Defect detection and classification on metallic parts

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ABSTRACT

The topic of this research is to the study the feasibility of a machine vision prototype for the control of metallic tubes (used in water pomp). Nine different kinds of defects located everywhere on the tube have to be detected:
The defects are: on the top: little hollows, bumps, and excesses of material on the body: horizontal bumps, vertical bumps, vertical scratches and finally on the bottom: vertical ridges, holes, and bumps.
As the defects on the top of the tube are very small, a grazing angle is used to light the tube. The camera is set on the opposite side of the tube with the same angle. Hollows and bumps are both detected by a vertical Sobel gradient. For the third defects, the excess of material projects its shadow on the top of the tube, and defects are detected by looking for a dark region instead of a lighted one.
To inspect the rest of the tubes, a neon tube with a diffuser is employed to homogenously light the body and the bottom of the tubes. Association of gradient operators, threshold procedures enables to find all the defects.

Key-words: lighting system, machine vision, metallic tubes, segmentation, classification

1. INTRODUCTION

This paper deals with a machine vision system designed to control and inspect metallic parts. These parts (see figure 1) are mechanically processed leading to various mechanical defects .

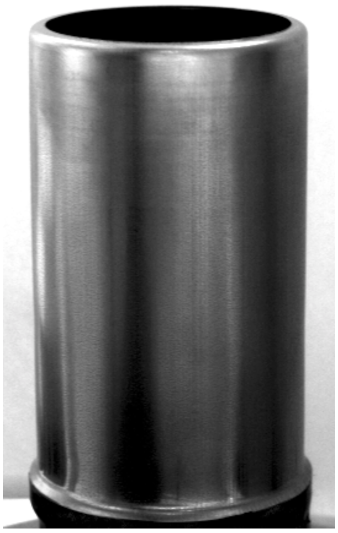

Fig 1 : Metallic part to be inspected.

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Defects can be present everywhere on the tubes implying a sequence recording (36 images) of the whole surface of the tubes (one second to realize the entire sequence acquisition). The tubes consist of three parts: the body, the top part where the metal faces the inside of the tube, and the bottom where the metal is slightly curved, facing the outside of the tube. After a massive survey on the production site, an inventory of nine different defects was done (see figures 2 to 10): Three on the top, three on the body, and three on the bottom.
The three defects on the top can be defined as follows: a little “hollow” which size can be very small, a “bump”, and an “excess of material”. On the body, the defects are: “horizontal and vertical bumps”, “vertical scratches. Whereas on the bottom, the various defects are several “vertical ridges”,” holes”, and “bumps”.
Prior to this study, the only visual inspection was done by a human expert. Nonetheless, manual control tasks being fastidious subjective and cost effective, a machine vision system prototype was developed to perform the control task.


Fig 2 : “Hollow defect”

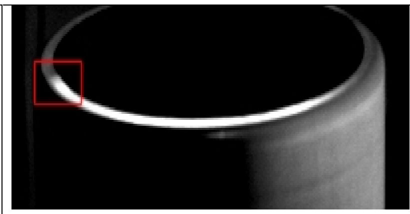


Fig 3 : “bump”

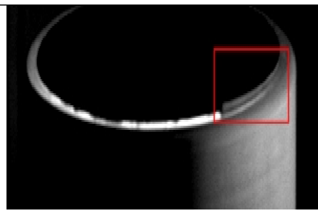


Fig 4 : “Excess of material”


Fig 5 : “Vertical scratch”

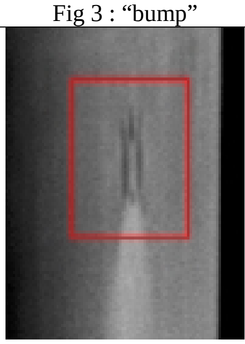


Fig 6: “Vertical bump”

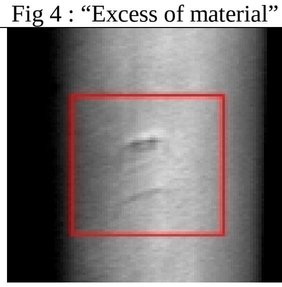


Fig 7 : “Horizontal Bump”

