7
Air-jet texturing and yarns

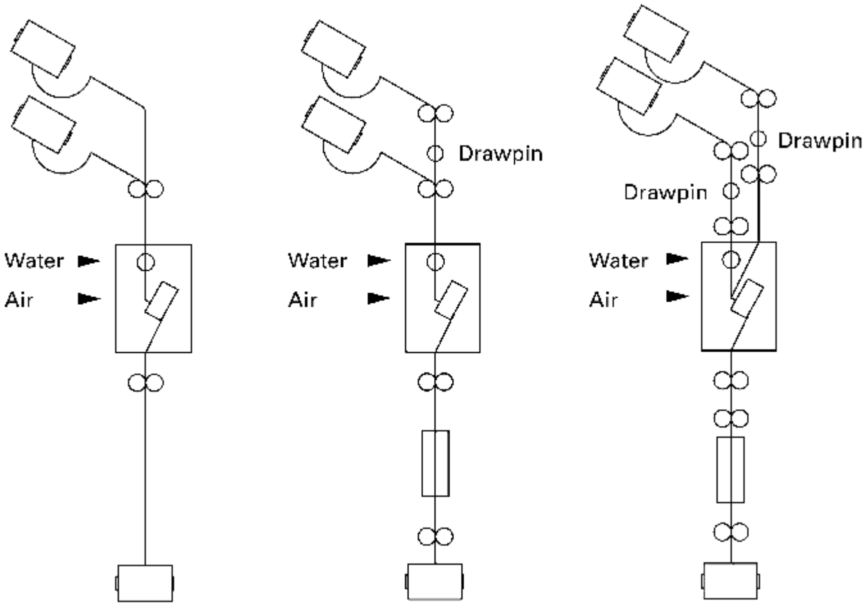
7.1 Introduction

Air-jet textured yarns are produced from thermoplastic, cellulosic or non-organic filament yarns using a turbulent fluid, which is usually compressed air. Loops are formed on the surface of the filament yarn, giving it a voluminous character. Depending upon the material used, the loop structure results in a yarn with characteristics which resemble those of the conventional staple-fibre product. At one time the yarns were known as spun-like yarns.

Thus, in its simplest form, the air-jet texturing machine consists of no more than a supply of yarn (in a creel), a suitable winding head fitted with yarn transport including an extra pair of feed rolls and an air-jet interposed. Since the loop formation results from a shortening of the yarn, the feed rolls before the air-jet are operating at a higher rate of feed than those drawing the yarn out of the air-jet. This is known as overfeeding. The process is illustrated in Fig. 7.1.

When processing certain thermoplastic yarns, chiefly those that are readily available as POY, it is common for the machine to be fitted with a predraw zone, which consists of at least one extra set of feed rolls and a draw-pin. If the machine is to be used for processing polyester POY then the draw-pin will be heated, in order to raise the temperature of the yarn to above the second glass transition temperature T_g (see Section 2.2.3).

Similarly, thermoplastic yarns are often subjected to a heat-setting process, in order to reduce the residual shrinkage of the textured yarn and (it is claimed) reduce the size of some or all of the surface loops. The addition of a heater and at least one further set of yarn feed rolls situated after the air-jet allows this heat-setting to be carried out in-line. Two further pairs of rolls are preferred if the textured yarn can be shown to benefit from a so-called ‘mechanical stabilisation’, which is nothing more than the tightening of knots by pulling on each end of the yarn, i.e. by stretching. This results in a yarn which is more stable, meaning



7.1 Air-jet texturing processes – single, parallel and core-effect (left to right). Courtesy of Heberlein Fiber Technology Inc.

that its structure cannot be altered by the application of further tension such as would be encountered during weaving.

Many air-jet textured yarns are produced from two or more feeder yarns and these may well be processed using different levels of overfeed through the jet. Add to this the need for predrawing each of the feeder yarns and it is apparent that what was originally a simple process can become quite complex. This is illustrated by comparing the first and third examples in Fig. 7.1.

7.2 Air-jet texturing machine

Air-jet texturing machines come with many different profiles and configurations. However, there are two main groups: the first consists of machines with individual drives and the second resembles the false-twist, draw-texturing machine in having a headstock with motors, drives and shafts at each position. The latter may be called lineshaft machines.

Machines with individual drives are characterised by the very wide range of yarns that can be produced and by the fact that each machine position can be set up to produce a different yarn. Components can be added to the machine, either at the time of assembly or as part of a conversion, so that all of the process technologies described in the previous section can be achieved. Individual winding heads mean that doffing is on a random basis, an essential when yarns of high denier are being produced. These are now available with automatic doffing of the textured-yarn packages.

Lineshaft machines have winding heads of similar specification to those used for false-twist processing and are therefore commonly doffed in groups by machine side. Winding heads fitted to these machines are usually limited to about 1500 denier and so this type of machine is only used for finer yarns. They are available with automatic doffing, which makes random doffing a feasible alternative. They are fitted with a short setting heater that is identical to that fitted to the false-twist texturing machine to which the lineshaft-driven, air-texturing machine is closely related.

The thread-path components are the same, though several are optional:

1 two shafts (yarn transport), between which the yarn is drawn, often fitted with a heated pin;
2 two shafts between which the yarn is textured. The texturing jet is housed in a sound-proof box, which also contains a device for wetting the yarn before it enters the jet;
3 two shafts between which the yarn can be stretched;
4 two shafts between which the yarn can be heated and relaxed;
5 an oil application device;
6 a yarn collection and winding head.

Most air-jet texturing machines are equipped for two different feed yarns. This means that 1 is represented twice and in parallel on the machine. On the other hand the simplest form of air-jet texturing involves only 2 and 6. However, if two feeder yarns are to be handled, then the input feed unit of 2 has to be present twice.

Summarising, the simplest machine has three shafts and a winder and the most complex (in common use) possesses seven shafts and a winder. The *Stähle* (*SSM*) *RMT-D* air-jet texturing machine represents the individual drive machine here as shown in Fig. 7.2. Lineshaft, air-jet texturing machines made by *Giudici*, *ICBT* and *RPR* are to be found operating in European plants.

7.2.1 Creels

In most respects the creel of the air-jet texturing machine is similar to that of the false-twist machine (see Section 4.2.2). However, because a greater number of feeder yarn ends are provided for each texturing position, the creels are larger and require more floorspace.

Even with lineshaft machines the single-package, magazine creeling of the false-twist machine is replaced by two feeder yarn packages, the first

7.2 SSM Eltex Stahle RMT-D air-jet texturing machine. Courtesy of SSM.

for the core and the second for the effect yarn. This means that the creel must provide for at least four POY packages at each winding position, since magazine creeling is practised.

In the case of individual drive machines, there may be up to eight supply packages plus eight in reserve for each texturing position. Although the gauge of these machines is around 600 mm (though reduced to 440 mm in the latest *SSM* model *DP2-T*), the number of feeder yarn packages provided means that the creels for air-jet texturing machines require considerable floor space. It is necessary for missing feeder yarn ends to be detected, which means that the creel is considerably more complex than that on the false-twist texturing machine.

7.2.2 Yarn cutter or stop motion

A yarn cutter is provided on lineshaft machines that operates in the same way as on false-twist machines (see Section 4.2.3). A stop motion is preferred on machines with individual drives, so that the missing end may be repaired and the position restarted. This is an advantage of the process, although the extensive use of yarn heaters may render stopping and starting an undesirable practice. This is because yarn that is resting on a heater may be overcooked and this results in a length of textured yarn with a faulty appearance.

7.2.3 Yarn transport system

The same yarn transport systems are used on all lineshaft machines, whether for false-twist or air-jet texturing; namely nip rolls or apron feeds (see Section 4.2.4). The *SSM-Stähle RMT-D* machine (illustrated in Fig. 7.2) will be described throughout this chapter, since it is the most widely used air-jet texturing machine with individual drives in Europe. It also contains many of the same components as its predecessor – the *Eltex Model AT*.

This individual-drive machine is fitted with two kinds of yarn transport system. The first and most common consists of a rubber-covered feed roll with a separator to achieve several yarn wraps and thus to ensure adequate grip. The separator consists of either a fixed ceramic or rotating roll guide. Alternatively the machine may be equipped with ceramic-coated metal rolls and rotating separator rolls. The latter have the advantage of longer life but more yarn wraps are required.

