IEEE ICIT' 02 Vol. II

http://www.ise.ait.ac.th/conferences/icit02.htm

…14 December 2002, Shangri-La Hotel, Bangkok, Thailand

2002 IEEE International Conference on Industrial Technology Proceedings

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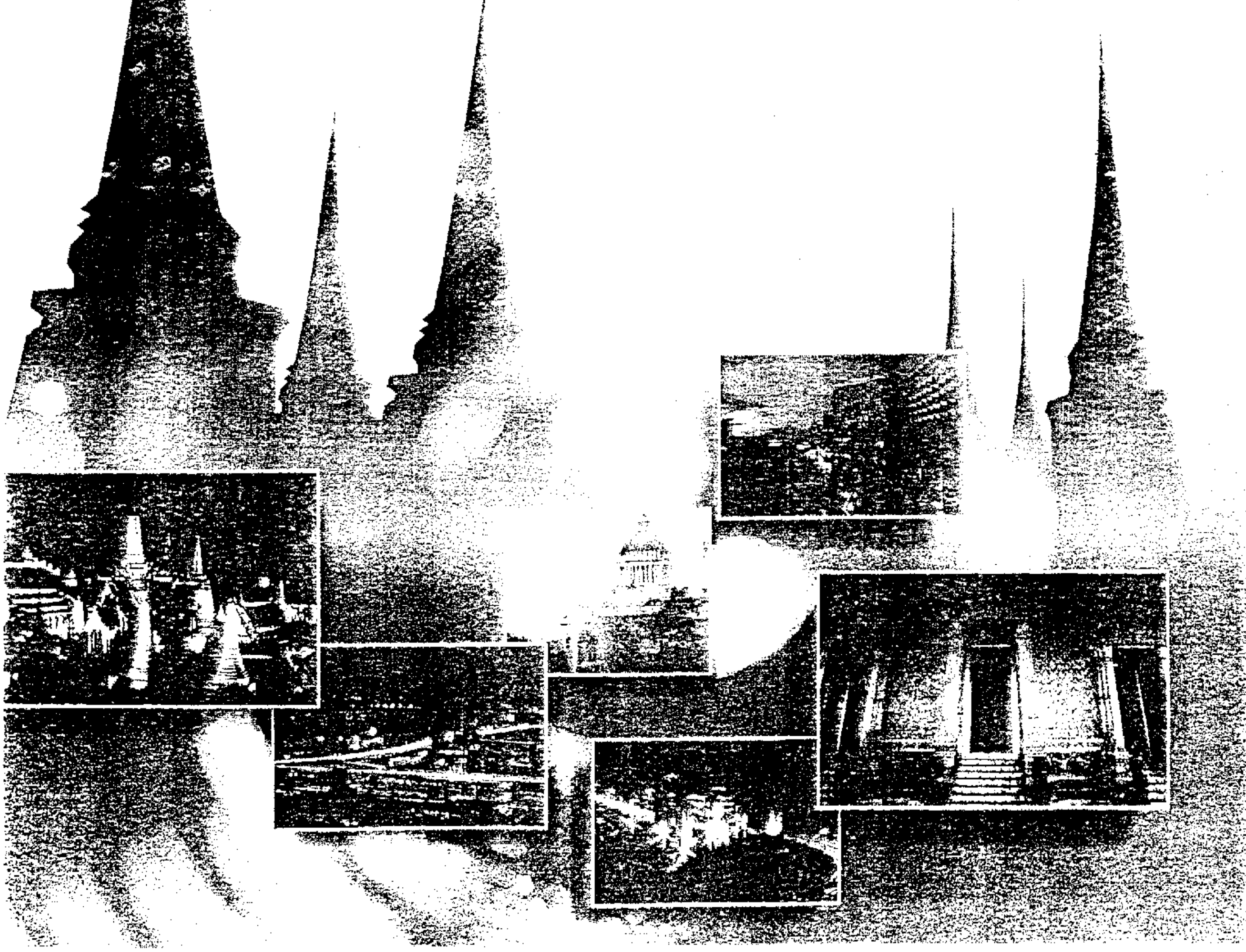

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Table of Contents

IEEE Catalog Number: 02TH8654
ISBN: 0-7803-7657-9
Library of Congress: 2002112704

