/THE DETECTOR MAKES THE DIFFERENCE

X-RAY INSPECTION SYSTEMS IN THE FOOD INDUSTRY

Industry ePaper

WIPOTEC

CONTENTS

ENSURING FOOD SAFETY AND QUALITY

In the European Union, Regulation (EC) No. 852/2004 prescribes what are known as the HACCP principles (Hazard Analysis & Critical Control Points). Article 5 (2) of the regulation sets out these seven principles in detail. Among other things, they include the duty to identify and observe critical control points. It is also the food producer's task to establish critical limits to ensure that products are correspondingly perfect.

Metal detectors are often used at critical control points to implement these principles with regard to foreign bodies. They identify faulty products based on changes in the electromagnetic field which are caused by the electrical and/or magnetic properties of metallic foreign bodies. This, however, limits detection to these foreign bodies alone. In addition, what are known as product effects (e.g. high salt content and high moisture content) and packaging effects (e.g. aluminium foil) make detection more difficult. As a result, X-ray inspection systems have established themselves increasingly in the food industry in recent years. The X-ray inspection system finds foreign bodies based on their specific absorption of X-ray energy and, to keep it simple, this depends on their density and thickness: basically, it looks for differences in absorption. When examining foods, which mainly have a density similar to water (1g/cm^3), it is relatively easy to identify stainless steel (density approx. 8 g/cm^3). Due to the functional principle, the range of detectable foreign materials is extremely wide: it is therefore possible to detect many different metals as well as glass, ceramics, stones and some types of plastic.

In addition to this, X-ray inspection systems can be used for many other quality assurance tasks. One system carries out all the inspection tasks simultaneously, meaning that there is no need for several systems one after another. Even further inspection systems **>>**

can be installed in the product space of an X-ray inspection system. This gives rise to multi-inspection systems. Installing one or several weigh cells enables the X-ray inspection system to weigh the products in a calibrated and verifiable manner. This combination reduces the number of different machines as well as the space required. It also simplifies integration into existing production lines. The same benefits are achieved when an X-ray inspection system is combined with vision inspection. It is also possible, for example, to inspect the printing of the expiry date and other properties of the label. The product can be examined from both above and below. Combining all three of these inspection systems in one unit saves even more space. ▲

Fig. 1: Frozen quiches are inspected for foreign bodies with an X-ray scanner

/ QUALITY ASSURANCE TASKS OF X-RAY INSPECTION SYSTEMS

The following applications are conceivable depending on the product and packaging:

- Foreign body detection
- Filling level check (e.g. on yoghurt pots)
- Checking the mass (in a complete packaging unit or in special zones, e.g. in yoghurt pots with several compartments)
- Completeness check by counting (e.g. chocolates in a package)
- Shape check (e.g. roundness of pizzas)
- Break and hole detection
- Automatic ripeness determination in complete cheese wheels and cheese blocks
- Clip check (e.g. for bread or sausage)

DESIGN OF AN X-RAY INSPECTION SYSTEM

Fig. 2: Design of an X-ray scanner

Transport systems

Belt or chain conveyors are usually used for transport through the X-ray inspection system. The transport system is a high priority not only for correct detection results and successful ejection of faulty products. Transport systems form the basis for linking various systems to each other as required and making it possible as a result to implement the most individual infeed and discharge configurations even with high production speeds. Advanced inspection systems in a modular design frequently have more than one conveyor belt. Flexible design of the mechanical components even enables the system to automatically generate the gaps between the products to be inspected which are necessary for reliable ejection.

Components for generating the X-rays

The X-rays are generated by an X-ray tube. A high-voltage generator supplies power to the tube. In most systems, these two components are combined in one container, known as the X-ray tank. Alternatively, there are versions in which both components are arranged separately. Tubes or tanks are basically wear parts. In systems with a separate arrangement of high-voltage generator and X-ray tube, they can easily be replaced in the event of a failure due to their small dimensions and low weights. They can also be replaced separately.

>>

X-ray detector

Product inspection using X-ray technology requires a component which is responsible for taking the monochrome X-ray image – this is known as the X-ray detector. To convert the invisible X-ray beams into visible light, a so-called scintillator is located between the product and the actual detector. This is a film or a special paint depending on the design.

