Management of Quality in Knitting

Part 1: Fabric Appearance & Knitting Efficiency

Introduction

So far as the dimensions, weight and shrinkage of the fabric are concerned management of quality in knitting means controlling the key production parameters that affect the Reference Dimensions, i.e. the average yarn quality (count, type) and the average knitted stitch length

However, the management of quality in knitting implies more than just the control of dimensions, weight and shrinkage. Fabric appearance and knitting efficiency must also be considered which means that fabrics should also be produced with the minimum number of faults and as efficiently as possible.

Fabric Appearance

Fabric appearance is fundamentally dependent on the quality of the yarn from which it is produced. Most often, however, it is the consistency or rather lack of consistency with which a particular yarn is spun that causes appearance problems in the knitted fabric.

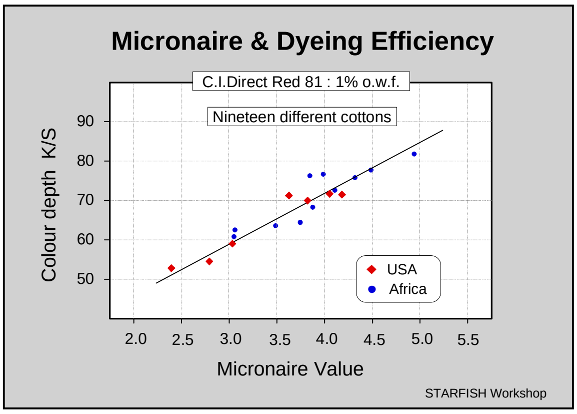
Fabric appearance is influenced by

- Fibre Quality
- Yarn Type
- Yarn Count Variation & Evenness
- Yarn Imperfections & Faults
- Yarn Twist Variation
- Yarn Hairiness

Effect of Fibre Quality

The basic fibre properties e.g. the length, strength, Fineness and Maturity etc. influence the quality of the yarn that can be spun from them. From the fabric appearance point of view, perhaps the two most important basic fibre properties are the Fineness and the Maturity of the cotton.

Fibre fineness or Micronaire is a reflection of two important physical properties, the fibre perimeter and the cell wall thickness.



Perimeter (fibre surface area) is largely a function of genetics. Cottons of the same variety have approximately the same perimeter. Cell wall thickness (amount of cellulose) on the other hand is determined by environmental factors (growing conditions).

Both the perimeter and the cell wall thickness determine the amount of dye that is absorbed by the fibre. Differences between colour shades of dyed yarns and fabrics are often associated with differences in the Micronaire Value of the raw cotton.

Spinners will usually attempt to maintain a constant average Micronaire Value of the fibre, which they spin for a particular yarn quality. However, this average may change over time (growing seasons) and may be different between different spinners.

If yarns from different deliveries or from different suppliers are mixed on the knitting machine - even if the average yarn count is the same - then there is always the potential that weft stripes or bars may appear in the fabric after dyeing, which can be attributed to differences in the Micronaire Values of the basic fibre.

Yarn Type

The basic fibre properties and whether the yarn is carded or combed, ring spun or rotor spun, singles or folded have an overall influence on the appearance of the final fabric. Different standards therefore have to be applied to the quality characteristics of these fundamentally different yarns.

Within each particular class or type of yarn, there are certain key properties that have to be controlled during the spinning process because high levels of variation will have a detrimental effect on the fabric appearance. These are:

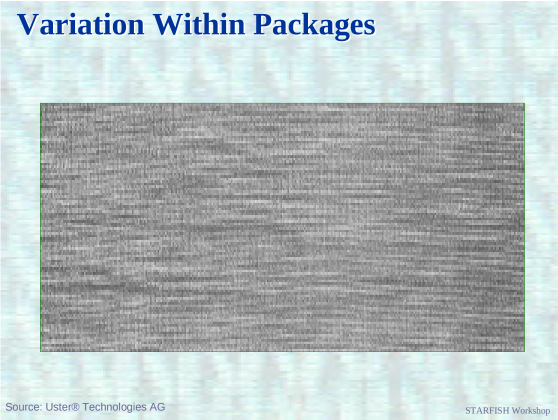
- **Yarn Count Variation**
- Yarn Irregularity
- Yarn Imperfections
- Seldom Occurring Yarn Faults: Classimat Definitions
- Yarn Twist Variation
- Yarn Hairiness

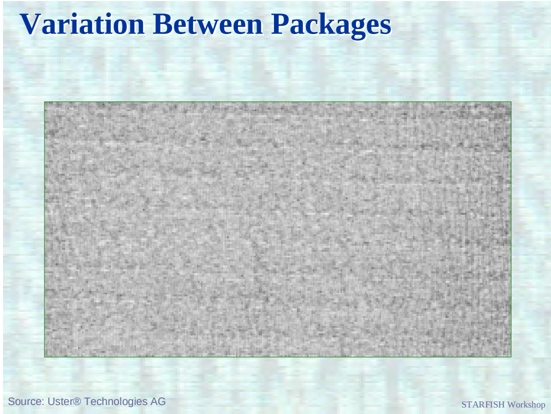
Note: Uster® Technologies AG publishes experience values for these parameters. The values are deduced from test data and information received for yarns produced by spinners throughout the world. Reference to these "Uster® Statistics" can provide invaluable information on worldwide yarn quality characteristics as measured on Uster® testing equipment. Since the 2001 edition a distinction has been made between weaving and knitting yarns determined by the Twist Multiple. Knitting yarns are classified as yarns with twist multipliers below αe = 3.7 / 3.9 respectively for combed and carded cotton yarn. Yarns with twist multipliers above these levels are classified as weaving yarns.

