Practical inspection systems for nonwoven diaper liner fabrics

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ABSTRACT: Disposable diaper manufacturers demand continuously improving quality and reduced costs from their roll goods suppliers. This highly competitive consumer products segment continues to challenge the nonwovens industry. Diaper liner producers are increasingly turning to continuous on-line inspection systems to accurately identify the most important areas for improvement. This paper describes recent diaper liner applications, specifically developments in on-line, camera-based continuous inspection systems. Field results indicate that reliable defect detection and mapping lead to both process and product quality improvements. These findings have resulted in a proven system technology that is practical for carded, thermal-bond diaper liner applications.

KEYWORDS: Cameras, defects, diapers, disposables, fabric, inspection, measurement, nonwovens, on line measurement, quality control, utilization, webs.

Disposable diaper manufacturers demand improved quality from their roll goods suppliers. This highly competitive consumer products segment challenges the nonwoven industry, and the uniformity and surface properties of the diaper web are increasingly important. These properties define the uniformity of water permeability, strength, and sensitive-skin touch effect.

In the paper industry, modern web inspection technologies have been used successfully to detect visual defects of paperboard. These technologies were challenged in the nonwoven industry until recently. However, the recent introduction of charge-coupled device (CCD) camera technology has permitted inspection of the nonwoven web. This paper describes two Measurex/RoiBox web inspection systems at Fabriano Soft, Cerreto Castello, Italy, which operate on PM Nos. 1 and 2. Both machines are trimmed, 330-cm (130-in.)-wide units that run at 100 m/min (330 ft/min). Product range is from 13 to 40 g/m^2, carded nonwoven, mainly for diaper cover stock.

Web inspection system

Modern web inspection systems are based on line-scan CCD cameras. Instead of taking a matrix picture, like TV cameras do, the line-scan camera has only one line of CCD elements, called pixels, with typically 2048 elements in a row. Any digital video image consists of small picture elements called pixels. These elements have a single value, and together they form a picture.

On a moving web, the inspection image is formed by taking line pictures of the web. Storing the lines into computer memory permits generating a picture as the basis for the inspection analysis. With the on-line scan camera, a section of the web in the cross direction is covered. Several cameras are typically used to cover the cross direction line of the entire sheet. At the edge of each camera's field of vision, the viewing areas slightly overlap, providing full-sheet inspection. A typical setup is shown in **Fig. 1.**

Pixel size, which defines the performance of the system, is important. Although smaller pixels provide higher resolution, pixels that are too small can provide too much detail. In the cross direction, the pixel size equals the viewing width of one camera/2048. At Fabriano Soft, there are three cameras, each viewing 1100

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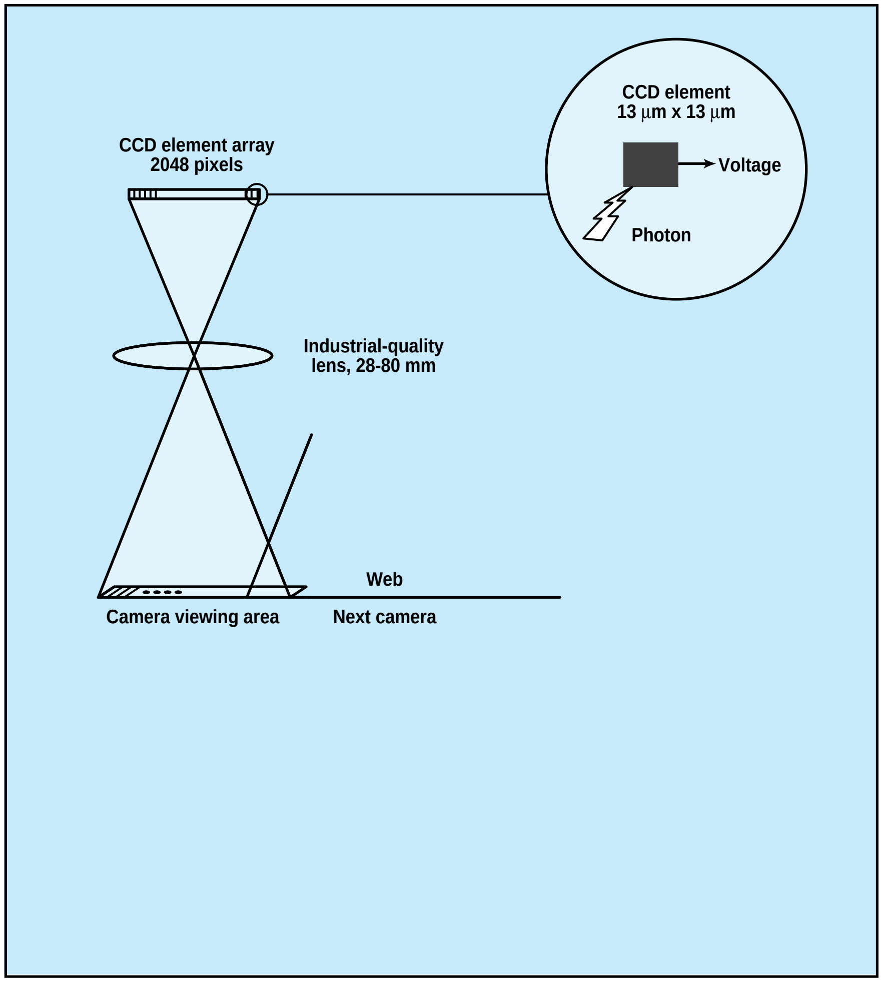
mm. The pixel dimension is therefore 1100/2048 = 0.537 mm in the cross direction.

