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"A review on yarn quality parameter measurement"

Deepganga.I.Dhang
Department of Electronics
Textile and Engineering Institute,
Ichalkaranji 416115

V. Jayashree, IEEE Member
Associate Professor
Department of Electronic & Telecommunication
Textile and Engineering Institute, Ichalkaranji
416115

Abstract- **Yarn quality depends upon physical properties like yarn strength, unevenness, heaviness and geometrical parameters like diameter. This paper presents the research review on Yarn Diameter Measurement (YDM) and also proposes new method for YDM using image processing. There are traditional methods as well as electronic methods which are currently used for Yarn Quality Parameter Measurement (YQPM). The traditional method for YDM has two methods viz., rod method and travelling microscope method whereas the electronic methods used for YQPM are optical and capacitive sensor method. These methods are based on sensor characteristics for measurement of yarn diameter unevenness and yarn irregularity. The principle used for optical sensor is based on an absolute measurement principle which computes the difference between the quantity of light received without yarn and that received with yarn. The output image of optical sensor is subjected to simple image processing algorithm to obtain yarn diameter, whereas in the capacitive sensor method yarn mass is computed in terms of voltage when yarn is inserted between two metal plates of capacitor which is proportional to changes due to variation in linear mass of yarn. Focus of this review is mainly on YDM. As the sensors of both electronic methods are prone to errors due to environmental effect, an alternative method using entirely image processing technique for Yarn Diameter Measurement (YDM) is suggested in this paper.**

Key Words- Yarn Strength, Unevenness, Heaviness, Optical sensor, Capacitive sensor, Image Processing.

I. Introduction

The most important and first of the textile industry is the quality analysis and control of yarn which decides fabric quality. The correct and accurate evaluation of yarn parameter measurement is a subject of major importance to the textile industry, as the final fabric quality directly depends on the yarn quality. It is observed that nearly 10% of industrial expenditure occurs in the quality control of fabrics. Fabric property is dependent on yarn quality and yarn quality depends upon its certain physical properties like yarn strength, unevenness, heaviness and geometrical parameters like diameter. Yarn diameter is the most important fabric parameter which decides the fabric properties viz., cover factor, porosity, thickness, air permeability etc.

There are two traditional methods used for yarn diameter measurement viz., rod method and traveling microscope method. The electronic methods for this purpose are optical and capacitive sensor method. But the results obtained by these methods are prone to errors due variation in temperature, pressure and humidity. An alternative to these methods is yarn diameter measurement is using purely image processing algorithms.

In this direction this paper presents a research survey on yarn diameter measurement methods such as traditional methods and electronic method. A well known traditional method set by Textile Testing Bureau of Indian Standards [1], [2], [3]. Current researches for YQPM using coherent optical signal processing is reported by V.H.Carvalho et al. [4]. A comparative study of yarn diameter measurement using optical and capacitive sensors was reported by the same author in [5] who have also published a paper on automatic yarn characterization system [6]. There are still very few researches reported on YDM using image processing. The brief review of these researchers work and summary is explained in the next section.

II. Theoretical Background of YQPM

A yarn consists of number of fibres which are spun into a strand. The basic property of yarn is variation in mass per unit length along the yarn. A yarn in which the variations in mass per unit length are small is said to be even, while the one in which this quantity exhibits considerable changes is regarded as irregular. Yarn is used in production of textile, sewing, knitting, weaving, embroidery and rope making. The yarn configuration is as shown in Fig 1.

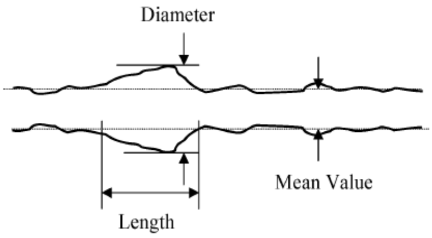

Fig.1. Yarn configuration example

The variation in the linear mass of textile yarns is a key quality parameter in the textile industry. Yarn irregularities are generally classified as thick place, thin places and neps which are explained as below:

• **Thick places:** It is the region of yarn where the local linear yarn mass is well above the average value normally by at least 35%.

• **Thin places:** It is the region of yarn where the local linear yarn mass is well below the average value normally by at least – 30%.

• **Neps:** There are regions of yarn where local linear mass increases at least 100% of the normal region. These regions are called as neps.

