Thresholding Techniques for Detection of Defects Using Dark-field Illumination

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Abstract – Textile ring components are coated with chrome coating during their manufacturing process. At the end of the manufacturing process, all the rings have to be examined for coating defects with high speed and accuracy of inspection. A machine vision set up has been designed to automate this inspection. Segmentation of defect regions in images is a major aspect of the system to be designed. Fractional Change in Derivative approach to threshold dark-field images in inspection of reflective chrome coated ring components is proposed. The new thresholding approach can be used to quickly and accurately detect and segment defective areas from the image of the coated ring surfaces. Dark-field illumination is used to capture images with very high contrast for the defective surfaces. To achieve still better segmentation of defective regions, to facilitate qualitative analysis of defects and their categories at later stage, a multiple illumination based approach is also briefly explained. These approaches can be used to locate the defective regions from the images of textile ring components thus enabling 100% inspection and full automation of the inspection process.

1. INTRODUCTION

Currently in industries, inspection of components is automated to a very large extent. In this context, optical inspection always has been a tricky problem to solve since each situation needs a unique approach. Machine vision is a form of non-contact inspection, which can be used for a wide range of electro optical sensing techniques from triangulation, profiling, 3D object recognition to bin picking based on image processing routines. In addition, it is being used for simple detection and measuring tasks to robotic control. The most common applications are measuring critical dimensions, detecting flaws, counting/sorting, assembly verification, position analysis, character or bar-code reading/verification, and determination of presence/absence of features on small parts. The machine vision task involves capturing an image of the object to be inspected using vision sensors and then processing it to measure the features of interest. The major advantage of this kind of control is avoidance of human error. Additionally very important benefit of machine vision systems is that 100% inspection if required can be achieved.

A major part of any machine vision set up is the development of an image processing methodology which satisfies the inspection requirements. Thresholding process is a method of finding the suitable gray scale value such that the pixel values corresponding to the area of interest is separated out from the rest of the pixel values. Every new application demands a newer thresholding process. The thresholding is done based on the application requirements, type of illumination, inspected surface characteristics, details to be separated out and the speed required for inspection. This paper deals with image thresholding process used for inspection of chrome coated textile ring components.

Textile ring components used in ring spinning machines have highly reflective hard Chrome coating to reduce frictional wear during usage. These components were visually inspected for coating defects which was tedious and time consuming. This paper presents a thresholding methodology to automate this process using machine vision. The images were captured using an illumination technique called dark-field illumination [1,2]. A thresholding method by name Fractional Change in Derivative (FCD) is proposed to effectively segment a dark-field image. Another approach based on multiple images also has been proposed. This was used to get better results for thresholding operation. These algorithms were developed such that detection of defects in Chrome coated ring components can be done accurately and quickly. The illumination and the algorithm are part of the machine vision proposed for automated inspection of Chrome coated ring components in industry.

Rosati et al [3] have attempted a real-time defect detection on curved reflective surfaces using a set of mirrors. Bright field illumination approach was used, where the machine vision sensor was in the path of specularly reflected light rays. In another approach by Khalili et al. [4], where multiple wavelength illumination technique was used for defect detection on hemispherical surfaces. These approaches were developed to inspect reflective and curved surfaces similar to the Chrome coated ring surfaces. In all these cases an illumination based approach is used to accomplish the inspection task. Wiltschi et al. [5] devised a method of finding steel quality from the microscopic images of etched and polished steel specimens. The process was automated with a very significant accuracy. This was attempted for specially prepared steel surfaces and was based on image processing techniques. In the next section a new method based on FCD is presented to detect and segment defects on Chrome coated ring surfaces. This method is applied on a dark field captured image. In Section 3 a second approach based on multiple images and co-occurrence matrix is presented.

