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# THE QUALITY OF FANCY YARN: PART I: METHODS AND CONCEPTS

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## ABSTRACT

This article aims to introduce new quantitative concepts and parameters which may be used objectivity to account for the structure and quality of several types of fancy yarns which have multiple-thread structure. Those concepts and parameters were divided into two groups. The first groups pertains to fancy yarns where the effect profile or project is not elongated in shape. The parameters of this group were the Number of Fancy Profiles, the Size of Fancy profile, the Circularity Ratio of Fancy Profile, the Shape Factor of Fancy Yarn, and the Relative Shape Index of Fancy Yarn. However, the parameters and concepts of second group are related to fancy yarns where the effect profiles and projects are elongated in shape. These parameters were the Actual Length of Elongated Fancy Profile, the Total Length of Elongated Fancy Profiles and the Fancy Length Index of Fancy Yarn. To apply those concepts and parameters, suitable methods were also presented in details to help fancy yarn spinners and buyers use them. The concepts and parameters of each group were introduced as complete packages to assess the structural features and quality of fancy yarns. This article may make the subject of quality of fancy yarn reach a new perspective where quantitative methods can be used effectively to assess the structure and quality of fancy yarn without relying on the subjective judgement of experts on fancy yarn.

**KEYWORDS:** Fancy Yarn Quality & Fancy Yarn Structure

## INTRODUCTION

Fancy yarns, or novelty yarns, are defined by as “special products of carding, drawing, Dref spinning, rotor spinning, twisting, texturing, etc. technologies with introduced visual irregular characteristics, in either diameter and unevenness and/or in colour” (S. Petrulyte, 2003). It is also defined elsewhere as “A yarn that differs from the normal construction of single and folded yarns by way of deliberately produced irregularities in its construction. These irregularities relate to an increased input of one or more of its components, or to the inclusion of periodic effects, such as knops, loops, curls, slubs, or the like” (Denton & Daniels, 2002). To obtain a detailed assessment of the quality of fancy yarns, one may need to account for the different features of fancy yarns, such as:

- Forms and types of material which are used to make fancy yarns;
- Aesthetic features, e.g. colour, handle, compressibility, etc.;
- The structural characteristics which define the shape of fancy projections on the fancy yarn surface. In particular the overfeed ratio of the effect component and the number of wraps of the binder are the most important parameters of the fancy yarns structure. Those characteristics differ from fancy yarn to another depending on the type of fancy yarn;
- The technology used to make a particular type of fancy yarn;
- The linear density and any other measure of the bulkiness of fancy yarn; and so forth.

Amongst those features, the structural features have attracted the attention of many researchers. Several researchers used them as the basic parameters to characterise fancy yarns. Admittedly, they provided ideas which contributed to the literature and gave an insight to combine them with other methods, which are not subjective or restricted to the personal viewpoint of experts in fancy yarns, in order to evaluate and assess the quality of fancy yarns. Many researchers counted the number of the effect profiles (or projections) in the unit length of fancy yarn and measured the length, diameter and the distances between fancy projections (Baoyu & Oxenham, 1994; Grabowska, 2008; Nergis & Candan, 2006; Salvinija Petrulyte, 2007, 2008; Audrone Ragaisiene, 2009a, 2009b; A. Ragaisiene & Petrulyte, 2003). Grabowska, however, evaluated the effect profiles by introducing a parameter which she called "*shape coefficient of fancy yarns*" (Katarzyna Ewa Grabowska, 2010). This parameter is the reciprocal of another parameter suggested by Testore and Minero (1988) who used it to assess the structure of slub yarns (Testore & Minero, 1988). The shape coefficient of fancy yarns as suggested by Grabowska is dimensionless and its value does not exceed one and it is given by the formula:

$$K = \frac{D_{Rs0}}{D_{Es0}} \tag{1}$$

Where K is the shape coefficient of fancy yarns; $D_{Rs0}$ is the diameter of the helix line formed by the external edge of the core yarn in a multi-thread structure (i.e. fancy yarn made by combining yarns only without drafted fibrous strands) when it is stretched by a preliminary load; $D_{Es0}$ is the diameter of the helix line formed by the external edge of the effect yarn in a multi-thread structure when it is subjected to a preliminary load.

Grabowska assumed her "shape coefficient of fancy yarns" as an objective parameter to assess fancy yarns (Katarzyna Ewa Grabowska, 2010). Her other assumption was that the shape coefficient of fancy yarns can be used to determine the tensile properties of fancy yarns. Different values of that shape coefficient for different types of fancy yarns were calculated. Experiments were conducted on spiral yarns (mouliné), wrapped yarns, loop frotté yarns with sinusoidal effects, loop yarns with bouclé effects and snarl yarns. Those experiments emphasised that spiral yarns had the best strength (tenacity), while loop yarns had the lowest values of tenacity. It is demonstrated that loop frotté yarns are similar to bouclé yarns in which there are at least three components, i.e. the core, the effect and the binder, but the overfeed ratio should be as small as possible and sufficient to prevent the continuous contact between the effect component and the core component (Katarzyna Ewa Grabowska, 2010).

