

Automated Surface Defect Detection using Area Scan Camera

Somer M. Nacy^{1*} and Wisam T. Abbood²

1. Al-Khwarizmi College of Engineering, University of Baghdad, Baghdad, Iraq
2. Al-Khwarizmi College of Engineering, University of Baghdad, Baghdad, Iraq

*Email of the corresponding author: nacys2@asme.org

Abstract

This research comprises the design and fabrication of an automated surface defect detection system in which the defected part is automatically rejected. A special purpose rejection mechanism is designed in a manner to whether accept the defect free parts or reject the defected parts. The inspection vision system adopted in the design is an area scan camera, which works in conjunction with the MATLAB image acquisition tool. The control process is achieved via a PIC16F84A microcontroller, where it controls the image capturing and the defected part rejection mechanism. To validate the performance of this designed system, three types of plates were used, namely, defect free, punch defected and crack defected. Results showed that all the defected plates were rejected thus insuring the high efficiency of the system.

Keywords: area scan camera, inspection vision system, surface detection

1. Introduction

Due to the fast development in industry, traditional inspection methods are less considered or almost removed from production lines. Automated inspection technologies are widely used nowadays. These technologies are mainly dependent on vision system inspection, especially those used in surface defect detection. On-line quality control has many benefits, such as, early detection of defects, rapid feedback, reduced costs and finally reduced customer claims.

Many researchers have investigated the application of automated inspection systems in different industrial disciplines, such as, fabrics, Conci and Proenca (2002); float glass fabrication, Peng et al. (2008); solder joint segmentation, Mar et al. (2009); weld beads, Li et al. (2010); coatings in metal lids, Kamal and Adnan (2010); rotationally symmetric parts, Laurowski et al. (2011); transparent parts with non-plane surfaces, Martinez et al. (2012). Others worked on different applications, where Seulin et al. (2001), implemented a vision surface inspection system as a tool for design and optimization. A study on automatic thresholding techniques for defect detection was achieved by Ng (2006). Surface image synthesis through an area scan camera was conducted by Tabata et al. (2010).

The present work consists of a design for an automated surface defect detection using area scan camera. This system comprises three main subsystems, namely, the mechanical subsystem, including the conveyor belt and a special purpose rejection mechanism; the electrical subsystem, including motors, IR sensors, microcontroller and the host computer; and finally the software subsystem, in which programs were established to control the detection and rejection processes.

2. System Description

The basic idea in designing this system is to achieve an on-line inspection mode, making decisions of rejection for defected surfaces and acceptance for defect free surfaces without any waste of time. A schematic diagram of the system is presented in figure 1, showing all the dimensions adopted in fabrication. Figure 2 depicts two views of the system, showing all the fixtures, conveyor belt, motor drivers, area scan camera, IR sensors and the rejection mechanism which consists of a gate driven by a geared DC motor.

The duty of the IR1 sensor is to sense the arrival of the plate to be inspected thus allowing the camera to capture an image for the plate. While the IR2 sensor is to sense the arrival of the plate near the rejection gate, thus in case of rejection, i.e. the plate is defected; it activates the DC motor to open the gate. The microcontroller circuit diagram is shown in figure 3. It is of type PIC16F84A, which belongs to a class of 8-bit microcontroller of RISC architecture with program memory made in FLASH technology, which can be programmed and cleared for many times. Two main tasks are to be accomplished by the microcontroller, where it regulates the trigger pulses of the area scan camera and it controls the movement of the rejection gate.

3. Programs

Two main programs were implemented and used by the system. The first is the control program, written in assembly language as listed below,

```
LIST P=PIC16F84A
INCLUDE "P16F84A.INC"
__CONFIG _XT_OSC & _WDT_OFF

    GOTO MAIN
    DELAY
LOOP1 DECFSZ     COUNT1,1
      GOTO     LOOP1
      DECFSZ     COUNT2,1
      GOTO     LOOP1
      RETURN

TRIGGER

      BSF       PORTB,4
      CALL      DELAY
      CALL      DELAY
      BCF       PORTB,4
      RETURN

CHANGE

      BTFSC     PORTB,1
      GOTO     BB
      BSF       PORTB,2
      CALL      DELAY
      CALL      DELAY
      CALL      DELAY
      CALL      DELAY
      CALL      DELAY
      CALL      DELAY
      CALL      DELAY
      GG
      BTFSS     PORTB,1
      GOTO     GG
      BCF       PORTB,2
      RETURN

MAIN

      BSF       STATUS,5
      MOVLW     b'00001011'
      MOVWF     TRISB
      BCF       STATUS,5
      MOVLW     b'00000000'
      MOVWF     PORTB
AA      BTFSS     PORTB,3
      CALL      TRIGGER
      BTFSS     PORTB,0
      CALL      CHANGE
      GOTO     AA
      END
```

