1
The origins of texturing

1.1 Introduction

In the 1950s, a new branch of the textile industry – the texturing of continuous-filament yarns – became established as a commercial success, although, at that time, it was more common to talk of '*bulked yarns*', '*stretch yarns*' and '*crimped yarns*'.

The words '*textile*' and '*texture*' have the same root, and the development of the meaning of *texture* is interesting, as shown by the following extracts from *The Shorter Oxford English Dictionary*.

Texture [noun] . . . 1. The process or art of weaving –1726. 2. The produce of the weaver's art; a woven fabric; a web. *arch*[aic], *1656*. **b** *transf* [erred] Any natural structure having an appearance or consistence as if woven; a tissue; a web e.g. of a spider 1578. 3. The character of a textile fabric, as to its being fine, close, coarse, ribbed, twilled, etc., resulting from the way in which it is woven 1685. 4. The constitution, structure, or substance of anything with regards to its constituents, formative elements, or physical character 1660. 5. *fig*[uratively] Of immaterial things; Constitution; nature or quality, as resulting from composition. Of the mind; Disposition as 'woven' of various qualities; temperament, character 1611. 6. In the fine arts; The representation of the structure and minute moulding of a surface (*esp*[ecially] of the skin), as dist[inct] from its colour 1859. . . . [verb] to construct by or as by weaving; to give a t[exture] to.

The '*minute moulding of a surface*' and the consequent verb *to* '*texture*' is the closest to the meaning of yarn texturing, as now applied to a '*useful art*' of the textile industry. There is also a semantic paradox: '*an absence of texture*' is itself '*a form of texture*'. A yarn composed of long, parallel filaments, which is lightly twisted or interlaced to give coherence, will form dense, smooth fabrics with a minimum of textural features. The first woven nylon was excellent for parachute fabrics, but unsatisfactory for shirts, though, for a short time, it was sold for this use.

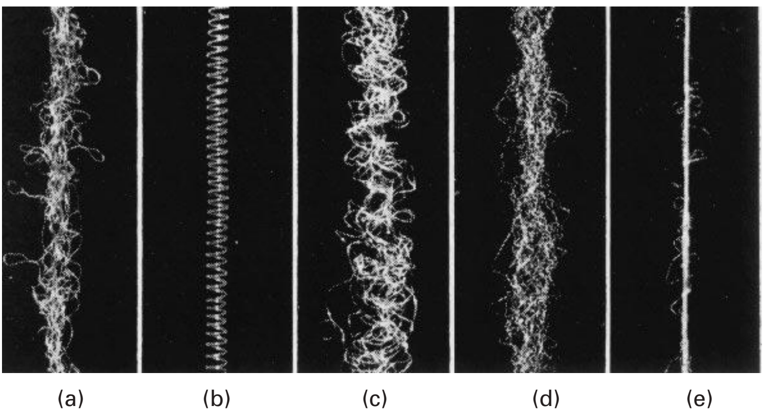
For the natural filament, silk, which is the most expensive and luxurious of the traditional fibres, the triangular shape of the filaments, the variability in cross-section and the physical properties of the material do give a subtle texture and an attractive feel and hand. When rayon and acetate yarns were produced in the early years of the 20th century, they were marketed as '*artificial silk*', by exploitation of the basic continuous-filament form, even though they lacked the special features of the natural fibre. The market was limited: another factor dictated the need for change, in order to create a larger market for manufactured fibres. Just as we would not want to live on a diet of caviar, so do we prefer the texture of fabrics made from cotton, wool, flax and other natural fibres for much apparel. Yarns spun from short, staple fibres have more softness, bulk, warmth and extensibility than fabrics from flat (i.e. untextured), continuous-filament yarns, and a different surface texture.

The first response was to cut filaments into short lengths and spin yarns on cotton or wool machinery. It also proved possible to cause the uncoagulated, liquid core of viscose rayon to burst out of the skin and give bicomponent fibres, which simulated the crimp of wool. Nevertheless, there was a challenge to inventors to find ways to avoid the route of cutting and disorganising the filaments and then reorganising the staple fibres in spun yarns. Could continuous-filament yarns be modified to compete with spun, staple-fibre yarns? A stimulus came from highly twisted, crepe yarns, whose torque forces caused woven fabrics to be crinkled and puckered. The invention of the false-twist process of twisting, setting and untwisting by Finlayson at *Celanese* led to textured acetate yarns for hand-knitting, and by *Heberlein* to the use of textured viscose rayon during the 1939–45 war. However, the set of cellulosic yarns is easily lost; the crimp can be pulled out. The market for these forms of textured rayon and acetate did not survive.