A New System for Direct Measurement of Yarn Mass with 1mm Accuracy

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Abstract
In Textile production, measurement of the yarn mass in 1 mm range is utmost importance to properly evaluate the evenness, as several irregularities occur in 1 to 4 mm yarn length. Until present, measurements in 1mm range are still not directly performed.
In this paper we present a direct mass measurement in 1mm range based on capacitive sensors and signal processing techniques.
The results point out that the evaluation of yarn mass, with this approach, is feasible in the 1 mm range. The new approach allows on-line measurement (1 mm yarn mass) in a spinning frame for real-time control. Several Digital Signal Processing techniques are used to improve the results. A value of capacity variation is close to 2,08E-17 F for a 57 tex (0,057 g/m) yarn. It is possible, with this equipment, to detect small variations but signal to noise ratio (SNR) is still low. With the current electronic conditioning it is possible to detect these variations in spite it is in microvolt range. As a spin-off the developed sensor is being used in knitting machines to control the yarn break and bobbin end.
Keywords: Yarn Evenness, Capacitive Sensor, Signal processing.

1. Introduction

The quality of any textile product is strongly influenced by the type of its components, e.g., fibers and yarns. These must be manipulated in bulk and the resulting structure has many varying characteristics, which depend ultimately on the variation in mass per unit of length. It is thus important to determine the linear density variations and the total irregularity to predict the effect of the yarn's properties on the production and appearance of the finished fabric.
For detection of such irregularities it is still applied nowadays, electronic capacitance testers as a convenient and a 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, thin points or neps [1].
Mass yarn evaluated in 1 mm range is of utmost importance for a correct detection of irregularities as most of them have a short length (between 1 and 4 mm length).
This paper presents a new system for measuring directly 1mm yarn mass using a capacitive sensor.

2. Theoretical Considerations

Some of the most important parameters to identify specifications for yarn quality are linear density, structural features and fiber content. The combination of different number of fibers per cross section with varying forces binding them together due to twist variation, leads to unlike yarn properties. An example of yarn configuration is shown in Figure 1.
In order to obtain yarn mass irregularity electronic capacitance tests are established as a convenient method [2]. The basic requirement of this type of unevenness tester is that the output of the measuring circuit is directly proportional to the linear density of that part of the strand within its capacitor, that is, the relationship between capacitance and the mass of fiber between the plates must be linear. The changes of capacitance brought about by alteration of the total fibre cross-sectional area between the plates enables the automatic indication of the mean deviation (U%) and coefficient of variation (CV%) [3].

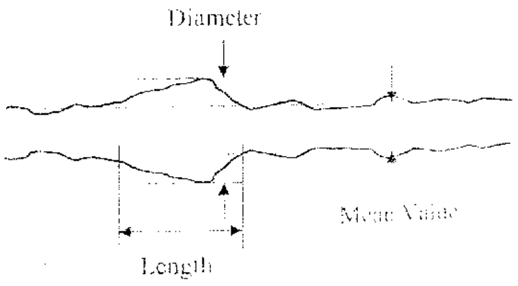

Figure 1 Example of yarn configuration

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

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

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 with homogeneously distributed mass variation.
The mass variation can be considered to conform approximately to a normal distribution when a homogeneous fibre composition is available. As a measure of the size of these mass variation is the standard deviation s, which is defined as the distance from the mean value to the point of inflexion of the normal distribution curve. The standard deviation is equated to the mean value as defined in equation 2.

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

The irregularity U% and CV% can be described graphically according to Figure 2 [3].

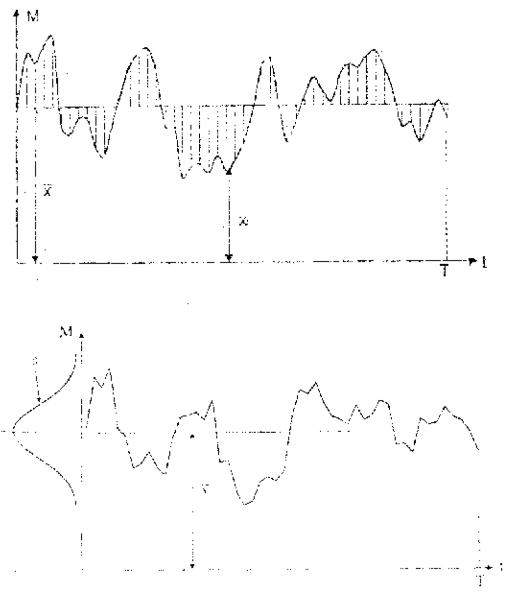

Figure 2 - Graphical representation of U and CV

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

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

The number of faults and mass measurements enable a quality rating of the product. An accurate measurement of these properties is of major importance [4].

