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High Resolution Yarn Mass Measurement

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Abstract

Yarn structure is subject to periodic or random irregularities. In order to be able to quantify the yarn evenness, the principle often applied is based on 8 mm capacitive sensors. The capacitance variations enable the automatic indication of the mass mean deviation and the coefficient of variation. Knowledge of the yarn mass 1 mm range is of most importance to evaluate properly the yarn evenness; furthermore several irregularities can only be properly detected if this mass evaluation is possible in this range. We present a methodology to extract yarn mass in 1 mm range with signal processing techniques and statistical analysis. However, the ultimate goal is the direct measurement of mass in the 1 mm range. To achieve this goal, a solution with cylinder sensors with different diameters is under test.

1. Introduction

Yarn properties assessment has been subject to a considerable amount of work. There are many characteristics, which combine to give distinctive properties to an individual yarn. Yarns can vary in properties such as strength and twist as well as some mass variation per unit length "yarn irregularity". Variations in factors mentioned above are to a large extent secondary or tertiary effects of variations per unit length. It is important to appreciate that all spun yarns are to some extent irregular, and it is the degree of irregularity, which determines whether it is acceptable, or not for a particular end-use. Because the appearance of many fabrics is influenced by yarn irregularity this is frequently regarded as one of the most important yarn characteristics.

For detection of such irregularities it is still applied nowadays, to a great extent, electronic capacitance testers as a convenient an reliable method of testing irregularity (determination of mass every 8 mm). The system signals when the mass value is greater or lower than pre-defined thresholds. These thresholds are related to the mass average value, and allow the detection of either thick points (mass greater than the mass average plus a fixed amount) or thin points in the opposite case. The system does not recognise deviations just within these thresholds (or tolerance limits for defects) [1].

Moreover, the test results are influenced by the material properties and the testing conditions so that they are not easily reproducible.

With the proposed solution for measuring mass variation each 1 mm, we shall be able to assess the most difficult irregularities of the yarn, namely those that have high mass variation during a short period.

2. Theoretical Considerations

All spun yarns vary in linear density, and most problems of yarn quality are related to this basic property.

The uneven distribution of fibers along the length of the yarn is the cause of this irregularity. This produces variations in the number of fibers per cross section and in linear density. When twist is inserted, it is distributed in such a way that the angle of twist is approximately constant. In this way thin places have more turns per unit of length than tick places, and are relatively hard, whereas tick places are soft and comparatively bulky. This accentuates the visual appearance of the irregularities. The combination of different number of fibers per cross section with varying forces binding these fibers together because of twist, leads to various tensile properties [2].

Figure 1 shows an example of yarn configuration, with the representation of the corresponding diameter and means value as well as the sample length.

The main factors involved in the formation of short term irregularity are: limit irregularity due to random fibre arrangement, imperfect fibre control which in roller drafting leads to drafting waves varying in amplitude and length and mechanical defects [3].

In order to obtain yarn mass irregularity electronic capacitance tests are established as a convenient method of testing [4]. A strand of textile material is passed at a constant speed between the two parallel plates of a capacitor. As the strand varies in linear density and displaces the air present, this produces a variation in capacity that is proportional to the mass of textile material between the plates, giving us automatic indication of the mean deviation (U%) and coefficient of variation (CV%).

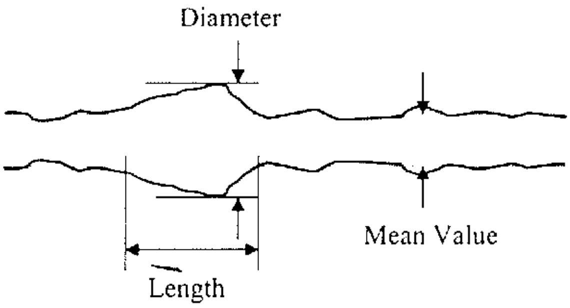

Figure 1 – Example of yarn configuration

The irregularity U% can be described graphically according to Figure 2 [5].