The rubber rolls are supplied with a range of diameters. This enables finer adjustments to be made to the overfeed (or draw ratio) than would be possible by gearing alone. Colour-coded roll covers have been available in the past to simplify the process of checking that the machine (position) is set up correctly.

In all but the most recent versions of the individual-drive machine, the rolls are driven by belt drive. This means that pulleys must be changed on each head when making step changes to the process. The latest machines have rolls that have independent, inverter-driven motors. This means that speeds and ratios can be changed quickly from the central machine-control panel. The latest machine from *SSM-Stähle* is the model *DP2-T* and this incorporates independent, motor-driven rolls (see Fig. 7.3).

7.2.4 Yarn displacement system

As with most of the drive and feed equipment, a yarn displacement mechanism is fitted to line-shaft machines as part of the standard equipment (see Section 4.2.5). The *SSM Stähle RMT-D* machine has forward-facing rolls. The provision of yarn displacement systems on this type of machine was restricted initially to the draw roll where yarn tensions are highest.

7.3 SSM Stahle DP2-T air-jet texturing machine. Courtesy of SSM.

7.2.5 Heated draw-pins

By far the most common method for providing heat in the draw zone is by using a static-heated pin (often known simply as a hotpin). Rotating hotpins of 80–100 mm diameter have also been used, as have driven-heated rolls of 130 mm diameter.

For the hotpin to work effectively there must be a frictional force which retards the yarn as it is pulled over the surface. Experience shows that the ratio of yarn tension before and after the hotpin should be approximately 5:1. Of course the choice of hotpin surface will vary depending upon the type of yarn to be processed and its frictional characteristics. There is often a need to compromise between a hardwearing hotpin surface and one that has the required frictional characteristics. In practice either an orange peel surface in ceramic or a knurled, matt chrome surface is used.

Machines have been available for some time which feature the use of heated rolls for drawing. When used in place of the input feed unit they have the advantage of avoiding the problem of wear. That they work should not be doubted, since they are used extensively on draw-winding machines. The extra cost and higher power consumption have left them as an expensive alternative, so far. Now they are gaining in popularity not only because there is little or no wear but also because their greater heat input makes them ideal for producing yarn with a low residual shrinkage without resorting to the autoclave batch process (see Section 7.3.7).

7.2.6 Yarn wetting system

Most air-jet texturing machines employ a water applicator before the jet. This is because the efficiency of the process is greatly improved if one of the yarns being fed into the air-jet is wet. The introduction of yarn wetting enabled an increase in production rates from 150 to 450 m/min to be realised. This is because the application of water brings about a beneficial reduction in interfilament friction, since the filaments are required to travel through the jet with different velocities and therefore need to be able to slide alongside each other.

Water is applied by an applicator, which is similar to that used for spin finish or for applying coning oil on false-twist texturing machines (see Section 4.2.11). The water must be supplied to each position of the machine in a well-regulated quantity and quality. Metering pumps at each position would be regarded as too expensive and unnecessary, but some system of metering needs to be provided for each row of positions. This is achieved usually by a combination of flow and pressure control.

By water quality is meant a clean, filtered and reliable supply. Hard water should be treated to soften it and demineralised water should be avoided if metal jets are used, since there is a small risk of corrosion.

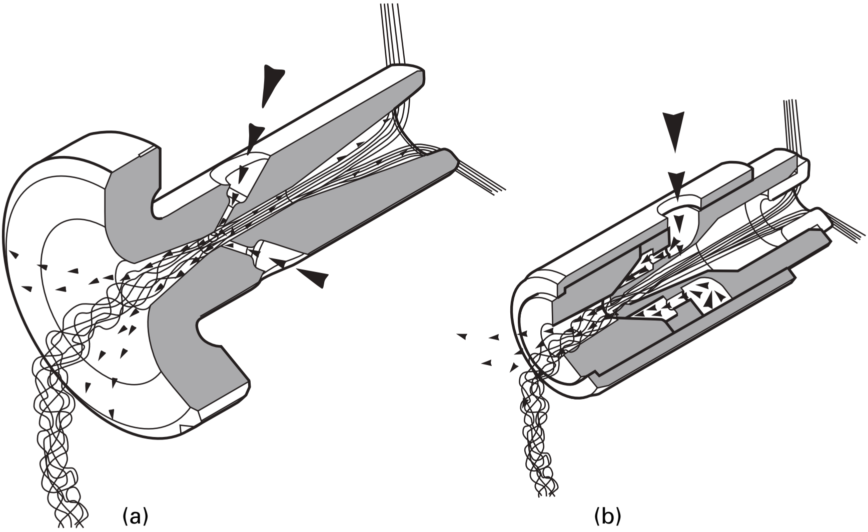
7.2.7 Air-texturing jet

The air-jet is the heart of the process but modern jets require little or no adjustment in use. Most important is the selection of the correct jet, since the *Stähle RMT-D* machine is capable of processing yarns from 50–5000 denier (55–5500 dtex) but individual jets are limited to a narrower range. Furthermore the choice of jet is determined by the material to be processed and by the end-use and characteristics of the yarn to be produced.

There are two basic types of texturing jet, the axial and the radial. Figure 7.4 shows these two types side by side. The first is the axial jet (see Fig. 7.4 (b)). This was the first type of jet to be developed for air-jet texturing, initially by the *DuPont Company* (*DuPont*), using the trademark *Taslan* ®. The principle of the jet has remained the same for many years, but there have been many detailed improvements. There are still many *Taslan* ® jets in use from Mark XIV onwards and there is also the equivalent made by *Heberlein*, which has the designation *EO52*. *Heberlein* became the owner of the *Taslan* ® trade name and patents when *DuPont* decided to cease licensing air-jet texturing technology.

The second generic type is known as the radial jet (see Fig. 7.4 (a)). This jet was developed originally in Czechoslovakia using the *Mirlan* name but has been manufactured by *Heberlein* since 1977. Again, what was originally a single model has developed into a wide range for different yarns and production rates. Radial jets are made from both ceramic and tungsten carbide materials.

Whereas the axial jet was developed initially to be adjusted during production, in order to obtain the optimum yarn processing tension, the radial jets have always been fixed. They require only cleaning, and the replacement of seals and damaged surfaces during their lifetime. Both the axial



7.4 (a) Radial and (b) axial jet. Courtesy of Heberlein Fiber Technology Inc.

and radial jets are fitted with a form of baffle device at the point where the yarn leaves the jet. These have been given various names such as baffles or coanda bars. Baffle devices are described in more detail in Section 7.3.5.4.

7.2.8 Jet box

Both the air-jet and the water applicator are enclosed in a sound-proof box. Eyelets are provided where both the input yarns and the textured yarn enter and leave the jet box. There is also provision for the water to drain to a central point (for treatment) and an air extract. The air extract is connected to a central fan and maintains the jet box under a slightly negative pressure, even when the air-jet is working. This reduces the escape of air and mist into the plant environment.

Of course, the jet box must be opened for access and especially when threading the machine. Although the wearing of ear protection is recommended (and in many plants compulsory) when working close to the machine, the noise level close to an air-jet texturing machine is quite acceptable when the jet boxes are designed correctly and all are closed.

7.2.9 Mechanical stabilisation

Just as a shoe knot must be tightened after formation, so must an air-textured yarn be stretched slightly, in order to anchor the loops in the core of the yarn. On most machines this is achieved by having two extra feed-roll units after the jet. By setting the speed of the second typically 2–3% higher than the feed roll immediately after the jet, this can be achieved simply.

7.2.10 Heat-setting

All manner of heaters have been fitted to air-jet texturing machines in attempts to produce a textured yarn with a very low residual shrinkage (see Section 7.3.7 below). Lineshaft machines are often fitted with secondary heaters taken from the 'sister' false-twist machine (see Section 4.2.10). However, the core of an air-jet textured yarn is much denser than the equivalent false-twist yarn and it is acknowledged that heat-setting in-line is not as effective. Much has been written about shrinking so-called wild loops but there has been little published evidence that this actually occurs.

