X-ray inspection: more than just foreign body detection

Since the early 1990s, the food industry has relied on x-ray technology to detect potentially harmful foreign bodies, such as glass and metal, to protect consumers and maintain brand reputations.

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But can x-ray inspection do more? Could x-ray technology be a multi-tasking defender of product safety and brand quality?

This article looks at the potential of x-ray inspection to solve a wide range of product safety and quality control issues typically found within food manufacturing. It explores how x-ray inspection can detect faulty products before they leave the factory, avoiding product recalls and customer disappointment.

It describes how in a single pass – and at high line speeds – x-ray systems can perform several inspection tasks simultaneously.

Why use x-ray to inspect food?

Food manufacturers use x-ray inspection technology to ensure product safety and quality. X-ray inspection gives them exceptional levels of detection for stainless steel, ferrous and non-ferrous metals. The technology is also extremely good at detecting other foreign bodies such as glass, stone, bone, high density plastics, and rubber compounds.

X-ray systems can, however, simultaneously perform a wide range of other in-line quality checks, such as measuring mass, counting components, identifying missing or broken products, monitoring fill levels, inspecting seal integrity, and checking for damaged product and packaging.

Increasing line speeds and consumer expectations have put pressure on manufacturers to adopt more reliable methods of product inspection.

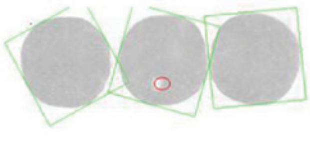

Fig. 1. Void in patty.

Although there are no legal requirements to use x-ray inspection, guidelines such as Hazard Analysis Critical Control Points (HACCP), the Global Food Safety Initiative, Good Manufacturing Practice, and ad hoc standards set by individual retailers put the onus on manufacturers to establish reliable product inspection programmes.

Incorporating x-ray inspection systems into a company-wide product inspection programme, to ensure product safety and quality, helps manufacturers comply with national and international regulations, local legislation and standards set by retailers.

How does it work?

X-rays are invisible. Like light or radio waves, they are a form of electro-magnetic radiation. Because their wavelength is short, x-rays can pass through materials that are opaque to visible light. But they do not pass through all materials with the same ease.

The transparency of a material to x-rays is broadly related to its density, which is why x-ray inspection is so useful in the food industry. The denser the material, the fewer x-rays that pass through. Hidden foreign bodies, like glass and metal, show up under x-ray inspection because they absorb more x-rays than the surrounding product.

An x-ray system is essentially a scanning device. When a product passes through the unit, it captures a gray-scale image of it. The software within the x-ray system analyses the grey-scale image and compares it to a predetermined acceptance standard.

On the basis of the comparison, it accepts or rejects the image. In the

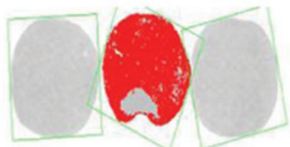

Fig. 2. Malformed patty ±5%.

case of a rejection, the software sends a signal to an automatic reject system which removes the product from the production line.

By exploiting simple density differences and analysing the resulting grey-scale x-ray images, x-ray inspection equipment has moved beyond product safety into other areas of quality control.

In addition to detecting foreign bodies, modern x-ray systems are multi-tasking defenders of product and brand quality.

In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously, including:

- Measuring product weight, width, area, and volume.
- Identifying missing or broken products.
- Monitoring fill levels.
- Measuring mass.
- Inspecting for compromised seals while still catching contaminants.

Measurement of product

Measuring the length, width, area, and volume of a product, in conjunction with contaminant detection is the simplest form of product inspection. The process is known as 'object finder'.

As previously explained, an x-ray image is a grey-scale image. The darker the grey, the more product is in the path of the x-ray beam. By converting those grey tones into a 3D image, the software can calculate, for example, the area of the product.

This type of image analysis takes quality control to a new level of sophistication.

