DAMAGE INSPECTION OF COTTON MODULE COVER USING MACHINE VISION

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Abstract

Module covers are critical for protecting seed cotton modules from rainfall. Because of repeated use of module covers, an automated, accurate method of examining the moisture resistance of a cover is needed to determine if that cover can be safely reused. In this research, a prototype inspection system based on machine vision techniques is evaluated. Based on the hypothesis that the loss of moisture resistance is related to visual defects on the covers, a light transmission inspection system was constructed to count the number and size of pinholes on the cover. The quantified defect characteristics extracted from digital images of module cover sections were compared with measured water penetration rates. Regression modules were built to predict the moisture resistance of module covers. For film and vinyl coated module covers, this inspection system accurately evaluated the moisture resistance. But for woven, coated polyethylene covers, indirect paths that did not appear as pinholes caused the loss of moisture resistance. For that cover type, light transmission image inspection was not reliable.

Introduction

During the harvest season, seed cotton is stored outdoor in the form of cotton modules and protected from wind and rain by a module cover. During that storage period, the shape of modules and the quality of the cover may or may not prevent moisture penetration, impacting the quality and ginning rate of produced lint. Previous research (Simpson and Searcy, 2005) compared modules ginned before and after an extended period of rainfall, and found the total lint value per module for different conditions : (1) no significant difference for well built modules with a good cover, (2) -$409 for well built modules with poor covers, (3) -$208 for poorly built modules with a good cover, (4) -$652 for poorly built modules with a poor cover. Because the cost of a new module cover is only $65 to $120, it is false economy to use a worn cover. Unfortunately, predicting the moisture resistance of a cover is difficult and costly. Therefore, the development of reliable methods to determine the quality of used module covers becomes an important issue.

Currently, the method of quality inspection is to hold the cover open so that the workers can go underneath and look for light passing through the covers. However, the inspection process has not been standardized, and there will be unavoidable subjectivities and error with inspection done by workers. The light inspection method works well to identify larger holes and tears, but when only pinholes exist, the threshold for rejecting a cover is difficult to evaluate manually. Therefore, this research was focused on developing a repeatable, objective and accurate method to examine the moisture resistance of module covers.

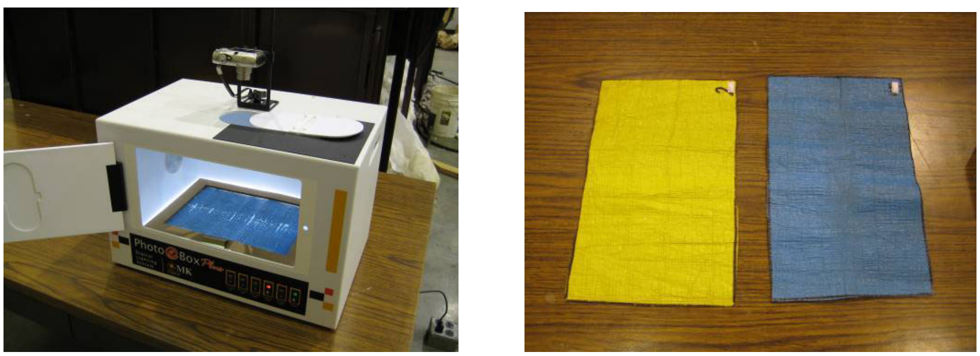
Materials and Methods

The research was initiated using the hypothesis that the amount of light passing through the cover material would be related to the rate of water penetration (similar to current manual inspection). The initial stage of the research utilized samples cut from new and used covers and evaluated in previous studies for the penetration rate of water under rainfall and ponding conditions. Those sample specimens were placed in a light box and still images were taken with backlighting to expose any existing pinholes. With the experiences and results of inspection on still images, a prototype real-time machine vision inspection machine was developed to inspect long strips of cover that were pulled beneath a video camera by a roller. In the both kinds of inspection, morphological characteristics of defects were extracted from the images, included the number of pinholes, total area of pinholes, largest pinhole's area and average area of pinholes. Those parameters were then compared with the actual moisture penetration rate for the cover specimen or sections of the longer cover strips.

For both still samples and moving module strips, the images were processed with the same algorithm to identify the defects. A program was developed with MATLAB® (MathWorks) to automatically identify the defects and extract the morphological parameters from the images. After the program obtained a color image, the first step was to convert the color image to a gray level image by selecting the most appropriate color band from the RGB bands. The program automatically selected the band which had the lowest over all intensity to make ensure the gray image had the highest contrast between undamaged region and pinholes. Following band selection, an automatic threshold selecting algorithm was applied to select the single threshold used to convert the gray level images uinto binary images. In this image, the pixels with values of 0 represented undamaged area on the cover and the pixels with values of 1 represented the pinholes or any damages on the cover. The morphological characteristics of those white spots on the binary image were than quantified and recorded by the software.