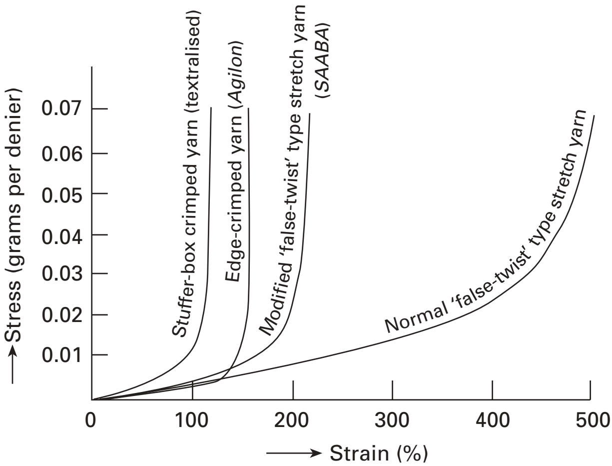
It was the '*permanent set*' of nylon that led to the commercial success of yarn texturing. At first, it was thought necessary to set nylon in steam, so the continuous false-twist process was not used. *Heberlein* developed a long, multistage process with setting in an autoclave. Despite the high cost, their *Helanca* yarns were a great success because the elastic extensibility up to around 400% made them excellent for stretch stockings, men's socks, swimwear and other form-fitting garments. The next invention was by Stoddart and Seem, who found that nylon could be set by continuous processing in a dry heater, provided the temperature was closely controlled. They modified uptwisters by adding heaters and twist-tubes, and licensed the production of *Fluflon* yarns, which took over the market and led on to the production of custom-built, false-twist texturing machines.

The next driving force for invention was the need to make yarns with high bulk and softness, but only a small degree of stretch. Such yarns were needed for firmer woven and knitted fabrics. One method was to stabilise a stretch yarn in a slightly contracted state: the bulk is there, but the high stretch is eliminated. In the late 1950s, a stabilised nylon yarn called *SAABA* ('soft as a baby's arse') was marketed, but did not last. The big surge came from set polyester yarns. *ICI* developed *Crimplene* yarns, which, until the fashion bubble burst, were extraordinarily successful in double-jersey knit fabrics. At first the setting was a separate process in an autoclave, but then double-heater machines, which had been invented by Stoddart and Seem in the 1950s, came into use. The market in the USA for textured polyester yarns increased from six million pounds in 1966 to 845 million pounds in 1973, and 17 companies were listed as making false-twist texturing machines. Since then, the industry has been rationalised. There are fewer yarn producers and two companies, *Barmag* and *Murata*, dominate the supply of machinery.

Twist-texturing was not the only method to be invented in the 1950s. A book based on a 1959 symposium (Wray, 1960) contained chapters on four different methods of making bulked yarns: *the **false-twist** method*; *a **stuffer-box** method* [*Ban-Lon*]; ***edge crimping*** [*Agilon*]; ***air-texturing*** [*Taslan*]. Pictures of these yarns are shown in Fig. 1.1 and their stretch characteristics are shown in Fig. 1.2. All of these methods seemed important at the time, but only the false-twist methods and, to a smaller extent, air-texturing, which depends on mechanical interlacing, are now important for the apparel market. Jet-screen texturing is used for coarse, BCF (bulked continuous-filament) carpet yarns. The remainder of this chapter will provide an overview of these three methods, with additional comment on their historical development. Some scientific approaches to fibre properties, process mechanics and yarn structural mechanics will be covered in Chapters 2 and 3, and then the three will be described in detail in Chapters



1.1 Bulked nylon filament yarns from the 1950s. (a) Stretch yarn by false-twist technique. (b) *Agilon* (edge-crimped) monofilament. (c) *Agilon* multifilament yarn. (d) *Ban-Lon* (stuffer-box) yarn. (e) *Taslan* (air-textured) yarn. Reproduced from Wray (1960).



1.2 Stretch characteristics of 1950s yarns, up to about 1% of fibre break load. *Taslan* (air-textured) yarns have no geometric stretch – only fibre extension, which is negligible at the stresses in this diagram. Set polyester yarns, developed in the 1960s, have stretch in the 10–20% range. Reproduced from Piller (1973). Courtesy of World Textiles Publications, Bradford.