The latest edition of the Uster® Statistics was published in 2007. Information from these statistics can be accessed via the Uster® web site http://www.uster.com

Yarn Count Variation

Although the average yarn count can have a significant effect on the Reference Dimensions of a knitted fabric, of equal importance, so far as fabric appearance is concerned, is the Count Uniformity. Count Uniformity is a measure of the variation in yarn count within and between different cones taken from the same lot or delivery.





A between package count variation of CVc_b > 3% is a universally accepted standard above which fabric appearance problems are known to be present – especially in knitted fabrics. In knitted fabrics this is usually characterised by weft stripes or bands of differing density (barré).

The "Uster® Statistics" show that a good quality spinner should be able to deliver with a much better level of variation than this and indeed the knitter should demand much better than this if quality problems in the fabric are to be avoided.

Obviously, the level which needs to be specified depends on the end use requirements of the yarn and fabric. Critical fabrics - e.g. plain dyed fine gauge plain jersey require much higher standards (lower levels of count variation) than some other types of fabric. An optimum value of CVc_b% (cut length 100m) of less than 1.8 has been suggested.

In general, it is not only important that the average yarn count is delivered consistently but also that the count variation is maintained at as low a level as possible.

Mass Variation (Yarn Irregularity)

Although there has been a continual improvement in yarn evenness over the last 50 years it is still the case that short-term variations - within package variation - have a detrimental effect on fabric appearance especially with more critical fabrics - e.g. plain dyed, fine gauge plain jersey. High values will result in a cloudy appearance of the fabric.

Yarn evenness or mass variation within a cone is commonly measured on the Uster® Tester 4 and expressed in terms of the Coefficient of Variation of yarn mass CVm.

The values for yarn irregularity that can be achieved depend on the basic yarn type (combed, carded, ring spun or rotor spun), the yarn count and also on the Effective Fibre Length. The higher the CV% values the more irregular the yarn. Lower (better) values should be expected for combed ring yarn than carded ring yarn or carded rotor yarn.

The more critical the end product the more rigorous the standard that needs to be imposed. It has been suggested that for critical end uses, yarn irregularity or mass variation should not exceed the values reported in the "Uster® Statistics" corresponding to the 25% level. i.e. equivalent to the best 25% of the world's production.

For a singles combed ring spun yarn of 30 Ne spun from medium staple cottons, this value is approximately CVm% 11.4.

Note: Quality characteristics are nowadays usually determined using the coefficient of variation CV%. Consequently, the use of unevenness U has been discontinued. The conversion factor CV = 1.25 U can be used for mass variations with normal distribution.

Yarn Imperfections

Yarn imperfections are defined as the frequently occurring thick places, thin places and neps. They are assessed by comparison to the average yarn diameter. The levels depend on the Yarn Type and the Effective Fibre Length.

Thick places, Thin places and Neps

Thin places are usually defined as those places in the yarn which have a diameter less than 50% of the mean, thick places are those with a diameter 50% greater than the mean. Neps in ring yarn are usually counted at +200%, in rotor yarn at +280%. This is because, it is claimed, neps in rotor yarns tend to be spun into the core of the yarn and therefore are less visible to the human eye in the finished product. With ring spun yarns, in general neps tend to remain on the surface of the yarn and are therefore more easily visible.

Lower values should be expected for combed ring yarn than either carded ring yarn or carded rotor yarn, but carded rotor yarn should be better than carded ring yarn.

Yarn imperfections can not be completely eliminated from the yarn but if a yarn contains very high values then they will certainly down grade the fabric appearance and can also impair knitting efficiency. For critical end uses higher standards are required and it has been suggested that for these products values for yarn imperfections should not exceed the values reported in the "Uster® Statistics" corresponding to the 25% level. i.e. equivalent to 25% of the world's production.

For cleared packages of singles combed ring spun yarn of 30 Ne, spun from Medium Staple cottons, these values are approximately Thin places 0.4, Thick places 11.2 and Neps 21.5.

Note: Due to the improvements in the mass unevenness that have been achieved in recent years Uster® have introduced additional data for lower thresholds with the 2007 statistics. Statistics are now also available for the following thresholds. Thin = - 40%, Thick + 35%, Neps + 140% for ring spun yarn and + 200% for rotor spun yarn.

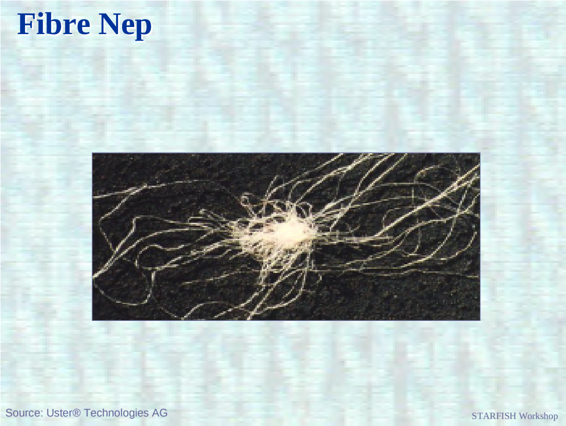
Yarn Neps

Neps can be a particular source of appearance problems in knitted fabrics. It is not just the quantity but also the type of nep, which has an influence.

Generally, a nep can be described, as an entangled knot of fibres. Various types of neps have been more precisely described, as follows: -

Mechanical Neps

This type of nep most closely fits the description given above. They are formed by mechanical action on the fibres during harvesting, ginning, opening, cleaning and carding. Fibres with low longitudinal rigidity such as very fine fibres or immature fibres are more likely to form mechanical neps than coarse fibres with thick secondary walls.



This type of nep may be considered to be not too serious as usually they do not adhere very strongly to the fabric surface and will often become dislodged during subsequent processing. However, if the nep is large, and comprises mainly immature fibres, it will give rise to a pale speck in dyed fabrics. Problems may arise with printed fabrics if large neps are present during printing but later become dislodged. The place on the fabric where the nep has been present may appear as an undyed speck.