This program allows the microcontroller to receive inputs and transmits controlling outputs. It contains four subroutines. The DELAY subroutine produces the required delay time for the rejection gate after the plate passes IR2 sensor. The TRIGGER subroutine activates the area scan camera to capture an image. The CHANGE subroutine activates the DC motor of the rejection gate in case of a defected plate is passing. The MAIN subroutine is the previous subroutines.

The second program works under the MATLAB software, as listed below,
clc

```
daq=daqhwinfo('parallel');  
dio=digitalio('parallel', 'LPT1');  
addline(dio,0:7,0,'out');  
putvalue(dio.line(1),0);  
  
A = imread('A1.jpg');  
K = graythresh(A)  
E= imread('A2.jpg');  
F = graythresh(E)  
vid = videoinput('winvideo', 1, 'RGB24');  
src = getselectedsource(vid);  
vid.FramesPerTrigger = 1;  
preview(vid);  
vid.ReturnedColorspace = 'grayscale';  
for j=1:50  
clc  
F8 = waitforbuttonpress;  
close  
B = getsnapshot(vid);  
save B  
C = ('B.jpg');  
str = sprintf('%s',C);  
imwrite(B,str,'jpg');  
C = graythresh(B)  
if K==C;  
    msgbox('similar','OK');  
elseif F==C;  
    msgbox('similar','OK');  
else  
    dio=digitalio('parallel', 'LPT1');  
    addline(dio,0:7,0,'out');  
    putvalue(dio.line(1),1);  
  
    h=0;  
    for i=1:100  
        h=h+1;  
    end  
    dio=digitalio('parallel', 'LPT1');  
    addline(dio,0:7,0,'out');  
    putvalue(dio.line(1),0);  
end  
end
```

This program conducts two jobs, the first is to compare the image captured by the camera with a previously stored image of a defect free plate, while the second job is to analyze the light intensity of the captured image.

4. Experimentation and Procedure

The inspected products are rectangular Aluminum plates; each is 100 mm X 110 mm in dimension. These plates fall in one of three categories, defect free, notch defected and crack defected. The total number of plates inspected by this system is 1000, 350 of them are punch defected with different locations of the punch defect on the plate surface, 350 are crack defected with different crack locations and positions on the plate surface, while the rest 300 plates are defect free. A block diagram clarifying the procedure of the inspection process is presented in figure 4. When any plate passes on the IR1 sensor, a signal is generated as an input to the microcontroller, which in turn delivers a signal to the area scan camera, through the MATLAB program in the host computer, thus an image of the plate to be inspected is captured and returned back to the host computer. The MATLAB program analyzes the image, stores its light intensity data, compare it with a previously stored defect free image and makes a decision on whether this inspected plate is defected or not. If the decision is made as the

plate is defected, the host computer generates a signal to the microcontroller, which in turn takes an action after receiving a signal from the IR2 sensor, hence activating the DC motor of the rejection gate. While, if the decision is made as the plate is defect free, the inspected plate passes as an accepted one.

5. Results and Discussion

The results to be presented here are those obtained from the MATLAB program, concerning the light intensity of three selected samples representing a defect free plate, a plate with punch defect and a plate with crack defect. The MATLAB program used in this work was constructed in a way to convert the image captured by the area scan camera to a gray scale, hence to remove the noise and the contrast of colors that result from the analysis of white light.

Light intensity graphs for the three samples, defect free plate, plate with punch defect and plate with crack defect are shown in figures 5, 6 and 7, respectively. It is very clear that for the defect free plate, light intensity is more concentrated around the gray color, in the range between 100 and 200. While the light intensity spreads out of this range for the punch defected plate, reaching a range between 100 and 235, and as the defect becomes larger on the plate surface, as for the case of crack defected plate, light intensity spreads more, reaching a range of 90 to 250. Where any defect acts as a disturbing factor on the light intensity distribution, and as the defect takes more area on the plate surface, the disturbance becomes greater.