Grabowska used her "shape coefficient of fancy yarns" as a tool to classify fancy yarns, in particular spiral (mouliné) yarns, wrapped yarns and bouclé yarns (Katarzyna Ewa Grabowska, 2010). Further, she plotted the relationships between K and the tenacity of the core and the effect of a two-component fancy yarn and a three-component fancy yarn (including the binder) (Katarynza Ewa Grabowska, 2010). Furthermore, she used it to build mathematical models of the structure and mechanical properties of some types of fancy yarns (Grabowska, 2008).

There are, however, some points related to that "shape coefficient of fancy yarns" and it might prove to be of minimum practical usage. The shape coefficient of fancy yarns suggested by Grabowska will indeed give the same value for loop yarns, bouclé yarns, knop yarns, knot yarns, and snarl yarns if all of them have the same diameters for the core and effect helices and if they are multiple yarn structures. Additionally, that shape coefficient of fancy yarns ignores:

- The real shape and dimensions of the effect profiles because it focuses only on the diameter of the outer edge of the effect profile;
- The shape of the loop whether it is opened, closed or uneven, i.e. bent loop rather than not being round;

- The linear density of the effect component although it is important in defining the shape the effect profile;
- No indication for the type and flexural stiffness of the material used for the effect component which are very important to define the shape of the effect profiles;
- The twist in the effect component whether it is lively twist, moderate or zero twist;
- The case when there are knots or slubs made from fibres or multi-loop knots; and
- The case where there is a multi-effect fancy yarn, that is, one fancy yarn that has snarls, knots, slubs, loops of different types, wraps, knobs and spiral effects.

Therefore, to overcome most of these issues, this article presents new concepts and parameters which deal with different types of fancy yarn. The structural features of fancy yarn were the prime features which were used to evaluate and compare the quality of fancy yarns. Those concepts and parameters are objective and practical. They are also based on scientific methods, which require no subjective viewpoint of an assessor of the quality of fancy yarns.

## SCOPE OF APPLICATION

This research defines the parameters which may be used to assess the structure, the aesthetic characteristics and quality of several types of fancy yarns. The same parameters may also be used to compare those fancy yarns. Fancy yarns which can be measured using the parameters presented in this article are those which have multi-thread structure (e.g. doubled fancy yarns) and fancy yarns which are made from drafted slivers or rovings (i.e. where the effect is made from loose fibres). It may also include more complicated structures which resemble the structures of loop yarns, bouclé yarns, button yarns, bunch or knop yarns, slub yarns, eccentric yarns, cloud yarns, stripe yarns, snarl yarns, tape yarns, gimp yarns, nepp yarns and all derivatives of such novelty yarns.

Types of fancy yarn which are made with intentionally randomised-size or -length of the fancy profiles and projections are out of the scope of this article. If the fancy profiles have the same intended size but the distance between them is randomised then those parameters can be applied. Admittedly, those concepts do not account for the colour and appeal of fancy yarn.

## DEFINITIONS AND CONCEPTS

For the purpose of this article, the following terms and definitions apply.

### Linear Density of Fancy Yarn

The Linear Density of Fancy Yarn is the mass per unit length of the fancy yarn, after being preconditioned then conditioned to conform to an international standard, such as ISO 139:2005. It is measured depending on the procedures mentioned in an international standard, such as ISO 2060:1995. The Linear Density of Fancy Yarns is usually measured in tex or its multiples or submultiples as convenient.

### Number of Fancy Profiles (N)

The Number of Fancy Profiles (i.e. the effect profiles or projections) of fancy yarn is the number of the main fancy profiles of the effect component in the unit length (usually one meter) of the same fancy yarn. It does not include the number of any other type of profiles if they exist as secondary or companion profiles in the fancy yarns.

There are two exceptions to this rule. The first case is where the fancy yarn is an overfed fancy yarn and cannot be designated as one of the main typical types of fancy yarn. The second case deals with derivatives of the main types of fancy yarns. The Number of Fancy Profiles may be measured in $m^{-1}$ or $dm^{-1}$ as convenient. Typically, several measurements are taken (i.e. ≥ 31 fancy profile) and the average value of those measurements is calculated.

**Area of Fancy Profile (A) and Size of Fancy Profile**

The Area of Fancy Profile is the average area of an ultimate fitted polygon drawn to match the circumference of the 2D projection of fancy profile on a plane. The unit of measurement can be $mm^2$ or $cm^2$ as convenient. Typically, several measurements are made (i.e. ≥ 31 fancy profile) and the average value of those measurements is calculated.

