Novel Sensors in Rieter CZ

Yarn Sensors for Spinning Machines

22.6.2015  Jiří Sloupenský  Rieter CZ s.r.o.
Position of Rieter company in textile production chain

Cotton flower → Spinning → Packages with yarn

- Cotton bale
- Rotor and air jet spinning
- Ring spinning
History of spinning

Principle of spinning = production of textile yarn from fibrous material
→ process of parallelization + twisting

Hand spindle

Spinning wheel
Step by step development of spinning devices

Different principles of yarn creation based on the combination of twisting and winding in one step → combination of ring and traveler → ring spinning
Ring spinning principle

Basic principle

Real ring spinning unit

Delivery of parallel textile fibers

Drafting to required fines of the yarn

Twisting and winding in one step

The package is rotating at twisting speed => high demands on dynamics
Modern ring spinning mill

Machines with more than 1000 units – max speed up to 30 000 r.p.m.

Advantage: Yarn quality  Disadvantage: Low productivity (25 m/min), rewinding needed

Machines have no sensors for yarn break detection ➔ when break occurs, material goes to the waste
Rotor (open end) spinning principle

Invented in former Czechoslovakia VÚB Ústí n.O. in the year 1965

Separated twisting and winding because of “free yarn end”

1. Raw material – band of fibers
2. Switchable fiber supply driver
3. Combing roller
4. Transport of unified fiber by air
5. Spinning rotor – twist inserting device
6. Yarn outlet
7. Ready yarn
8. Yarn break sensor
9. Take up rollers
10. Final package

High speed spinning and risk of overloading of the rotor → necessary to install yarn break sensor

Package is turning only on winding speed => weight up to 4 kg possible
Modern rotor spinning machines

Semiautomatic machine BT 923
400 – 600 spinning positions,
Spinning speed up to 250 m/min

Advantages:
high productivity, low sensitivity to fiber quality, easy automation

Disadvantage: lower yarn quality
Air Jet spinning principle

1. Input material
2. Drafting system
3. Air jet
4. Yarn quality sensor
5. Delivery rollers
6. Yarn break sensor
7. Final yarn package

Key element: Air jet

Surface fibers of the fiber stream are twisted around the core by the air vortex.

Advantages: High productivity (up to 500 m/min.), good yarn quality
Disadvantages: High energy consumption, high sensitivity to fiber quality
Air jet spinning machine

Central drives and control

Spinning units

service robot
Two functions of yarn break sensors

1. Control of fiber delivery

2. Central control system (for statistical purposes)

Yarn break sensor = Transducer of non electric value to electrical signal
Electro-mechanical sensors for yarn break detection based on yarn tension

Movable lever

Yarn output from the unit

Reed relay + magnet

Microswitch with lever

Inside arrangement of the sensor
Electronic yarn break sensors based on piezo principle

Piezo element, generating charge by friction of the yarn around ceramics

Disadvantages: influence of humidity, required high speed of yarn and big wrapping angle, still used on man made fiber machines
Electronic sensors based on optical principle

Massive entry together with the LED technology.
In the past the light source was a problem.

Advantages: high sensitivity and stability, low costs
Disadvantages: dust deposit, ambient light (fluorescent tub – 50 Hz !)
Examples of Rieter optical sensors

Outside shape

Inside arrangement

Sensor in combination with other mechatronic device

solenoid
Faults in the yarn – not accepted in the final product

Mass variation faults

Colored foreign particles
Basic principles of detection of mass faults

Yarn quality sensor = Transducer of non electric value to analog signal

Capacitive

1. Hi frequency generator
2. Electrodes of open capacitor
3. Running yarn
4. Measuring slot
5. Output signal

Problems to be solved:
1. High sensitivity to humidity
   \[ \varepsilon_r \text{cotton} = 1.4 \quad \varepsilon_r \text{water} = 80 \]
2. Deposit of dust
3. Length of measuring slot – masks short faults

Optical

1. Light source
2. Optics
3. Running yarn
4. Measuring slot
5. Light detector
6. Output signal

Problems to be solved:
1. Stable yarn position
   (Intensity of the light is varying)
2. Dust deposit
3. Only relative variation available
Definition of the length and size of mass fault

**Simple approach**
Size of fault is preferred

\[ D\% = \frac{M\% + D_v\%}{2} \]

\[ L_M \times M\% = L \times D\% = L_v \times D_v\% \]

**Sophisticated approach**
Preference of „energy“ of the fault
Evaluation of mass faults and setting of cleaning curve

Classical approach for individual mass faults:
sorting to the matrix according the length and diameter

Modern approach:
based on histogram of yarn fault distribution in the yarn
**Periodical fault - Moiré**

- Impurity in spinning rotor
- Sensor signal
- Input of the fibers
- Rotor circumference
- Typical Moiré
- Yarn with Moiré fault

Diagram showing the relationship between impurities in the spinning rotor, sensor signal, and the resulting Moiré fault in the yarn.
Periodical faults, detectable by spectrogram

Typical spectrogram of good yarn

Yarn with periodical faults
Capacitive sensor - example

Disadvantages:

- High sensitivity to humidity changes  \( \varepsilon_r \text{ cotton} = 1.4 \quad \varepsilon_r \text{ water} = 80 \)
- Dust deposit
- Not possible to measure the absolute values – continuous compensation necessary
  \( \Rightarrow \) difficult to detect slow changes - very long faults not easy to discover
- Relatively long measuring zone – difficult to detect very short faults

Uster® Quantum 2
Produced by Zellweger, Uster, Switzerland
Optical principle with compensation

