Lightweight containers and glass inspection systems

The move towards lightweight containers that has taken place in the last few years has challenged inspection systems and continues to do so. At the hot end, systems based on near infra-red sensors are becoming less effective or even in-operative. At the cold end, one of the main problems is capacity and mechanical handling. **Jørgen Læssøe*** discusses what the move towards lightweight containers means for the efficiency of today's inspection equipment.

Gob monitoring equipment relies on near infra-red (NIR) radiation. Making the gobs smaller does not appear to present any problems and the higher speed is also easily accommodated.

Further down the line, typically just after the IS machine and before the coater, hot end systems are installed. Some of these inspection or monitoring systems rely on NIR radiation.

Heavy containers radiate enough NIR energy for a standard NIR camera to obtain images - the thicker the wall, the more NIR radiation. However, NIR reflections from neighbouring containers also affect the image. The Stefan-Botlzmann law states that total radiated power relies on the temperature as to the power of four (see ***fig 1***). This makes bottle cooling, from the forming point to the inspection point, a factor when acquiring NIR images.

Good image

A good image with constant intensity is practically unattainable due to factors like cooling and neighbour radiation. Furthermore, as wall thickness increases, heat is better retained and the signal received at the sensor increases at a very steep rate. Overall, the NIR signals are a wild function of mass and temperature.

In contrast, when wall thickness falls, mass is reduced and the temperature falls rapidly. Again, temperature multiplied by mass on a lightweight container results in a very low signal.

The temperature falls during transport from the cavity to the inspection equipment. The difference in time travelled from the first section or from the last section of the IS machine is significant. Therefore, the temperature of the individual containers varies a lot on when they arrive at the inspection system. The equipment relying on NIR must take this into account and must attempt to compensate. Lightweight containers make this temperature difference much greater and the compensation very hard to achieve.

Sensitivity

The measurements in ***fig 2*** are average sidewall temperatures measured in the 5µm wavelength for containers of different wall thicknesses. The measurements were taken 5m from the last section on the IS machine.

Below 400°C, virtually no signal is detected by the NIR camera and any dimension or defect becomes hard or impossible to find. If you increase the sensor gain you get a noisier picture and greater blur. Silicon transmits wavelengths above 2µm so the NIR radiation tends to cross the boundaries between the pixels in the silicon chip.

To measure mass and temperature at depth in the glass wall requires sensors operating between 1 and 2.2µm wavelengths. Silicon has a little sensitivity left at 1.1 µm and this is used in the common NIR hot end systems.

Using other detectors sensitive to higher wavelengths (lower temperatures) is not a way forward. If you wish to guess the wall thickness by estimating the radiation from the glass, moving up to longer wavelengths does not work as glass is non-transparent above 3-4µm. Consequently you only measure the surface temperature or surface reflection from the neighbouring container.

$$P = e\sigma AT^4$$

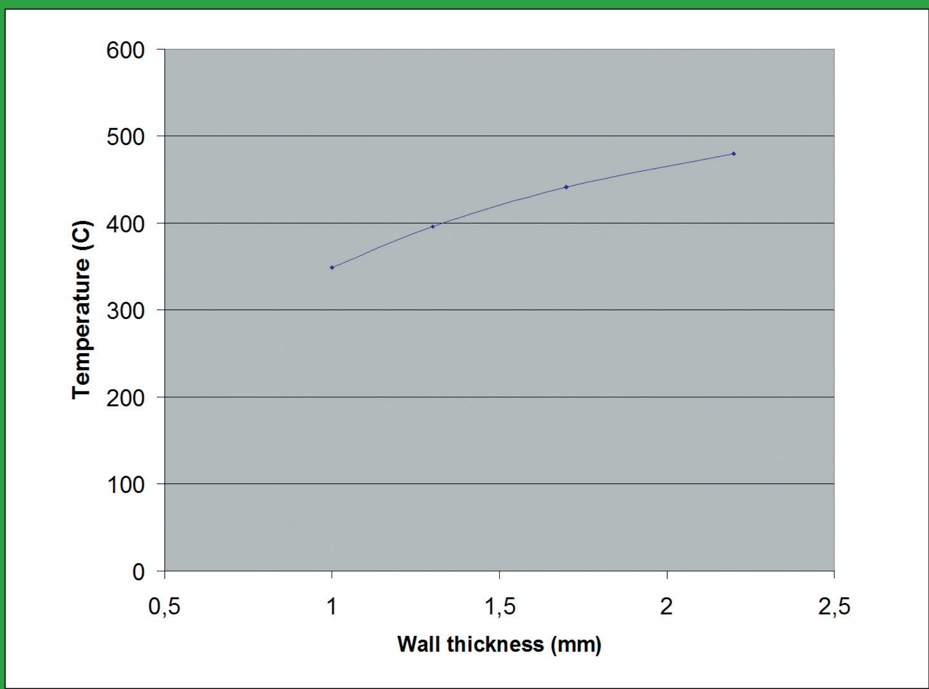
P = radiated power; e = emissivity (=1 for ideal radiator)

