# FLUORESCENCE MAGNETIC PARTICLE FLAW DETECTING SYSTEM BASED ON LOW LIGHT LEVEL CCD

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**Abstract:** This paper introduces a new kind of fluorescence magnetic particle flaw detecting system. It mainly includes a microcomputer, a magnetic particle flaw detector and a low light level CCD (Charge Coupled Device) camera as a photo-electronic receiver. In order to get the result of detection, the fluorescent image of an automotive part, which is shoot by the low light level CCD camera, is put into the computer to be analyzed and processed. The method of fluorescent image processing of the flaw is also given in this paper. It is testified that the fluorescence magnetic particle flaw detecting system controlled by the microcomputer is practically useful and has high precision.
Keywords: Low Light Level CCD Camera, Fluorescence Magnetic Particle Flaw Detection, Image Processing, PLC (programmable logical controller), Microcomputer

**Introduction:** Fluorescence magnetic particle flaw detecting is a common NDT (Non Destructive Testing) method for the surface or near surface detecting of the ferromagnetism material produces, including raw and processed materials, semi-manufactured goods, accessory etc. There are many kinds of fault, for example crack, air hole and delamination can be detected by this method. So fluorescence magnetic particle flaw detecting has been widely used in the field such as mechanism, railroad, metallurgy, automobile, navigation and so on. But until now most devices of fluorescence magnetic particle flaw detecting for bent axle, radial axle or half rear axle of vehicles are handled by people. Although some fluorescence magnetic particle flaw detectors controlled by microcomputer had been developed, the act of identifying fault from the magnetic particle indication has always been done by people with eyes. The disadvantages of this kind of fluorescence magnetic particle flaw detector not only include lower reliability and less detailed information about the fault, but also consist in it is non-real time. In fact a detector must have the ability of analyzing and recording the information at the same time, especially its speed of data processing is fast enough to be real time during the online detecting process of the workpiece. To reduce the people’s influence on the detecting result and improve fluorescence magnetic particle flaw detector capability, a new kind of fluorescence magnetic particle flaw detecting system has been developed, in which a high sensitive low light level CCD camera is employed [1].

This fully automatic system, which is used to on-line identify crack defect in bent axle, radial axle or half rear axle of vehicles, was developed from a kind of partially automatic fluorescence magnetic particle flaw detector with PLC. Compare with the former detector, the system employed equipment which can automatically put the accessory on the clamp for detecting and take it away after detection. The high sensitive low light level CCD camera of the system obtain image of magnetic particle indication and send the image to microcomputer for processing in order to satisfy the requirement of crack identification automatically.

**Hardware of defect inspection and analysis system:** Figure 1 illustrates the process and function of the defect automatic inspection and analysis system on the production line.

