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TRAINING FOR INDUSTRY SERIES NO. 3

THE ŁÓDŹ TEXTILE SEMINARS

1. Textile fibres

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

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UNITED NATIONS
New York, 1970

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FOREWORD

This publication is the first of a series devoted to textile engineering and closely related fields. It is part of the Training for Industry Series published by the United Nations Industrial Development Organization (UNIDO).

Rapid world-wide increases in population and industrialization are reflected in the textile and allied industries. In any ranking of human needs, fibres and textiles for clothing and industrial purposes are second only to foodstuffs. The continuing quantitative and qualitative changes in textile production require the broadest and most complete dissemination of information in this important area.

The purpose of the present series is to make available to the developing countries the most recent scientific and technical information in order to help them to establish textile industries or to improve the effectiveness and economic viability of existing textile industries that are still in the earlier stages of economic development.

At the suggestion of UNIDO, with the support of the authorities of the Polish People's Republic, a post-graduate in-plant training course in textile industries was held in Łódź from May through September 1967. The course was repeated from May through October 1968, and its content was modified and up-dated on the basis of experience and new information. It was repeated again in 1969 and it is planned to continue this programme, up-dating its subject matter and improving its usefulness to the textile industries of the developing countries. It is on these courses that the present series is based.

The courses were organized by the Textile Research Institute in Łódź with the object of training a group of already highly qualified specialists in all branches of industry relating to textiles. Under normal conditions, such training would require work in mills and in research and development over a period of several years.

The courses give the participants an opportunity to become acquainted and to do actual work in conjunction with some of Poland's leading research centres and industrial enterprises, and to discuss with experts problems connected with techniques, technology, economics, organization and research in the field of textiles. In organizing the courses, the Textile Research Institute endeavours to co-ordinate the content of theoretical lectures, technical discussions and practical studies in laboratories and mills, covering all the fundamental problems of textile industries.

The main object of the seminars is to adapt the broad range of problems presented by Polish specialists to the direct needs of the developing countries. Lectures by the research workers of the Institute formed the core of the programme. The lectures do not review or repeat the basic problems usually studied at technical colleges and high schools in the course of normal vocational training; rather, they deal with subjects most often of concern to the management and technical staff of a textile enterprise.

The lectures, as presented in this series, have been grouped in eight parts: textile fibres; spinning; knitting; weaving and associated processes; non-conventional methods of fabric production; textile finishing; testing and quality control; and plant and power engineering.

It is hoped that the experience gained from these courses, as presented in this series, will contribute to the improvement of textile industries everywhere, and particularly in the developing countries.

The views and opinions expressed in this publication are those of the individual authors and do not necessarily reflect the views of the secretariat of UNIDO.

THE ŁÓDŹ TEXTILE SEMINARS

1. Textile fibres

CONTENTS

EXPLANATORY NOTES

References are indicated in parenthesis in the text, by name of author and year of publication. The full references are listed, alphabetically by author, at the end of each article.

References to "tons" indicate metric tons and to "dollars" ($), United States dollars, unless otherwise stated.

The following abbreviations have been used:

cpi means "courses per inch".

Denier (den) is the weight in grams of 9,000 metres of yarn.

gg is "gauge".

kcal is kilocalorie.

Metric count (Nm) is the number of kilometres of yarn per kilogram.

A nanometer (nm) is 10^{-6} mm.

rev/min is revolutions per minute.

Tex is the weight in grams of 1,000 metres of yarn; millitex (mtex) is 0.001 tex.

wpi is "wales per inch".

Worsted count is the number of 560-yard lengths per pound of yarn.

PRINCIPAL TECHNICAL DEVELOPMENT TRENDS IN THE TEXTILE INDUSTRIES

by

T. Jędryka

Various factors determine the rate and trends of development in textile production. They are of both economic and technical nature and appear not only in the textile industries, but also in some associated areas, particularly in the chemical, electrical, and engineering industries.

The principal technical factors that affect the production of textiles of new kinds are:

(a) Stress on man-made fibres;

(b) Dynamics of technical developments,

(c) New techniques in textile processing.

The man-made fibres being produced in ever-growing volume and variety by the chemical industry offer new opportunities for the design of increasingly perfected fabrics that incorporate constantly increasing percentages of man-made fibres.

The man-made fibres, which as recently as in 1925 were of no importance in world textile supplies, constituting only 1 per cent of the total fibre production, in 1965 have a 25 per cent share in total production of textile fibres (including bast and glass fibres for textile use).

The great growth of man-made fibre production has not been caused by any decline in the supply of natural fibres nor by any lack of possibilities for the increase of their production. It is simply a result of the fact that man-made fibres are now textile materials with their own value for the industry.

Man-made fibres no longer imitate, with varying degrees of success, some properties of the natural fibres. They are now produced with built-in characteristics for use in technological processes and for the optimum wearing properties of products made of them. Figures 1 and 2 illustrate the development of production of the major textile fibres.

Synthetic fibres are in some respects superior to natural ones. They enable us to produce fabrics with characteristics that cannot be attained with natural fibres, such as high resistance to abrasion, great tensile strength and high dimensional stability in the finished product.

Man-made fibres presently produced are of a great variety of types and have properties that make them useful in blends with natural fibres. The blended fabrics may be successfully processed to produce special-purpose articles.

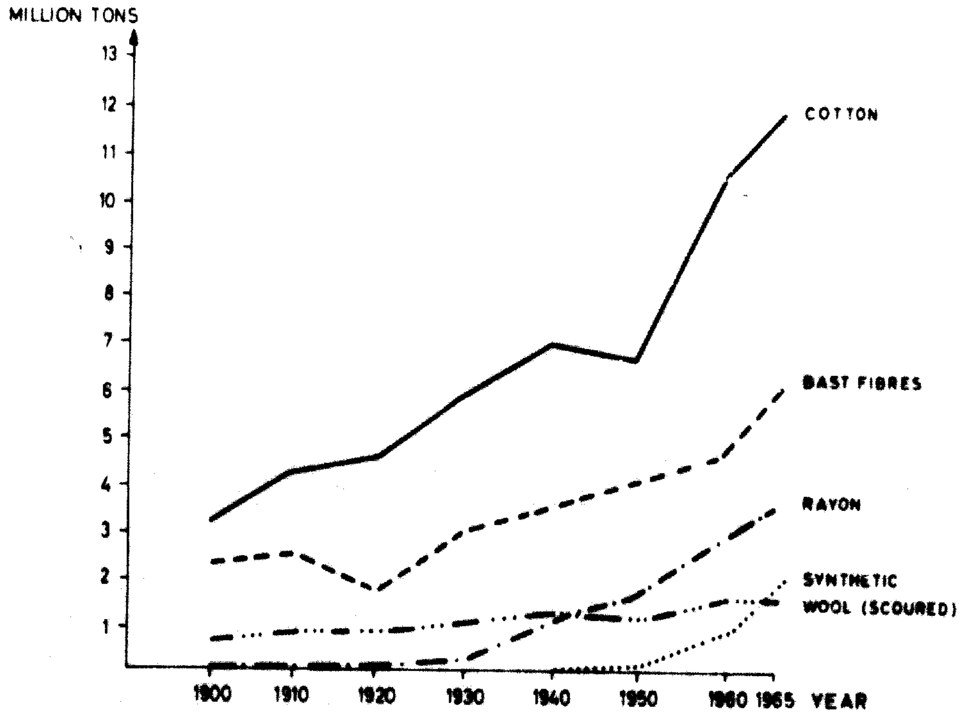


Figure 1. World production of major textile fibres

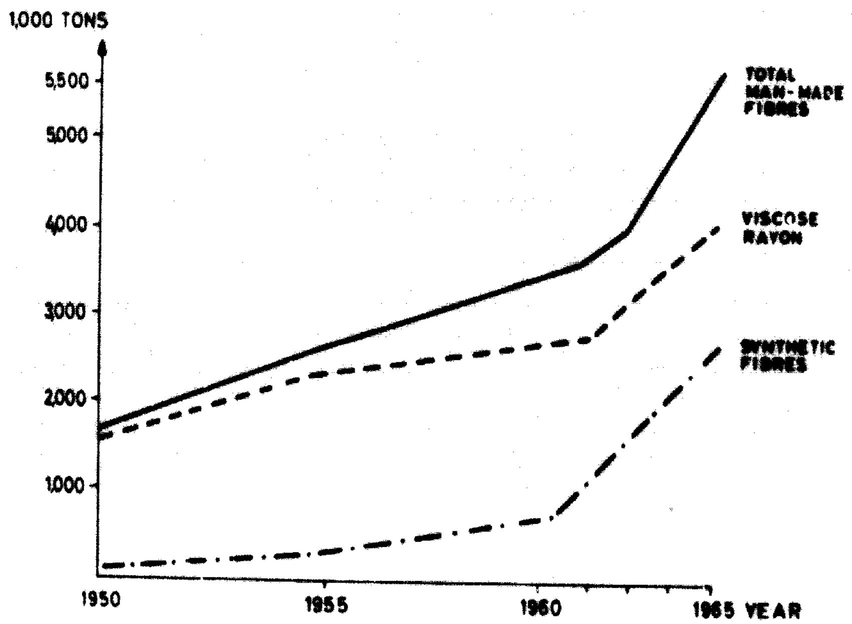


Figure 2. World production of man-made fibres, 1950 to 1965

Man-made fibres not only possess some properties that are superior to those of natural fibres but also have others that are not present in natural fibres. Among these may be mentioned:

(a) The thermoplasticity of some synthetics which permits the use of texturing techniques;

(b) The existence of acrylic fibres of both standard and high shrinkage, which makes possible the production of high-bulk yarns;

(c) The low specific gravity of polypropylene fibres, which makes them useful in the manufacture of marine cordage that floats.

Many other such examples of new technical and wearing properties which are available in synthetic fibres could be cited. Suffice it to say, however, that there is continuous progress in this direction, and still newer species of synthetic fibres appear occasionally, with still more attractive applications.

A whole new area for the textile raw materials has been opened by the foils. Until quite recently, two varieties of these materials were in general use in the textile industry, namely, polyurethane foam and oriented synthetic films. The former was bonded by various means to conventional woven or knit fabrics of somewhat modified design. The resulting "foamback" has been widely used and has good wearing properties. The foambacks are an example of a partial replacement of conventional textile fibres by new materials of chemical origin.

Oriented films in textile applications represent a new concept that is still under development as regards techniques and range of use. However, it can already be said that oriented films will be widely used for wrapping and industrial fabrics.

Plastic materials of forms other than fibres are now the basis of new technical developments in textile trades.

Dynamics of technical development

Intensification of production processes is a goal in itself for any manufacture; this can be seen by steady developments in technique and technology. However, recent years have brought to the textile industry such fundamental changes in technological methods that we are now witnessing the creation and formation of a quite new textile industry.

As examples of these changes, with regard to spinning, weaving and finishing processes, let us consider the following:

It is a well-established fact that the card is one of the most essential machines in fibre-spinning. The flat carding machine, as used in cotton-spinning, seems to have attained its present form in the middle of the nineteenth century.

It has, of course, been modified slightly since then, but none of these changes has altered the working principle or basic parts, or affected traditional forms or dimensions of the machine, nor the co-operation of working elements established by practice. In these circumstances output had levelled out at 3 to 5 kg/hour long ago.

It is only very recently that a new design of the carding machine was made, resulting in a great increase in its output, that is, to more than 25 kg/hour. The new design concerns essential elements of the machine, particularly at the feed and delivery end, with intensified speed of all remaining parts of the machine. Further design changes now planned may bring about a further increase in output, although even the present permits the inclusion of carding machines into unitary production flows together with blowing and breaking sets.

The draw-frames used in cotton-spinning mills have had a delivery speed of 30 m/min for many years. It is only in the last decade that this speed was raised to 90 and 120 m/min, then to 200 m/min, and machines are now available that can deliver 400 m/min. It is of interest that such a notable rise in the delivery speed is attributable primarily to a new design of the feed system and to the use of new materials for working elements of the machine.

The spinning frame, which is a major component of any spinning operation, was subject to essential alterations in the basic operational elements that form the twisting and winding-up unit. Beginning with flyer spindles with speeds of 3,000 rev/min, then over caps of 7,000 rev/min, we now have ring frames of as many as 15,000 rev/min, which seems to be the highest speed obtainable with this spinning system.

However, advanced research work and experiments with spindle-less systems of 45,000 to 60,000 rev/min lead us to expect that commercial use of such machines is not distant.

The loom, which is the basic machine of any weaving shed, was developed in a manner greatly similar to that of a continuous spinning frame. From power-looms, weavers changed to the automatic loom, which has an output of 200 to 250 metres of weft per minute, then to the rapier loom with 400 m/min, next to jet looms with 420 m/min, and recently gripper looms weaving over 600 m/min. Furthermore, it seems certain that a loom will soon be developed whose output will reach 3,000 m/min.

The bleaching of cotton fabrics had since the 1940s been carried out in two separate operations with outputs of about 200 kg/hour. A newly introduced system based on a set of dollies and pipe containers yields as much as 600 kg/hour. Announced for the near future is the use of steaming chambers, working continuously, which may permit achievement of outputs of about 1,000 kg/hour.

Discontinuous dyeing processes had, over a period of many years, reached a production per hour within a range of 25 to 40 kg. About 1925, the first continuous dyeing systems were developed that used sets of dollies. Washing was, however, limited in extent but output was about 500 kg/hour.

At present, continuous processes are used everywhere. The fabrics are treated first with a dyestuff solution and then with saturated steam. The so-called "pad-steam" method is very versatile and, although it does not increase output, it eliminates the discontinuity of the dying process entirely. Further developments in production of dyestuffs and in the use of continuous steaming chambers make it reasonable to expect a production rate in the range of 900 kg/hour.

The above-mentioned examples illustrate trends in textile manufacture. They are not the only ones, nor are they exceptional examples of recently accelerated intensification of particular operations or technological processes.

They are, without doubt, the starting points towards a continuous evolutionary transformation of methods for an integration of the various production processes. Figure 3 shows how a relatively long period of technological stability has been followed by recent pronounced changes. There are no reasons to think that these changes represent the final achievements in textiles manufacture. Quite the contrary, there are many prospects for an even higher rate of development in the coming years.