A = radiating area; T = temperature of radiator

σ = Stefan's constant; $\sigma = 5.6703x10^{-8}\,watt / m^2K^4$

▲ *Fig 1. The Stefan-Botlzmann law states that total radiated power relies on the temperature as to the power of four.*

▼ *Fig 2. Average sidewall temperatures measured in the 5µm wavelength for containers of different wall thicknesses.*

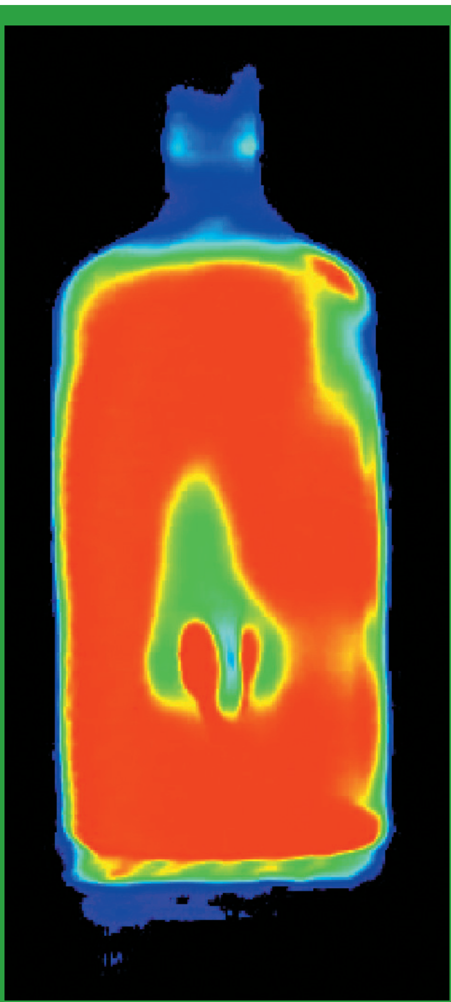


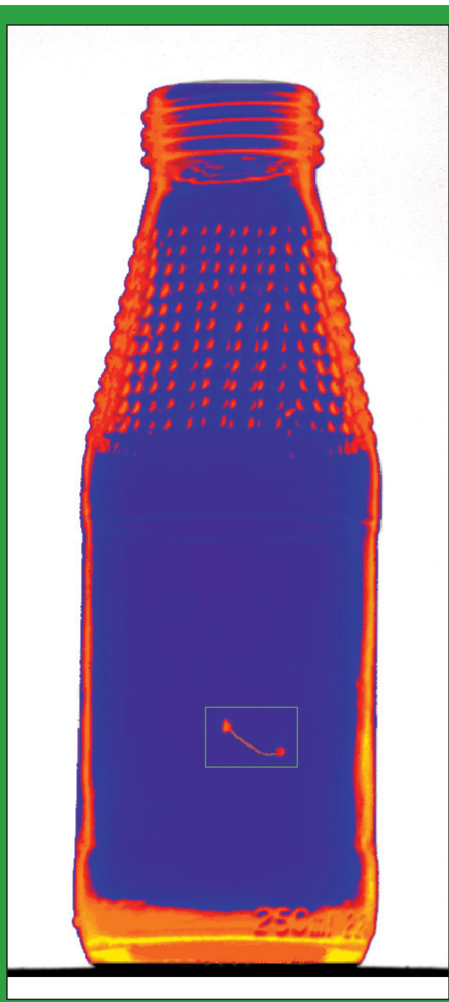
IR cameras also tend to have poor resolution and are still very costly. Working in the IR range requires expensive Germanium lenses for transmittance of the radiation from 2μm to 20μm. However, cheaper lenses based on a different material will become available.

