MICROFIBRES, MICROFILAMENTS & THEIR APPLICATIONS

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Abstract

This article is a review which concerns microfibres, their classification, manufacturing methods, different fibre forms, general properties, as well as their various applications. A brief attitude related to economical problems and future prospects is presented.

Key words:

microfibre, microfilament, manufacturing methods, fiber cross-section.

Introduction

The growing demand to increase the fibre properties hitherto known, and to create new sophistical application fields for textile materials have been the causes of the rapid growth of microfibre technology and the rising potential for the textile industry. Microfibres are half the diameter of a fine silk fibre, one-third the diameter of cotton, one-quarter the diameter of fine wool, and one hundred times finer than human hair. In order to be classified as a microfibre, the fibre must be less than 1 dtex in width. Fabrics made from microfibres are generally lightweight, resist wrinkling, have a luxurious drape and body, retain shape, and resist pilling. They are also relatively strong and durable in relation to other fabrics of similar weight, and they are more breathable and more comfortable to wear.

A microfibre is defined as a fibre (including staple fibres and filaments) of linear density approximately 1 dtex or less, and above 0.3 dtex [1]. Even finer fibres are produced, of 0.3 dtex or less, but these are commonly referred to as super-microfibres.

Table 1. shows the relationship between fibre linear density and classification. [3]

Fibre count, dtex/f	Fibre classification
> 7.0	coarse
7.0-2.4	medium fine
2.4-1.0	fine
1.0-0.3	micro
< 0.3	super-microfibres including nanofibres when their cross-sectional dimmentions are within a range of nm, that is of <0.1dtex or <1μm

<u>History of microfibres</u>

Japanese fibre manufacturing companies introduced the first ‘micro-denier’ products during the 1970s [4]. Then followed the developments in Europe during the 1980s, and since the 1990s American fibre manufacturers have been following suit. At present, polyester and nylon are generally used for manufacturing microfibres. However, ‘micro-denier’ versions of rayon and acrylic products are on the horizon.

For as long as microfibre technology has been around, ultra-microfibre technology has existed as well. These are fibres that are less than 0.3dtex, and especially within the range of 0.1dtex. Several different processes can be used to make these fibres, all involving the splitting of a larger fibre into many smaller ones.

Production of microfibres

Microfibres are generally considered to be fibres with a linear density of less than 1.0 dtex [2]. Although the technology for microfibre production has been available for many years now, strong demand for these fibres did not begin until the 1980s. The currently available microfibres are different from ordinary fibres mainly in their dimensions, but have much lower property differences than the standard fibres. Toray was the first company in the world to introduce microfibres, followed by Teijin, Hoechst, ICI, DuPont, and others. Recently Toray has introduced an ultra-fine polyester microfibre with a linear density of filament of about 0.05 dtex. This may be called the finest synthetic fibre so far produced commercially.

Quality of the chips for microfibre

Demands on polymer quality during the production of microfibres are very stringent. For example, the polyester composition has to be consistent and it should not contain foreign matter. [2] The molecular weight distribution should also be narrow and short-term viscosity must be kept as consistent as possible. Polymer chips need to be smooth, tailless and identical in shape/size. As microfibres are a high-value product, the use of 'off-quality' chips should be avoided, as they would otherwise cause undue problems in processing. It is advisable to use chips of the best available quality for the production of microfibres.

It is also important to maintain the quality of the product in all subsequent steps. The drying process should be as consistent as possible, and chips must have an even residence time. The moisture regained of the dried chips should be less than 0.005%, to minimise the hydrolytic degradation in molten stage. Thus specifying the precise moisture level in the dried chips is essential for trouble-free production of microfibres. For drying quality chips, a continuous drying process is better than batch drying.

