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Preface

This first part of this book is based on the lecture "Textiltechnik 1" that I have given at the RWTH Aachen for students of textile engineering, trade school teacher students, and students of economics with a minor in textile technology.

It covers all processing steps for the manufacturing of textiles. The book starts with an overview of the textile industry, its history, and the current market. This is followed by a description of the various raw materials, the different methods of yarn and fabric manufacturing and an introduction to knitting technology, nonwovens, finishing, and ready-made garment production. As technical textiles are becoming more and more important, one chapter is focused on their production as well as on typical applications. The book concludes with a discussion of current recycling processes.

To provide a better understanding of the individual textile processes, an example is given at the end of each chapter that describes the respective processing step with regard to a particular textile product.

In addition, current and future development trends are discussed at the end of each chapter.

An extensive references list at the end of each chapter can be used for further studies.

I would like to express my gratitude towards the following former and current scientific employees of the Institut für Textiltechnik der RWTH Aachen who contributed to this book: Dipl.-Ing. E. Berndt, Dr.-Ing. Th. Bischoff, Dr.-Ing. Dipl.-Wirt. Ing. C. Cherif, Dr.-Ing. E. de Weldige, Dr.-Ing. R. Knein-Linz, Dr.-Ing. N. Elsasser, Dr.-Ing. R. Kaldenhoff, Dr.-Ing. M. Leifeld, Dr.-Ing. O. Maetschke, Dr.-Ing. K.-U. Moll, Dr.-Ing. M. Osterloh, Dipl.-Ing. M. Pasuch, Dipl.-Ing. M. Reintjes, Dipl.-Ing. G. Satlow, Dr.-Ing. M. Schneider, Dipl.-Ing. P. Sommer, Dr.-Ing. D. Veit, Dipl.-Ing. St. Zaremba.

Special thanks go to Mrs. C. Cremer M. A., Dr.-Ing. N. Elsasser, Mrs. S. Izlakar, and Mrs. M. Steffens, who prepared the book for publication.

Prof. Dr. h.c. K.-P. Weber used to give lectures on knitting technology and Dipl.-Ing. A. Gräber used to give lectures on nonwovens at the RWTH Aachen. Both are co-authors of the respective chapters for which I am grateful to them. Dr.-Ing. N. Elsasser co-authored the chapter on processes and machines for textile finishing.

Univ.-Prof. Dr.-Ing. Dipl.-Wirt. Ing. Th. Gries edited the chapter on chemical fibers. Mr. Ph. Moll and Dr.-Ing. G. Tetzlaff read the chapter on processes and machines for making-up proofs.

Our special gratitude goes to the Carl Hanser Verlag for their excellent cooperation and the production of this book.

Aachen, 1998 Burkhard Wulfhorst

Preface to the English Edition

Due to the demand for an English edition of this book, the text was revised and new references added.

Dipl.-Ing. I. Parker PhD and Mrs. A. Itterbeck translated the German version of the book into English.

Aachen, 2006

Burkhard Wulfhorst
Thomas Gries

Contents

1 Introduction

1.1 Evolution of Textile Technology

Food, housing, and clothing are fundamental human physical needs. Clothes both serve a utilitarian function and express personality and living standard.

The evolution of apparel manufacture can be traced back to the Neolithic Age. Textile mass production started with industrialization. In recent years, technical textiles are being used in many different applications ranging from protective clothing and wearable computing to automobiles and aircrafts. The constant development of textiles production will always be essential.

As early as 4000 B.C., the hand-operated spindle (Figure 1-1) and the loom (Figure 1-2) were the most important tools for the production of textiles in central Europe. It has been found that materials used were wool and flax (linen). 2000 B.C., silk wovens were produced in China and linen fabrics were made in Egypt.

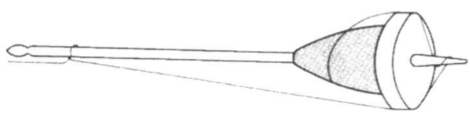
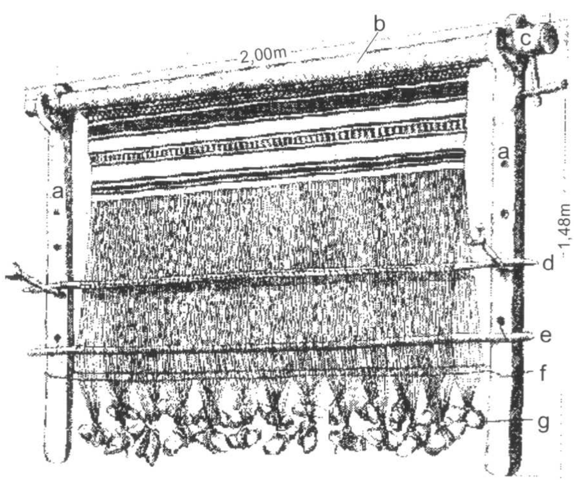