So, as for any defect happened to be on the surface of the plate, light intensity becomes more non-homogeneous and spreads more outside the gray color limits. On these bases the decision was taken on whether the plate is defected or not.

6. Conclusions

From the inspection tests conducted on all the 1000 plates, it was found that all the 700 defected plates were rejected. According to this result, it can be concluded that the method adopted, which relays on light intensity in its decision making, is an efficient and reliable method in distinguishing between defect free and surface defected plates.

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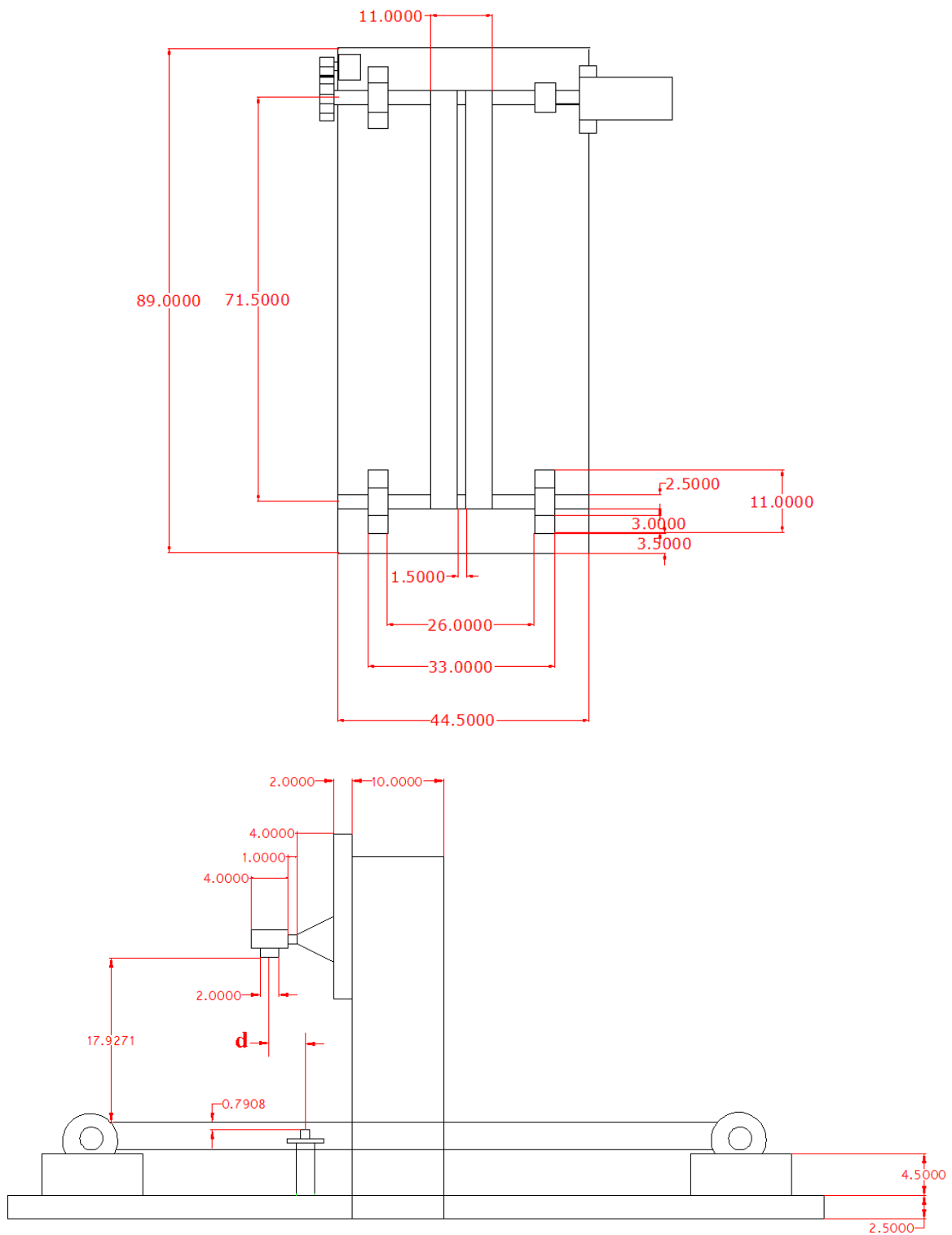