• **Hairiness:** It specifies the length of hairs in a meter of yarn.

Due to these irregularities the diameter of yarn varies with variation in linear mass of yarn. Based on the literature survey and exsisting methods and practices, the YDM method can be classified as shown in classification tree of Fig2.

Yarn Diameter Measurement

A.Traditional method

a. Rod method

b.Travelling Miscroscope method

B.Electronic method

a. Optical sensor method using image processing

b. Capacitive sensor method

Fig.2. Classification Tree for YDM

A. Traditional methods

Traditional methods of yarn diameter measurement are most popular and robust. These methods have been investigated in very early days at the time where no electronic methods were existing. Traditional methods work for all types of yarn such as cotton, polyester, shefon etc. These methods are still used in industries and institutes for yarn quality measurement. The traditional methods are rod method and travelling microscope method. These are explained further.

A .Rod Method

In rod method, yarn is wound on the glass rod of known diameter taking care such that no yarn turn overlaps each other [1], [2]. The yarn diameter is calculated by dividing the length of yarn wound on rod by the total number of turns and is given as below,

$$D = L_{yr}/N \qquad (1)$$

where, D is diameter of yarn,
L_{yr} is length of yarn turn wound on glass rod

N is number of turns of yarn wound on glass rod

b. Travelling Microscope Method

In this method the yarn is kept under the travelling microscope having reference pointer. This microscope has vernier caliper for measurement of yarn diameter [3]. After yarn image is magnified and focused, the reference pointer of microscope is adjusted on the first edge of the yarn along the diameter and the corresponding reading of caliper scale is noted as d_1. Next the microscope reference pointer is adjusted to second edge of the yarn again along the diameter and again the caliper reading is noted as d_2. The diameter is then calculated by obtaining the difference between d_1 and d_2.

$$D = d_1 - d_2 \qquad (2)$$

In this way successive readings are taken at different places of yarn. Average of several such readings is taken as the actual yarn diameter.

B .Electronic Methods

The electronic methods are most widely used now days for detecting yarn irregularities, hairiness and yarn diameter. There are different sensors used for YDM such as optical and capacitive sensors as suggested in [4], [5], [6].

a. *Optical Sensor*

Vitor H. Carvalho et al. has reported on yarn diameter measurement using coherent optical signal processing [4]. In their method a coherent optical sensor technique is used to quantify yarn irregularities associated with diameter variations. These are also linearly correlated with yarn mass variations. They carried out a diameter characterization under real-world conditions for cotton yarn of three different linear masses viz.; 49.17, 62.00 and 295 g/Km. They have reported a correlation of this method with capacitive measurements [5].

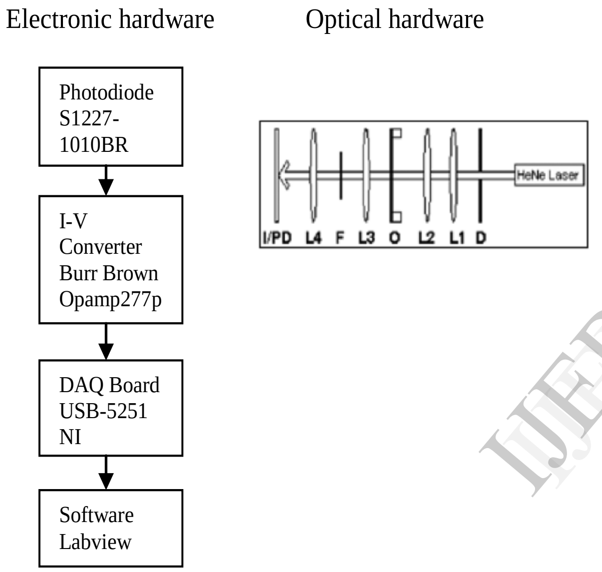

Fig3.Electronic and optical hardware

The setup as shown in Fig 3 consisting of electronic and optical arrangement was used by them. The objective of the optical setup was to obtain the signal which is directly related to the yarn diameter in the final image plane (I) i.e at position of the photodiode (PD) in Fig. 2. Coherent light (HeNe) laser with 15 mW was first spatially filtered by a diaphragm, (D) to guarantee a smooth transverse spatial profile, and then passed through a two planoconvex lens beam L1 and L2 with focal lengths of 60 mm to produce a beam diameter of roughly 1 cm. This beam was directed to the yarn, fixed in the object holder (O). Lens L3 forms a spatial Fourier transform of the light transmitted through the object plane at its principal focal plane (F). The size of the final image was controlled by the final lens L4. Then they have designed an electronic hardware to obtain a voltage that is proportional to the total optical power incident on the detector.