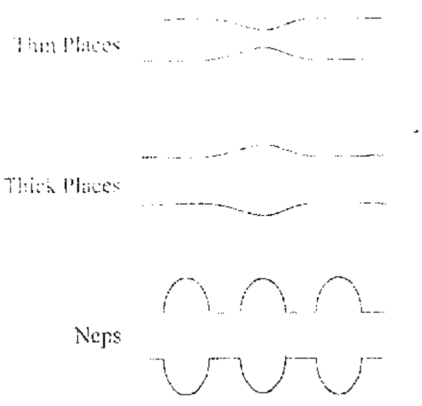

Figure 3 Types of yarn faults

3. Previous experimental set-up

The first step of the work consists in the use of an experimental apparatus (Uster Tester I) based on a commercial 8 mm capacitive sensor and a Labview data acquisition system to achieve yarn evenness.
After the validation of the results obtained with this experimental rig with the ones obtained with a more recent device, Uster Tester III equipment, the research objective is to extract 1 mm mass values, using measurements of 8 mm length sensor. Using signal processing techniques, sequential samples of the mass signal are then acquired in such a way that the length interval is in the 1mm range [5]. The mathematical study aimed to extract 1 mm mass values, using measurement of 8 mm length sensor acquiring with a sample rate proportional to a 1 mm yarn length.
In order to analyse the influence of measurement length (portions of 1 to 8 mm) in the determination of yarn evenness, a statistical study is carried out. We use 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 [6].
Due to technology used in development of 1 mm capacitive sensors, parallel plates configuration capacitive sensor of with 1 mm length cannot be found in the market.
Instead, a 1 mm diameter cylindrical sensor is tested. By regulating the measurement instrument we try to get the maximum resolution. The yarn is approached to the sensor, but its presence is not detected, or at least, it is not possible to distinguish the alterations caused by the yarn from the oscillations of random noise inherent to the equipment. Some improvements in the electronic conditioning allow acceptable results but due to yarn oscillations in a spinning frame this kind of sensor will not be acceptable [7].

4. New sensor design

A new capacitive sensor with parallel plates is developed, together with the electronic conditioning circuit, which allows 4 mm yarn mass reliable measurements. Based on the results obtained with this 4 mm capacitive some improvements are made in order to measure 1mm yarn mass.

Regarding accuracy, a theoretical study is undertaken to quantify the capacity variations due to the difference in dielectric constant corresponding to the analysis with/without cotton yarn between plates. A value of capacity variation is estimated in 2,08E-17 F for a 57 tex (0,057 g/m) yarn. Although it is possible, with this equipment, to detect small variations, some difficulties in terms of signal to noise ratio (SNR) are still present. These small variations of capacity are translated in variations of μV tension, resulting in a very small SNR. In order to reduce the noise some attempts are made using traditional filters, but with relative success, as noise has it main component in 50Hz range, which is the interval of signal frequency.

To overcome SNR problems a study on the influence of the electromagnetic radiation is carried out using two identical sensors, in a differential configuration, with different distances between plates (Figure 4). With this technique it would be possible to use the same equipment for two different yarn diameters.

The use of a differential set-up makes the electric circuit more robust to temperature and air humidity variations, which are particularly important in textile industries.

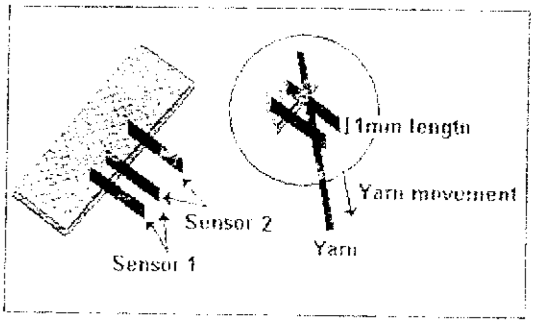

Figure 4 - Representation of the two sensors

This system is to be used for on-line control of a ring spinning frame in order to evaluate the yarn evenness produced. Presently, in spinning mills this kind of evaluation is made off-line in laboratory using a small percentage of yarn.

The tests made with this system show good performance in laboratory environment. The experimental set-up used consists on a PC with LabView (National Instruments) data acquisition system together with two sensors and electronics.

Figure 5 shows the system schematic diagram used in the project development. In order to have two condensers with a common electrode, three metallic conductors placed in parallel were used in the system design. The air and the yarn are the capacitor dielectric.