Seed Coat Neps

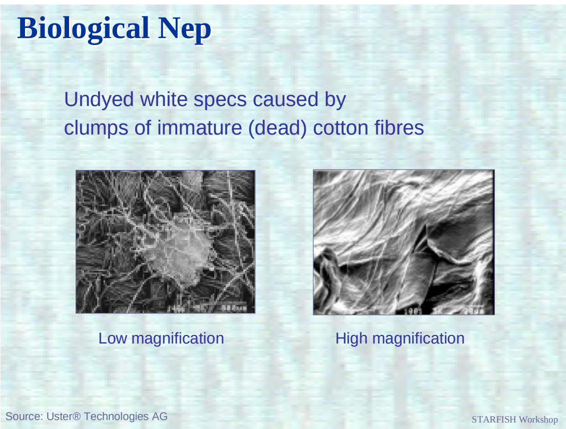
Seed coat neps are fragments of seed coat with fibres attached to them. They can also form the nucleus around which mechanical neps will form.

Seed coat fragments can usually be seen in the machine state (grey) fabric as tiny dark specks. In fabrics dyed to a pale shade these can have a detrimental effect on fabric appearance, although a good bleach usually eliminates the problem.

In deep dyed fabrics the problem of seed coat fragments can be potentially more serious. This is because quite often the fibres attached to the fragment of seed coat will be immature. Immature fibres give the appearance of having been dyed to a lighter shade than normally mature fibres and this can give rise to the problem of light or white specks in the dyed fabric.

Unfortunately, it is very difficult to detect the presence of immature fibres in the fabric before dyeing.

Biological Neps



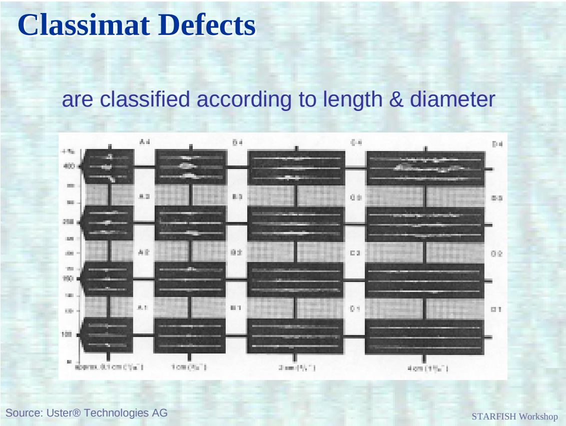
These are clumps of very immature (dead) fibre. They exist in both highly entangled form or as bundles of fibre that are parallel to each other and pressed tightly together. These clumps of fibre can be found in seed cotton before any mechanical processing has occurred. They are typically found in the unginned lint near malformed or aborted seeds. These clumps are normally much larger in the unginned lint and are broken into smaller fragments by ginning and mechanical processing. The clumps of very immature fibre, also called "shiny neps" are the source of dye resistant neps that cause the problem of "Undyed White Specks" in knitted fabric. These neps are dangerous in printing, because they can be removed by mechanical action after the print paste has been applied, leaving an unprinted speck behind.

The main problem with this type of nep is that they are very difficult to detect until the fabric has been dyed. In addition, there are no standard testing procedures available for measuring the number of "shiny" neps in the fibre and / or in the finished fabric. This can cause significant problems especially when the fabric manufacturer is in dispute with his yarn supplier.

Seldom Occurring Yarn Faults

Potentially more damaging to fabric appearance than yarn imperfections is the incidence of the "seldom occurring yarn faults" as defined by the Uster® Classimat values.

These are the more exceptional thin or thick places of various lengths that occur in yarns. The Classimat values are a record of the incidence of these yarn faults ranked according to strict definitions of length and cross-sectional variation from the mean.



Long thick or thin places in the yarn that are knitted into the fabric will cause very visible periodic stripes, which seriously detract from the fabric appearance. In addition, thick slubs can cause damage to needle hooks and latches. This can result in irregular stitch formation, holes in the fabric or needle lines. Very thin places will often be weaker than the average and may cause yarn breaks.

A high incidence of "Classimat faults" in the uncleared yarn will result in a high incidence of knots or splices in the cleared yarn. Knots will impair fabric appearance and may cause knitting faults. Spliced yarn is preferable. A high frequency of knots or splices may be a sign that the original yarn, before clearing, was faulty.

Classimat defects are removed during winding and clearing according to a clearing profile. For knitting yarns, the recommended clearing profile should be at least A3, B3, C2, D1. This will remove the majority of the most serious faults.

Classimat analyses on the cleared yarn, to indicate the number of faults cleared and remaining, are often carried out by good spinners and may be available, if requested.

Yarn Twist, Twist Variation

It is important to maintain approximately constant levels of average twist / twist liveliness in the yarn because it can influence both fabric dimensions and fabric spirality.

It is equally important that the variation in yarn twist either within or between cones is kept as low as possible. One yarn with a higher or lower average level of twist will cause the knitted loops to distort by different amounts. This can cause weft stripes and appearance problems in the fabric.

Yarns with low twist are more sensitive to abrasion. Fabrics that receive intensive wet processing (e.g. in high velocity jet dyeing machines) can suffer a large change in appearance due to the abrasive action of the process.

Twist Factor, Twist Multiple

The amount of twist in a yarn is often characterised by the term Twist Factor. The Twist Factor is an indication of the average spiral angle that the fibres make with the yarn axis, due to the twist. For a uniformly twisted yarn, the tangent of the spiral angle is proportional to the yarn diameter and the number of turns per unit length.

