DETECTION OF DEFECTS IN ALUMINUM SURFACE THROUGH COMPUTER VISION TECHNIQUES

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***Abstract* - In this paper is described a prototype of a computer vision system for inspection, over aluminum surface, of defects without dimensional component to macroscopic scale. For this has been designed an acquisition system and have been developed specific image processing algorithms that permit to approach the problem in a robust manner.**

1. INTRODUCTION

The industrial inspection problems require generally specific and highly complex solutions that could be implemented to a reasonable cost, what has carried to devote a great research and development effort within the field of computer vision. Within these problems the web inspection systems are those which outline one of the greater challenges for the researchers exceeding the capacity of the current systems.

The manual inspection, that continues being employed in many cases, does not meet the requirements of the detection, precision, repeatable measurements, and high volume that demands the inspection of web-based manufacturing. Also the automatic inspection systems are generally very specific and require special architectures that allow to deal with the great quantity of product to analyze and the demanded resolutions [1].

The defects detected by the system are produced randomly in the aluminum surface in the rolling process. This is produced when exists a disorder of eccentricity and alignment of the rollers that accomplish such process, producing unexpected microscopic vibrations. These vibrations originate in the aluminum surface the appearance of not homogeneous thickness zones, though at microscopic levels. When this is produced, the aluminum surface presents certain transverse stripes to the advance direction. In function of the lighting angle on the defective plate zone, the stripes can arrive to be visualized. In the not defective plate zones this stripping effects does not appear.

The purpose of the first developed prototype is to detect when are produced such vibrations and to generate in such a case an alarm, in order to that the rollers could be adjusted avoiding the defects in the final product. The selection and location of the sensor as well as of the control of the lighting has constituted a crucial stage in the design of the inspection system.

2. STRUCTURE OF THE PROTOTYPE

The structure of the detection system is composed by:

• *Structured light source*: made up of a 660 nm laser, equipped with an optics that permits the generation of a plan that is projected on the aluminum surface.

• *Acquisition system*: made up of a CCD sensor camera and an acquisition board. The camera has been chosen by his optimum response in the range of operation of the laser, that permits the maximum image response in the corresponding range of the light emission laser. Furthermore, it is equipped with lenses that permit to improve the quality of the image. The digitizer board is housed by a PC processing system.

The source of structured light as well as the CCD sensor are located in a black box through which passes the analyzed product, with this is procured to minimize unexpected external influences.

The model of solution is based on the detection of distortion of light structured patterns upon impacting on the aluminum surface, due to different reflection angle produced in the material during the productive process.

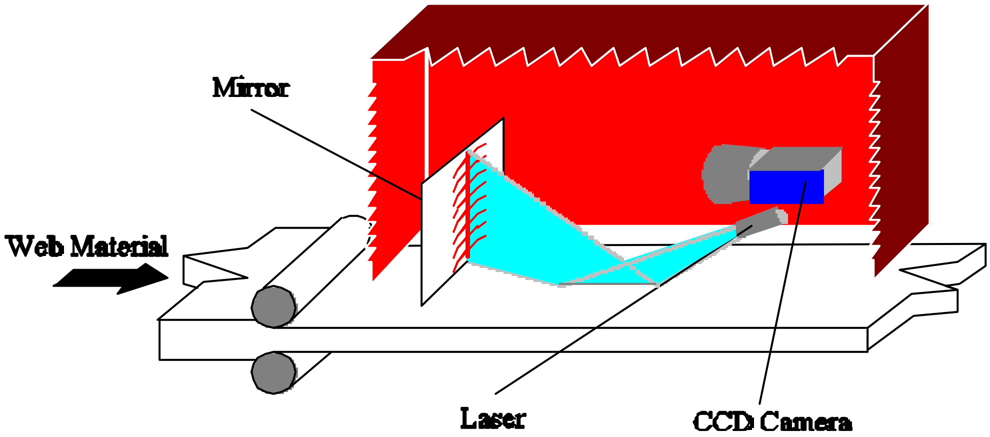

Figure 1. Architecture of the inspection system

The adopted solution integrates an automatic detection system of defects through computer vision, that implies a series of stages, from the image acquisition until the detection and final recognition of the defect.