The less intensively the product, packaging and potential foreign bodies absorb X-rays, the more light these detectors detect. X-ray detectors are usually designed as diode detectors or TDI camera systems. The next section explains the details and differences between these two technologies and provides further information about general detector parameters.

Image processing computer

The monochrome image generated by the detector is analysed or evaluated using highly developed image processing algorithms on an image processing computer. Additional coloured markings are visible in Fig. 4 indicating the detection of five foreign bodies, with each colour representing a different algorithm. Each pixel has a specific grey value, depending on the amount of X-rays absorbed. Fig. 4 shows the grey values of the X-ray image from Fig. 5. The deflections caused by the stainless steel foreign bodies are clearly visible. The image, and therefore the product, is examined for differences and specific patterns with regard to the grey values.

Once a foreign body has been detected, the software graphically marks this contamination and transmits a corresponding command to the control system for further action, e.g. for ejection of the contaminated product. In many cases, foreign bodies can be detected due to deflections which are as clear as those in Fig. 5. More complex algorithms are used for this purpose. **>>**

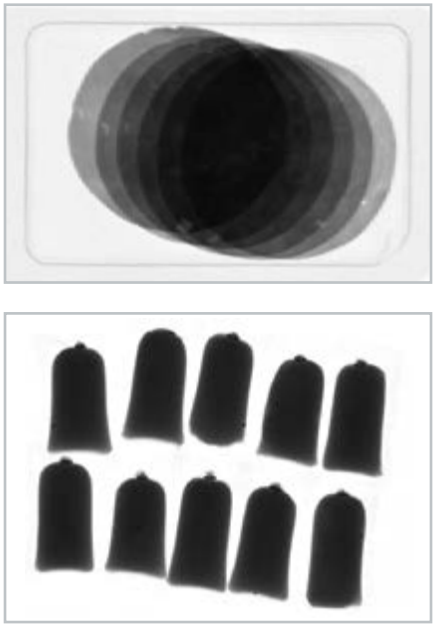

Fig. 3: top: X-ray image of thermoform package containing sliced meat;