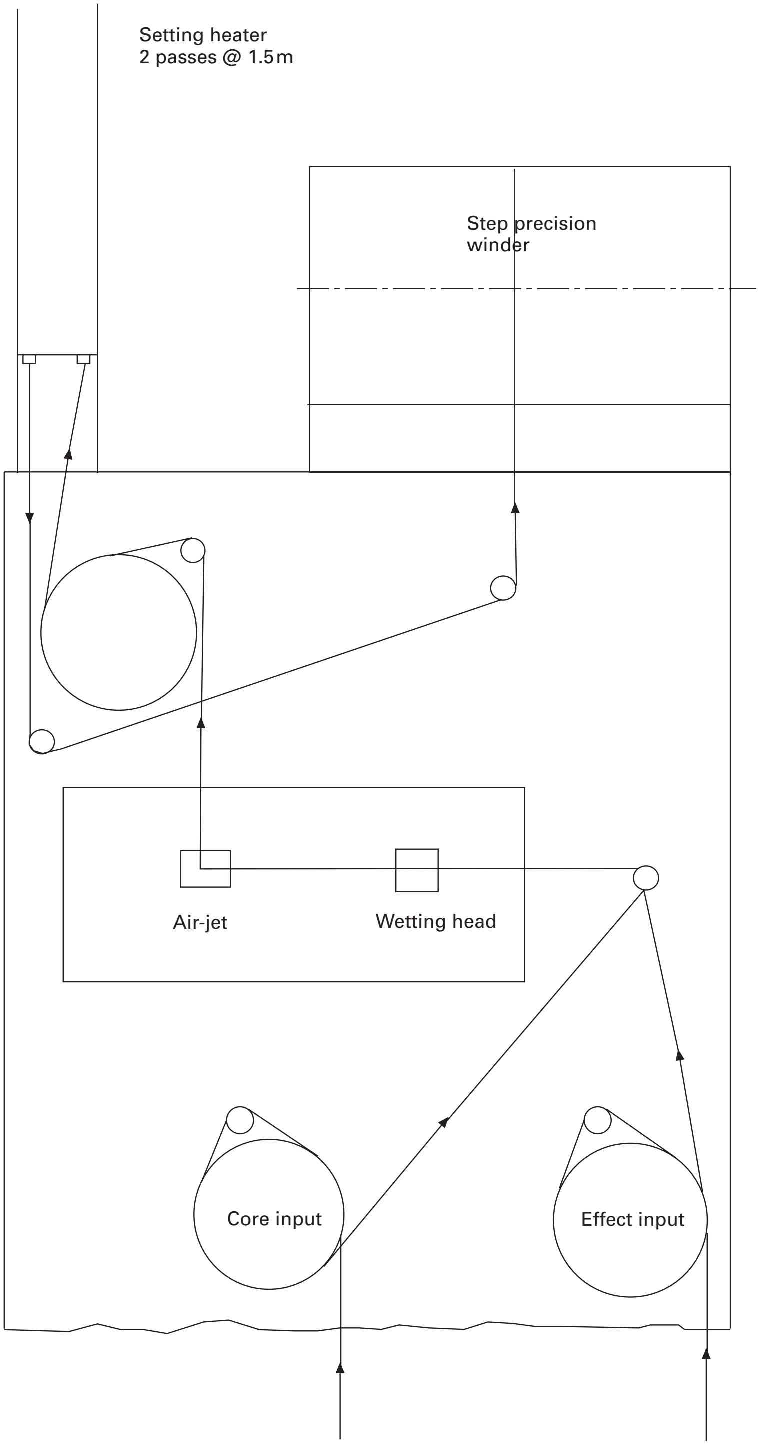
Machines such as the *SSM Stähle RMT-D* allow scope for fitting different optional heaters. Perhaps the two most common are long non-contact heaters and heated rolls. The long heater is placed above the machine as shown in Fig. 7.5 and this allows a double pass, thus effectively doubling its length. Heated rolls having 130 mm diameter are also effective, though sometimes up to 20 yarn wraps are specified, which must make operating procedures a nightmare to check.

7.2.11 Coning oil application

The same techniques are used here as with false-twist texturing machines (see Section 4.2.11).

7.2.12 Take-up/package build

A lineshaft-driven, air-jet texturing machine is fitted with the same type of winding head as that fitted to the false-twist machine (see Sections 4.2.12 and 4.3.5). Automatic doffing is now generally available as an option. The individual-drive machine has been fitted with relatively simple winding heads in the past. The compensation for package build-up was by weights and the random wind combined with a slight variation built into the traverse cam was sufficient to avoid serious patterning. A major variation was the modification to allow the winding of conical packages. This is important for good unwinding of heavier furnishing yarns. Of course it requires a compromise, since the yarn is being textured at a constant speed and no cone winder with a friction drive can match this. It works, because the yarn (usually polypropylene) is textured with high



7.5 Air-jet texturing machine with setting heater. Courtesy of SSM.

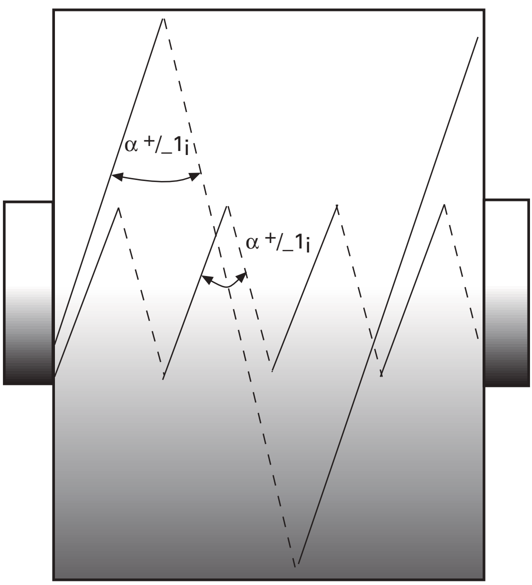
overfeeds and has a residual elasticity or stretch. Whatever the theory, very acceptable cones are produced for this segment of the industry with few problems.

Since the introduction of the *SSM Stähle RMT-D* with individual heads, a step precision-winder has been offered as an alternative (see Figs 7.2 and 7.3). The fact that each head is separate with its own winder and traversing mechanism means that the advantages offered by a precision-winder can be contemplated. The problem is that a conventional precision-winder maintains a constant wind angle, but not a constant winding speed, since the package is driven directly through the spindle.

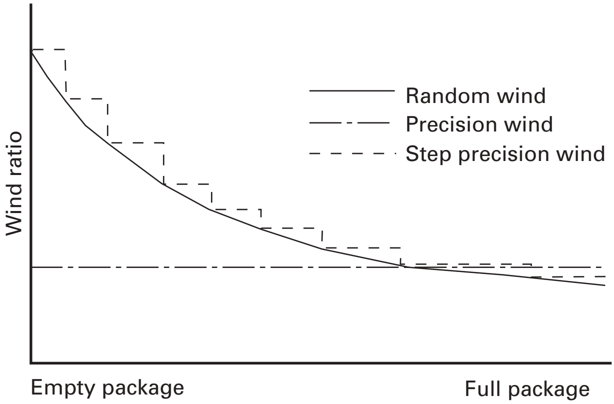
A step precision-winder is a compromise between a random but constant speed friction-drive winder and a precision-winder. Instead of the ratio between the winding and the traverse being fixed throughout the package build, it is varied in predetermined steps, as the name implies.

First, by changing the speed of the traverse relative to the constant winding speed, the number of windings per traverse length decreases whereas the crossing angle is the same at the end of the package wind as at the beginning (see Fig. 7.6). The reason why these changes take place stepwise rather than continuously is so that the regions where patterning is likely to occur, i.e. where the traverse lays each layer of yarn exactly on top of the previous one, can be avoided.

The advantages of this mechanism are:



7.6 Stepped precision wind – crossing angles. Courtesy of SSM.



7.7 Wind ratios – empty to full yarn package. Courtesy of SSM.

1 no patterning or ribbon zones;
2 higher and homogenous package density;
3 crossing angle can be optimised to give best unwinding characteristics;
4 unwinding tension variations at a minimum;
5 little or no danger of sloughing during unwinding;
6 leading to higher unwinding speeds.

