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Recent Innovations in Yarn Technology: A Review

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Abstract- A significant amount of studies have already been devoted to the advancement of spun yarn production technology. This article has critically evaluated some recent innovations in spun yarn production such as twisting mechanism based on superconducting technology in ring-spinning system, concept of manufacturing cluster spun composite yarn and development of bobbin tracing system based on RFID technology. All the above mentioned technologies consist of huge potentiality and have not been commercialized yet in the industrial sector. This paper depicts the above aspects and their feasible interactions.

Index Terms- Bobbin tracing system, Cluster-Spun Yarn, RFID technology, Superconducting magnetic bearing (SMB).

I. Introduction

Most of the latest innovations in spun yarn production are modifications of current techniques as well as advances in processes and product qualities. A foremost drawback of existing twisting mechanism of ring spinning is the friction between the ring and traveller. The implementation of 'superconducting technology based twisting mechanism' remarkably reduces the friction between ring and traveller during production [2].Another new concept of producing composite yarn called cluster-spun yarn. Here, polyester multifilament are spread by applying a slotted roller and then blended with cotton fibre. This yarn reduces the slippage tendency of staple fibres relative to the filaments in core spun composite yarns [1] . Besides, the purpose of 'Radio Frequency Identification (RFID)' bobbin tracing technique is to identify the bobbin to spindle in the spinning frame during the process of production. The target bobbins are traced and recorded in the spinning frame via non-touching dual-directional data communication. The bobbin information can be implemented to observe the quality of spun yarn from each spindle [6].

II. INNOVATIVE TWISTING SYSTEM BASED ON SUPERCONDUCTING TECHNOLOGY

A. Background

In the short staple spinning process, the ring-spinning technology is most extensively used nowadays. A combined action of ring and traveler is applied for inserting twist and winding the yarn on cops. However, the principal drawback of this twisting system is the friction between the ring and traveler. At higher speed this friction generates heat and thus decreases the productivity. A magnetic bearing system based on superconducting technology can be implemented to overcome this limitation by replacing the existing ring/traveler system. This superconducting magnet bearing includes a circular superconductor and a durable magnet ring [2].

B. Principle of superconducting magnetic bearing

The SMB is the collaborating force between an agent system (such as a permanent magnet (PM)) and High Temperature Superconductors (HTSC) components. These bearing acts as self-stabilizing, that is, they stay as completely passive devices without any essentiality for position sensing and control [2].

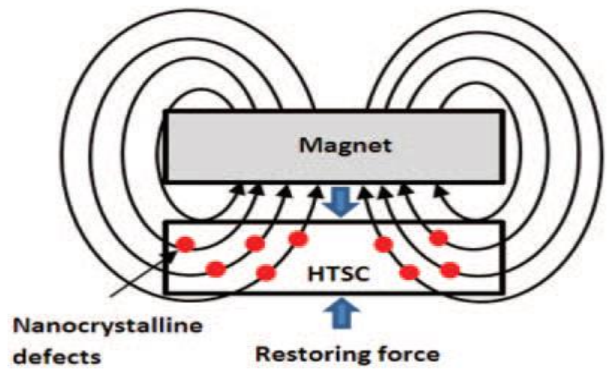

Figure-1: Levitated magnet over superconductor (HTSC)[2].

A PM is positioned over a superconductor at few millimetres distance. The flux lines of the PM go through the superconductor are pinned by nano-crystalline defects. This is executed by cooling the superconductor at -196^{o}C with liquid nitrogen, which is termed as the 'flux pinning effect' [8].

C. Designs of superconductor magnet bearing ring

Hossain(2010) [3] suggested two renowned designs of SMBthat can be implemented as twisting and winding devices in the conventional ring-spinning machine.

- SMB1, where a magnetic ring rotates coaxially overa superconductor ring;
- SMB2, where a magnetic ring rotates coplanarinside the superconductor ring(Hussain, 2010) [3].

In Figure 2(a), the PM (rotor) and the superconducting ring (stator) are organized coaxially with the spindle axis instead of the typical ring/traveler system. The PM is levitated and free to rotate, while the superconductor ring stays fixed[2].