The steps and equations used for this method are given below.

Sensitivity measurement:

To compute the sensitivity of the setup, firstly they have measured the signal in volts without yarn V_{sf} & with yarn V_{cf}. The average of signal with yarn V_{cfa} was obtained, which considers the average diameter. Then they have calculated the average signal blocked by the yarn was computed as,

$$V_f = V_{sf} - V_{cfa} \tag{3}$$

Yarn diameter measurement:

The theoretical relation for the yarn diameter based on the linear mass was used and is given by,

$$d(mm) = 4.44 \times 10^{-2} * \sqrt{(tex(yarn\ linear\ mass\left(\frac{g}{km}\right))/\rho} \tag{4}$$

where, tex is unit for linear mass of yarn considering the sample length, S_l of the system & have estimated they have estimated the average area blocked by the yarn in the image plane I,

$$A_{fsj} = S_l * d\ (mm^2) \tag{5}$$

The attenuation sensitivity for the tested yarn was determined by,

$$S_a = Vf / A_{fsj}\ (V/mm^2) \tag{6}$$

For yarn diameter determination they have computed the area blocked by each yarn sample given by,

$$A_i = V_{sf} - V_{cf} / S_a \tag{7}$$

Then the diameter in each yarn sample was determined by,

$$d_i = A_i / S_l \tag{8}$$

Yarn irregularity measurement:

Yarn irregularities was computed by first measuring the signal without yarn V_{sf}, then the signal with yarn was measured V_{cf}. The average of all the samples was determined as V_{cfa} . The reference was set up as,

$$V_r = V_{sf} - V_{cfa} \tag{9}$$

Percentage variation of each sample with yarn is proportional to irregularity which was computed as,

$$d_i \% = 100*(V_{sf} - V_{cf}) / V_r \qquad (10)$$

They have acquired 6000 samples in steps of 1 mm for three different linear masses of 49.17, 62.00 and 295 g/Km for each yarn. For thicker yarn results obtained were 1.22mm and 0.99mm for maximum and minimum diameter respectively for above stated yarn. For thinner yarn the maximum and minimum diameter obtained was 0.147 mm and 0.103mm respectively.

In another paper by Vitor H. Carvalho et al. use of an optical sensors arrangement as shown in Fig.4 to perform yarn analysis [5] was used. A cotton yarn of 295gm/km was used for 1mm yarn diameter samples. It is based on an absolute measurement principle i.e algebraic difference between the quantity of light received without yarn and that received with yarn for each analyzed sample.

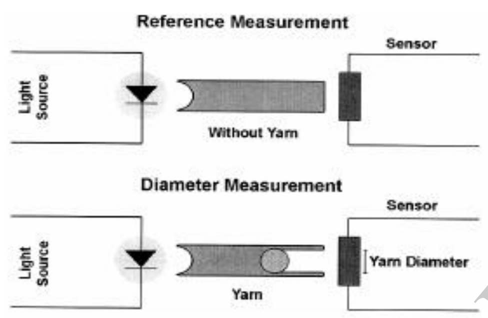

Fig.4 Diameter measurement principle using optical sensor

A coherent light source from laser diode was used. They have used the procedure similar to reported in [4].

It was observed that the laser light, which was blocked by the yarn produces black shadows in the image plane. Simple image processing algorithm of subtracting the reference optical image without yarn from the optical image with yarn was computed. The hairiness shadows were removed with the help of high pass spatial filter. The minimum / maximum variation in the diameter measurement result obtained was -14% / 13.81% respectively by them from normal [5].

b. Capacitive sensors

Research based on usage of capacitive sensor is presented by Vitor H. Carvalho et al [5]. They have constructed the experimental setup which consists of personal computer (PC) with a data acquisition system together with 1mm capacitive sensor.

The sensor consists of three metallic conductors which are placed in parallel to form two capacitors with a common electrode as shown in Fig 5.