Fig. 1-1: Hand-operated spindle [1]



a) Supports
b) Front roller
c) Crankshaft
d) Ridge bar
e) Separator bar
f) Warp separator
g) Warp weights

Fig. 1-2: Vertical loom [1]

Table 1-1: Evolution of textile technology [2]

Time period	Evolution	Raw materials	Spinning	Weaving	Knitting
Stone age	Animal skins	•			
4000 BC	Wool, flax (linen) Hand-operated spindle Loom	•	•	•	
1350 AD	Cotton in Central Europe Manual spinning wheel Treadle loom	•	•	•	
1530	Flyer spinning wheel of Leonardo da Vinci narrow fabric loom		•	•	
1589	Manual knitting loom of W. Lee				•
around 1750	Start of the industrialization				
1764	Cotton, wool, flax First spinning machine "Spinning Jenny"	•	•		
1768	James Watt's steam engine				
1769	Flyer spinning machine "Water Frame" - continuous fine spinning -		•		
1775	Manual warp knitting loom of J. Crane				•
1785	First use of steam engines Mechanical weaving loom		•	•	
1793	Cotton gin	•			
1795	"Jacquard machine"			•	
1830	"Self-acting mule"		•		
1844	"Ringspinning machine"		•		
1846	Production of guncotton	•			
around 1855	Circular knitting machine				•
1863	Flat knitting machine of J. W. Lamb				•
1892	Viscose fiber; Cupro fiber	•			
1899	Acetate	•			
1900	Weaving loom with automated weft change and electrical drive			•	
1914	Weft insertion with air jets			•	
1935	Polyamide PA 6.6	•			
1937	Polyurethane	•			
1938	Polyamide PA 6	•			
1939	Polyester (PES)	•			
1942	Polyacrylnitrile (PAN)	•			
1950	Loom with shuttles (200 min^{-1})			•	
1955	Open-end spinning technology Water jet weaving machine		•	•	
1960	Projectile shuttle and rapier loom			•	
1965	OE-rotor-spinning machine		•		
1967	Wave-shed weaving machine			•	
1974	OE-friction-spinning machine		•		
1992	Air jet weaving machine (900 min^{-1})			•	
1995	Multiphase weaving machine			•	

At the end of the first millennium, the spinning and weaving processes changed considerably. In the middle of the 14th century, cotton was introduced in Central Europe (Table 1-1).

The industrial era started with the invention of the steam engine and was decisively influenced by textile machinery engineering.

From the beginning of industrialization, textile technology had been confronted with two demands: First, the constantly growing demand for textiles caused by population growth had to be satisfied. Second, textiles needed to be reasonably priced, so everyone could afford them. The spinning and weaving machines that to that time had been operated manually or with waterpower could no longer meet these requirements. Thus, it was necessary to mechanize the current machinery or to build new machines so as to use the new powering potentials (steam, electricity) effectively. An outstanding example is the development of the first mechanical weaving looms, which were used at a weaving mill in England and driven by a steam engine.

For the next 180 years, the development was continuous. An innovative peak was reached in the 1960s with the introduction of nonconventional spinning techniques and a weaving loom without shuttles. With these new techniques, production could be increased almost fivefold, while the need for manpower was reduced drastically.

In step with development of machines for spinning, weaving, and knitting technology, raw materials had to be made available at a reasonable price. A successful example is the cotton gin, which for the first time allowed the industrialization of cotton production.

At the end of the 19th century, important advances in the area of cellulose chemistry led to the development of chemical fibers from natural polymers. Inventions in the 1920s and 1930s in macromolecular chemistry, by H. Staudinger, initiated the development of chemical fibers from synthetic polymers such as polyamide (PA), polyester (PES), polyacrylnitrile (PAN), and polyurethane (PUE).

The introduction of nonconventional spinning technologies, such as open-end rotor and friction spinning, and air-jet spinning, caused a 10- to 15-fold increase in yarn production speed over the last three decades.