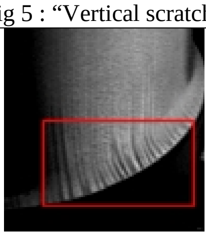


Fig 8: “Vertical Ridges”

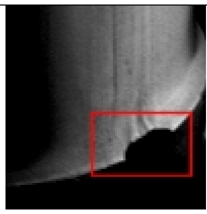


Fig 9 : “Lack of material”

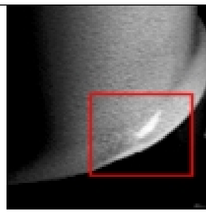


Fig 10 : “Bump”

The first part of this paper presents the selected lighting configuration. The second part deals with some of the image processing tools used to detect the defects. The last part outlines the results as well as our future work.

2. LIGHTING SYTEMS

Quality control in industrial application has greatly benefited from the development of tools like artificial vision. However, even with the ever growing computer processor performances, the key factor in every control by artificial vision is still the lighting system. Many research papers present various lighting conditions [1-4] whereas others use computer simulation to find the best lighting system [5]. In our case, 90% of the defects are located on the top part of the tubes, therefore the lighting system was optimized to reveal these preponderant defects. Different lighting conditions were tried [6], the selected configuration is presented on figure 11. At the time of the present study, only configurations involving one CCD camera were tried, this aspect was required by the manufactory.

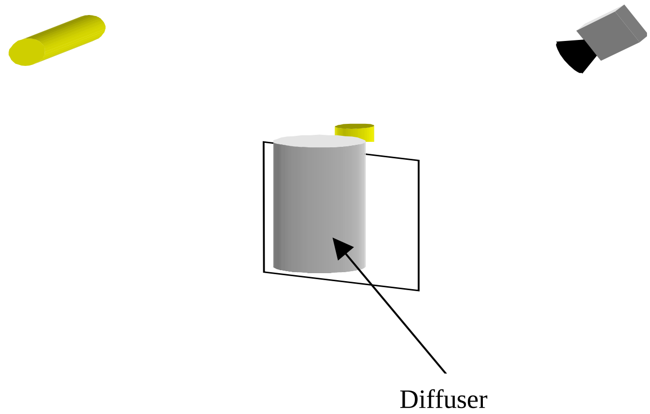


Fig : 11: Selected lighting configuration.
Two lighting sources. One neon light associated with a diffuser and one neon light set at a grazing angle.

3. DEFECT DETECTION

3.1 On the top of the tube.

3.1.a) Bumps and hollows

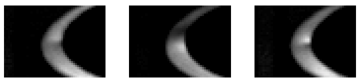


Fig 12: Different examples of defects located on the top part of the tube and revealed thanks to the low angle lighting system.

Defects having their signature only on one peculiar spot (figure 13), the first stage is to locate this peculiar window on the tube. This is done by thresholding the original image (figure 13) using a very low threshold (figure 14) so as to totally reveal the crown.

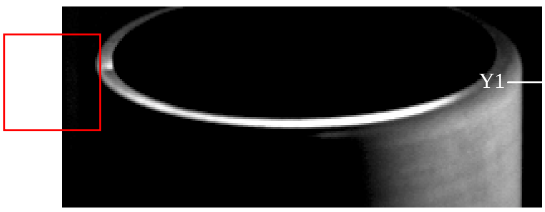


Fig 13: Original image

Fig 14: Binary image obtained after the threshold procedure

Then by scanning the binary image from the top to the bottom, the pixel coordinates X1 and Y1 (see figure 14) are easily determined. Then a window of 7 x 7 pixels is centred on X1 and Y1 and an vertical Sobel's gradient is applied to the original image.

1	2	1
0	0	0
-1	-2	-1

Table 1 : Vertical Sobel's gradient

The window size (7 x 7) was experimentally determined so as to optimise the false and non-detection rates.
The defect signature being most of the time an horizontal line, the detection is done by adding the grey level values on a each line of the gradient image (in the 7 x 7 window) and comparing its value to a set threshold (dependent of the lighting intensity). The value can also be used to classify small defects from larger ones.