The Size of Fancy Profile is another term that is mainly related to three-dimensional fancy profile and it is defined as the average volume of 3D fancy profiles or fancy projects, such as fancy slubs, fancy bunches or knops, and fancy buttons. The unit of measurements can be $mm^3$ or $cm^3$ as convenient. Typically, several measurements are made (i.e. ≥ 31 fancy profile) and the average value of those measurements is calculated. When dealing with 2D fancy profiles or projects, it is not unusual to quote the term “The Size of Fancy Profile” to measures the area of their projects on a plane, and the unit of measurement shall be $mm^2$ or $cm^2$ as convenient.

**Circularity Ratio of Fancy Profile (CR)**

The Circularity Ratio of Fancy Profile (CR) is a description of the circularity or the roundness of the representative projection of the fancy profile on a plane, e.g. when it is observed under a microscope. The Circularity Ratio of Fancy Profile can be calculated as follows:

- Using the central moments of a fitted polygon which is drawn to match the circumference of a projection of fancy profile on a plane. This method is relatively sensitive to the lengths of the major and minor axes of the measurand. This method will be used in Part II of this article (Alshukur, 2013).
- In another method, the circularity ratio may be defined as the ratio between the area of the aforementioned ultimate polygon and a circle that has the same perimeter.
- Finally, it is possible to use following relationship:

  $CR=4\pi A/P^2$, (2)

  where $A$ is the area of the ultimate polygon while $P$ is its perimeter.

This method is well-known and used to measure the circularity in many occasions (Stojmenović & Nayak; Zunic, Hirota, & PaulL.Rosin, 2010).

Regardless of the method used, the maximum value of the circularity ratio is 1 (or 100 %) and it represents perfectly circular shapes.

**Shape Factor of Fancy Yarn (Shf)**

The Shape Factor of Fancy Yarn is absolute fancy bulkiness of the fancy profiles available in a unit length of a fancy yarn regardless of the original thickness of the fancy yarn. The Shape Factor of Fancy Yarn (ShF) is a dimensional factor and it is given by the equation:

$$ShF = N \cdot A \quad (3)$$

Where:

N is the Number of Fancy Profiles, (measured in $m^{-1}$ or $dm^{-1}$ as convenient), and

A is the Area (or size) of Fancy Profile (measured in $mm^2$ or $cm^2$ as convenient)

The Shape Factor of Fancy Yarn may be measured usually $mm^2m^{-1}$ or $cm^2m^{-1}$ as convenient. For example, in the case of gimp yarns or an overfed fancy yarn made using only one effect component it is convenient to use the first unit, but in the case of loop or bouclé yarns, it is advised to use the second unit. If the fancy yarns have similar linear densities, higher values of the ShF mean larger absolute fancy bulkiness of the fancy yarn. However, it is not convenient to compare similar fancy yarns if they have different thicknesses, i.e. linear densities.

**Relative Shape Index of Fancy Yarn (Or Profiles) (RSI)**

The Relative Shape Index of Fancy Yarn or Profiles (RSI) is a measure of the relative fancy bulkiness of the fancy profiles available in one unit of the fancy yarn and taken into account the thickness of the whole fancy yarn. The Relative Shape Index of Fancy Profiles is also a dimensional factor and it is given by the equation:

$$RSI = \frac{ShF}{T_{tex}} \quad (4)$$

Where: ShF is the Shape Factor of Fancy Yarn, (measured in $mm^2m^{-1}$), and

$T_{tex}$ is the linear density of the fancy yarn, (measured in tex),

The Relative Shape Index of Fancy Yarn may be measured in $mm^2m^{-1}tex^{-1}$. The higher the value of the RSI the higher the relative bulkiness of the fancy profiles. Accordingly, if there are several, but similar fancy yarns, e.g. either loop fancy yarns or bouclé fancy yarns, etc., the bulkiest of them is the one which has the highest value of the RSI. For instance, considering the specifications of the two fancy bouclé yarns given in Table 1. If there is a need to compare the bulkiness of both of them, the value of the Shape Factor of Fancy Yarn (ShF) alone indicates that the second bouclé yarn has more fancy bulkiness than the first bouclé yarn. However, these two yarns do not have the same linear densities (or thicknesses). Thereafter, such comparison is not as useful as it should be. Consequently, to obtain a more meaningful comparison, the value of the Relative Shape Index of Fancy Profiles (RSI) must be used as it takes into account the weight or thickness of each yarn. Accordingly, the first bouclé yarn is relatively more bulky, i.e. relatively has more fancy bulkiness, than the second yarn because the value of the RSI is 4 $mm^2/m \cdot tex$ for the first bouclé yarn, whereas it is 3 $mm^2/m \cdot tex$ for the second yarn. Similar argument can be presented to compare all types of fancy yarns which are capable to be defined by the Shape Factor of Fancy Yarn.

