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A comparison of mass parameters determination using capacitive and optical sensors

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Abstract

This paper presents a comparison study between the use of 1mm resolution capacitive and optical sensors for the determination of yarn mass parameters. A parallel plate capacitive sensor to determine yarn mass variations and a yarn diameter and hairiness determination solution using optical sensors and integrating optical signal processing based on Fourier analysis are described. As there is a high correlation between yarn diameter and yarn mass, it is possible to determine yarn mass and infer variations in yarn diameter and vice-versa. Moreover, by optically detecting the degree of yarn hairiness, one can quantify its influence on the capacitive sensor mass variation measurements. Here we present the results of a signal processing analysis and statistical description of measurements carried out on a 100% cotton 295 g/km linear mass yarn. We conclude that an accurate yarn characterization can be carried out using optical sensors alone, reducing systems cost, complexity and increasing efficiency.

Keywords: Yarn Mass Parameterization; Diameter and Mass Correlation; Optical Sensors; Capacitive Sensors;Optical Signal Processing.

1. Introduction

Mass parameters are important elements of yarn quality assessment. These include yarn diameter, mass and hairiness. To measure yarn mass, electronic capacitance testers are usually applied as a convenient and reliable method (determination of linear mass). The most commonly used industrial systems, such as ZT5 (Zweigle) and Tester 5 (Uster) use capacitors with 8 mm length, allowing measurements with 8 mm resolution. However, as most of the irregularities have a shorter length (1-4 mm), an assessment evaluated in 1mm range is of utmost importance for a correct and direct characterization [1].

Optical sensors are also used to measure yarn diameter and hairiness directly, but allow also an indirect measurement of yarn mass due to the relationship between linear mass and yarn diameter. The most commonly used commercial system based on this methodology is the Oasys from Zweigle, which considers a sample measurement field of 2 mm. Also, in this system yarn hairiness can have a significant and undesired influence by reducing the signal received by the optical sensor, consequently leading to diameter measurement with an error by excess [2]. To measure hairiness, the traditional equipment ZT5 (Zweigle) and Tester 5 (Uster) use a dark field optics based

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technique. However this method has several drawbacks, that can cause a significant measurement error, namely the inexistence of a 0% of hairiness reference, the consideration of the yarn contours, between others [3, 4].

The present work is aimed at carrying out tests with 1 mm samples using capacitive and optical sensors to compare yarn mass parameters results.

2. The Measurement Hardware

This section describes the yarn mass, diameter and hairiness measurement hardware applied. These characteristics of the measurement hardware allow a superior yarn parameterization, high resolution and precision [1].

2.1. Yarn Mass Variation System

The yarn mass variation system employed uses a 1 mm parallel plate capacitive sensor based on the integrated circuit MS3110 from Irvine Sensors, allowing direct yarn mass measurements over sample lengths 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 1 [1].

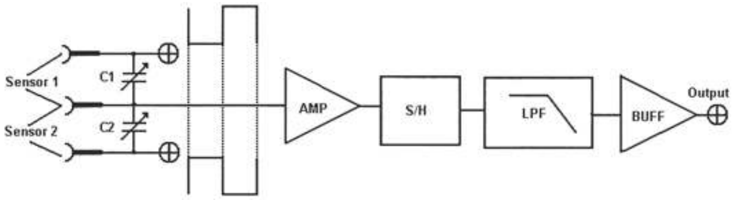
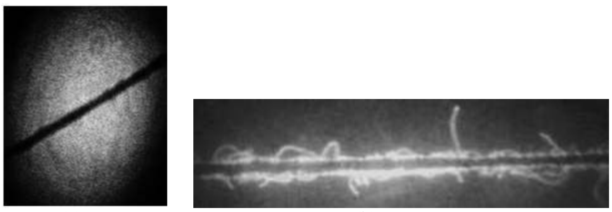


Fig. 1: Capacitive sensor configuration [C1,C2 – Adjustable capacitors to calibrate the sensors, AMP – Capacity to voltage converter and amplifier, S/H – Sample and hold, LPF – Two pole low pass filter, and BUFF – Output buffer].

2.2. Yarn Diameter and Hairiness Quantification

The yarn diameter and hairiness quantification, based on two single photodiodes (S1227-1010BR from Hamamatsu) configured for a 1 mm sample length analysis, uses an optical setup with a low-pass spatial filter, to perform the diameter measurement (eliminating the influence of hairiness, Figure 2a), as well as with a high-pass spatial filter, to perform the hairiness measurement (eliminating the influence of the light which is not blocked by the yarn, Figure 2b) [1-4].



(a) (b)

Fig. 2: Example of an image resulting from the application of a (a) low-pass spatial filter, (b) high-pass spatial filter.

Figure 3 presents the optical hardware employed to determine yarn diameter and hairiness.

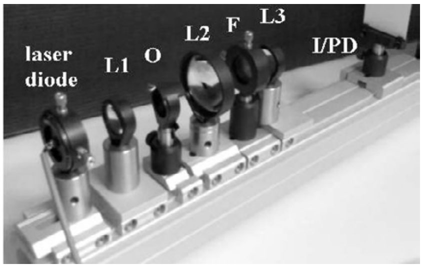


Fig. 3: Custom developed optical yarn measurement hardware for a single direction

The coherent optical imaging technique is employed to obtain an optical signal proportional to the amount of hairiness present on the yarn being sampled. The main components of the optical system are a collimated coherent illumination source (laser diode), aperture lens (L1, L2, L3) used to form the Fourier transform image of the sample yarn under study, a custom made high-pass spatial filter (measurement of hairiness) or a custom made low-pass spatial filter (measurement of diameter) and a second lens to create a final image in the detector plane (position of the photo detector in Figure 4) (I/PD).