The most specific phases of the application have been developed in the stage of preprocessing, in order to improve the quality of the image; and in the segmentation and recognition stages, in which are applied specific mathematical algorithms based on spectral response produced by the reflection of the laser beam on the aluminum surface.

3. DEFECT SEGMENTATION

The segmentation and featuring of the defects constitutes the key stage in any superficial inspection system for quality control. This stage is intimately bound to the acquisition process and preprocessing of the image captured by the sensor, it is because of this, that the election and design of the acquisition system, as well as the control of the conditions in those which operates, determines the final capacity of the inspection system to fulfill the detection and robustness specifications.

The nature of the defects produced on the material to analyze has carried to a careful design of the lighting conditions that permit to segment and parametizer in a correct way the microscopic deformation produced by the lamination rollers. The analyzed defect does not present a meaningful dimensional component to macroscopic scale, but appears as a variation of the reflection angle of the light waves under a certain incidence angle. This process produces a phenomenon of diffraction characterized by a periodic alteration in the phase and magnitude of the incident wave [2][3]. Texture homogeneity methods [4][5] does not present a correct application as far the defects are not produced at the macroscopic scale of the material texture. The defect presents a high directionality along the shaft of the roller appearing periodically on the aluminum surface.

The acquisition system has been designed using an black box through which passes the web product to analyze. Over his surface is projected a light plan laser of 660 nm of wavelength, in a way transverse to the defect direction. The utilization of coherent light formed by an single wavelength permits disacouple the phenomenon of diffraction between different wavelengths. Upon impacting the plan on the defective surface is produced a phase-shifting between the reflected waves that are projected on a mirror. The produced phase-shifting provokes the interference between the different reflected waves being generated a interferencial pattern formed by periodic bands (figure 2.b). The separation between these bands depends, according to the ondulatory optics, on the incident wavelength and on the dimension of the defect bands on the analyzed surface.

This interferencial information is collected by a CCD sensor and used for the segmentation of the defect. This periodicity behavior can be analyzed and described in a robust way through the frequency analysis, more specifically using the power spectrum of the image. In the figure 3 is observed the corresponding power spectrum for a correct (3.a) and wrong (3.b) samples. The central peak in both spectra corresponds to the term of autocorrelation, and the small two peaks superior and inferior corresponds to the periodic components of the interference. The phase graph does not present a discriminative power that permit to segment the defect.

The Fourier transform results useful to accomplish the error estimation due to the fact that permits to detect the spatial echo between the components of the interference signal. This signal can be modeled as a combination on random distribution functions with a certain displacement that will be translated into an echo in the frequency spectrum. The main problem resides in the computational cost of Fourier transform. For sampled images of finite scope, the power spectrum (Fourier transform of the function of autocorrelation of the signal) can be approximated, unless a scale factor related to the picture size, by the squared magnitude of the discrete Fourier transform $^{*}\mathbf{F(\grave{u})}^{*2}$ [6]. This type of developments were introduced by Bogert [7] to analyze signals containing echoes. Such signals **R(t)** can be modeled as an original signal **S(t)** convolved with a train of impulses in intervals ($\mathbf{t_0}$, $\mathbf{t_1}$, ...):

$$\mathbf{R(t) = S(t) * (\ddot{a}(t) + a_0\, \ddot{a}(t-t_0) + a_1\, \ddot{a}(t-t_1) + ..)}$$

When it is taken the logarithm of the power spectrum transforms the received signal into a sum of two terms, one that depends alone on **S(t)** and the other that it is a combination of distorted sinusoids with frequencies related to $\mathbf{t_0}$, $\mathbf{t_1}$, ...

This type of estimators can be applied for the analysis of the interference signal detecting the presence of the defect and characterizing his magnitude. Considering that only exists radial displacement can be considered as the original image plus a series of echoes displaced $\mathbf{d_r}$. The periodic term of the interference image will have fundamental frequencies of $\mathbf{1/d_r}$ (high-frequency signals). The image dependent component will be composed of low-frequencies.

Due to the directionality of the considered defects the interference record captured by the camera shows a radial periodicity (figure 2.b). This periodic echo is presented in the power spectrum response (figure 3.b) through the two peaks located in $1/d_r$.