In Imperial Units (α_e)	Twist Factor	=	turns per inch/ $\sqrt{Ne}$
In tex Units (α_{tex})	Twist Factor	=	turns per cm * $\sqrt{tex}$
In Metric Units (α_m)	Twist Factor	=	turns per m / $\sqrt{Nm}$

To convert

α_e	=	α_{tex} / 9.57	α_{tex}	=	α_e * 9.57
α_e	=	α_m / 30.254	α_m	=	α_m * 30.254
α_{tex}	=	α_m / 3.162	α_m	=	α_{tex} * 3.162

It has been suggested that for a good quality cotton knitting yarn produced by ring spinning the Twist Factor should be between 3.1 and 3.6 English Twist Factor or between 94 and 110 Metric Twist Factor.

Yarn Hairiness, Pilling

The hairiness of a yarn has an effect on the general fabric appearance and also on the development of pills.

Yarn hairiness decreases as the yarn twist is increased and the fibres are bound more tightly into the yarn structure. Hairiness also becomes less, as the yarn count becomes finer. This can be explained by the fact that as the numbers of fibres in the cross-section are reduced there are fewer fibres available to protrude from the surface of the yarn.

For most knitted fabrics, it is not so much the average hairiness of the yarn, which causes appearance problems, but the variation in hairiness either within a cone or between cones.

It has been suggested that the between bobbin hairiness variation as measured by the Uster® Technologies AG Hairiness Module should be below 7% if the problem of weft stripes (barré) in plain dyed fabric is to be avoided.

In critical plain dyed fabrics differences of 1.5 measurement unit between adjacent yarns have been found to cause the appearance of stripes in the fabric after dyeing. This is said to be partly due to the protruding fibres, which have a higher dye uptake than the fibres in the body of the yarn and therefore appear darker. In the undyed fabric the difference is hardly noticeable.

Variation in hairiness along the length of a yarn has also been found to cause appearance problems in critical single colour fabrics produced from dyed yarn, if the level of variation in one yarn is significantly different from all the other yarns.

In addition, the tendency of a fabric to pilling increases with increased yarn hairiness. This is more of a problem with blended yarns than with 100% cotton.

Hairiness is also associated with yarn type. Combed yarns are usually less hairy than carded yarns; Rotor yarns less hairy than ring yarns. In addition, rotor yarns develop less hairiness during laundering and wear.

Knitting Efficiency

Many of the yarn quality characteristics that can influence fabric appearance also affect the efficiency of the knitting operation. In addition, there are certain other characteristics which can be important.

Knitting efficiency can be affected by-

- Yarn Strength, Strength Uniformity, Elongation
- Yarn Uniformity (Irregularity, Imperfections, Faults)
- Yarn Hairiness
- Fibre Fly
- Yarn Friction (Waxing)
- Yarn Twist, Twist Liveliness

Note: Uster® Technologies AG publishes experience values for some of these parameters. The values are deduced from test data and information received for yarns produced by spinners throughout the world. Reference to these "Uster® Statistics" can provide invaluable information on worldwide yarn quality characteristics as measured on Uster® testing equipment. The latest edition of the Uster® Statistics was published in 2007.

Yarn Strength, Strength Uniformity, Elongation

Yarn strength is strongly influenced by the fibre length and length uniformity, fibre strength and elongation, and the amount of twist. Thus, combed cotton yarns will usually be stronger than carded cotton yarns since they are spun from fibre with a longer and more uniform fibre length distribution, the shortest fibres having been removed during the combing process.

The average strength of a knitting yarn is usually far less critical than for a weaving yarn because the peak tensions generated in knitting are usually much lower than in weaving. It has been suggested that a Breaking Tenacity greater than 10 cN/tex should be sufficient, provided also that the yarn extensibility is sufficient.

For certain end uses, e.g. if the fabric is to be crosslinked (resin finished), a high yarn strength may be important since the application of crosslinking chemicals can cause the yarn to be weakened considerably (up to 50% strength loss). In this situation, in order that the fabric after finishing will have adequate strength and durability, the initial yarn strength may need to be higher than if the fabric is not to be crosslinked.

Although a certain average minimum strength requirement is obviously necessary for efficient trouble free, high-speed knitting, of greater importance is the variation in strength and the yarn elongation. It is the weak places (and faults) in the yarn, which cause the problems of end breaks. If the variation in yarn strength is high, problems may occur with yarn failures during knitting if the weakest place is not sufficiently strong to withstand the tensions, which are generated. This will be the case even if the average strength of the yarn is much higher than may ordinarily be required.

As in the case of yarn count, it is the variation in yarn strength which must be considered. A yarn with lower average yarn strength but low strength variation may be preferable to a yarn with high average strength but with high strength variation. It has been suggested that variation in breaking force should be less than 7.5%.

Elongation (extensibility) allows the yarn to stretch during knitting - especially during stitch formation - without breaking. Low elongation values can cause problems in knitting and may be the cause of yarn failures - especially in the knitting zone. Elongation at breaking force should be greater than 5.5%.

Yarn Uniformity

Evenness, Imperfections and Classimat Faults

The uniformity of the yarn has an influence not only on fabric appearance but also on its processing efficiency. Yarns with high levels of thick or thin places, or neps will run less efficiently.

Thin places are usually weak places in the yarn, which can cause yarn breakage when knitting tight fabrics at high speed. Large slubs can cause damage to the needle hooks or latches, causing holes or needle lines in the fabric.

Yarn packages that have a high incidence of knots or splices can also cause problems in knitting, either because they cause needle damage or because they have a higher incidence of weak places.

Knots passing through yarn guides can collect the loose fibre fly that has accumulated and take it into the fabric. This may then cause additional problems with needle damage or holes. In some cases, if the yarn guides have become partially closed due to fly build up, a knot can cause the yarn to jam causing a tension peak that can cause the yarn to break. In either case machinery must be stopped in order to correct the situation reducing knitting efficiency.