In the machine direction, pixel size depends on the machine speed and the selected scan speed of the cameras (**Fig. 2**). The Measurex/RoiBox system typically reads cameras at 20 million pixels/s. Because there are 2048 pixels in every camera, each pixel is read 20,000,000/2048 = 9765 times/s. At Fabriano Soft, the line speed is 100 m/min = 1666 mm/s, so during one reading cycle, the sheet moves 1666/9765 = 0.17 mm.

The pixel information in every camera is processed in two stages: defect edge detection and visual image processing. In defect edge detection, the edges toward and away from any defect are detected from the natural variation of the sheet. This is performed by various algorithms, which form the heart of the defect detection. The less a defect differentiates from the acceptable variation (e.g., formation) of the sheet, the more difficult it is to detect. The edge information is sent with the defect type information to a visual image processor, which converts the edge information into a complete visualization of a defect, i.e., the size, shape, dimensions, and location.

When the visual image is complete, the information is sent to the host computer, which processes the data (e.g., completes periodic analysis, stores data, sends alarms, communicates with the operator, and reports data).

1. CCD camera technology



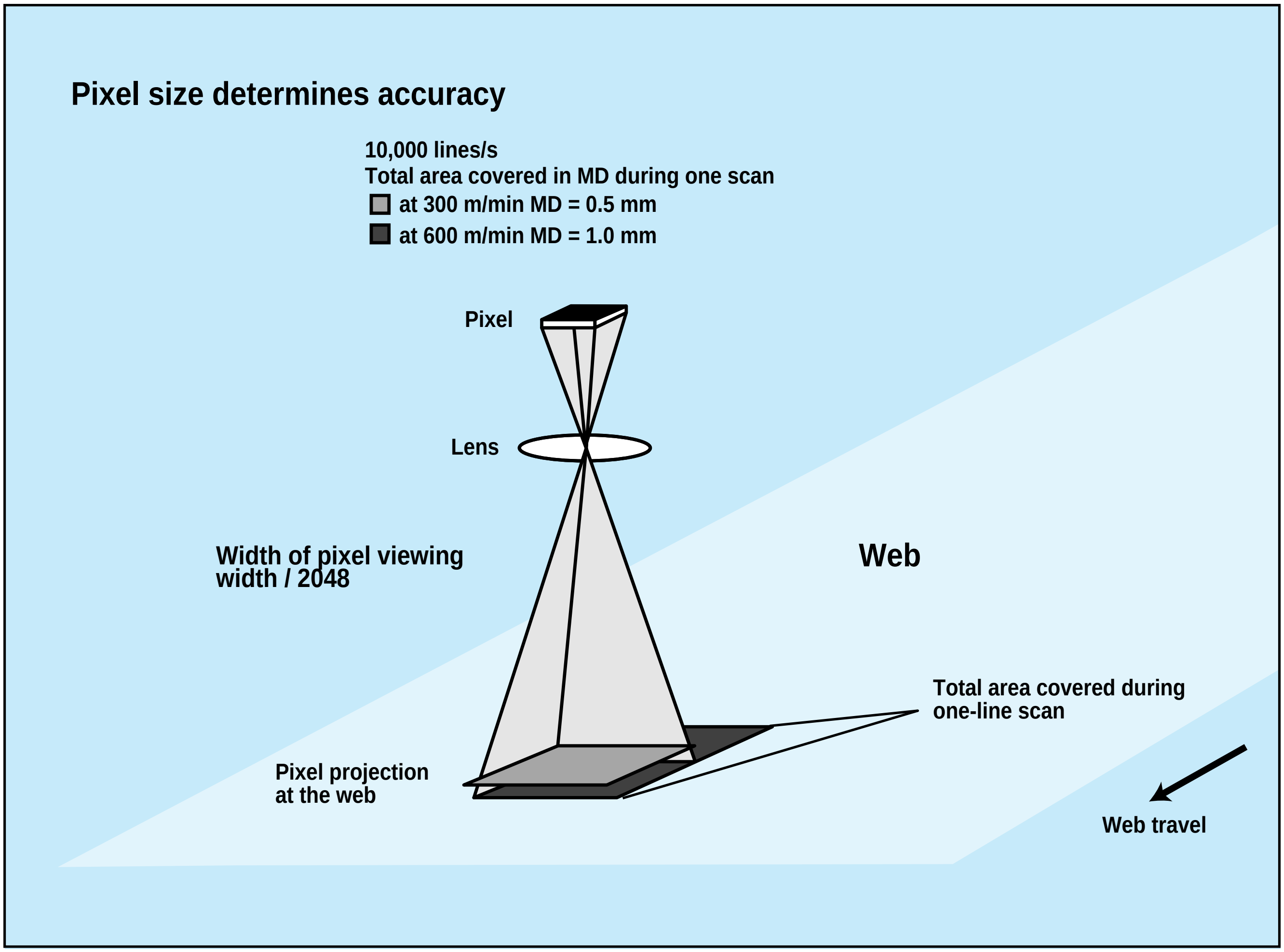
The defects of a carded nonwoven sheet