4–7, with the common features of quality control and logistics in Chapters 8 and 9. A fuller list of texturing techniques, including later inventions, is given in Table 1.1. This book is concerned with the texturing of continuous-filament yarns as a separate part of textile processing. Other technologies with similar purposes, such as the production of crimpable, bicomponent yarns by fibre producers or the use of differential shrinkage to produce high-bulk, staple-fibre yarns, are not appropriate for detailed coverage. However, the last chapter, as well as describing the minor methods, will review the whole field, since old methods could be revived in new guises in the future and some recent academic research may eventually lead to industrial use.

1.2 Twist-texturing

1.2.1 The basic principles

The basis of twist-texturing is to twist a yarn as highly as possible, set it by heating and cooling, and then untwist it. This gives '*a twist-free bundle of twist-lively filaments*' (Arthur, 1960). In order to relieve the torque, the filaments snarl into 'pig-tails', which cause a large yarn contraction. The yarn can be stretched to over five times its fully contracted length before

Table 1.1 Texturing methods

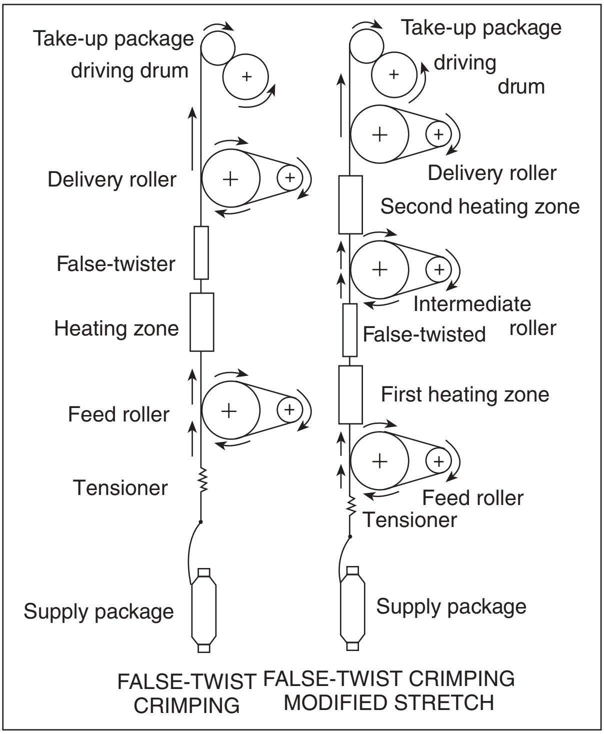
Method	Yarn character	Current status
Dependent on heat-setting		
Single-heater, false-twist	High-stretch	Major use of nylon
Modified false-twist	High bulk, medium stretch	Obsolete for nylon
Set, double-heater, false-twist	High-bulk, low stretch	Major use of polyester
Trapped twist texturing	Variant twist textured	Obsolete
Stuffer-box	High-bulk, medium stretch	Obsolete (*Ban-Lon*)
Edge-crimped	High-bulk, medium stretch	Obsolete (*Agilon*)
Knit-de-knit	Yarn crimp	Minor use
Hot-fluid jet (BCF)	High bulk, low stretch	Major use in carpet yarns
Impact texturing and moving cavity texturing	High bulk, low stretch	Variants of BCF, little used
Jet-tube (*Fibre M*)	High bulk, low-stretch	No longer made
Mechanical method		
Air-jet	Projecting loops	Significant production
Other methods		
Bicomponent filaments	Fibre crimp	Revived interest
Differential shrinkage	High-bulk, low-stretch	Only staple fibre yarns
Gear-crimping	Fibre crimp	Staple fibres, obsolete

the filaments are straightened out. The recovery power is strong. Fabrics can be highly stretched, but come back when released.

However, it is not only the fibre twist setting that is important. The filaments are in a helical configuration in the twisted yarn, and, after setting, they want to return to the crimped form. This dictates the initial form of fibre buckling. When a fully extended stretch yarn is allowed to contract by 10 to 20%, the filaments follow helical paths, which alternate from right-handed to left-handed. When a yarn is set in this form, it has high bulk and low stretch. The basic form of the machines for both stretch and set yarns was established in the 1950s, as shown by Fig. 1.3.