Inspection on still cover images

The apparatus for taking still images included a photo box (Photo *e*box II plus, MK DigitalDirect) with a uniform back lighting panel and a digital camera (PowerShot A75, Cannon). The size of cover samples was 17.5”×8” as shown in figure 1 (b). While taking images, the photo box was closed and the sample was put on the light panel which was the only light source.



(a) (b)

Figure 1. a) The set of photo box with mounted digital camera, b) cover samples cut from real module covers.

To test the water resistance of those cover samples, a “rainfall simulation” was applied on those samples. The test apparatus was constructed with a support surface which was set at 15° to the horizontal in order to make the simulation closer to the conditions on real cotton modules. An amount of 500 mL ± 10 mL of deionized water was poured into a funnel attached to a machined spray head. The water fell 24 inches to the sample which was mounted with a blotter paper backing. The blotter paper was pre- and post-weighed to determine the water amount that penetrated the sample.

Inspection on moving cover

To inspect large areas of a cover, a serials of images were taken instead of a single image. To simulate a system that would be compatible with inspection as a part of the operation of rolling up the module covers, the video camera was mounted above the strip of cover material to be inspected. The prototype inspection system was designed to inspect a 30 inch wide strip of cover which had been cut from module covers. This prototype allows us to simulate the situation of grabbing images while the object was moving and test the different setting of camera and lighting condition.

An industrial CCD video camera was used for image grabbing on this prototype to make the system had a higher adaptability to different imaging condition. The key features of the CCD are listed in table 1. With the full resolution, the dpi is 53.3 pixels/inch, therefore, theoretically, the diameter of smallest pinhole it can detect is 0.47mm. However, because of the over exposure at pinholes’ region, smaller pinholes are still detectable.

Table 1. Key features of the CCD camera.

Manufacturer	Imperx Incorporated
Model	IPX-2M30_L
Active Image Pixels	1600 x 1200, Mono or Color
Video Output	Digital, 8/10/12 bit
Frame Rate	33 fps
Shutter Speed	1/40000 sec to 1/15 sec

The inspection machine diagram is shown in figure 2. The strip of module cover is attached on the roller, which is driven by a DC motor. While the cover strip is pulled forward by the roller, the linear speed of the cover strip will be measured by an encoder. The encoder generated pulses when the cover moved a fixed distance and triggered the image capture of the cover, allowing a series of images from the whole length of the cover section that are adjusted for any variation in forward speed. The size of the sub-image is 300 x1600 pixels (figure 3). In the imaging region, the cover is back lit by a LED light panel, causing the pin holes and other defects to be displayed on the image as white spots. The grabbed images are immediately uploaded to a PC through the CameraLink® interface. During the time interval between grabbing images, the image processing algorithm analyzes the image, recognizes the pinholes and defects and records the necessary information. Figure 3 (a) shows one of the serial images of a cover strip, figure (b) shows the image of same region after image processing. After the entire cover section has gone through the inspection machine, the distribution of defects on the whole cover is known.