Spliced yarn is generally agreed to be better than knotted yarn because the splice causes less disturbance to the yarn surface and therefore the fabric surface appearance. However, a spliced joint is usually weaker than a knotted joint and this may cause problems unless the quality of the spliced joint is high. For a knitter, the quality of spliced joins in his yarn is one of the major characteristics of a spinner that needs to be evaluated.

Yarn Hairiness

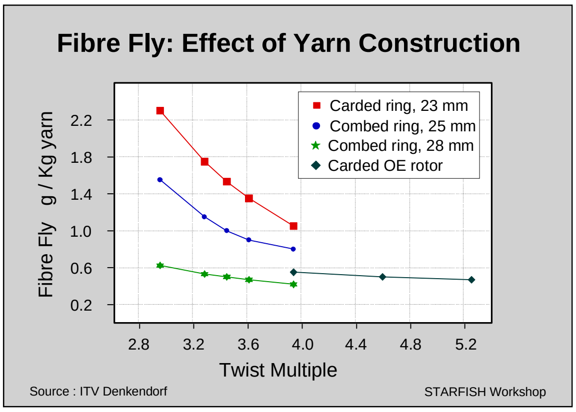
A very hairy yarn will generate more fibre fly or lint than a less hairy yarn. Liberated fibre fly can collect around yarn guides and can be pulled into the fabric. This will be exacerbated where there is a coincidence of high numbers of yarn imperfections and knots.

Hairiness can be exaggerated during wet processing - especially in a loosely knitted fabric.

Fibre Fly

Fibre Fly can have a considerable effect both on fabric appearance and knitting efficiency. Accumulations of fibre fly which build up on the knitting machine around yarn packages, yarn guides and stop motions, positive feed mechanisms and at the feeders can cause end breaks and machine stoppages. If these accumulations of fly are then collected by the yarn, they can cause damage to needle hooks and latches and produce holes and other faults in the knitted fabric.

It has been calculated that fibre fly can reduce machine efficiency by up to 25%. Therefore, the control of fly in the knitting room is of some importance to the knitter of cotton yarns.



For several years researchers at the Institut für Textil-und Verfahrens-technik, Denkendorf, Germany (1987, 1988, 1990) carried out studies to try and identify the yarn quality characteristics which affect the generation of fibre fly.

The main conclusions from these studies can be summarised as follows: -

Fibre length

The greater the short fibre content and the more inferior the fibre orientation the more fibre fly is generated. Thus, carded yarns generate about 30% more fibre fly than combed yarns.

Yarn Structure

Open-end rotor spun yarns generate half as much fibre fly compared to ring-spun yarns - all other conditions being equal.

Twist Level

Small variations in yarn twist can cause substantial changes in the amount of fibre fly that is generated, especially in ring spun yarns. The higher the twist in the yarn the less fly is generated. Conversely at lower levels of twist more fly is generated. The effect is more pronounced in yarns spun from a shorter average fibre length, and in carded yarns. The same is also true of open-end spun yarns but the effect is much less pronounced. In addition, rotor spun yarns are usually spun with a higher level of twist than ring spun yarns in order to maintain the efficiency of the spinning operation.

Yarn Finishing

Dyed yarns were generally found to generate much lower levels of fibre fly than undyed yarns, whereas bleached yarns showed a significant increase in fibre fly generation.

Moisture Content

The moisture content of the yarn was also found to influence the degree of lint shedding. When the moisture content of the yarn is too low (yarn too dry) lint shedding increases. Increasing the moisture content of the yarn reduced the amount of fibre fly that was generated.

This is probably due to the fact that cotton fibres are stronger and more flexible at higher moisture content; dry fibres will tend to break more easily. In addition, the inter fibre friction will be reduced at low moisture content, allowing the fibres to be more easily liberated from the body of the yarn. Increasing the moisture content of the cotton increases fibre strength and elongation and increases the adhesion of the fibres making them more difficult to pull out from the yarn structure.

Increasing yarn moisture content to very high levels is not very practical, both for cost reasons and also because of the possibility of attack by micro-organisms (e.g. mildew). In addition, increased moisture content increases the coefficient of friction of the yarn. However, in knitting trials using specially conditioned carded and combed cotton yarns it was found that dry yarn (moisture content 2.1%) caused increased fly generation (between 8% and 9%) compared to yarn having an average moisture content of 5.5%. Increasing the moisture content of the yarns to 6.9% decreased the lint shedding by between 2% and 12%. A bigger effect was found for combed yarns (12% reduction) than carded yarns (2% reduction).

If the relative humidity of the knitting room is consistently lower than about 50%, then consideration might be given to humidification. Modern, enclosed yarn creels are available which can be humidified, thus avoiding the need to humidify the whole room.

Yarn Friction

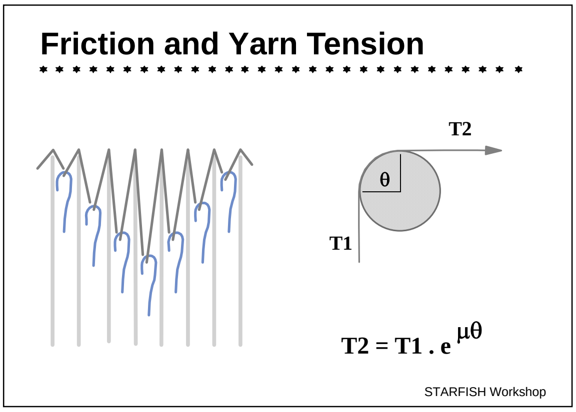
In earlier investigations into the factors that influence the generation of fibre fly carried out by the USDA-SRRC, it was found that the yarn friction played a significant role. A reduction of almost 50% in the coefficient of friction of the yarn by waxing brought about a reduction of almost 40% in the amount of fibre fly generated.