1.2.2 Reducing the steps

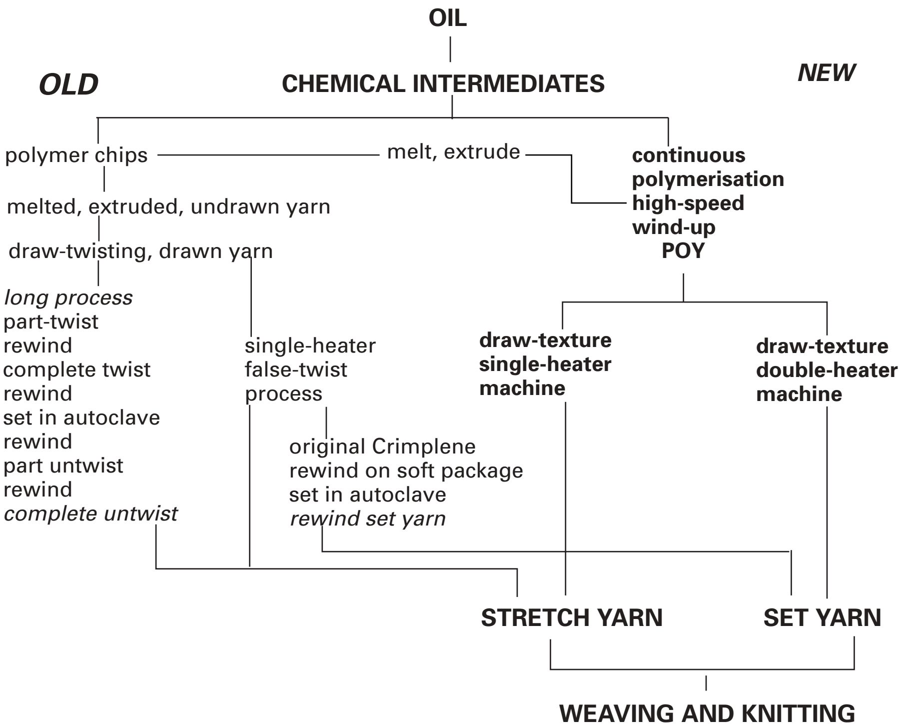
The production of synthetic fibres, such as nylon, polyester and polypropylene, involves extraction and preparation of chemical intermediates by oil-refining companies, followed by polymerisation and extrusion by



1.3 Layout of single-heater machine for stretch yarns and double-heater machines for set yarns. Reproduced from Wray (1960).

fibre producers. Polypropylene, which is easier to convert into fibres, is more commonly produced on a smaller scale by user-companies from polymer chips. '*Throwsters*', to use a term derived from the silk industry meaning to twist silk filaments into yarns, carry out the texturing operations and supply textured yarns to the weaving and knitting industries. Since the 1950s, as shown in Fig. 1.4, the number of steps necessary to make textured nylon and polyester yarns has been reduced from over ten to two.

Three developments made it possible to reduce fibre production from three steps to one. These are continuous polymerisation, high-speed wind-ups and interlacing by an air-jet, instead of a low level of twisting to give coherence to the yarns. In a coupled process, the draw rolls below the spinneret collect solid undrawn yarn at about 800 m/min and then the wind-up at about 3000 m/min draws the yarn. Much greater productivity is possible if coarser, undrawn yarn can be wound up and the drawing is combined with texturing. From the spinneret, the yarn goes directly to high-speed

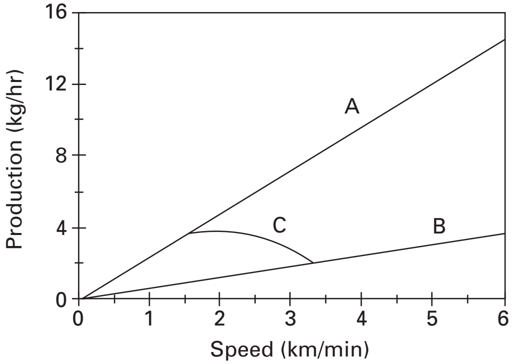


1.4 The contrast between the current two-step processing and the many steps of earlier operations.

rollers and wind-up. However, there is an economic and, for polyester, a technical problem.

As the withdrawal speed is increased, the time-scale for orientation induced by elongation and attenuation in the molten thread-line becomes less than the time-scale for disorientation by molecular relaxation. Consequently the yarn becomes partially oriented and its residual draw ratio is reduced. In order to give the required linear density (tex) in the final drawn yarn, the yarn that is wound up must be finer than would be required if the full draw ratio was to be imposed. Figure 1.5 is a schematic indication of the change in productivity as speed is increased. The optimum depends on how orientation increases with wind-up speed, but would be a wind-up of about 2000 m/min.

The technical objection to draw-texturing polyester yarns is that undrawn polyester is an unstable, amorphous material. Its properties change with time, which, in turn, affects the properties of the textured yarn, and eventually it becomes impossible to process. The only way to use undrawn



1.5 Schematic illustration of change in productivity with wind-up speed for textured yarn of 100 dtex. (A) Undrawn yarn with draw ratio of 4. (B) Drawn yarn with draw ratio of 1. (C) POY changing from draw ratio of 4 at 1.5 km/min to 1 at 3.5 km.

