An Overview Over Yarn Mass Parameterization Methods

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Abstract—**This paper presents a description of two different approaches to determine and measure the yarn mass parameters. The first approach (YSQ) is based on: a capacitive sensor to determine yarn mass and on optical sensors with Fourier optics to determine yarn hairiness and diameter. The second approach determines all yarn mass parameters using image processing techniques. Both approaches present innovative, low cost, portable and high-precision yarn evaluation testers, for quality control of yarn characteristics under laboratory conditions. It is believed that the solution based on image processing techniques allows a high level of advantages, among others, reduced hardware and maintenance necessities with a very high resolution. The software was developed in LabVIEW, using the toolbox IMAQ Vision for image processing.**

Keywords-yarn mass parameters; optical signal processing; yarn hairiness; yarn diameter;capacitive sensors; optival sensors; image processing.

I. INTRODUCTION

The correct and accurate evaluation of yarns is a subject of major importance to the Textile Industry, as the final fabric quality depends directly on the yarn quality. To undertake these yarn tests several companies have developed specific equipment. The Tester 5 from *Uster* [1] is important for its relevant contribution to the development of quantitative yarn characterization.

However, these yarn testers have a significant cost, require a considerable area for their installation and present limited resolution and precision in the evaluation of certain yarn parameters.

As a result, many yarn producers do not have their own yarn testers and, instead, choose to subcontract dedicated testing laboratories for yarn quality determination. This process is time consuming and eliminates the possibility of acting in useful time during yarn production, reducing efficiency.

To overcome these drawbacks, we have developed new equipment, entitled YSQ (Yarn System Quality) [2]. The YSQ measures the yarn diameter, the yarn hairiness and the yarn irregularity based on optical and capacitive sensors. Moreover, it integrates an external module to obtain yarn production characteristics, based on image processing (IP). At present, in the Textile Industry there are no available commercial equipment or known prototypes to obtain these characteristics automatically. Instead, they are obtained manually by human ocular inspection or by using an analogue microscope, being the results susceptible to errors [3, 4].

The high precision levels of parameterization performed by the YSQ, together with its low cost and high portability make it a reliable and efficient solution for the Industry.

Furthermore, and after studying the image processing possibilities in the production characteristics module of the YSQ, we started considering to specify the traditional yarn mass parameters as technological solutions based on IP, as they are characterized by high reliability and efficiency and can present some advantages over the traditional methods (very low cost, small size and weight, reduced hardware, reliability and possibility of very high resolution).

IP based applications have been used in the textile field since 1964 [5], although they have not yet been converted to viable quality control methods [6].

Due to its influence on the quality of textiles, yarn hairiness is considered to be one of the most significant parameters. In textile industry the equipment used to measure the hairiness are based on photoelectric methods, like the Shirley's apparatus and the Uster Tester 3 devices [7]. Several algorithms are currently under development to characterize the yarn hairiness with IP. The method proposed by [8], measures the real length of the protruding fibers from the yarn core, as well as, their number in order to quantify hairiness. Reference [9] introduced a new method to measure hairiness, based on the assumption that the hairs close and parallel to the yarn core would be a better indicator of hairiness, proposing then a new parameter: Hair Area Index. This concept measures the area covered by hairs and is divided by the area of the yarn core to obtain a dimensionless quantity. Nevertheless, it is still necessary to develop algorithms to detect and characterize loop fibers length and to clearly distinguish between protruding fibers and loop fibers when they are interlaced.

Another important parameter is the yarn diameter, since it is used to predict fabric structural parameters such as width, cover factor, porosity and fabric comfort [10]. The characterization of yarn diameter with IP can also be achieved with algorithms already applied to the extraction of yarn core [11, 12]. But, algorithms to measure the exact length of yarn irregularities (thin places, thick places and neps) [13] need to be developed. The characterization of yarn mass can be inferred from the yarn diameter, depending, among other parameters, on the yarn fiber density and porosity [14, 15].

Besides the YSQ, this paper also presents a new solution to automatically characterize the mass parameters of yarn and a preliminary study to identify and quantify the loop and protruding fibers (hairiness) based on IP.