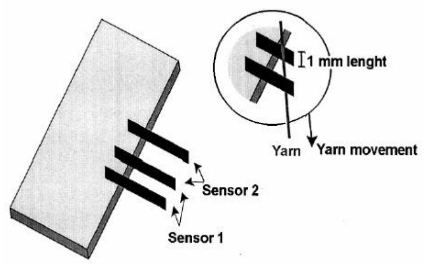

Fig.5. Arrangement for diameter measurement using capacitive sensor

Fig 5 shows the principle of evaluation of diameter measurement using capacitive measurement. Parallel plate capacitive sensors were formed using two electrodes of cross section area A, separated by a distance d. The capacitance obtained depends on the plates section, their distance and dielectric susceptibility of material between the plates. A relationship has been established between the capacitance and the yarn mass, as the dielectric susceptibility between plates (yarn) will vary depending on the yarn composition and diameter.

The capacitance variation is converted into a voltage signal which is then amplified. This capacitance is measured by using the equation:

$$C = €0\ €r\ A/d \qquad (11)$$

Equation (11) shows that if the dielectric constant (€r) is changed, the capacitance also changes. This phenomenon occurs when the yarn is inserted between two the plates.

They have developed a system as shown in Fig 6 for the analysis of a cotton yarn with a linear mass of 295 g/Km.

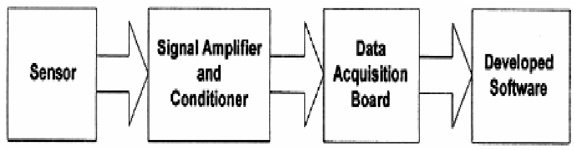

Fig.6. Yarn mass measurement flowchart

The Integrated Circuit(IC) MS3110 used performs functions related to transducer amplification and signal conditioning. Then the sensor capacitance variation is converted into a voltage signal and amplified. The second order low pass filter is used to attenuate high frequency interference and to improve SNR. The filtered signal is then amplified. The signal output is converted into a digital signal using ADC which is included inside the data acquisition DAQ board which is then monitored with Lab VIEW developed software. The software developed allows storage, manipulation and processing. The standard deviation obtained for capacitive sensor method was 4.36%.

The minimum and maximum variation obtained for yarn mass measurement was -13.47%, 13.35% resp [5]. However capacitive sensor very sensitive to humidity levels, causing error in the results. So to overcome the problem of sensor sensitivity to humidity an integrated amplification circuit was used to auto correct effect of humidity on capacitive sensor.

Another system developed by Vitor Carvalho et al. evaluates a diameter characterization using photodiode array (optical setup) for 0.5mm width samples and linear mass variation using capacitive sensor on samples of 1mm [6]. This system is named as Yarn System Quality (YSQ) which firstly uses photodiode array (optical setup) for diameter evaluation. They have evaluated the statistical parameters such as U absolute mean deviation given by,

$$U = \frac{\text{sum of deviation from the mean}}{\text{total number of observations}} \tag{12}$$

And CV coefficient of variation given by,

$$C = \frac{\textit{standard deviation}(\sigma)}{\textit{arithmatic mean } (\overline{x})} \tag{13}$$

The optical setup as shown in Fig 7 consisted of two beam splitters S1 and S2 placed in Src, two high pass filters, single low pass filter, Fourier Lens FL and L1 to L4 plano-convex lenses.

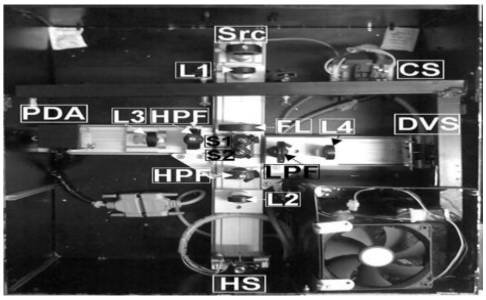

Fig.7. YSQ optical setup

The first beam splitter makes an equal signal division, whereas second beam splitter transmits the signal 48% to the forward direction. This was done because the yarn contours and hairiness require stronger signal intensity and the majority of the signal component is filtered by high pass filter. The images obtained by lenses L3 and L4 showed only the yarn core with hairiness part has removed. Only the contours and hairiness have filtered by low pass filter maintaining the strongest signal components. The image obtained in the image plane of lenses L2 and L3 has only yarn contours and hairiness was highlighted by high pass spatial filter (the yarn core and light which was not blocked by the yarn were eliminated). The other image obtained in the image plane of lens L4 has only a shadow of the yarn core and light that is not blocked by the yarn which is transmitted by low pass spatial filter (the yarn contours and hairiness were eliminated). After removal of hairiness only the yarn core remains in the image which is further used to obtain diameter.