**Table 1: Using Relative Shape Index of Fancy Yarns to Compare the Bouclé Yarns**

| Bouclé Yarns | ShF ($mm^2/m$) | Linear Density (tex) | RSI ($mm^2/m \times tex$) |
|---|---|---|---|
| First Yarn | 1000 | 250 | 4 |
| Second Yarn | 1200 | 400 | 3 |

In some special cases where the ShF to be used to account for unwanted profiles, such as the case of unwanted non-gimp profiles over a gimp yarn surfaces, the Relative Shape Index of Fancy Yarn can be used but interpreted in a different way. In other words, the higher the value of the RSI the lower the quality of the gimp yarn.

**Actual Length of Elongated Fancy Profile (AL)**

The Actual Length of Elongated Fancy Profile may be defined as the length of the *elongated* fancy projection or profile. This length may be measured from the point at which the fancy profile/projection becomes apparent, distinguished or different from the ground component (e.g. the sigmoidal or doubled sections) of the fancy yarn to the end of the fancy projection or the point at which the fancy profile tapers back into the ground yarn. The elongated fancy projections (or profiles) are usually attached or incorporated into the ground component depending on the types of fancy yarn and the technology used to make those fancy yarns. The Actual Length of Fancy Profile is a parameter that accounts for elongated fancy profiles regardless of their commercial or generic description. Typically, several measurements are made (i.e. ≥ 31 elongated fancy profile) and the average value shall be considered and it is usually measured in mm or cm as convenient.

### The Total Length of Elongated Fancy Profiles (TL)

The Total Length of Elongated Fancy Profiles is the sum of lengths of all *elongated* fancy projections (or profiles) in one unit length of the fancy yarn. This term is usually applied in conjunction with the Actual Length of Elongated Fancy Profile. The Total Length of Elongated Fancy Profiles is given by the equation:

$$TL = N \cdot AL \qquad (5)$$

Where: AL is the Actual Length of Elongated Fancy Profile, measured in mm or cm as convenient; and

N is number of the fancy profiles in one unit length of the fancy yarn, measured in $cm^{-1}$ or $m^{-1}$.

The Total Length of Elongated Fancy Profiles (TL) may be usually measured in $mm \cdot m^{-1}$, $mm \cdot cm^{-1}$, or $cm \cdot m^{-1}$ as convenient. Higher values of the TL mean longer effect profiles of the fancy yarn.

### The Fancy Length Index of Fancy Yarn (FLI)

The Fancy Length Index of Fancy Yarn (FLI) refers to the relative visual appearance of fancy yarn and it is given by the equation:

$$FLI = TL / T_{tex} \qquad (6)$$

Where: TL is the Total Length of the Fancy Profiles, measured in mm/m; and

$T_{tex}$ is the linear density of the fancy yarn, measured in tex.

Therefore, the Fancy Length Index of Fancy Yarn (FLI) may be measured in $mm \cdot m^{-1} \cdot tex^{-1}$. This term was is put forward to compare the structure, quality and appearance of several fancy yarns which have the same basic structure (i.e. type) with elongated fancy profiles but differ in thickness. Suppose there are two fancy yarns that have elongated fancy profiles and similar in their structure, i.e. generic description. Suppose also they are made from the same materials, but have different values of the Fancy Length Index of Fancy Yarn (FLI). This means that the fancy yarn which has higher value of FLI will be the one that also has relatively longer fancy profiles and the visual appearance of its effect/profiles/projects will be relatively higher. Further, if such a yarn to be used to make fancy fabrics, the fancy effect such a fancy yarn will be more noticeable, accentuated or pronounced on the fabrics than the other fancy yarn. Consequently, the visual aesthetics and the appearance of its elongated effect profiles on fabric surface will be higher.

## FANCY PROFILES TO BE MEASURED BY THOSE PARAMETRES

It is important to define the shapes and main characteristics of fancy profiles for the various types of fancy yarn which can be tested using the parameters mentioned above. A list of those fancy yarns and the way of assessing each one are shown in this part of the article, while the application of those parameters and methods to some fancy yarns will follow in Part II.

**The Case of Loop Yarn**

Loop yarns are characterised by fancy profiles which take the shape of well-formed circular loops, while the other sections of the yarn take usually the shape of sigmoid spiral (Denton & Daniels, 2002). The assessor may be interested in measuring the average size of those circular loops, their number per unit length and their circularity ratio. The circularity ratio must be 1 (or 100 %) for perfectly-shaped loop yarns. Good-quality loop yarns usually have a circularity ratio in the range 0.85 ~ 1. Values of circularity ratio provided in this article are based on Figure 1 supplemented in Appendix A and on a reprehensive structure of each type of fancy yarns as available in textbooks. However, such values of the circularity ratio may differ slightly depending on the method used to calculate the circularity ratio.