This paper considers the following organization: Section I – Introduction, presents an overview over the traditional methods of yarn parameterization as well as describes the evolutions obtained with the solutions presented in this work; Section II – Textile Parameters Theoretical Considerations, describes the theoretical concepts of the yarn parameters quantified; Section III – YSQ Sensors System, presents the electronic and optical hardware used as well its configurations over the technical solutions of this work; Section IV – Yarn Mass Parameterization Using Image Processing, describes the image processing algorithms used to quantify the yarn parameters measured in this work; Section V – Conclusions and Future Work, presents the final remarks and the project following steps.

II. TEXTILE PARAMETERS THEORECTICAL CONSIDERATIONS

This section describes the typical configuration of a yarn, the definition of faults, hairiness and the most important yarn production characteristics [3, 4, 16-18].

A. Yarn Configuration, Faults and Hairiness

The most important parameters used to specify yarn quality are linear density, structural features and fibre content. An example of yarn configuration is shown in Figure 1.

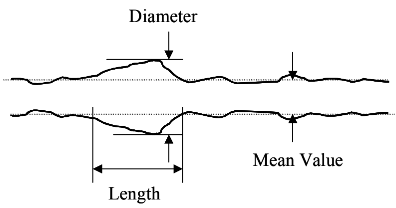

Figure 1. Yarn configuration example

As Figure 1 suggests there is a direct relationship between the variation of yarn mass and the yarn diameter. Thus the calculation of the diameter can be obtained by d(mm) = 0.037sqrt(Tex) , where Tex is the mass of the yarn in one kilometer of length (g/km) – yarn linear mass. This relation allows the possibility of determining yarn irregularity based on yarn diameter measurements.

The number of yarn faults and yarn mass measurements enables a quality rating of the products tested. There are three kinds of yarn faults, classified as (Figure 2): thin places - a decrease in the mass during a short length (4 mm); thick places - an increase in the mass, usually less than 100 % of the sensitivity, and lasting more than 4 mm; neps - huge amount of yarn mass (equal or superior to 100 % of sensitivity) in a short length (typically from 1 mm to 4 mm).

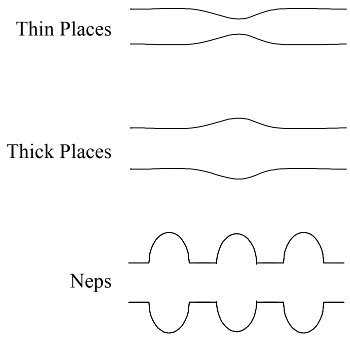

Figure 2. Types of yarn faults

Apart from faults, another important feature which greatly influences the appearance of fabrics is the level of yarn hairiness. Hairiness is the result of released fibres over the strand. Figure 3 presents an example of hairiness [3, 17, 19-21].

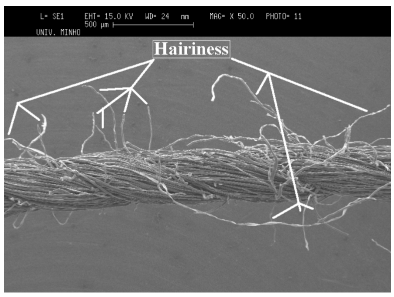

Figure 3. Identification of yarn hairiness in an electron microscope picture

The hairiness coefficient (H) specifies the length of hairs in a meter of yarn.

Measurements of the yarn hairiness, mass and diameter, allow the determination of several statistical parameters which are relevant when characterizing yarn quality and, subsequently, the fabrics.

B. Yarn Production Characteristics

Four important production characteristics of commercial yarns are the fiber's twist orientation, the number of cables (folded yarns and non-folded yarns), the folded yarn twist step and the folded yarn twist orientation [3, 4]. The two final production characteristics mentioned are only obtained when dealing with folded yarns. Figure 4 identifies the four described production characteristics using as an example an electron microscope image of a 4.2 g/km cotton yarn. It is a folded yarn as two separate cables are clearly visible. The folded yarn twist step (d) is 0.3334 mm, with an orientation clockwise and a fiber twist orientation opposite (anti-clockwise) to the folded yarn direction.

