  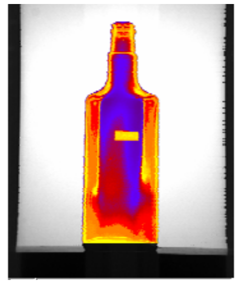

Advanced vision systems for quality control in glass manufacturing.

What can be achieved by using on line inspection and production control.

Vision systems has become an accepted and often essential part of quality glass making.

Vision systems do not only reject faulty products but gathers statistical data to be used in optimizing batch and production parameters, providing a competitive edge in a very demanding market place.

JLI vision a/s has been very successful in entering the backlight marked, and many of our customers have significantly increased their market share after investing in our vision systems. In general we see an increasing demand for quality inspection, not only in the glass industry but in other industries as well, for example Steel, Food and Medicine.

The paper will discuss general issues relating to the design of the optimal vision system for glass inspection, and present vision systems for inspection of glass tubing, tableware and container glass, and highlight the benefits and problems integrating vision systems in the production flow.

The function and performance of various installed solutions will be explained. Both standard systems and customer specified systems developed for special applications.

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Foreword:

The demand for high quality glass products and the increasing line speeds require constant development of inspection systems.

The size and number of defects together with high speed production makes it virtually impossible to rely on the human eye for inspection.

Furthermore different glass products have different faults and it is often impossible to find standard equipment for the applications. The high-end vision companies offer custom designs and can in most cases solve the inspection task satisfactory.

When planning a production it is important to take contact to the vision company who is going to engineer the system at a very early stage. The early dialog is important in order to reach the optimal design.

Also, the vision company may be able to reduce the cost of developing if the part is specified and the measurements are set in a way that makes it easy for the system to get a good image of the details. If a good image can be generated, the vision software will be much simpler, more reliable and of course less costly.

General technical considerations :

Glass, like any transparent object, is difficult to illuminate as the material diffracts the light. Furthermore different defects in the glass require different illumination techniques. Experience from different applications and systems is therefore a great advantage when you design and arrange an optimal illumination.

In the following we will look at the different components that make up a vision inspection system. They are: the system software, camera, lights and mechanics

Cameras: When choosing the camera for the job, the main areas of interest are:

- chip type (ex. matrix, linescan, CCD, CMOS),
- resolution (measured in number of pixel),
- pixel-sensitivity of chip (directly linked to the size of chip),
- exposure time.

Example of exposure time	Standard camera (most systems)	1/19000 per sec.
for line scan cameras:	Advanced cameras (JLI, others)	1/30000 per sec
	JLI second gen. cameras	1/58000 per sec.

Lightning: developing the right structured lightning as well as arranging the illumination itself is key to success in glass inspection. It is therefore often necessary to test a prototype under different configurations of light sources, cameras etc.
And at high speed production, such as the glass industry, it is important to have a powerful light source with very short exposure time.

Surveillance of the system is achieved with a software based monitoring system. It monitors and measures temperature, voltage, fan RPM, hard disk conditions etc. The application software also report to this monitoring system. If set alarm levels are exceeded the system can send an email to our office describing the problem.

Integration into customers system:
Running the system in can take some time, as calibration and tolerances has to be adjusted. After the introduction of the internet also on the factory floor this has become much easier.
After installation and a basic setup, the system is run in under actual production typically with wide tolerances. These tolerances are then progressively narrowed down giving the desired product quality.

The user aspect: The importance of the user aspect should not be underestimated. For all the systems that JLI has delivered we take great pride in guiding our customers in the optimal use of our technology, hereunder first line support, so that they may reap the full benefit when using our systems. Both training at the factory site and long distance on-line support are important in fulfilling this goal.

Durability: finally a well engineered, durable design ensures a good service life even in a harsh industrial environment.

Glass tubing.

The optimal tube is fully round (circular) with an even wall thickness and of course defect-free.

One basic rule of design is good to keep in mind:

diameter x linespeed = constant

The tube diameter and linespeed are interrelated, which means that inspection at high speed requires tubes with not too large a diameter.

Exposure time:
Tubes are today drawn at speeds up to 15 meters per second and finding defects down to 0.02mm is therefore a real challenge. The key to this problem is exposure time.
With a very fast exposure time you are able to avoid motion blur. A rule of thump is that the tube shall not move more that 1 pixel pr. exposure.
An exposure time of say 25micro seconds demands a very powerful light source. At JLI we have solved this problem by employing sodium lighting pulsed by special electronic drivers.

Centring of the tube is not critical as the programme will compensate for positioning. The tube is thus allowed to move a few mm as it is transported through the inspection system.