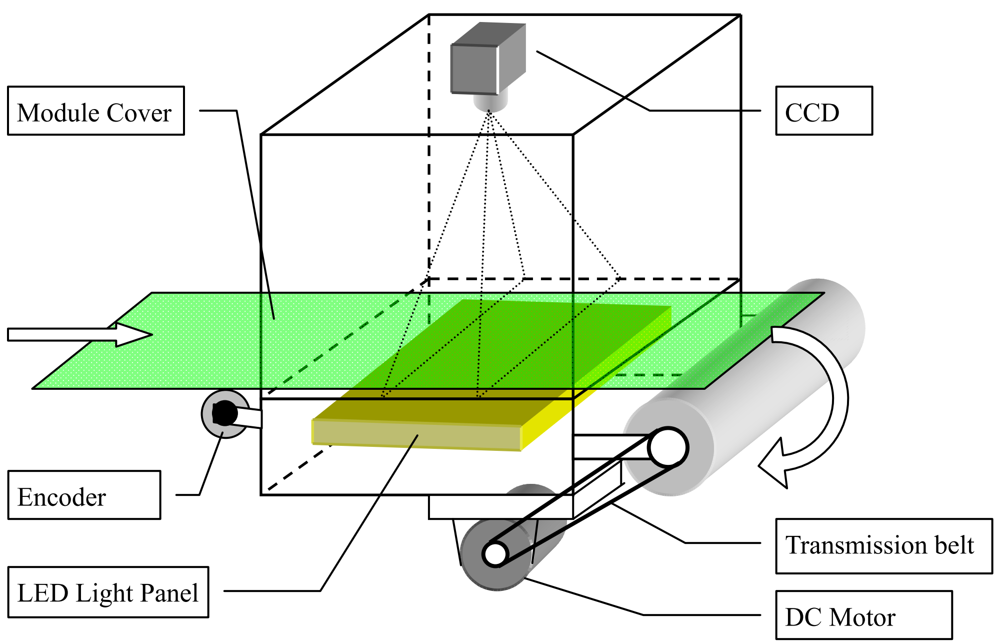


Figure 2. The diagram of the prototype of machine vision inspection system.

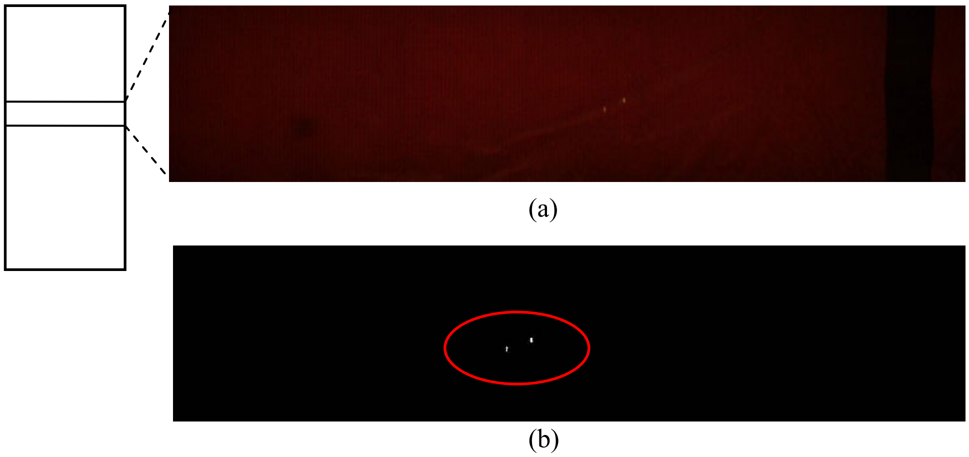
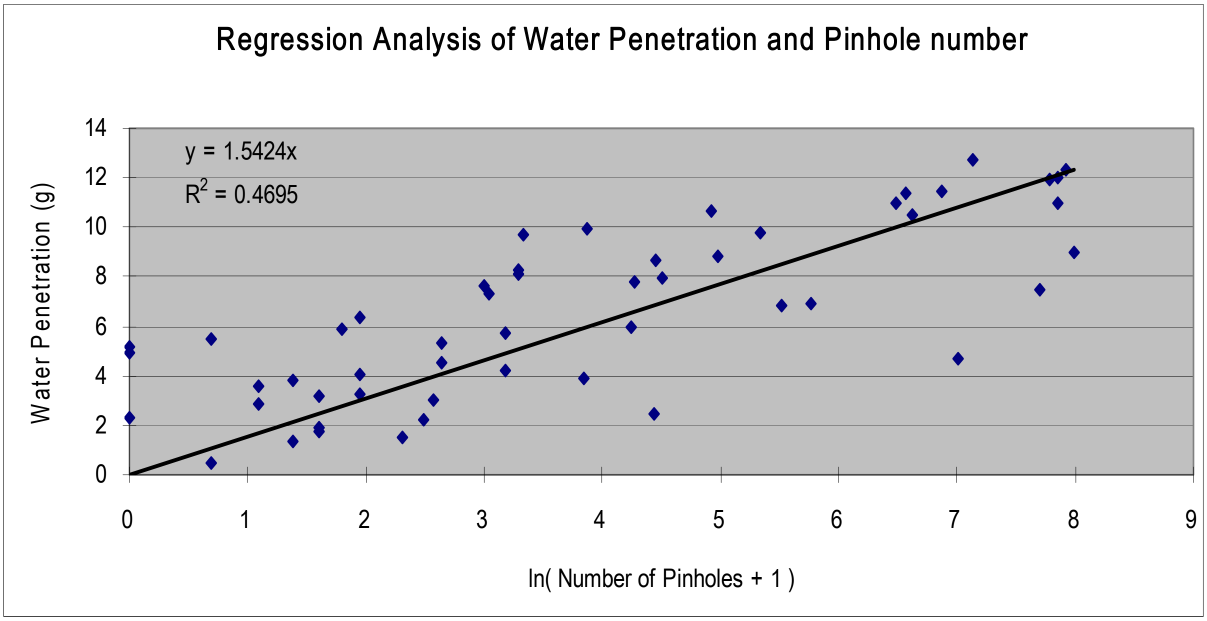


