AUTOMATED BOBBIN INSPECTION SYSTEM

Josef Baumgartinger a, Roman König b

a Lenzing Technik GmbH&CoKG, Div. Lenzing Technik, Werkstrasse 2, Lenzing, Austria
b Glanzstoff Bohemia s.r.o., Lovosice, Czech Republic

Abstract
Automated bobbin inspection systems will take over the present monotonous visual inspection which is difficult and tiring for human operators and which causes so many wrong or faulty decisions in today’s manual inspection. Latest technology and the fast progress in the field of laser optics, data and image analysis do offer further progress and time saving possibilities, which will continue to increase the profitability of such automated systems like Lenzing Instruments LIS.

Keywords: bobbin detection; optical inspection; artificial vision inspection

Introduction
In a filament production process (POY, HOY, FDY) and also during texturing usually a certain number of bobbins do not comply to higher quality levels because of either obvious structural faults like deformations, oil or dirt stains, etc., or because of faults in the fine structure – like overturned ends or broken filaments which usually are very difficult to detect.

Certainly a desired ideal case would be a 'zero-error-production', and more and more companies are undertaking big efforts in this direction.

However, to identify problematic components within a production plant, it is necessary to check and inspect every single bobbin thoroughly and to evaluate the detected faults statistically. The resulting statistics may allow one to fully sort out some problems and to at least minimize others.

With an online data connection to the SQL database the quality level of the production is always present. The traceability within the production flow improves significantly. To achieve as well as to maintain zero-error-production it is and always will be crucial to inspect the product before it leaves the plant site.

Nowadays usually a significant number of human inspectors are responsible for this sophisticated task. However, for human reasons (tiring and monotonous work, varying ability of concentration) as well as for technical reasons (shiny or glossy bobbin surfaces, light conditions etc.) human inspection is never as constant and reliable as an automated inspection could be. See figure 1.

Hence reliability and the cost of manpower have been the reasons for quite a few institutions and companies to think about how to automate the process of bobbin inspection in recent years.

Figure 1. Physiological variation of human performance / ability of concentration [1]
1 Classification of Nonconformity

The classification of bobbin defects has always been an individual matter for each company, depending on requirements and quality levels. An automatic inspection system should easily comply with individual classifications and of course also threshold values for different defects have to be selectable individually.

Different kinds of quality parameters, depending on the application of the filaments, have to be classified:

- **Geometry:**
  - Diameter
  - Winding length and position
  - Density / weight
  - Taper angle
- **Macro structural defects:**
  - Bulges and ridges
  - Saddle
  - Tube- / bobbin damages
- **Micro structural defects:**
  - Overthrown ends
  - Dirt spots or colour defects
  - Whiteness differences
  - Transfer tail and waste bunch
  - Broken filaments, loops, fluff
  - Tight spots

The design of the LIS in hardware and software is very flexible and allows of course an individual combination of quality parameters, which have to be detected.

Anyway, to make a system like the LIS 200 feasible, all required inspections have to be taken over by the system.

2 Automated Inspection

It seems to be obvious that a human optical (visual) inspection can only be replaced by an automatic system, which works on an optical basis. However, a series of comparative experiments has proven that a plain camera system is not suitable to identify the above-mentioned errors at a satisfactory level as compared to the human eye. The quality and repeatability of the results have been poor, particularly in the range of micro structural defects.

Therefore the Lenzing Instruments automated bobbin inspection system LIS 200 is based on latest laser technology, illumination and digital camera systems, which shows a tremendously better detection quality, resolution and repeatability compared to common camera based systems.

2.1 How does the LIS 200 work?

The LIS measurement is based on different technologies.

While the bobbin is being rotated around its axis in the testing position by a handling robot, the surface of the bobbin is inspected with digital cameras and / or lasers including special illumination.

The basic method of the LIS 200 as described before, and the sophisticated evaluation software allow one to detect defects of a bobbin in the geometry, macro structure and micro structure at a result rate comparable to the human inspection – except for the reliable detection of broken filaments.

Detection of Broken Filaments:

Single filaments are usually too fine to be identified at the resolution used for scanning the topography of the bobbin’s surface. A laser beam (wave length of the laser is 685 nm) is emitted on to a bobbin's face side under a flat angle and a CCD matrix camera, which is mounted under a flat angle as well, records the reflection of the surface.

While the surface of the bobbin itself appears as a solid line for the CCD camera, single filaments sticking out from the surface appear like flash lights, when they are hit by the laser beam.

Counting the number of such flashes during one full rotation of the bobbin allows one to detect broken filaments, loops or fluff at a very high accuracy and reliability. Due to the fact that the counting takes place on two different levels the
quantity is separated into long and short broken filaments.

With the same detection system some other quality parameters (winding length, bulges and ridges, saddle) can be detected.

**Detection of Overthrown Ends**

Extremely difficult is the recording of overthrown ends because they hardly show a difference from the bobbins face structure. The intelligent human vision system is able to automatically ignore unimportant structures therefore it can concentrate on certain patterns and identify them quite easily.

An automatic system has to obey to the fact that besides the unique pattern of one or more overthrown ends every picture contains usually a lot of noise and insignificant disturbances.

The detection of overthrown ends by the LIS 200 has been realized by introducing a learning mode, which enables the system by comparison to distinguish between bobbins with overthrown ends exceeding a certain length and others without.