Yarn Friction

On a knitting machine the yarn is required to pass over a number of different surfaces. The friction between the yarn and any surface it passes over manifests itself as a tension generated in the moving yarn. Although a certain amount of tension is acceptable and indeed necessary to control the yarn's movement, if the tension generated becomes too great, it can seriously affect knitting efficiency.

If the initial friction of the yarn is high then the tensions that can develop during knitting can become excessive. Excessive tensions can cause loop distortion, miss knitting and affect fabric appearance. In addition, the build up of tension in the yarn can have an effect on the range of qualities (stitch lengths) that can be knitted efficiently on a given gauge of machine at a given speed. In extreme cases, when tensions become excessive, the yarn will fail, causing faults in the fabric. High yarn tensions can also accelerate wear on the knitting elements thus increasing maintenance costs.

The effect of friction on tension is cumulative and can be calculated from an equation, which relates the ratio of output tension and input tension to the coefficient of friction of the yarn.



where

T2 = Output Tension
T1 = Input Tension
e = natural log. base (approx. 2.718)
μ = Coefficient of Friction
Θ = angle of wrap (yarn winding angle)

The generation of tension in a yarn on a knitting machine is dependent on four variables.

1. The frictional properties of the yarn
2. The number of surfaces the yarn passes over
3. The frictional properties of the surfaces
4. The angle at which the yarn passes over the surfaces, i.e. the angle of wrap.

Therefore, to maintain yarn tension at an acceptable level for knitting, the effect of these four variables on yarn tension must be controlled.

Tensions generated between the supply package and the needles can be reduced by avoiding large changes of direction and by keeping the number of yarn / solid contacts to a minimum, also by ensuring that the surfaces over which the yarn must pass have low frictional coefficients. This will create some reduction and control of tension as far as the needles. Once the yarn enters the knitting zone, the path of the yarn, the number of contacts and the angles of wrap are, to a large extent predetermined and cannot be reduced. Consequently, the coefficient of friction of the yarn must be kept as low as possible to avoid excessive tensions building up during loop formation.

Furthermore, the coefficient of friction of the yarn can also have an adverse affect on fibre fly – i.e. higher friction leads to higher tensions in the yarn, which leads to more fly generation. Consequently, ensuring that the coefficient of friction of the yarn is as low as possible is very important for maintaining knitting efficiency.

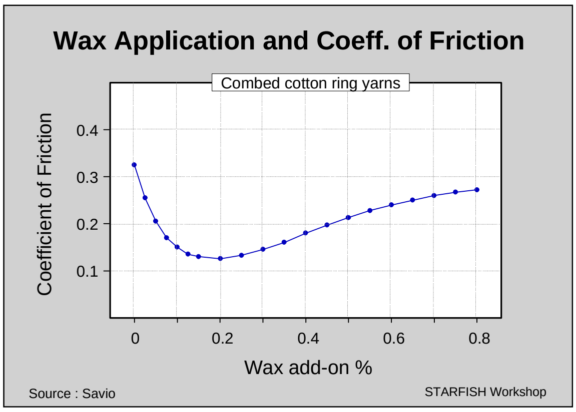
Yarn Waxing

The coefficient of friction of the yarn is important for maintaining knitting efficiency and should be maintained at the lowest level possible. This is because the coefficient of friction has a direct influence on the tensions, which can develop during knitting and also on the generation of fibre fly.

In order to minimise the effect of yarn friction, yarns for knitting should always be waxed. Values for the coefficient of friction higher than 0.2 will inevitably cause problems in high-speed knitting. Ideally the coefficient of friction measured against steel should be between 0.1 and 0.15.

In some countries, obtaining reliably waxed yarns from the spinner can be difficult. If this is the case then it may be necessary for the knitter to invest in winding equipment that will enable him to rewind and wax the yarn himself prior to knitting.

Note that rewinding always degrades the general quality of the yarn and is to be avoided wherever possible.



The quality of the wax that is applied and the efficiency of the waxing process (evenness and distribution) are both important. Various types of wax are available and these can be distinguished by their structure (crystallinity), oil content and other additives, melting point and penetration (roll hardness).

The coefficient of friction of the yarn is reduced by the application of wax up to a certain level of wax add-on, after which the friction coefficient begins to increase again. If too little wax is applied the reduction in the coefficient of friction will be insufficient. On the other hand, if too much wax is applied to the yarn the friction coefficient will rise again. In extreme cases the situation can be worse than if no wax had been applied at all.

If too much wax is applied it will rub off and accumulate on the yarn guides, feeders and knitting elements. This will attract the fibre fly, which is liberated from the yarn, and cause it to form into clumps. These fibre clumps can then be taken into the fabric, causing disturbance to the fabric appearance. In severe cases, damage to needle hooks and latches and holes or lines in the fabric can be caused. Wax contamination can also have an effect on the efficiency of positive feed mechanisms causing yarn slippage and inefficient course length control.

Wax always has to be removed by the dyer and finisher. It does not help to apply excessive amounts of wax, since the efficiency of scouring processes can be impaired. In extreme cases this leads to deposits of wax or other non-absorbent materials on the cloth which results in patchy dyeing.

The optimum amount of wax which needs to be applied in order to obtain good frictional properties on the yarn is quite small, between 0.1 % - 0.3 % on the weight of yarn.

It is also important that the uniformity of waxing during winding is carefully controlled so that yarn packages do not contain sections of yarn with either too much or insufficient waxing as these will cause problems during knitting.

In hot climates the choice of wax quality may be particularly critical. If the melting point of the wax is too low, the wax will soften and too much will be applied. Similarly, if the hardness of the wax roll is insufficient the yarn can cut into the roll during winding which can also lead to too much being applied.

Good quality wax discs, which are suitable for most climatic conditions, can be obtained from a number of suppliers throughout the world.