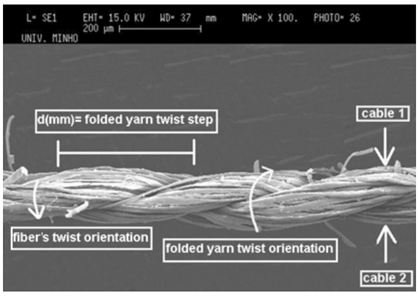

Figure 4. Identification of the yarn production characteristics in an electron microscope picture

III. YSQ SENSORS SYSTEM

This section describes the optical and electronic setups used to obtain the measurements of yarn hairiness, yarn diameter and mass variation in the YSQ [22-24]. Moreover, it also describes the hardware of the external YSQ module, employed to obtain the yarn production characteristics.

A. Three Directions Optical Configuration – Main Module

In order to reduce YSQ volume and cost, one diode laser source was employed (Eudyna FLD6A2TK [18]) to establish three different beams. This single source (Src) was divided in three beams using two beam splitters (S1, first beam splitter division 50 % / 50 % of full signal for each resultant direction, S2, second beam splitter division ≈ 2 % / 48% of full signal for each resultant direction), as presented in Figure 5.

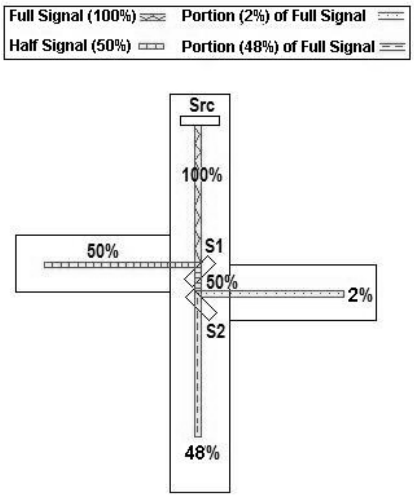

Figure 5. Light signal source intensity beam division

Figure 6 presents the YSQ optical setup employed where, Src is the diode laser source that emits light at 685 ± 10 nm in both a single transverse and a single longitudinal mode, with a low aspect ratio of 1.3, the two HPF represent a high-pass spatial filter, LPF is a low-pass spatial filter, FL is the Fourier lens, S1 is the first beam splitter, S2 is the second beam splitter and L1 to L4 are plano-convex lenses.

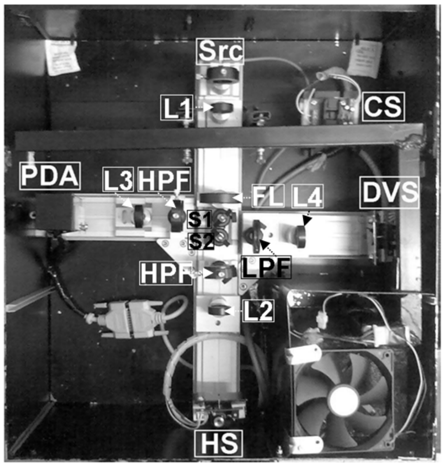

Figure 6. YSQ optical configuration

Observing Figure 6 one can see that the beam splitters were placed immediately after the Fourier lens. As in this case there are two different types of spatial filters (high-pass filters, HPF and low-pass filters, LPF), the beam division should be performed before the signal filtering to allow the application of different filters. Figure 7 presents an image obtained in the image plane of lenses L2 (HS-Hairiness Sensor) and L3 (PDA-Photodiode Array), where only the yarn contours and hairiness are highlighted by the high-pass spatial filter (the yarn core and light which is not blocked by the yarn were eliminated).

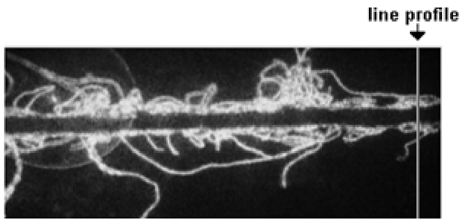

Figure 7. Image plane of lenses L2 and L3

Figure 8 presents an image obtained in the image plane of lens L4 (DVS-Diameter Variation Sensor), where only a shadow of the yarn core and light which is not blocked by the yarn are transmitted by a low-pass spatial filter (the yarn contours and hairiness were eliminated).