**The Case of Bouclé yarn**

Bouclé yarns exhibit an irregular pattern of semi-circular loops and sigmoid spiral in their simplest structure (Denton & Daniels, 2002). The assessor may only be interested in measuring the average size of the semi-circular loops (i.e. bouclés), their number per unit length and their circularity ratio. The circularity ratio is always smaller than 0.9 (i.e. 90 %) for bouclé yarns. It is also greater than 0.5 (i.e. 50 %) because values less than that represent another type of fancy yarns, i.e. arc yarns. Good-quality bouclé yarns should have bouclé profile that have circularity ratios in the range of 0.60 ~0.85.

**The Case of Button Yarn**

Button yarns have effect profiles (i.e. button) which resemble short, dramatic, bulged slubs dispersed usually over sigmoid spiral. The assessor may measure the average size of such buttons, their number per unit length and their circularity ratio. The circularity ratio for button yarns usually takes values which is in the range 0.55 ~0.65 depending on the length of the button profiles. The longer the button profile the lower the circularity ratio. The highest, acceptable value of the circularity ratio should not exceed 0.65, otherwise, the actual length of the button profiles should be considered instead of their circularity ratio. For this last case, the Actual Length of Elongated Fancy Profile, the Total Length of Elongated Fancy Profiles and the Fancy Length Index of Fancy Yarn are recognized with or without the Shape Factor of Fancy Yarn, the Relative Shape Index of Fancy Yarn, and the Circularity Ratio.

**The Case of Knop Yarn (or Bunch Yarn) and Nub (or Slash) Yarn**

Knop or bunch yarns have prominent bunches (i.e. tight wraps or knops) arranged at regular or irregular intervals on the yarn surface, whereas the other sections of the yarn are spiral segments (Denton & Daniels, 2002). In the case of knop yarns, the assessor may measure the average size of the bunches, their number per unit length and their average circularity ratio. The value of the circularity ratio usually falls in the range 0.6~ 0.7. Nub or slash yarns may be dealt with in a similar way.

If the knop yarn has elongated knop profiles, then measuring the circularity ratio is not a useful procedure; instead, the assessor may measure the length of the elongated bunches. Therefore, the Total Length of Elongated Fancy Profiles and the Fancy Length Index of Fancy Yarn are calculated.

**The Case of Slub Yarn**

Slub profiles are thick places in the fancy yarn and can reach three or four times the thickness of the base sections of the slub yarn (Gong & Wright, 2002). To account for the structure and quality of a slub yarn, the assessor should measure the average size of the slubs, their number per unit length and their length. Measuring the circularity ratio of the slub is not as useful as their length. Hence, the Total Length of Elongated Fancy Profiles, and the Fancy Length Index of Fancy Yarn are calculated.

**The Case of Eccentric Yarn (or Slub Gimp Yarn)**

Fancy eccentric yarns are made by binding or entwining together components which at least one of them is an already fancy yarn (e.g. a knop or slub yarn) in the direction opposite to the initial stage of twist to give gradual half-circular loops along the final yarn. Therefore, the assessor may use the same parameters devised to measure the original fancy yarns, e.g. ShF and RSI or AL, TL, and FLI. The circularity ratio in this case is usually in the range 0.5~0.65.

**The Case of Cloud Yarn (i.e. Grandrelle Yarn)**

The fancy profiles of fancy cloud yarns are simply alternating coloured bunches (i.e. tight wraps or knops) as they appear on the yarn surface. The fancy profile in this case is made using two or more threads in such a manner that each one of them wraps around the other yarn (or yarns) in an alternative and usually successive way (Denton & Daniels, 2002; Gong & Wright, 2002). The assessor therefore may measure the average size of each type of the coloured bunches, their number per unit length and their circularity ratio if they are short bunches. In the case of elongated cloud sections, it is advised to measure the length of each coloured section in addition to their average sizes. Hence, values of the ShF, the RSI, the TL, and the FLI are calculated for each coloured section.

**The Case of Stripe Yarn**

The fancy profiles of fancy stripe yarn are alternating, elongated, coloured, thin knops (Denton & Daniels, 2002). The assessor may measure the length of each group of the coloured knops, the TL and the FLI.

**The Case of Snarl Yarn**

The fancy profiles of fancy snarl yarn are snarls or kinks projecting from the core of this type of fancy yarns (Denton & Daniels, 2002). The assessor may measure the length of these snarls, their number per unit length, and calculate the values of TL and the FLI.