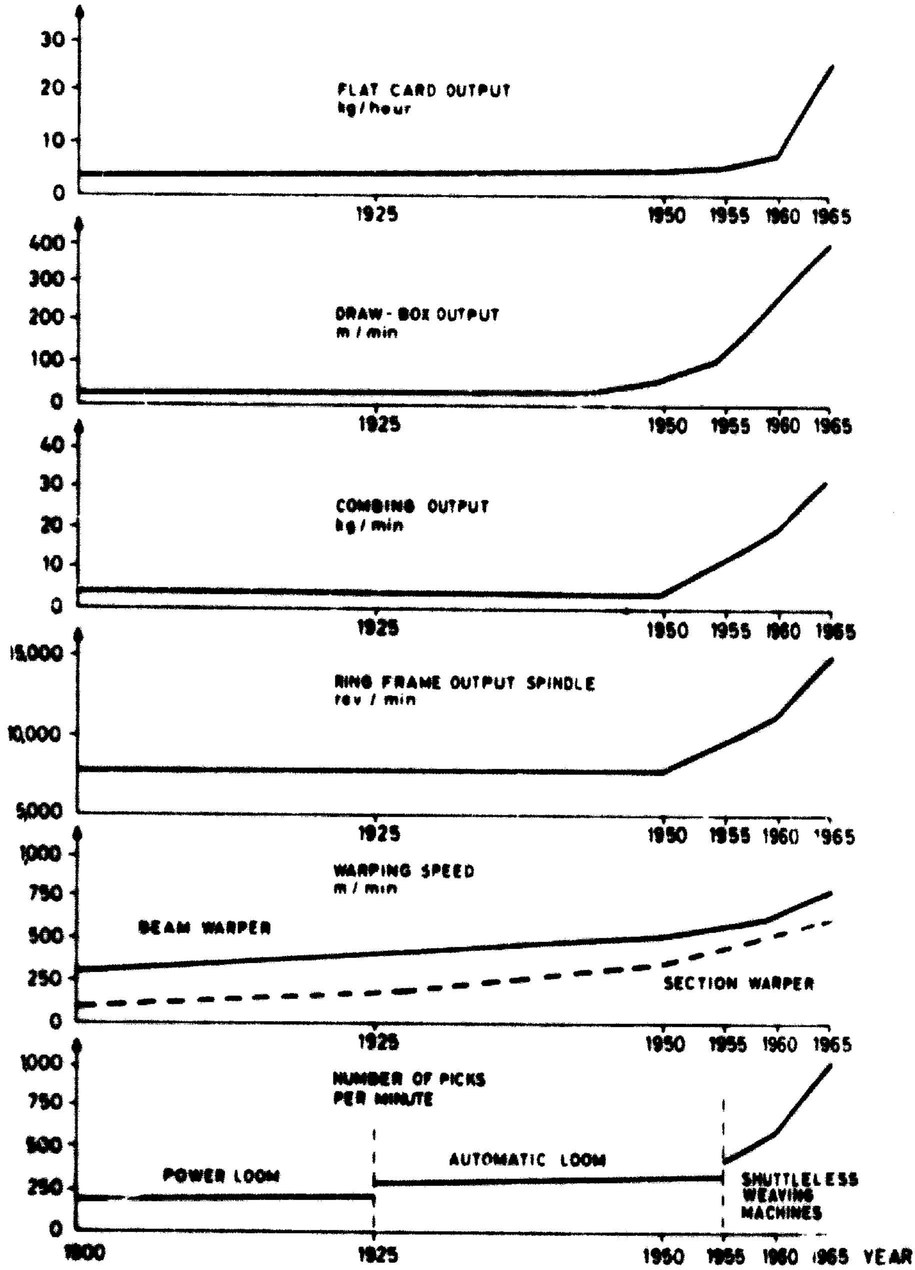


Figure 3. The increasing output of some textile-producing equipment

New production techniques

The use of many new methods in textile production allows a much more versatile inner structure of the industry and a production assortment best suited to demands and economic possibilities of a given geographic area. Non-woven fabrics, quilted fabrics, foambacks, tufted carpets, textured yarn products and the like have all been developed over the last few years. By far the most important of these is, indubitably, the technique of non-woven fabrics. These are new textile products that require no spinning, weaving or knitting; a finished product is made directly of loose fibres by the use of various techniques.

Relatively long ago, that is, as far back as 1860, the first patent for a bonded, non-woven fabric was granted in the United States of America. However, it was only after the production of man-made fibres and plastic materials was developed that bonded non-woven fabrics were introduced commercially. From 1940 onwards an increased demand for fabrics of that type could be felt, first in the United States and then in many other countries. A new branch of the textile industry had come into being. It will play an ever-increasing role, partly eliminating some conventional production methods of textile goods still in use. The rate of growth of this new industry is shown in figure 4.

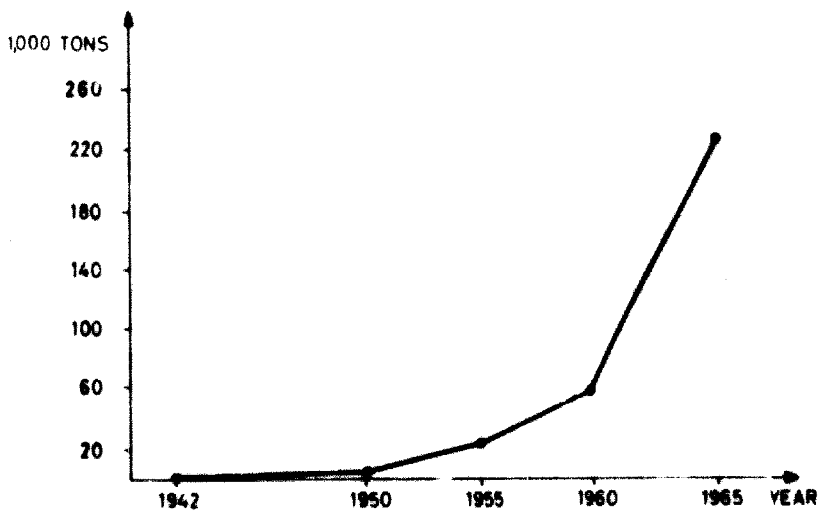


Figure 4. World production of non-woven fabrics

Aside from the fact that the production techniques for non-woven fabrics permit a considerable broadening of the assortment of products for end-uses not otherwise attainable to that extent, from the economic point of view they have the following three great advantages:

(*a*) They require a much smaller capital investment for machines and equipment than do conventional methods of production.

(*b*) They are suitable for large-scale machine output and lower production costs.

(*c*) They permit the matching of a wide assortment of bonded fabrics with the available supply of fibres.

As noted above, non-woven fabrics are products formed of loose fibres subjected to bonding with special agents or sewn into a fabric on special machines.

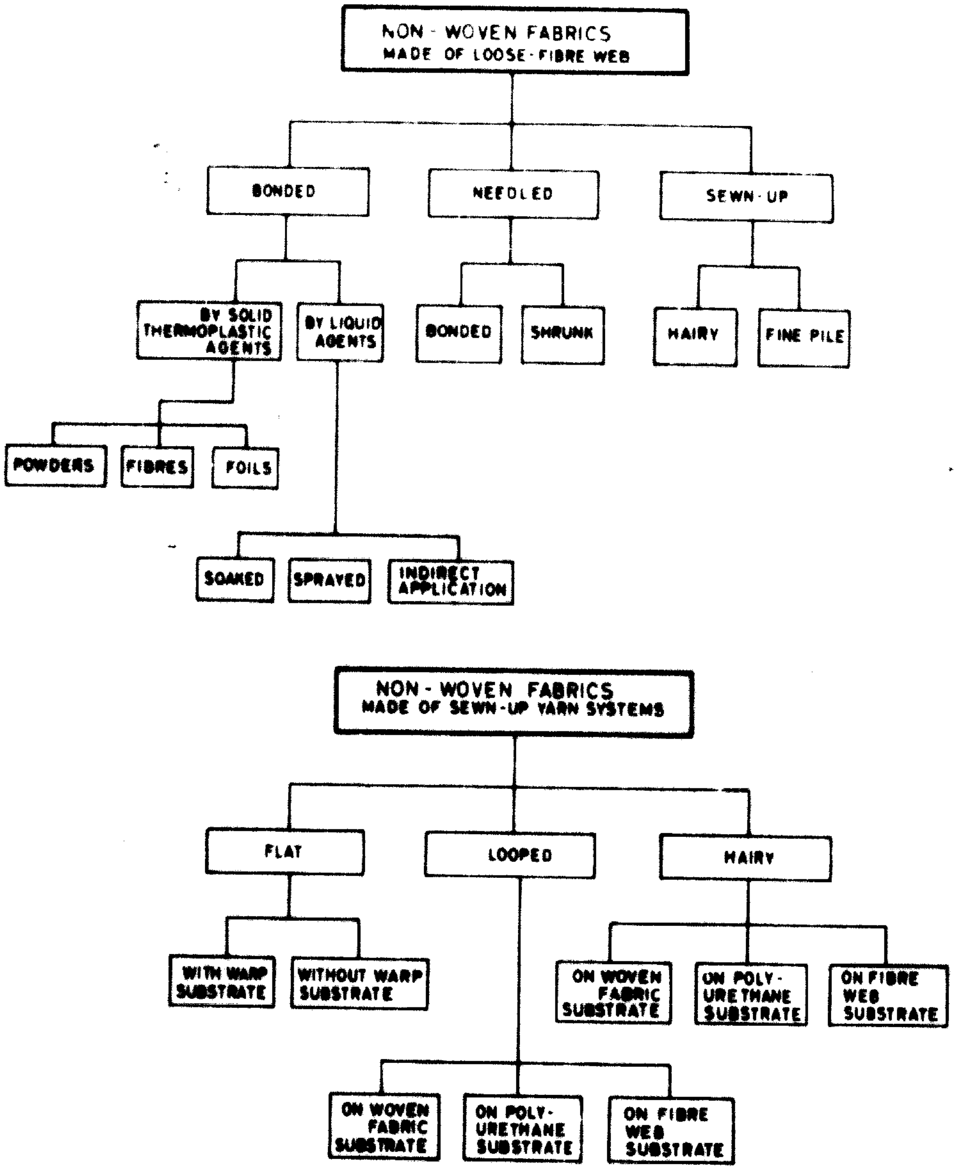


Figure 5. Systematics of non-woven fabrics

For want of suitable bonding agents, the former fabrics had limited use. It was only after the marked production growth of man-made fibres in recent years and because of the development of chemical bonding agents that the quality of these fabrics was improved and consequently the demand for them increased.

The yarn-sewn non-woven fabrics are formed either by the sewing-up of some yarn systems or by a suitable sewing-in of yarn (outer cover) into a woven fabric.

This type of fabric is now marketed by millions of kilograms, in ever-increasing quantities, being an important item of textile supply.

Both of these groups of non-woven fabrics may be manufactured with various techniques, depending upon end-uses and required wearing properties.

Figure 5 shows how the non-woven fabrics are classified.

The so-called non-woven fabrics can be produced by three basic techniques, namely by bonding of a suitably thick layer of fibres, by needle-felting or by sewing them together.

In their turn, the bonded fabrics can be glued up with some thermoplastic material in the form, for example, of a powder which, when sprayed over the fibre web, melts while the web is driven over hot rollers, binding together the fibres into a bonded material.

Similarly the same results may be achieved if the web contains thermoplastic fibres which, blended with other fibres, will form the above-mentioned bonded fabric. When pressed at some suitable temperature, the thermoplastic fibres melt and bind all of the fibres into one entity. Thermoplastic yarn may be used as well. Placed between two webs of fibres pressed against each other, the yarn binds both the layers into a fabric that appears as if it were stitched.

The bonding agent used in the production of bonded fabrics may have a liquid form as, for example, the solution of natural or synthetic latex, a viscose solution, and such compounds as acrylic, melamine and phenolic resins. The application may be done by spraying with a pneumatic spray gun or by soaking of cotton or other yarn, which is then introduced between the two webs.

The next basic technique, needle-felting, consists of piercing the web with metal needles that have saw-like cuts in their surfaces. When the needles penetrate the web, they bring with them some fibres, leaving them behind in their return stroke. The fibres now lie across the web, binding it rather securely after the shrinking operation.

The third technique for making non-woven fabrics uses yarn, with which the web is sewn up with needles similar to those used in the knitting industry. Using this technique with a bulky web, an imitation fur can be obtained. Such a fabric may be cropped or can be left with fibres of irregular natural length, depending upon how they are to be used.

Non-woven fabrics produced by sewing-up techniques are usually bound with parallel stitches, as with the Eastern German Maliwatt machine for example. The stitch may be of a knit type, as made by the Arachne machine of Czechoslovak design, or by the WP 180, made in the Soviet Union.

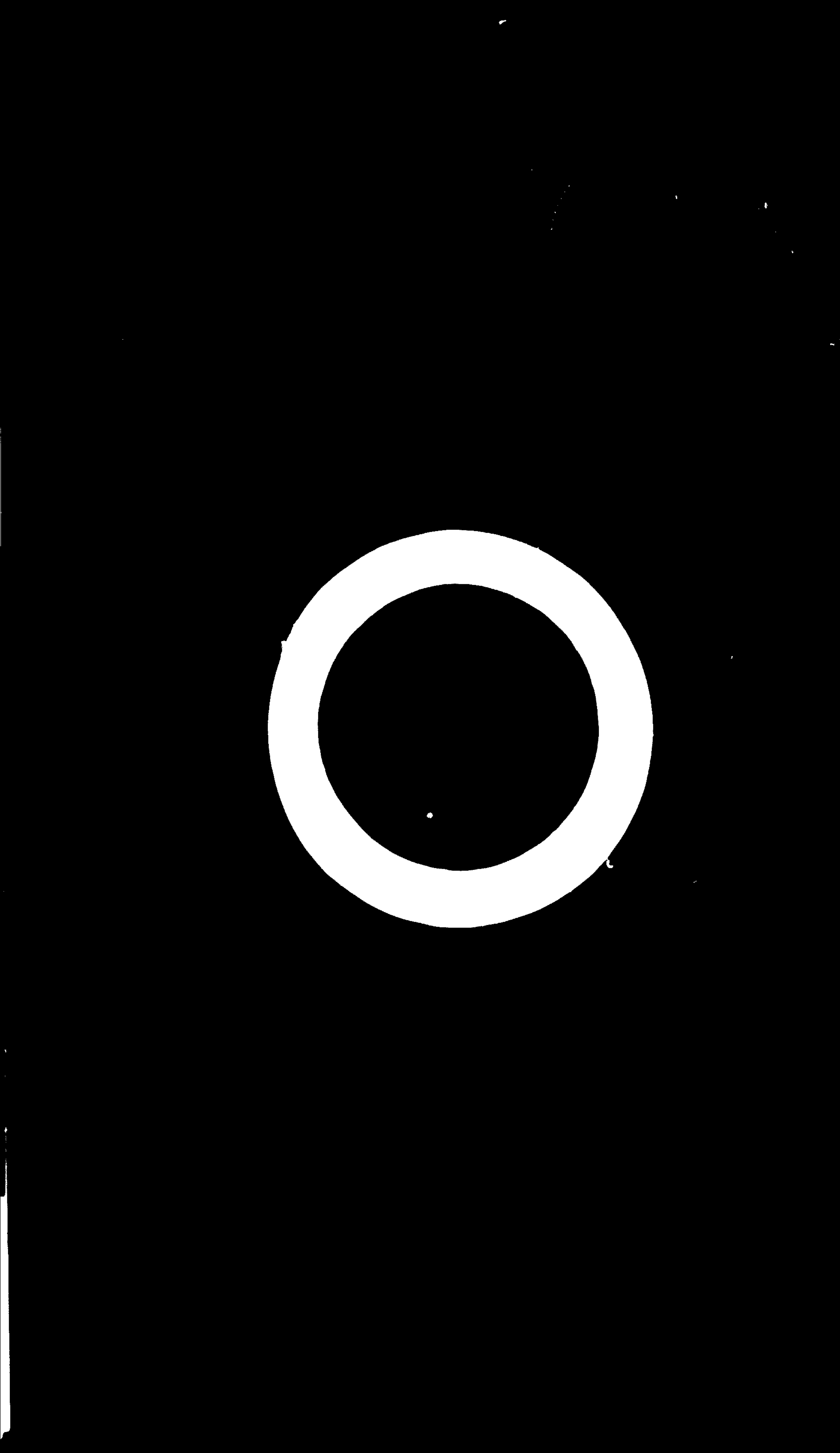
The fabrics made with these machines may be finished, depending on their end-use, by milling and cropping, or by milling, raising and cropping. They may also be used as substrates for goods, the surface of which is covered with a plastic or rubber.

A combination of sewn-up and bonded fabric consists of a web, usually with a heavy weight per unit area, which is first strengthened by sewing-up and then impregnated with a binding agent. The fabric thus may be composed of several layers, forming a thick insulating surface which may be used instead of felt for footwear or as an insulating material.

A separate group is formed by yarn-sewn fabrics. Depending on the manufacturing technique, they may be flat-surfaced, looped or hairy.

The first group comprises all fabrics with a plain, flat surface, with no protruding elements. They are produced with Eastern German Malimo machines for such end-uses as towels, bath sheets or sacks. They may have yarn arranged into warp and weft systems, sewn through by a binding yarn, or only into a weft system, sewn in a similar way. The latter results in a fabric of very low density.

Looped fabrics are produced with Malipol machines and are similar to woven fabrics of the terry type. The loops are formed here by yarn sewn into a substrate of woven or non-woven fabric. The length of the loops may vary within very great



theoretical limits. Such fabrics are used for some outerwear such as bathrobes and blazers.