The precise yarn diameter is obtained using line profile analysis as shown in Fig8. They have carried out line profile analysis for 512 pixels, in which the red plane intensity line profile signal was proportional to the voltage signal which results from the hairiness distribution image of the linear photodiode array. The yarn diameter was determined by considering the number of pixels between the left and right yarn contour pixels with the optical amplification of 0.37 and the pixels pitch.

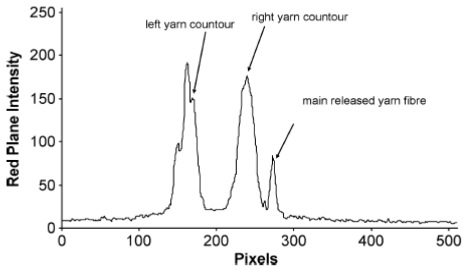

Fig.8. Line profile analysis

Secondly they have also used capacitive sensor method for yarn mass evaluation similar to [5]. The sensor capacitance variation was converted into a voltage signal and then amplified.

The results obtained using optical sensor in terms of absolute mean deviation (U) was 15.68% & coefficient variation (CV) was 20.20% whereas that obtained by the use of photodiode arrangement for mean deviation (U) was 16.43% and coefficient variation (CV) 22.91%. This YSQ test helps to monitor the quality of yarn produced, which results in a superior production efficiency. The most important advantage of this system is its compactness.

The results of the papers in [4], [5], [6] are summarized below.

Table1: Comparision of research review for YQPM & YDM

Author	Weight of samples/ type/ nos.	Sensor	IP algorithm used	Results	comments
Vitor Carvalho et al.[4]	295g/Km of 100% cotton, 6000 images	optical	*ABDM	Max. Dia: 1.22 mm	Diameter obtained matches with traditional method
				Min. Dia: 0.99 mm	
	4.29g/Km of 100%cotton 6000 images			Max. Dia: 0.147 mm	
				Min. Dia: 0.103 mm	
Vitor Carvalho et al.[5]	295g/Km of cotton	optical	*ABDM	Variation: 0.17 %	----
		capacitive	**YMM	Variation: 0.03 %	
Vitor Carvalho et al.[5]	59g/Km, 22g/Km	Photodiode array sensor	Signal processing	U(%): 15.68	----
				CV(%): 20.20	
	59g/Km, 22g/Km	Capacitive & optical sensor	**YMM	U(%): 16.43	
				CV(%): 22.91	

*** ABDM Absolute Diameter Measurement:**
Absolute algebraic difference between light received without yarn and that received with yarn.

**** YMM Yarn Mass Measurement:**
Evaluates the yarn mass on the variation of capacitance, when the yarn is inserted between two metal plates of capacitor.

From the comparison of Table 1, it is observed that in the sensor based methods diameter accuracy varies due to environmental conditions. So an alternative method for YDM using image processing is proposed here.

III. Proposed Work

For the proposed yarn diameter measurement system the images of cotton yarn sample will be captured by Zeiss Microscope with 1.3 Mega-pixel & image resolution of 1280×1024 camera. These images will be then subjected to preprocessing operations viz. filtering by median filter or Wiener filter etc[7]. For the image analysis morphological operations / FFT may be performed to find the object of interest in the image after removing yarn protrusions.

After finding the region corresponding to object of interest i.e. yarn region, an appropriate algorithm could be applied to measure yarn diameter in terms of pixels.The computed diameter can then be compared with the yarn database for finding the accuracy of yarn diameter obtained by the proposed image processing algorithm.

IV. Conclusion

Yarn diameter is an important quality parameter out of many fabric parameters and properties. In this paper we have reviewed YDM methods using optical/ capacitive sensors. Researchers have reported the measurement and analysis of yarn irregularity, diameter and variability based on different principles of sensors. The evaluation of YQP is different. They are accurate in performing the function efficiently in their own domain.

However, it is found that with the diameter measurement it is possible to determine the irregularity intervals of a given yarn. However the techniques have certain limitations that they are sensitive to atmospheric temperature and humidity. So to overcome these drawbacks a new system can be developed using image processing technique which may overcome the manual errors as well as sensors due to atmospheric variations.

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