The obtained results are promising a non-detection less than 1% was found, unfortunately the false-detection rate is quite high (3%). In fact, when carefully looking at the tubes, the false detection correspond to small real defects which were not seen by the operators.
Surveys are currently being done on the assembly line to see if these small defects have to be counted as defects or not. If they don't have to be taken into account, the decision based on the threshold would have to be adapted.

3.1.b) Excess of material

The detection of the excess of material is done as follows:
Figure 19 presents the image of a flawless tube whereas figure 20 shows an excess of material. The detection is performed by looking inside a window centred on the border tube (the window is automatically detected based on the same procedure as seen on paragraph 3.1.a) (figure 20) and looking for a dark area on the thresheld image.
All the defects were detected, and no false detections were seen. However big bumps or hollows car generate a detection but because they are previously detected as bumps or hollows (3.1.a) the classification is easily done and no-misclassification occurred.

Fig 15 : Flawless tube

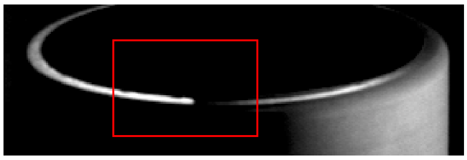


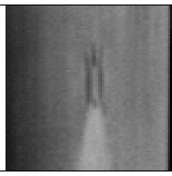
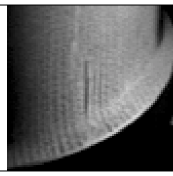
Fig 16: Tube with an excess of material

3.2 On the body tube.

All the defects present on the body tubes have a known orientation, their detection is easily done through the use of directional derivative detector (such as Sobel), the only problem is mainly due to some vertical ridges which are mechanically done but don't have to be detected.

3.2.a) Vertical and horizontal bumps Bumps

The vertical and horizontal bumps can be everywhere on the tubes (see figures 17 to 19) leading to an important interest zone (see figure 20). However because derivative operators are used the interest zone for horizontal bumps is shortly different from the vertical ones to prevent form having false detection due to the bottom part curvature (see figure 21).

		
Fig 17 : vertical bumps on the top part of the body tube	Fig 18 : vertical bumps on the middle part of the body tube	Fig 19 : vertical bumps on the bottom part of the body tube

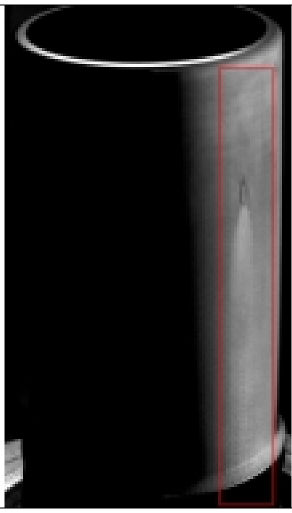


Fig 20: Interest zone for vertical defect detection

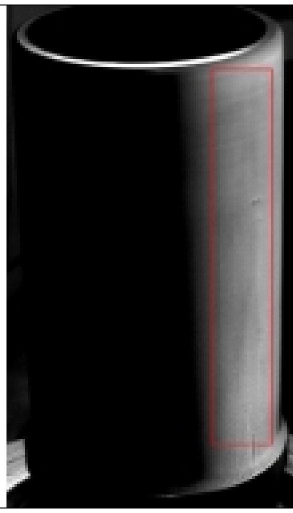


Fig 21: Interest zone for horizontal defect detection

Then once the interest zone are detected, a Sobel Gradient or a Canny filtering followed by a threshold procedure are done (the threshold values have been optimised on the sample set so as to obtained the best results). Then, on the resulting binary image, a window of 10x10 pixels is scanned over the interest zone and white pixels are counted. If the numbers of pixels are above a set value, they are identified as belonging to a defect.
Figure 22 to 23 present some results.