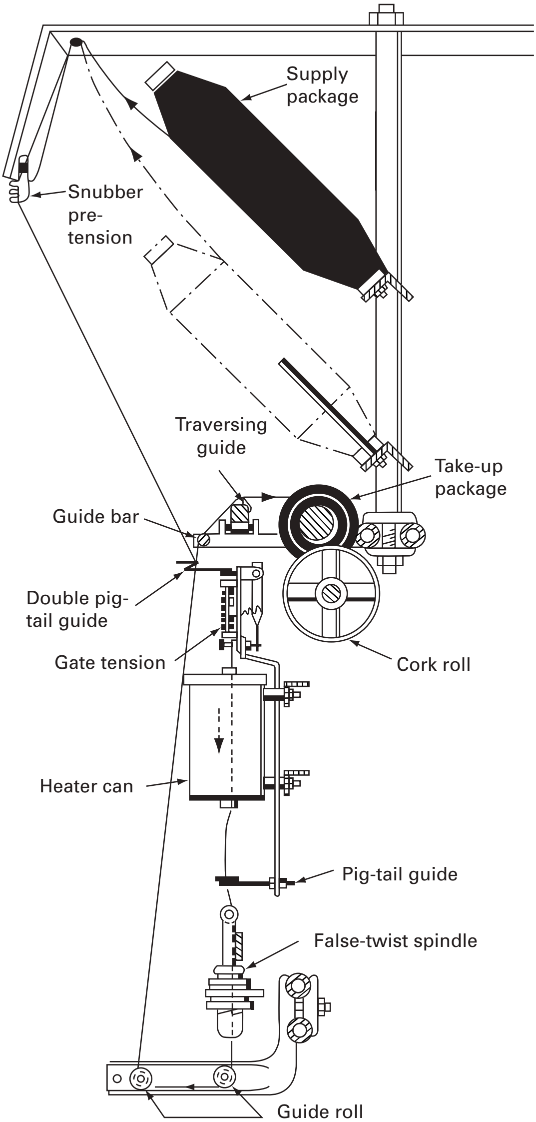
polyester as the supply yarn is to process at a controlled short time after fibre production. However, the partial orientation induced by withdrawal above a critical speed at about 3000 m/min produces an incipient crystallisation, which stabilises the yarn. Such partially oriented yarn (POY), with a residual draw ratio of around 1.5, is what is supplied for draw-texturing.

The long *Helanca* process, which in 1963 was still described as 'conventional' (Chemstrand, 1963), involved three basic steps, twist–set–untwist, but many more actual steps because of the need for rewinding onto suitable packages and because all the twist could not be inserted or removed in single operations. The major advance was the change to the continuous false-twist process in the late 1950s. A similar advance occurred a decade later, when the batch process for producing *Crimplene*, the set-textured polyester yarn, was replaced by continuous double-heater machines.

Until the 1970s, when a fully drawn yarn was supplied to a single-heater texturing machine, it was usually run at a small overfeed. The yarn contraction generated the necessary tension. With undrawn yarn or POY, two methods of draw-texturing were tried. In sequential draw-texturing, another set of rolls is added at the entry to the machine. The next set of rolls runs at a higher speed, so that a drawn yarn is overfed into the false-twist zone. In simultaneous draw-texturing, which proved to be the better method, the draw is accomplished by feeding in POY through the entry rolls and running the output rolls from the false-twist zone at a higher speed, in order to draw the yarn at the same time as it is being twisted. This has consequences for the yarn form, which are described in Chapter 2.

1.2.3 Increasing the speed

The *Fluflon* machine, shown in Fig. 1.6, which was the first to be used to false-twist texture nylon, has a number of interesting features, which differ from practice today. These are worth noting as examples of the technical options and as the starting point for a period of rapid technical advance.