Carded nonwovens have reasonably good formation, thus continuous control of the formation is unnecessary. However, fibers may accumulate in some areas and may be sparse in others (**Fig. 3**). A light area on a diaper cover is unacceptable. There will be problems with thermal bonding and water permeability on such areas. There may also be a thick area of fibers, typically 5–20 mm in diameter, that forms a long-chain configuration (**Fig. 4**). These areas may get burned during the drying process, with a resultant hard, rough, and slightly brown surface. The softness properties may also be compromised.

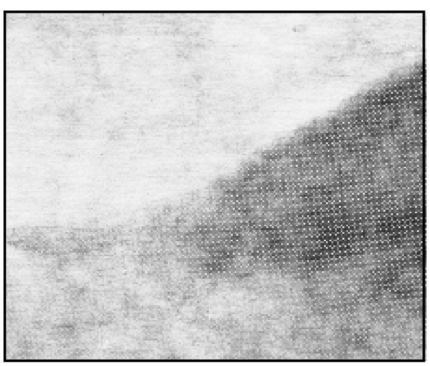
In a carding process, metal pieces can also get into the web (**Fig. 5**). These pieces can range from 0.2 mm to several millimeters in width. Because the smallest defect detected defines the camera viewing area in the cross direction, the metal pieces define the maximum number of cameras needed. To detect metal pieces down to 0.2 mm in diameter, cameras should each cover only 200 mm in the cross direction. This leads to an excessive number of cameras, and real-time image processing must deal with too much information. Therefore, cameras are typically selected so that they can detect metal pieces as small as 1.0 mm, and this can be achieved with each camera viewing about 1000 mm in the cross direction.

There is an additional metal detector connected into Roibox System at Fabriano Soft, so the defect reporting and alarming cover all sheet anomalies. Holes, thin areas, fiber bundles, edge cracks, and breaks in the nonwoven sheet are also detected by the CCD cameras.

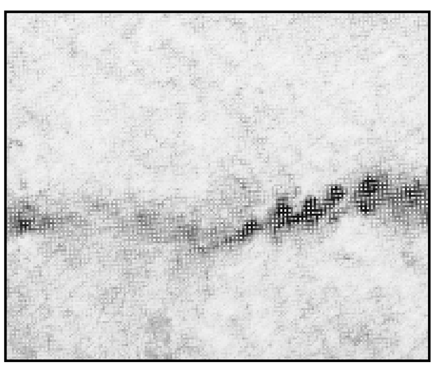
2. MD projection of a CCD pixel and a moving web



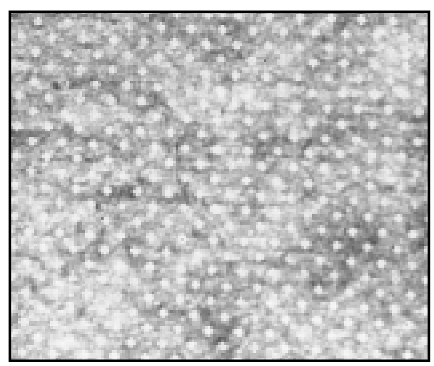
3. Fibers in dense (right) and sparse areas



