Research Article

Development of Yarn Detection Sensor for Circular Patterned Yarn Dyeing Machine

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Abstract

The textile industry has undergone a radical transformation in recent years, driven by digitalization, automation, and the pursuit of sustainable production. In this transformation, electronic and computer-based sensor technologies are gaining prominence in critical areas such as production line monitoring, process control, quality assurance, and energy efficiency. This study examines the development of a yarn detection sensor for a circular machine featuring patterned yarn dyeing technology. Unlike traditional dyeing methods, this technology combines the yarn transfer process with the dye spray system, enabling direct patterning of the yarn. Only the required amount of dye molecules chemically reacts with the yarn, resulting in significant savings in water and energy consumption. The system, with 36 independent dyeing stations, offers flexible production; however, yarn breaks, resulting from factors such as yarn raw material, *strength, twist, and friction, lead to production losses and defective package formation. The import of currently used yarn detection sensors poses a significant disadvantage in terms of cost and lead time. Therefore, this study has developed a domestically produced sensor that can instantly detect yarn breaks, communicate with the machine in real time, and automatically stop the station. The developed system will minimize production losses and delivery delays, saving energy and resources. Consequently, the design and integration of a domestic yarn detection sensor will not only improve production quality and efficiency, but will also contribute to reducing external dependency and promoting environmental sustainability. In this respect, the study can contribute to advancements in smart production technologies in the textile industry.*

Keywords: Yarn break sensors, Patterned circular dyeing technology, Smart Production and Automation in Textiles

1. Introduction

The textile industry has undergone continuous development since the industrial revolution and has become one of the fastest-adapting sectors to technological innovations. Increasing competition, diverse customer expectations, and the need for sustainable production have made the use of automation systems and sensor technologies essential in textile production processes. Sensors, particularly used in spinning, weaving, knitting, and dyeing processes, play a critical role in improving production quality, minimizing errors, and increasing productivity.

Sensors are widely used to measure parameters such as yarn tension, yarn presence, yarn breakage, fabric surface defects, color variations, temperature, and humidity, and to monitor the production process. In the yarn production process, yarn breakage is critical for all technological processes related to yarn processing. Detecting yarn breakage at the right time is one of the crucial stages of yarn production[1]. Many sensors have been developed to detect yarn breaks. Currently, the typical methods used to detect yarn breaks in weaving processes are capacitive sensors and piezoelectric sensors[2]. Capacitive sensors detect changes in capacitance generated by yarns. Piezoelectric yarn break sensors detect the mechanical movement of the yarn. However, capacitive and piezoelectric sensors must be very sensitive, and because each sensor can only detect one yarn, each yarn must be passed through the sensor. Furthermore, due to the moisture content of the yarns in circular pattern yarn dyeing machines, these sensors cannot provide accurate and efficient detection. Today, due to their non-contact nature, optical methods are widely used to detect various parameters of textile products[3]. These sensors make it possible to detect production errors at an early stage, reduce waste rates, optimize energy and chemical usage, and ensure product quality.

The circular pattern yarn dyeing machines developed by our company are an important technology for the production of multicolored fancy yarns. These machines dye yarns in different colors to create fancy yarns with unique effects. These yarns are then weaved or knitted to produce uniquely patterned fabrics. However, yarn breaks during production can lead to quality problems. Continuing to operate the machine during a break causes effect errors, color tone variations, increased waste rates, and unnecessary dye chemical consumption. This increases production costs and poses a significant disadvantage in meeting customer expectations. Because the standard yarn detection sensors used in existing systems are not specifically designed for circular dyeing machines, they cannot always reliably detect yarn breaks that occur during production. This points to a significant gap in the industry.

As part of this study, a sensor that can be integrated into circular yarn dyeing machines, instantly detects yarn breaks, and automatically stops the machine has been designed. The designed sensor operates using the transmitter (IR LED) and receiver (photo diode) principle, detecting the shadow cast by the yarn and evaluating yarn presence information. In the event of a yarn break, the shadow is eliminated, the receiver directly detects the light, and this signal is processed and transmitted to the machine control system. This reduces waste rates in production, optimizes chemical consumption, prevents quality losses, and increases overall production efficiency. To evaluate the performance of the developed sensor, electrical tests such as voltage, current, and power consumption were conducted, as well as sensor operability tests with different raw materials and yarn thicknesses. Consequently, the primary motivation for this study is to develop an innovative sensor technology that will contribute to the automation and digitalization processes of the textile industry and increase quality and efficiency in production.