The crossing angles at the start and finish of the package are shown in Fig. 7.6 and the variation of winds per revolution compared with the package diameter is shown graphically in Fig. 7.7.

Newer versions of the *Digicone* winder are fitted with the *Preciflex* traversing system. A stepper motor drives the traversing guide now. This not only eliminates the changing of gears or pulleys according to the package required but also facilitates the programming of the package build for any individual or collective winding position from the machine console. It also means that open or closed winding, straight or tapered packages and even unusual package shapes can be programmed and set at will. The only moving parts are the stepper motor and the drive belt and the only part that needs changing is the traverse guide itself. Even this change only occurs if there is a requirement for the winding of many heavier or finer yarns.

7.3 Process variables

7.3.1 Draw ratio

The draw ratio is the amount by which the yarn is stretched before entering the texturing zone. Therefore:

$$\text{draw ratio} = \frac{\text{shaft speed after draw-pin (m/min)}}{\text{imput shaft speed before draw-pin (m/min)}} \qquad [7.1]$$

This can be seen in Fig. 7.1. When two yarns are being processed the calculation has to be made separately for each input yarn.

Unlike the false-twist, draw-texturing process, the draw ratio is not the only parameter that influences the denier of the textured yarn, since this is also affected by the overfeed through the texturing jet and by subsequent stretching and relaxing.

The formation of loops during texturing means that the strength and elongation of the filaments, which both result from the draw ratio, have only a secondary influence on the properties of the textured yarn. Stretching and applying a load to an air-jet textured yarn initially will cause the loops to be pulled out. Only when the filaments have returned to the original untextured structure do they start to extend so that their properties show up in the load–extension diagram.

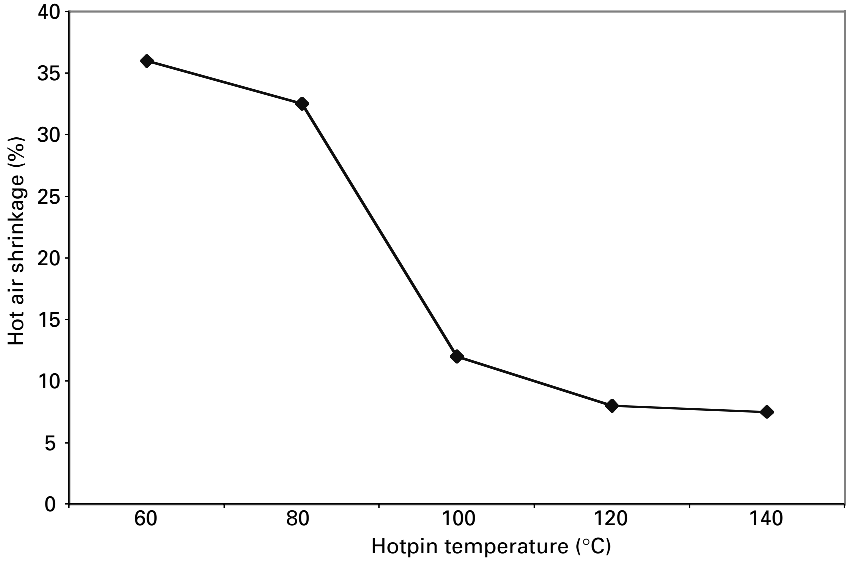
Draw ratio does affect levels of faults such as numbers of broken filaments (caused by a ratio that is too high). Underdrawing will produce a yarn that exhibits some plastic, i.e. non-elastic, stretch under load. This is sometimes done intentionally to produce a fabric which can be stretched into the shape of the seat for which it is intended.

The draw ratio has an influence upon the molecular orientation and hence the dye-uptake of the textured yarn. This influence is magnified if heat is applied during the drawing process. This is the case when hotpins are used for drawing polyester (as described in the following section).

7.3.2 Hotpin or draw-pin

Since the largest single market for air-jet textured yarns in Europe consists of yarns for car seat fabrics made from polyester, the process for making such yarn will be used as the basis for the following description of process variables. Polyester is widely available in the form of POY and therefore any texturing process suitable for this market has to include the means for drawing POY. The common practice is for a heated draw-pin or hotpin to be used when processing polyester. The pin is located between the first two rolls and provides a fixed draw point and a means of heating the POY to above its second-order glass transition temperature T_g which ranges from 70–100°C for polyethylene terephthalate (PET) (see Section 2.2.3).

Typical hotpin temperatures range from 135–160°C. This is higher than would be necessary to exceed the second-order transition temperature. However, air-jet texturing is basically a process that does not require heat. Sometimes the hotpin is the only source of heat and so is used to reduce the residual shrinkage of the textured polyester yarn by running at a higher



7.8 Variation of yarn shrinkage with hotpin temperature. Courtesy of Chemical Fibers International.

than normal temperature. The effect of hotpin temperature on the hot-air shrinkage of a drawn yarn is shown in Fig. 7.8.

Where hotpins are fitted, they can be used for other fibres such as nylon and polypropylene. Although nylon can be drawn cold, the use of a hotpin reduces the yarn tension during drawing from approximately 4 to 1 g/denier (dtex). Also if a coldpin is used it takes time for the pin to heat up as a result of the friction and the natural heat of drawing. Provision of a pin that is already heated will stabilise this situation and ensure that the same processing conditions apply immediately after a 'cold' start. If a heated draw-pin is provided on the machine, then it is usual for it to be used for nylon with a set-point of typically 80–100°C.

Polypropylene requires heat to assist the drawing process and a hotpin can be used to provide this. However, the heat generated by friction can both raise the yarn temperature too much and cause damage to it. Therefore, heated rolls are preferred for drawing polypropylene. This is not yet seen much in practice, since most continuous-filament polypropylene for texturing is produced by the spin-draw process and requires no further drawing. This may change as more polypropylene POY becomes available.

In general the blind application of draw ratios as specified by the feeder yarn supplier should be avoided. It is always preferable to establish the elongation properties of the POY by producing a load–extension diagram in the laboratory. This will enable a more appropriate draw ratio for the specific yarn to be determined and applied.

7.3.3 Yarn overfeed

7.3.3.1 Single and parallel yarn processing

The overfeed through the jet, which is approximately the same as the difference between the input feed and the speed at which the yarn is being removed from the jet, has a direct influence upon the bulk or specific volume of the yarn. The word approximate is used here, because the heat that may have been applied during the previous drawing process often leads to a delayed shrinkage or shortening of the yarn.

Since overfeeds applied during the air-jet texturing of single yarns are higher than those that were used in false-twist texturing (even before the advent of draw-texturing), there is also a direct and proportional increase in denier, which cannot be ignored. The formula that is used to calculate the final denier during air-jet texturing does not, unfortunately, take into account the possible shrinkage of the yarn as a result of heating during drawing and rapid cooling on reaching the expanding, and therefore cold air, inside the air-jet.

The formula is:

$$\text{Rdtex} = \text{core}(\text{dtex} \times n_{\text{C}} \times Of_{\text{C}}) + \text{effect}(\text{dtex} \times n_{\text{E}} \times Of_{\text{E}}) \qquad [7.2]$$

where Rdtex = final denier of the textured yarn, n_{C} = number of ends in core, Of_{C} = core overfeed expressed as an integer, n_{E} = number of ends in effect and Of_{E} = effect overfeed expressed as an integer.

As an example, if we are processing four ends of 300 denier (330 dtex) polypropylene, two each in the core and effect, the former with 15% overfeed and the latter with 80% overfeed:

$$\text{Rdtex} = (330 \times 2 \times 1.15) + (330 \times 2 \times 1.80) = \text{approx. } 1750 \text{ denier}(1950\,\text{dtex})$$

It must be remembered that this is an approximation. One reason for this has been given already. But polyester is usually drawn as part of the texturing process. Therefore the POY denier must be taken and be divided by the draw ratio (again, as an integer, see Section 4.3.1) to obtain the core and effect denier used in the above formula. Even with a drawn feeder yarn such as polypropylene, care must be taken to use the overall overfeed, taking into account the fact that some stretch is applied to the yarn after texturing. The gearing charts in most machine manuals enable the overall overfeed to be calculated, once the settings on the machine are known.