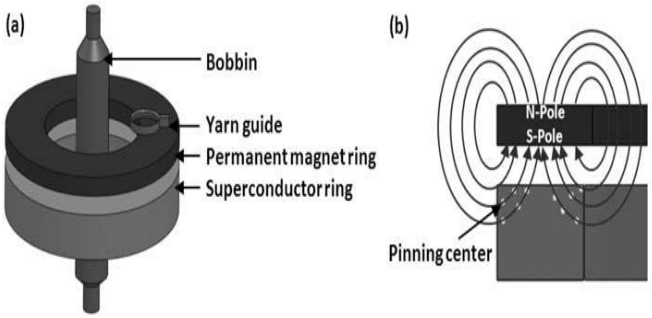

Figure-2: Superconducting magnetic bearing, SMB1: (a) topology; (b) cross-sectional view of SMB1 [2].

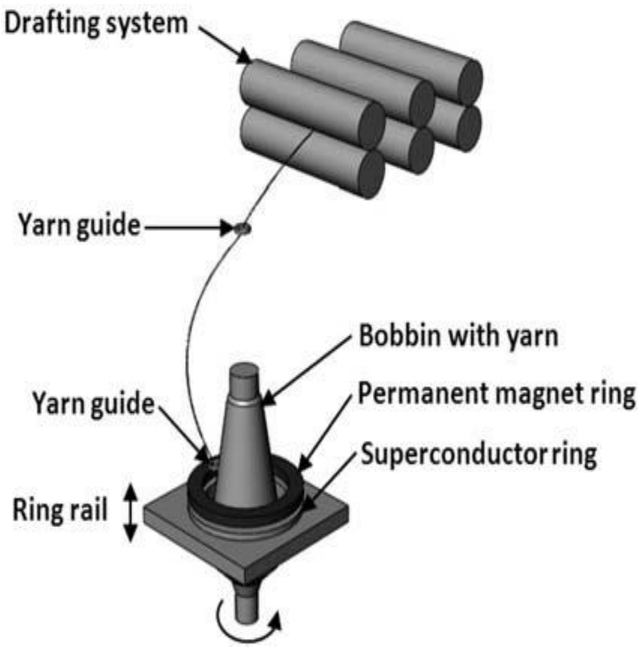

Figure-3: New concept of ring-spinning using SMB1 [2].

D. Ring spinning with SMB

The superconducting ring has been placed on a non-magnetic brass pot, which is utilized as a container for liquid nitrogen in order to cool down the superconductor shown in Figure 4(a). In Figure 4(b), the entire SMB system is represented after its placement in the ring-spinning tester [2].

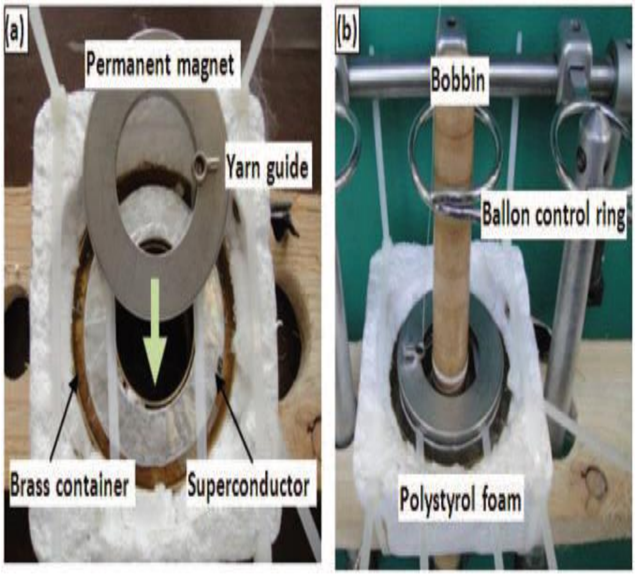

Figure-4: Superconducting magnetic bearing: (a) construction; (b) implementation in the ring-spinning tester [2].

The YBCO ($YBa_2Cu_3O_{7-X}$) superconductor is cooled at -196^o C and kept at this temperature throughout the entire spinning process before yarn production in SMB [2].