It identifies products that do not look right, even if they are the correct weight, in the correct position, and free of foreign bodies. It is hugely useful for manufacturers

Fig. 3. Two garlic baguettes with one low-fill.

of products that depend on visual appeal. For example, one of the three meat patties shown in Fig. 1. has a hole in it and it shows up as a light patch amid the uniform grey. In Fig. 2 one of the three patties is misshapen.

The two flow-wrapped garlic baguettes (Fig. 3) take the process further still. The quality control issue here is the potential under filling of garlic butter in each slot because the butter injection machine could block up or run out of butter.

Since the x-ray system can see the individual blobs of butter, it can analyse each zone separately.

It checks that the surface area or volume in each zone meets a preset standard. If it does not the product will be rejected from the line.

Detecting damaged products

The detection of damaged products relies on the same principles as length and volume measurement.

By setting minimum and maximum sizes for pack width, height, volume or surface area, x-ray analysis software can spot a deformed pack.

Detecting missing products

X-ray systems can look inside the final sealed packaging to check that all components are present. It can count products and components that cannot be seen or counted by cameras or human eyesight.

For example, it can count cheese cubes in a tray, or pralines in a gift

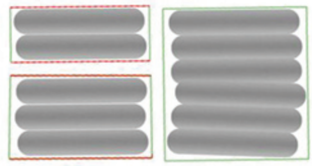

Fig. 4. Detection of missing sausage.

box. Spotting the missing sausage in Fig. 4 was easy. The software found five dark zones in the grey-scale x-ray image when it was programmed to expect six.

Spotting the presence of caps or lids can be done by the human eye, but the process is far faster and far more reliable with x-ray technology. If the cap area appears brighter, then the product will be rejected from the production line.

Insert inspection

If x-ray inspection can identify objects that should not be in a pack, it can also find ones that should be there. For example, many meat-based products contain oxidisers (known as 'scavengers') to help keep the product fresh. Oxidisers can be quite dense, which could reduce the effectiveness of foreign body detection.

Fig. 5 shows how, in a packet of cooked ham, the x-ray system not only checks that the oxidiser is present, but also removes it from the x-ray image for optimum foreign body detection.

Measuring mass and monitoring fill levels

Maintaining the correct mass and fill levels of a product is a constant challenge in food manufacturing. Measuring overfills and under fills has an effect on manufacturing costs as well as consumer satisfaction.

X-ray inspection can analyse:

- The overall mass of a product.
- The individual masses within various zones or compartments of a product.
- The overall fill level of a product
- The individual fill levels within various zones or compartments of a product.

Overall mass measurement

An x-ray image shows up as varying tones of grey. By converting those grey tones into a 3D image, the x-ray software can calculate how much product is in the pack. This 3D volumetric check is also used for mass measurement.

The x-ray system has an auto-learn facility whereby an acceptable weight pack (close to the nominal weight) is passed through the x-ray system, typically 10 times. The gross weight of the pack is then entered into the system. (The user must have previously weighed this pack on a set of calibrated static scales offering a suitable weight range and accuracy.)

That way the analytical software can calculate the weight of subsequent packs by comparison to the weight of its learned reference pack. The x-ray inspection system can now compare all future products against its ideal reference product. If the calculated mass falls within a programmed tolerance, the package is good. If it deviates, the package will be rejected.

The quantity of jam inside a doughnut is an example of how x-ray inspection can be used to exert better quality control. From the outside, a doughnut with too much or too little jam in the centre looks perfect. No one knows until they take a bite. Too much jam increases production costs. Too little jam leads to disappointment.

With x-ray inspection, every doughnut can be checked, even when the line runs at 600 doughnuts a minute. The x-ray inspection software examines each grey-scale x-ray image. From the overall level of blackness, it calculates the mass of jam inside the doughnut. If the mass meets the preset standard, the doughnut passes the test. If it fails, it is rejected from the line and the manufacturer can adjust filling equipment to maintain the standard (Fig. 6).

The relationship between mass and total product x-ray absorption is not a straight line. Using a single product auto-learn feature is quite accurate when production pack weights are near the target weight.