Figure 1. Schematic diagram of the inspection system
(All dimensions in cm)

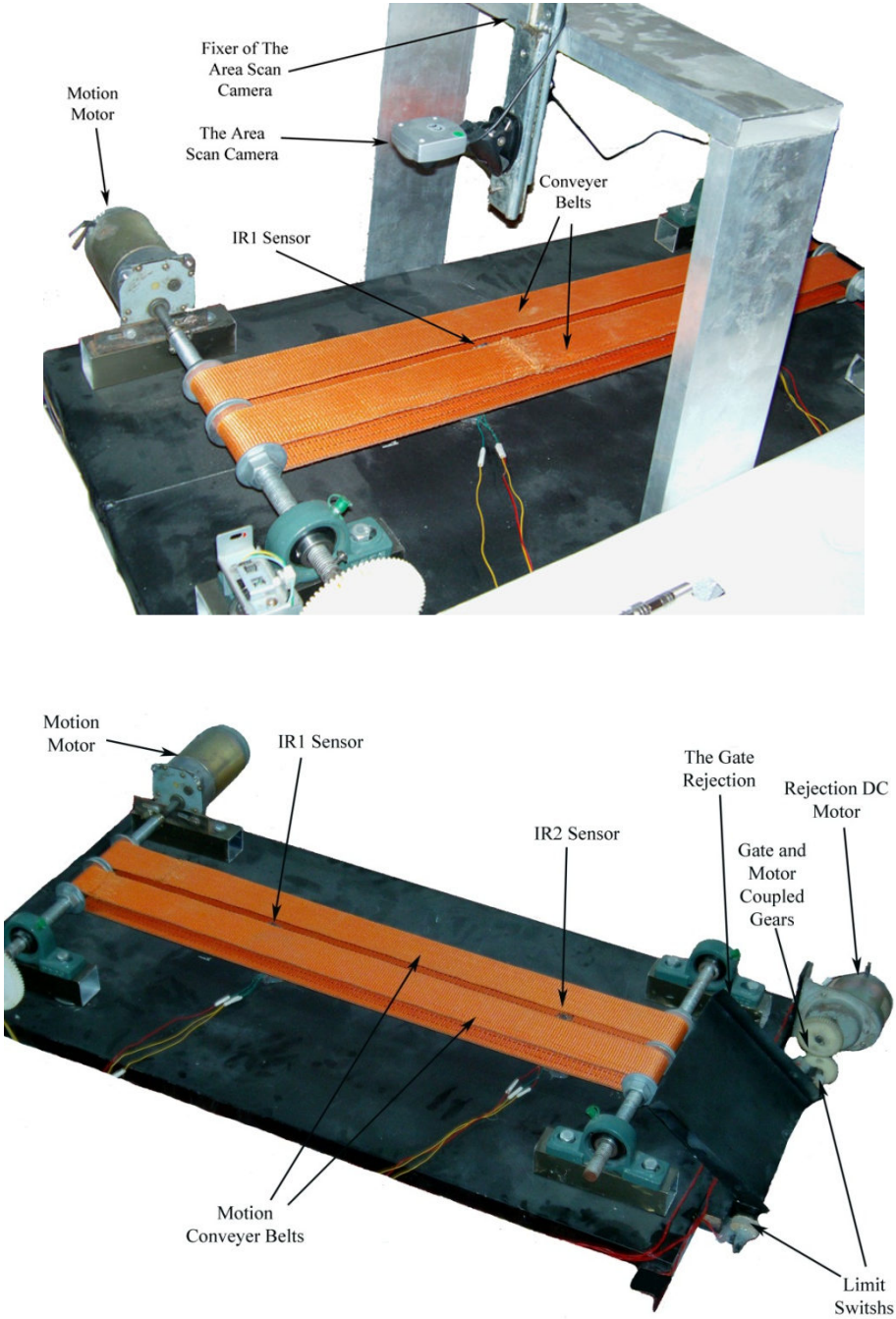


Figure 2. Details of the inspection system

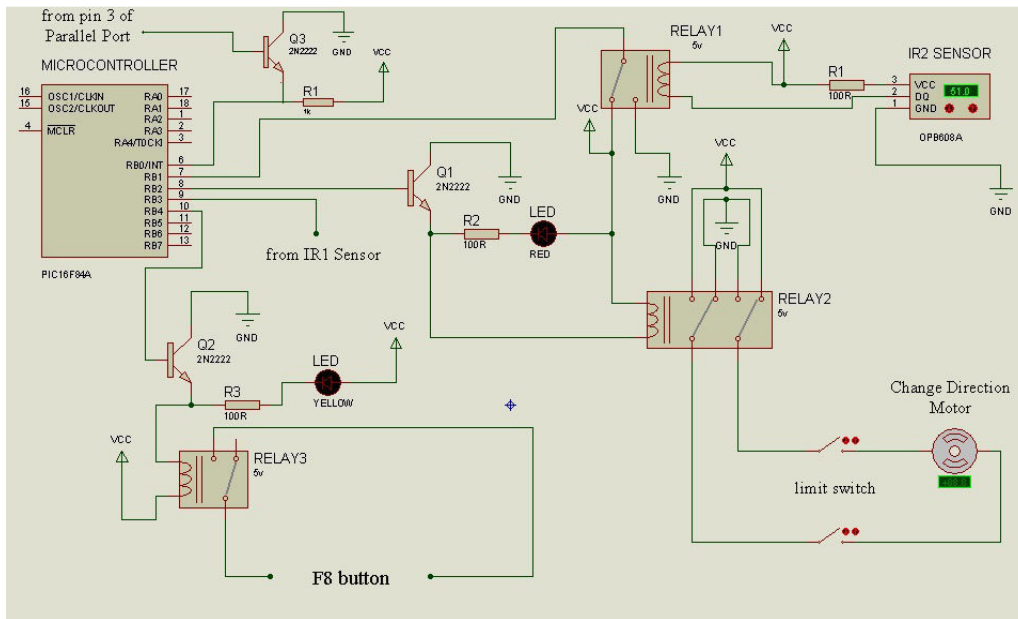