In the area of weaving, the speed of weft insertion was increased further. Novel nonconventional weft insertion techniques using projectile, gripper, water, and air started replacing the shuttle. The currently realized insertion speed of about 2,500 $m \cdot min^{-1}$ may still be increased.

Multiphase weaving is another step toward increasing production speed; however, in spite of serious efforts of several weaving loom producers, the so-called wave-shed weaving, which is a multiphase weaving process, has not become successful due to technology-specific disadvantages.

At the ITMA 95, the Sulzer Rüti AG corporation introduced a so-called multiphase weaving machine with weft insertion speeds of 5,000 $m \cdot min^{-1}$ and higher. Further developments can be expected in the future.

1.2 Importance of the Textile Industry

The textile industry is one of the largest industries worldwide. Figure 1-3 shows the distribution of the most important industrial branches in terms of sales, with the textile industry in third place.

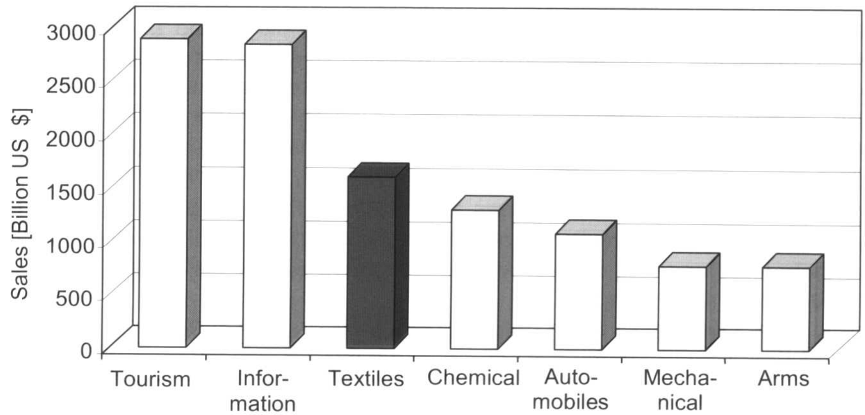


Fig. 1-3: Worldwide sales statistics for important industries

In Germany, the textile industry is one of the most powerful and modern industrial branches. The total turnover of the textile and apparel industry, the textile machinery industry, and the chemical fiber production was about 34 billion € in 2000. The number of workers employed is recorded as 240,000 in 2000.

Figure 1-4 demonstrates the importance of the textile machinery industry. Over 30% of the new textiles machines worldwide come from Germany, followed by Japan, Italy, Switzerland, and France.

Textile products can be divided into

- Apparel,
- home and furnishing textiles, and
- technical textiles.

Figure 1-5 shows the use of woven fabrics between 1990 and 1994 divided into the different fields of application. Generally, a quantitatively decreasing tendency can be observed. The decrease in apparel production results from the increase in imports from countries with low-wage economies. The home and furnishing textiles show only minor variations in production volume throughout the years, whereas for technical textiles, a growth in turnover is obvious. Because of their great flexibility, technical textiles can be used in many fields. Novelty products are being developed and becoming more and more important for the textile industry.

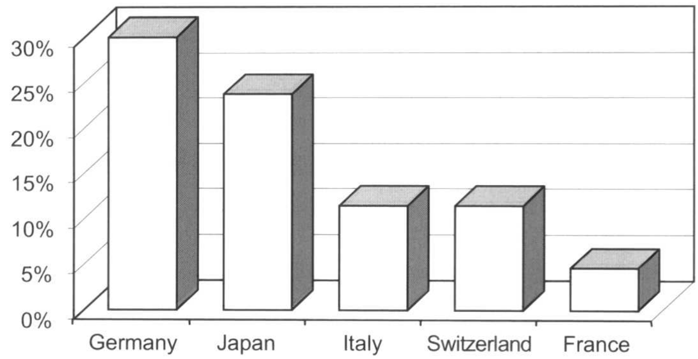


Fig. 1-4: The most important export countries for textile machinery and their world share [3]

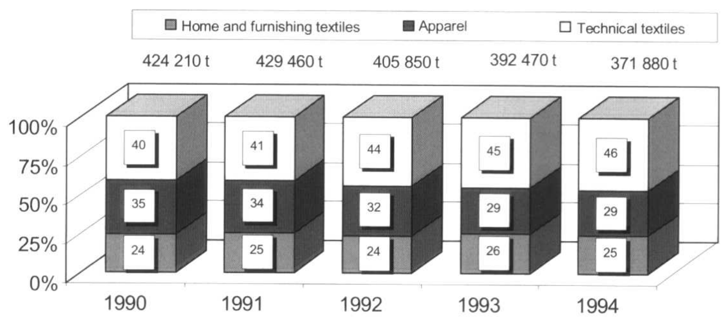


Fig. 1-5: Use of woven fabrics by field of application [4]

1.3 Manufacturing Steps

Multiple production steps are necessary for the manufacture of textile goods. Figure 1-6 gives an overview of raw materials and processing steps according to information from the “Arbeitgeberverband Gesamttextil e.V.”.