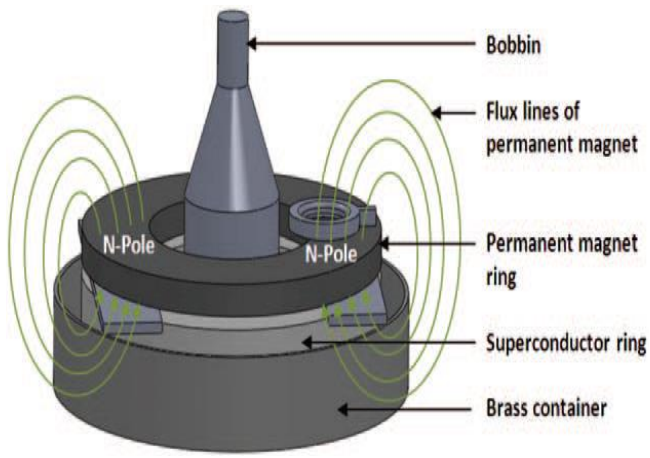

Figure-5: Schematic diagram of superconducting magnetic bearing SMB1 before cooling [2].

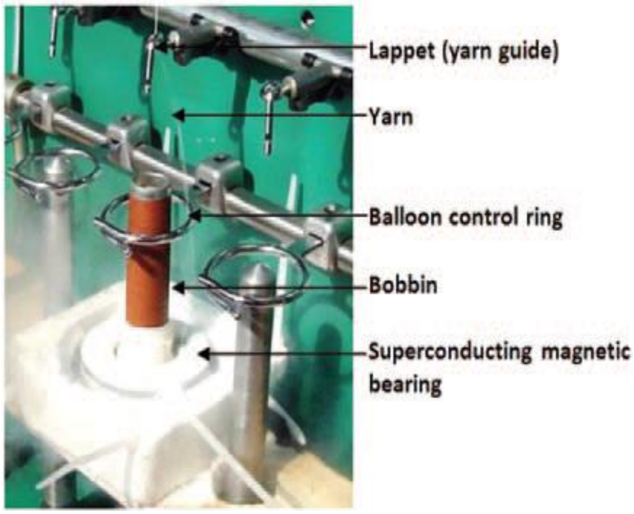

Figure-6: Spinning with the superconducting magnetic bearing ring-spinning machine [2].

In order to affix the levitation distance a non-magnetic spacer has been utilized between the PM ring and superconductor. The flux lines of the PM ring penetrate the superconductor ring, as represented schematically in Figure 5[2].

E. Advantages of SMB over the conventional ring/traveler system

The core advantages of SMB over the conventionalring/traveler system mentioned by Hossain, Abdkader, Cherif, et al., (2013) [2]summarized as follows.

- The SMB is a type of passive magnetic bearing system.
- No need of extra system and sensor to run SMB.
- This bearing technique can be executed as a radial, axial, linear bearing system for high-speed applications like in linear transport systems, turbo machines, etc.
- In comparison with active magnetic bearing system the construction of this kind of bearing is simple.
- The SMB is a durable bearing system, which is essential to prevent tension variation of yarn during the spinning process.
- The friction-free SMB can increase the productivity of the ring-spinning machine because of its stable rotation at high speed.

F. Future Prospects

SMB system proposes an enormous possibility to replace the current ring traveler system. However, the weight and the size of the PM and the superconductor ring is required to be more optimized. A theoretical method has to be established in order to predict the yarn tension, balloon formation, the weight of PM, etc.by considering the superconductor magnetic bearing system. As there is no friction in the SMB during running, it is possible to spin yarn to double the speed of the ring spinning machine. Hence, the SMB can bring revolution at the twisting mechanism of yarn by eliminating the friction of the ring/traveler system in the typical ring-spinning machine [2].

III. CLUSTER-SPUN YARN – A NEW COMPOSITE YARN MANUFACTURING TECHNIQUE

A. Background

In recent years, researchers are giving emphasis on further developments of Composite yarn spinning methods. A general drawback with core-spun composite yarns manufactured on the ring spinning frame is the slippage of the staple fibres comparative to the filament [7] .To build up the required cohesion between the sheath and the core component a high level of twist can be applied. But this will rise production costs and reduce production speed as well [5] . To resolve these deficiencies a new concept of composite yarn production called "cluster-spun yarn", where polyester multifilament is drawn by a slotted roller and cotton fibres are act as the staple part. The multifilament is divided into two or three (even four) substrands by a slotted roller with fine grooves and thus a clustered spun yarn is produced [1] .

B. Production of Cluster Spun Yarn

A modified conventional ring spinning frame with a slotted roller to facilitate feeding of polyester multifilament to the front rollers of the drafting system is applied in order to manufacture cluster-spun composite yarn [1] .