2. Materials and Methods

The sensor system developed in this study consists of two main components: the electronic part (sensor circuit) and the mechanical part (protective housing and mounting assembly). The purpose of the sensor is to detect yarn breaks in circular yarn dyeing machines in real time and to automatically stop the machine.

2.1. Electronic Part

The sensor's basic operating principle is based on an optical transmitter-receiver system. Light from the IR LED used as the transmitter is passed through the yarn and detected by the photodiode on the opposite side.

In normal operation, the yarn blocks the light path, creating a shadow on the photodiode. If the yarn breaks, the shadow disappears, and full light falls on the photodiode. This signal is converted into an electrical signal, and the output, which is +9VDC, is increased

to +24VDC using a transistor circuit. The output signal is transferred to the PLC digital input via a 3x0.5 mm² cable. When the PLC ladder program detects this signal, it stops the machine and prevents faulty production.
The electronic board contains a voltage regulator, transistors, diodes, and a red status LED. The status LED remains off when yarn is present and illuminates when yarn breaks, providing a visual warning to the operator.

2.2. Mechanical Part

The electronic board is housed in a special enclosure made of ABS material using a 3D printer to protect it from external factors. Slots for the IR LED, photodiode, and red LED are designed into the enclosure. Optical detection is achieved consistently through the channel through which the yarn passes. ABS was chosen for its impact resistance and electrical insulation properties.

After the yarn break sensor was created, tests were conducted to measure the sensor's electrical performance, including parameters such as voltage, current, and power consumption, and to evaluate its measurement performance on thick and thin counts.

3. Results

As part of this study, a sensor was designed that can detect yarn breaks in circular yarn dyeing machines and cause the machine to stop. Based on the electrical test results, the current drawn by the sensor was measured with a multimeter as 1 ampere, and the total power consumption of the sensor was approximately 6W.

Table 1: Sensor Operation Test Results at Different Yarn Counts

Yarn Count	Sensor Output Voltage
In the absence of thread	9,98 V
3/1	3,1 V
4/1	3,7 V
20/1	7,8 V
30/1	8,4 V

Data obtained from laboratory and field tests of the developed sensor demonstrated effective detection of yarn breaks, as shown in Table 1. In idle tests, the sensor was observed to produce a stable output signal and ensure accurate transmission to the PLC system. It was determined that the system's sensitivity was particularly high for fine yarns, while detection became more stable with thick yarns, with shadow formation becoming more pronounced. The 3D-printed housing used in the mechanical section provides protection against external environmental influences, and the easily visible red LED indicator speeds up operator intervention.

4. Discussion and Conclusion

Within the scope of this study, the yarn detection sensor developed for use in circular yarn dyeing machines has been enhanced with a more compact, ergonomic, and functional structure compared to existing systems. The sensor's reduced dimensions offer significant advantages in terms of ease of installation and reduced machine footprint. Furthermore, the red LED warning system, activated in the event of a yarn break, allows the operator to quickly detect the situation, aiming to minimize production losses. A key aspect of the study is that the sensor was developed using domestic production capabilities. This directly contributes to reducing dependence on imported products and lowering production costs. The fact that the sensor was designed in-house allows for easy software and hardware modifications in future processes. Laboratory tests and field trials have demonstrated that the sensor can operate reliably with yarns made from different raw materials and with varying finenesses. Furthermore, the sensor's high accuracy, particularly in production environments where moist yarns are processed, demonstrates that its application is not limited to circular machines.

In conclusion, the developed sensor: It is anticipated that it will be an alternative to existing sensors thanks to its advantages such as size, durability, cost-effectiveness and high detection accuracy and will contribute to uninterrupted production by increasing production efficiency in the textile industry.

5. Acknowledge

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