Fabrics made on the Malipol machine can be transformed into hairy pile fabrics when their loops are raised by metal hooks. When the raised surface is short, the fabrics are used for rugs and carpets. Fabrics with long, hairy surfaces are made up as imitation furs, linings and the like.

Polyurethane foam can be used instead of woven fabrics as the substrate for "Malimo" products. Tufted or needled carpets are made in this way.

General proportions of the end-uses of goods produced with the non-woven techniques are as follows:

End-use	*Percentage*
Suitings	11.4
Tailor's cloth	38.3
Upholsterer's padding	30.5
Coated fabrics (oilcloth)	8.0
Sanitary dressings	2.0
Industrial fabrics (filtres, insulations)	1.5
Sundries	8.3
TOTAL	100.0

Textured yarns represent yet another important sector of the field of new techniques of textile production. The variety of techniques applied and products obtained as well as great variety of end-uses has accelerated the development of this new area of the textile industries.

In texturing yarn, advantage is taken of the thermoplastic properties of synthetics as well as of some cellulose fibres such as acetate fibres.

The importance of texturing is justified by the three following reasons:

(a) Textured filament yarns completely eliminate the conventional process of spinning, since they have properties close to those that are characteristic of yarns spun from staple fibres.

(b) Textured yarns make possible the use of man-made fibres in many different kinds of textiles and thus increase the demand for those fibres significantly.

(c) Articles made of textured synthetic yarns have great value, not only because of their aesthetic qualities, but also because of their good wearing properties and because the high absorption of moisture by synthetics made from them provides greater comfort for the wearer.

The production of textured yarns is developing very rapidly almost everywhere in the world demonstrating the importance of the role these yarns play in the clothing of the contemporary man.

It was expected that, in the United States, within the decade of 1957 to 1967, production of textured yarns will have reached the following figures: 1957 10,000 tons; 1960 32,100 tons; 1963 75,000 tons; 1967 forecast 103,000 tons.

It is calculated that about 25 per cent of the total amount of filament synthetic yarn produced in Europe is being subjected to texturing, thus yielding about 60,000 tons of these yarns per annum. However, it should be noted that many European countries began this production only in recent years, so it can be said that yarn-texturing in Europe is still in the development stage. The systematics of textured yarns are shown in figure 6.

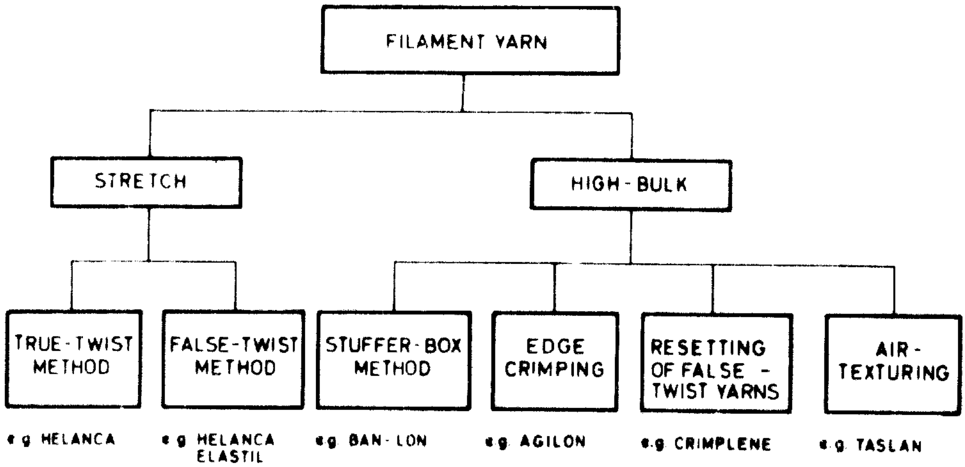


Figure 6. Systematics of textured yarns

Of the six methods used for the texturing of man-made fibres, the first one (that is, the true-twist method) is already being abandoned because of the very low output of each texturing unit (about 2.7 g/hour). This method will continue to be used, but only until the existing equipment is worn out.

The remaining five methods comprise:

(a) False-twist (Helanca)

(b) Stuffer-box (Ban-Lon)

(c) Edge-crimping (Agilon)

(d) Resetting of false-twist yarns (Crimplene)

(e) Air-texturing (Taslan)

The priority given to any of those methods will depend upon various factors, economic or more subjective, prevailing in the country in which texturing is being developed. Nevertheless, the false-twist method is bound to be used everywhere since it produces yarns best suited for hosiery and other end-uses that most cover human needs.

The uses of textured yarns are manifold, but essentially their destinations may be described as follows:

(a) Yarns textured with the false-twist method, produced of polyamide or, to a lesser extent, of polyester filament of 15 to 250 den are used mostly for hosiery and various stretch fabrics such as those for swimming suits.

(b) Yarns textured by the stuffer-box method are made from polyamide and polyester filaments in a very large range of deniers (60 to 3,000) and are used primarily for upholstery and carpeting and, to a much lesser extent, for outerwear.

The stuffer-box method involves relatively high outlays for machinery, but this is offset by its large output, which is the highest of all the texturing methods. This method is indispensable and is most profitable wherever carpet production must be based on the use of man-made fibres. In the United States, textured yarns for the production of carpets are used increasingly. In 1963 their production reached 32,000 tons, whereas in 1967 it was probably raised to about 41,000 tons.

(c) Edge-crimped textured yarns are also made of polyamide and polyester filaments in the range of 15 to 200 den and are used for interlock knitwear and for the manufacture of hosiery.
This method does not require a large capital investment, but production costs are rather high.

(d) Yarns textured by resetting (re-stabilized), made also of polyamide or polyester filament in the same range of deniers, are used for outerwear, knitted undergarments, pleated skirts and upholstery.
Both of these methods are characterized by the relatively low cost of the necessary processing equipment, especially since the recent colossal development of its manufacture. Only two or three years ago the top speed of spindles for that type of texturing machines varied between 30 and 80 thousand rev/min. However, the most modern machines have raised that speed to 250 to 400 thousand rev/min. The engineering works interested in the manufacture of that equipment are located in the United States and several European countries, among them Czechoslovakia, the Federal Republic of Germany, France, Italy, Switzerland and the United Kingdom.

(e) Air-textured yarns can be made of any of the man-made filaments, including those of cellulose, and are used for both weaving and knitting for a large assortment of goods. However, this method requires high-cost equipment, and for economic reasons will have a rather limited application.
As mentioned above, the true-twist method has the lowest output, whereas the stuffer-box method is the most productive. With presently available equipment the remaining four methods differ little from each other, having an average output about 50 g/hour for each texturing unit.

Although it is difficult to conceive of a textile industry incapable of producing textured yarns for various end-uses, it must be recognized that these texturing techniques are still new, and that further rapid progress in this area is to be expected as still newer and more effective production methods are developed.

The present achievements with regard to texturing of man-made filaments have already permitted a better and more advantageous disposal of the constantly increasing supply of man-made fibres. Although texturing is, for the time being, applied mostly to polyamide fibres (over 50 per cent of the total volume of textured fibres), techniques for modifying the structure of fibres and yarns of many other kinds are already under development. It is to be expected that texturing will be done with other kinds of man-made fibres and that many yarns will incorporate various textured components. This trend must necessarily result in textile products of entirely new wearing and other properties.

All of the aspects of textured yarns mentioned above, economic as well as with regard to end-use, make the problem of their production of paramount importance and cannot be overlooked by any developing textile industry anywhere in the world. New techniques will not, of course, replace entirely the traditional and classic textile fabrics. Nevertheless, these new developments cannot be overlooked in consideration of programmes of progress in the textile industry.

To sum up all of the considerations presented here, outlining briefly the developments in modern textiles, it should be stressed that never before in the history of mankind have there been so many favourable circumstances for the development of the textile industry.

Textiles follow foodstuffs closely at the top of the list of human needs. The need for textiles may be easily met, regardless of the geographical location of the country in question. At present the world is only partially dependent on natural raw materials. Furthermore, the construction of textile mills does not call for so great a capital investment or as much human effort as were formerly needed. Textile goods can be adapted better than ever before to the needs and desires of people in all parts of the world, since their cost, comfort and wearing properties can be matched against the climatic and economic conditions and social welfare needs of each country.

DEVELOPMENT TRENDS IN WORLD PRODUCTION OF TEXTILE FIBRES

by

S. Dowgielewicz

World production of textile fibres is steadily and intensively increasing. Table 1 and figures 1 and 2 present data illustrating this fact. The data refer to the period 1960 to 1965 and also to predictions for 1970, all principal textile fibres being taken into account, including bast and glass fibres for textile use.

Total world production of textile fibres, which amounted to about 20 million tons in 1960, rose to 24 million tons in 1965 and is expected to surpass 28 million tons in 1970. Table 1 shows that both the five-year periods 1960 to 1965 and 1965 to 1970 had the same increase of about 4 million tons. If the production index of 1960 is considered as 100, that of 1965 will be 122 and that of 1970 will be 145.

Table 1 also shows how the production of particular groups and types of fibres was developed. The data show the weight, in thousands of tons, of each variety of fibre produced during specific time periods, and the percentage of each variety to the total production of all textile fibres is also given.

Figures 1 and 2 present the same data in diagrammatic form, the curves of figure 1 being plotted for direct values of weight in thousands of tons and those of figure 2 for percentages of the total production of fibres.

The production of natural fibres in 1960, which amounted to about 16 million tons, increased to 18 million tons in 1965 and, according to expectations, should strike the target of 20 million tons in 1970.

The increase from the 1960 level is thus 13 per cent in 1965 and would be 24 per cent in 1970. Respectively, figures for man-made fibres are: 3.4 million tons in 1960, 5.5 million tons in 1965 and 8.3 million tons projected for 1970, 63 per cent increase up to 1965 and 143 per cent for 1970.

The proportion of natural fibres was 83 per cent of the total 1960 production, dropped to 77 per cent in 1965, and is expected to be only 71 per cent in 1970. Thus, natural fibres still make up more than three fourths of the total amount of textile raw materials. Nevertheless, their relative position declines as the years pass.

In the discussed periods 1960 to 1965 and 1965 to 1970 the share of the natural fibres shrinks steadily by 6 per cent every five years, or 1.2 per cent yearly. This demonstrates the increasing importance of man-made fibres.

TABLE 1. WORLD PRODUCTION OF MAIN TEXTILE FIBRES IN 1960—1970

	1960		1965		1970[a]		Growth as percentages of 1960	
	1,000 tons	per cent	1,000 tons	per cent	1,000 tons	per cent	1965	1970
Natural fibres								
Cotton	10,150	52	11,400	48	12,900	46	112	127
Wool (scoured)	1,450	8	1,500	6	1,500	5	103	193
Silk	30	—	30	—	30	—	100	100
Bast	4,530	23	5,350	23	5,600	20	118	124
Total	16,160	83	18,280	77	20,030	71	113	124
Man-made fibres								
Viscose	2,360	12	2,965	12	3,600	13	126	152
textile filament	540	3	583	2	600	2	108	111
industrial filament	404	2	456	2	500	2	113	124
staple	1,416	7	1,926	8	2,500	9	136	177

Acetate	252	1	373	2	400	1	148	159
filament	198	1	332	2	330	1	168	177
staple	54	—	41	—	50	—	76	93
Synthetic	704	4	2,035	8	4,000	14	289	568
filament	416	2	1,116	4	2,000	7	268	481
staple	288	2	919	4	2,000	7	319	694
Total	3,416	17	5,548	23	8,300	29	163	243
Glass fibres								
Total	100	—	175	1	300	1	175	300
Grand total	19,576	100	23,828	100	28,330	100	122	145

Source: FAO, 1964.
[a] Estimated.

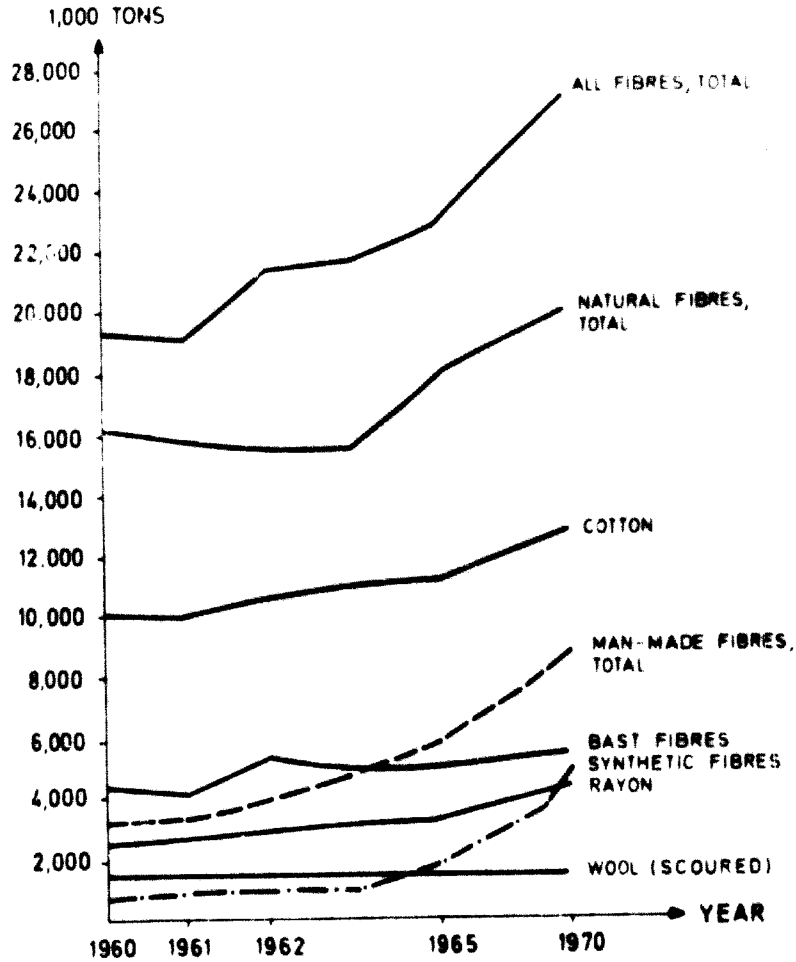


Figure 1. World production of the more important textile fibres, 1960 through 1970 (source: FAO, 1964)

Of all of the natural fibres, cotton has shown the most conspicuous increase, rising from a 10-million-ton crop in 1960 to 11.2 million tons in 1965 and 12.9 million tons expected in 1970. Indeed, cotton formed 52 per cent of the total world production of all the fibres. That percentage diminished to 48 per cent in 1965 and is expected to be 46 per cent in 1970. Cotton is the most important textile raw material from the viewpoint of its volume of production, constituting more than one half of the total amount of textile fibres produced in the world. Cotton also shows the highest rate of increase among all the natural fibres, being, in comparison to the 1960 production, 12 per cent greater in 1965, and probably surpassing it by 27 per cent in 1970.