In this operation, the spinning frame is modified with a spread slotted roller (Figure 7.) having fine grooves (1 mm). Before clustering and joining the staple fibres at the front roller nip, the filaments are passed over a flexible tensioning device. At the top of the drafting unit a thread guide is placed to ensure accurate positioning of the filaments at the centre of the drafted fibre strand [1] .

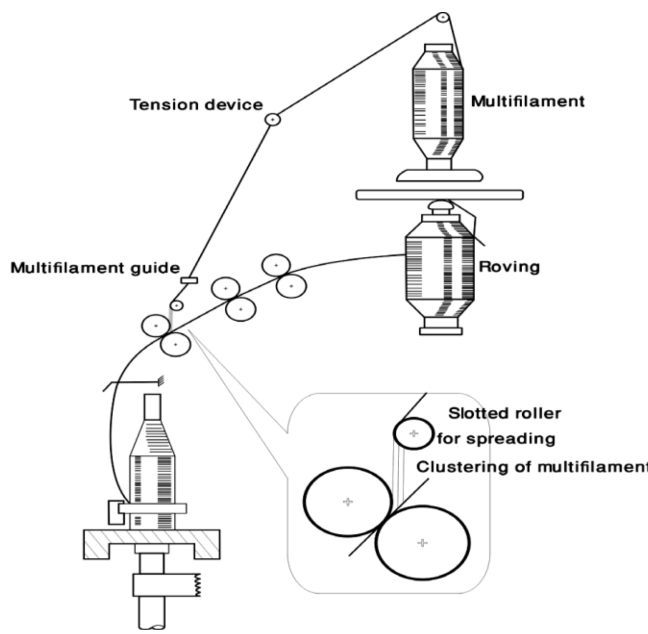

Figure-6: Schematic diagram of the device for the spinning of cluster-spun yarn [1] .

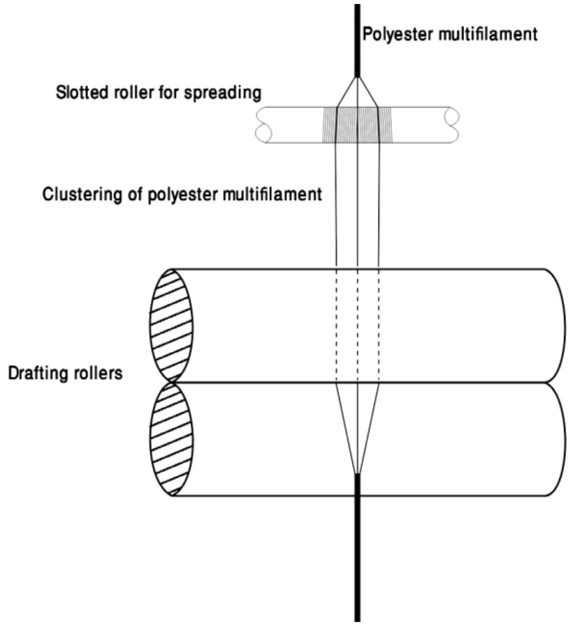

Figure-7: Schematic of the slotted roller for spreading [1].

C. *Properties of Cluster spun yarn*

The properties of cluster spun yarn are characterized by Gharahaghaji, Zargar, Ghane et al., (2010) [1] shown in the followings.

The tenacity and elongation of cluster-spun yarns is much higher than that of core-spun yarns. This indicates that clustering significantly influence the yarn properties as well as structure because of the reasons pointed below:

Polyester filament and cotton fibre blend provides a greater frictional force and fibre cohesion.

Reduces the slippage tendency of the staple fibres comparative to the filament. Enhanced fibre migration in the yarn.

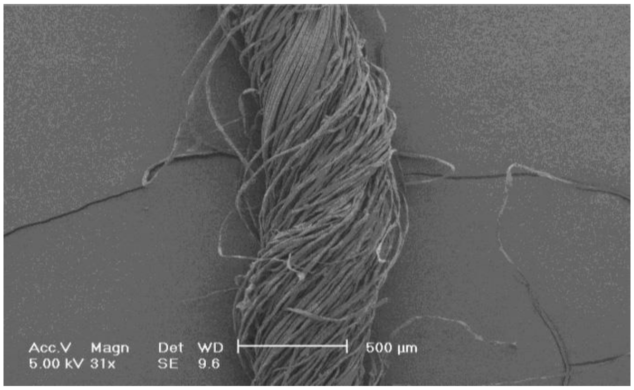

Figure-8: Longitudinal view of the cluster-spun spun yarn [1]