4. RESULTS

The objective of the first developed prototype is the detection of the defects, though this is not carried out in real time. Being object of a subsequent development the generalization of the prototype, that through the increase in the processing power could accomplish the inspection above all the product. The obtained precision permits to detect stripes of up to 2 mm. wide, over images taken with a frequency of 1 second.

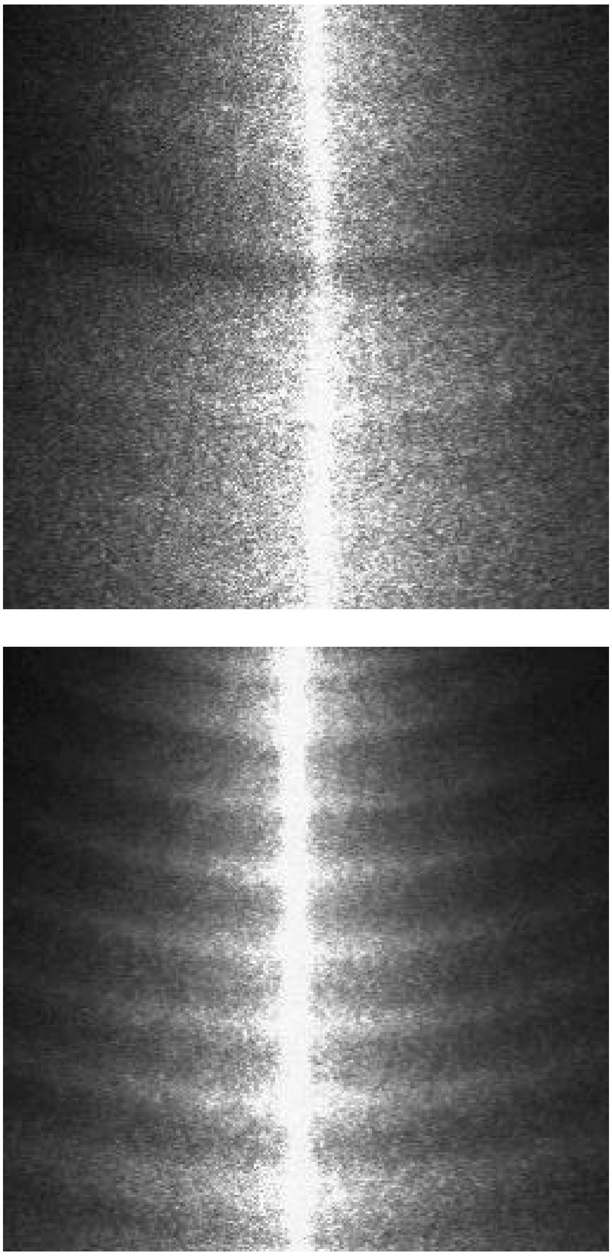

Figure 2. Images of the reflected interference signal of a laser plan on the aluminum surface. a) correct pattern image with a domed patch; b) defective image due to a incorrect work of the extrusion rollers.

The figures (2.a, 2.b) show two captures of the interference image of correct pattern and defective samples, obtained with the described acquisition system. In the pattern image can be observed effects of other type of distortions as domed patches that should not be detected by the system. On the images of the figure 3, is show the power spectrum of both samples, it can be observed clearly the two peaks due to the periodic components of the interference whose frequency comes determined by the width of the defect. In the figures 4 and 5 is shown a raising and a section of the previous results that show clearly the discrimination power. The characterization of the defect comes determined by the magnitude and said peak frequency. The response of the pattern image, filters the effect of other type of defects as domed patches that they should not be detected.

The system has been contrasted in production line, with a fully satisfactory results even within a range of 30º in the alignment of the laser plane with the defect direction. At present they are being conducting the necessary developments that permit to effect the analysis in real time.