Compared to that of cotton, the volume of the production of bast fibres is much smaller. From 4.5 million tons in 1960, their production reached 5.3 million tons in 1965 and is expected to reach 5.6 million tons in 1970. Their share in the total amount of all fibres was 23 per cent in both 1960 and 1965 and is expected to drop to 20 per cent in 1970. The rate of growth can be compared to that of cotton. The

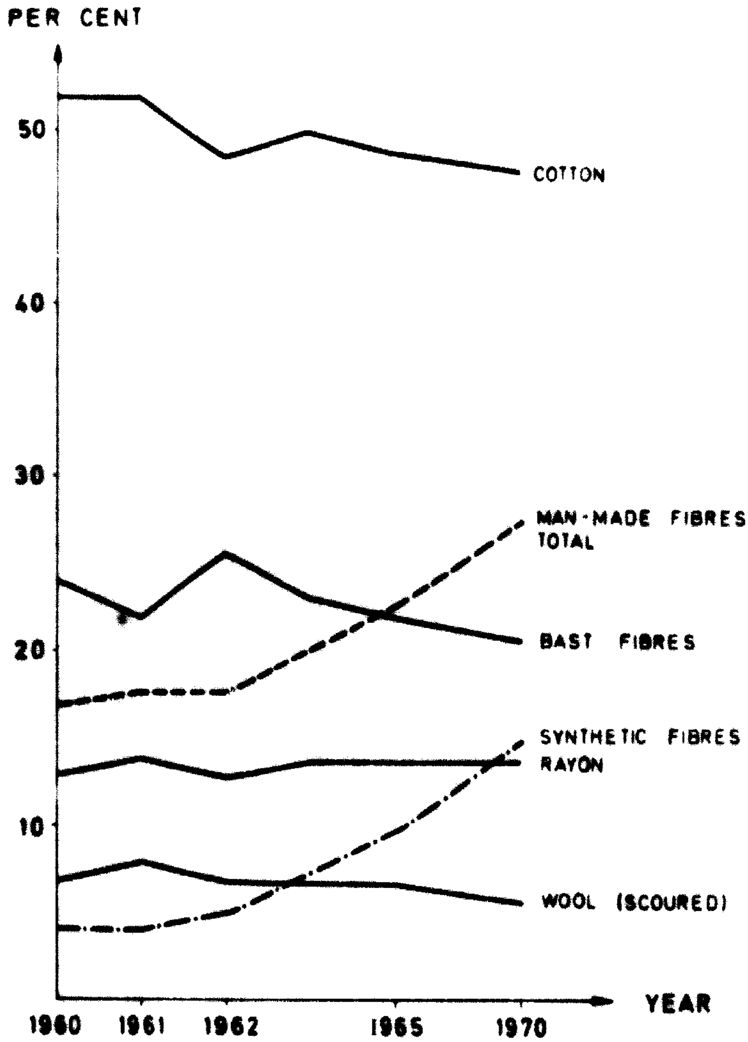


Figure 2. Comparative world production (per cent) of the more important textile fibres, 1960 through 1970 (source: FAO, 1964)

1965 production was greater by 18 per cent than that of 1960, and in 1970 the respective growth is expected to be greater by 24 per cent.

The production of wool has been practically unchanged since 1960, amounting to about 1.5 million tons (clean weight). However, its proportion to the ever-increasing volume of textile fibres in general was 8 per cent in 1960 and 6 per cent in 1965 and will drop to 5 per cent in 1970.

Natural silk in the period under discussion has also been produced in almost the same quantity of about 30,000 tons yearly. With this small volume it plays but a very minor role in the analysis of world resources of textile raw materials.

As far as man-made fibres are concerned, the production of viscose fibres has predominated, amounting to 2.4 million tons in 1960, after which it rose to 3 million tons in 1965 and is expected to reach the volume of 3.6 million tons in 1970.

The percentage of growth of production was in this case 26 per cent for 1965 and 52 per cent for 1970. In spite of that rate of growth, the production of those fibres remained at practically the same level of 12 to 13 per cent of the total. Relatively large growth is shown by acetate fibres, that is, by 48 per cent and 59 per cent. However, the absolute volume of this production is not significant being but 252,000 tons and 400,000 tons, respectively for these two periods. It is not expected that the total volume of acetate fibres will exceed 1 per cent of the total for all fibres in 1970.

The growth of production of synthetic fibres has been particularly notable. In 1960 their production amounted to 0.7 million tons, then rose to 2 million tons in 1965, and is expected to be 4 million tons in 1970. Taking 1960 as 100 per cent, this means a growth of 189 per cent, or nearly double, in 1965 and of 468 per cent, or nearly fivefold, in 1970.

In 1960 synthetic fibres formed hardly 4 per cent of the total amount of available textile raw materials, but their share doubled to 8 per cent in 1965, and in 1970 is expected to be 14 per cent, which would mean a 6 per cent increase in the next five years. Consequently, the aforementioned growth of the man-made fibre production by 1.2 per cent yearly will, from 1966, be due exclusively to synthetics. It should be noted that, according to expectations, the production of synthetics by 1970 will have caught up with the production of cellulose fibres, that is, viscose and acetate ones together, amounting to 4 million tons.

Glass-fibre production has a nearly negligible volume. From 100,000 tons in 1960 it rose to 175,000 tons in 1965 and is expected to reach 300,000 tons in 1970. This material constitutes no more than 1 per cent of the total world production of textile fibres.

Per capita consumption of fibres

Two factors affected the production of fibres, namely, the increase of population and improvements in the standard of living of that population, that is, demands for comfort and attractiveness.

Table 2 shows the past and projected increases of the world population, total consumption of textile fibres and consumption *per capita* from 1950 up to 1980. It can be seen there that the world population grew from 2.5 thousand million in 1950 to 3 thousand million in 1960. According to expectations, it will probably reach the figure of 3.6 thousand million in 1970 and 4.3 thousand million in 1980.

TABLE 2. WORLD FIBRE CONSUMPTION PER CAPITA

	Consumption of fibres (millions of tons)	*World population (1,000 million)*	*Consumption per capita (kg)*
1950	13.2	2.51	5.3
1960	19.6	2.99	6.5
1970[a]	28.3	3.57	7.9
1980[a]	37.2	4.27	8.7

Source: Data collected from various sources.
[a] Estimated.

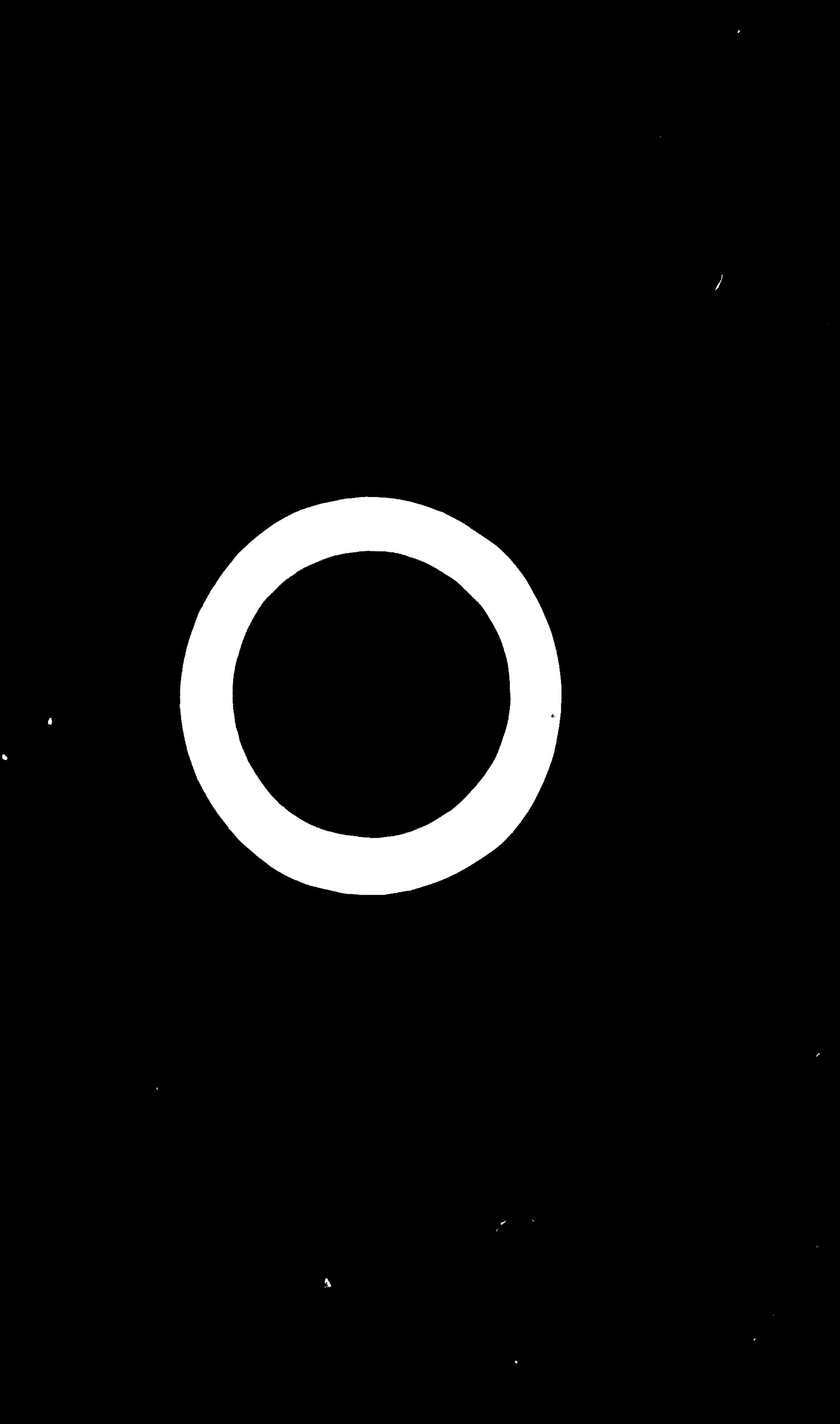


TABLE 3. PER CAPITA CONSUMPTION OF FIBRES FOR CLOTHING IN THE WORLD 1958—1961
(in kilograms)

	1958	*1959*	*1960*	*1961*
Cotton	3.39	3.42	3.46	3.39
Wool	0.47	0.48	0.49	0.49
Cellulose	0.85	0.85	0.88	0.91
Synthetic	0.17	0.20	0.24	0.29
Total	4.88	4.95	5.07	5.08

Source: FAO, 1964.

The growth of the production of fibres will match the growth of population, so that their *per capita* consumption will be not only kept level, but even may rise considerably. In 1950 *per capita* consumption was 5.3 kg, rising to 6.5 kg in 1960, and is expected to reach 7.9 kg in 1970 and 8.7 kg in 1980. (It is to be understood that "consumption" comprises all the fibres used for apparel, domestic and industrial purposes.)

Per capita consumption of apparel fibres is shown in table 3, the data referring to the period 1958 through 1961 (FAO, 1964). In the last of these years the use of fibres for clothing purposes amounted to 5.08 kg per inhabitant of the world. Cotton formed 67 per cent of that amount, viscose fibres formed 18 per cent, wool formed 10 per cent and synthetic fibres about 5 per cent. The last-mentioned group of fibres is expected to increase its share considerably in the years to come. This increase will of course affect the share of the other three varieties of fibres.

TABLE 4. PER CAPITA CONSUMPTION OF APPAREL FIBRES IN VARIOUS REGIONS OF THE WORLD IN 1961
(in kilograms)

	Cotton	*Wool*	*Cellulose fibres*	*Synthetics*	*Total*
Western Europe	4.9	1.6	2.3	0.8	9.6
Eastern Europe (including USSR)	5.8	1.0	2.1	0.2	9.1
North America	9.8	1.2	2.7	1.7	15.4
South America	3.1	0.3	0.6	0.1	4.1
Japan	5.4	1.3	2.7	1.4	10.8
Asia (excluding Japan)	2.0	0.1	0.2	—	2.3
Africa	1.4	0.1	0.5	—	2.0
Oceania	5.0	2.2	1.4	0.6	9.2

Source: FAO, 1964.

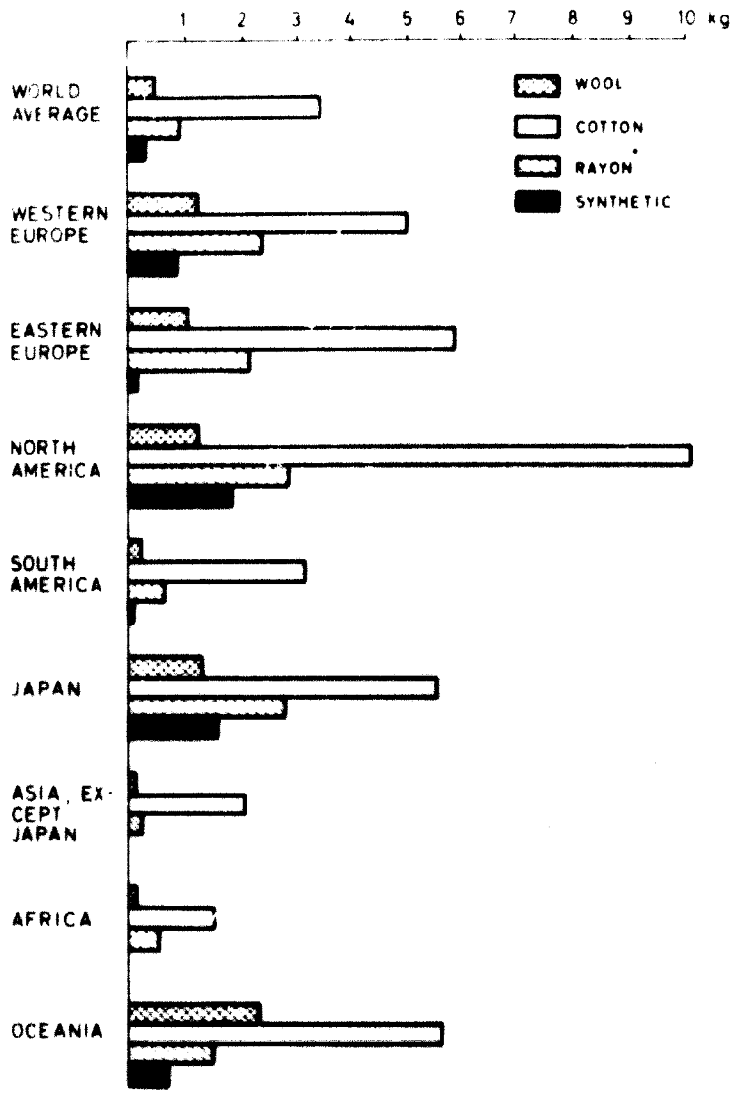


Figure 3. Per capita consumption of textile apparel fibres in 1961 (source: FAO, 1964)

Table 4 and figure 3 present the *per capita* consumption of apparel fibres in various parts of the world, as well as the shares of each group of fibres in that consumption. The data reflect the situation of 1961. The figures demonstrate striking divergences between textile consumptions in different regions. The highest position is held by North America, with consumption of 15.4 kg *per capita.* Next in succession are: Japan, 10.8 kg; Western Europe, 9.6 kg; Oceania, 9.2 kg; Eastern Europe, 9.1 kg; South America, 4.1 kg; Asia excluding Japan, 2.3 kg; and Africa, 2.0 kg. These divergences can be partly ascribed to climatic differences, but are due primarily to distinctly different industrial developments and to prosperity and standards of living, which vary greatly from region to region.

The next feature of textile consumption that will be noticed is the distribution of the various fibres. For example, cotton makes up 50 to 64 per cent of the total amount of all the fibres consumed in the better-developed regions, such as Europe, North America, Japan and Oceania. In developing countries of South America, Asia (excluding Japan) and Africa, the proportion of cotton consumed rises to 70 to 87 per cent. The more developed areas consume a considerably higher proportion of wool and of man-made fibres.

Development trends in the production of natural fibres

The greatest world producer of cotton, the United States, grows about 30 per cent of this fibre. In descending order follow the Soviet Union (15 per cent), mainland China and India (10 per cent each), Africa (9 per cent) and South America (8 per cent), the remainder (18 per cent) being produced by other countries.

It should be noted that the total area devoted to cotton is steadily diminishing. Nevertheless, the world cotton crop still tends to increase because of higher yields per unit of cultivated area.

In the United States this yield is about 500 lb/acre, whereas the Soviet Union has surpassed 600 lb/acre. However, in China (mainland) the yield was noted as 230 lb/acre and in India about 100 lb/acre.

It is well known that countries with a high production of cotton do their best to intensify its cultivation by raising per-acre yields, while the less-developed countries try to increase cotton production by enlarging the area of cultivation (Dowgielewicz and Szucht, 1965).