Figure 3. Microcontroller circuit diagram

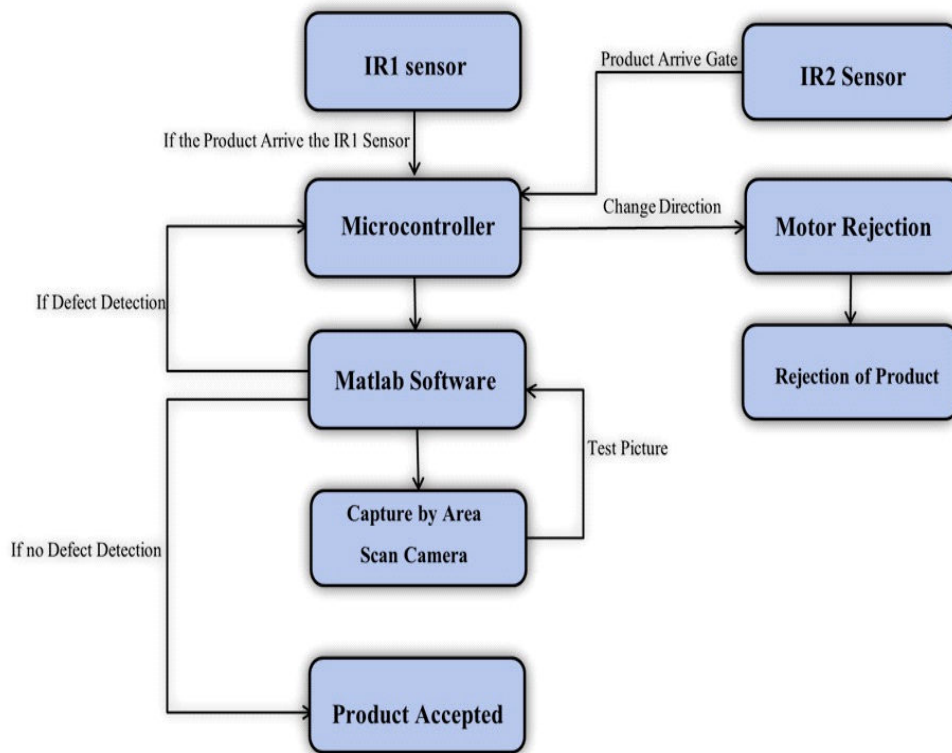


Figure 4. Block diagram of the inspection process

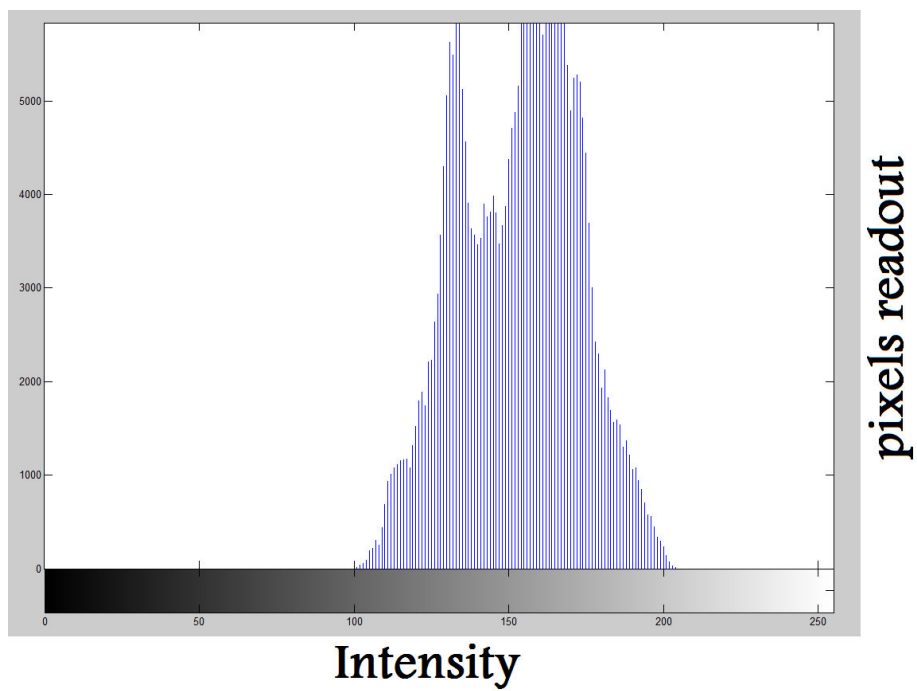