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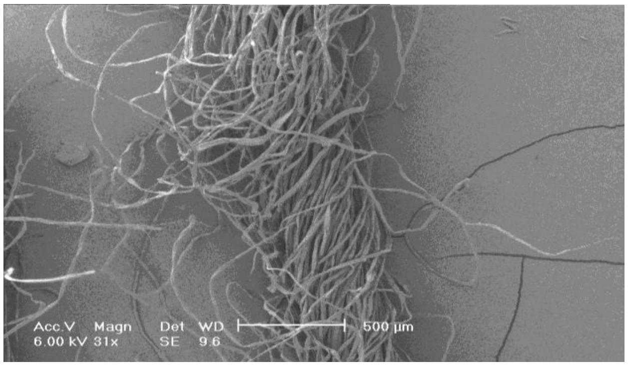

Figure-9: Longitudinal view of the core-spun yarn [1].

From Figure 8 and 9, it is noticeable that cluster-spun yarns have a clearer appearance than core-spun yarns. In addition, the cluster spun yarn structure is more packed and tighter than core spun yarns.

D. *Future Prospects*

The distinguished internal structures and structural mechanics of a cluster spun yarn have outcomes in superior properties of the yarn. This upgraded yarn properties and structure reduce the slippage tendency of staple fibres relative to the filament. Furthermore, higher frictional force and cohesion result in evenly and firmly blended polyester filaments and the cotton fibres in cluster-spun yarn. In addition, lower twist is necessary to produce a quality yarn. Overall, cluster-spun yarn has a huge potential to perform a significant role at the commercial application of composite yarn spinning in near future [1].

IV. RFID TECHNOLOGY BASED BOBBIN TRACING SYSTEM

A. *Background*

The predominant barrier of quality control for every spindle in spinning frame is the loss of information related with bobbins and spindles after the point-of-spinning. Based on RFID technique, the information of bobbins associated with serial number of spindles is identified and recorded automatically in this process. The RFID (Radio Frequency Identification) is termed as a non-contact automatic identification technique [6].

B. *Development of electronic spool*

Electronic spool and bobbin are the two substantial elements in the management of bobbins applying RFID technology [6]. As shown in Figure 8, the electronic spool is a spinning spool attached with a RFID tag [4].

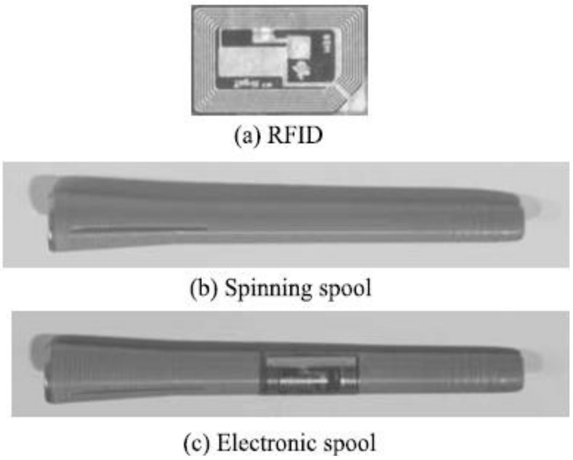

Figure-10: Structure of electronic spool[6].

The tracing management is an object database management system with ability of traceability. The information of bobbin can be obtained through the system [6].
Liu and Gao (2010) [6]stated that the tracing system of bobbin has the following two important aspects.

- It is essential to attain traceability of each bobbin. In order to trace a single bobbin, each bobbin needs to attain a unique identity (UID).
- It is appropriate to apply the information of tracing a bobbin for queries; the bobbin information is recorded and saved as database in case of tracing.

C. System structure

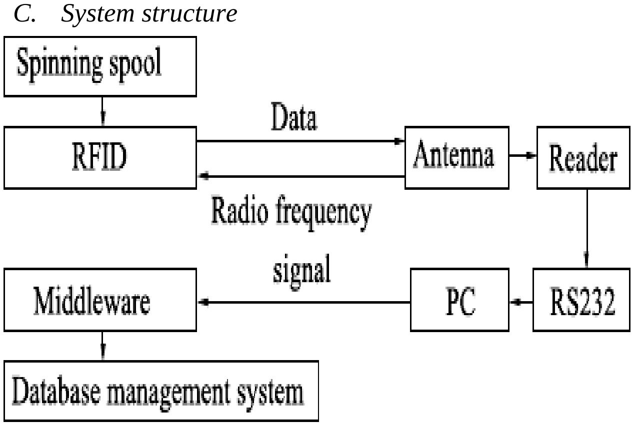

Figure-11: Diagram of system structure [6].