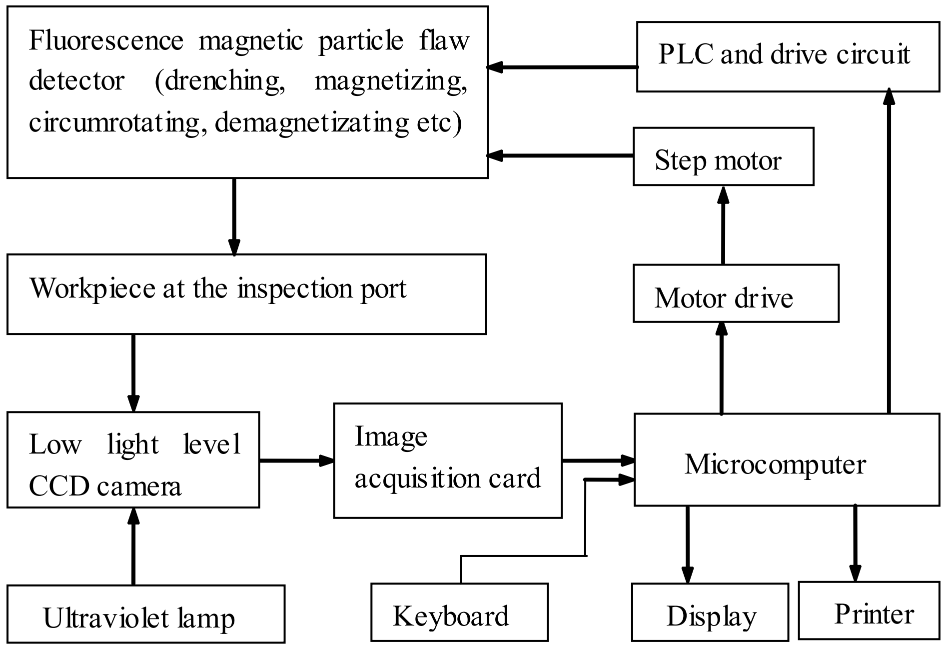


Fig.1 Principle of the fluorescence magnetic particle flaw detecting system

The system mainly consists of microcomputer, fluorescence magnetic particle detector, stepmotor, low light level CCD camera, image acquisition card and PLC. Ultraviolet lamp is used as illumination of the system and a piece of light filter was placed in front of the ultraviolet lamp to prevent visible light, for the visible light beamed from the ultraviolet lamp can be reflected by the workpiece and then cause interference on fluorescence to debase the contrast of magnetic particle indication. To get high quality image, we choose a low light level CCD camera whose pixel number is 768 ×576 and use image enhancer in it. Another piece of light filter is used in the front of the CCD camera to only permit fluorescence to throw out in order to improve image Signal-to-Noise Ratio [2]. In the system, stepmotor has two functions: on the one hand it makes the workpiece to equably revolve when suspension drenched to workpiece or magnetizing; On the other hand when the CCD camera begin to work, the stepmotor must make the workpiece to stop after revolving 120° to let the CCD camera get image. There is the motor drive logic circuit between microcomputer and step motor. Signals from the motor drive used to control stepmotor include power signal, impulse counter signal and reset signal. Control logic of these signals is easy to produce relatively. A method based on assemble language embed into VC++ language is used to obtain control logic signals. Fluorescence magnetic particle flaw detector, whose clamp has same axis with the stepmotor, is controlled by the microcomputer through PLC and its drive circuit. Image acquisition card get magnetic particle indication image from the low light level CCD camera and put the digital image to the microcomputer, where image processing software for the digital magnetic particle indication image works and identifies crack defect information. Then results of the testing are shown on the display and can be printout by the printer.

Under the PLC control, the fluorescence magnetic particle detector perform a series of work as followed: Put workpiece to the inspection port, clamp workpiece, drench workpiece with suspension, magnetize, demagnetize, loosen clamp and take workpiece away from the inspection port. The fluorescence magnetic particle detector has several magnetization methods such circumferential magnetization, longitudinal magnetization and resultant magnetization. In the PLC drive circuit, magnetizing circuit employed a method of controlled silicon voltage modulation to control and adjust magnetizing current [3]. Data traffic and instruction transfer between PLC and microcomputer are by means of the universal serial interface. After being magnetized and drenched with suspension, workpiece is under ultraviolet irradiation. Workpiece surface where exist crack will adsorb more fluorescent magnetic powder which beams strong fluorescent light under the ultraviolet lamp. The CCD sensor scan the workpiece surface when it stop circumvolving, then the fluorescent light image of the workpiece surface are collected to the computer. Position and size of defect can be estimated from magnetic particle indication image after a series of digital image processing in the computer.

**Magnetic particle indication image processing:** The input digital image signal has to be preprocessed because some disturbances, i.e. noise, come from testing environment and capability of CCD camera during image acquisition and transmission. That is the reason that image has to be preprocessed before identify the position and size of defect from the magnetic particle indication image to produce the main defect information relatively free from noise. Image processing is shown in Fig.2.