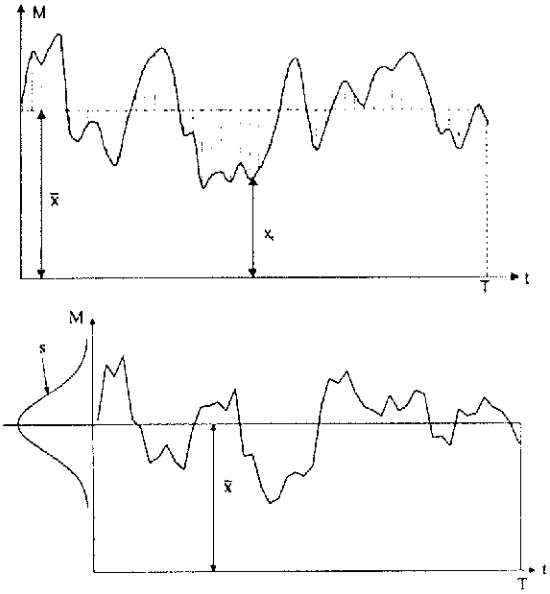

Figure 2 - Graphical representation of U and CV

In mathematical form U is defined (as a percentage) by Equation 1.

$$U = \frac{100}{\bar{x}.T}\int_0^T |x_i - \bar{x}|dt \qquad \textbf{(Eq. 1)}$$

where, x_i instantaneous value of the mass
$\bar{x}$- mean
T- evaluation time

The irregularity U is proportional to the intensity of the mass variation around the mean value, and is independent of the evaluating time or tested material length [illegible] homogeneously distributed mass variation.

The coefficient of variation CV is graph[illegible] represented in Figure 2.

The mass variation can be considered to [illegible] approximately to a normal distribution when [illegible] homogeneous fibre composition is available. [illegible] measure of the size of these mass variations [illegible] standard deviation s, which is defined as the distance [illegible] the mean value to the point of inflexion of the [illegible] distribution curve (Figure 2). The standard deviation [illegible] equated to the mean value as defined in equation 2.

$$CV = \frac{100}{\bar{x}}\sqrt{\frac{1}{T}\int_0^T (x_i - \bar{x})^2 dt} \qquad \textbf{(Eq. 2)}$$

It can be considered that if the fibre assembly [illegible] tested is normally distributed with respect to its [illegible] variation, a conversion is available between the two [illegible] of calculation according to the equation 3.

$$CV = 1.25\ U \qquad \textbf{(Eq. 3)}$$

Apart from this yarn irregularity it is important, in [illegible] to produce a quality yarn, to provide data on the [illegible] and kind of imperfections. These are commonly [illegible] faults and are of three kinds (Figure 3):

- thin places - a decrease (50%) in the mass [illegible] short length of about 4 mm;
- thick places - an increase in the mass, usually [illegible] than 200% and lasting more than 4 mm;
- NEP's - huge mass of yarn in a short length, typ[illegible] from 1 to 4 mm.

The number of faults and mass measurements [illegible] quality rating of the product. An accurate measurem[illegible] these properties is of major importance [2].

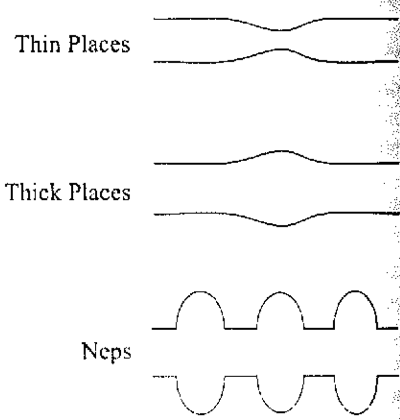

Figure 3 – Types of yarn faults

3. Experimental procedure

The experimental set-up developed (Evenness Tester) use an Uster Tester I equipped with an 8 mm capacitive sensor and a LabVIEW based data acquisition for data collecting and signal processing (Figure 4). This tool allows setting the normal parameters such as speed, yarn length and sampling rate. The input signal to the data acquisition system is a tension (0 to 10 V) from the galvanometer proportional to the dielectric between the plates of the condenser sensor, i.e. proportional to the yarn mass [6].

After the validation with an Uster Tester III equipment (the compared values were: U%, CV%, number of thick and thin places; the parameters used in data collection were the same in both apparatus), the objective was to extract 1 mm mass values, using measurements of 8 mm length sensor acquired with a sample rate proportional to a 1 mm yarn length. Sequential samples of the mass signal are acquired in such a way that the length interval is the 1mm range.