More sophisticated systems use a three product auto-learn process: the low rejection point, the target weight, and the high rejection point. This method allows calculation of the mass from variations in x-ray absorption within a narrower range. It provides greater accuracy than that offered by the normal production weight range. Accuracy

Fig. 5. X-rays check if the oxidiser in ham is present.

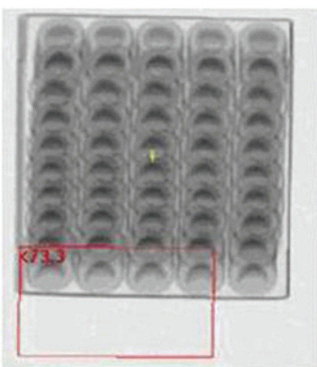

Fig. 6. Pack of doughnuts with one low-fill and one contaminated.

of mass measurement is good on homogeneous packs (a block of butter), but less good on loose packed products (sausages in a bag, or products for which ingredients can vary between batches).

X-ray mass measurement is particularly effective for high-speed applications where traditional in-line weighing systems may not offer the same level of accuracy.

It lets manufacturers comply with minimum weight, EU average weight, or US zoned weight regulations. In every case, the system produces relevant statistics on rejects. Mass measurement does not offer a global solution to weights and measures compliance. Some countries expect R51 type approval, which only applies to gravitational weighing systems.

Zoned mass measurements

For products that are in defined compartments, such as a box of chocolates or a two-compartment ready meal, mass measurement can provide results for each individual zone/compartment. It lets manufacturers check the overall mass of a product and the masses within each compartment.

The overall weight might be right, but if there is low fill in one compartment, the pack is rejected.

Overall fill-level inspection

Fill-level inspection is different to mass measurement. It is a 2D process based on a simple inspection process: you set maximum and minimum fill levels and reject any product that falls outside them. It does not matter what the product is made of, or the mass of it. It simply has to reach a certain height within the pack or container. Fill level becomes a simple 2D image check instead of the 3D volumetric check required for mass measurement.

A tube of crisps is an example of fill-level check. By checking the height of the stack, x-ray analysis can tell if the fill level has dropped below an acceptable standard, and reject the pack.

You could also add an optional feedback to the filling machine to adjust the fill level. This is especially relevant for fluid products like yogurt drinks or loose products like milk powder.

Zoned fill-level inspection

X-ray inspection is as good at checking zoned fill-levels as it is at checking zoned mass measurements. An underfill in one pot of a yogurt multipack could potentially be compensated by an overfill in another pot. Another example could be the fill level inspection of each pot in a six-pack of yoghurts. X-ray inspection will examine the fill level in each pot. If any one of them is under filled, the entire pack would be rejected.

Product-in-seal inspection

The integrity of airtight seals is a vital quality control issue for manufacturers of sealed food packs. The safety and freshness of food products depends on the seals, yet they are easily compromised by stray particles of product, foreign bodies, or misplaced products.

Anything trapped within the seals could mean that the pack is no longer airtight. The seal inspection x-ray tool can identify particles as small as 1mm caught in the seal areas.

On low-density packaging, a special ultra-high contrast detector system can simultaneously check for foreign bodies and seal integrity.

Conclusion

X-ray inspection equipment gives manufacturers the tools to maintain quality control and product integrity at every stage of production for raw, bulk, pumped, and packaged products.

By setting appropriate parameters and fine-tuning the sensitivity, manufacturers can investigate numerous quality issues from catching foreign bodies to checking that a product looks exactly as a customer expects it to look. The product that successfully passes x-ray inspection contains no shocks, surprises, or disappointments. The manufacturer knows that it fulfils its brand promise.

Modern x-ray systems are multi-tasking defenders of product and brand quality as well as detectors of foreign bodies. In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously.

They can measure product mass, count components, check fill levels, identify faulty products, inspect seal quality, spot missing giveaways – and still catch foreign bodies.

In short, x-ray inspection is a highly effective tool for maintaining production costs and product integrity. Most of all, it is a tool for keeping customers happy – for checking that a product looks and performs exactly as they expect. ■