Figure 5. Defect free plate with its light intensity distribution

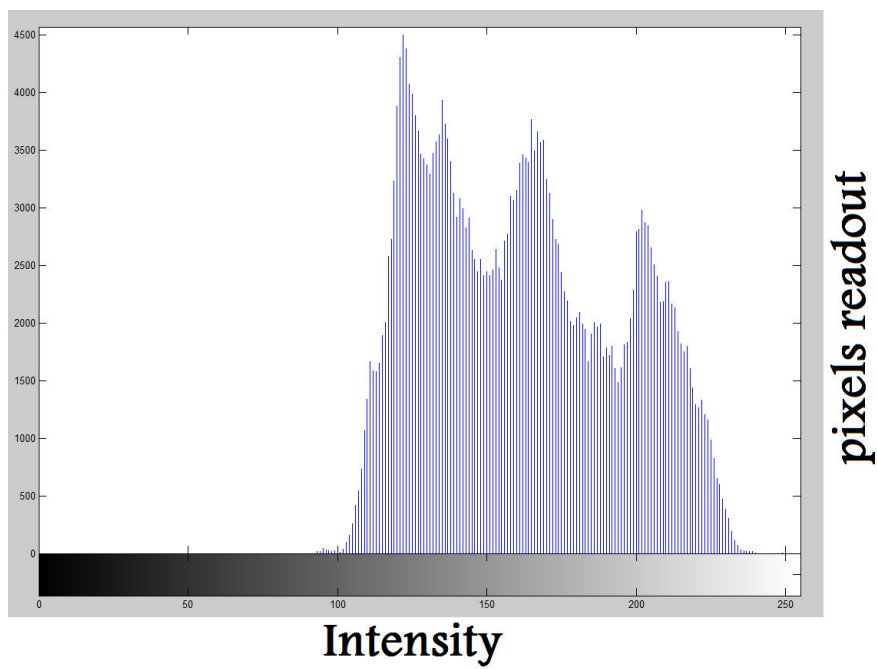


Figure 6. Punch defected with its light intensity distribution

