Defect Detection System
For Aluminum Caps
INTRODUCTION

FALCON EYE (Alluminium Caps Inspector) is an Italian Artificial Vision System for the inspection of aluminium closures to detect the typical defects of this kind of production. However, the modularity of the system allows to install fewer modules, depending on the customer requirements.

The proposed solution requires the installation of the system on a mechanical device designed to properly transport the aluminium closures under the acquisition units. This device is placed at the end of the production line, before packing the caps. The inspection is performed while caps are properly conveyed on a star wheel or a conveyor belt. The shell-border and the liner are inspected with a top view. The top-printing (public side) is inspected with a bottom view through a hole in the plate that supports the starwheel, while the cap is kept in the star's pocket by a rubber belt.
TECHNICAL SECTION

1. Scope of supply

Defect detection in production process of aluminum caps, duly transported and oriented by a dedicated mechanical device.

2. Basic data provided by customer

| Aluminum caps dimensions: | to be defined (*) | Maximum Productivity: | up to 1.500 caps/min; |

(*) If caps with different combinations of diameters and heights have to be inspected on the same machine, a mechanical device to adjust the position of the border inspection unit can be supplied (see § 6.3 Option for Caps with different heights).

3. Name of the proposed system

“FALCON EYE – GLOBAL INSPECTION OF ALUMINIUM CAPS”;

4. Inspection operated by the system

4.1. Shell-Border Inspection

A B/W high-speed digital camera equipped with a very wide-angle lens, in order to enhance also small border cutout, composes this unit. The lighting system is a high intensity led ring-light, designed for an optimal detection of the border edge.

With this camera it's possible to detect defects as:
- Shell cut out (lack of material);
- Ovalization;
- Folded border;
- Corrugated cap (only large defects)
- Deformations;
Thanks to the special wide-angle lens it is possible to enhance lacks of material on the cap border: these are detected by analysing and measuring the circular shape of the profile. With this configuration it is possible to detect also very small defects.

**Defect detection reliability: high**

This defect has the same appearance of the previous one (missing material). Therefore the same consideration can be made.

**Defect detection reliability: high**
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This defect is located on the side surface of the cap. It can be observed also with the camera for border inspection, thanks to the special wide-angle lens, but the contrast is very low.

Defect detection reliability: low (depends on the extension and on the depth of the traces of the defect)
4.2. Liner Inspection

This unit is composed by a B/W high-speed digital camera and a coaxial lighting system, with high intensity white LEDs used in strobo mode (flash). The lighting system has been designed to enhance the typical defects on liners.

With this camera it's possible to detect defects as:
- Liner cut out (lack of material);
- Dark spot;
- Wrinkled liner;
- Missing liner;
- Liner badly inserted;
- Upside down liner (only metal foil liner);
- Scratched liner;

Photo gallery:

Liner inspection (EPE)

Good sample

Liner wrinkled

Liner wrinkled 1

Liner wrinkled 2

This defect affects the uniformity of the “good” liner, with the presence of shadows caused by the wrinkles.

Defect detection reliability: medium-high
It is possible to detect this defect by analyzing the circular shape of the liner: when it isn’t inserted a shape error or ovalization error occurs.

Defect detection reliability: high

This is a typical high contrast defect; it is easily detected by analyzing the surface of the liner, looking for dark colour spots.

Defect detection reliability: high

It is possible to detect this defect by analysing the circular shape of the liner: if a cutout is present, a shape error or ovalization error occurs.
Defect detection reliability: high

**Scratched liner**

On this kind of liner (EPE) the defects on the samples are almost invisible.

Defect detection reliability: NO

**Liner inspection (tin foil - metallized surface)**

This defect affects the uniformity of the “good” liner, with the presence of shadows caused by the wrinkles.

Defect detection reliability: high

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It is possible to detect this defect by analyzing the circular shape of the liner: when it isn't inserted a shape error or ovalization error occurs.

**Defect detection reliability: high**

![Liner badly inserted](image)

**Badly inserted liner 1**  **Badly inserted liner 2**

This is a typical high contrast defect; it is easily detected by analyzing the surface of the liner, looking for dark colour spots.

**Defect detection reliability: high**

![Dark spot](image)

**Dark spot**

It is possible to detect this defect by analyzing the circular shape of the liner: in case of missing material a shape error or ovalization error occurs.