Another important aspect in designing the optical system is getting an acceptable depth of field. In order to inspect both front end and back end of the tubes you need a depth of the picture field of say 10mm.
And a good depth of field demands a very small aperture.

Typical defects: stones, knots and airlines.

Stones are inclusions, typically refractory material that finds its way through the process. Knots are lumps from badly dissolved glass.

Stones are found by simply detecting the black inclusion as it passes the line scan cameras. Typically a small lump of glass will act as a lens dissipating the light from the illumination, making the dark defect appear larger.
Knots have similar optical effects as stones and are detected in more or less the same way.

It is important to note that in order for the factory to optimize the process, it needs to know the relation between stones and knots. The inspection system is able to distinguish between stone and knot if the stone is large enough – size above 0.5mm.

Airlines occur when air is trapped in pockets at the mandrel. They consist of small air-pockets that are stretched as the glass tube is drawn. The airlines are down to 3micro meters which poses a real challenge for the vision system.

Sometimes it is necessary to make sure that a small section of the glass tube is 100 % defect free. The main problem here is thin airlines.
JLI has an offline 'Airline Detection system' specially designed to cover this market need. In this system the tubes are mechanically rotated in front of a high resolution CCD camera, with a powerful light source behind.

Depending on the type of tube being produced it may be acceptable to let faults below a certain size pass. The system software evaluate each section of the tube to make sure that the limits are not exceeded.
The system is also capable of detecting clusters of faults in a predefined small area.

Tableware.

The tableware manufacturing is characterised by its large number of different models. Many different forms and sizes create various difficult diffractions. Especially stemware has a complicated range of shapes

Typically the shape of the stemware is displayed allowing the particular stemware to fit in the illuminated area bordered by black.

The inspection demands a lot of different and often complicated masks. In traditional illumination systems, there is a compromise as the patterns that are used for inspection have to cover many different products, which again have different sizes and shapes. The only alternative up till now have been that the operators manually changes blinds and covers.

The Dynamic Lightbox:
It was to meet these challenges that JLI developed the Dynamic Lightbox (DLB). The DLB has a background lightning where a pattern composed of light and shadow precisely enhance the type of defect that you want to highlight.

Certain defects like mould rings, waves and cracks can only be detected if the tableware is inspected against a special pattern. The DLB can display all patterns, black and white or color. It is synchronised with production to achieve maximum intensity.

In order to measure geometry, the light box pattern is changed to show a bright uniform background with a mask following the profile of the glass at a precise predetermined distance. Measurement accuracy is 0.1mm.

The tableware products passes on a conveyor where the LCD screen right behind the conveyor itself opposite the camera. The vision system will generate the different patterns displayed on the DLB providing exceptional control and feedback for quality inspection of critical patterns.

The Dynamic Lightbox is an easy to install, reliable, and very adaptable solution to detect and measure geometry in tableware industry

Container Glass.

Glass containers can be inspected both in the hot and cold end of the production. In the hot end there are a few restricting factors. It is not possible to handle the container manually and one can therefore not pick up a red hot bottle or jar to inspect the base.
The best solution for inspection in the hot end is to use backlighting. Seen from the camera the light-box must only illuminate the back of the container plus approximately 5mm on each side. A larger opening in the light-box will generate reflections from the sides of the container and the dimensional accuracy will be reduced.

With a good illumination system the dimensions can easily be measured at an accuracy of 0.1 mm.
As this is far better than the factory tolerances, but this accuracy allows for an efficient way of monitoring the production process. Any change in the production parameters instantly shows up on the dimensions. For example if one cavity is running hot the containers from this form will sink due to high temperature, and this is easily spotted on the trend graphs.

A well regulated and monitored backlighting system can also be used for measuring wall thickness. The light passing through the glass wall is dampened and with tight control on the measurement loop, this reduction can be calibrated and translated to wall thickness dimensions with a resolution of 0.01mm.

Final remarks:

The glass industry has many challenging inspection applications and with more than 20 years experience in providing practical solutions for this market segment, JLI has a very broad experience in designing and running in vision inspection systems.

Even though the major part of glass-factories have become highly automated their productions still need continued surveillance in order to maintain a high quality level.

A Vision system will provide you with a more smooth production flow that gives you:

- More accurate and stable quality control
- Continued 100% inspection
- Improved production flow
- Fast feedback from production and automatic data logging

From a commercial point of view, buying a high-end vision system is seen as a long term investment, even if feedback from our customers shows that the payback period can be as short as a few months.

In order to keep a high and consistent standard of their products in today's market place customers has acknowledged that investing in advanced vision technology may be the only viable way.