7.3.3.2 Core and effect yarn processing

Since two different yarns are being fed into the air-jet at the same time, the result of varying the overfeed when processing under core and effect conditions is more complex. By definition the core yarn overfeed is lower than that of the effect yarn. This means that the majority (but not all) of the filaments that comprise the 'core' yarn find themselves in the centre (core) of the textured yarn and those of the effect form the surface loops. Of course this distinction is not complete, since there is a considerable interchange or migration of position between the filaments. Indeed the textured yarn would not hold together, if this were not the case.

Changing the core yarn overfeed has a direct influence on the strength of the textured yarn, i.e. the breaking load, and also on the so-called stability. By stability is meant the resistance to removal of the loop structure under load. Since the core overfeed affects the length of the textured yarn, it has a major influence on the denier of the yarn. Core overfeeds usually range from 2–15%. The effect yarn overfeed determines the size of the loops. It also has an indirect influence upon the number of loops per unit length and also on the denier.

Perhaps the most important influence of the effect yarn overfeed is to be seen in the structure and appearance of the yarn, not only as an entity but also in the fabric. This is because loops are seen on the surface of the yarn in the same way that hairs are visible in a spun yarn of similar filament or fibre fineness. The loop structure together with the filament fineness also affects the frictional properties of the yarn (see below).

Effect yarn overfeed ranges from 15–150% and in exceptional cases can exceed 150%. The maximum overfeed is usually determined by the type of air-jet in use, the number of filaments present and the fact that a yarn with frequent large loops can be very difficult to process in certain fabric constructions.

7.3.4 Yarn wetting

The amount of water that is required has been shown to be very small. However, minimum practical levels of application range from 0.5–2.5 l/hr per jet. Of course the heavier the yarn, the more water is applied. These levels used to be approximately ten times higher until the introduction of reliable methods of metering small quantities of clean water to each head without the risk of the jet running dry. Many machines are still supplied from a header tank. Using a header tank alone makes the accurate adjustment of the water supply to each jet very difficult, both to set and to reproduce.

Water and spray is collected in the jet box and removed by means of a gravity drainage system. It should be remembered that this water contains pollutants washed from the yarn during processing, mostly of the oil-based type used in the spin finishes that are applied to the feeder yarns during the spinning process. Thus suitable precautions are required before this water can be reused or passed into the plant's effluent disposal system.

7.3.5 Air-texturing jet

7.3.5.1 Selection of jet

The first choice that has to be made concerns whether an axial or radial jet is more suitable for the process under development. Although radial jets were introduced for finer yarns than the original axial jets (largely for reasons of economy, since they were designed to consume less air), there is now a considerable range of yarns which can be produced using either type of jet. This range is from 500–5000 denier (550–5500 dtex).

The axial jet can be operated with considerably higher net overfeeds. The practice is to use core overfeeds in the range 4–20% to impart stability to the textured yarn. This enables the effect yarn to be overfed at up to, and in some cases over, 100%. Since the increase in denier is proportional to the average overfeed, it can be understood that yarns made using the axial jet are often bulky and voluminous. More will be written later about applications but in general it can be said that these bulky yarns are most suitable for furnishing fabrics including some of those used to cover car seats.

A typical example would be a yarn used widely for flat-woven, car seat fabrics and having a final textured denier of 1215 (1350 dtex) when prepared for weaving. This product is usually made from feeder yarns, which have a combined denier of only 750 (835 dtex) at the point of entry into the jet. This means that the total increase in denier is 60%.

However, caution should be used when deciding which overfeeds to set on the machine. Polyester yarns of this type are often wound as soft cheeses in preparation for package dyeing. Before dyeing they are steam-set in an autoclave. In the autoclave the yarn is allowed to shrink and this contributes around 10% to the increase in denier.

Radial jets are used where lower total overfeeds are required and where high processing speeds are desirable. This would be the case where the input and final yarns are closer in denier, when the total denier is below 700 (<770 dtex) or where a smooth yarn with small regular loops is required. Not only must the total overfeed through the radial type of jet be kept below 40% but also the difference between the core-and-effect overfeeds should not exceed 30%.

7.3.5.2 Jet material

The jet cores of a radial jet are made from sintered material. This material is either high-grade ceramic or tungsten carbide. Sintered titanium carbide has also been used. There is no easy way of determining which material to choose. Because the yarn is lubricated during spinning and wetted before entering the jet, the friction between the wall of the jet and the yarn does not appear to exert a great influence upon texturing performance. However, there does seem to be a link between water quality, i.e. hardness and constituency, and the texturing performance. Furthermore the spin finish applied and the water quality interact and can have a strong influence on jet cleaning cycles. All things being equal the jet material that has the greatest resistance to wear should be chosen. This would be a high-grade ceramic material in most cases. It may be necessary either to conduct trials with different materials or to ask the yarn and/or the jet supplier whether experience of the yarns to be processed in the chosen locality indicates a preference for a specific jet material.

Axial jets have not hitherto been offered in alternative materials to the same extent as radial jets. Nevertheless there is a variety of materials in different jets. The venturi can be made from either sintered metal or ceramic material. Also the needles are supplied with both ceramic and sapphire inserts at the tip and even without any insert at all for yarn materials such as glass fibre.

These choices need to be made when the type and size of jet is specified. If problems arise which appear to be related to the material used in the jet it is necessary to discuss alternatives with the jet supplier.

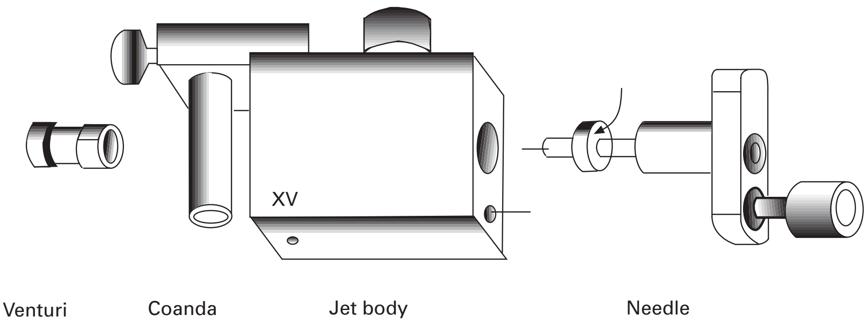
7.3.5.3 Size of jet

Since most types of jet have no adjustment, selection of the correct size is important. However, the ranges given in the jet manufacturers' data sheets must be treated only as a guide. Whereas it is obvious that a yarn with a total denier which is too high for a given size of jet cannot be forced through it, there are circumstances when the use of a larger than normal jet can be beneficial. An example is a yarn which has particularly stiff filaments, due either to the material or the diameter or cross-section of the filament. In this case the extra energy which can be generated in a larger jet may help to achieve a stable and well-integrated textured yarn.

In determining which size of jet to use, it is important to note the large differences in specific volume of different yarn materials. The highest volume and therefore the largest yarn channels are required for polypropylene. Glass fibre yarns have the highest density. Table 7.1 shows the densities of the yarns which are most commonly processed using air

Table 7.1 Density of fibre materials for air-jet texturing. Courtesy of British Textile Technology Group (BTTG)

Material	Density (g/cm^3)
Glass Fibre	2.50
Cellulosics	1.53–1.32
Polyester	1.38
Polyamides	1.18–1.17
Polyolefins	0.93–0.90



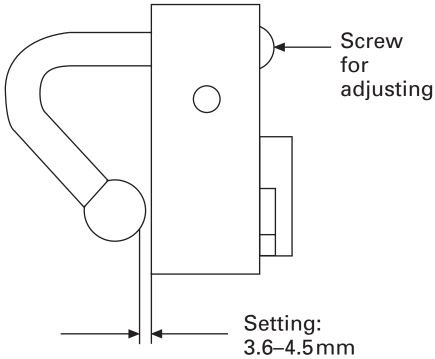
7.9 Type XV axial jet components. Courtesy of Heberlein Fiber Technology Inc.

jets. Some jet data sheets clearly specify different jet sizes for different materials.