The method proposed determines the yarn mass variation in portions of 1 mm, from 1 to 8 mm, using an 8 mm experimental measure. Figure 5 displays, graphically, the method employed in order to obtain this measurement.

To evaluate the value of this new segment, it is necessary to know previous samples in the 1mm range.

In order to obtain the mass value of the yarn with a step of 1mm it is always necessary to know the mass of previous samples, using the following approach,

$$a_i = \sum_{j=i-7}^{i} a_j - \sum_{k=i-8}^{i-1} a_k + a_{i-8} \qquad \textbf{(Eq. 4)}$$

where a_i are the values in the 1mm range.

As the sums are the values of each acquired sample with the 8mm sensor, there is only the need to know previous values of a. To achieve this, the calibration procedure corresponds to acquiring signal from the sensor without material.

To analyse the influence of measurement length (portions of 1 to 8 mm) in the determination of yarn evenness, a statistical study was carried out. In order to evaluate the hypothesis that several population means are equal an Anova method in SPSS package (Statistical Package for Social Sciences) was used [7]. The significant F statistics obtained only indicates that the population mean are probably unequal; it does not point out where the differences are.

In order to do so, we used a Scheffe method for pairwise comparisons of means. Pairs of means that are significantly different at the 0.05 level are those obtained in comparison with 1 mm range.

As can be seen from Table 1 the only measurement that is significantly different is the one obtained from 1mm range (subset 4). The other measurement lengths are correlated in groups of four, as point out by subsets 1 to 3.

