile structures are used to create structures of higher complexity by forming and assembling several plies in multi-step preforming processes. An alternative technology is the use of 3D textile structures and preforming technologies. The relevance of textile and preforming technologies for use in automotive applications is discussed.

In Chapter 15, Frank Ko writes about advances in textile composites as automotive components. He describes the benefits of using textile composites in the automotive industry and the advances in products and technologies. In this chapter, after a review of textile structures for composites, the role of fibre architecture in the manufacturing of automotive composite parts is discussed. Various textile preforms are classified according to fibre architecture and manufacturing technology. The author then reports the results of a special programme – The Sunrise^{TM} electric vehicle programme – which is used as an example to illustrate the design procedure and feasibility for large-scale manufacturing of automotive structural composite components at targeted weight and affordable cost. Specifically, composite pillars and wheel wells are used as examples to demonstrate the procedure in the integrated design for manufacturing (IDM) of automotive structural composites based on the Fabric Geometry Model (FGM). The chapter concludes with a summary and discussion of future trends in the use of textile composites for automotive structural components.

This book is intended for a broad spectrum of readers including students, scientists, researchers, designers, technologists, product development staff and company strategists. It gives in-depth information about the design and development of automotive textiles along the whole supply chain and provides the state of the art knowledge about the recent advances made in technical textiles for a variety of automotive applications. The book should also be very useful for companies thinking of entering into the automotive textiles market.