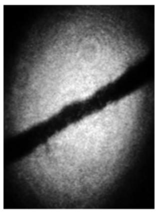

Figure 8. Image plane of lens L4

B. Electronics Configuration – Main Module

The images obtained in the image plane of lenses L2 (HS) and L4 (DVS) are aquired by two equal configurations of the developed electronic yarn measurement hardware shown in Figure 9 [22, 23].

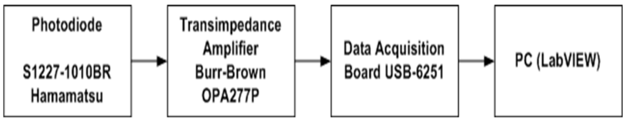

Figure 9. Custom developed electronic yarn measurement hardware for the HS and DVS

The measurement of precise yarn diameter (PDA) was based on line profile analysis [24]. Figure 10 presents the line profile analysis indicated in Figure 7 for 512 pixels, where the red plane intensity line profile signal, is proportional to the voltage signal resulting from the hairiness distribution image of the linear array photodiodes.

Considering the typical hairiness distribution profile (Figure 10), starting from the yarn core signal (reduced signal intensity of between the two main distribution peaks), in the right and left directions, respectively, the first signal peak intensity is obtained for the yarn contours.

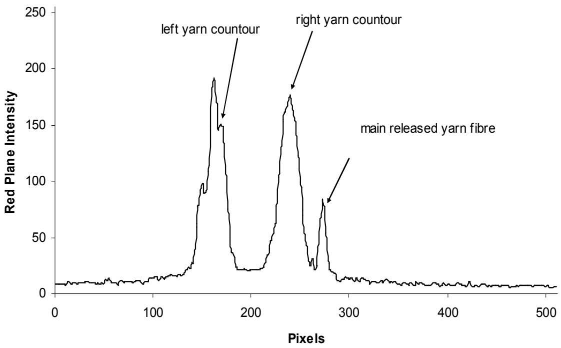

Figure 10. Line profile analysis example

The yarn diameter characterization can be determined considering the number of pixels between the left and right yarn contour pixels, the optical amplification (0.37) and the pixels pitch.

The experimental setup was developed based on the S8378-256Q CMOS line array and the C9001 Driver Circuit, both from Hamamatsu [25].

The yarn mass variation system considers a 1 mm parallel plate capacitive sensor based on the integrated circuit MS3110 from Irvine Sensors [16, 26, 27], allowing direct yarn mass measurements in samples of 1 mm. The sensor adopts a differential configuration to assure a higher robustness to variations in temperature, air humidity and pressure. It integrates transducer amplification and signal conditioning as shown in Figure 11.

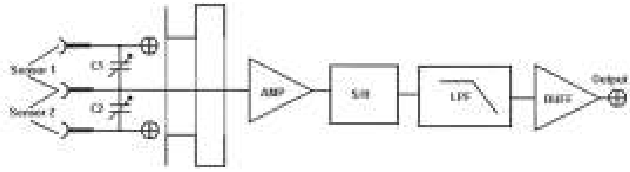

Figure 11. Capacitive sensor configuration [C1,C2 – Adjustable capacitors to calibrate the sensors, AMP – Capacity to voltage converter and amplifier, S/H – Sample and hold, LPF – Two pole low pass filter, and BUFF – Output buffer]

The software to acquire and process the data was developed in LabVIEW from National Instruments [28].

C. Yarn Productions Characteristics ExternalModule Hadware Design – Optics and Electronics

In order to keep the total system price at an acceptable level, a low cost analogue microscope coupled to a web CMOS camera was used. The microscope provides sufficient amplification and image detail, while there are no special requirements regarding the camera resolution. Figure 12 shows the flowchart of the designed system.

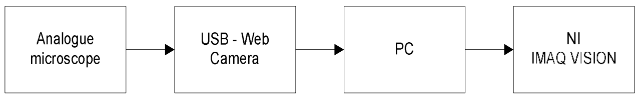

Figure 12. Yarn Image Acquisition Flowchart

The analogue microscope employed is the Biolux Al from Bresser [29] and the USB Web Camera used is the Deluxe from Hercules [30]. The web camera was placed at the exit plane of the microscope ocular, capturing the analogue image produced by the microscope. With an optical amplification of 40X, it was found that a sensor resolution of 640x480 pixels is adequate to correctly evaluate the yarn production characteristics.