It is also important that the wax can be easily removed during scouring and bleaching processes. Some qualities of wax can be purchased which contain special additives to aid the emulsification of the wax during scouring and bleaching. Although this should not normally be required if the scouring / bleaching is carried out efficiently, many spinners prefer to use this type of product as a safety feature.

Attention may also need to be paid to yarn storage conditions especially in hot climates. If yarn storage areas become very hot, the wax on the yarn can soften and migrate inside the yarn. To be effective at reducing the coefficient of friction the wax must remain on the surface of the yarn. If yarn storage conditions cause the wax to migrate then problems will be encountered during knitting. Yarn should never be stored in direct sunlight. After a long period of storage, the wax can degrade and become discoloured and more difficult to remove during scouring.

On the other hand, if the yarn is stored in cold conditions - and if the production area is significantly hotter than the yarn storage areas - condensation can form on the yarn when it is brought into the knitting room. Increasing the moisture content of cotton adversely affects the yarn friction and therefore the knitting efficiency. In this situation (and maybe in any case) yarn should be brought into the production areas at least 24 hours before it is required, to allow the yarn to acclimatise.

Yarn Twist, Twist Liveliness

The amount of twist in the yarn has a direct effect on the yarn strength (all other things being equal). The amount of twist and the twist liveliness of the yarn also affect the fabric Reference Dimensions and spirality in single jersey fabrics.

Twist liveliness can also cause problems in knitting if the liveliness of the yarn is such that it causes snarling in free lengths of yarn in the yarn path. In extreme cases this can lead to faults in the fabric and yarn breaks.

Low levels of twist liveliness are therefore to be preferred, both from the point of view of fabric spirality and also that of knitting efficiency. However, because twist liveliness and twist (turns per unit length) are closely correlated, and the amount of twist in the yarn also has a direct influence on, for example, yarn strength, hairiness, fibre fly generation and spinning efficiency, the practical range available will be fairly limited.

As with many other yarn quality characteristics the knitter and spinner together must arrive at a compromise in order to balance the effect of twist on e.g. yarn strength and spinning efficiency on the one hand with its effect on e.g. spirality, fabric dimensions or abrasion resistance on the other.

Note that, although the amount of twist in the yarn is the dominant factor in determining twist liveliness of raw yarns, it is not the only factor. Yarns produced to the same Twist Factor by the same spinning system but from a different fibre mix can exhibit marked differences in twist liveliness and generate different levels of spirality in knitted fabrics. In general, the better the fibre quality (longer, finer cottons) the lower will be the twist liveliness.

Yarns that have been conditioned after spinning in a steam autoclave will often have reduced values for twist liveliness. However, reductions in twist liveliness achieved by steaming are not permanent - the full liveliness will return after wetting. Therefore, conditioning after spinning can improve yarn processing characteristics, but does not necessarily improve the spirality of knitted plain jersey fabrics.

Yarn dyeing achieves a permanent reduction in yarn twist liveliness, but this is about of the same order as is later achieved in dyeing the fabric. At this stage, it is not clear whether plain jersey fabric made from dyed yarns has lower spirality than dyed fabric made from raw yarns.

Minimising Knitting Faults

Yarn Quality

Many fabric faults and loss of efficiency can be associated with the quality of the yarn that is used. A poor-quality yarn will not only be detrimental to fabric quality but may also increase wear and maintenance requirements on the knitting machine. For example, very dirty yarns that shed large quantities of dust during knitting. The dust particles can combine with the lubricating oils and act like a grinding paste abrading needles, sinkers, tricks etc.

Any improvements that can be made to the overall quality of the yarn that is used, therefore, will automatically help to upgrade overall fabric quality (appearance and faults rates), improve knitting efficiency and contribute to a reduction in the cost of machine maintenance.

Yarn Input Tension

Even with a positive feed system, if significant variations in yarn input tension are allowed between feeders this will often be the cause of problems with fabric appearance - horizontal stripes - and if they become excessive may cause the yarn to fail. In addition, high yarn tensions will increase the problem of fly generation.

Localised variations in yarn input tension can often be traced to problems with an individual cone of yarn. For example, the yarn may be insufficiently waxed, or the package badly wound, the cone may be misaligned on the creel or the yarn path restricted due to fly contamination of yarn guides and feeders etc. In addition, it may be due to incorrect settings or contamination of individual positive feed units or by badly adjusted or sticking stitch cams.

If the problem can be traced to an individual cone of yarn then the cone must be replaced, otherwise the yarn path should be checked for contamination, misalignment of guides, rough surfaces etc.

Fibre Fly

One of the main sources of faults in knitted fabric is fibre fly. Fibre fly is associated with yarn quality and is affected by

- fibre quality - mean fibre length
- fibre preparation - carded or combed
- yarn type - ring or rotor
- yarn moisture content
- yarn friction

Even with the highest quality cotton yarns the problem of fibre fly can not be totally eliminated - therefore, ways have to be found to contain or control it in the knitting room in order to minimise the potential damage it can cause to fabric appearance and knitting efficiency.

It has been calculated that 25% of all faults that occur during the knitting process can be traced directly back to the incidence of fibre fly excluding such faults as needle stripes and dropped stitches. This in turn can reduce machine efficiency to 75 - 80%.