Afterwards, in order to obtain a voltage proportional to the brightness of the final image, a conditioning circuit was developed for yarn hairiness quantification. A high precision current to voltage converter based on a Burr-Brown operational amplifier OPA277P was used.

3. Experimental Results

Considering the optical resolution of the yarn diameter and hairiness measurements and the known relationship between yarn linear mass (tex(g/km)) and diameter (m) (diameter=0.060√tex) [5]), it is possible to correctly determine the traditional yarn parameters using only optical sensors [5, 6]. In order to compare these two systems a 100% cotton 295 g/km linear mass yarn (Figure 4) was evaluated.

The influence of hairiness in the capacitive sensor was on average about 4E-11%, and so essentially negligible. Table 1 presents the statistical parameters obtained and Figure 5, the signal processing results of mass variation determined directly with the capacitive sensor and inferred with the optical sensors.

Table 1. Statistical results parameterization

Statistical Parameters	Capacitive Sensor	Optical Sensors
Mean Deviation U(%)	13.9	16.0
Coefficient of Variation CV(%)	17.5	20.6
40% Sensitivity Thin Places /km	12800	12600
40% Sensitivity Thick Places /km	11400	37800
200% Sensitivity Neps /km	0	0
Hairiness Index H(m/m)	------	2.2
Standard Deviation H sH(m/m)	------	0.6

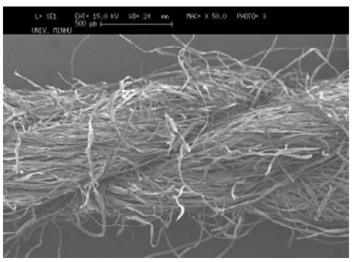


Fig. 4: Electron microscope picture of the 295 g/km yarn analyzed.

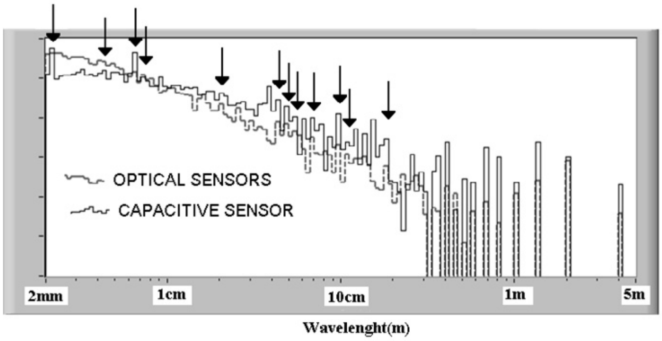


Fig. 5: Mass variation signal processing results based on the FFT. Arrows indicate the presence of similar protruding peaks in both spectrograms.

As the data in the above table show, comparable results are obtained from the capacitive sensor and optical sensors for the main statistical parameters of mass (U%, CV% and irregularities). Furthermore as can be seen in Fig. 5, a high number of similar protruding peaks where obtained over the same wavelengths of mass variation and diameter variation characterization indicating that equal pattern distributions are present in both signals.

4. Conclusion and Further Work

Considering the data obtained it is possible to state that there is a strong similarity in the parameterization data acquired using optical and capacitive sensors, implying a strong linear relationship between mass and diameter variation. These results indicate that a valid characterization of yarn mass parameters (U%, CV% and irregularities, between others) can be obtained using optical sensors. However it must be noted that, the methods employed for mass measurement and diameter measurement are not absolutely equal, and that a fully accurate parameterization of mass requires a capacitive sensor, considering the different geometries and material density used in yarns. Nevertheless, using optical sensors it is possible to obtain very short sample lengths (< 1mm, if desired), allowing one to characterize yarn with a much higher spatial resolution than can be obtained with capacitive sensor measurements.

In summary, it is possible to conclude that using only optical sensors is sufficient for an accurate yarn characterization of mass parameters, reducing systems cost, complexity and increasing efficiency of textile industry.

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References

1.V. Carvalho, M. Besley, R. Vasconcelos and F. Soares, *Automatic Yarn Characterization System*, IEEE Sensors 2008, 7th IEEE Conference on Sensors, 26-29 October 2008, Lecce, Italy.

2.V. Carvalho, P. Cardoso, M. Belsley, R. Vasconcelos, F. O. Soares, *Yarn Diameter Measurements Using Coherent Optical Signal Processing*, IEEE Sensors Journal, Vol. 8 (11), 2008, pp.1785-1793.

3.Barella, *Yarn Hairiness*, Textile Progress, 1981, 13, p.1.

4.V. Carvalho, P. Cardoso, M. Belsley, R. Vasconcelos, F. O. Soares, *Yarn Hairiness Characterization Using Two Orthogonal Directions*, IEEE Trans. Instrumentation & Measurement, Vol. 58 (3), 2009, pp.594-601.

5.V. Carvalho, M. Belsley, R. Vasconcelos, F. O. Soares, *Yarn Diameter and Linear Mass Correlation*, Journal of Non-Destructive Evaluation, Vol. 28 (2), 2009, pp.49-54.

6.B. Goswami, J. Martindale and F. Scardino, *Textile Yarns: Technology, Structure and Applications*, 2nd Edition, John Wiley & Sons, New York, 1977.