In order to obtain higher contrasts for the yarn geometry relief, the illuminated yarn surface must be as close as possible to a monochromatic light source. As the white led illumination available on the microscope emits a wide range of wavelengths, an external yellow light source was used, which is somewhat closer to an ideal monochromatic light source. Figure 13 presents an example of a picture of a 22 g/km linear mass yarn obtained using the described setup.

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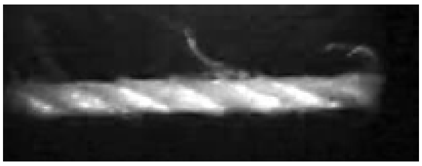

Figure 13. Picture of a 22 g/km yarn

Therefore, considering the clear contrast between the yarn zones with higher relief, corresponding to the most accentuated twist areas or yarn areas which are closer to the light source (as seen in Figure 13), a tool was developed using the IMAQ Vision software [31-33] for LabVIEW®, to determine the yarn production characteristics. Then it was possible to classify the yarn production characteristics by the following:

- Folded (multiple cable) yarn twist step: obtained by the average of the horizontal pixel distance between particles;
- Folded yarn twist orientation: determined by the orientation angle for each particle, under the following conditions: If the orientation angle lies between 90º and 180º, then the twist orientation is anti-clockwise; if the orientation angle lies between 0º and 90º, than the twist orientation is in the clockwise direction.
- Number of cables (folded or non-folded (single) yarn): If only one particle is identified - single cable (non-folded yarn); if the number of particles is greater than one - multiple cables (folded yarn).
- Fibers twist orientation: in folded yarns, the fibers twist orientation is opposite to the twist orientation. This is a general fact in Textile Industry to avoid the fibers untwist over the yarns [3, 4].

IV. Yarn Mass Parameterization Using Image Processing

This section describes the methodology used for measuring the diameter, for calculating of the hairiness coefficient and the detection of imperfections in the yarn, through image processing techniques. Furthermore a preliminary study for the detection and differentiation between protruding and loop fibers is also presented.

A. Diameter Determination

Figure 14 represents the block diagram of the algorithm used to determine the diameter by image processing techniques.

The algorithm summarizes the application of various techniques of image processing that allows obtaining, as final result, the contours of the yarn core, excluding, all hairiness around the core. The diameter calculation is made through the detection of all the edges along a set of parallel searching lines. Once all edges are detected, the distance is calculated between the pairs of edges detected by all the search lines. The diameter is obtained by, the average of all the distances calculated. Once calculated the diameter, the yarn mass is easily obtained through the theoretical correlation between mass and diameter, presented in section II-A.

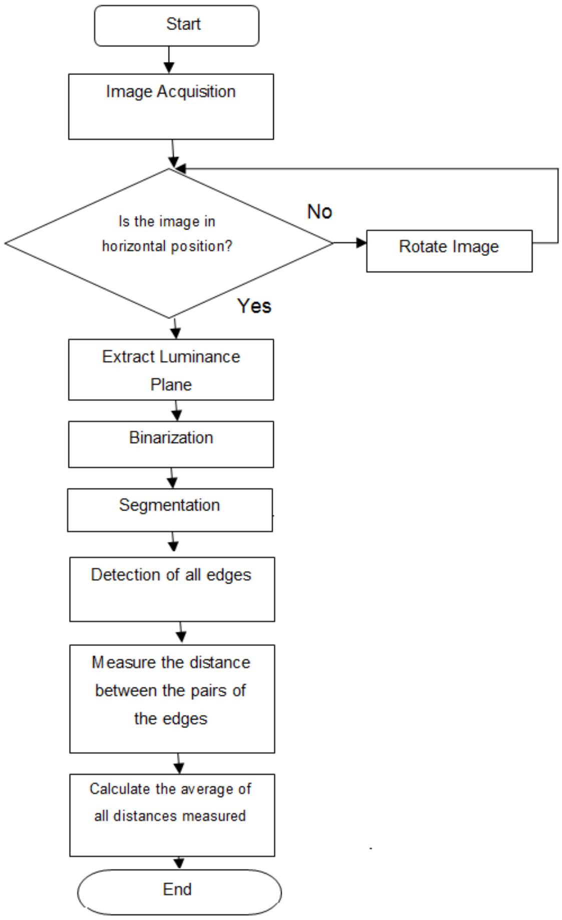

Figure 14. Diameter determination block diagram

Figure 15 presents the image-based sample of the yarn captured by the image acquisition system and Figure 16, the result after the application of the sequence of functions presented in Figure 14.