bottom: X-ray image of sausage with clip

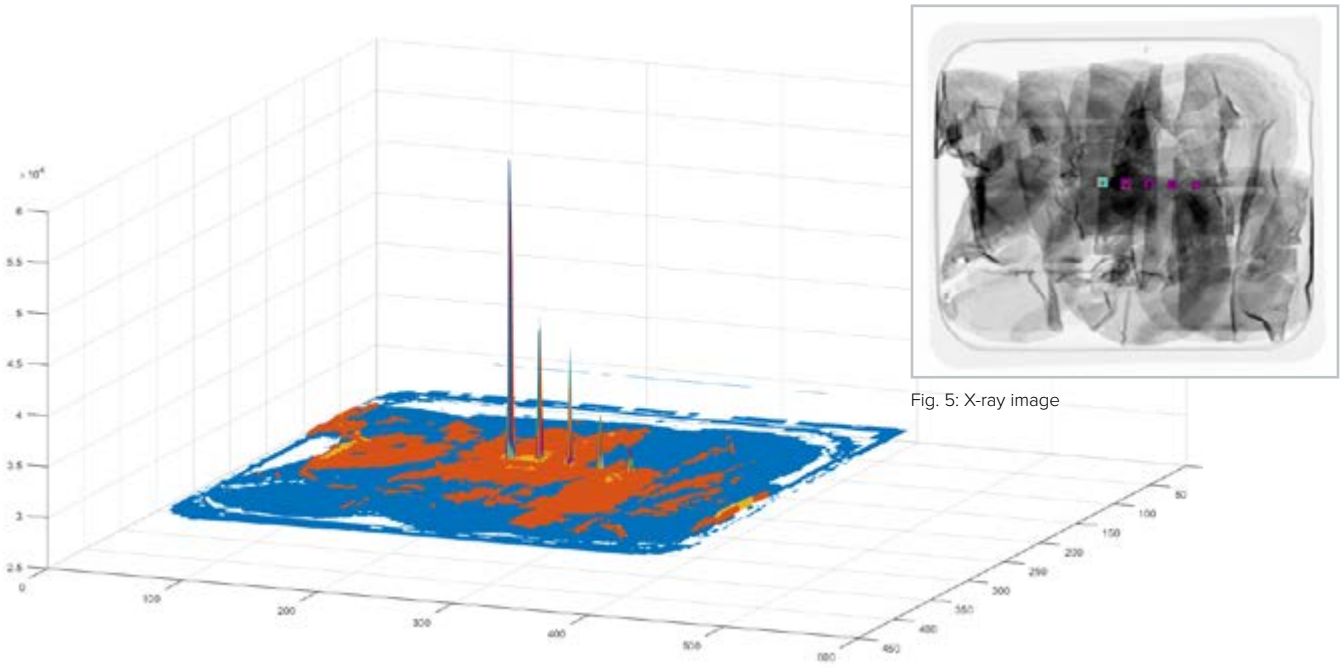

Fig. 4: Grey values

Fig. 5: X-ray image

Ejection system with collecting bin

Faulty products are separated from the product flow with the help of one or more ejection systems. Pushers are frequently used for heavier products and blower systems for lighter products. In many cases, various sensors are used at this point to ensure an error-free process. So, for example, cross checks in the good and/or bad channel check whether a product marked as faulty has been correctly ejected. Other safety features are filling level sensors and lockable openings on the collection boxes. The latter prevent uncontrolled removal of ejected products and any (accidental) return to the good channel. Many retailers require their suppliers to use inspection systems with such safety features. ▲

DIFFERENCES IN IMAGE CAPTURE

Detectors are usually designed as diode detectors or TDI cameras. The (classic) diode detector detects each pixel once. The VioX TDI technology used by Wipotec detects each pixel 128 times. The final grey value of each pixel is determined by subsequently integrating the values of all 128 individual images. ▲

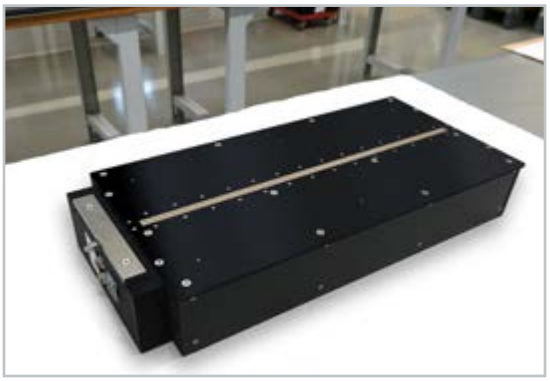

Fig. 6: WIPOTEC VioX X-ray camera

DIFFERENCES IN BIT RESOLUTION

If an object absorbs a lot of radiation, the detector can detect very little light and the image is relatively dark. With low absorption, the image is correspondingly lighter. The bit resolution of a detector describes how many grey values (gradations) are differentiated from complete darkness, i.e. complete absorption, (black) to complete light (white).

The effects of different bit resolutions become clear in Fig. 7: the product has a certain grey value in the X-ray image due to the specific absorption. In addition, there is a foreign body which has a slightly higher grey value than that of the product. If an X-ray inspection system with low bit resolution is used, this shows up as a less differentiated gradation from light to dark (brown line).

It follows from this that it may not be possible to distinguish the two grey values of product and contamination due to a lack of **>>**

differentiation in the intensity of absorption. If, on the other hand, we look at the X-ray inspection system with high bit resolution (pink line), in this example it is possible to differentiate the foreign body from the product and therefore detect it.

A large number of X-ray inspection systems work with 8-bit technology. This means that these systems can differentiate between 256 grey values in total. All X-ray inspection systems from Wipotec use 16-bit technology which can differentiate between more than 60,000 grey values. ▲