Production of wool, as noted above, has not changed much within recent years, nor is it expected to increase in 1970. Australia, the most important wool producer, accounts for about 30 per cent of the world production of that fibre, followed by the Soviet Union (14 per cent), New Zealand (11 per cent), Argentina (7 per cent), South Africa (6 per cent), the United States (5 per cent), Uruguay (3 per cent), mainland China and Mongolia (3 per cent) and the United Kingdom (2 per cent), the remainder (about 19 per cent) being produced by other countries.

Jute and related fibres dominate the group of bast fibres, followed by hard fibres, flax and hemp. Data with regard to the production of those materials in 1960, 1965 and 1970 are presented in table 5.

The volume of production of jute and related fibres rose from 2.6 million tons in 1960 to 3.3 million tons in 1965 and is expected to reach 3.5 million tons in 1970, showing then an increase from the 1960 level by 36 per cent. The quoted figures refer primarily to jute (80 per cent), the remaining 20 per cent to related fibres such as kenaf.

Practically all jute comes from India and Pakistan, each of these countries producing about 45 per cent of the world supplies of that material. The remaining 10 per cent is grown in Brazil, Burma, China (mainland), China (Taiwan) and the Soviet Union. Most (85 per cent) of the fibres related to jute are produced in China (mainland), India and Thailand. Minor quantities are grown in Brazil, Congo (Democratic Republic of), Iran, the Soviet Union and some other countries.

A group of bast fibres that is of some importance includes the "hard fibres", which is a general term for such fibres as sisal, manila and the like. The volume of their production has not changed over the period discussed here and amounts to about 1 million tons. The most important producers are Africa, Central and South America, the Philippines and Indonesia.

TABLE 5. WORLD PRODUCTION OF BAST FIBRES IN 1960, 1965 AND 1970 IN THOUSANDS OF TONS AS PERCENTAGE OF TOTAL WORLD PRODUCTION OF TEXTILE FIBRES

	1960		*1965*		*1970[a]*		*Growth as percentage of 1960*	
	1,000 tons	*per cent*	*1,000 tons*	*per cent*	*1,000 tons*	*per cent*	*1965*	*1970*
Flax	630	3	650	3	700	3	103	111
Hemp	380	2	400	2	400	1	105	105
Jute and related fibres	2,580	13	3,300	14	3,500	12	128	136
Hard fibres	940	5	1,000	4	1,000	4	106	106
Total	4,530	23	5,350	23	5,600	20	118	124

Source: Data from various sources.
[a] Estimated.

It is very unlikely that the production of these fibres will expand further; indeed, it might very well contract. The reason for this is the increasing competition of synthetic fibres primarily the recently appearing polyethylene and polypropylene fibres. Tapes made from oriented films derived from these synthetics form an excellent material for the manufacture of wrappers and of various types of cordage. Even aside from the excellent wearing properties of those materials, they are particularly attractive because of their elimination of the spinning process, since the tapes may be directly woven or plaited. This production is increasing at a rapid rate, especially since the cost of the raw materials, polyethylene and polypropylene, is relatively low.

Three countries of Western Europe, namely Belgium, France and the Netherlands, are the leading producers of high-quality flax. Czechoslovakia, Poland and Eastern Germany are also important producers. Total world production of this fibre is expected to reach 700,000 tons at the end of the period under discussion (table 5).

The principal grower and exporter of hemp is the Soviet Union, although this fibre is also grown in Hungary, Italy, Poland, Romania and Yugoslavia. Total world production is expected to reach 400,000 tons in 1970 (table 5).

Development trends in the production of man-made fibres

The growth of world production of man-made fibres over the years 1930 to 1970 is illustrated by data presented in table 6. That growth is shown diagrammatically for the period 1960 to 1970 in figure 4, in which it can be seen that the production of staple fibres is developing at a rate faster than that of filaments.

TABLE 6. WORLD PRODUCTION OF MAN-MADE FIBRES (EXCLUDING GLASS FIBRES), 1930—1970

(in thousands of tons)

	1930	*1935*	*1940*	*1945*	*1950*	*1955*	*1960*	*1965*	*1970*[a]
Cellulose	209	489	1,104	599	1,609	2,282	2,612	3,338	4,000
textile filament	206	425	524	306	672	701	738	915	950
industrial filament	—	—	12	95	199	347	404	456	500
staple	3	64	568	198	738	1,234	1,470	1,967	2,550
Synthetic	—	—	2	24	69	263	704	2,035	4,000
filament	—	—	—	—	54	181	416	1,116	2,000
staple	—	—	—	—	15	82	288	919	2,000
Total	209	489	1,106	623	1,678	2,545	3,316	5,373	8,000
filament	206	425	538	425	925	1,229	1,558	2,487	3,450
staple	3	64	568	198	753	1,316	1,758	2,886	4,550

Source: Vits, 1966.
[a] Estimated.

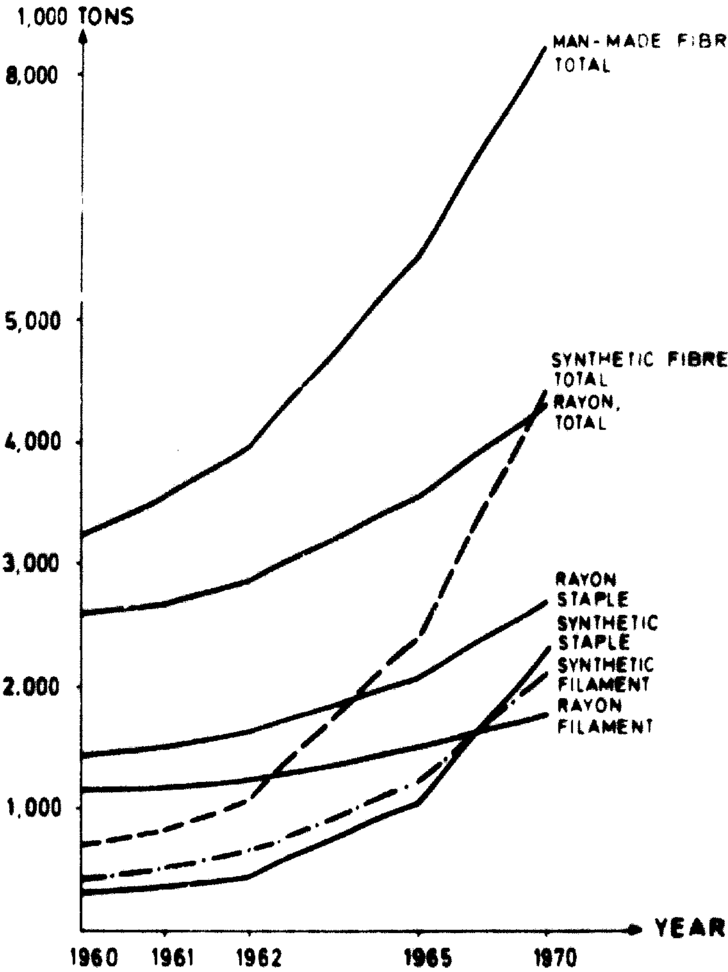


Figure 4. World production of man-made fibres, 1960 through 1970 (source: Vits, 1966)

The production of rayon staple fibres in 1965 was 36 per cent higher than that of 1960, whereas a similar comparison made for synthetic staple fibres shows a growth of 219 per cent. In 1970 the increases will be 77 per cent and 594 per cent respectively. The production of continuous filament is not so dynamic, the growth for 1965 being 8 per cent (filament) and 13 per cent (staple) for viscose rayon and 168 per cent for synthetics, whereas for 1970 the respective figures will be 11 per cent and 24 per cent for viscose rayon and 381 per cent for synthetics.

It is to be expected that the rate of growth of production of the staple fibres will become slower relative to that of the continuous filaments. This assumption is based on the rapid developments of textured-yarn techniques. Yarns of this kind are increasingly replacing yarn spun of staple fibres in many apparel fabrics.

Table 7 shows data concerning production of man-made fibres in the world as a whole and in some of its more highly developed areas. It can be seen that Western Europe was the largest producer of man-made fibres in 1965 (33 per cent of world production), followed by the United States (28 per cent), Japan (16 per cent), the rest of the world producing the remaining 23 per cent.

TABLE 7. PRODUCTION OF MAN-MADE FIBRES IN SOME DEVELOPED REGIONS OF THE WORLD, 1965

	World		*USA*		*Western Europe*[a]		*Japan*		*USSR*	
	1,000 tons	*per-centage of 1960*	*1,000 tons*	*per-centage of 1960*	*1,000 tons*	*per-centage of 1960*	*1,000 tons*	*per-centage of 1960*	*1,000 tons*	*per-centage of 1960*
Viscose	2,965	126	491	146	766	113	[illegible]59	110	[illegible]13	162
textile filament	583	108	77	115	142	93	86	84	62	138
industrial filament	456	113	120	95	110	110	25	91	86	160
staple	1,926	136	294	207	524	121	348	122	165	174
Acetate	373	148	202	155	71	125	27	153	18	600
textile filament	332	168	1[illegible]	172	[illegible]5	151	24	173	18	600
staple	41	76	25	90	6	43	3	85	—	—
All cellulose	3,338	128	693	148	837	114	486	112	331	168
filament	1,371	120	374	125	317	107	135	94	166	163
staple	1,967	134	319	188	520	118	351	121	165	174
Synthetic	2,035	289	807	262	517	268	380	321	78	521
filament	1,116	268	453	228	279	245	166	356	54	515
staple	919	319	354	325	238	301	214	300	24	534
Total	5,373	162	1,500	194	1,354	146	866	157	409	193
filament	2,487	160	827	166	596	145	301	158	[illegible]	195
staple	2,886	164	673	240	758	146	565	156	189	189

Source: Ivanova and Kirsanova, 1967, and other sources.

[a] Federal Republic of Germany, France, Italy and the United Kingdom.

TABLE 8. WORLD PRODUCTION OF SYNTHETIC FIBRES

	1960		*1965*		*Growth in 1965 as percentage of 1960*
	1,000 tons	*per cent*	*1,000 tons*	*per cent*	
Polyamide	406	58	1,009	50	250
including staple	(43)	(6)	(107)	(5)	(250)
Polyester	123	17	459	23	370
including staple	(87)	(12)	(322)	(16)	(370)
Polyacrylic	109	16	398	20	360
including staple	(109)	(16)	(396)	(19)	(360)
Other synthetic	66	9	169	7	260
including staple	(44)	(6)	(97)	(5)	(230)
Total	704	100	2,035	100	290
including staple	(281)	(40)	(922)	(45)	(330)

Source: Ivanova and Kirsanova, 1967.

The picture regarding synthetics is quite different. Here the largest producer is the United States (40 per cent of world production), followed by Western Europe (30 per cent), Japan (19 per cent), and the rest of the world (11 per cent).

The changes in the kinds and amounts of synthetic fibres produced in 1960 and 1965 are shown in table 8. World production, by region, of man-made fibres in those two years is shown graphically in figures 5 and 6 (Vits, 1966).

In 1960 polyamide fibres formed the main variety of synthetics, and in 1965 they still constituted 50 per cent of the total production. This would appear to be their stabilized position for the foreseeable future. In any case, the already mentioned technique of texturing indicates the demand for polyamides, which are the fundamental material for textured yarns. The next reason for the demand of polyamides is their use for the manufacture of carpets and tire cords.

Polyester and polyacrylic fibres constitute the next group of synthetic fibres, with respective shares of 23 per cent and 20 per cent of the 1965 production. These fibres also have good prospects for development, as evidenced by their respective increases in volume by 260 per cent and 270 per cent in 1965 (figure 7).

It is to be noted that the majority of polyamides are produced as continuous filaments, whereas polyester and polyacrylics are usually produced as staple fibres.

The classification of "other synthetics", shown by a graph in figure 5, comprises polypropylene, elastomeric fibres of the "Spandex" type and the like. Polypropylene fibres are expected to take the fourth position on the list of synthetics, that is, after the polyamides, polyesters and acrylics. Polypropylene production is accelerating sharply. The success of these fibres also may be attributed to the demand for oriented foils mentioned above. The fibres will undoubtedly have a great use in the manufacture of such products as carpets, medical dressings, furnishings, filters, fishing nets and cordage of various kinds.

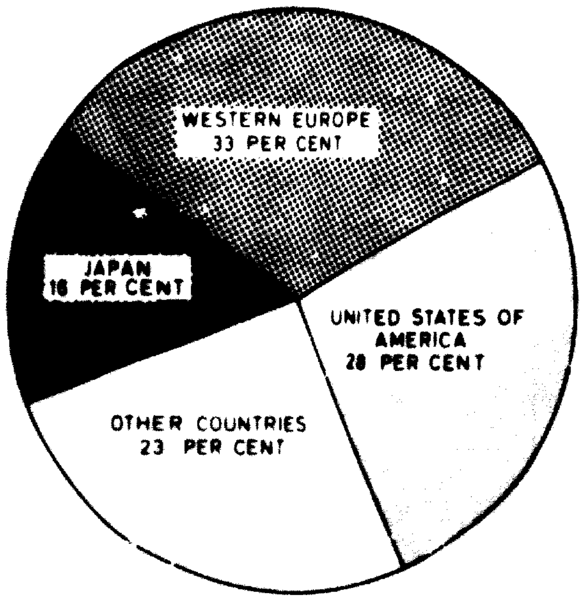


Figure 5. Production of man-made fibres in the more important regions and countries in 1965 (source: Vits, 1966)

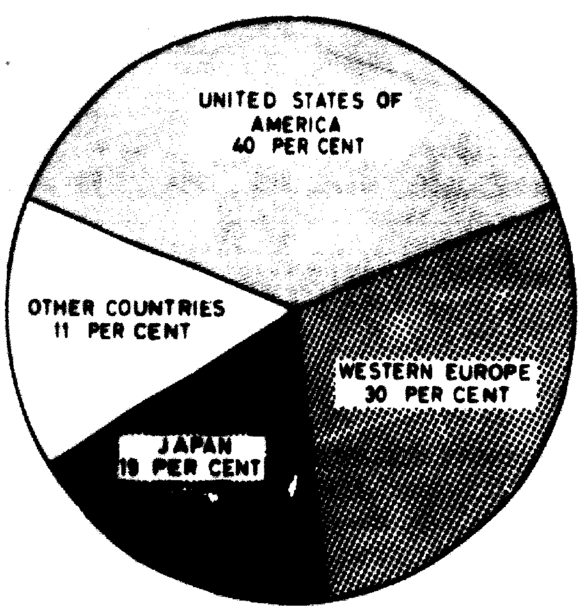


Figure 6. Production of synthetic fibres in the more important regions and countries in 1965 (source: Vits, 1966)

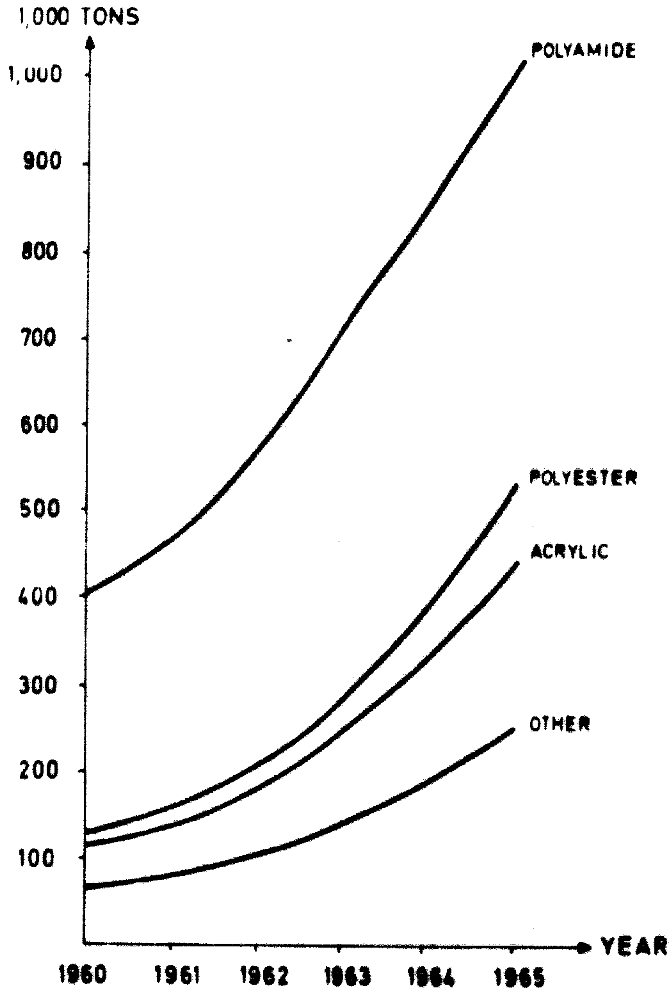


Figure 7. World production of synthetic fibres according to kind, 1960 through 1965 (source: Ivanova and Kirsanova, 1967)

The above-mentioned elastomer Spandex has opened completely new perspectives for textile techniques. It has been foreseen that this fibre will soon find use, not only for bathing suits, foundation garments, suspenders and the like, but also for the manufacture of outerwear.