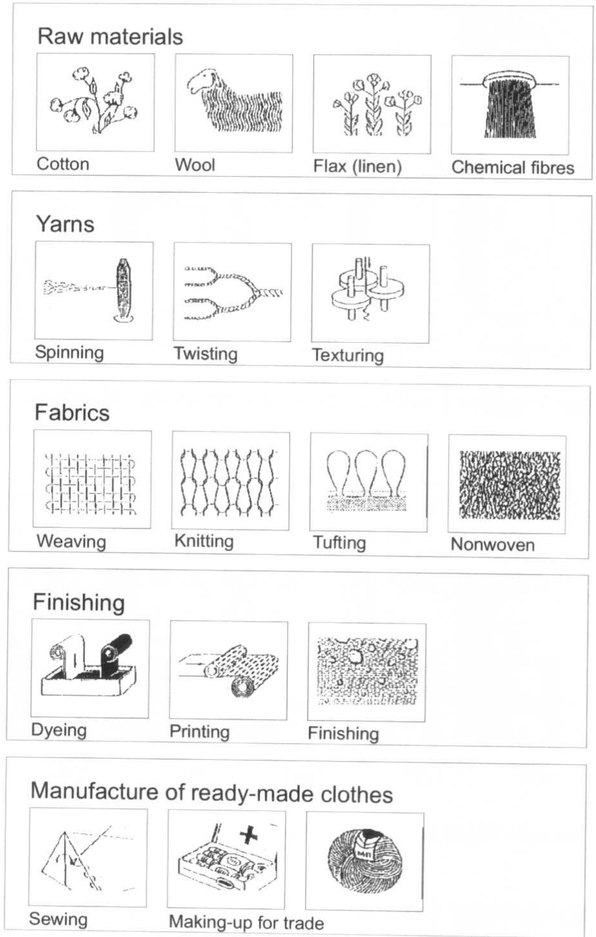


Fig. 1-6: Raw materials and processing steps [5]

The production chain from raw material to waste disposal is often called the "textile pipeline" or "value-added chain" (Figure 1-7). The expression "value-added chain" can be derived from Figure 1-8, where the increase in added value for the manufacture of a three-piece suit is illustrated.

Raw materials for the manufacture of textile products are fibers, both natural and man-made. The choice of material – natural or man-made fibers or even blends – depends on the field of application and the desired product properties.

The technological properties of natural fibers – for example, length, fineness, strength – may vary. For cotton, the properties listed above depend mainly on the growing area and the growth conditions. For wool, these properties are essentially influenced by the breed of sheep, but also by the animals' environment (food, diseases). The listed criteria are crucial for quality, amount, and price of natural fibers.

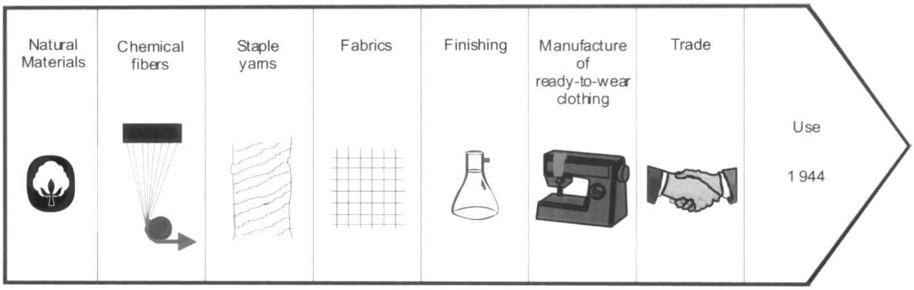


Fig. 1-7: “Textile pipeline” or “value-added chain” in 1,000 t [1994]

In contrast to natural fibers, the properties of man-made fibers can be designed depending on the chemical constitution and the conditions of polymer synthesis. In addition to fineness and strength, the fiber length can be adjusted as required. Chemical fibers are produced and processed as filament fibers or as staple fibers (with continuous yarn cut or broken into pieces of defined length).
Natural and man-made fibers are initially processed in different production steps.