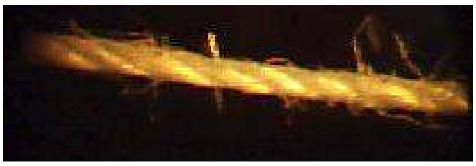

Figure 15. Original sample image acquired

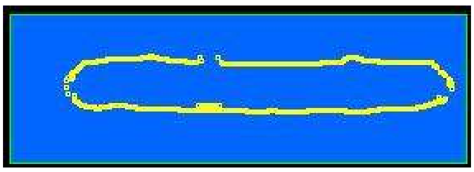

Figure 16. Image resultant from the aplication of the Figure 14 functions to Figure 15.

B. Determination of yarn faults (Thin and Thick places)

With the yarn diameter and due to the correlation between the mass and the diameter, thick and thin places can be analyzed by comparing the distances measured along the yarn with the average diameter at several levels of analysis. Figure 17 shows the algorithm applied.

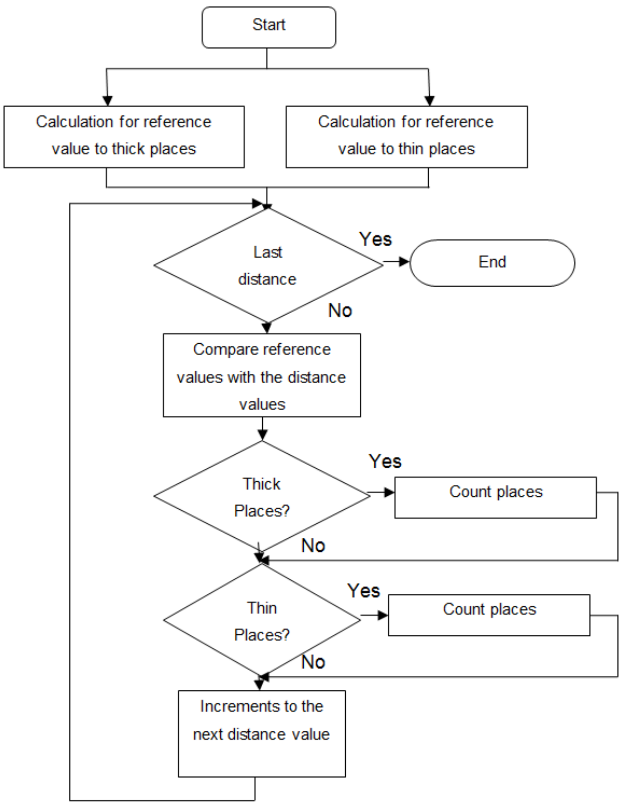

Figure 17. Algorithm used to detect yarn faults

C. Yarn Hairiniess Determination

In this study, spatial pre-processing techniques, as well as segmentation and spatial filtering techniques were used to isolate the yarn core and to highlight and quantify the protruding and loop fibers from the original image. In order to isolate the protruding and loop fibers from the yarn, logical operators were used between the image with the highlight fibers and the yarn core. Figure 18 presents the algorithm implemented.