**Advantages:**
- Ambient light compensation,
- Aging of LED and partly also compensation of dust deposit

**Disadvantages:**
- Sensitive to yarn position in the slot
- Only relative measurement possible with floating reference value
- => Difficult to detect slow changes as long faults

**YarnMaster® 3N1**

Produced by Loepfe Brothers Ltd.
Wetzikon, Switzerland
Cross optical principal

Lower sensitivity to yarn position

Detect straight though light and reflected light => possible to detect foreign colored material (see later)

MSC-F
Produced by Murata machinery Ltd.
Japan
Digital optical principal – solution of Rieter (1997)

During patent search we have found an old patent of Zellweger Uster GB 2064106, from 1979, which was never used before and now is free.
Processing of data from digital sensor

Output signal from the sensor (influenced by yarn hairiness)

Principle of composing of digital samples

Single light slices

Shadow of yarn

Yarn relief

Comparision of samples

Průměr příze
First Rieter digital sensor with SONY chip ILX 521A

Disadvantages:
- low resolution
- difficult read out (bit by bit) demanding processing of high volume of bit data, difficult assembly of DIL 12 housing.

Problem:
SONY stops the production of it in the year 2000

CCD sensor 256 pixels 14 x 14 um in DIL 12 housing

Mikroprocesor Fujitsu MB90F497 16 bits

IQclean

1999 - 2003
Development of special line chips for textile sensors

Finding of replacement of the SONY chip at the market was not successful (in the year 1999)

→ survey of the possibilities for our own special chip

Basic requirements:

- CMOS technology 1 μm → optics and logics on one chip
- Hither resolution (more narrow pixel)
- Rectangular pixel for basic signal filtration (signal integration)
- Integrated data pre-processing – output just a shadow size and position
- Integrated control of the LED
- SPI communication

→ collaboration with ASICentrum Prague – part of SWATCH, Switzerland
Why rectangular pixel ??

Over this length signal is integrated

When illumination and reading is synchronized, it is possible to analyze complete yarn length

Yarn

5 μm

200 μm

29
First special chip MSBF 032 – details

Deliver information about size and position of the shadow

⇒ not necessary to read single pixels

integrated function of LED intensity via PWM

VDD
VSS

PIXOUT
VREF

CLOCK
RES_N
REFOUT
SYNCHRO

1024 pixel array

5 x 200 μm Active pixels zone

Shift register

Digital control block

SCK
SI
SO
LED
Sensors with the chip MSBF032 for different machines

**IQplus**  
Semi-automated rotor machine BT923

**RYC**  
fully automated rotor machine R40

**Q10**  
Semi-automated rotor machine R35  
Automated rotor machine R60  
Airjet machine J20  
( with foreign fiber detection )

**Used microprocessor:**  
Freescale MC 56F8345 16 bits
Second generation of the optical chip

Reasons for new development:
- Availability of new CMOS technology 0.35 μm at SWATCH
- Increasing of precision and speed
- Implementation of new functions directly to the chip
- Analysis of surface structure of the yarn (hairiness)
Internal structure of the measuring chip MSBF034

Line of axial pixels (information about absolute yarn diameter)

Line of wide lateral pixels (information about surface structure)

chip in evaluation housing
This project Nr. TA01010162 from ALFA program was financially supported by Technology Agency of Czech republic
## Comparison of characteristics of special optical chips

<table>
<thead>
<tr>
<th>Chip labeling</th>
<th>MSBF 032</th>
<th>MSBF 034</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of realization</td>
<td>2001</td>
<td>2013</td>
</tr>
<tr>
<td>Technology CMOS</td>
<td>1 μm</td>
<td>0.35 μm</td>
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<tr>
<td>Chip dimensions</td>
<td>7.84 x 2.11 mm</td>
<td>4.73 x 2.73 mm</td>
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<tr>
<td>Number of digital pixels</td>
<td>1024</td>
<td>1024</td>
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<tr>
<td>Dimensions of digital pixels</td>
<td>5 x 200 μm</td>
<td>2 x 200 μm</td>
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<tr>
<td>Number of analog pixels</td>
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<td>16</td>
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<tr>
<td>Dimensions of analog pixels</td>
<td>-</td>
<td>50 x 250 μm</td>
</tr>
<tr>
<td>A/D convertors</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>D/A convertors</td>
<td>-</td>
<td>1</td>
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<tr>
<td>Communication speed</td>
<td>20 k samples.sec⁻¹</td>
<td>40 k samples.sec⁻¹</td>
</tr>
<tr>
<td>Maximal speed of yarn</td>
<td>1200 m.min⁻¹</td>
<td>2400 m.min⁻¹</td>
</tr>
<tr>
<td>Minimal yarn diameter</td>
<td>0.15 mm</td>
<td>0.08 mm</td>
</tr>
<tr>
<td>Communication interface</td>
<td>SPI - 3 MHz</td>
<td>SPI - 18 MHz</td>
</tr>
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Jiří Sloupenský

Rieter CZ s.r.o.
Prototype of the sensor with new chip MSBF 034

New functions:
- Absolute, precise yarn diameter measurement
- Higher speed, finer yarns
- Spectrograms (32 bit processor) and detection of special faults
- Detection of weak yarn and abrasion of spinning components
- Automatic regulation of LED intensity for compensation of dust and aging
- Detection of foreign fibers based on changing of reflected light

Used microprocessor 32 bits: STMicroelectronics 32F405
Principle of foreign fiber detection

Level of reflected light is compared with actual yarn diameter and in case of difference there is the foreign color fault.

The light source is synchronized with the reading of light sensor to suppress the influence of ambient light.
Sensor installation on the spinning machine
Thanks for attention

questions, remarks?