The integrated circuit (IC) MS3110 from Microsensors® implements the functions related to transducer, amplification and signal conditioning. This is an IC specific for capacitive sensors and has the following characteristics (Figure 6):

- Capacitance resolution up to 4.0 aF/rtHz
- Single Variable or Dual differential variable
- On-chip dummy capacitor for quasi-differential operation and initial adjustment
- Gain and DC offset trim.
- Programmable bandwidth adjustment 0.5 to 8 kHz
- 2.25 V DC output for ADC reference/ratiometric operation.
- Single supply
- On-chip EEPROM for storage of settings.

The sensor capacitance variations are converted in a voltage signal and amplified. A second order low pass filter attenuates the high frequency interferences, which come from the internal oscillator and from other external noise sources. The filtered signal is then amplified by using an output buffer.

The MS3110 output voltage is filtered and then converted in a digital signal with an ADC incorporated in a data acquisition board (6024E from National Instruments).

The acquired signal is monitored in a PC using the control software from National Instruments, LabView. This software allows the data storage, data manipulation and data processing for the analysis and evaluation of the results obtained.

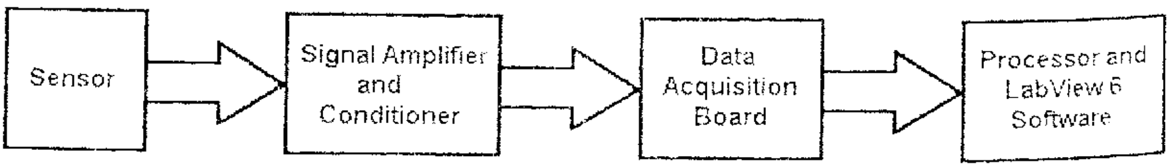

Figure 5 - System flow chart

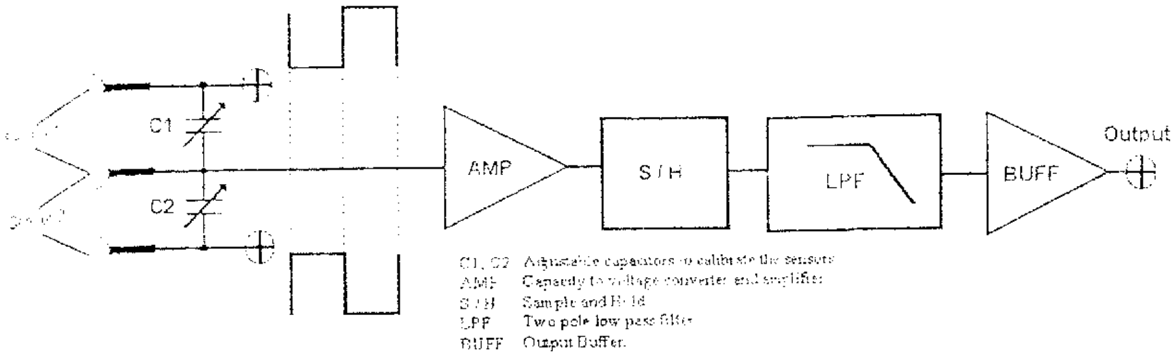

Figure 6 – MS3110 electric diagram

Figure 7 is a print screen of the software developed. It is shown the acquired signal in the big screen; in the right top is shown the yarn mass and in the left corner are the values obtained for U% and CV%; in the bottom is the Fast Fourier Transform graphic (FFT).

Now, it is under development an industrial net based on micro controllers RISC allowing Digital Signal Processing and distributed and real time control. The central unit monitors the events (such as broken ends, neps, bobbin ends), reports production data and updates control algorithms. The final result is the absolute necessity to improve monitoring, for example, to provide signals (lamps) indicating those positions at which the operative's presence is currently needed.

5. Results

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

Several tests were performed with different bobbins (from open end spinning system, ring spinning system and filament type fibers) in order to detect the influence of the linear mass.

Table 1 displays the U% and CV% values in several yarn samples.