**Defect detection reliability: high**

![Lack of material on liner](image)

**Lack of material**
It is possible to detect this defect by comparing the measurement of the diameter of a reference good liner with that of the circular shape of the bottom of the cap that will have a lower value.  
Defect detection reliability: high

If a tin foil liner is inserted upside-down, its colour appears darker than the metalized side.  
Defect detection reliability: high

The reliability of the system in detecting this kind of defect depends on the “depth” of the scratches. It is possible to detect only coarse scratches, otherwise the contrast is too much low.  
Defect detection reliability: low (depends on the extension and on the depth of the traces of the defect)
4.3. Top-Printing Inspection (public side or logo inspection)

Top-Printing or Public side inspection: the system uses a high speed digital color camera with dedicated lens in order to check, in addition to the logo centring, also macro defect on printing and coarse colour errors. The lighting system uses high intensity white LEDs, in strobo mode (flash).

With this camera it's possible to detect defects as:
- Colour variations;
- Colour and logo centring;
- Macro defects on print logo;
- Mixed deco;

Photo gallery:

**Logo centring inspection**

![Photo of logo centring inspection](image1)

- Good sample
- Logo out of centre

The system verifies the position of the logo, respect to the border of the cap (it is possible to detect errors higher than 0.3 mm).

**Defect detection reliability:** high

**Logo defects inspection**

![Photo of logo defects inspection](image2)

- Reference model
- Acquired image with defect
Macro defects on printed logo
(Result after the rotation for the alignment with the model and the analysis of the defect)

The system verifies the quality of the logo comparing it to the gold sample.

Defect detection reliability: medium-high

Logo colour inspection

Colour variation

The system verifies the colour shift of the logo comparing it to the gold sample. It is useful for macro-variation.

Defect detection reliability: medium (about 3 Delta E)
5. **System innovating features**

The Hot Spot of the system is to perform fast and reliable inspections without forgetting the ease of use. The software, customized for the inspection of aluminium closures, is fast and intuitive. The management of all the control parameters (inspection tolerances), protected by password, is reduced to a few simple variables, which can be easily set in a single mask on the screen.

Also the new job procedure is almost completely automatic: the software defines the level of threshold for each inspection and verifies the quality of the sample under test, before to save a new Job.

FALCON EYE uses the latest GigaE (Gigabit Ethernet) digital CCD cameras!

According to the results of the application we performed on Aluminium Caps, the system will use a custom led light illuminations that was found optimal to enhance and detect the typical defects.

The illumination systems are implemented using a state-of-the-art solid state lighting technology using strobo lights with custom design, with a high power white LED projectors to enhance the illuminator performance, reducing in the same time the maintenance requirements because of the much higher life of this kind of illumination respect to fluorescence lamps.

The strobo light supply also eliminates the need of high voltages and the possible optical beat interference between the high speed cameras and the high frequency driving used in ionised gas lamps.

FALCON EYE allows to be controlled by remote assistance through the Internet, using our remote desktop control tools.

6. **Transportation Unit**

The inspection of the closures can be performed with the caps moving on a star wheel or also on a conveyor belt, provided that pieces are properly lined and spaced. If caps move on a belt it must be ensured that the movement is stable, without oscillations. This is important specially if the height of the cap, compared to the diameter, is large (for example $\varnothing 30 \times 60$ mm).

If the caps move on a star wheel the defective ones can be rejected after a configurable number of steps starting from the inspection position.

If the closures move on a belt the reject has to be done in the same position of the image acquisition.

**A co6.1. Solution with star wheel: example of installation on Maca MSV**

A complete example of solution for the transportation of the Caps, referring to Fig. 1, is described below. Caps, that must be oriented with the opening upward-facing, are vehicled by (1) a conveyor belt (optional) into a MSV Unit (2) a star with 30 stations. This way closures reach (3) the control area, where they are held in the star’s pocket by a rubber belt. In this area is placed the Liner inspection camera, an upper camera to inspect the liner. Synchronized with a proper position signal the images start to be recorded, digitized and finally processed by a dedicated software.

Then closures reach (4) the rejection area where the defective ones are rejected in a box. The closures unaffected by defects reach the conveyor end where they are packed (5). The System automatically manages also the package change (optional box change), once the forecasted quantity of pieces is packed.

The solution with MSV is designed to include all the three inspections, of the border (inspection camera 3 in the picture), of the Liner and of the printing (in the same position of the liner inspection but from bottom, observing the top printing surface of the cap through a hole in the main plate while the cap is held in the star’s pocket by a rubber belt).
The maximum working speed with this Transportation Unit is \( \sim 60,000 \) pcs. / hour (with Ø30 x 60 “high” caps). This maximum speed is a limit of the Transportation Unit.

