Solar Cell Crack Inspection by Image Processing

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Abstract

The aircraft works in space with terrible circumstance far from the Earth, so it is necessary for the solar cell with the property of anti-radiation to perform bonding process. After bonding, an essential process to the solar cell assembly is to inspect the cracks on the edge or inside of the solar cell. To avoid utilizing the unqualified products and to improve the reliability of products, this paper presents a method to detect the cracks of solar cell by image processing, which contains gray transform, image adjustment, Gauss-Laplacian transform, contour detection, crack distinguishing and so on. The correctness of this method has been verified by experiment results.

Key words:

solar cell; crack distinguishing; contour detection.

1 Introduction

Power supply is an important part of aircrafts such as satellites. Almost all orbit satellites employ solar cell array and storage cell as power supply [1]. The solar cells work in space with severe condition, so they should possess the property of anti-irradiation, reliability and so on. What is worse, if the solar cells with large cracks are exposed to space full of low-energy protons, the electrical performance will be badly impaired, even the lifetime will be shorten [2]. In order to avoid the unqualified solar cells to be put into use, it is vital to detect cracks after bonding.

Adopting image processing to detect the flaws of solar cells will be concerned with several technologies [3]. The reference [4] presents a nonclassical method for contour detection. Hankyu Moon gives a novel operator which can work by reducing the intensity of the contour and the difference between input and output [5]. The following parts will illustrate the mechanism of employing image processing to detect cracks. The flowchart is given in Fig.1.

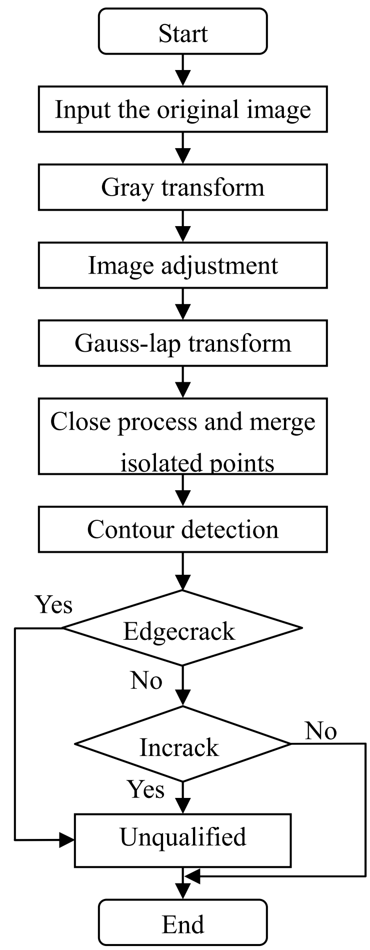

Fig.1 Software flowchart

2 The mechanism of crack inspection of solar cell

2.1 Crack

The cracks of solar cells can be classified into two types. Generally, the rate of crack's presence on the edge of solar cells is far more likely than that inside it. It is called edge crack when the crack extends to the edge, or it is inside crack. Because it is necessary to improve the foregoing processes based on different origins, classifying the cracks is required. It is easy to detect the edge cracks, but hard for inside cracks, especially for the cracks with the shape of ridge, which has small gray level difference. The different cracks do not have the same effect on the performance and lifetime of solar cells. The inside cracks can be remedied when the cracks are not large enough [6], but the edge cracks with large width do not have the luck.

2.2 Gray Image

The format of the original picture is JPG (see the Fig.2), for the sake of convenience to process the picture, it is necessary to transform the original image to gray image (Fig.3). The image remains most of the useful information and do not affect the crack inspection [7].

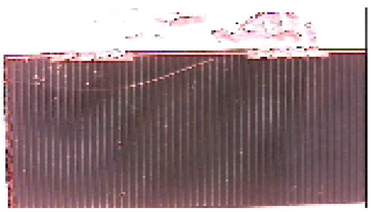

Fig.2 Original image

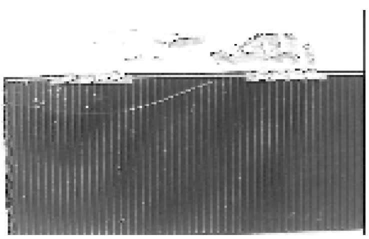

Fig.3 Gray image

2.3 Image adjustment

In Fig.3, due to the dispersed gray values of pixels and the ambiguous characteristic of cracks, inverse operation on histogram equalization should be taken to centralize the distribution of gray value, and then transforming the image to black-white one, which can outstand the cracks. The adjusted result is shown in Fig.4.

Fig.4 Adjusted image

2.4 **Gauss-Laplacian transform**

According to the definition of inside crack, the difference of the gray value of the pixels between inside crack and its surrounding pixels is small. The inside crack locates on the turning point where the intensity changes from increase to decrease, so it is hard to be directly detected. For the purpose of enhancing the character, the operator of Laplacian is adopted to sharpen the image. The Laplacian is a scalar quantity operator of two-rank derivation used to calculate the two-dimension function, also called shift invariant operator. For the operator is a two-rank derivation, it can produce a steep zero crossing. If a non-noise image has a steep edge, cracks can be easily detected [3]. Unfortunately, the existence of noise makes the lowpass necessary to filter the image before using Laplacian.

It is suitable to choose Gauss filter to smoothen the image. Now, for the sake of convenience, the two operators are combined to form Gauss-Laplacian operator (see matrix (1)).

$$\begin{matrix} -2 & -4 & -4 & -4 & -2 \\ -4 & 0 & 8 & 0 & -4 \\ -4 & 8 & 24 & 8 & -4 \\ -4 & 0 & 8 & 0 & -4 \\ -2 & -4 & -4 & -4 & -2 \end{matrix} \quad (1)$$

After that, the boundary and cracks of solar cells are all exposed, it can be seen in Fig.4

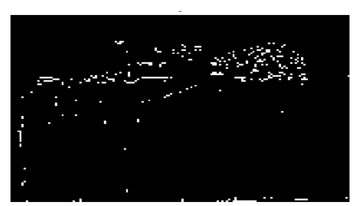

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Fig.5 Transformed image

2.5 Close image and merge the isolated points

Now, the cracks are distinct. But there are some noise points in the image remained by the camera when it gets the picture of the solar cell with some dirt on it. According to Fig.5, the edge and cracks appear in form of points with different size, and then the distributed points are merged to some connected regions by close process. The close process has two steps: firstly, dilate the character and then erode it, just like Fig.6.

2.6 Contour detection

In Fig.6, the background is black, in order to change it to white background, the black and white are exchanged. The detailed steps of contour detection are given as follows:

Fig.6 Closed image

Firstly, eight orientations in the image are defined: left top, top, right top, right, right bottom, bottom, left bottom and left, which are formed by regarding the central pixel as the base point and directing to eight neighborhood pixels. The method can be depicted as follows: firstly searching for non-isolated point A at the left bottom, then starting to probe the next edge point from the point at the left top, regarding it as the edge point if it is black and not final point, or else turning to the next direction pixel along the clockwise orientation until the point is black again, then marking it as point N and regarding it as the base point. Subsequently, contrarotating 90º and looking for the next edge point along clockwise direction, repeating the same steps, until returning to starting point A. The result is shown in Fig.7 [8].

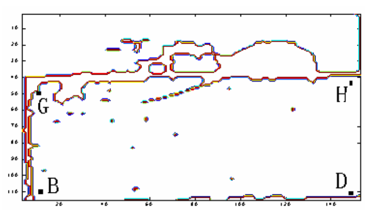

Fig.7 Boundary of the image

2.7 Crack inspection

The crack is defined as follows: a continuous district has the width n changing from 3 to 6 pixels, and the length m more than n+3.

2.7.1 Edge crack inspection

Here are the steps for edge crack inspection (Fig.7):

1） First of all, it is vital to find the theoretical starting point in the left bottom, marking it $A(x_1,y_1)$. Taking into account of the curved border, the starting point $B(x_1+a, y_1-a)$ is worked out, here a is an integer varying from 4 to 6.

2）Secondly heading from B upward and the rightward to search for cracks, and incidentally finding point $C(x_2, y_2)$ at the right bottom, based on the same reason, ending point $D(x_2-a, y_2)$ is calculated.

3) Heading upwards to scan from the D, and judging whether the crack exists or not. If the crack is determined, the solar cells are regarded as unqualified ones and labeled as “edge crack”, or else coming to the next step.

2.7.2 Inside crack inspection

The steps are given as follows:

1）Heading upwards from B and D to find respective top edge points, then marking $E(x_3, y_3)$ and $F(x_4, y_4)$. Similarly, $G(x_3, y_3+b)$, $H(x_4, y_4+b)$ can be determined, here b is also a variable integer changing from 8 to 12.

2）Scanning in the region $BDGH$ to see whether the crack exists or not, if present, it can be considered as unqualified one and marked “inside crack”, or the solar cell can be put into use.

3 Conclusion

The inside cracks generally result in internal open circuit and wrongly interconnection. This method aiming to cracks detection presented by this paper is effective to the inside cracks, especially to the cracks in shape of ridge. The correctness of this method has been verified by experiment results.

Acknowledgments

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