4. Chain of fiber clumps



5. Metal piece in the diaper cover stock

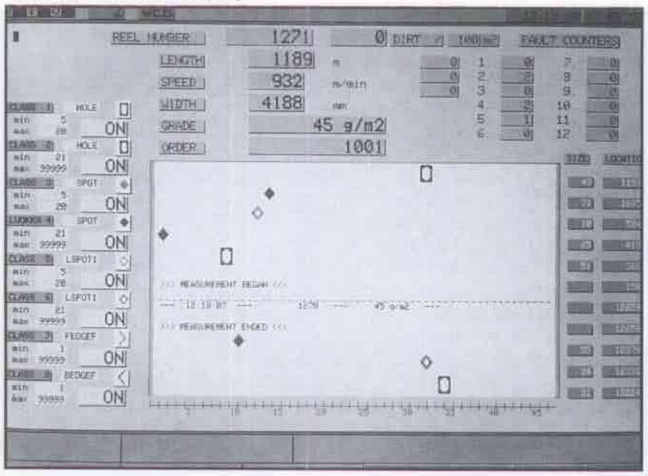


Reporting and alarming

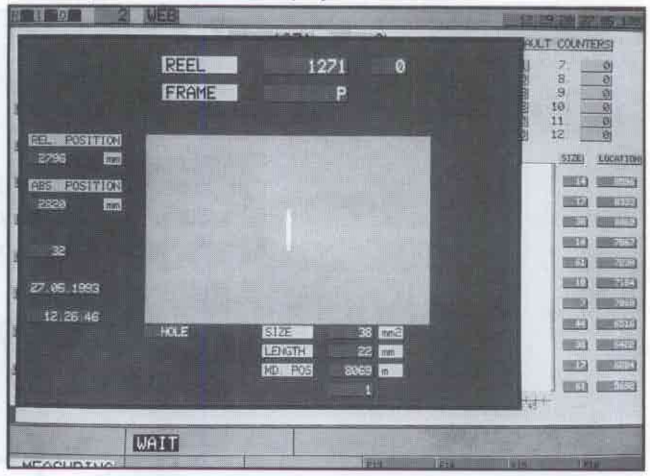
The operators use a color monitor and keyboard as the primary tools to communicate with the system. The most important monitor displays are as follows:

- **Real-time web display.** All current defects are located, and different symbols are used to represent the various defects (**Fig. 6**).
- **Scrolling web display.** This is similar to the real-time display but can also be used to view previous defects.
- **Detailed defect display.** Details of a defect can be viewed from the web displays (**Fig. 7**).

6. Real-time web display



7. Example of a defect as displayed on a monitor



Other displays include trend curves, cross profiles, periodic fault analysis, log book, and alarming. Programmable optical and acoustic alarms are used.

At Fabriano Soft, a defect's position is marked on the reel with a label that is inserted at the sheet edge. Although color markers may also be used to highlight defects, the soft edges of the reel may hide a color indication of a defect. Each reel's anomalies are printed on a defect map. By using this map in conjunction with the defect labels, the operator can remove the defects at the winder.

Experiences

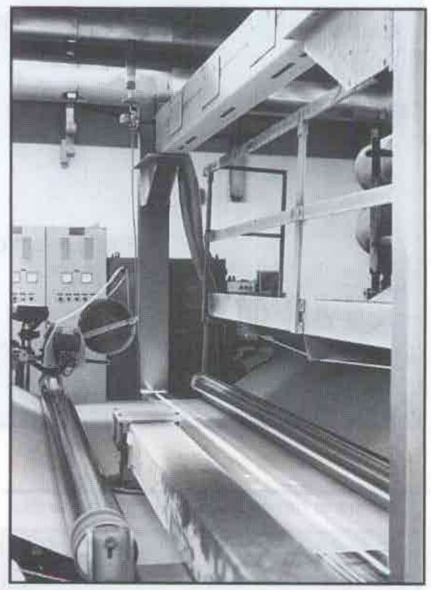
The Measurex/RoiBox web inspection system was installed on PM No. 2 in February 1993 (**Fig. 8**). Resolution was improved by adding one camera in March 1993. After initial tuning, the system has operated well. A key element of the successful defect detection is the special light source, which is especially designed for nonwovens.

The system was initially too critical, locating certain defects that were actually acceptable. After adjusting the system and further training the operators, the RoiBox unit was accepted as a tool that would improve quality. The system monitors the process and alarms the defects, and most defects are removed at the winder. It is important that the operators accept this type of quality system. With their cooperation, the results can be dramatic.

Conclusions

The new CCD camera-based web inspection technology allows 100% online inspection of nonwoven webs. Applying the technology to nonwovens is more challenging than adapting it to paper applications; special tuning, algorithms, and light sources are needed. However, once the system is installed, visual defects can be detected, alarmed, and removed. The result is better quality and an improved understanding of the manufacturing process.

8. Installation at Fabriano Soft



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