**Figure 1**

*Note:* the caps are not oriented before the input belt of the MSV module, a proper device is needed to put them with the opening upward-facing: for example a **hopper** with vertical elevator, bowl in stainless steel and motorized conveyor belt and a **Mechanical feeder** for orientation of aluminum caps.
6.2. Solution with conveyor belt

In this solution (figure 2) the lined and oriented caps (with the opening upward-facing) enter in the conveyor belt where they are spaced by a proper spacing device and then they reach the inspection area. In this area is made a vacuum system, "Synchronized with the signal of a position sensor the images start to be recorded, digitized and finally processed by a dedicated software. The rejection of the defective pieces is performed immediately after the processing of the corresponding images.

The closures unaffected by defects reach the conveyor end where they are packed. The System automatically manages also the package change (optional box change), once the forecasted quantity of pieces is packed.

This solution is designed to inspect border and liner of the closures but not the top-printing. To inspect also the public side is necessary to realize a device that allows to observe the top surface.

The maximum working speed with this Transportation Unit is ~ 25,000 pcs./hour (with Ø30 x 60 “high” caps). This speed can be increased with shorter Caps or with a different transportation system.

Note: If the caps are not oriented before the input on the belt of this module, a proper device is needed to put them with the opening upward-facing: for example a hopper with vertical elevator, bowl in stainless steel and motorized conveyor belt and a Mechanical feeder for orientation of aluminum caps.
6.3. Option for Caps with different heights

If caps with different heights have to be inspected on the same machine, a mechanical device to adjust the position of the border inspection unit can be supplied:

The camera is mounted on a mechanical slide, which is driven by a wheel: This allows you to adjust height different closures with a very simple operation. An indicator with a value stored in files set up will indicate the height to which lead the group to exchange format.
7. Element of the supply

A complete supply includes the following elements: Acquisition Units (three: border, liner and public side), Processing Unit, Software Package and Transportation Unit.

The Shell-Border Acquisition Unit is composed by:

- 1 monochrome high-speed digital CCD camera equipped with lens.
- 1 dedicated coaxial lighting system, whose shape and dimensions are designed to properly enhance the typical defects on the caps. It uses high intensity white LEDs with custom designed.

Both the camera and the lighting system are enclosed in a special case to be installed in the proper inspection position on the production line.

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The **Liner Acquisition Unit** is composed by:

- 1 monochrome high-speed digital CCD camera equipped with lens.
- 1 dedicated coaxial lighting system, whose shape and dimensions are designed to properly enhance the typical defects on liners. It uses high intensity white LEDs working in strobo mode (flash).

Both the camera and the lighting system are enclosed in a special case to be installed in the proper inspection position on the production line.
The **Public-side Acquisition Unit** is composed by:

- 1 color high-speed digital CCD camera equipped with lens.
- 1 dedicated diffuse lighting system, whose shape and dimensions are designed to properly enhance the typical defects on liners. It uses high intensity white LEDs working in strobo mode (flash).

Both the camera and the lighting system are enclosed in a special case to be installed in the proper inspection position on the production line.

Note: the dimension of the case and the position of the fixing holes of this unit are the same of the previous one but the characteristics of emitted light are different.
The **Processing Unit** is enclosed in an industrial cabinet and is composed by:

- Falcon Processing Platform, equipped with 17" touch-screen monitor;
- 4 Protected I/O interfacing unit NPN/PNP logic, to interface the system to the line
  (Synchronization input signal to start the image acquisition, output signal to command
  Reject of defective pieces,...)
- Electrical Panel with power supply for the acquisition unit.
- UPS Unit
- Cooling fan group
- Main switch
- Connecting cable to the acquisition unit.

The **Software Package** operating in Windows XP and processing the images coming from the camera. The current image of the object is instantly compared to a referenced image, recorded during the calibration phase. On the basis of the tolerances established by customer, the object is rejected or considered in compliance. The result of the control is communicated via I/O Unit, managing the rejection of defective pieces and of their counting. The interface machine-operator is very easy to use. The operator has the access to all functions by touch-screen monitor.

Not about the **Transportation Unit** (not included) it is possible to install the vision system on existing mechanical transportation devices, provided that the needed requirements are fulfilled (alignment, spacing, background characteristics, etc.). In any case we are be able to prepare a complete offer that include our solution of transportation units, so that to offer a turn key solution.