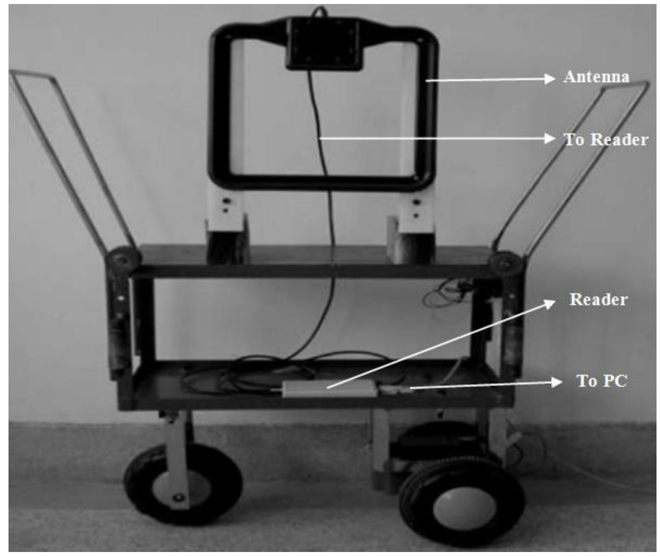

Figure-12: Hardware of bobbin management information system (B-MIS)[6].

According to Liu and Gao(2010)[6], the reading system is principally consists of three components.

- An RFID tag (Texas Instruments Incorporated (ISO15693) established on the bobbin to be recognized.
- Tag reader (ID ISC.MR100/101) as a read or write/read device.
- An antenna (Texas Instruments Incorporated: RI-ANT-T01A, 13.56 MHz) discharging radio signals to operate the tag and read/write data to it.

D. System function

Liu and Gao(2010)[6] suggested that this system can be acquired with the following main functic To Reader

- Spool login: Newly purchased electronic tags are attached on each spool of spun yarn.
- Bobbin login: Based on the spindle order of spinning frame each spindle is ranked and the spool is established to the ranking spindle of spinning frame.
- Bobbin use: The winder information about the bobbin used and the time of use are stored in the database.
- Bobbin management: Inventory inspection and analysis of bobbin location in the warehouse are contained in the management of bobbin stored in the warehouse.
- Bobbin information tracing: The ambiguous bobbin will be analysed from the database and the entire information about it will be displayed.

Liu and Gao(2010)[6] exhibited the development of primary functional module in the following three aspects:

- Real-timing: A multi-thread programming technology is implemented in research to enhance the actual timing of software.

- Reliability: Application program is accountable for processing, storage, and presentation of the reader's identification information.
- Universality: This software method is assembled for a particular intension to assist the application of other incidents without much alteration onto the system.

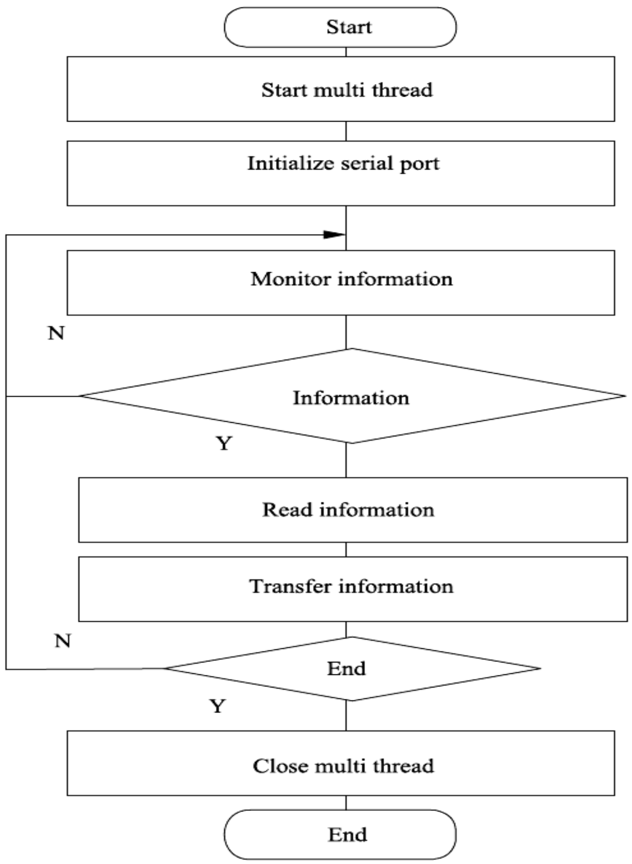

Figure-13: Main module of electronic tag system [6].