7.3.5.4 Jet Baffles

Although most types of jet offer no adjustments during production, there are two factors, which need to be considered:

1 First, the distance or size of the jet baffle does vary with the yarn to be processed. *Taslan* ® jets employ a baffle device known as a coanda bar at the point where the yarn leaves the jet (this can be seen in Fig. 7.9). Coanda bars are available with two different diameters, namely 3/8″ (9.5 mm) and 15/32″ (12.0 mm). The *Heberlein* axial jet baffle comes in only one size and with one setting. Radial jets can be supplied with or without baffles but are fitted with them for all but the coarsest yarns. These baffles have three settings, which depend upon quite wide ranges of yarn and are preset in the user's workshop using feeler gauges. The



7.10 Setting of baffle on air-texturing jet. Courtesy of Heberlein Fiber Technology Inc.

method of setting using the adjusting screw and feeler gauges can be seen in Fig. 7.10.

2 The second factor is the orientation of the jet with respect to the yarns, both entering and leaving the jet. Both types of texturing jet function in part as a result of the yarn being drawn out of the jet at 90° to the main yarn axis through the jet. It is this fact, combined with the yarn overfeed through the jet, that facilitates loop formation.

However, the angles at which the yarns enter the jet are also important. This is especially relevant when core and effect yarn overfeeds differ greatly. The net effect is that the core and effect yarns enter the jet with different velocities (observe the surface speeds of the respective input feed rolls). It is therefore desirable to keep them separate for as long as possible, even after they enter the yarn channel within the jet. Guides located either in the jet box or on the jet housing facilitate this. Both these input and output angles were shown clearly in Fig. 7.4.

Jet manufacturers and the suppliers of machines collaborate to ensure that these angles are correct. However, the manuals should be consulted when changing jet type, in order to find out whether any changes to the yarn guiding and jet orientation are necessary.

7.3.6 Mechanical stabilisation

Rather like tightening a knot in shoelaces by pulling, the stability of an air-jet textured yarn is improved considerably by stretching after the texturing zone. Incorporating at least two yarn feed units after the jet box does this. The ratio is set to suit the yarn. The higher the (core) overfeed the greater will be the effect of stretching upon the yarn stability. In practice the stretch will range between 2 and 10%. Heat may be applied within the mechanical stabilisation zone as a means of inducing tension in the yarn.

7.3.7 Heat-setting

Air-jet textured yarns are much denser than false-twist textured yarns of the same denier and therefore the effect of heat-setting is not so noticeable in the end product. Nevertheless the effect of applying heat means that overfeeds of up to 10% are used, depending upon the residual shrinkage of the textured yarn. The applied overfeed has to be 'absorbed' by the shrinkage of the yarn or else the process would break down. Apart from this, much of the information contained in Section 5.3.5 applies here.

The alternative heaters available for the *SSM-Stähle* machine are described above in Section 7.2.10. The choice between these different heaters and no heater depends upon the purpose for which the textured yarn is intended. In many cases polyester is dyed as a yarn on the package. To ensure even dye penetration it is important that no further yarn shrinkage takes place during dyeing. This is achieved by steaming the textured yarn in an autoclave for approximately 20 minutes at about 130°C. Since this is extremely effective in reducing the residual shrinkage of the yarn to below 1% (measured in hot air at 180°C) there has been no rush to complicate the texturing machine by adding optional heaters and consuming an extra 1–2 kW of power. However, newer machines are being fitted with heated rolls immediately before the jet for both the core and effect yarns. These do reduce the residual shrinkage of polyester yarns significantly. Furthermore they can be used in place of hotpins provided that the draw zone is capable of withstanding the higher tensions that result from cold drawing.

Polypropylene is rarely heat-set on the texturing machine, though for different reasons. There has simply been no perceived benefit for a yarn which usually goes directly from texturing to weaving. Polypropylene has a low melting-point of around 160°C which means that severe heat treatment is impossible.

Sewing threads based on air-jet textured yarns present a different problem. Although these yarns are also dyed, there is no opportunity to build a softly wound package suitable for autoclaving during the texturing process, because of the need to twist the yarn. Therefore it is desirable to reduce the shrinkage of the yarn to below 1% by some other means, preferably during the draw-texturing process. It is here that the heated roll or godet has been applied successfully, in conjunction with the use of hotpins and sometimes also hotplates before texturing. This is because the residual shrinkage of polyester yarns can be reduced step by step. In other words the effect is cumulative.

7.3.8 Yarn lubrication and package build

Most of the information contained in Section 4.3.5 applies equally to air-jet textured yarns. Since the yarn has a much lower stretch (elongation) the take-up overfeeds applied are lower. Methods of applying lubricant to the yarn and varying the quantity are identical to those for false-twist textured yarns.

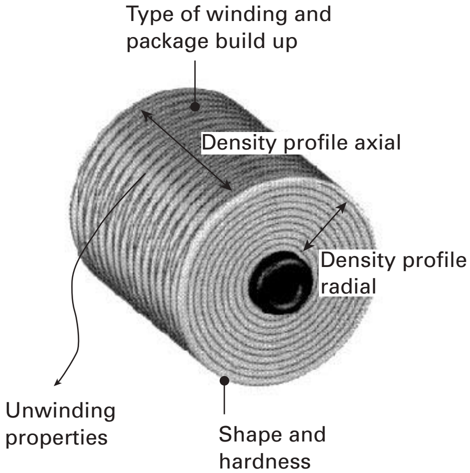
The winding of soft packages of air-jet textured yarns prepared for the autoclave and for package dyeing presents a different set of challenges. If the residual shrinkage is high at the point of winding the yarn coils within the package are compressed during the steaming process. This causes density variation from the inside to the outside of the textured yarn package that can cause unacceptable differences in dye-uptake.

In earlier times the only countermeasure which was found to be effective was to even out the winding tension variation as far as possible by using a long thread-path from the last yarn feed unit to the winding head. An element of tension compensation has also been added, bringing with it a marginal improvement. This step has been taken to its ultimate limit on some machines by using a yarn storage feeder placed between the last driven yarn feed unit and the winder. This effectively ensures a constant winding tension apart from some variation caused by the traversing motion.

Another effective countermeasure has been the employment of a step precision-winding head (see Section 7.2.12). Since precision winding can produce an open or closed type of wind, it is obviously the former that is selected. The setting of the winding parameters has been greatly simplified since the introduction of the *Preciflex* winding head. The selection of these settings and the principle of the *Preciflex* winding head can be seen in Fig. 7.11.

Apart from the use of step precision winding most of what has been written about package dye yarns in Chapter 5 applies to air-jet textured yarns. Compressible tubes are usually employed. However, air-jet textured yarns for package dyeing are normally wound with a zero taper angle, i.e. as a cylindrical package (straight-sided cheese).

Some air-jet texturing machines are provided with winding heads which produce random-wind, conical packages. This applies especially to textured polypropylene yarns destined for woven furnishing fabrics. Such yarns are produced using high effect overfeeds of up to 100%. This can present unwinding problems especially from cylindrical packages. On the other hand these yarns are also produced with sufficiently high core overfeeds to allow the winding of conical packages. This is because the resulting textured yarn has a higher degree of stretch or elasticity compared with other air-jet textured yarns.



7.11 Preciflex – setting parameters. Courtesy of SSM.

7.4 Air-jet textured yarns

7.4.1 Yarn form

Whereas false-twist textured yarns fall into two main groups, namely textured polyester and nylon (with polypropylene as an outsider) and BCF yarns are made either from nylon or polypropylene, but destined for one market, air-jet textured yarns are very diverse. To quote from the respective catalogues, one can buy an *SSM-Stähle* air-jet texturing machine (the latest model being the *DP2-T*) capable of use with a wide range of yarns from 50–5000 dtex (even coarser, as far as glass fibre yarns are concerned). From the *Heberlein* jet data sheets it is possible to select five jets (four of these are radial and fit into the same housing) and the whole of this range of yarns can be covered from one installation.

To cover this wide range in one chapter, it is necessary to look at three groups, with a fourth as an extra:

1 fine air-jet textured nylon for woven and knitted fabrics;
2 medium air-jet textured polyester for woven and knitted fabrics (automotive applications);
3 medium to coarse air-jet textured polypropylene for woven furnishing fabrics;
4 polyester air-jet textured sewing threads.

Table 7.2 shows the range of end uses for which air-jet textured yarns are produced. It also shows the characteristics of the air-jet textured yarn which

Table 7.2 Air-jet textured yarn properties and applications. Courtesy of Heberlein Fiber Technology Inc.

Property	Application	Remarks
Low friction character	Sewing thread	By means of protruding loops: * cooler needle * lower needle friction * good cover
Spun yarn	Sports and leisurewear	* mainly nylon and polyester
	Car seat cover Interior furnishing	* from polyester POY * mainly polypropylene
	Outerwear	* mainly nylon *with* polyester * with raised surface
High friction	Skiwear, tablecloth Bed sheeting Belts and straps Luggage, rucksacks	* slip resistance
Dimensional stability	Tarpaulin Coated fabric Tyre fabric chafer Printed circuit	
Blended yarns	Composites comprising: * different fibre materials * coarse and fine filaments * yarns with different properties * heather effects (spun-dyed) * combinations of these	
Structural effects	Curtains Wall coverings	* variable texture * flame resistant i.e. glass fibre
Functional wear	Rain and sportswear Leisurewear Sports underwear	* microfilament * double layer fabric from wicking yarns

make it suitable for each of the applications. These desirable characteristics should be borne in mind when deciding the specification of the yarn to be produced.

7.4.2 Yarn designation

The fact that many air-jet textured yarns are made from core and effect feeder yarns that are not necessarily the same, slightly complicates the search for a clear and agreed method of designating the yarns. *Heberlein* suggest the following in their jet manuals:

1 a single yarn has no symbol or × 1
 e.g. PES (for polyester) 167 dtex 64 fils;
2 a parallel yarn (which means two or more yarns with the same speed into the jet, e.g. PP (for polypropylene) 330 dtex 47 fils × 3 (ends);
3 a core/effect yarn (which means that the core yarn and the effect yarn are fed into the jet at different speeds), e.g. PA 66 (for nylon 66) 78 dtex 34 fils + PA 66 78 dtex 51 fils.

Clearly the other designations mentioned in Section 5.2 can also be used. The main point is to use the + sign to separate the core yarn from the effect yarn, when designating the make-up of the yarn.

There is as yet no agreed method of describing whether a yarn has been stabilised or heat-set after texturing. Nor is the drawing process (if used) indicated in the product designation. Add to this the facts that polypropylene is still often referred to in terms of denier and that glass fibre yarns and finished sewing threads both have their own 'count systems' and the problems of achieving clarity multiply. One can only recommend that yarn conversion tables are kept handy!

7.4.3 Air-jet textured nylon for weaving

Textured nylon for skiwear was the first market for weft yarns made by the air-jet texturing process. Previously the process economics made it economical only for yarns over 300 denier (350 dtex) destined for furnishing fabrics. The breakthrough came as a result of new jets and machines which enabled processing speeds of over 300 m/min to be reached. That the yarns were still limited to weft applications was a result of the tendency of the loops of adjacent yarns to cling to each other. This is known as the *Velcro*™ effect. This effect caused problems during unwinding, which caused some limitation of weft insertion rates and also made the use of these yarns in warps problematical without sizing or twisting.

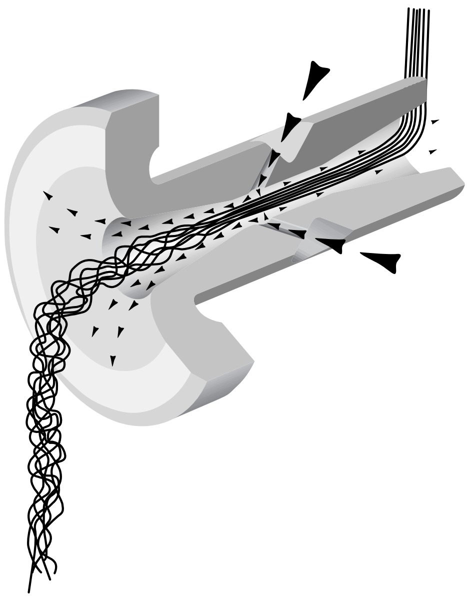
These limitations no longer exist. First, the yarn manufacturers have contributed by introducing nylon yarns with lower filament denier. Whereas originally the finest nylon yarns had a filament denier of around two, now the average is lower with filaments of one denier and even finer being available. Secondly, the use of storage feeders such as the unit made by *Memminger-IRO* on the weaving or knitting machine, has enabled the unwinding problems to be overcome. Last but not least, the modern air-jet texturing machine is fitted with step precision winders, as we have seen (see Section 7.2.12) and these enable packages with much improved unwinding characteristics to be produced.

This has not only enabled woven fabrics to be made from 100% air-jet textured yarns, but also that the breakthrough into knitting has been achieved. Spun-like characteristics are desirable but so also is the ability to blend easily yarns with different properties, including dye uptake, during texturing.

Modern machines are fitted with hotpins or heated godets for drawing POY. This is used to advantage when processing nylon. Not only are lower draw tensions obtained, but also a better, more uniform yarn results from the consistency of the draw-pin temperature.

For producing a typical, air-jet textured nylon yarn with a final count of 190 dtex either a lineshaft (*ICBT*) or individual drive machine (*Stähle*) can be used. A step precision or similarly adjustable winding head is an advantage. Drawing zones fitted with draw-pins are required with the addition of a hotpin considered as a bonus. The air-jet should be of the radial type, typically a jet designated *S 315* from *Heberlein* (see Fig. 7.12).

Two different nylon yarns or even a combination of nylon with polyester will be processed under conditions of core and effect. The yarn component with the finer filament denier would normally be processed as the effect component, so that the loops have a softer feel with a significantly reduced tendency to snag. An example of the set-up is given in Table 7.3.



7.12 Air-jet – 'S'–core for high speed processing. Courtesy of Heberlein Fiber Technology Inc.

Table 7.3 Set-up for air-jet textured polyamide for woven fabric. Courtesy of Heberlein Fiber Technology Inc

Texturing	Units	
Jet type		Heberlein radial
Jet size		S315
Pressure	bar	9.0
Yarn wetting	l/hr	1.0
Drawing		
Draw roll – core	m/min	896
Input roll	m/min	728
Draw ratio		1.23
Hotpin	°C	100
Draw roll – effect	m/min	1040
Input roll	m/min	845
Draw ratio		1.23
Hotpin	°C	100
Texturing zone		
Core overfeed	%	12
Core input	m/min	896
Effect overfeed	%	30
Effect input	m/min	1040
Roll after jet	m/min	800
Stabilisation		
Second roll after jet	m/min	816
	%	2
Heat-setting zone		
Roll before take up	m/min	808
	%	–1
Heater type/temperature	°C	200
Take-up		
Winder	m/min	816
	%	1
End product		
Core	Material/dtex	PA66/96/66 × 1
Effect	Material/dtex	PA66/96/66 × 1
Final	Material/dtex	PA66/185/132

7.4.4 Air-jet textured polyester for automotive products

As far as the interior furnishing of the car is concerned (seat covers, seat backs, door and roof liners) polyester predominates in the medium price category of vehicle. Although air-jet textured yarns have been used in all of these areas, it is the seat cover for which the properties of textured polyester are ideal. Although not the subject of this textbook it is first and foremost the dyeing of the polyester combined with the abrasion resistance of the fabric that make the product very suitable for this application. Car seats are subject to heat, intensely bright sunlight (in some parts of the world) and a lot of wear and tear. Air-jet textured yarns, especially made from polyester, have been shown to meet these demands and at a competitive price. They form by far the largest single market for air-jet textured yarns in Europe (Bösch, 2000).