Tables 9, 10 and 11 show the specification of man-made fibres produced in some better-developed countries. The figures refer to the years 1960 to 1965 and are interesting because of the demonstration of trends in developments regarding particular types of synthetic fibres in those countries.

TABLE 9. PERCENTAGES OF MAN-MADE FIBRES PRODUCED IN THE UNITED STATES AND JAPAN

	United States		*Japan*	
	1960	*1965*	*1960*	*1965*
Viscose	43	33	75	53
Acetate	17	13	3	3
Synthetic	40	54	22	44
Filament	64	55	34	35
Staple	36	45	66	65
Cellulose filament	64	54	33	28
Cellulose staple	36	46	67	72
Synthetic filament	65	56	39	44
Synthetic staple	35	44	61	56

Source: Ivanova and Kirsanova, 1967.

TABLE 10. PRODUCTION OF SYNTHETIC FIBRES IN THE UNITED STATES, 1963 AND 1965

	1963		*1965*		
	1,000 tons	*per cent*	*1,000 tons*	*per cent*	*1965 as percentage of 1963*
Filament					
Polyamide	286	55	385	48	135
Polyolefin	13	3	29	4	223
Other	24	4	39	5	162
Total	323	62	453	57	140
Staple					
Polyacrylic	95	18	167	21	176
Polyamid	28	5	41	5	146
Other	78	15	145	18	186
Total	201	38	353	44	176
Grand total	524	100	806	100	154

Source: Ivanova and Kirsanova, 1967.

TABLE 11. SPECIFICATION OF SYNTHETIC FIBRES PRODUCED IN WESTERN EUROPE, 1960 AND 1965

	1960		*1965*		*1965 as percentage of 1960*
	1,000 tons	*per cent*	*1,000 tons*	*per cent*	
Polyamide	130	60	307	50	236
including staple	(20)	(9)	(38)	(6)	(190)
Polyester	51	24	151	25	296
including staple	(31)	(14)	(90)	(15)	(290)
Polyacrylic	21	10	116	19	552
including staple	(21)	(10)	(114)	(18)	(543)
Other synthetic	13	6	36	6	277
including staple	(11)	(5)	(26)	(4)	(236)
Total	215	100	610	100	284
including staple	(83)	(39)	(268)	(44)	(323)

Source: Ivanova and Kirsanova, 1967.

Specific consumption of textile fibres

Tables 12 to 15 demonstrate the consumption of specific textile fibres in the United States. Since that country has the largest *per capita* consumption of fibres and is one of the principal producers of both cotton and man-made fibres, the trends shown in that country may be considered as indications of future developments regarding *per capita* consumption in the world.

Especially interesting are the data given in table 15, showing groups of industrial textiles in which natural fibres are being successfully replaced by man-made ones.

TABLE 12. PRESENT AND EXPECTED CONSUMPTION OF FIBRES IN THE UNITED STATES

	1965		*1970[a]*		
	1,000 tons	*per cent*	*1,000 tons*	*per cent*	*1970 as percentage of 1965[a]*
Natural fibres					
Total	2,169	58	1,955	46	90
Man-made fibres					
Viscose	515	14	544	13	105
Acetate	200	5	252	6	126
Polyamide	392	10	567	14	145
Polyester	156	5	381	9	244
Polyacrylic	160	4	270	6	168
Polyolefin	32	1	73	2	228
Total	1,455	39	2,087	50	143
Glass fibres					
Total	120	3	168	4	140
Grand total	3,744	100	4,210	100	113

Source: Ivanova and Kirsanova, 1967.
[a] Estimated.

TABLE 13. TYPES OF FIBRES CONSUMED IN THE UNITED STATES, 1964
(in percentages)

	Domestic and similar textile	*Industrial products*
Cellulose	80	20
filament	66	34
staple	96	4
Synthetic	76	24
filament	61	39
staple	97	3
Total	78	22

Source: Ivanova and Kirsanova, 1967.

TABLE 14. PRODUCTION OF VISCOSE AND SYNTHETIC TIRE CORDS, 1960 AND 1965

	1960		*1965*	
	1,000 tons	*per cent*	*1,000 tons*	*per cent*
Viscose cord	109	63	97	45
Nylon and polyester cord	63	36	118	55
Cotton cord	1	1	—	—
Total	173	100	215	100

Source. Ivanova and Kirsanova, 1967.

TABLE 15. CONSUMPTION OF FIBRES FOR VARIOUS INDUSTRIAL END-USES IN THE UNITED STATES, 1964

	1,000 tons		*Percentage*				
				Man-mades			
	Man-mades	*Total*	*Natural*	*Cellulose*	*Synthetics*	*Glass*	*Total*
Tire cords	191	195	2	48	50	—	98
Reinforcement of plastics	52	65	13	—	—	87	87
Ropes	30	55	45	16	25	14	55
Industrial articles (driving belts, fire hoses etc.)	14	44	68	20	11	1	32
Electrical insulation	9	19	52	5	2	41	48
Coverings for transported goods	9	39	77	11	12	—	23
Awnings	6	39	85	1	12	2	15
Sewing thread	7	49	86	5	9	—	14
Felts	2	12	84	3	13	—	16
Filters	5	9	44	27	22	7	56
Wrappers	—	28	99	—	1	—	1
Various	11	50	78	7	15	—	22
Total	336	604	44	21	23	12	56

Source: Ivanova and Kirsanova, 1967.

Developments regarding man-made fibres

The great growth of production of man-made fibres in recent years is associated with the developments in the techniques of their manufacture. There has also been a simultaneous improvement of the fibre quality, with an ever greater ability to design them for particular end-uses. The range of various applications is being constantly broadened.

Continuous viscose filaments have much improved in quality. Because of their properties they find many uses, especially for industrial products, and mainly for tire cords. However, viscose filament yarn is also worked into other industrial articles such as heavy-weight conveyers, transmission belts and fire hoses. The recently developed types of viscose filament yarn are as strong as the corresponding polyamide yarn of extra strength (Koch, 1966).

Some of the properties of viscose staple fibres have also been much improved. Indeed, some types, especially those of a modified structure can compete successfully with synthetics (Koch, 1966). This is the case with the so-called "modal fibres", which are distinguished by a high wet modulus, great strength (both wet and dry), low swelling value, high resistance to alkali and improved stability of form in the final product. The properties of these fibres suggest those of cotton, with which they may be readily blended. In many articles they may completely replace cotton.

Developments regarding synthetics are of particular importance. Many varieties of synthetic fibres have recently been produced for special purposes. Some are especially prepared to avoid the defect known as "pilling". This has been done by modifying the cross-section of the fibre. This process also modifies the lustre and handle of the fibre (Koch, 1966).

Polyamide fibres are now more resistant to light. They may be produced with various affinities to dyestuffs, and this fact may be exploited in the production of tufted carpets with colour designs.

Polyacrylic fibres may now be dyed more easily.

Fibres have been produced now with a bilateral structure, due to which they are distinctly crimped in an irregular but stable way (Koch, 1966). Particularly noteworthy developments are occurring with regard to the manufacture of new, interesting, two-component fibre varieties.

Progress has been made with the developments of elastomeric fibres of Spandex type, as well as of nonflammable polyvinyl chloride, polyacrylic and polyamide fibres. Essential progress has been achieved with regard to the production of fibres which are resistant to effects of high temperature and other conditions.

This brief review cannot cover all the details with regard to developments of man-made fibres, especially since progress in that line continues incessantly. It seems evident that man-made fibres should, by the end of this century, become the fundamental textile raw materials of the world.

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CRITERIA FOR THE SELECTION OF TEXTILE FIBRES

by

E. Szucht

The best use of textile fibres depends on many factors, the most important of which are: Wearing conditions of final products, fibre properties, economic factors of the end-use, availability of fibres, availability of necessary processing equipment, and standard of living of the prospective consumers.

Each of these factors has an important effect on the applicability of various fibres, and serious economic difficulties may result if these factors are not taken into consideration. There are no rules or principles regarding the mutual relation of the above-mentioned factors, nor are there any criteria for the assessment of their relative economic importance. They can be looked upon variously, depending on circumstances in a given country with regard to social conditions, traditions and technical possibilities. An accurate analysis based on scientific and technical aspects should have a decisive effect on the proportions of particular varieties of fibres selected for consumption.

Wearing conditions of final products

The conditions under which the final products made from them will be used is the primary consideration in the selection of fibres for a specific purpose. This factor concerns the ways in which the product is to be used and the function that it is expected to fulfil. These criteria should be studied with great care so as to avoid mistakes and misapprehensions that could impair, or even destroy, the usefulness of the final products.

High temperatures, strong chemical reactions, moisture, intense light and great mechanical stress are examples of highly important conditions of use that would require specific properties of fibres.

Fashion is an essential factor that affects wearing conditions. In many countries, especially in highly industrialized ones, fashion seriously influences the selection of raw materials used in the production of consumer goods. Rapidly changing fashions call for production of inexpensive, not necessarily durable, but attractive articles. Selection of suitable fibres is here of paramount importance.

Climate is the classic example of a factor that determines the nature of clothing. For example, the tropics, with their high moisture and temperature, require clothing with good hygroscopic properties, that cools the body well, readily absorbing its perspiration. On the other end of the scale, the garments used in polar regions should retain warmth well. As well as having good insulating properties, these textiles should have a good handle and be comfortable to the wearer. Figures 1 and 2 provide examples of the properties required of two textiles designed for quite different purposes.

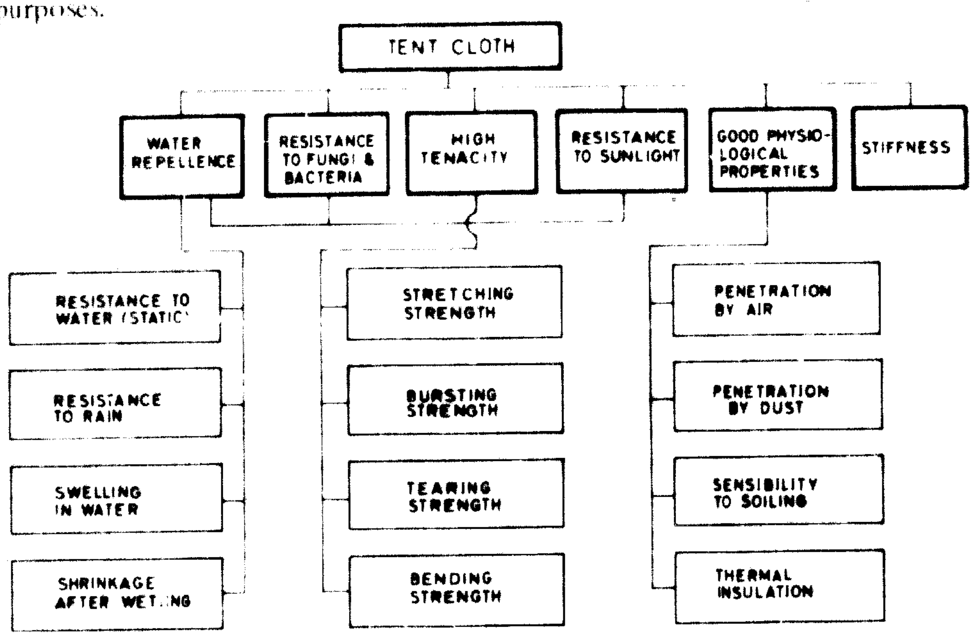


Figure 1. Specifications for a textile with particular end-use: tent cloth

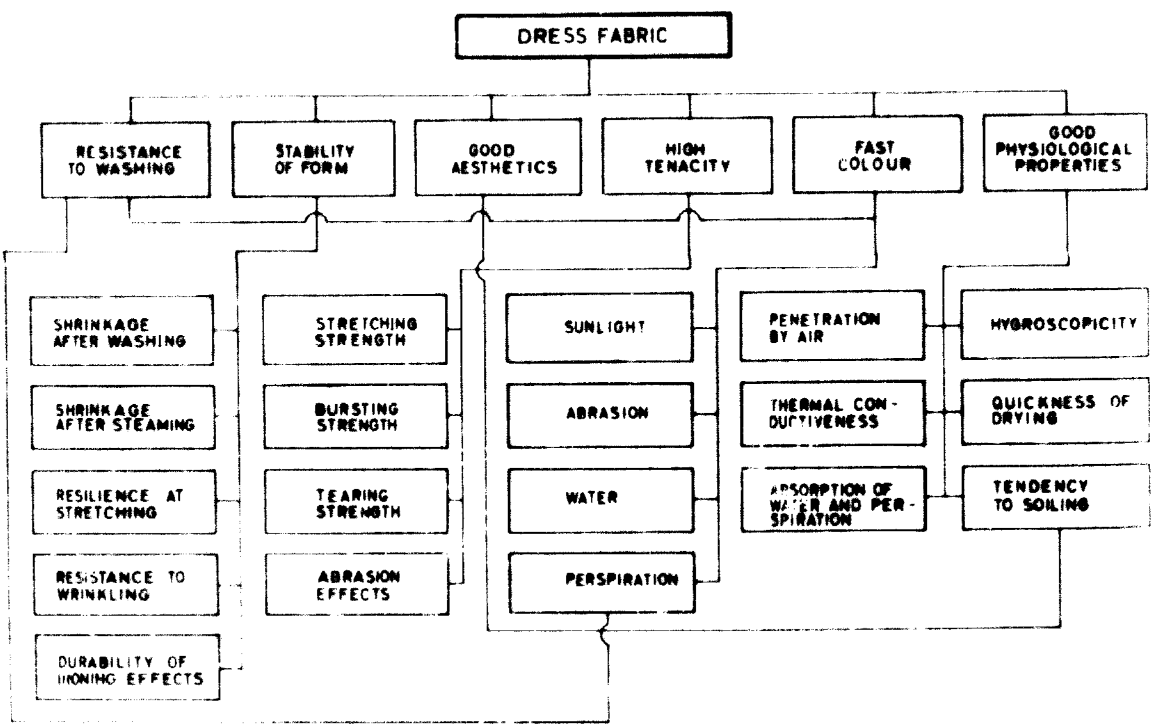


Figure 2. Specifications for a textile with particular end-use: dress fabric

Fibre properties

The properties of any given fibre limit its usefulness for various purposes and impose the use of certain processing techniques. However, some of these limitations may be overcome, in part, by proper design of the textiles made from them. For example, the blending of fibres with different properties is very useful in producing textiles for specific end-uses.

Although some properties are common to all the fibres, each of them has its own characteristics. It is well known that wool provides good hygroscopicity, thermoinsulation and aesthetics but has poor tenacity; polyester fibres have excellent physical properties, high resistance to creasing and to the effects of light but are not satisfactory as regards their hygienic properties; viscose fibres are sensitive to the effects of moisture, are not resilient and are easily affected by chemicals, but have good hygroscopic properties. The matching of suitable fibres to form well-balanced blends permits the widening of the range of applicability, makes possible the use of substitutes and permits the production of goods of high quality.