**The Case of Tape Yarn (i.e. Ribbon Yarn)**

The fancy profiles of tape yarn are tapes incorporated into or forming the ground yarn. The assessor may measure the length of these tapes, their number per unit length of the fancy yarn, and calculate the values of the TL and the FLI.

**The Case of Gimp Yarn (i.e. Ratiné Yarn or Frisé Yarn) and Wavy Yarn**

The actual structure of gimp yarn (and ratiné yarn, frisé yarn or wavy yarn) is simply wavy corrugations (Gong & Wright, 2002). If the structure of a gimp yarn is likewise, the quality of the yarn is considered to be excellent. If the yarn structure displays additional non-gimp profiles on the yarn surface, those non-gimp profiles are considered defects. Therefore, the average size of those non-gimp profiles, their number per unit length and their circularity ratio are measured. Values of the ShF and the RSI are calculated. Therefore, higher the value of ShF the lower the quality of the gimp yarn assessed.

**The Case of Nepp Yarn (i.e. Knickerbocker Yarn or Knicker Yarn)**

The fancy profiles in the case of nepp yarn appear on the yarn surface as small lumps or balls of fibres which resemble spots of different colour contrasting the colour of the basic yarn (Gong & Wright, 2002). The assessor may count their number per unit length of the fancy yarn. Other measures reported here are not practical.

## MTHODS AND PROCEDURES OF APPLICATION

It is necessary to give detailed explanation to the apparati needed and the procedures required to apply the previous parameters to assess the structure, quality and appearance of fancy yarn and because these parameters and methods are suggested and presented for the first time.

### Apparati

#### Microscope

The microscope shall have a magnifying power which is at least 4 times the original size of the fancy profile to be measured (i.e. measurand). This level of magnification may be adequate to help taking images of the fancy profile and to use those images to draw an ultimate polygon around its perimeter. It is possible to use a flatbed scanner to acquire the images, but the problem lies in the nature of fancy yarns and the way the fancy profiles or projections are distributed along the yarn length, i.e. in a 3D manner. Sometimes the projections are twisted, for reasons that are beyond the scope of this article. Any attempt to obtain an image of the fancy projections using a flatbed scanner might not be successful, in particular if the fancy yarns have several fancy projections confounded, tangent to each other or, in more severe cases, clustering together. Those last three cases may results from several reasons and mostly observed when the fancy yarns comprises two or three effect components making the fancy profiles or projections.

#### Digital camera

The digital camera must be fitted on the microscope to take images of the fancy profiles needed to complete the procedures included in this article.

#### Digital image analysis software

This software must be linked to the digital camera and the microscope to control both of them and to analyse the digital images. The digital image software must include suitable tools to draw an ultimate polygon around the fancy profile. The assessor must take the precautions necessary to make such ultimate polygons coincide with the perimeters of the fancy profiles in the images. It is important to note that such involvement of the assessor in the measurement process does not render it subjective for the reasons given in Appendix B.

#### Auxiliary equipment

There is a necessity to use a piece of adhesive tape to control the wraps or twists of the fancy yarn so as to prevent them from unwrapping or unravelling. To obtain a still better quality digital photo of the fancy profile with its full size, a suitable transparent plate made from glass can be used to fix the fancy profile underneath it.

### Sampling

There are several things that must be considered during sampling:

- Sampling shall be carried out according to procedures approved by ISO or any international standard for textile yarns so as to account for the variability between shipments, lots, consignments and packages.
- The bulk sample shall be taken is such a manner which is representative to the lot to be tested.

- The few meters of yarns at the beginning and at the end of the package shall be discarded so as to avoid damaged sections or sections made at the start up or stopping down of machines.
- The number of packages must be as large as possible; and the number of the fancy profiles should ≥ 31 so as to comply with Central Limit Theorem (in Statistics) which may help obtaining reasonably accurate results. If the measurements have a normal distribution, i.e. bell-shaped distribution, the number of measurements may be > 15.
- If there are few packages available for sampling it is advisable to use the systematic method of sampling which is explained in Statistics textbooks.

**Procedures and Calculations**

To calculate the Linear Density of Fancy Yarn, the reader is referred to the procedures mentioned in ISO 2060:1995 (BSI). Further, the following issues shall be considered:

- Samples must be preconditioned then conditioned in a standard atmosphere, where the temperature is 20±2 $C^o$ and the relative humidity is RH=65±4%, in accordance with ISO 139:2005 (BSI).
- Since the linear density of fancy yarns is more than 100 tex in general, the length of each specimen must be 10 m in order to comply with ISO 2060:1995 (BSI).
- Since the variation in the linear density of fancy yarns are normally higher than that of the normal folded (plied), multiplied or cabled yarns, the number of packages required to calculated the linear density must be at least 10 packages representing the shipment, lot or consignment. 3 or 4 specimens taken from each package after ignoring the few meters of yarn at the beginning or at the end of the package would be suitable for testing.
- In the end the test will be conducted on more than 30 specimens, i.e. ≥ 31.
- Since fancy yarns are expensive materials, the interested parties may agree to reduce the number of packages to 5 packages, but the number of specimens taken from each package must be kept 3 or 4. Accordingly, the total number of specimens will be greater 15 and will be still representing the variation between packages and the variation within packages. If the packages are taken randomly from different cases, the sample taken is also representing the variation in the shipment.