What is more, the process shows its versatility in that yarns are made for flat woven, warp and circular knit fabrics. Both parallel and core/effect texturing processes are used. Which type of machine will depend mainly on the product denier range. Above all, most of the yarns are dyed on the package, in order to meet the demand. This brings its own problems:

1. A step precision winder is essential in order to ensure the open windings required for good dye penetration (see Fig. 7.11).
2. Tension variations during winding will affect the package build, since air-jet textured yarns do not have much stretch.
3. Any residual shrinkage after texturing will lead to actual shrinkage during steaming in the autoclave. This can affect the density from the inside to the outside of the package and lead to variable dye uptake.
4. The loops can cause yarns on adjacent packages to snag, leading to damaged filaments.

Some of these problems are overcome by choosing the correct machine specification, namely 1 and 2. The residual shrinkage can be reduced by using a higher hotpin temperature in the draw zone (see Section 7.3.2) or by using a heated roll before the jet. Although attempts have been made to heat-set the yarn after texturing but before autoclaving, this is not yet widely practised. Depending on the type of post-texturing heater chosen, the reasons for this are different. If a non-contact heater is chosen, this needs to have a length of 1.5 m and should incorporate two passes of the heater. It adds as much as 1.5–2.0 m to the height of what is otherwise a compact and accessible machine (see Fig. 7.5). Furthermore it may still not provide a significant reduction in the residual shrinkage of the yarn. Using a heated roll after the jet requires between 10 and 20 wraps and tends to iron the yarn flat. It then has a ribbon-like structure, which does not always have the desired appearance in fabric.

Wrapping each cheese in a muslin or plastic sleeve with perforations can prevent snagging of the yarn on different packages. This holds in the loops whilst allowing the dye to penetrate fully.

Perhaps the best example of the process is the one that is used to make yarn for flat woven fabrics. The yarn is produced from POY and processed under core/effect conditions, although sometimes parallel processing is used for yarn under 700 denier (800 dtex). One or more ends of POY may be spun-dyed to enhance the colour effect produced. An example of the set-up for polyester with a resultant denier of 1235 (1350 dtex) is given in Table 7.4.

7.4.5 Polypropylene for furnishing fabric

Of the air-jet texturing processes described here, this is the simplest, since most polypropylene for furnishing end uses is produced using the spin-draw process and requires no further drawing before texturing. The problems arise from other sources. First, the feeder yarn is inevitably dyed in the melt (see Section 6.3.2). Up to six ends may be placed in the creel at one time, which means that detection of broken or lost ends in the creel is essential. For a process that depends so much on interfilament friction within the jet, the fact that the pigments used to produce a range of colours impart different frictional characteristics to the filaments causes some problems that are unique to this process.

Many of these problems are manifest in the jet itself. Earlier jets of the axial type were adjustable, in that the distance between the needle tip and the cone of the venturi could be varied (see Fig. 7.9). It is no coincidence that this type of jet, epitomised by the *Taslan ® Mark XV* jet, is still in widespread use in this segment of the yarn processing industry. Putting it another way, those that do use the fixed jet, usually of the radial type and for finer yarns of less than 700 denier (<770 dtex), have a struggle to produce yarns with the same characteristics from feeder yarns of all colours and combinations. Furthermore the mixture of pigment, polymer and spin finish that is deposited rapidly inside the jet means that cleaning must be more frequent and thorough.

Polypropylene yarns used in furnishing fabrics have a filament denier in the range from four to six. Since the effect overfeeds can be very high, snagging problems can occur. It is for this reason that the texturing machines used are fitted with a conical wind attachment. An example of the machine settings that can be used for producing a yarn of 1500 denier (1650 dtex) from spun-dyed polypropylene is given in Table 7.5.

Table 7.4 Set-up for air-jet textured polyester for automotive fabric. Courtesy of Heberlein Fiber Technology Inc.

Texturing	Units	
Jet type		Heberlein EO52
Jet size		N70/V180
Pressure	bar	9
Yarn wetting	l/hr	1.5
Drawing		
Draw roll – core	m/min	339
Input roll	m/min	199
Draw ratio		1.7
Hotpin	°C	140
Draw roll – effect	m/min	600
Input roll	m/min	353
Draw ratio		1.7
Hotpin	°C	140
Texturing zone		
Core overfeed	%	13
	m/min	339
Effect overfeed	%	100
	m/min	600
Jet input roll	m/min	300
Stabilisation		
Roll after jet	m/min	324
	%	8
Heat-setting zone		
Roll before take up	m/min	317.5
	%	−2
Heater type/temperature	°C	1.5 M/220
Take-up		
Winder	m/min	333
	%	5
End product		
Core	Material/dtex	PET (POY) 285/30 × 2
Effect	Material/dtex	PET (POY) 285/72 × 3
Final	Material/dtex	1235/276

Table 7.5 Set-up for air-jet textured polypropylene for furnishings. Courtesy of Heberlein Fiber Technology Inc.

Texturing	Units	
Jet type		*Taslan*™ Mk XV
Jet size		Needle 40 C Venturi 78
Pressure	bar	9.5
Yarn wetting	l/hr	2.0
Texturing zone		
Core overfeed	%	14
	m/min	285
Effect overfeed	%	36
	m/min	340
Jet input roll	m/min	250
Heat-setting zone		
Roll before take up	m/min	252
	%	1
Heater type/temperature	°C	150
Take up		
Winder	m/min	273
	%	8
End product		
Core	Material/dtex	PP 330/74 × 2 spun dyed
Effect	Material/dtex	PP 330/74 × 2 spun dyed
Final	Material/dtex	PP 1500/296 heather effect

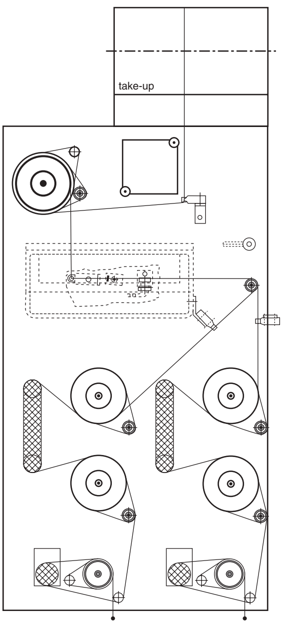
7.4.6 Polyester sewing threads

This is a very specialised area of yarn production where air-jet textured yarns and the thread resulting from them have shown considerable promise if not yet success on a large scale. When ranking sewing threads for performance air-jet textured products are ranked probably second or third with core-spun polyester/cotton at the top. In fact the air-jet textured product has superior tensile strength, when measured as specific strength or tenacity. It also has an excellent abrasion resistance and because of the surface loop structure it allows sewing at over 6000 stitches/min without melting or breaking.

Two things have probably hindered their large-scale acceptance so far. The textured yarn still requires the addition of real twist before dyeing and spooling. Thus the large package size potential of a texturing process starting from POY is spoiled by the need to restrict the textured yarn package to that which fits into the two-for-one twister. This means that the potential cost savings are reduced and perhaps are no longer sufficient, when considering the whole process chain from raw material to finished thread. However, this problem will be overcome and then a real cost saving will have been achieved as well as a reduction in labour cost by the application of automation. This is important where it is hard to find people willing to work shifts or weekends.

An interesting factor that warrants a study of the air-jet texturing of yarns is that almost all the methods of applying heat to the process are utilised. In order to retain yarn strength at the same time as to reduce the residual yarn shrinkage to below 1%, heat is applied in a different way to the core and to the effect thread:

1 The core yarn denier should comprise well over two thirds of the total and the core overfeed into the jet must be as low as is practicable. Both



7.13 Air-jet texturing machine for making sewing threads. Courtesy of SSM.

these steps contribute to minimising the loss of tenacity between the feeder and the final textured yarn.

2 The effect yarn is there only to provide a very subdued loop structure. Thus it comprises a feeder yarn of lower total and filament denier. Although the overfeed through the jet may be >25% the yarn is not pre-shrunk. Instead a heated roll is used after the jet. The temperature used combined with the dwell time on the heated roll (determined by the number of wraps) are sufficient to cause the loops to shrink into the core of the yarn, leaving what the *Coats* patent describes as 'bud-like projections' on the surface. These are sufficient to impart an enhanced sewing performance to the finished product.

The thread-path of a machine suitable for producing these yarns is shown in Fig. 7.13. The processes involved are the subject of several patents of which the most important by *Coats* (1981) is still valid at the time of writing. So it is a question of 'user beware'!