Table 1 U% and CV% values

Fiber	*Yarn Mass (tex)*	*U (%)*	*CV%*
Cotton	57	14.96	18.69
Cotton	25	12.7	15.88
Cotton	37	11.28	14.09
Cotton	20	14.04	17.55
Cotton	20	21.35	26.68
Cotton	30	12.85	16.06
Polyamide	76.5	7.28	9.10

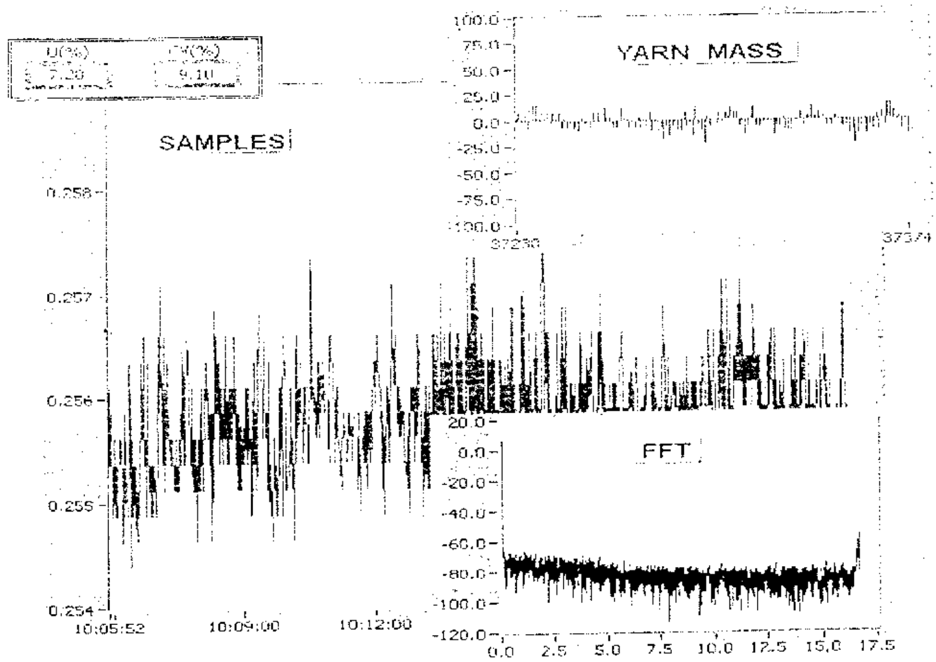

Figure 7 – Control panel software components

In order to evaluate the yarn faults, previously defined as a decrease (50%) in the mass during a short length (thin places); an increase in the mass, usually lower than 200% (thick places); and a huge mass of yarn in a short length (NEPs), we must state that with a short difference in the irregularity threshold, results have a strong change. These results are displayed in Table 2.

We must point out that neither thin places can be obtained in a 182% threshold or neps in less than 182% range.

The primary goal of the project was to analyse only cotton yarns, but in order to expand the system application field some tests were made to detect Lycra yarns with small linear mass (less than 6 tex, g/km). Although Lycra has a bigger dielectric constant, its small linear mass prevents the good performance of the system.

At the moment we are working on the adaptation of the developed system to be able to detect Lycra yarns and all types of yarn with less than 6 tex.

6. Conclusion

The results point out that the evaluation of yarn mass (bigger than 6 tex), with this approach, is feasible at least in the 4 mm range.

Nevertheless, results are still under the goal and mixed combination of sensors is being tested.

An alternative step in this work is, by using two sensors with 4mm and 5mm length, respectively, the 1 mm yarn mass will be determined employing digital signal processing techniques.

The main goal of this project is to develop a new technique that allows the on-line measurement of 1 mm yarn mass in a spinning frame.

7. Acknowledgement

The authors are grateful to FCT project funding, PRAXIS XXI contract n. PRAXIS and POSI/P/EEI/13189/98).

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Table 2 Yarn faults in several yarn samples

Fiber	*Yarn Mass (tex)*	*Thresholds (%)*	*Thin places (1000 m)*	*Thick places (1000 m)*	*Neps (1000 m)*
Cotton	57	182	-	0	2
		60	0	17	-
		40	7	47	-
		20	104	147	-
Cotton	25	182	-	0	0
		60	0	4	-
		40	12	18	-
		20	208	108	-
Cotton	37	182	-	0	0
		60	0	1	-
		40	1	10	-
		20	131	102	-
Cotton	20	182	-	0	0
		60	0	6	-
		40	34	31	-
		20	283	161	-
Cotton	20	182	-	0	12
		60	2	22	-
		40	109	42	-
		20	358	106	-
Cotton	30	182	-	0	0
		60	0	5	-
		40	10	20	-
		20	274	146	-
Polyamide	76.5	182	-	0	0
		60	0	0	-
		40	0	2	-
		20	59	27	-

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