5. REFERENCES

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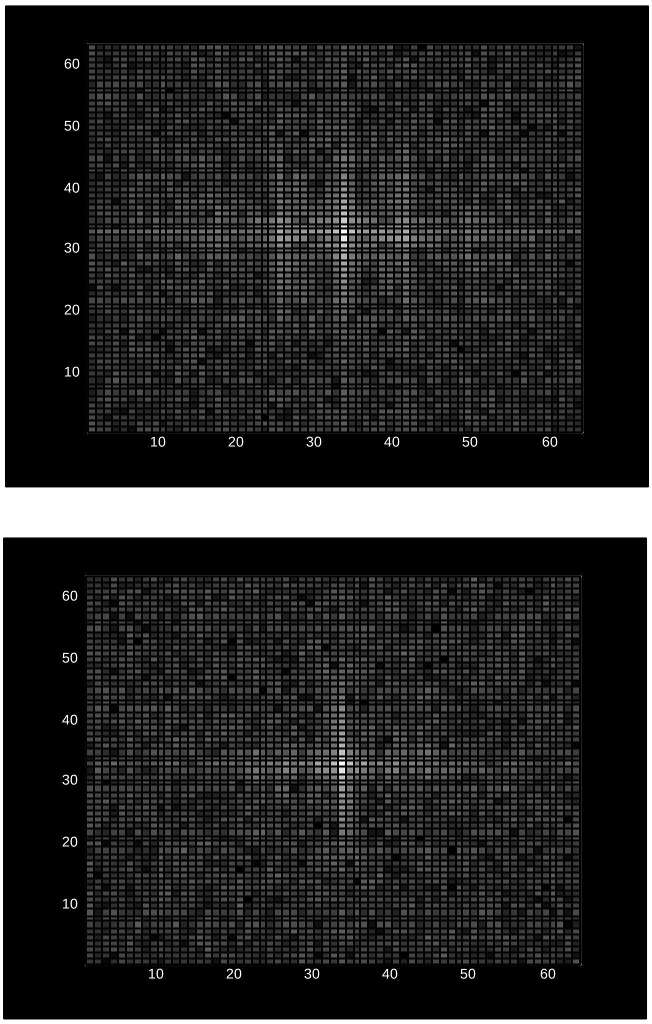

Figure 3. Power Spectrum of the images of interference of the defect sample(a) and correct pattern (b). Log Scale.

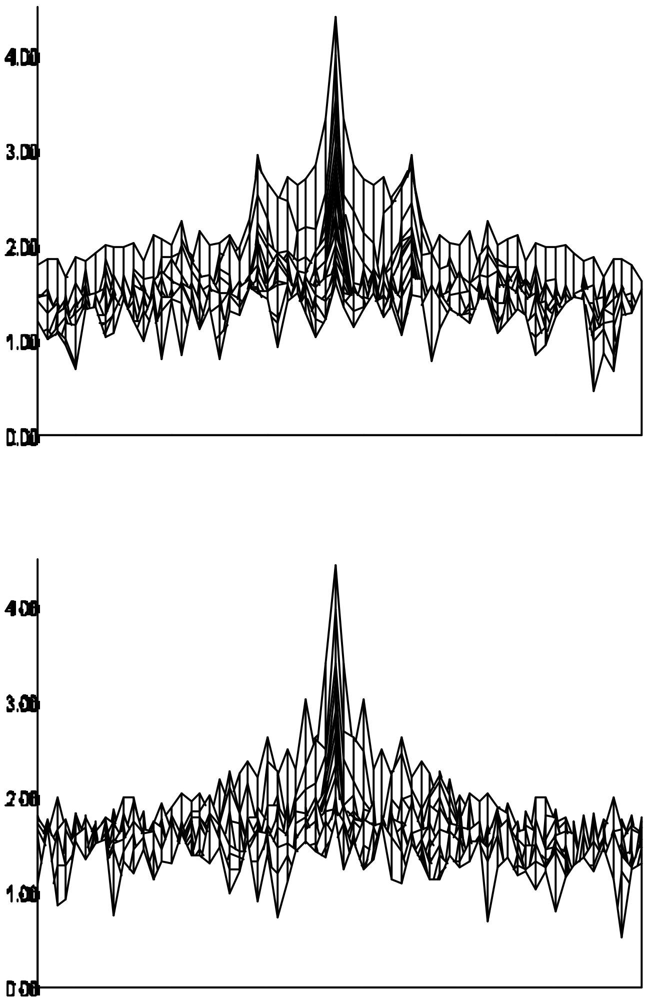

Figure 4. Profile of spectral response where are observed the two peaks related to the periodic term of the interference. (a) defective sample; (b) correct sample.