Economic factors of the end-use

Economic considerations constitute the most important factor with regard to the applicability of particular kinds of fibres and the formation of the raw materials basis. If these considerations are not taken into account, it would not be possible to operate any textile enterprise economically. Relatively great differences in the prices of these fibres and in their processing costs, with great possibilities of making fibre blends tailored to the requirements of various end-uses, form the basis of economic factors in fibre selection. Table 1, which shows the world prices (in US dollars per ton) of the major staple textile fibres, demonstrates that some fibres are only fractionally as costly as others. The judicious use of the less costly fibres can yield reasonably priced textiles well suited to their end-use, with no sacrifice of wearing qualities.

TABLE 1. PRICES OF MAJOR STAPLE FIBRES

	Price (US dollars/ton)
Acetate	750–900
Combing wool (scoured)	2,400–2,800
Medium-staple cotton	500–750
Polyacrylic	1,450–2,200
Polyamide	2,000–2,600
Polyester	1,850–2,000
Polypropylene	1,450–1,700
Spandex (filament)	4,500–15,000
Triacetate	1,200–1,600
Viscose rayon	420–500

Some fibre varieties or their blends require special and expensive processes such as heat-setting of fabrics, pressure dyeing and treatment with chemicals. The costs of making-up and of maintenance can also affect the demand and consequently the range of applications of a given fibre group.

Availability of fibres

The availability of fibres, that is, an easy access to them, good variety, marketing conditions and the like also have great influence on the use of particular fibre groups. Many countries producing significant quantities of natural fibres such as cotton, wool and bast fibres avoid the use of man-made fibres despite the fact that they often are more economical or better adapted to the securing of high quality of products made from them.

On the other hand, a good local supply of raw fibre materials contributes to a high versatility of textile production and to its better adjustment to the requirements of the market, as well as to better economic effects. Furthermore, the relative ease of adjustment of mills to the processing of easily accessible local raw materials should not be overlooked.

Large fibre-producing organizations have at their disposal special research centres for the study of technical processes and of the best use of the fibres produced.

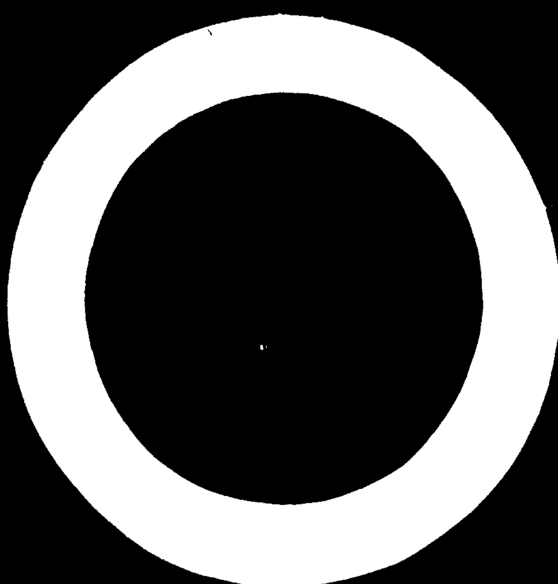
The constant growth of world population and the steady increase of *per capita* consumption of textile fibres, has resulted in an enormous rise in demand for the fibres in individual countries as well as in the world as a whole. The consequence of this is a shift in the proportions of particular fibre varieties used for textiles, especially in countries where there was formerly a great consumption of natural fibres. In many countries the near future will witness a further shift of those proportions toward a greater share for the man-made fibres, all the more so because their variety is steadily growing and their quality improving.

In countries with large consumptions of natural fibres, the intended use of man-made fibres should be based on such of their properties that suit them for highly economical blending. Such countries should invest first of all in chemical plants for the production of man-made fibres of the kinds best suited for blending with the most readily available natural fibres.

Availability of necessary processing equipment

Availability of processing equipment is not a decisive factor affecting the proper destination and economic use of fibres. Conditions can be changed to suit the circumstances by adjusting equipment or processing techniques. However, these adjustments can be costly and may require skilled personnel. This is why new techniques for the processing of man-made fibres are applied in many countries after a long delay.

The change-over from conventional processing techniques to newer ones adjusted to man-made fibres requires modernization of equipment, new technology and new dyestuffs and auxiliary chemicals. Failure to ensure proper construction of the end product, inept planning or incomplete processing operations may affect technical and economical results very adversely, thus discouraging the utilization of new developments in the textile industry.



Standard of living of the prospective consumers

The standard of living enjoyed by the people of a country greatly influences the selection of textile fibres. Obviously, the demand for textile products, backed by a readiness of the population to spend a large part of its income for them, creates incentives for the textile industry to produce new and attractive goods with high price margins, or inexpensive goods for frequent replacement.

Textile factories that use large quantities of low-cost fibres such as viscose, acetate or cotton have special ways of processing and finishing their final products. Many articles are produced of quite expensive materials such as textured yarns, elastomers or synthetic filament yarns with special and attractive effects.

The population of a country with a low standard of living demands textiles that are cheap but durable. In this case standard fibres must be used, with processing techniques as inexpensive as possible. The use of multicomponent blends of man-made and natural fibres would appear to be a very sound approach in this situation.

TECHNICAL AND WEARING CHARACTERISTICS OF TEXTILE FIBRES

by

E. Szucht

The quality of any raw or partially finished material may be considered as the degree to which its properties conform to the requirements of its processing and end-use.

Technical as well as wearing characteristics may be referred to many physical properties of fibres, of which only a few may be determined by suitable testing. Actually, it is hardly possible to separate the characteristics that may be said to be purely technical from those that refer only to wearing. In most cases these groups overlap and affect the processing as well as the wearing conditions of fibres.

Differently from many other materials, textile fibres have many characteristics whose values differ considerably between varieties. This fact creates a large range of possibilities, as far as end-uses are concerned, that the manufacturer can exploit if he has the know-how that enables him to take advantage of them.

Foreign-matter content

The fact that some fibres are contaminated by foreign matter is usually independent of their internal structure. Foreign matter content is a well-known parameter, frequently tested in mill laboratories.

The content of fatty substances is most characteristic of wool. All who work with this fibre are well acquainted with this fact, which so greatly affects all stages of wool processing. Similar importance may be attributed to the amount and quality of lubricants with which man-made fibres are dressed. They play an essential role in spinning, particularly with regard to static electricity and the adherence of fibres being worked into intermediate textile products.

The presence of vegetable and mineral impurities are important considerations in the classification of natural fibres, since those characteristics are of prime importance in spinning and finishing as well as for the aesthetic qualities of the final product.

Co-operativeness of fibres

Co-operativeness is a property that is related primarily to the technological characteristics of fibres. It concerns the interaction of the fibres that are used in combination. This property includes coefficient of friction, spinnability and adherence of fibres. All three of these parameters influence the conditions of spinning and intensity of felting. They can be altered by treatment with special dressings and lubricants or by alteration of the geometry of the fibres, as by crimping or changing the cross-section area.

A serious defect of fibres that is associated with their co-operativeness is the formation of knots and neps while the fibres are being processed. This phenomenon occurs with varying intensity and can be controlled by the use of suitable dressings and selection of proper dimensions of fibres.

In some cases, nepping can occur at the surface of fabrics made of synthetic fibres, and there it appears in the form of tiny "pills". This pilling affects the aesthetics of woven and knit goods adversely and is sometimes very difficult to eliminate.

Dyes and dyeing processes

Because of its individual chemical composition and internal structure, each type of textile fibre requires the use of dyestuffs and dying processes specifically adapted to it. Thus, synthetic fibres require more intensive treatment (high pressure, the use of carriers) than do natural fibres or those, such as viscose rayon, that are made from regenerated natural materials. The general capacity of a fibre of assuming colour is referred to as its affinity for, or absorption of, dyestuffs.

The basic indicators of quality of a dyed material are those that determine colour-fastness. There are numerical indexes of that fastness that have been tested in various conditions of physical and chemical stress, light, moisture and the like.

Hygroscopicity

The hygroscopic properties of a fibre refer to its affinity for moisture, such as perspiration and water vapour. These properties determine physiological features of many textile products, primarily clothes, as well as of end-use applicability of textile fibres.

The low hygroscopicity of synthetic fibres restricts their range of usefulness and in many instances reduces the wearing properties of articles made from them. On the other hand, this same low hygroscopicity favours their use for various industrial products such as tent cloth, conveyor belts and fishing nets.

Morphology

The techniques used in textile processing are determined primarily by the morphology of the fibres. This includes properties such as length, fineness, cross-section area, crimp, surface smoothness, lustre and colour. Among the most important of these is length, which determines the suitability of a fibre for certain spinning and felting processes and is accounted for in all systems of fibre classification. Length may be determined by several indices that often differ widely for various types of fibres.

Fineness is of similar importance. It affects yarn properties directly, particularly spinnability, which is the capability of a fibre to be spun to a high yarn count.

Much recent study has been devoted to the crimpedness of fibres. This interest has resulted mainly from developments in man-made fibres, in course of the manufacture of which the degree and durability of crimpedness can be altered. In this way the spinnability of fibres, as well as some properties of final products made from them, can be controlled

Other morphologic properties can be controlled in man-made fibres but are of no particular importance, although some of them, such as lustre and cross-section area, have recently attracted more attention.

Strength

Naturally, strength is of paramount importance in most of the materials used by man. This is the case with textile fibres, since their strength determines the end-use and wearing properties of final products.

According to the character of the stresses to which it is subjected, the following fibre-strength characteristics may be listed: tensile strength, bending resistance, torsion resistance and pressure resistance.

Although all of these parameters influence the processing and use of textile products, only the first (tensile strength) is universally determined, since the others are less easy to establish reliably.

However, all four parameters may be tested at once in several different ways, that is, in loop, knot or tie form of the specimen, as shown in figure 1, with the stress due to bending being predominant. These parameters are in universal use and are often taken as indices in classification systems of textiles. Their low values may be evidence of brittleness and of low resistance to abrasion of final products.

a b c

Figure 1. Loop (a), knot (b) and tie (c) forms of specimens tested for strength

Most textile materials are subjected only to insignificant stresses in the course of use; only a few industrial textiles are subjected to heavy external stresses. The wear of most textiles results rather from frequently repeated but relatively small bending stresses. Hence high tensile strength of the fibres is of no special significance in these cases.

Some textile products used for industrial purposes are tested for their behaviour while shock or frequently pulsating stresses occur. Such tests can hardly apply to fibres and are usually made with woven, knit or otherwise made-up fabrics.

Stability of form

Stability of form is one of the most essential wearing properties of fibres. The ability of textiles to retain their initial dimensions is a direct function of recovery from deformations after the stressing forces have ceased to act. Durability of textiles depends also very much upon the elasticity of fibres, that is, upon their ability to recover from deformations back to their previous dimensions after yielding to deforming forces.

The parameters that are most frequently determined refer to resilience and express the relation of resilient strains to total strains that result from particular stresses such as stretching, bending or pressing.

Changes in dimensions or of form of textile products reflect the amount of deformation. Therefore, parameters of resilience are usually determined at set levels of fibre deformation.

Duration of the stress and of the time elapsed after the stressing forces have ceased to operate are also factors of significance. Usually textile products are subjected, during their use, only to periodic stresses, followed by a length of time suitable for recovery.

Therefore, the parameters of resilience should be determined only after a suitable relaxation time has been determined.

Thermal insulation

The thermal properties of fibres also form an essential group of parameters determining the processing technique and end-use of final products. Developments in the manufacture of synthetic fibres have contributed particularly to adjustments regarding the technology and designing of textiles as well as to the conditions of their maintenance.

The thermal properties of fibres comprise two principal groups of parameters. One consists of a set of indices that refers to the resistance of fibres to effects of elevated temperatures, and the second one of a set referring to insulating (warmth-retaining) properties.

The first group is characterized by such indices as temperatures of softening, melting and deterioration of fibres. Fibres with low values at those temperatures have poor applicability and require special processing techniques. If the limits of those temperatures are surpassed, the wearing properties of products may be very poor, or even non-existent owing to complete deterioration of the material.

The second group of indices refers primarily to the thermal conductivity of fibres, on which their capability to retain warmth depends.

Electrical properties

The significance of electrical phenomena on fibres became evident with developments in synthetic fibre production. The very low hygroscopicity of those fibres favours the accumulation of electrical charges on them and hinders thus their processing. Attempts to eliminate the difficulties associated with those charges have forced us to seek methods of assessment of these phenomena by means of indices that have definite values. The methods that are being applied for that assessment do not differ greatly from those universally used in electrotechnics. The most frequently determined parameters include electrostatic tension, electrical conductivity and electrical resistance.

CHARACTERISTIC FEATURES OF NATURAL FIBRES

by

E. Szucht

The properties of the natural fibres have been the subject of theoretical consideration and practical study for several decades.

Throughout most of human history, consumption of textile fibres has been based on local supplies, with wool, flax and silk being most frequently used. After the Industrial Revolution, at the end of the eighteenth century, the proportions of specific types of fibres used was as follows:

Cotton	4 per cent
Flax	18 per cent
Wool	78 per cent
Total	100 per cent

In the following years the consumption of cotton increased considerably, while the consumption of the other natural fibres dropped sharply.

These changes in the types of fibres in use resulted not only from the development of new varieties but also from better understanding of their physical and wearing properties. Research centres established in major fibre-producing countries studied in detail the properties and processing techniques as well as the end-use of the fibres. Consequently, more was learned of the physical properties of those fibres, improvements in production techniques were made, and the quality of final products was greatly enhanced.

Wool

Because of its excellent physiologic and aesthetic characteristics, which make it readily applicable to a very wide variety of textile products, wool is one of the most popular and desirable textile fibres.

On the other hand, wool fibres are not particularly strong. Their resistance to stretching, bending and rubbing is considerably inferior to those of most kinds of synthetics.

The most specific properties of wool are resilience and suitability for felting; no other fibre is comparable to it in the latter respect. However, this felting property of wool is not always an advantage.

Wool contains relatively great amounts of various impurities. Their removal is rather troublesome and causes difficulties in processing. For example, contamination with vegetable matter requires carbonization, which does not always yield satisfactory results.

With the ever-increasing demand for textiles and the development of man-made fibres, the use of wool has been changing. Until quite recently, wool was used either alone or as the primary fibre of a blend. At present, however, because of its excellent physiologic properties, excellent resilience, low thermal conductivity and good spinnability, wool is increasingly used in blends with man-made fibres, especially with viscose and polyester fibres. These blends are used primarily for the manufacture of apparel fabrics such as suitings and dress fabrics. To a lesser extent, wool is blended with man-made fibres of other kinds, particularly for furnishings, blankets, decorative and uninflammable fabrics and the like.

Developments in man-made fibres, particularly the polyacrylic and acetate fibres, and textured yarns, are causing the gradual withdrawal of wool from use in knitwear. The easy felting and vulnerability to moths are two reasons why, in many instances, man-made fibres are replacing wool in this area.

Wool also has less present industrial application. The excellent physical and chemical properties of some types of man-made fibres will soon cause a complete elimination of wool from that end-use. The same is true of the production of furnishings and upholstery, in which wool may be replaced by more suitable fibres. Nevertheless, wool is irreplaceable as far as felt and milled cloth is concerned.

Any further increase of demand for textiles while the supply of wool remains limited will call for a careful economic use of this excellent and versatile material.

Cotton

Cotton is popular because it is inexpensive and has very good physiological and tensile properties. Its resilience and recovery from strain are less good, and therefore it cannot be used in several textile applications.

The characteristic property of cotton is its high resistance to the effects of water. This property permits the use of cotton for products that are often washed, since there is little deterioration.

As with wool, the uses of cotton are presently changing. This fibre has already been withdrawn almost completely from many end-uses (industrial articles, ladies' lingerie, hosiery), and its share in many other end-uses is declining in favour of man-made fibres.