**Detection of Dirt**

The detection of dirt is done under special illumination by 3 line sensor color digital cameras with more than 2000 pixels. The cameras scan 100 % of the surface and system determine the RGB-value [2]. A color difference (dirt) leads to a different RGB-value, which is used for the classification.

**Detection of Diameter**

This is done with a triangulation laser distance sensor. The resolution is in the range of 0.5 mm.

**2.2 Evaluation System**

Digital image processing requires significant computing resources; on the other hand bobbin inspection is a highly time critical task - therefore every sensor of the LIS 200 is connected to its own evaluation PC.
The evaluation system is built by a complex hierarchy of personal computers (see Figure 5 and Figure 6), featuring rapid parallel calculation of the inspection results with a highly sophisticated digital image processing software and a flexible and simple user interface.

The front end allows interfacing to many common computer systems, enabling an easy integration of the LIS 200 into existing Process Control Systems as can be seen on Figure 6, which represents the installation at Glanzstoff-Bohemia / CZ.

**Evaluation and tolerance limits**

The results are transferred to a data concentrator, which collects all results of the sensors installed, and compares them to the tolerance limits defined by the operator. The system allows one to issue a simple 'Good – Bad' decision, or to differ between 3 or more different quality grades or to issue a complete result sheet with single inspection results for each bobbin.

The LIS allows one to determine tolerance values for each detectable defect. However, human inspectors hardly go for fixed tolerances – by experience they develop a feeling for whether a bobbin complies to the required quality level by only looking very shortly at it. Often a quality decision is not unanimous but will depend on the individual inspector. In such an ambiguous environment the introduction of an automatic inspection system will create a lot of discussion; the definition of significant tolerances will require a certain time for every individual customer. Here the learning software of the LIS is a tremendous advancement to optimize the correspondence of quality decisions by the human and by the machine.
Once an acceptable inspection level has been thought out and achieved by the LIS 200, additional units will work at exactly the same quality level continuously, which is a significant advantage compared to the ambiguous human inspection.

Apart from issuing quality decisions and inspection results for single bobbins the LIS 200 stores all results into a database system. With a flexible query interface it is easy to set up statistics, which show certain trends and regularities of repeated defects (e.g. machine regularities, shift wise differences, etc.) and hence to eliminate them.

2.3 Handling Unit

The physical interface between the LIS 200 inspection and the process flow is realized by the handling unit. Depending on the type of transport system (e.g. conveyor, buggy or shuttle) a range of transport means are possible:
- robots from 2 axes up to 6 axes
- conveyor with single trays and portal robots
- or manual supply can be used to take one after the other bobbin for presenting them to the inspection system and putting them back into the process flow.

3 Economic Benefit

The return of investment on an automatic bobbin inspection with the LIS 200 will be determined by many different factors, e.g. the technical and automation level of a production unit, the cost of manpower and certainly the quality level and cost of customer claims.

In general an automatic system like the LIS 200 yields the following major economical effects and benefits:

- **Cost reduction**
  Cost effects include the reduction of manpower, reduction of inspection costs as well as of B-grade products and waste.
  Immediate reaction on detected malfunctions and hence a reduction in internal quality costs and customer claims.

- **Increasing product quality**
  The unanimous and repeatable inspection level of the automatic system leads to an exact reliable product quality at the end of the process.

The statistical evaluation of defect occurrences and trends allows one to immediately identify and react on problems in the production process. The actual status of the quality is monitored online.

![Figure 7](image-url) Statistical evaluation of the quality level based on data from LIS 200.

For each product, which is running there is an overview or a comparison between different days as shown in Figure 7 for 7 days. If there is a need for some more detailed information the traceability to the single spinning machine and position is possible. Due to continuous evaluation faults are systematically detected.

On the other hand the investment for installing an automatic bobbin inspection depends on three main parameters:

- **Throughput**
  How many bobbins have to be inspected per hour, shift or day?
  As an upper time limit for inspection the LIS 200 requires approximately 5 seconds per bobbin from scanning to the final result. The handling time to get the bobbin from the transport system into the testing position and back again depends on the transport system and the logistic concept. In ideal cases handling time may even overlap the inspection time. A realistic handling time shall be in the range of 0 to 4 seconds per bobbin.
  The production or testing volume has to be
divided by the performance of a system including inspection and handling time – the result is the number of complete LIS 200 units required. The standard measuring including handling of 7 to 10 seconds per bobbin enables a fully automated inspection of approx. 8,600 bobbins per day and line.

- **Inspection level**
  Answering the question which defects are to be inspected for in an individual case leads to the configuration of a LIS 200, and the number of sensors required does certainly determine the price of a LIS 200 unit.

**Handling unit**

Finally the optimal integration of the LIS 200 into the product flow requires a certain robotic system laid out to be strong enough for handling the bobbins, and to flexibly interface with the transport system.

Proper system integration and an adequate logistics concept are important to optimise the handling time and hence to increase the throughput as discussed above.

The large number of variables determining the feasibility of an automatic bobbin inspection makes it very difficult to issue general statements about the cost-benefit ratio. But realistic payback times of installing an automatic inspection with the LIS 200 shall range from 12 to 30 months.

**References**


[2] A color value expressed in the RGB color space is composed of red, green, and blue component values.