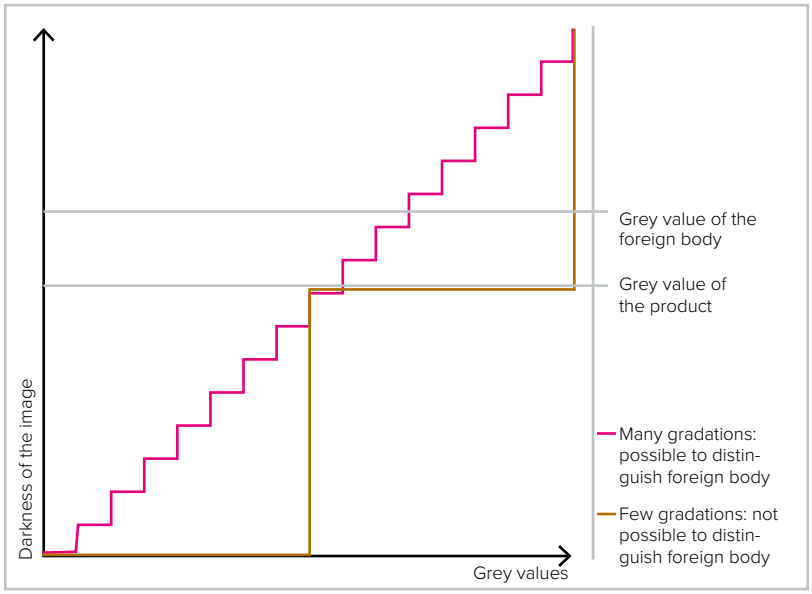

Fig. 7: Comparison of different bit resolutions

DIFFERENCES IN GEOMETRIC RESOLUTION

Even the smallest foreign body contaminants in food result in expensive recall campaigns. The consequence is often massive damage to the brand image. Detector technologies with smaller pixel sizes (depending on the operating parameters) also enable the detection of smaller contaminants. The standard resolution for Wipotec diode detectors is 0.4 mm. Resolutions up to 0.1 mm are possible with the VioX TDI camera from Wipotec.

As a general rule, the pixel size must be selected according to the application. Selecting an inspection system with the appropriate resolution depends, for example, on the belt speed. The higher the speed, the less time there is to detect the light that is vitally necessary for the inspection. The consequence: the image quality and therefore the detection results may deteriorate. An X-ray inspection system with very low resolution is nevertheless an advantage if it is capable of so-called “binning”. In this case, the camera combines several pixels in order to work with a higher resolution. For users, this means more flexibility since there is no need to change the hardware for different application scenarios. In these cases, the resolution is merely a parameter that can be changed via the touchscreen. It also allows the use of multi-resolution algorithms in which image processing algorithms examine the image simultaneously at different resolution levels. ▲

DIFFERENCES IN LIFETIME AND TOTAL COST OF OWNERSHIP

The sensitive electronics of diode detectors are situated directly in the X-ray beam, leading to wear. In contrast, the Wipotec TDI cameras have no electronic components that are exposed to direct X-rays or scattered radiation. As a result, these cameras have a significantly longer lifetime, so we can no longer talk about wear parts. At Wipotec, customers receive a 7-year warranty on all VioX cameras that is not tied to the conclusion of any service contracts and is irrespective of any maximum operating time of the cameras.

The use of durable camera technologies is reflected in the total cost of ownership (TCO). This is linked in particular to fewer production losses. In case of doubt, the entire production line stops if a diode detector has to be replaced. If it is not possible to install a replacement directly, production cannot continue for reasons of food safety. No monitoring of the critical control point takes place. Long downtimes automatically increase costs due to the reduced output or result in lost revenues and therefore opportunity costs. The use of durable Wipotec TDI cameras reduces this risk of downtimes and thus increases the productivity of the entire production line. It also eliminates costs for repairs, procurement of spare parts and any need to stock them.

When calculating the total cost of ownership, consideration also has to be given to retaining the value of the plant. The TDI cameras from Wipotec remain a valuable element within the X-ray in- **>>**

spection system in the long term. If a user plans to resell an X-ray inspection system on the used machinery market, it is likely that the resale price will be higher with durable camera technology. This should be taken into account in the cost comparison calculation before the X-ray inspection system is acquired.

Finally, using high-quality detectors can reduce the total cost of ownership, as it significantly reduces the number of products ejected incorrectly. These products can be put on sale. A higher false rejection rate leads not only to losses of good products but also results in additional costs for waste disposal and increased staff costs.

Furthermore, it is advisable to consider the total planned operating time of the X-ray inspection system. A consideration of only 5 years, for example, is not particularly expedient if the operating time and lifetime of the complete system and individual components, such as the detectors, is considerably longer. X-ray inspection systems from Wipotec, for example, are used for 10 years and more. ▲

CONCLUSION

To sum up, Wipotec TDI cameras use an extremely advanced inspection technology which can detect the smallest foreign bodies using high bit resolution with very low geometric resolution. So-called “binning” enables highly flexible use of the scanners, since it is possible to change the resolution of the system without modifying the hardware. An optional 7-year manufacturer’s warranty on the VioX camera is not tied to any preconditions and therefore represents excellent process reliability and maximum productivity, even over very long periods of time. ▲