To calculate the Number of Fancy Profiles, the following must be considered:

- The specimen must be wound off the package smoothly in such a way which neither allows the fancy yarn to unwrap some of its binder wraps, nor allows the fancy yarn to snarl on itself.
- The specimen which has the specific unit length must be fixed by an adhesive tape at a ruler (which has a sufficient length) without being cut off or separated from the package. Further, it is advisable to keep the specimen under a pre-tension of 0,5 cN/tex to ensure that the fancy yarn is always straight.
- It is possible to use the same packages used to calculate the linear density of the fancy yarn.
- It is advisable to define the number of the fancy profiles in one meter; otherwise it is possible to count their number in smaller or larger lengths if the interested parties agreed on this.
- The number of (similar) fancy profiles or projections must be counted per meter separately from the other types of

fancy profiles or projections if there is more than one type of fancy profiles or projections on the same fancy yarn.

- The average number of each type of fancy profiles or projections must be calculated; the same procedures apply for the all types of fancy profiles on the same fancy yarn.
- The number of specimens, i.e. fancy profiles in this case, to be used is also greater than 30, i.e. ≥31; otherwise any number greater than 15 can be used after the agreement is secured by all parties interested.

To calculate the Area of Fancy Profile and Circularity Ratio of Fancy Profile or the Actual Length of Elongated Fancy Profile, the following is considered:

- The same packages sampled previously may be used.
- The total number of the fancy profiles selected must be greater than 30 fancy profiles to conform to the Central Limit Theorem explained in Statistics textbooks, i.e. ≥31 fancy profile.
- Once the packages were sampled according to the ISO standards or textile textbooks which deal with quality in textiles, the fancy profiles on the selected fancy yarn(s) must be randomly sampled. Although any method appropriate for sampling could be used, it is advised to use the systematic method of sampling. This methods can be conducted in two different way:
- Choosing any fancy profile randomly and measure its size and after that selecting the fancy profile which comes after a specific number of fancy profiles (this number called the sampling pitch and it can be any number, e.g. 5 fancy projections) to be tested. Following this, it is possible to select the fancy profile which comes after the same number of fancy profiles, and so forth until reaching more than 30 fancy profiles required to complete the test, i.e. ≥31 fancy profile.
- In the second way of applying the systematic method of sampling one may use a sampling pitch which is a specific length (e.g. 20 cm or 1 m) and selecting the fancy profile which comes directly after this length, and so forth.
- The fancy yarn shall be attached to its package when testing to secure it from unwrapping after being wound off the package. Additionally, it should be secured underneath the microscope lens via a plate of glass.
- The assessor should be able to take an appropriate digital photo for each fancy profile using a digital camera.
- Using a suitable digital image analysis software package, the assessor shall draw a polygon fitted to the circumference of the fancy profile as it appears in the digital photo if the profile is not elongated one.
- The digital image analysis software shall have the tools needed to calculate the size and the circularity ratio or the actual length of the fancy profile depicted in each digital photo.
- The digital image analysis software shall have the tools needed to calculate the average and the standard deviation of all measurements related to size and the circularity ratio of the fancy profiles measured.

To calculate the value of the Shape Factor of Fancy Yarn (ShF), the following is considered:

- The average value of the Number of Fancy Profiles is multiplied by the average value of the Area of Fancy Profile.

- If there are several types of fancy profile or projection on the same fancy yarn, each type of fancy profile is dealt with separately. Therefore, the fancy yarn will have multiple values of the Shape Factor of Fancy Yarn to account for each type of fancy profile or projection.

To calculate the value of the Relative Shape Index of Fancy Yarn (RSI) the value of the Shape Factor of Fancy Yarn is divided by the average value of the linear density of the same fancy yarn. For the case where the fancy yarn has more than one type of fancy profile or projection, the multiple values of the Shape Factor of Fancy Yarn are added up and divided by average value of the linear density of the same fancy yarn.

To calculate the value of the Total Length of Elongated Fancy Profiles (TL):

- The average value of the Number of Fancy Profiles is multiplied by the average value of the Actual Length of Elongated Fancy Profile (AL).
- If there are several types of elongated fancy profiles at the same fancy yarn, each type of elongated fancy profile is dealt with separately. Therefore, the fancy yarn will have multiple values of the Total Length of Elongated Fancy Profiles to account for each type of them.