The blurring effect on NIR images is pronounced as seen in ***figs 3*** and ***4*** which are taken with NIR technology and with visible light backlighting.

The NIR image is a gin bottle and the backlit image is a soft drink container. Both have bird swing defects. Note the detail in the bird swing in the backlit image.

On the backlit image, the colour scale has nothing to do with temperature but indicates wall thickness. This is measured as the attenuation of intensity of the background light passing through the container. The image is compensated, averaged and translated into colours to indicate glass distribution.





▲ *Fig 3. Typical NIR image (left). Fig 4. Typical backlit image (right). The blurring effect on NIR images is pronounced as seen in the two images (one taken with NIR technology and one with visible light backlighting). The NIR image is a gin bottle and the backlit image is a soft drink container. Both have birdswing defects. Note the detail in the birdswing in the backlit image.*

Research

The data presented herein is based on research that has been ongoing since 1991 when JLI first experimented with NIR camera technique for inspection of hot containers. The research was sponsored by a Danish government industry scheme and drew on knowledge from glassworks and universities. The conclusion was that NIR technology had a lot of problems and constraints. One of the great obstacles was the low radiation from lightweight containers. Sixteen years later, more and more containers are lightweight and NIR technology becomes less practical.

Equipment based on backlighting will have no degradation at a lower container temperature and slimmer walls. In fact, the optical effects in the walls are reduced with thinner walls and this makes it easier to inspect a larger part of the container wall. Backlit hot end monitoring systems that also measure wall thickness by gauging the attenuation of the transmitted light can easily maintain the 0.01mm wall thickness measurement accuracy, at least for amber and green.

Cold end equipment

With reduced wall thickness, the strength of the container becomes critical and inclusions become more problematic. It may be necessary to check for stress in the glass walls. This can be done with vision systems with polarisers.

The first of these systems was developed for champagne bottles as such high-pressure vessels cannot be allowed to have weak spots. By polarising the light vertically and having a horizontal filter in front of the lens the images will be dark. Only where stress is introduced from stone or Pyrex inclusions the light polarity is twisted and makes the defect visible as a star easily detectable by the vision system.

Some of the inclusions are invisible to the ordinary backlit inspection systems so it may be necessary to add new equipment for these critical defects.

The stress detection systems work well on thin walled containers and it is easier to set up the inspection areas closer to the glass walls and thereby get excellent cover from just two cameras placed under 90°C.

Normal inspection equipment for side wall and base inspection performs well on lightweight containers. However, the mechanics may need fine tuning as the containers have less mass.

Moving to lightweight containers also means faster production speed and hence greater demand for inspection capacity. This may be very expensive as the cold end may have to branch out in more lines serving each IS machine. The typical hot end monitoring systems will have no problem with the increased speed.

Company profile

Jørgen Læssøe Ingeniørfirma Aps was founded in 1985. However, the founder's experience dates back to 1980 when the first industrial vision systems were developed. In 1998 the company changed its name to JLI vision a/s (JLI).

JLI is involved in the development, manufacture and installation of computer vision systems for industry and laboratories. JLI systems are delivered as turnkey systems providing reliable and flexible production control.

Such systems are fully automatic inspection and measuring systems, based on digital cameras connected to computers running specially developed programmes.

JLI has solved quality control tasks for companies in Europe, the USA, Japan and its home base, Denmark. JLI has partners for some of its products operating worldwide and agents in many countries.

Glass inspection

JLI glass inspection systems are custom designed turnkey solutions for measuring dimensions, shapes, surface defects and material distribution. The systems cover a wide range of production processes in both the hot and cold end. All equipment is designed for the actual environment and can withstand the tough conditions on the glass production floor.

Examples of systems commissioned by JLI include stress detectors, digit/mould readers, backlighting, tubes, bulbs, containers, tableware, float glass, optical fibres, ampoules and tube ends.

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