2. FRACTIONAL CHANGE IN DERIVATIVE (FCD) METHOD FOR FINDING OPTIMUM THRESHOLD VALUE

Second Derivative of histogram values has been used to threshold images in [6]. FCD which is also based on derivative of histogram can be used in an image of ring surface to segment out the defects completely from the surrounding non defective surface. Given a histogram $h(g)$ (see Fig. 1a) for the gray scale values $g\ in\ [0,255]$, the FCD function is defined as follows (see Fig. 1b and 1c):

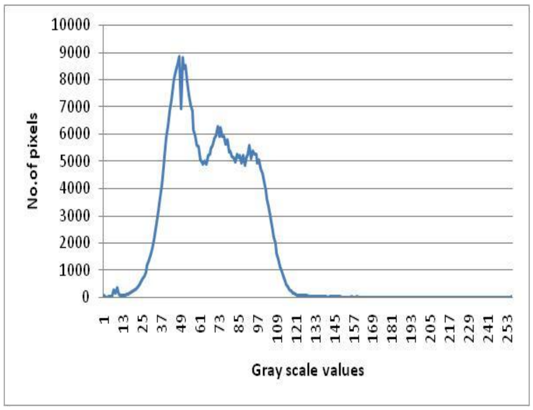
$$FCD(g) = h'(g-1)/h'(g) \quad (1)$$

where $h^{'}(g)$ represents the first derivative of the histogram $h(g)$.

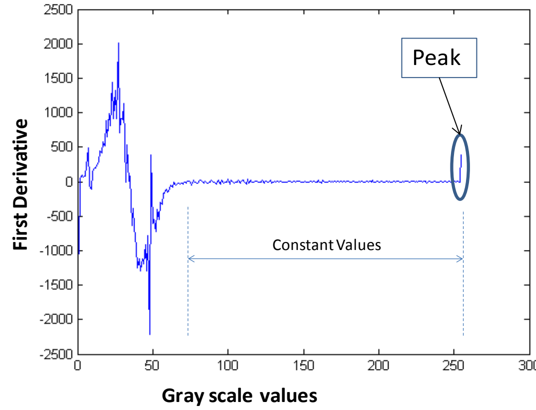
The optimum threshold value is given by the gray scale value g' such that:

$$FCD(g^{'}) = max_g\big(FCD(g)\big)\ \forall\ g \in [g_{min}, 255], \quad (2)$$

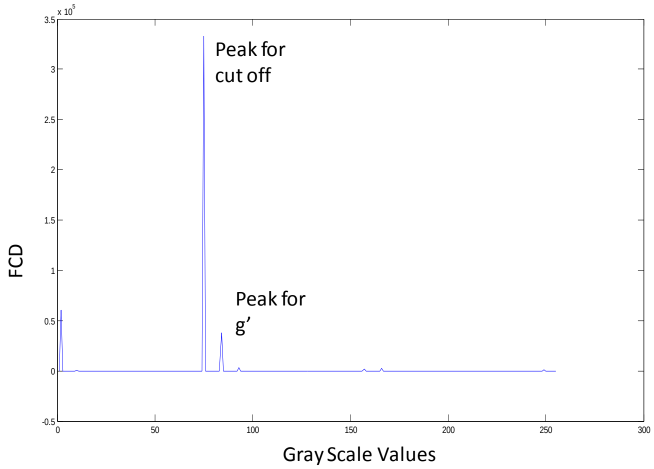
where g_{min} is given by the minimum value of g that provides a positive segmentation of a defect area for all considered images. In the example considered in Fig. 2 $g_{min} = 70$. From the analysis of first derivative plots for different images of defective surfaces it has been found that the dark field region of interest is represented by the gray scale regions where the plot of first derivative is constant (see Fig. 1b). The rest of the regional variation corresponds to other ring characteristics like edges. The major variation is representing the boundary of the background and ring surface. Then the exact defective region will be represented by an optimum gray scale threshold value within the region of constant values of first derivative i.e. between g_{min} and 255. FCD is used to find the point of maximum variation in the region of constant values of first derivative as is shown in Fig. 1b. This is depicted in Fig. 1c. The information about the defective ring surface will be visible above this value represented by a spike in Fig. 1b. The first column of Fig. 2 shows three images of defects (blister and yellow stain) and a non defective surface. Fig. 2b, 2f and 2j show the defective region segmented out by using the value of g' derived from FCD approach. In Fig. 2c, 2g and 2k the threshold value was set close to half of the maximum value of 255 for illustration purpose. This gives a fair idea about the approximate spread of the defective area, if any, present in the image. Both the threshold values obtained by maximum $FCD(g)$ and $g = 127$, fails for non defective images. Hence a very high threshold value of 230 was fixed such that none of the non defective areas are segmented out as defects. The resulting images are shown in Fig. 2d, 2h and 2l (230 corresponds to the spike shown in Fig. 2b). The image of non defective sample in Fig. 2m has been subjected to thresholding based on all the three values and the respective resultant images are shown in Fig. 2n, 2o and 2p. It can be found that only from Fig. 2p with threshold value, 230 as discussed before; resultant image is obtained without false



(a)



(b)



(c)

Figure 1: Image characteristics for defective surface of Chrome coated ring. **(a)** Histogram of image of defective surface (blister) of ring under dark-field illumination. , **(b)** Plot of first derivative of $h(g)$ in Fig. 1a showing the peak in $g\rightarrow 255$ **(c)** The plot of FCD for the region of constant valued first derivative. The first biggest peak shows the value for the cut off. The next biggest peak shows the optimum valueg'.

positives being detected. The conclusions based on these observations are given below.

1. Threshold value of 230 can be used to identify the presence of defects on the imaged surface.
2. After ascertaining the presence of defects, the maximum $FCD(g)$ method can be used to correctly segment out the defects for further processing. This may be used only on images of defective regions after the identification of defects by using single threshold value of 230, since the non defective images will give erroneous results when directly operated upon by the algorithm. Details in segmented image can be used to quantitatively assess the type of defect.

The images of non defective surfaces will not show any distinct area representing defects while threshold value of 230 is used.

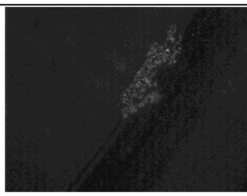
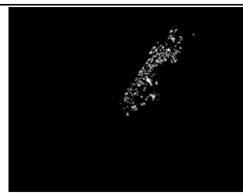
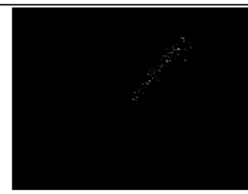
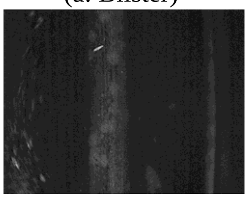
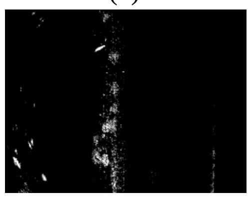
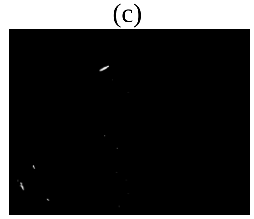
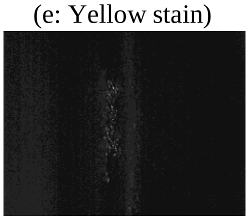
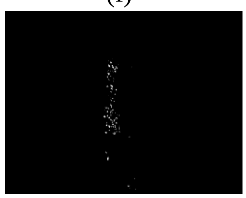
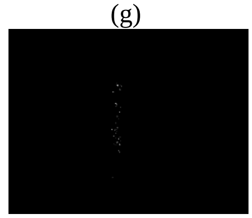
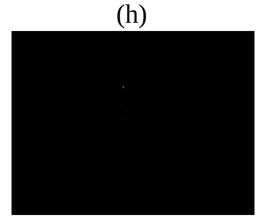
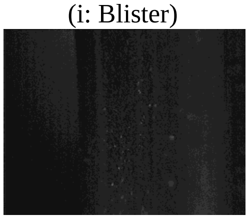
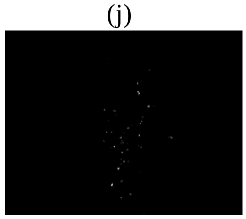
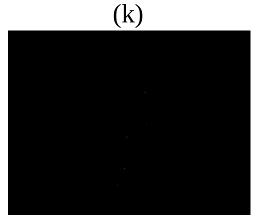
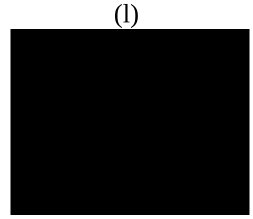
Original dark-field image	**Thresholded image using FCD approach**	**Thresholded at g=127**	**Thresholded at g=230** (Few white pixels present for defective)
 (a: Blister)	 (b)	 (c)	 (d)
 (e: Yellow stain)	 (f)	 (g)	 (h)
 (i: Blister)	 (j)	 (k)	 (l)
 (m:Non defective)	 (n:False detection)	 (o:Few white pixels)	 (p:No white pixels detected)

Figure 2 Effect of using different threshold values Note: White pixels represent the defective regions. Images in each row are obtained by thresholding the images shown in the first column. Images were taken from different rings.

3. THRESHOLDING FOR MULTIPLE IMAGES

The disadvantage of dark field illumination is the loss of information due to scattered light going out of the CCD sensor. The presence of multiple images can be used to circumnavigate this problem. Multiple images of the same region can be captured under different dark-fields configurations, which results in a series of images. Different Gray Level Co-occurrence Matrix (GLCM) parameters are calculated from this series of image [7-8] and used as the input for the thresholding algorithm, which is based on information fusion techniques. The extracted parameters are combined in couples, for example, Fig. 3 shows the binary image formed using scatter plot of the parameters ‘Sum average’ against the parameter ‘Contrast’ [8]. In this approach, the threshold is applied to statistical values, the GLCM parameters, and not to gray values as was done previously. By using morphological operations and based on the fact that defects are much smaller that the ring surface, threshold values are found to separate out the background from defects. Each combination of two GLCM parameters results in two threshold values. Figure 4 shows the results of applying the obtained threshold, when the parameters Sum square, Sum average, Contrast and Difference variance [8] are considered. The union of these individual results reveals the defect region with maximum details. The major disadvantage is the fact that the computation is time consuming and hence the whole detection process becomes slow. Therefore a combination of both the threshoding processes can be used to achieve quick and accurate defect region segmentation.

4. CONCLUSIONS

Two methods to threshold dark-field images and segmenting out the defective areas have been proposed. These methods can be used to detect the presence of defects in Chrome coated ring component surfaces. At the next stage the thresholded images can be used to analyze and study the extent and nature of defective surfaces thus making it possible to automate the inspection process and even incorporate it in defect classification process.

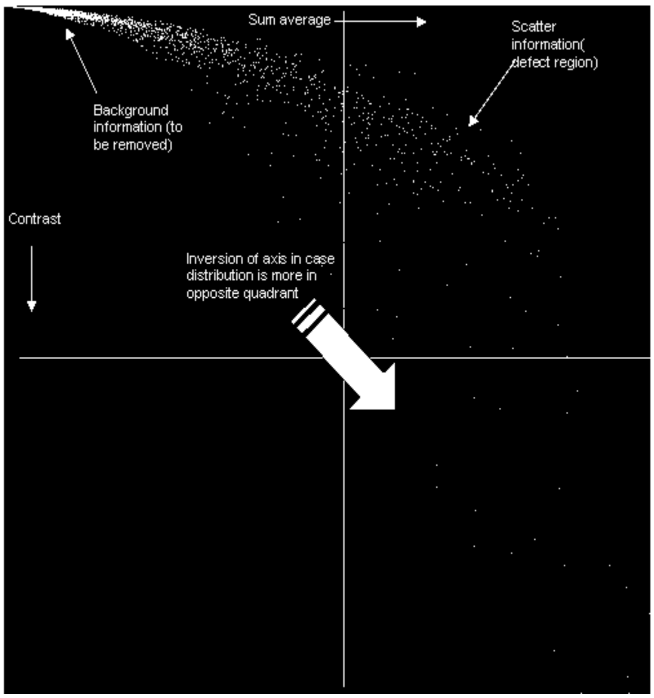


Fig. 3 Image used in thresholding operation. Contrast parameter values are plotted against those of Sum average. The region of higher density represents the background, while the scattered values correspond to defects.

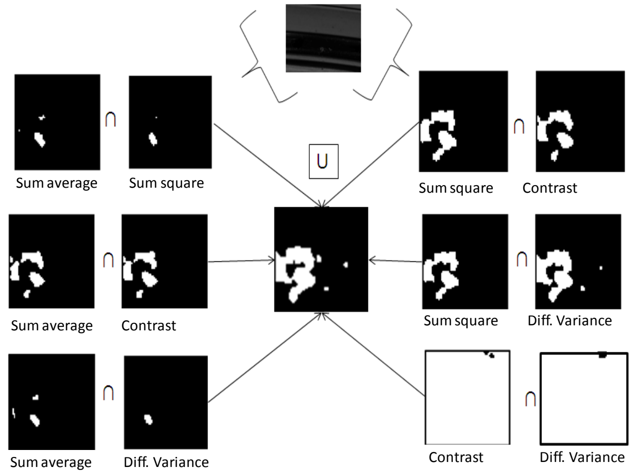


Figure 4 Information fusion for thresholding operation showing final thresholded image from sample threshold images.

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