Manufacturing of microfibres

The technology involved in the extrusion of microfibres is more sophisticated and costly than that of conventional deniers. Microfibres are delicate yarns that require great care in handling during textile mill processing. [1]

There are various methods of producing microfibres, including modified conventional spinning. All three conventional spinning methods, namely melt spinning, wet spinning, and dry spinning can be employed to manufacture microfibres. For this method, carefully selected polymerisation, polymer spinning and drawing conditions are required. Polyester, nylon, and acrylic microfibres may be manufactured by this method. The extrusion spinnerets should contain many holes of very fine diameter, each of which will make one uninterrupted filament, in spite of complex thermal and rheological changes. Detailed aspects of the various manufacturing methods are presented in the following chapter.

Methods of manufacturing microfibres

a) Dissolved type [2]

Microfibres of this type are manufactured from bi-component fibres with different types of polymers. Comparatively thick bi-component filaments containing different types of incompatible polymers are spun, and the fabric is made using them. When the fabric is treated chemically with solvent, one component is dissolved and removed, and the other component remains as the microfibre. Polyester and nylon microfibres can be made by this method. Commercial production has been reported to use 20/80% ratios of soluble/insoluble polymers to produce a bi-component filament of up to 2 dtex fineness, and a final dissolved filament with linear density of about 0.50 dtex. The main considerations for selection of suitable polymer component are:

- high solubility;
- stability at extrusion temperature;
- the polymers' rheological properties should be compatible at extrusion temperature;
- it should be recoverable for use, so that the cost of solvent and soluble polymer is affordable;

- it should be non-toxic, non-corrosive, and non-polluting.

The various combinations of soluble/insoluble polymers reported to form fibres successfully are polystyrene/polyamide and polystyrene/polyester.

b) Split type [2]

The microfibres of this type are obtained by physically or chemically treating the bi-component filaments containing two types of polymers and splitting them into different types of filaments. It is easier to split the segment in filament from itself than in the fabrics. Suitable polymer combinations for splittable bi-component filament spinning are polyamides/polyester and polyester/polyolefines. The main considerations for selecting the polymer combinations are as follows:

- the polymers must be incompatible;
- the polymer should have reasonably similar melt viscosities at common extruder temperature;
- the polymers should have weak adhesivity.

An example of a splittable fibre is presented in Figure 1.

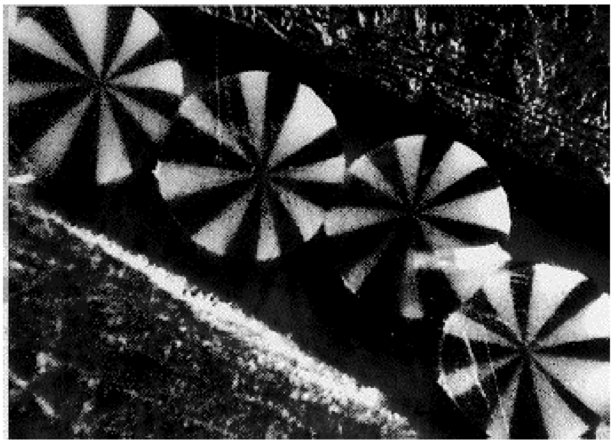


Figure 1. Cross-sectional photomicrograph of a 16-segment splittable fibre [20].

c) Direct spun type

This microfibre is directly manufactured by melt spinning. For this method, highly selected polymerisation, polymer, spinning conditions, and drawing conditions are required [2].

Special melt spinning dynamics should be considered for the production of low linear density polyester by the direct extrusion method. When polymers have similar dynamic viscosities at the given temperature, the polymer with the lower dynamic viscosity permits the spinning of finer fibres. This result has been attributed to the lower spin-line tension generated when spinning polymers with lower dynamic viscosity. It is postulated that the important parameter in the production of finer PET fibre is the spin-line tension level, which must be kept low in order to obtain finer fibres. The increase in take-up velocity, and the fibre line length beetwen the spinnered and the take-up device increase the spin-line stress level, and therefore the minimum fineness attainable increases.

There are the following areas where microfilament spinning requires care:

- The die-swell formation must be minimised by using the lowest possible melt viscosity at the capillary entrance, and by limitation of the horizontal component of the elastic melt expansion spinnerets' exit.
- In the solidification phase, the quenching air must not stress the filament. Therefore, the hole distance and the arrangement of the spinneret holes must allow the turbulence-free quenching air stream to penetrate the whole filament bundle.
- processing all filaments equally in order to obtain evenness in density.
- After solidification, the individual capillaries should be guided side by side in one layer. Due to the large number of fine capillaries which form a microfilament yarn, the stationary guides become problematic, and crossing of capillaries may result in deviations in linear density and drawing failures.

(d) Super-drawing technique [1]

In this technique, no molecular orientation is involved. Staple fibre with linear density less than 0.5 dtex can be produced with high drawing ratios. This technique is based on the principle that yarn can be stretched as much as 10-75 times; much beyond their conventional draw ratios (3-6 times) if the drawing is carried out at a minimum crystallising temperature and at special selected drawing conditions, including the temperature range and the type of heating the fibre.

(e) Sheath-core spinning method [1]

In this method, two different polymers are mixed, melted, and mix-annealed under specified conditions. The conjugate fibre comprising of a concentric circular sheath and a core is manufactured, and the sheath portion is removed to form ultra-fine fibres.

(f) Some other methods [1]

- Flash-spinning method
- Solution flash-spinning
- Emulsion-spinning method
- Jet-spinning method
- Centrifugal-spinning method
- Turbulent forming method
- Conjugate-spinning method

Bi-component Fibres [20]

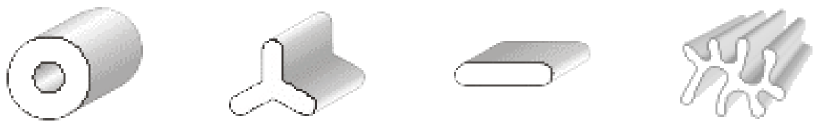
Bi-component fibres are co-extruded with two different polymers in the cross-section. This allows the fibre to use the properties of both materials, and vastly expands the array of possible fibre performance characteristics. Bi-component fibres are available in staple, filament, and microfibre forms. Typical bi-component fibre types are presented in Figure 2.

a) sheath/core   b) eccentric sheath/core   c) side-by-side   d) pie wedge   e) hollow pie wedge   f) islands/sea   g) three islands

Figure 2. Typical bi-component fibre type.

Specialty Cross-Sections [20]

A modified cross-section can provide added functionality, such as unique lustre or moisture transport. These cross-sections are available in staple, filament and microfibre forms, and in most cases, are also available as bi-component fibres. Typical microfibres with special cross-section shape, commonly used, are presented in Figure 3; many application find especially the hollow fibres (Figure 3a).



a) hollow   b) trilobal   c) ribbon   d) 4DG™

Figure 3. Typical microfibres with special cross-section shape [10,17,18].

Complex microfibres' cross-sections commonly representing the bi-component fibre form are presented in Figure 4. More detailed schemes of the fibre cross-sections shown in Figure 2 and 3 with identification of the polymer used are presented in Figure 5. The views of microfibres and its cross-sections in a microfibre cloth, taken by a scanning electron microscope are presented in Figure 6.

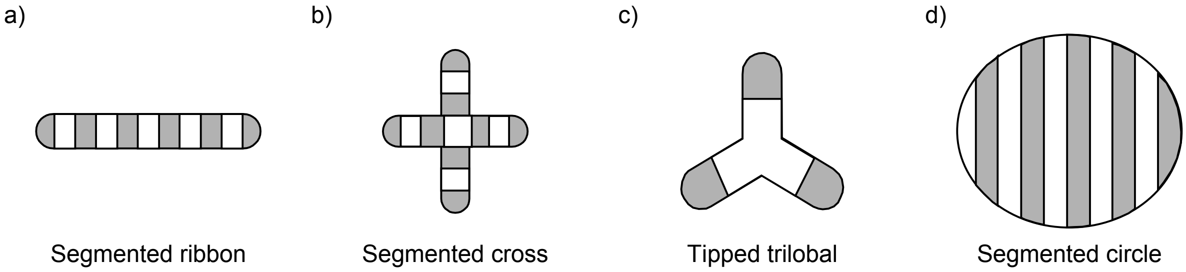


Figure 4. Complex microfibres cross-section.

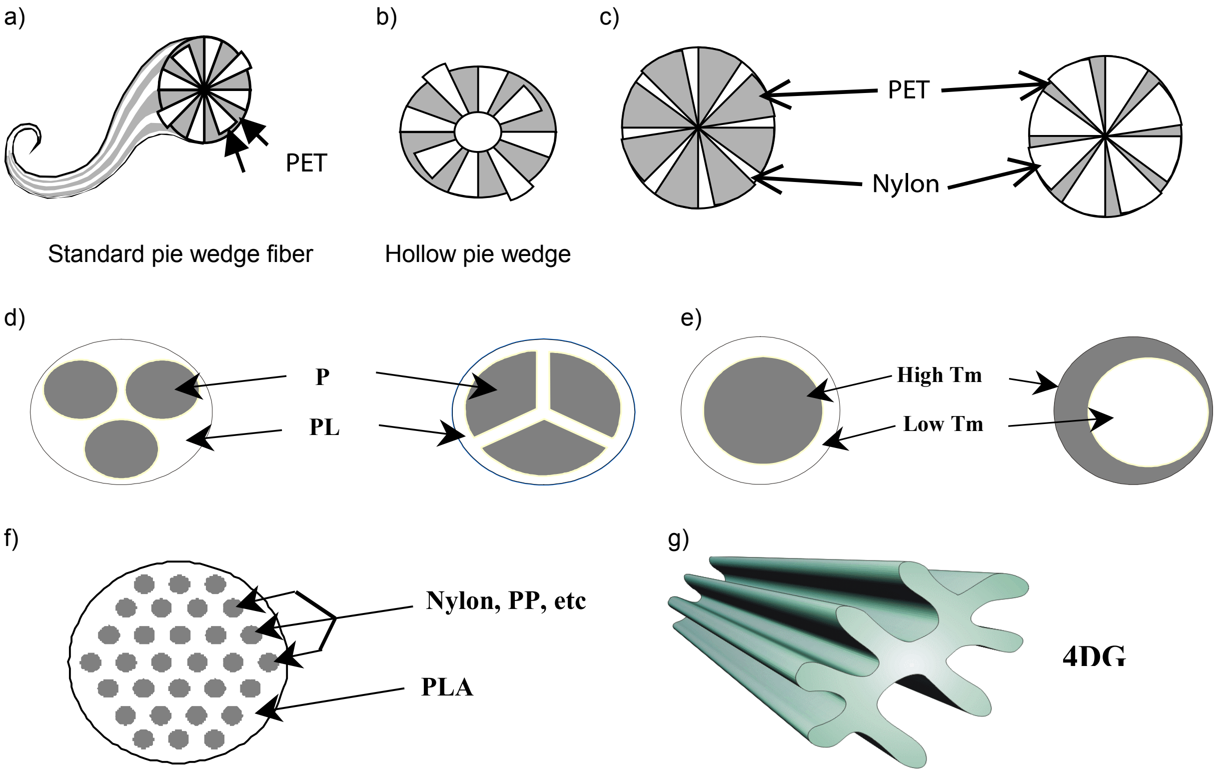


Figure 5. Schemes of fibre cross-sections with identification of the polymer used. The types presented in Figure 2 and 3 are given in brackets: a) standard pie wedge (Figure 2d), b) hollow pie wedge (Figure 2e), c) pie wedge with different polymer ratios (Figure 2d), d) three islands and three islands modified (Figure 2g), e) sheat/core and eccentric sheat/core (Figure 2a and 2b), f) islands/sea (Figure 2f), g) 4DG^{TM} (Figure 3d).

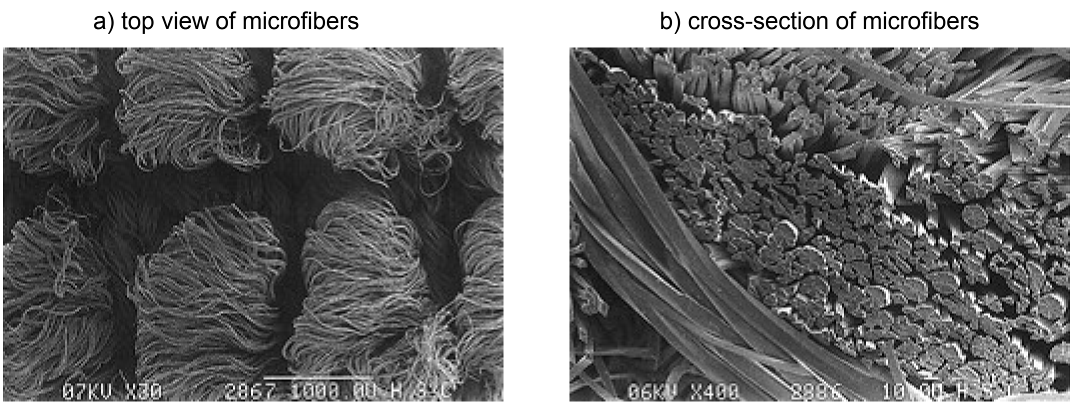


Figure 6. Scanning electron microscope images of microfiber cloth [21].

Processing of microfibres [4]

Carding

It has so far proved impossible to card microfibres at production rates which are comparable with conventional type of fibres, and so the cost per unit weight of production is much greater. In carding it is necessary to have a greater density of carding wire points.

Winding and warping

All guide surfaces must be very smooth and in the best mechanical condition, as microfilaments are likely to break more easily than regular filament. The frictionless rotating discs type of tension devices are desired to minimise the drug.

Sizing

Warp sizing of microfibres should ideally be done on single-end sizing machines to minimise filament breakage at splitting rods. If single-end sizing is not available, then a pre-dryer is essential. The size pick up on microfibre yarn is higher and it is also more desirable. The size recipe should be decided by trial and error determining.

Weaving

Generally the tensions should be kept as low as possible. Weft yarn for air jet or water jet looms will need some finish to perform at maximum efficiency.

Textured microfilaments [11,12]

When processing filament yarns, the microfilaments are being subjected to powerful twisting forces that may result in filament breakages, thereby damaging the loss of reflecting surfaces.

Textured microfilament yarns show light spots of tension variations while texturising, a high level of broken filaments, a low bulk (due to low twist) and very poor unwinding performance. Therefore microfilament draw-texturising will require a draw ratio setting lower than the theoretical draw ratio, which will result in:

(a) a reduction in broken filaments,
(b) a reduction in tenacity,
(c) an increase in elongation, and
(d) a better twist level resulting in higher and better bulk.

A solid ceramic disc with a surface finish of 0.5 μm is most suitable to avoid roughness, and giving the yarn a hairy look. Better results can be obtained by using polyurethane discs which allow less abrasion and a higher twist level.

Microfilaments, which were textured, impart special characteristics to the fabric, such as:

- soft touch and softness, due to very low flexural rigidity of microfilaments;
- light weight and high bulk;
- special surface characteristics and silk-like appearance;
- easy pliability/compatibility with cotton, rayon, wool etc.;
- good drapeability and suppleness;
- good wear properties covering from lightweight dress material and lingerie to wind and waterproof sportswear;
- novel applications in furniture and upholstery materials, drapes, curtains and industrial textile products. [5]

General properties of microfibres [2]

- Ultra-fine linear density (less than 0.1 dtex/f), finer than the most delicate silk.
- Extremely drapeable.
- Very soft, luxurious hand with a silken or suede touch.

- Washable and dry-cleanable.
- Shrink resistance.
- High strength.
- Insulates well against wind, rain and cold.
- Anti-microbial agents help to protect both family members and work staff from the dangers of the bacteria that cause odour and mildew.
- Microfibre is hypoallergenic, and so does not create problems for those suffering from allergies.
- Microfibre is non-electrostatic.
- Microfibres are super-absorbent, absorbing over 7 times their weight in water.
- Microfibre dries in one-third of the time of ordinary fibres.
- Microfibres are environmentally friendly.

Comparison between fibres of standard linear density & microfibres

Tenacity [8]

- The tenacity value of fine dpf POY spun is higher than that of normal dpf POY.
- The tenacity value of fine dpf acrylic spun is higher than that of normal dpf Acrylic.

Elongation at break

- The elongation at breake value of fine dpf POY spun is lower than that of normal dpf POY.

Uster

- The Uster value of fine dpf yarn is slightly higher than that of normal dpf yarn.

Draw force

- The draw force value of fine dpf yarn is higher than that of normal dpf yarn.

A comparison of the properties o polyester and acrilic microfibres with different linear densites are presented in Table 2.

Table 2. Physical properties of polyester & acrylic microfibres with different linear densities [8,9,15,16].

Property	Type of fibre					
	Polyester		Acrylic			
Linear density, dtex	1.3	0.8	1.3	0.5	0.5	0.8
Length, mm	38	32	32	40	32	40
Tenacity, cN/dtex	6.32	5.53	3.6	4.92	2.8	3.8
Elongation at break, %	19.5	19.5	32	24.9	20-30	30

Applications of microfibres and micro-filaments [6]

Microfibres are characterised by advantageous properties such as pleasant softness of handle, good draping qualities, lustre, bulk and outstanding surface properties. At the start of development, the researchers searched for suitable fields of application for their microfibres, since they had properties which had not yet existed in previous clothing and technical textile concepts.

Synthetic game leather and imitation leather [6]

When it was proved that natural game leather collagen fibres have diameters within the range of 4 micrometers, imitation game leather and artificial leather could be developed with great success, since the new microfibres equated with this level in dimensional terms.

Synthetic game leather and leather products are today produced industrially in Japan by impregnating nonwovens produced from PET, PA or PAN microfibres with polyurethane (UP). These products offer outstanding advantages compared to natural leather and game leather in terms of uniformity, dimensional stability, ease of care, colour fastness, and low mass.

Fashion clothing textiles [7]

Woven fabric was produced from even a 0.1 dtex UFF hollow microfibre combined with a single hollow staple fibre. This product offers softness, bulk, dry handle, a sense of warmth, good recovery, and is lightweight.

High-performance filter fabrics [6,22,24]

Owing to their fine, compact structure, microfibre textiles offer excellent filtration effects for both air and fluid filtration. Independently on common microfibres, also ultra-fine microfibre products, such as 0.05 dtex PP microfibre nonwovens, in combination with a high electrical voltage, which will provide permanent polarisation to the nonwoven, attract and absorb charged dust particles.

Microfibre textiles can produce excellent filtration effects in the process of filtering solid or liquid materials. The characteristics of microfibre liquid filters are as follows:

- high water passage speed,
- high extraction performance (retention of particles up to micrometers dimensions), and
- ease of cleaning micro-particles from the filter.

The micrometer-sized fibre segments add mechanical filtration properties to the filter medium. Also, two different dissimilar polymers can be selected that will generate turboelectric properties under flow conditions. The two polymers may also be electrostatically chargeable to enhance first-step filtration properties. These filtration mechanisms, when combined properly, may be able to create a higher efficiency, lower pressures drop-filter materials that will last longer before plugging in both air and liquid applications.

Many potential applications exist where synthetic splittable fibres can be used to add value, and create marketing advantages and a head start onto the market for innovative filter suppliers.

The addition of a small amount of splittable fibre should increase the dust spot efficiency of filter materials significantly due to its low fibre diameter, in relation to the other fibre diameters currently being incorporated into the filter medium.

In pulsing applications where the filter medium is continuously flexed but also requires stiffness, splittable synthetic fibres add a high degree of reinforcement to the filter medium because there are number is at least 16 times the number of fibres available for reinforcement when they are spilt for segmented fibres or more than 33 times for the islands-in-the-sea type fibres.

Protection against the weather [6]

Woven sportswear fabrics are also used for protection against wind and weather, and also for insulation purposes. Woven fabrics for protection against the weather were previously coated with polyvinyl chloride (PVC) in most cases.

The PVC coating guarantees absolute waterproofness, but has a serious disadvantage. It allows no passage of air, the wearer perspires after only a few minutes, and has no opportunity of expelling his body moisture to the outside of the garment. This coating is equivalent to an airproof package, and is used nowadays only for heavy duty rainproof clothing (the so-called oil-cloth).

Today, there is a wealth of alternative coatings and methods to replace PVC, such as microporous fluorocarbon coatings, which guarantee some breathing activity on the part of the fabric.

Thanks to ever finer yarns, fabrics can now be produced to meet practically all functional sportswear requirements without additional coating or membranes. They are wind- and water-repellent, yet can breathe.

Microfibres for cleaning [19]

Microfibre products are suitable for cleaning anything. Unlike ordinary cleaning fabrics that move or push dirt and dust from one place to another, microfibres actually ‘scrape’ the dirt or stain from the surface, and then store the dirt particles in the fabric until it is washed. Microfibre cleaning clothes trap dirt and dust inside the cloth, and do not spread dust or dirt around. The user can clean the cloths with water alone; no chemicals are needed. The scheme of cleaning dirt by common fibres and microfibres are shown in Figure 7.

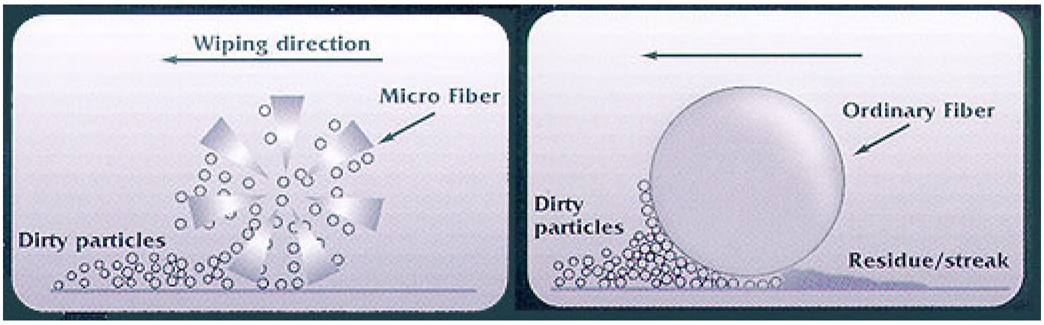


Figure 7. Scheme of cleaning dirt by common microfibres.

Microfibres are the well-kept secret of professional housekeepers, custodians and car retailers. They are perfect for asthma and allergy sufferers, as they remove dust and dust mites without chemicals. They are also excellent at removing fingerprints from any surface. Grease, tar, splattered bugs come off with the cleaning cloth. They changes the static charge on the surface so it will stay cleaner longer which is important for TV screens, computer monitors, and mirrors.

Energy conservation

Experiments have shown the drastic savings in the energy consumption in heat exchanges which are brought about by using metal-coated microfibres. In this case, the microfibre shows its heat conveying properties. By using the metal-coated microfibres inside the tubes of heat exchangers, heat transfer enhancement can be achieved. The findings of the above experiments are as follows:

- Heat transfer increases with the number of metal-coated microfibres.
- Pressure drops increase with the number of microfibres.

Medical applications [18]

When it comes to the medical market, microfibre nonwovens are exactly what the doctor ordered. Both manufacturers and consumers are already aware of the many benefits microfibre nonwovens offer to the medical market. When compared the commonly textiles to microfibre nonwovens, they are lower in cost, easier to use, more versatile, safer, and features of better disposability. With this in mind, it is no wonder that microfibre nonwovens are found in hospital surgical drapes and gowns, protective face masks, gloves, surgical packs, and bedding & linens.

On the other hand, nanofibres help stimulate living tissues to repair themselves in various parts of the human body, such as cartilage, blood vessels, bones and so forth, due to diseases or wear and tear. Nanofibres are about 10,000 times smaller in diameter than the width of a human hair, but of greater dimentions than a typical cell, which is of the order of one micrometer depending of the type of cell. Nanofibres have a large surface area in comparison to their size. Smaller than usual fibres, they allow cells to adhere to them better, speeding up the healing process.

Another advantage of using nanofibres to grow tissues stems from the fact that natural scaffolds themselves are of fibres in the nanometre-size range. In another words, nanofibres are closer replicas of the natural environment of the cells than micron-range fibres.

Construction applications [23]

Composites are multilayer materials consisting of different layers with distinct properties in each layer. The composite is constructed in order better to utilise a combination of properties from different layers. Polypropylene and bi-component microfibres can be very important components of fibre-reinforced composites, as they function not only as a reinforcing element, but also as a binder fibre between the individual layers. Polypropylene and bi-component microfibres are used in many different composite products: Micro-fibre-reinforced concrete (to reinforce and prevent cracks), insulation material (to avoid the use of chemical binders), multifunctional liquid transport media (acquisition and distribution layers), woven fabrics (as a dimensional stability network), and laminated products (lamination between textiles and boards). Polypropylene and bi-component (PP/PE) microfibres have the ability to add structural performance and functionality to the composite materials. Polypropylene and bi-component (PP/PE) microfibres provide the following advantages in fibre-reinforced composites:

- they enable lightweight constructions (PP fibres have the lowest specific gravity of all fibres);
- easy to process and environmentally friendly thermoplastics;
- good mechanical properties, toughness and impact strength;
- stability in rigid environments (resistant to deterioration from chemicals, mildew, perspiration, rot and weather);
- ability to add bulkiness and softness to the composite.

Some examples of general and spectacular applications of microfibres [6,2]

- automotive application to improve air oil filtration, allowing improved engine performance and extended life;
- perfect for asthma and allergy sufferers, removing dust mites without chemicals;
- used extensively for hair transplantation, which works to conceal thinning hair.
- Microfibres are also used in sports applications such as sports wear, sports materials, etc.
- Microfibres are extensively used as a luxurious apparel wear.
- Microfibres as swing threads.
- Microfibres for production of synthetic leather.
- Use in the technical textile sector, as well as outside the clothing industry.
- Computer mouse pads, along which the mouse can slide easily, keeping the mouse ball clean at the same time.
- Polishing cloths for wafers and hard disks, acoustic insulation, high performance sound absorption panels and concert hall seat covers, among other products.

Economics aspects of microfibre processing and future prospects for microfibres [4]

The microfibre processing results in:

- 5-10% higher price than conventional fibres,
- pushing up yarn prices by 4%,
- reduction in twist by 5-10%, and
- 2% net increase in yarn cost

The microfibres command high prices. The cost of producing microfibre is high in relation in common fibres, and microfibres cannot substitute conventional products without significant changes and adjustments to processing methods. This is likely to inhibit the development of microfibres in many textile and industrial applications. In the use of microfibre, the target concept has so far been ‘luxury’ rather than ‘utility’, and so the question of costs is perhaps of lesser importance. However, the size of the luxury market is not very large, and with so many companies rushing into the field of microfibre manufacturing, an inevitable price war may bring down the prices of new fibres, obliterating those that are unable to compete effectively. There is also an emphasis on blends, which may have advantages. The question is what ratio of microfibres is required in blends to qualify the product for the microfibre level, and how the proportion of microfibres will cause to pay a premium on price. The industry will have to do the policy in this case.

Conclusion

Microfibres are a completely new generation of ultra-fine synthetic yarns, which have not yet reached their peak of development. There are still a wide range of possibilities to be explored in the design, production, processing and use of this type of fibre. In addition to the common raw materials, PES, PA, and PAC, this specialty range will in future include other raw materials such as cellulose.

‘Micro denier’ yarns have a wider horizon of applications in India due to the traditional dress material designed and made by using natural fibres like cotton and silk. ‘Micro denier’ yarns have varied simulations of natural fibres, especially silk. We can foresee a brighter future in the Indian market due to the aesthetic properties of the fabrics made out of the yarns. However, the industry has to gear up to handle these delicate yarns in the downstream processes, such as twisting, sizing, warping, weaving, dyeing, and finishing.

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