1.6 The *Fluflon* adaptation: the first machine for false-twist texturing of nylon. Reproduced from Chemstrand (1963).

The machine was a modification of existing uptwisters. Supply packages of fully drawn nylon yarn, with about 1 turn/cm of twist, were about 0.5 kg. Tension in the texturing zone was controlled by a pig-tail tensioner, which consisted of interleaved teeth under spring control: it was thus a ***constant-tension*** and not a ***constant-extension*** process (strictly contraction, if there is overfeed). The heaters, which were about 15 cm long, were ceramic tubes wound with electric heater coils and contained in a cocoa-tin filled with insulation: it was thus a ***non-contact*** and not a ***contact** heater*. The false-twist spindle consisted of a pulley that was mounted on the end of a tube. What would normally be the rotation drive for the take-up package of the uptwister drove the rotation of the tube. The rationale for this design was that the rotation of the pulley about its bearing allowed forward motion of the yarn to be unimpeded, while the grip of the yarn on the pulley meant that the yarn on the heater was twisted by the rotation of the tube. The whole spindle was comparatively massive: the tube was over 5 cm long and about 1 cm in diameter. At about 30 000 rpm, the production speed was about 10 m/min. Nevertheless, as shown by Table 1.2, this was a major increase in productivity compared to the *Helanca* long process.

By 1960, machines specifically designed for false-twist texturing were on the market. Contact heaters became the norm and their lengths increased by over ten times to around 2 m. The cooling zone also had to be increased in length for higher speeds. For spindles, it was soon realised that a pulley was unnecessary. The yarn could be dragged forward over a rotating pin:

Table 1.2 Production speeds for false-twist texturing. All figures approximate; partly based on Wray (1960) and Chemstrand (1963) for 77 tex (70 denier) nylon

Date	Technique	Spindle speed (rpm)	Linear speed (m/min)	Production (kg per spindle per week) (168 hr)
	Twist–set–untwist			
1950	*Helanca* long process			effectively 0.1
	False-twist process			
1955	*Fluflon*	30 000	10	0.8
1970	Magnetic pin	300 000	100	8
1990	Friction twist	3 000 000	1000	80
	Others			
1960	*Agilon* (edge-crimp)		60	5
1960	*Ban-Lon* (stuffer-box)		250	20
1960	*Taslan* (air-jet)		100	8
1990	Air-jet*		500	80 (two-ply)

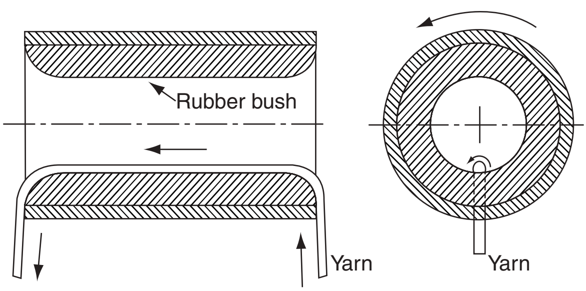
* Normally used on heavier yarns.

the normal force exerted on the yarn by the pin generated the twisting torque, but the axial friction increased yarn tension. The spindles could be reduced tenfold in size to about 2 mm by 1 cm and were held by magnetic action against rotating rolls. Spindle speeds increased by an order of magnitude to around 300 000 rpm.

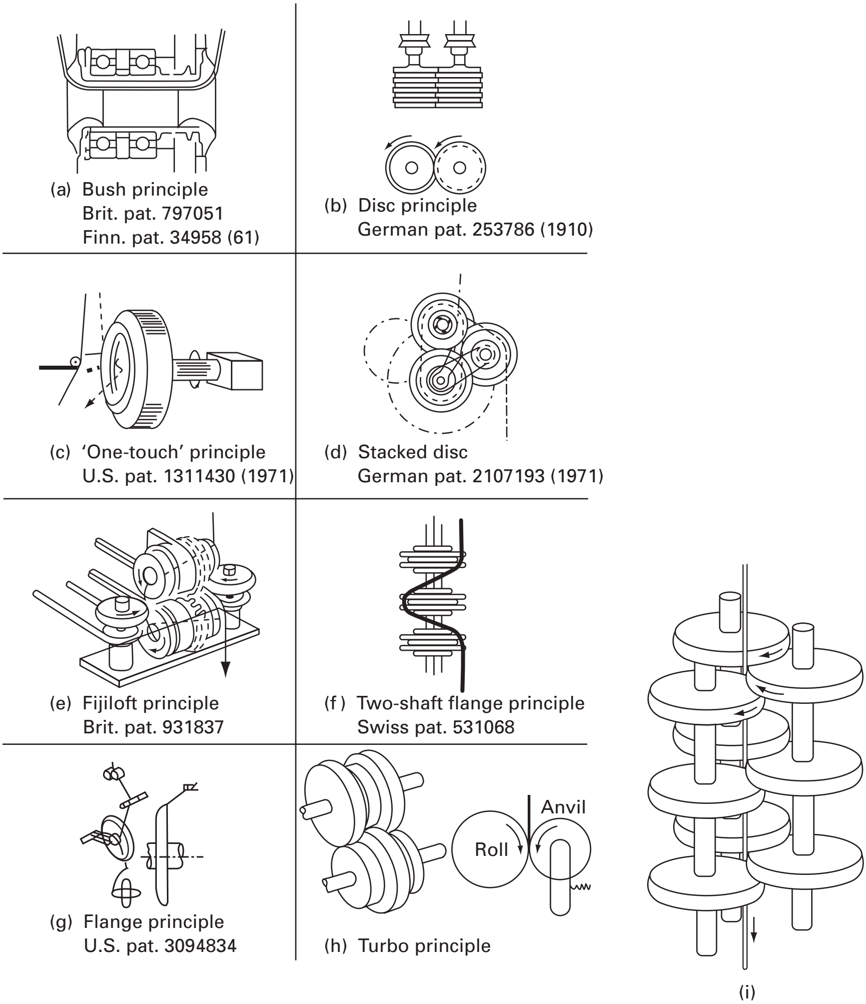
In the mid-1950s, at the time when commercial false-twist texturing was just starting with *Fluflon* machines, friction twisting was invented by Arthur and Weller at *British Nylon Spinners* (which later became part of *ICI Fibres*, and, in turn, of *DuPont*). They realised that there was a terrific gearing advantage, if, instead of using a rotating pulley or pin, the yarn was directly rotated by contact with a moving surface. As will be discussed in Chapter 2, there are complications in the mechanics, but the order of magnitude of the advance is given by the equation:

$$\text{yarn rpm} = \text{spindle rpm} \times (\text{spindle diameter}/\text{yarn diameter}) \quad [1.1]$$

The *British Nylon Spinners (BNS)* friction twister was a hollow tube lined with rubber, through which the yarn passed as shown in Fig. 1.7. About ten machines were produced and used commercially, but then became obsolete. The industry used magnetic pin-spindles, and a decade passed before *Spinner Osakeyhtiö* from Finland introduced a new friction-twisting machine and set the scene for modern false-twist texturing. Many companies experimented with designs for friction-twisting heads, some internal and others external, as shown in Fig. 1.8. The final solution, which is the current design, was a hybrid. The yarn is driven against the outer edge of discs, but is constrained in a three-dimensional, zig-zag path within three sets of overlapping discs. Another method of twisting was invented by *Murata* from Japan and is used on their machines. The yarn is held between two belts moving in opposite directions, which both forward and twist the yarn, as shown in Fig. 1.9. Twisting by an air-jet was also tried, but the machine did not achieve commercial success.

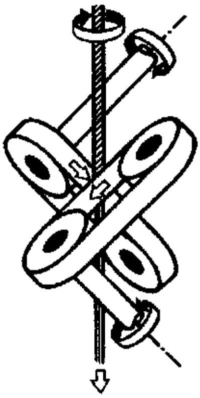


1.7 Friction twisting as invented by Arthur and Weller. Reproduced from Wray (1960).



1.8 (a)–(h) Various forms of friction twisting. (i) Another view of (d), stacked discs, which became the common form. Reproduced from Goswami *et al* (1977), *Textile yarns: technology, structure and applications*. Reprinted by permission Wiley-Interscience, New York, USA.

Table 1.2 shows the increases in speeds and productivity which came between 1950 and 1990 as a result of these advances. Coupled with the integration of processes through draw-texturing, this shows how a new textile operation, which started with crude adaptations of old machines, can be transformed by the talent of inventors and the skill of machinery makers. When synthetic fibre production started, the maximum available wind-up



1.9 Belt twister. Reproduced from *Murata* technical literature.

speed was about 1000 m/min; now it is around 10 000 m/min. There is no mechanical reason why a false-twist texturing machine should not operate at such a speed, although unless improvements were made to reduce the length of heating and cooling zones, the machines would be too high to fit in most factories. The limitation is the interaction between the yarn and the machine. At around 1000 m/min surging in yarn tension starts and the yarn ceases to be properly twisted.