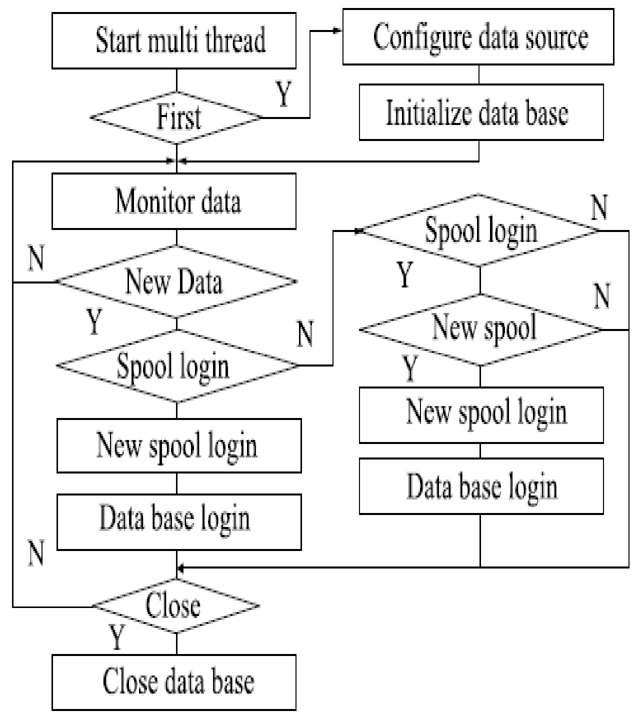

Figure-14: Module of electronic tag database system [6].

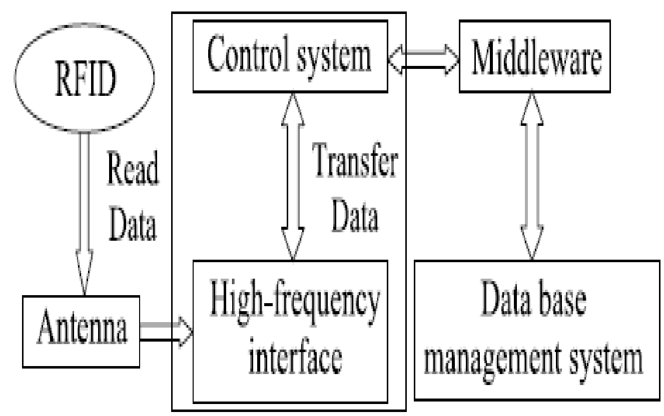

Figure-15: Reading process of electronic tag [6].

A specific spool code is stored in the database due to the registration of spool in the bobbin management system; this step is termed as spool registration [6].

E. Advantages of utilizing RFID in Bobbin Tracing System

The benefits of applying RFID in bobbin tracing system asserted by Liu and Gao(2010)[6] outlined below.

- To comprehend shared information among bobbins, spindles, winding, and other connected techniques.
- RFID for quality control automation of bobbin can be applied to differentiate precisely individual bobbin from distinctive spindles.
- Application of bobbin real-time and closed loop tracking information can enhance yarn quality and achieve possible economic benefit.

- Improve the efficiency of data collection by multi-tag identification.

F. Future prospects

There are various areas for future prospects on the RFID based bobbin tracing system. Firstly, RFID management system of bobbins needs to be organised for the transaction of data among enterprises to attain tracking, tracing, and other exchange in a broader extent. Currently, the internal exchange of data in an enterprise information management system can be executed in this process, which could act as the foundation for exchange of information among enterprises. Secondly, management areas are required to be expanded in the textile industry to form new application solutions. The application of RFID is the only technique restricted in the aspect of bobbin management till now [6].

V. CONCULSIONS

The inventions discussed in this paper exhibit huge potential in spun yarn production. They can play a vital role as all of them are time saving, cost effective and ensure to manufacture a better quality yarn. This definitely will create a momentous influence in the spun yarn production if these technologies can be commercialized appropriately at the industrial sector. However, further research is still required to bring successful commercialisation of these concepts.

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