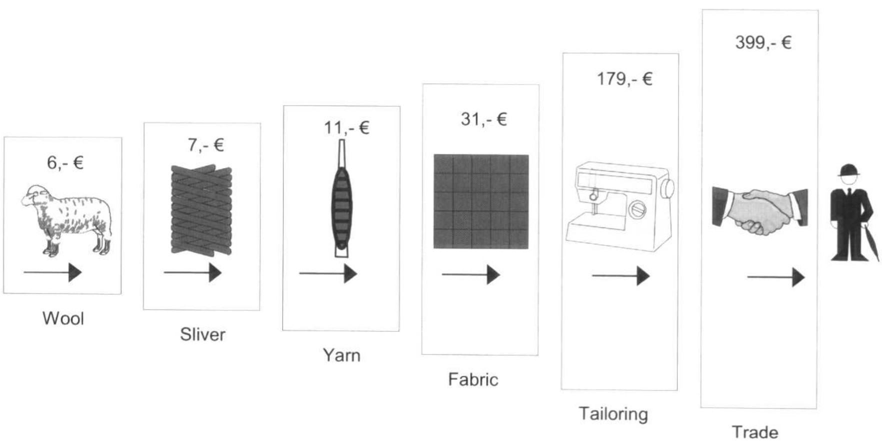


Fig. 1-8: Added value for a three-piece suit (jacket, pants, vest)

After harvest and ginning, cotton fibers are pressed into bales. The bales are delivered to the spinning mill and first enter the spinning preparation (Chapter 3). Here, the pressed and condensed fiber material is resolved into flocks. This separation into individual fibers is accompanied by an intense cleaning and parallelization. Subsequently, the fibers are reunited to a band of fibers, called web. This fiber web is evened out and reduced in weight in several steps and then produced into the roving. Further increase in fineness (by drafting) and subsequent introduction of a twist (strengthening) leads to the yarn. The final yarn is wound onto tubes (cops) or cross-wound bobbins. Other natural fibers are processed in different production steps (Chapter 3).

Processing of chemical fibers is completely different. Many chemical fibers are spun from a spinning solution or a polymer melt (Chapter 2), resulting in a single primary thread (monofilament) or a smooth filament yarn of multiple single fibers (multifilament). Smooth filament yarns are textured to add bulk and crimp. In the so-called converter process, large cables of filament yarns can be torn or cut to staple length. Accordingly, the procedure is called "ripping" or "cutting conversion". The resulting staple fibers may be processed into staple yarns in combination with natural fibers.

The next processing step is the weaving preparation, where the system of warp ends necessary for woven production is built. This is a system of threads in longitudinal direction, which is combined to an assembly of parallel threads and wound onto the warp beam. The warp beam is inserted in the loom. During weaving (Chapter 4), the subsequent manufacturing step, a textile fabric, the woven fabric, is produced. A woven fabric is characterized by the rectangular crossing of two systems of threads (warp and weft yarn). The way in which warp and weft yarn is crossed is called woven structure or weave pattern.

An alternative method of producing textile fabrics is the manufacture of knit fabrics (Chapter 5). As a result of the way the stitches are constructed, knitted structures are rather loose and voluminous. Characteristics for knit fabrics are a soft handle, high porosity, thermal isolation, and good drapeability.

Textile fabrics may also be produced as what is known as nonwovens (Chapter 6). The production process can be divided into:

- Manufacture of the fiber web,
- stabilization of the fiber web resulting in the nonwoven, and
- finishing of the nonwoven.

A fiber web is a coherent assembly of fibers. It may be constructed from several layers of fiber webs on top of each other or from several layers of nonwovens. According to the different directions of fiber orientation, isotropic webs and webs nonisotropic in cross and machine direction are distinguished. Fiber webs can be produced mechanically, aerodynamically, or hydrodynamically.

After the production of wovens, knits, or nonwovens, the fabrics are finished (Chapter 9). Finishing may also be done earlier during the production process as fiber or yarn finishing.

The purpose of finishing is:

- Removal of dirt and contamination,
- dyeing or printing,
- surface modifications in order to improve product properties and wear comfort.

The last step in the manufacture of a textile product is the production of ready-to-wear clothing (Chapter 10), a process in which the textile fabrics are put together by mass production according to their application – apparel, home and furnishing textiles, or technical textiles. Processing steps for this processing step are: