Automatic Visual Inspection System
- Detection of Insulator's Minute Crack -

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Abstract

Because minute cracks of suspension insulator shells seriously affect the nonconductivity, they must be detected by the total inspection. It is not easy for workers to inspect and detect the minute cracks of all insulator shells with only naked eye during all day. In this paper, we propose the method to detect them using computer vision. After the shells are enalmeled and baked, it is easier to detect the cracks. But the detected shells should be cast away in that case. However, as our system inspects the minute cracks just after forming and drying the insulators, the raw material of the insulators can be used again and money is saved.

I. Introduction

A machine vision system as nondestructive inspection takes the place of man's eyes to inspect external appearance of products.

Suspensory insulators are used to insulate electric wires on transmitting towers and electric poles. A minute crack of these insulators makes bad effect on insulating property. As time goes by, the crack will become larger and the insulator will break down at last. Therefore insulator industries have tried to remove all defective products which have cracks through the total inspection. But all the domestic industries inspect the cracks by man's naked eyes. This inspection is a very tedious and hard job. Especially the minute cracks are not easily detected on afternoon because the eyes become tired. Thus the defective products are accepted sometimes. To prevent the problem, an automatic visual inspection system should be needed.

The process to make an insulator consists of mixing, forming, drying, enameling, and baking one. Most of the industries totally inspect them after drying and baking process. The inspection system which had developed before was used after baking the insulators. The reason is because at that time it is easy to inspect the insulator. Though the most part of the insulator is glossy after enameling and baking process, the area around cracks is not glossy. So, it is easy to differentiate whether cracks are or not. The detected parts are useless and should be thrown away.

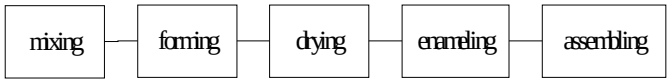


Figure 1. The insulator manufacturing processes

If we detect the cracks just after drying process, the insulator can be made into powder and formed into another one again. In other word, the company can save the cost of material and don't waste money to enamel and bake the insulator with minute cracks. Thus we would develope a system that can inspect minute cracks just after drying process in this research.

II. The System Structure.

The system we have developed consists as the figure 1. The pulses which the motion control board generates can activate the stepping motor, and the motor rotates a

suspension insulator and then we take images by using CCD cameras and a frame-grabber. After acquiring the images, we pre-process them and try to detect minutes cracks. At this time, the role of illumination is very important.

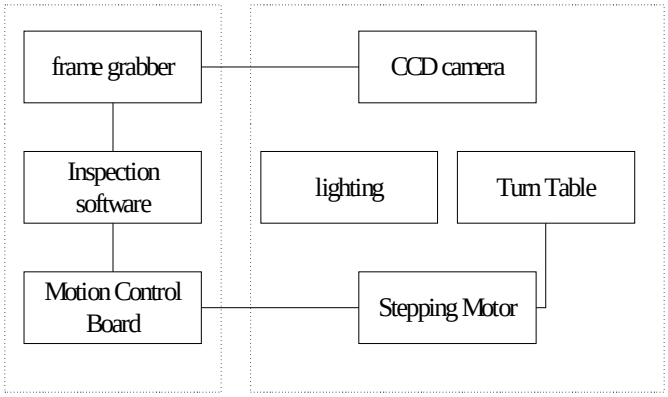


Figure 2. Components of the System

2.1 Selection of a camera and a lightning

In the reason that we have to take the insulator images with rotating very fast, a progressive scan camera is needed. The target insulator in this research has two valleys, so two cameras, one per valley, are used. As the distance between ridges of it is 2.5cm, we set the image size as 2.5 × 2.5cm.

The company required that the system's performance as the same or above as man's one. The accuracy of man's eye is 0.11 mm when the range of clear vision is 380 mm [1]. Thus we set the distance of a camera to an object being from 150 mm to 200 mm and the precision of measurement is 0.05 mm. In order to satisfy these conditions, the resolution of the camera has to be 1,024×1,024 pixels and its focal length is to be 35mm.

We analyzed three lighting : a halogen lamp, a high brightness LED, a ring-type lamp using optical fiber. As the result we concluded to use the high brightness LED. The halogen lamp radiates high heat, so it can make bad effects on other components including the camera. The ring-type lamp is meaningless. To take images where we want to inspect, local lightning to the place is enough. In case that the high brightness LEDs attaching diffusion plates illuminates the valley of the insulator, brightness of the area is even.

2.2 The detection ability of outer defectives

There are three kinds of defects on the face of a insulator : unevenness of surfaces, discoloration, and cracks. Our system can detect all the three kinds of defects. As the matter of the fact, it is easy to detect the unevenness of surfaces and discoloration. We don't concerned about the two defects. The reason will be explained as below. The main purpose of this research is to detect the minute crack. Because we are concerned about the minute cracks in the valleys, lens of cameras are focused on the valley.

After forming process, the insulators have been dried upside down on plane plate in a drying dock for a long time . So, the rib of the insulator is not clean and some remnants stick on it. Because the insulators are easy to break after drying and arbitrarily placed on the drying plate, it is not easy to make an automatic system. So workers pick it up one after another from the drying plate and remove remnants with a scraping knife and put it down on conveyor belt. When the workers remove remnants, they also inspect the insulator with their eyes. They can easily detect unevenness of surfaces, discoloration, and big cracks. But their main job is to remove remnants, so the inspection of minute cracks is forgotten sometimes. That is the reason why the inspection system should be developed.

To remove the noises of images taken by the progressive scan camera, some image processing techniques are used. After pre-processing them, the system scrutinize the images to find whether crack images are or not. At this point, the most important point is the system have to do it as real time.

We used a rectangle area camera to take the insulator image while top view of an insulator is a circle. As the result, the images were overlapped each other. Moreover, the first camera took inner valley's images, and the second camera took outer valley's images. So, the images from the first camera were much more overlapped each other. The overlapped images themselves were not problem. Because we could calculate the amount of overlapped area, we saved the unnecessary computational time with not processing the overlapped area.

The problem is that a part of a minute crack is appeared in the boundary of one image and the other part of it is appeared in the boundary of another image. In other words, a crack appears in two consecutive images which are divided into

two. In that case, the crack image is too small, so the system regards it as a noise. Of course, we can handle the problem as software. But it is complicate that two consecutive images were held and it is hard to handle as real time. Therefore as we set the length of the overlapped area to be longer than the minimum allowable length of minute crack, the problem was solved.

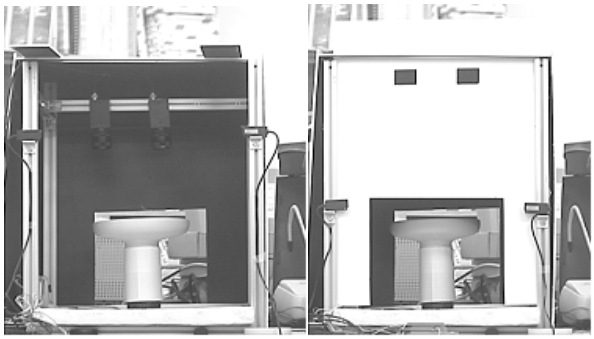
Because we have to take and process the insulator images with rotating very fast, the shutter speed and the rotation speed are important. And the algorithm efficiency is also important. As the shutter speed depends on the hardware, it is not impossible to control arbitrarily. The rotational speed is controllable. As the result of tests, we could take clear images when it takes 2 seconds per rotation.

III. Implementation and Experiments

The automatic minute cracks inspection system of suspension insulators consists of two parts : the visual inspection module and the insulator handling module. The insulator handling module is a mechanical part and it is not a viewpoint of this paper. We assumed that the insulator was loaded on the turning table by the handling module.

The inspection module or system is composed of two cameras, two lightings, a frame grabber, a stepping motor, a motion control card, and a PC. The camera is XC-HR 300 CCD one of Sony, its lens is made by Fuji. The lighting is KB-5016 LE. An Meteor-II MC board is used as the frame grabber and software is developed with Visual C++ 6.0 and MIL library 7.1 on Pentium IV 1.6GHz computer.

The two cameras were installed on opposite side to the center of an insulator so that the light of the other camera takes effects as less as possible. Figure 3. shows two valley images of an insulator. There are black bands along the direction of the circumference of the insulator. The deep valley's shape causes the bands to exit. The bands can be not removed with illumination.