Owing to its good wearing properties, cotton finds much use in light-weight, fine and frequently washed textiles such as bedding and table-cloths. It will continue to be used very much for outerwear in hot and moist climates, but it is to be expected that in this case cotton will be blended with man-made fibres, mostly with viscose, polyester and polyvinyl alcohol fibres.

Cotton will continue to be among the cheapest fibres produced in large quantities for the manufacture of the most popular goods. It is expected to have a 48 per cent share in the grand total of all fibres in 1970. Refined finishing and admixture of synthetics should strengthen the position of cotton among the various types of textile fibres.

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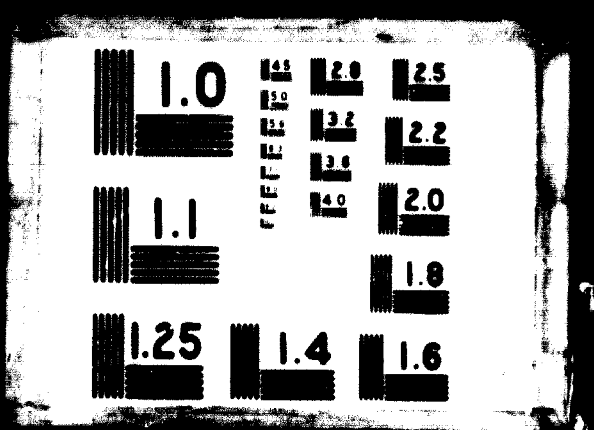

Bast fibres

The relatively large share of bast fibres in the world production of textile raw materials (about 22 per cent in 1964) places them among the most important sources of supply for the demands of the textile industry. These fibres are notable for their very great strength and excellent resistance to moisture and are well known for their aesthetic qualities. They should continue to find use in many industrial fabrics such as sacking, awnings and tent-cloth, in marine use (ropes, fish nets, sails) and to a lesser extent for bed-sheets, table-cloths and garments.

Bast fibres, like cotton, recover poorly from deformation. This inadequate shape-retaining property calls for use of special finishing processes to improve the aesthetic and wearing properties of the final products.

Because of a specific spinning technique that must cope with the physical properties of bast fibres, their blending with man-made fibres is very limited. However, trends are already evident regarding technology that may lead to broader usefulness of those blends. In any case, some types of man-made fibres have been designed especially for use in blends with bast fibres. These new man-made fibres are produced with special cross-section, fineness and length.

The increasing demand for textiles should bring about a distinct regrouping in the range of bast fibre applications. It seems to be necessary that their quality should be improved greatly so that they can be used by themselves and in blends with man-made fibres for such end-uses as apparel, decorative textiles, bedding and table-cloths, while reducing their use in industrial fabrics. For the latter purposes, synthetic fibres such as polypropylene, polyvinyl chloride and polyamides will be more suitable, leaving thus bast fibres as a reserve of cheap textile raw material for use in clothing.

CHARACTERISTIC FEATURES OF MAN-MADE FIBRES

by

E. Szucht

Developments in the textile industry such as modernization and automation of technological processes have necessitated a more thorough investigation of the properties of textile fibres and particularly of the man-made fibres. Since their physical properties can usually be modified, such a study was all the more necessary so that the man-made fibres produced could be better adjusted to their processing and wearing conditions. Many studies and much research into several technical aspects of man-made fibre manufacture have revealed much about the interrelations between the various physical properties of these fibres. The present paper is restricted to only the most essential features of man-made fibres.

Figure 1 presents the characteristics of the textile fibres that are in greatest use at this time.

Viscose fibres

Viscose fibres constitute an entirely separate group of man-made textile raw materials. Because of their structure and properties, they form a link between natural and synthetic fibres. Owing to their hygroscopicity, their excellent affinity for dyestuffs, their ease of processing and their exceptionally low manufacturing costs they have come to be very widely used in the production of most textile goods. Principal drawbacks of viscose fibres are: very low resistance to moisture, small tenacity at bending stresses (brittleness), little resilience, bad thermoinsulation and high shrinkage in aqueous media. These disadvantages place serious limits on the use of viscose fibres in textile production.

Developments in synthetic fibres in the 1950s resulted in great improvement in the wearing properties of viscose fibres. Intense research done in several institutes and laboratories have resulted in the production of new and modified types of these materials.

Modification of viscose staple fibres has taken three directions. The first of these consists in increasing the tensile strength of the fibres, all other properties being unchanged. Such fibres have a tensile strength twice as high as that of normal viscose fibres. They are processed in the same way as cotton. The principal end-use of these new fibres is the production of industrial goods.

PROPERTIES	FIBRES							
	COTTON	WOOL	VISCOSE (ORDINARY)	POLYAMIDE	POLYESTER	ACRYLIC	POLYVINYL-CHLORIDE	POLYPROPYLENE
HYGROSCOPICITY	Very good	Very good	Good	Satisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory	Unsatisfactory
STRENGTH	Good	Satisfactory	Satisfactory	Very good	Very good	Good	Good	Very good
RESISTANCE TO ABRASION	Good	Satisfactory	Satisfactory	Very good	Good	Satisfactory	Good	Very good
RESISTANCE TO WRINKLING	Unsatisfactory	Very good	Unsatisfactory	Very good	Very good	Good	Good	Very good
RESISTANCE TO SHRINKAGE	Satisfactory	Unsatisfactory	Unsatisfactory	Very good	Very good	Very good	Good	Very good
RESISTANCE TO EFFECTS OF HEAT	Very good	Very good	Very good	Satisfactory	Good	Good	Unsatisfactory	Unsatisfactory
RESISTANCE TO FORMATION OF ELECTRICAL CHARGES	Very good	Very good	Very good	Satisfactory	Satisfactory	Satisfactory	Unsatisfactory	Unsatisfactory
HANDLE	Good	Very good	Good	Satisfactory	Satisfactory	Good	Unsatisfactory	Unsatisfactory

VERY GOOD GOOD
SATISFACTORY UNSATISFACTORY

Figure 1. Characteristics of some varieties of textile fibres

The second kind of modification is directed toward the production of highly crimped woollike fibres. Such fibres are characterized by great bulkiness, good thermoinsulation and high resilience, their tensile strength being unchanged. Their end-uses are primarily in the production of outerwear, blankets, carpets, furnishings and the like.

The third kind of modification the newest and most significant concerns HWM (high wet modulus) fibres and the so-called "polynosic". Their tensile strength, both dry and wet, is high, and their elongation is small, being similar to that of cotton, with much lower swelling than ordinary rayon, with a particularly high initial modulus when wet and, in the case of polynosic, a high resistance to sodium hydroxide.

Acetate fibres

The properties of acetate fibres have remained at the same not very high level for many years. The staple 2.5 denier acetate and triacetate fibres, as produced until now, have now tensile strength that limits their usefulness. The recently introduced modified triacetate fibres such as Arnel 60 (USA), as well as the acetylized high-tenacity viscose fibres such as Tohalon (Japan) have brought about an essential improvement in this respect, but the decisive turning-point for the development of acetate staple fibres does not yet seem to have been reached.

The prospects for acetate filament fibres appear to be much brighter. The omission of spinning processes, with all the difficulties associated with them, as well as the possibility of using yarns of a great uniformity, with opportunities of getting them in textured form, permits the production of many attractive, although not very durable, outerwear articles.

Acetate fibres have good warmth-retaining properties. They are also thermoplastic to the extent that their final products retain their form well.

Acetate fibres are mostly used for dress goods, blouses (knitted or woven), kerchiefs and neckties. Minor quantities of staple fibres are used for blending with other fibre varieties to produce light-weight suitings.

Polyamide fibres

Polyamide fibres were the first synthetic fibres ever produced. Because of their excellent tenacity they are widely used in textile products. In spite of rapidly increasing competition of other synthetics, polyamides still constitute half of the total world production of synthetic fibres. Their greatest advantage is their resistance to abrasion. They are unsurpassed in that respect by any other fibres and are therefore excellent materials for products subject to intense rubbing, such as socks, stockings for women and children, ladies undergarments, men's shirts, carpets, rugs and upholstery.

The abrasion resistance of polyamide fibres is twice as great as that of polyester, tenfold that of cotton or of polyacrylics and fifteen times greater than that of wool. Even a small admixture of polyamides increases considerably the durability of products made from blends.

In addition to their high resistance to abrasion, polyamides have a resilience that is much greater than that of other fibres. In spite of a proneness to deformation, they recover well from stretching. This fact is of a great importance for the wear-resistance of many apparel and industrial products made from them.

The drawbacks of polyamides, which limit their use in clothing, include low hygroscopicity (as with all synthetic fibres), a low resistance to the effects of light, easy pilling and poor handle.

The proportion of polyamide staple fibres in blends is limited to a minor percentage only, just to improve the strength.

Filament polyamides have much wider use. The development of textured yarns and improvement of their aesthetic properties have greatly increased their applicability, especially for sportswear, ladies' blouses, shirtings, hosiery and the like.

Polyamides of the tire-cord type are of great importance. They have become necessary for the production of automobile tires, largely replacing viscose-cotton and entirely cotton cords. In future, they will probably eliminate viscose fibres completely, not only from tires but also in other industrial uses.

Present developments in the production of polyamides indicate progressive improvement of their quality and thus an increase in their use. New types have appeared as, for example, those with modified cross-sections and, especially in the manufacture of carpets and pile fabrics, fibres with a diminished proneness to pilling and of high adhesion. Investigations are being made of the possibility of crimping the fibres permanently so that they could resemble wool. Research is also directed toward obtaining polyamides with a greater absorption of water and of sweat, and thus with better physiological properties. There are already fibres well known for their fire-resistance that are used for flameproof fabrics. Still others of these fibres have a higher resistance to the effects of light.

Polyester fibres

The first polyester fibres produced on an industrial scale appeared in 1951 and 1952. The production grew quickly, and they now account for 20 per cent of all synthetics consumed in the world. The principal advantages of polyester fibres are: very high resistance to effects of light; very good resistance to creasing, whether wet or dry; excellent tenacity; and a thermoplasticity that permits them to be set permanently in a desired form.

The properties of polyester fibres may now be considered as stable; research in the world centres of their production aims chiefly at lowering costs, since the present level imposes limits on the application of polyester fibres. The fibres are chiefly used for the production of fabrics in blends with wool. They are also used for luxury fabrics of the cotton or silk types (men's shirts, summer coats and dresses). Some quantities of these fibres are processed into fabrics of the flax type and are also used for curtains, neckties and industrial fabrics.

Polyester fibres are practically of no use in the knitting industry. Owing to their high resistance to lateral stresses and because of the loose construction of knitwear, the resulting pilling effect is manifested to an unacceptable extent.

In recent years some producers of polyester fibres have marketed new types of them that are said to be suitable for knitwear; examples are Dacron 64 (United States), Terylene W 14 (United Kingdom), and Trevira WA (Federal Republic of Germany). Such fibres incorporate certain foreign compounds to diminish slightly the regularity of their structure and to lower the degree of polymerization. Fibre strength is thereby lowered and the tendency to pill decreased.

Polyacrylic fibres

Polyacrylic fibres constitute the third group of synthetics of major economic importance. They are the result of long-term studies performed during the Second World War in both the United States and Germany.

The principal advantages of polyacrylic fibres include excellent resistance to light, warm "woolly" handle and high bulkiness. However, they are rather brittle and not very resilient.

They are widely used in the knitting trades for fabrics, the structure or end-use of which requires high bulkiness, softness and thermoinsulating properties. Since the resistance to abrasion is less than with other synthetics, these fibres do not exhibit excessive pilling.

A large part of the supply of polyacrylics is used for woven dress fabrics, imitation furs, furnishings, blankets and a little for industrial use.

The structure of polyacrylic fibres is exceptionally easy to modify. In addition to the many polyacrylic co-polymers produced in the world, there are some polymers with differing properties, each variety having specific advantages. Thus, for example, DuPont (United States) markets several types of Orlon, each for a special purpose.

Their easy co-polymerization, their wide range of differing properties and their low cost of manufacture combine to make the prospects of developments for polyacrylic fibres appear very promising.

Polypropylene fibres

Polypropylene fibres have many features that should permit them to play a serious role in the textile field in coming years. Their physical properties are very good, they are not affected by chemicals, they have a small specific gravity and their manufacturing cost is low. However, for the time being, their drawbacks include low temperature of melting, poor resistance to light and high hydrophobic properties which exclude the usual dyeing techniques and greatly limit their use in textiles. Elimination of these faults is the subject of intensive studies by producers, so that the production of those fibres cannot be considered as already stabilized. Any predictions regarding the future of polypropylene fibres run the risk of being very inaccurate, since at any time radical changes may occur in the range of their application.

The polypropylene fibres produced at present are of a type especially suitable for furnishings and industrial purposes. Most of them are processed into carpets, filter, cordage of various types, workers' overalls, upholstery and the like.

If and when some of these faults are eliminated, the applicability of polypropylene fibres will be extended to apparel goods, and their low cost of manufacture will make them a universal textile material in many countries.

Polyvinyl chloride fibres

Polyvinyl chloride (PVC) fibres have been little developed, although they belong to the longest known synthetics. The reason for their limited use is the fact that many of their properties are not very satisfactory; for example, their tenacity is poor, they are easily deformed, sensitive to elevated temperatures and difficult to dye.

Some new types of PVC fibres have raised melting temperatures and slightly improved physical properties. Studies are continued to improve their processing qualities as well as wearing properties. Owing to their specific features, such as non-flammability, resistance to effects of moisture and chemicals as well as of light, and their great insulating properties, PVC fibres are used chiefly in the production of flame-resistant fabrics, overalls, industrial articles, blankets and other bedding.

Easier manufacturing techniques, more plentiful sources of primary materials, lower price and new ways for a synthesis of monomers should all widen the range of use of PVC fibres, as their quality is already being improved.

Polyvinyl alcohol fibres

Although a way has been found of producing polyvinyl alcohol materials that are insoluble in water, this alone will not widen the use of such fibres in the world. Their very difficult processing techniques, which require great humidity and high temperature, as well as such drawbacks as brittleness, small resilience and difficulty in making-up, make them unsuitable for most ordinary uses.

Polyvinyl alcohol fibres are used chiefly for the production of cordage, fishing nets, industrial fabrics, furnishings and table-cloths. Some quantities are used for apparel goods, particularly for underclothing, mainly in blends with cotton and rayon.

Although increased production of these fibres is planned, it appears unlikely that they will become very popular.

Spandex

The increasing demand for stretch fabrics and the poor properties of rubber for textile use have given rise to studies on the production of a synthetic elastomer. The most important feature of this new fibre is its ability to stretch and to recover from deformation after the stretch forces cease. The fibre has a tensile strength two or three times greater than that of rubber, and consequently much finer filaments can be used to produce much lighter and more comfortable products.

Contrary to the case with rubber, Spandex is easily dyed, so that no sheath fibres are necessary. Spandex is very resistant to light, sweat, sea-water and oil staining. Its disadvantage is vulnerability to elevated temperatures and to bleaching agents. Spandex is used primarily for the production of swimwear, foundation garments, stockings for varicose veins, sportswear and elastic tapes. Trials are being made to use it for suitings.

The high price of Spandex makes necessary a minute calculation of its use. It should be mentioned that in many articles, such as knitwear, even a low proportion of Spandex contributes to their high stretch properties.

Other man-made fibres

The characteristics and end-uses of the major textile fibres discussed above present possibilities for the industry to form its own basis of raw materials. Not all of the available fibres have been discussed. Those which were not are produced only in small quantities, for special end-uses, or have such poor wearing properties that they have little chance to be of appreciable industrial importance. Mention should be made of such materials as casein fibres, copper rayon, glass fibres, alginates, metal, polyethylene, polyvinylidene chloride and polytetrafluorethylene fibres. New groups, especially of mixed polymer fibres, may be expected to be developed, thus supplementing the principal fibre groups produced until now.

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