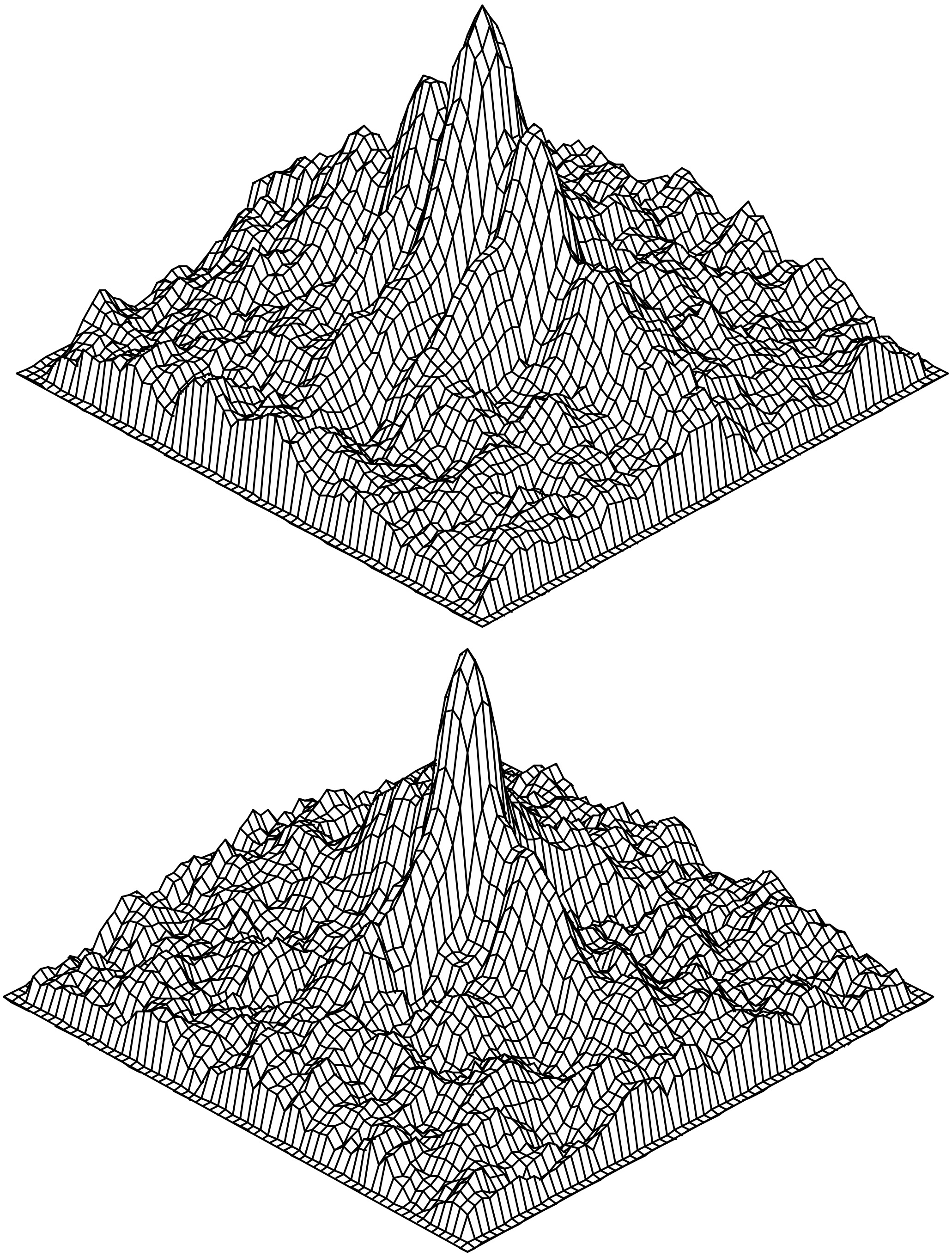

Figure 5. Representation of the power spectrum for the defective sample(a) and the correct pattern(b). Is observed corresponding spectral response to the interference pattern shown by the two left and right peaks.