1.3 Jet-screen texturing: BCF yarns

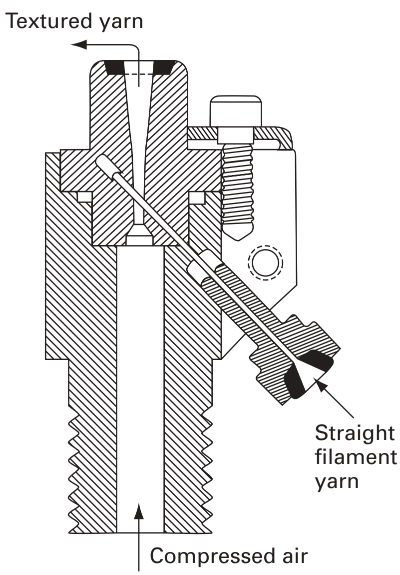
False-twist texturing depends on setting fibres in one geometry and then changing to another, which generates stress that can be relieved by buckling. Another principle is to set fibres in the required crimped form. This was the basis for stuffer-box and some other methods listed in Table 1.1, but, except for some limited use of knit-de-knit, these methods are no longer used for apparel textiles. Another approach is adopted to produce BCF yarns, which are used as coarse carpet and upholstery yarns. Its origins lie in *DuPont* research on jets. Turbulent hot fluid produces an asymmetric shrinkage, which causes filaments to buckle.

False-twist texturing is extensively described in the public domain, because the advances made by fibre producers and machinery makers had to be 'sold' to the many throwster companies, and this spawned considerable academic research. In contrast to this, BCF production methods are less well documented. Fibre companies produce and sell the yarn. They developed their own processes and machines, and had no incentive, except for patent protection, to disclose the technology. Only the yarn properties and performance are important in the market. The situation is changing to some extent as machinery makers have moved into the supply of fibre production equipment, but is still subject to proprietary secrecy. In the production of BCF yarn, the yarn is fed through a hot-fluid jet and then collected on a drum round which the yarn passes, like a caterpillar, as it cools to stabilise the set, before being taken to the wind-up.

1.4 Air-jet texturing

The third significant texturing process in current use, air-jet texturing, operates by mechanical interlocking and not by heat-setting. It can therefore be applied to any continuous-filament yarn, including rayon, glass and the new high-performance fibres, as well as nylon, polyester and polypropylene. The method was invented by *DuPont* in the 1950s and an early jet design is shown in Fig. 1.10. The basis of the method is that yarn is overfed into the compressed air jet-stream, so that loops are forced out of the yarn. The loops need to be locked into the yarn, and this can be achieved by twisting the yarn at the take-up. The alternative, which is the current practice, is to design the jets and the yarn path so that there is sufficient entanglement in the core of the yarn to stabilise the loops.

Over the years, a variety of jet designs have been produced. The major supplier to the industry is *Heberlein*. In addition to air-jet textured yarns as such, the addition of an air-jet to false-twist texturing enables yarns with a different character to be produced.



1.10 An early *Taslan* jet from DuPont. Reproduced from Wray (1960).

1.5 The future

The methods described in this chapter, single- and double-heater false-twist texturing, jet-screen BCF and air-jet texturing, are now mature technologies. Production is economical and a variety of yarns can be produced to meet the needs of apparel, household and technical textiles. Quality control is highly developed and the logistics is efficient. After a commentary on scientific principles, these are the subjects of the main chapters of this book.

What changes can be expected in future? There is always the opportunity to produce yarns with a different character to provide a new fashion market. This might be done by new variants of obsolescent processes or by new inventions. The other major challenge is to increase speeds beyond the false-twist texturing limit of about 1000 m/min. Linked to this is the possibility of reducing two steps to one by adding a texturing operation to fibre production. Economically, a texturing stage at the end of fibre production would need to lead to high-speed wind-ups at around 5000 m/min or more. It must also be remembered that the more stages there are in a process, the greater the chance of breakdown. The efficiency of each stage must be well matched.

The *FibreM* process, which is a jet-to-stuffer-box technique invented by the *Heathcoat* company, was used to a limited extent in the 1970s. Although commercially operated at around 1000 m/min, it was demonstrated at ITMA in 1975 with a high-speed wind-up running at 4000 m/min. The yarn character differed from conventional, set-textured polyester yarns. The market did not develop and manufacture by *Heathcoat* ceased, although the principles may have been adopted in some producer-texturing by *ICI* and formed the basis of a machine produced by the *Mackie* company for texturing coarse, polypropylene yarns. An important aspect of jet-screen and *FibreM* texturing is that the setting of the yarn by heating and cooling occurs in a large reservoir of piled-up yarn, and not, as in false-twist texturing, in the extended length of single yarns. The yarn takes time to pass through the reservoir and this means that the process can be run at high speeds without an excessive length for the setting zones.

It remains to be seen whether the reservoir principle will be adopted in some new form. In the meantime, some lessons from the steam-setting technology used in the *FibreM* process have been applied to false-twist texturing in research by Foster at *UMIST*. Together with more rapid cooling, this reduces the length of the texturing zone and enables speed to be increased without surging. This and other ideas suggested here are described in the last chapter of this book.