To calculate the value of the Fancy Length Index of Fancy Yarn (FLI) the value of the Total Length of Elongated Fancy Profiles (TL) is divided by the average linear density of the same fancy yarn. For the case where the fancy yarn has more than one type of elongated fancy profile or projection, the multiple values of the Total Length of Elongated Fancy Profiles are added up and divided by average value of the linear density of the same fancy yarn.

## CONCLUSIONS

The methods available in the literature to assess the structure, appearance and quality of traditional yarns fall short of doing so for fancy yarns as those are special types of yarn that have several peculiarities and irregularities. This article presented various parameters, concepts and methods to account for the structure, appearance and quality of various types of fancy yarn. Those parameters and concepts were classified into two groups. The first one accounted for fancy yarns which have non-elongated fancy projections or profiles and the second one accounts for fancy yarns which have elongated fancy projections or profiles. The first group of parameters includes the Area of Fancy Profile, the Size of Fancy Profile, Number of Fancy Profiles, the Shape Factor of Fancy Yarn (ShF) and the Relative Shape Index of Fancy Yarn (RSI). The second group of parameters comprises the Actual Length of Elongated Fancy Profile (AL), the Total Length of Elongated Fancy Profiles (TL) and the Fancy Length Index of Fancy Yarn (FLI). The various fancy yarn structures that can be assessed using those parameters and concepts were presented with the relevant parameters. Additionally, a detailed explanation of the methods of application of those parameters was introduced thoroughly. Part II of this article will present the practical work and the application of those methods to test, evaluate and compare the structure, appearance and quality of three types of fancy yarn which are gimp yarns, bouclé yarns and overfed yarns.

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## APPENDIX A: DEFINING THE CIRCULARITY RATIO

One method of calculating the circularity ratio is provided by the OLYMPUS digital image analysis software

AnalySIS FIVE. The circularity ratio used in the software is calculated by the equation:

$$circularity = \frac{(M_{xx} + M_{yy}) - \sqrt{(4.M_{xy}^2 + (M_{yy} - M_{xx})^2)}}{(M_{xx} + M_{yy}) + \sqrt{(4.M_{xy}^2 + (M_{yy} - M_{xx})^2)}}$$

Where: $M_{xx}$, etc. are the central moments.

Figure 1: provides practical examples to explain the method of calculating the circularity ratio of several objects.

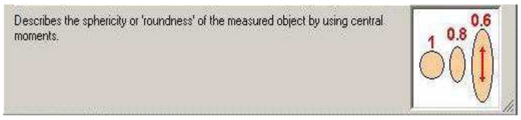


**Figure 1: Measurement of the Circularity Ratio of Objects Using the Central Moment Method (AnalySIS FIVE software)**

## APPENDIX B: NOTES ON THE INVOLVEMENT OF THE ASSESSOR IN THE MEASUREMENTS

The involvement of the assessor in the measurement process, in particular when drawing polygons around photos of the projections of the fancy profiles on a plane, does not make the methods of this article subjective because the nature of fancy yarns which are made to have high variability, especially those which are made from already ply components. The twist ridges on the surface of the effect components bring about an additional level of variability to the measurements. Those variations are normal to fancy yarns made from ply yarns in the effect component. It is not expected to obtain a further variability from the assessor of fancy yarns using this methods.

It should be noted that there are several methods reported in the literature regarding some semi-manual methods of measuring some of the textile properties. For example, the following methods are shown:

- The oiled-plate method of fibre-length measurements that is used for cotton fibres (Morton & Hearle, 1993);
- The semi-automatic single-fibre tester for wool and man-made fibres using a black velvet-covered board (Morton & Hearle, 1993);
- Another example is the semi-automatic Wira Fibre Length Machine devised by Anderson and Palmer (Morton & Hearle, 1993);
- The Comb Sorters which are used for most types of textile fibres (Morton & Hearle, 1993);
- The Pressley Dynamometer which is used to measure the strength of bundle of fibres, e.g. cotton fibres. For this particular apparatus, the rate of loading is not constant because it depends on the length of the leverage arm of the same apparatus. Another important factor is the speed at which the weight of such an apparatus travels along the arm, which varies during the test. The preparation of the fibre bundle must also be carried out by an individual using a special piece of equipment (Bona, 1994). Even though different individuals prepare such a sample in relatively different ways, the results of such test is still acceptable because the isotropic nature of textile fibres and the variation in natural textile raw materials is usually more than 10 %.
- Further, there is also the high level of agreement observed between the HIV values of cotton fibre classes and the results usually reported by the staple assessment made by hand (i.e. assessor).