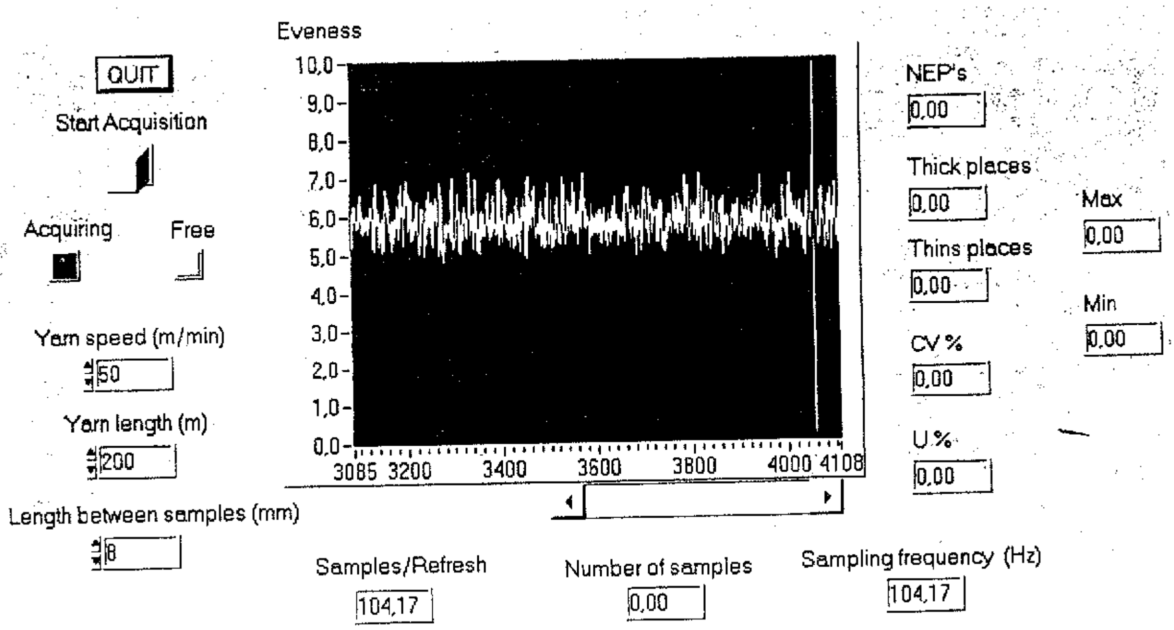

Figure 4 – Developed data acquisition software window

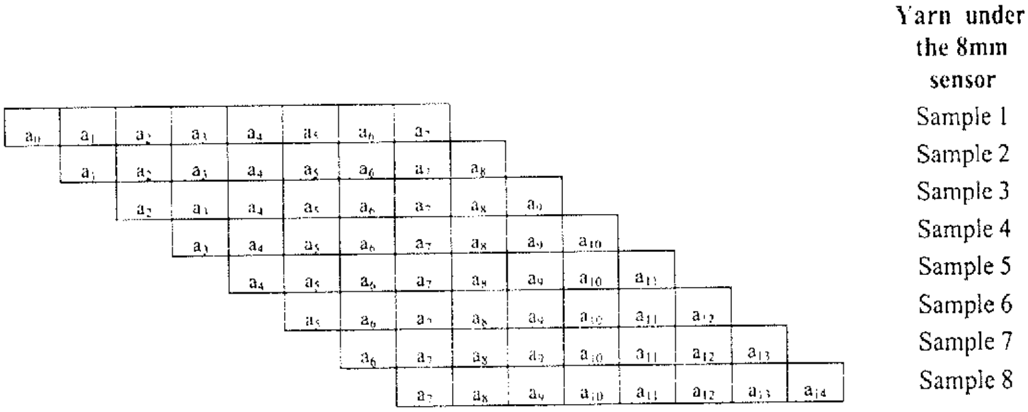

Figure 5 – Method used in the determination of mass in 1 mm yarn length

The research objective is to compare the values of 1 mm measurement obtained with the mathematical model developed with a specific sensor that measures directly yarn mass in 1mm range.

This technique will allow a great technological advance, face to the results obtained from the traditional measurements of 8 mm.

In order to obtain 1 mm measurements without mathematical models we intend to use an 1 mm capacitive sensor.

Due to technology used in development of this kind of sensors, we did not find an capacitive sensor of parallel plates with 1 mm length with ability to detect the irregularities of the yarn.

An 1 mm diameter cylindrical sensor could be the solution. These sensors are normally used to detect the proximity of objects, having as reply an ON/OFF digital output; nevertheless in our market research we found one with an analog output.

The behavior of the equipment, with the sensor pointed with respect to air, is expressed in a output tension of about 15 V. As an object enters in the area of detection of the sensor the tension acquired decreases.

With the aim of testing this kind of sensors, several materials with the different dielectric constants were tested (plastic, paper, wood). This sensor distinguishes properly this kind of material, for example a plastic object causes a higher decrease of the output tension than paper or wood do, at the same experimental conditions.

After this preliminary study some tests with cotton yarn with knots were carried out. When the sensor was pointed to the knot the tension lowered some volts. But the analysis of a cotton yarn without irregularities introduced was not possible because no alteration in the output signal was visible. We tried then to regulate the measurement instrument to get the maximum resolution. We approached the yarn to the sensor, but its presence was not detected or at least, it was not possible to distinguish the alterations caused by the yarn from the oscillations of random noise inherent to the equipment.

Table 1 - Means for groups in homogeneous subsets are displayed (Scheffe Method)

Measurement length	*Sample size*	*Subset for alpha=0.05*	*Subset for alpha=0.05*	*Subset for alpha=0.05*	*Subset for alpha=0.05*
		1	2	3	4
8.00	6	11.4537			
7.00	6	11.5582	11.5582		
6.00	6	11.6440	11.6440		
5.00	6	11.7397	11.7397	11.7397	
4.00	6		11.8370	11.8370	
3.00	6			11.9481	
2.00	6			12.0204	
1.00	6				12.3565
Sig.		0.075	0.091	0.086	1.000

An attempt to reduce the noise, through the introduction of a typical low passes filter between the output of the amplifier and the input of the measure device, was implemented. It was verified that this filter did not bring visible improvements and the idea was abandoned.

In order to improve the sensitivity of the equipment we coupled a metallic board to the external plate of the sensor (Figure 6). By doing this, the section of one of the two constituent plates of the capacitor (sensor) should improve and with this, it would have better sensitivity.

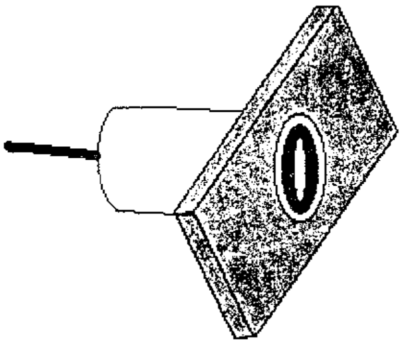

Figure 6- A metallic board coupled to the external plate of the sensor

Although test results were positive, the output signal due to the yarn presence continued to be insignificant.