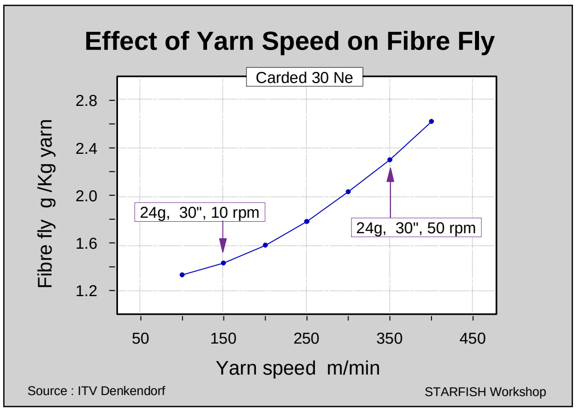
The studies carried out by ITV - Denkendorf (see Part 1), also identified those parts of the knitting machine where most fly is generated. These are

- yarn package 26%
- yarn path guide elements 9%
- yarn furnishing installation 36%
- knitting point 29%

Significant reductions in the amount of fibre fly, which is allowed to contaminate the environment, the knitting machine and potentially the fabric, can be obtained by the installation of fully enclosed yarn creels and especially those that have local atmospheric controls, air circulation and filters. e.g. Memminger-Iro Filtercreel.

Creels of this type contain and remove fly, which is generated by yarn / yarn friction, as the yarn is unwound from the package. In addition, humidification increases the moisture content of the yarn, which improves the strength, extensibility and cohesion of the fibres and helps to reduce fly generation. It is claimed that 50% less fly is collected in humidified enclosed creels than in un-humidified creels, although care should be exercised not to increase the moisture content too high as this has an adverse effect on the yarn's frictional properties. Increase in yarn friction can increase fibre fly generation.

Commercial trials with enclosed humidified creels have demonstrated their ability to make a significant contribution to the reduction of fibre fly related fabric faults and also improvements in knitting efficiency due to reduced downtime for fault mending and cleaning.



Enclosed yarn feeders (tubes) which take the yarn from the creel to the positive feed mechanism on the knitting machine also help to reduce atmospheric fly and therefore its tendency to settle on other parts of the machine and yarn.

It is also worth noting that the yarn speed can also make a major contribution to the release of fibre fly. More fly is generated at higher yarn speeds i.e. higher machine speeds. Consequently, if fly contamination is excessive some improvement may be gained by reducing the speed of the knitting machine.

Knitting Faults

However important the yarn quality may be, it is important not to overlook the contribution that poor machinery maintenance schedules or bad housekeeping in the yarn store and knitting room can make to the incidence of faults in the knitted fabric. In some cases, fabric faults which are due primarily to fabric production (knitting) can be much higher than those, which can be blamed directly on the yarn quality.

As an example, a few years ago a European knitwear manufacturer carried out an investigation into the source of faults in his knitted garments which were downgraded during final inspection. In this particular study 24% of all the faults which were found in the downgraded garments could be related to yarn faults, i.e. spun in coloured fibre, foreign matter, short and long thick places, thin places, knots/splices etc.

However, in the same study 54% of all the faults found in the downgraded knitted garments were attributed to knitting faults, e.g. holes, stains and contamination, missed stitches, fly, rings due to mixed yarn, etc.
The remaining 22% could be attributed to finishing (15%) and making up (7%).

The incidence of knitting faults in the fabric can be a significant cost factor for the fabric producer, not only because they affect the overall quality of the fabric and the appearance, but also because they will adversely affect knitting efficiency and the cost effectiveness of the fabric production operation.

Even in the best run knitting departments knitting faults can not be completely eliminated. However, - following the principles of quality assurance - early detection of fabric faults, e.g. to reduce the length of faults, on the knitting machine, will help to improve the cost effectiveness of the knitting operation by reducing fault allowances that have to be conceded to the garment maker.

There are many devices available to the modern knitgoods manufacturer to help him control the number and size of knitting faults in the fabric. These include such items as

- Slub and knot catchers, which will detect slubs, knots etc. as they pass through the yarn guides and stop the knitting machine before they can cause damage to needles or faults in the fabric.
- Needle detectors and latch openers, which detect damaged or broken needles, and automatically brush the needle latches to help avoid the problems caused by closed latches.
- Fabric fault detectors - such as those available from Memminger-Iro, LMW3 and Mayer & Cie, Argus which optically detect and record fabric holes or ladders in the fabric and can be programmed to stop the machine according to certain criteria which the knitter programs in.
- A considerable advantage of these instruments is that it also becomes relatively easy to build up a record and analysis of faults in the fabric so that steps can be taken to eliminate their causes.

Machinery Maintenance

Problems with fabric appearance, faults and knitting efficiency can also be associated with poor machinery maintenance, cleaning schedules and the quality of spare parts.

For example, the quality of the needles and sinkers is particularly important to the production of good quality fabric. Good quality spares should be used and a regular replacement schedule worked out. Advice on preventative maintenance schedules will be available from the machinery builders but it is difficult to be precise. It will depend on many factors not least of which will be the yarn and fabric qualities that are being produced, the speed at which the machine is being run, the number of shifts etc.

If the production of consistently high-quality fabric is the objective, consideration has to be given to replacing essential elements before there is a major deterioration in performance. If preventative maintenance schedules are correctly planned, they can be incorporated into production schedules without causing too much disruption.

If a system of demand replacement (i.e. only when there is a problem) is employed then there will inevitably be a gradual deterioration in fabric quality and knitting efficiency as fault rates rise. Production efficiency will also be impaired since, inevitably with this system, mechanical breakdown or re-needling will always occur at the most inconvenient time!

Preventative maintenance also includes:

- The cleaning down of machines at regular intervals in order to remove fly build up, wax accumulations on positive drive belts etc.
- Ensuring that all working areas are kept clean of dirt, oil and lint, to help prevent contamination and soiling of the fabric.
- The use of efficient lubrication systems and the use of high-quality oil will help to reduce wear on knitting elements.
- Regular flushing of the needle bed to remove dirt and fly. This will also help to maintain the wear life of cams, tricks and needles and help to reduce soiling of fabric etc.
- Regular checking of yarn guides etc. for wear and rough places which can damage yarns and increase the generation of fibre fly.