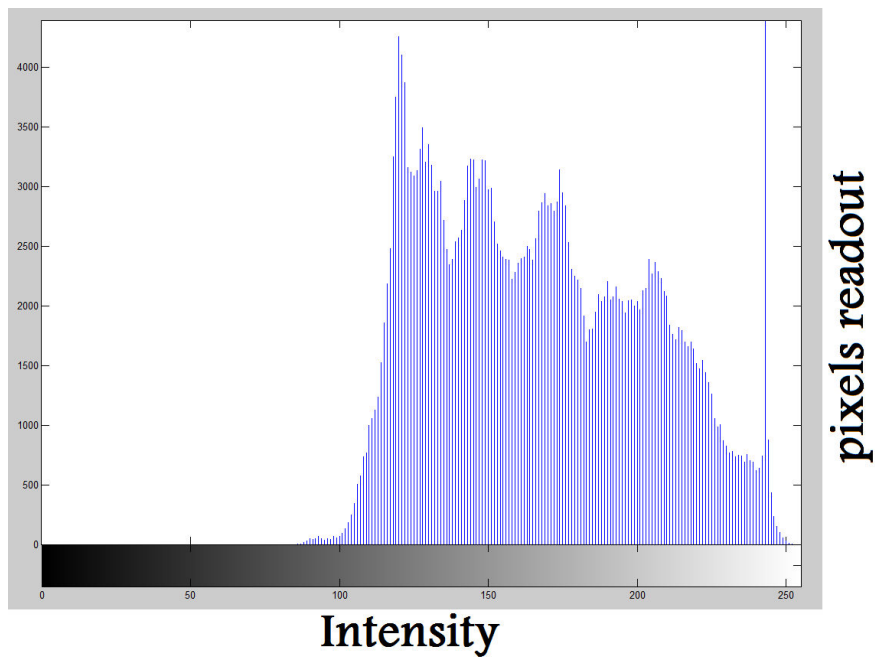
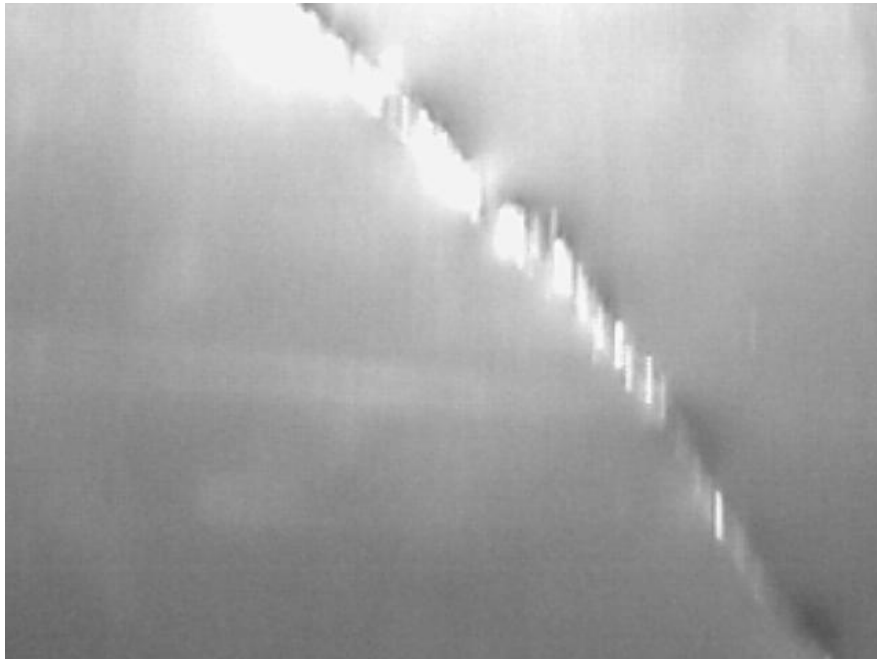


Figure 7. Crack defected plate with its light intensity distribution

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