Due to the results obtained, a different sensor configuration was tried: two sensors with respective conditioning electronics were guided to measure simultaneous the same point of the yarn. The acquired signals were summed. The idea was to get a signal with the double of the amplitude that would improve the resolution of the system.

The use of the two sensors in frontal position (Figure 7) improves the immunity to the oscillations of the wire, but on the other hand, as the sensor is essentially metallic, the presence of a sensor affects the measurement of the other. This fact harms the reading seriously as the metal of the opposing sensor starts to have a more important role than that of the yarn.

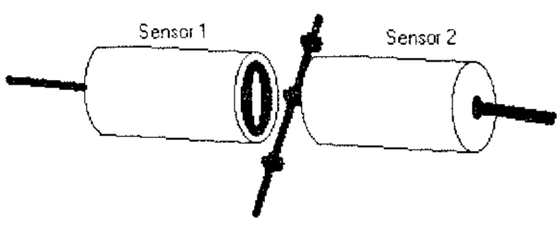

Figure 7 - Two sensors in frontal position

Another trial was placing the sensors out of phase of a known pitch (Figure 8) and, with signal processing features, add the two signs with respective delay in relation to the position. Again the experience was unfruitful: none of the sensors detected the presence of the yarn.

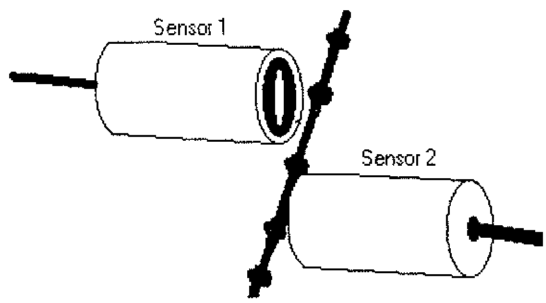

Figure 8 - Sensors out of phase of a known pitch

At the moment even without significant values obtained directly from the 1 mm sensor we are still trying the best configuration to obtain this objective.

4. Results

With the yarn mass evaluated signal it is possible to calculate all evenness values in several segment length, which is of utmost importance to extract information regarding the quality of the yarn.

In fact, only with values in this range it is possible to count the number of NEPs in the yarn that dramatically reduces its quality.

The algorithm proposed for obtaining the yarn mass in multiples of 1 mm (from 1 to 8mm length) was statistically tested. The only measurement that is significantly different is the one obtained from 1mm range. All the other multiple lengths (2 to 8 mm) are correlated in groups of four.

In order to validate experimentally the 1 mm measure several tests were developed using a cylindrical capacitive sensor with a 1 mm diameter.

Yet the development of a specific sensor that measures directly 1mm yarn mass is still under exploitation.

5. Conclusions

The results obtained with the mass yarn evaluated in 1 mm range are of utmost importance for a correct detection of irregularities as most of them have a short length.

A mathematical model was developed and statistically validated in order to obtain yarn mass in 1 mm range. Yet, an experimental measure in that range is still a target. The procedure described in the present paper is a low cost approach for operation. It has the advantage of using a sensor that measures the yarn mass, but has the drawback of suffer influence in the dielectric due to electric noise.

An off the shelf cylindrical capacitive sensor with an 1 mm diameter was used. The sensor has an electronic amplification stage and signal conditioning. The output signal is a tension between 0 and 15V and is directly correlated with the dielectric constants of samples materials. Several kind of materials were analysed, namely: metallic, paper, cotton mesh and cotton yarn. The analysis of yarn presents a variation of some mV coupled with noise.

Several experiments were done in order to filter and amplify the signal output with relative success.

In order to improve the sensibility, a metallic board was coupled to the external part of the sensor. Also, two sensors were used, positioned one in front of the other. This experiment improved the immunity to oscillations due to yarn position but the metallic parts of each sensor influences the other.

Nevertheless, results are still under the goal and mixed combination of sensors is being tested. The results point out that the evaluation of yarn mass, with this approach, is feasible at least in the 4 mm range.

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