The output of CCD camera is continuous image signal, which is transformed to gray image whose gray level from 0 to 256 after monochromatizing by the image acquisition card. To separate the flaw information from the image, the gray image has to be transformed to binary image by image segmentation. An image segmentation method of gray level thresholding is adopted in this system. After image segmentation, the pixels of magnetic particle indication image corresponding to the flaw are white and the other pixels of background image are black in the binary image. In fact there are some great shortages in the methods usually used before to deal with the image [4]. For example, it is difficult to choose adaptive threshold, identifying artifact at the edge of the workpiece and remove influence of the image background. To make our image processing method generally accepted, we adopt “difference image” way to process the binary image, i.e. one image minus another image of the same scenery at the different time, in our image processing system. As we discussed before, CCD camera gets one image every 120°. Because three images for one workpiece have the same scenery, the difference image method can eliminate the difficulty in threshold value choosing and influence of the edge of image on crack identifying [5]. To search the defect information from the binary image processed by difference image processing method, the white spot in the binary image should be marked. It is a region-dependent segmentation process. Some marked consecutive white spots inside an area consist of a white line namely consecutive region that may be the creak image. We scan the entire image from up and down to search and mark all the consecutive regions. Then we calculate the ratio of length to width and the average width of all the consecutive regions. Only the ratio of length to width of the consecutive region is larger than a threshold value which is chosen according to the result of experimentation is considered as a possible defect. Some consecutive regions of the possible defects thought to be noise image are rejected by us because their width is too large. We also eliminate other false defects by using feature extraction, for example shape parameter comparing, to get the final result. The image of creak and its position and size information are output to the display and the testing data is stored in the computer.

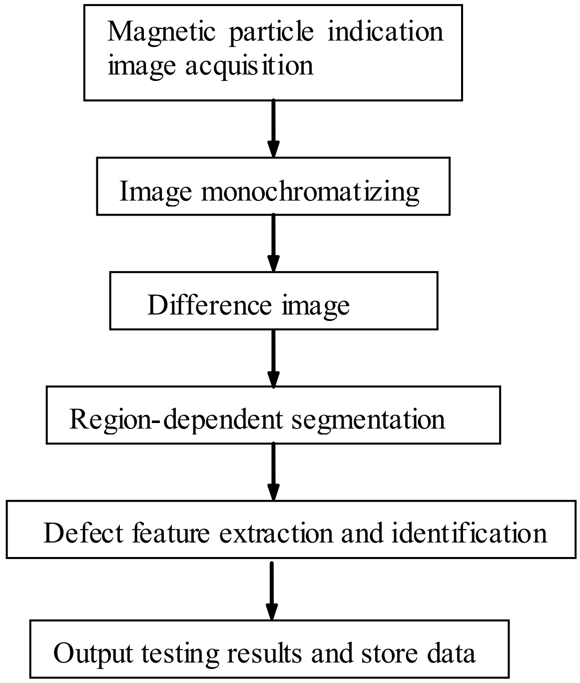


Fig.2 Automatic image processing

**Results:** The bent axle of automobile is detected by this fluorescence magnetic particle flaw detecting system. Figure 3 shows that gray image of the bent axle processed with monochromatizing by the image acquisition card. The defect information can not be obtained directly from the gray image of the bent axle magnetic particle indication. Then the gray image of the magnetic particle indication is dealt with image processing approach mentioned in the former part (i.e. automatic image processing shown in Fig.2). The results of every process step are shown in the figure 4, 5, 6. The Fig.4 shows binary image of the magnetic particle indication after processing the Fig.3 with gray level thresholding. The images of Fig.5 and Fig.6 are the results of difference image with the Fig.4 and region segmentation with Fig.5 respectively. Fig.7 shows the final magnetic particle indication image processed by feature extraction algorithm. From the Fig.7 we can conclude that there is a creak in the bent axle. In fact the output of the computer just shows the same result; meanwhile the position and size information of the creak is also given in detail.