(a) (b)

Figure 3. System a) the inside b) the front view

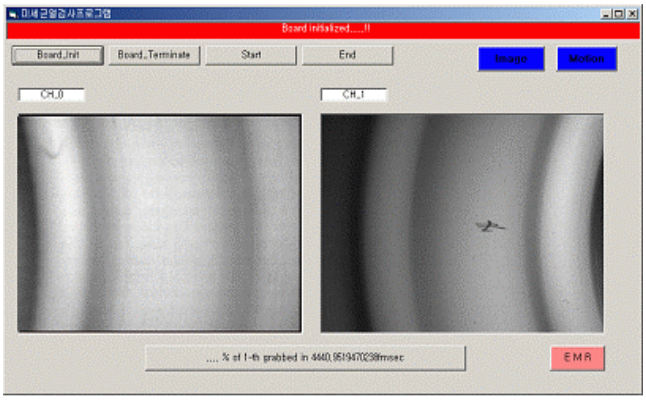
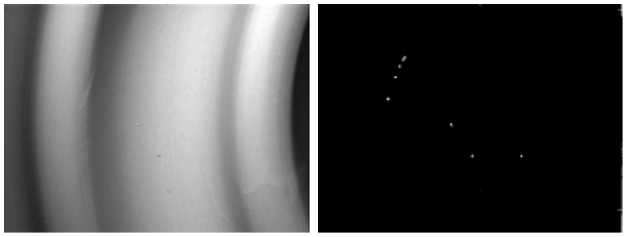


Figure 4. The software for the automatic minute cracks inspection system

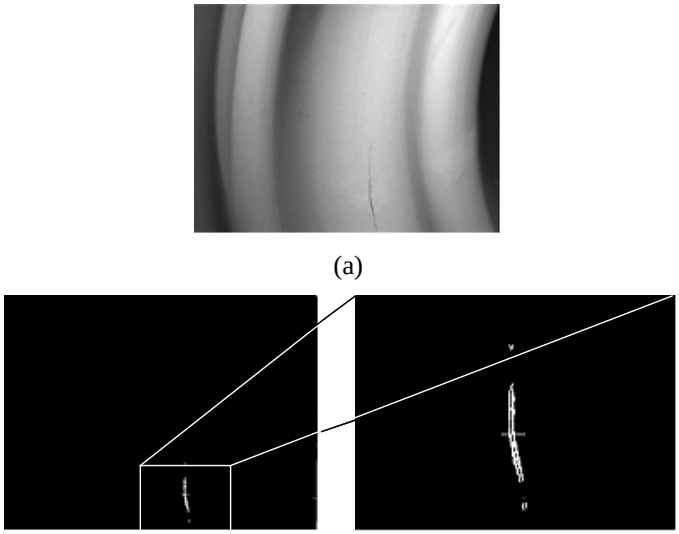
But, because there is not corner edge in the valley, the grey value of the black bands in the images changes by gradation. Therefore we can remove the black bands with the edge extraction operator, Sobel. The result image is figure 5 and 6. Figure 5 and 6 (b) show that the bands are removed perfectly and the edge of minute crack is extracted clearly. The cross mark in figure 6(c) is the sign that the system has found the crack.

Because the color of powder which is used to make insulator is not even, that makes some noises after the image processing(figure 5). But, the size of the powder particle is very small and the powder particles are mixed evenly before forming process. So, the image size of powder particles is not big. Therefore we can ignore the images as noises.



(a) (b)

Figure 5. An image processing a) an original image, b) a noise image because the colors of powder particles are not even



(a)

(b) (c)

Figure 6. Scenes of inspection a) an original image b) detection of a minute crack (c) zooming up the crack

In this research, The developed system can have taken and pre-processed 25 images per a rotation, and searched defects every two seconds. Because it takes time to display the insulator's images on the monitor, that makes effect to the system performance. So, only when the minute crack is detected, let the result image display the monitor.

We tested 100 insulators which was randomly selected in the factory. As the result, our system found the all minute cracks expect one. But the crack size was beyond the system's ability. The crack is very thin and short as about 3.5 mm. It was hard to find it with naked eye and we used a magnifying glass.

In this experiments, we could be satisfied with the result. But it wss natural to detect the bigger cracks than the system's ability. Besides, we wanted to test many insulators which had the same size cracks as our system could find. We were regretted it was hard to find such those insulators.

Of course, if we adopt more expensive cameras and a frame grabber, the inspection time can be lessened and less minute crack can be detected. But everybody knows there always be a conflict between cost and performance.

IV. Conclusional Remark

In this research, we have developed an automatic minute cracks inspection system of insulators. Our system takes 2 seconds to inspect an insulator and can detect the minute crack, width 0.2 mm and length 5 mm. In this experiments, we could satisfy the result.

Moreover our system can detect the minute cracks after forming and drying process, the raw material of the insulators can be used again. Therefore we save the cost of raw material and don't waste money to enamel and bake the insulator having minute cracks.

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