Fig 22 : Detection of a small vertical defects

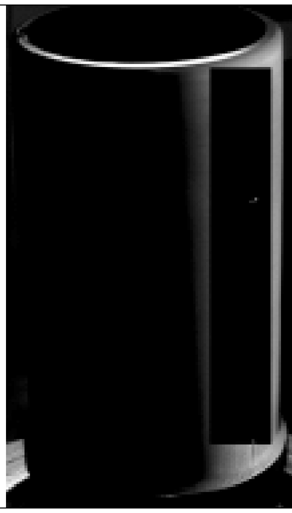


Fig 23 : Detection of a small horizontal defect

All the flaws were properly detected and classified, however our lighting system being diffused it also revealed colour stains which were counted as defect. This point will soon be addressed by using a second camera looking the body tube at a grazing angle.

3.2.b) Vertical scratches
The vertical scratches are found using the same procedure but by looking inside longer and narrower windows. Figure 24 and 25 show the detection of a vertical scratch.

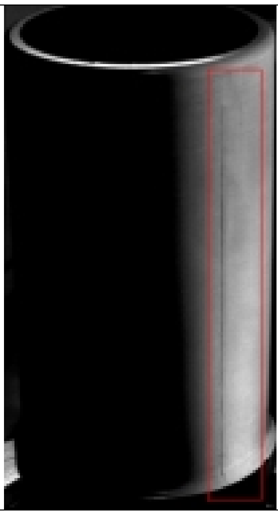


Fig 24 : Interest zone for vertical scratches detection

Fig 25 : Detection of a vertical scratch

Once again, on the sample test all the defect were detected and only one big stained with vertical edges created a false detection.

3.3 On the bottom part of the tube.

3.3.a) Vertical ridges

These defects (see figure 26) are pretty hard to defect due to their relative proximity to the border tube curvature. An horizontal edge detector is performed on a line (see figure 27 and 28) situated at five pixels above the border tube (automatically done). The decision is then based on the value of the gradient.

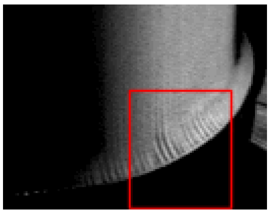


Fig 26 : vertical ridges on the bottom of the tube

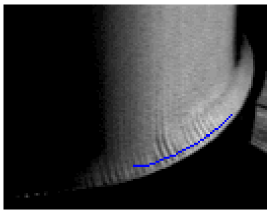


Fig 27 : Line onto which the horizontal edge detector is applied.

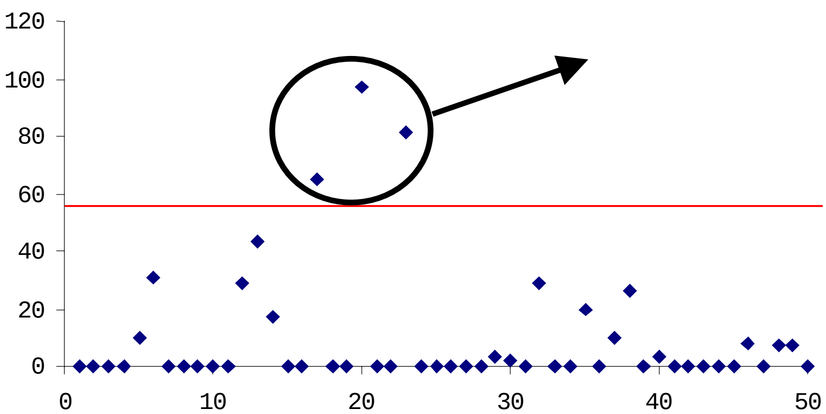


Fig 28 : Detection of the vertical ridges thanks to the horizontal gradient operator. Values above a set threshold are referred as defect.

On the sample test which had various tubes with different forms of vertical ridges, only 1% were non-detected, no false detection occurred.

3.3.b) Lack of Material
Figures 29 and 30 are examples of tubes having some lack of material on the tube base. As one can see, the lack of material can be relevant (figure 29) but can also be very small (figure 30). Statistically these peculiar defects represent less than 1% of the defects. The procedure we used to detect these defects, was based on a derivative procedure on a tube profile.