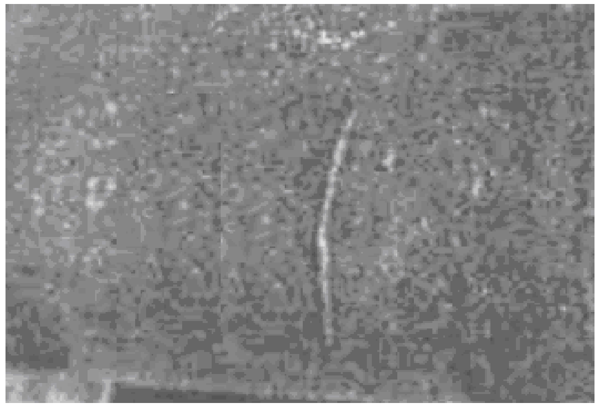

Fig.3 Gray image after monochromatizing

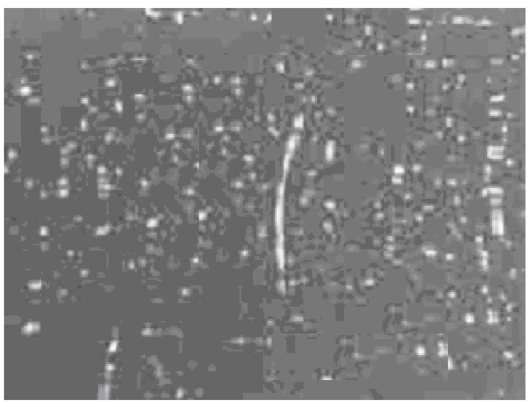

Fig.4 Binary image after image segmentation with gray level thresholding

Fig.5 Difference image of two images in same scenery

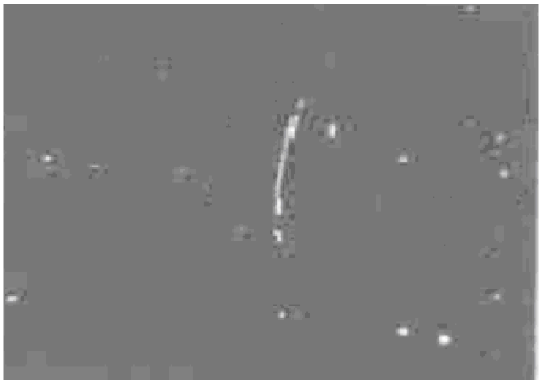

Fig.6 Image after region-dependent segmentation

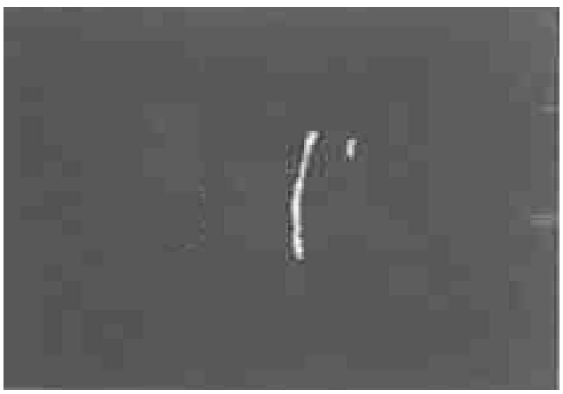

Fig.7 Result of defect identification

**Discussion:** From the images shown above we can see that after the gray image processed with monochromatizing method, the image of the magnetic particle indication only had be divided into two gray level, the white spots correspond to the defect and the black spots associate with the background. There are large numbers of small area consisting of white spot and some of them come from noises in the gray image. After process the binary image using difference image way, the influence of background noises has been eliminated greatly. The processing of region-dependent segmentation also remove some interfere spots which are not associated with the defect. When we processed the image with region-dependent segmentation, choosing an appropriate threshold value is the key problem of the algorithm. The threshold value choosing depends on large numbers of experiments. Form the Fig.7 we can conclude that the entire magnetic particle indication image processing is effective. In fact this image processing algorithm can also employ Neural-Network for the defect recognition [6]. It is another research task that we are going to develop.

**Conclusions:** The fluorescence magnetic particle flaw detecting system based on low light level CCD is described in this paper. This applied research study conducted in cooperation with an automobile accessory product manufacturing company has proved that the automatic flaw inspection and analysis system can directly contribute to achieving product quality improvements and reducing t he vision burden of workers . This is achieved through the efficient development and application of image techniques on the production line. By using this testing system, the beam shape, line shape and rotundity defect in the bent axle, radial axle or half rear axle of vehicles can be identified automatically. The experiment shows that the precision of fluorescence magnetic particle testing has been largely improved by using this system.

**References:**

1. Ness Stanley, Eugene Moss, Current concerns about optical radiation safety in fluorescent magnetic particle and penetrant methods, Materials Evaluation, 1996, 54(3) : 364- 367