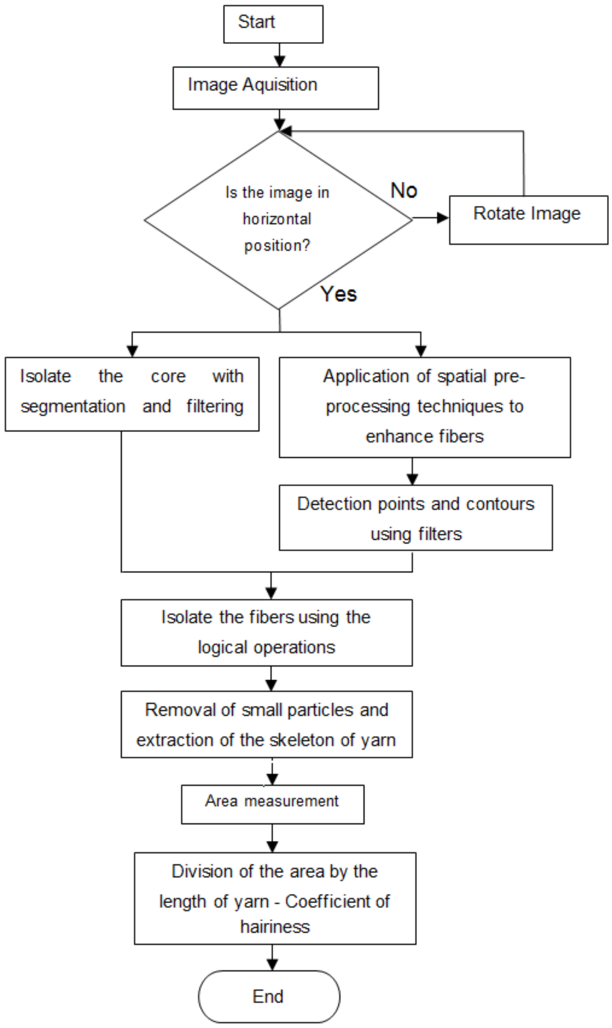

Figure 18. Algorithm used to measure the yarn hairiness index

Figure 19 shows the sample base yarn image where the image processing techniques were applied and Figure 20, its result.

Figure 19. Original sample image acquired

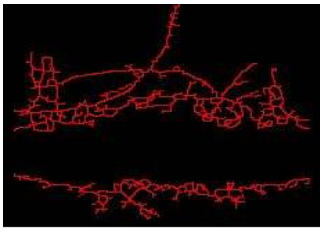

Figure 20. Image resultant from the aplication of the Figure 18 functions to Figure 19.

V. CONCLUSIONS AND FUTURE WORK

This paper presents two different approaches to quantify the yarn mass parameters, namely, based on capacitive and optical sensors and based on image processing techniques.

To perform the measurements of the first approach, the equipment YSQ was built. A capacitive sensor is used to measure yarn mass, and optical sensors, with optical signal processing are used to quantify yarn hairiness and diameter. An additional module of yarn production characteristics was developed using image processing. This equipment presents several advantages when compared to the commercial available equipment, like low cost, high portability and superior resolution (all the analysis is performed in steps of yarn length of 1mm or inferior).

Considering the computational power evolution of computers, a solution to measure the yarn mass parameters (diameter, hairiness and mass) with image processing was developed. This solution presents even more advantages to the traditional equipment, as low cost, equipment hardware, maintenance, dimension and high resolution.

Future work will consider a comparison of results between both approaches. Furthermore, the optimization of the algorithms of image processing applied in the second approach is still under work.

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REFERENCES

[1] www.uster.com (access in May 2011)

[2] V. Carvalho, M. Besley, R. Vasconcelos and F. Soares, “Automatic Yarn Characterization System”, IEEE Sensors 2008, 26-29 October, Lecce, Italy.

[3] B. Goswami, J. Martindale and F. Scardino, “Textile Yarns: Technology, Structure and Applications”, 2nd Edition, John Wiley & Sons, New York, 1977.

[4] M. Castro and M. Araújo, “Manual de Engenharia Têxtil - Vol. II”, Gulbenkian, Lisbon, 1986.

[5] Shiloh, M., “A computer for the evaluation of the crimp diameter of textile fibers” Textile Research Journal, 1964, 34(5): p. 430-434.

[6] S. Jaganathan, “Characterization Methods and Physical Properties of Novelty Yarn” , MSc Thesis, North Carolina State University, Raleigh, 2005.

[7] Anirban Guha, C. Amarenath, S. Pateria and R, “Measurement of yarn hairiness by digital image processing” The journal of the Textile Institute, Vol. 101, Issue 3, March 2010, pp. 214-222.