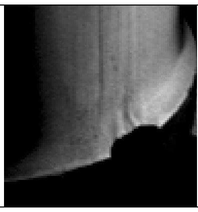


Fig 29 :example of lack of material

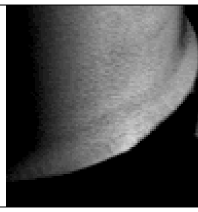
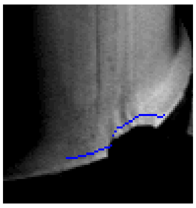


Fig 30 : Example of lack of material

This idea consists in following the border of the tube as previously done (see figure 31) and looking for a discontinuity by making a derivative of the border tube profile (see figure 32).



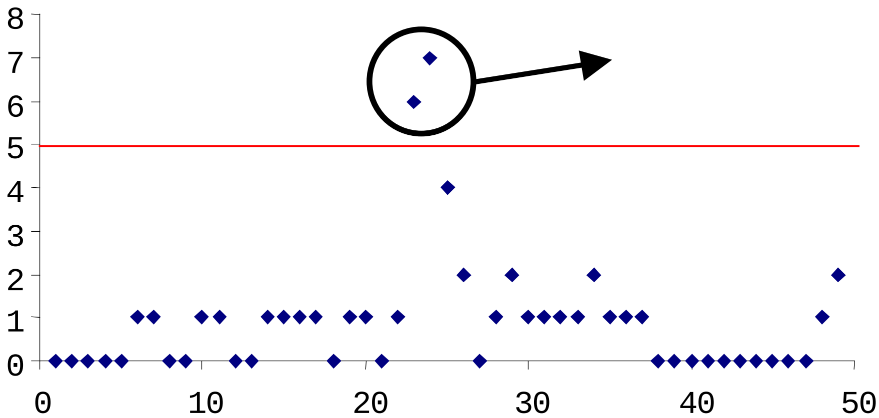


Figure 31 : Identification of the tube border. Figure 32 : Detection of the lack of material thanks to the horizontal gradient operator done on the relative position of the border tube. Values above a set threshold are referred as defect.

Unfortunately only tube having a sharp modification of their border can be detected by this procedure. For instance, the tube presented on the figure 30 was not detected. We are currently working on another procedure which will be efficient to detect “regular” lack of material.

3.3.c) Bumps
The bumps (see figure 10) on the bottom part of the tube are characterized by a shiny surface which is easily detected by a threshold procedure. The threshold used in this procedure is automatically calculated and based on the mean grey level of the tube bottom part. Consequently, if the tubes have various surface aspect, they can still be detected.
All the defects were detected and no false detections occurred.

4. CONCLUSION

This paper presents a feasibility study for the detection and classification of nine different types of defects being present on metallic parts. The tests were done over a panel of 140 tubes. Nowadays the false detection are about 6% but are mainly due to stains present on the body tube and which are well revealed by our diffused lighting system. This should soon be overcome by using a second CCD camera which would inspect the body tube under a grazing angle (see figures 34 and 35). Indeed the defects being mainly geometric defects (surface deformation), they have a signature under a low angle lighting which is not the case for aspect defect (stain).

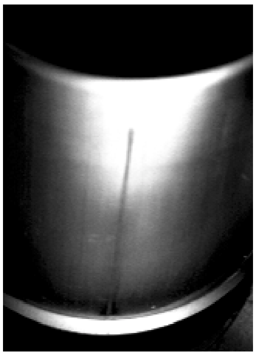


Fig 34 : Vertical scratches revealed by a grazing view point.

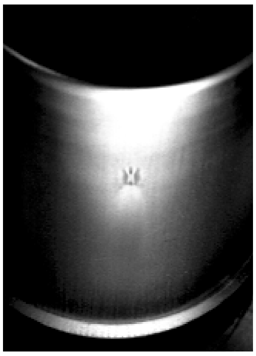


Fig 35: Horizontal bumps revealed by a grazing view point.

However, the non-detection ration which was the main criteria for this work is less than 1.5 %. These results are very encouraging and should soon lead to a factory implantation of the prototype. Also, some work is currently being done to reduce the processing time which is about 2.25 second for a tube (sequence of 36 images).

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