[8] M. Kuzanski and L. Jackowska-Strumillo, “Yarn Hairiness Determination – The algorithms of computer measurement methods”, MEMSTECH’2007, May 23-26, Lviv-Polyana, Ukraine, p.154-157.

[9] http://www.indiantextilejournal.com/articles/FAdetails.asp?id=552 (access in May 2011).

[10] M. Kuzanski, “The Algorithms of the Yarn Shape Detection and Calculation of the Protruding Fibres Length”, MEMSTECH’2008, May 21-24, Lviv-Polyana, Ukraine, p.98-100.

[11] W. Jian and Y. Li, “Evaluation of Yarn Regularity Using Computer Vision”, 9th International Conference on Pattern Recognition, Vol. 2, November 14-17, p.854-856.

[12] V. Carvalho, “Automatic Yarn Characterization System”, PhD Thesis, Minho University, Braga, 2008.

[13] B.C. Goswami, J.G. Martindale and F.L. Scardino, Textile Yarns: Technology, Structure and Applications, 2nd Edition, John Wiley & Sons, New York, 1977.

[14] A. Cay, S. Vassiliadis, M. Rangoussi and I. Tarakçioglu, “On the Use of Image Processing Techniques for the Estimation of the Porosity of Textile Fabrics”, Proceedings of World Academy of Science, Engineering and Technology – PWASET, Vol. 2, January 2005, p.73-76.

[15] J.G. Pinto, R. Vasconcelos, F.O. Soares and J. L. Monteiro, “A new system for direct measurement of yarn mass with 1mm accuracy”, IEEE International Conference on Industrial Technology, Bangkok, Dezembro, 2002, pp. 1158 1163.

[16] V. Carvalho, “Parametrização de Fio Têxtil Baseada na Análise de Massa”, Msc Thesis, Minho University, Guimarães, 2004.

[17] J. Neves, “A Irregularidade dos Fios Têxteis, Sua Origem, Medição e Análise”, Oporto, 1968.

[18] R. Furter, “Evenness Testing in Yarn Production: part I”, The Textile Institute and Zellweger Uster AG, Manchester, 1982.

[19] A. Anand, V. Chhaniwasl and C. Narayanamurthy, “Hairiness Measurement of Textile Yarns Using Crossed Polarizers”, Review of Scientific Instruments, 2005, 76.

[20] A. Barella, “Yarn Hairiness”, Textile Progress, 1981, 13, p.1.

[21] A. Barella, ”The Hairiness of Yarns”, Textile Progress, 1992, 24, p.3.

[22] V. Carvalho, P. Cardoso, M. Belsley, R. Vasconcelos and F. Soares, “Yarn Hairiness Parameterization Using a Coherent Signal Processing Technique”, Sensors and Actuators A: Physical, Volume 145, Issue 1, p217-224.

[23] V. Carvalho, P. Cardoso, M. Belsley, R. Vasconcelos, F. O. Soares, “Yarn Diameter Measurements Using Coherent Optical Signal Processing”, IEEE Sensors Journal, Vol. 8, Issue 11, November 2008, pp.1785-1793.

[24] V. Carvalho, P. Cardoso, M. Belsley, R. Vasconcelos, F. O. Soares, “Yarn Hairiness Characterization Using Two Orthogonal Directions”, IEEE Transactions on Instrumentation and Measurement, 2009, in press, doi: 10.1109/TIM.2008.2005082.

[25] www.hamamatsu.co.jp (access in May 2011)

[26] V. Carvalho, J. Pinto, J. Monteiro, R. Vasconcelos and F. Soares, “Yarn Parameterization Based on Mass Analysis”, Sensors and Actuators A: Physical, Vol. 115, Issues 2-3, September 2004, p.540-548.

[27] www.irvine-sensors.com (access in May 2011)

[28] www.ni.com (access in May 2011)

[29] http://www.bresseroptics.co.uk (access in May 2011)

[30] http://www.hercules.com (access in May 2011)

[31] IMAQ, IMAQ Vision Concepts Manual, National Instruments, Austin, 2004.

[32] T. Klinger, “Image Processing with LabVIEW and IMAQ Vision”, Prentice Hall, New Jersey, 2003.

[33] C.G. Relf, “Image Acquisition and Processing with LabVIEW” CRC, Boca Raton, 2003.