Figure 3. a) A sub-image taken from a strip of module cover, b) the result binary image after image processing; white spots represent the pinholes on the cover. The independent variables are the size

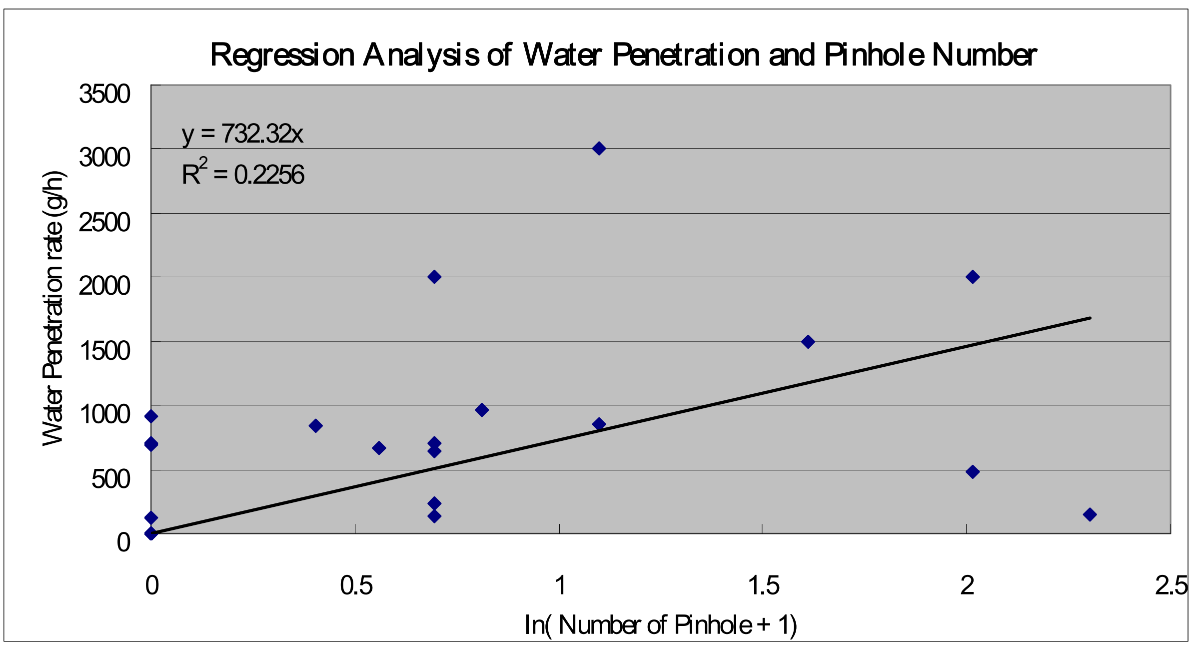
Unlike the cover specimen samples used with the still images, it was difficult to apply the "rainfall simulation" on a long strip of cover. Instead, a "bucket test" was applied on the strips. The cover strip was placed over a 0.3 m (1-foot) diameter bucket, pressed into the bucket mouth to form a depression, and filled with one liter of water. The setup was allowed to stand for one hour. The amount of water passing through the cover in a one-hour time period was recorded.

Results

The extracted morphological characteristics of defects on the cover images were compared throughlinear regression analysis with the water penetration test data. The independent variables were the number of pinholes, total area of pinholes, average and largest size of pinholes on each sample; the dependent variable was the water penetration obtained with the rainfall simulation or bucket test. After the multiple-regression test, the natural logarithm of the number of pinholes had the highest correlation with the water penetration in units of grams per test (the time to conduct a test was variable, so an accurate rate could not be computed). The independent variable used was adjusted to be ln(number of pinholes + 1) so that if no holes were found in an image that the independent data would still be a real number. In the bucket test for long strips of covers, the dependent variable was water penetration rate (grams per hour). The results and regression models are shown in figures 4a and 4b. The R^2 of regression modules are 0.47 for still images and 0.23 for moving strips.



a)



b)

Figure 4. The chart of water penetration vs. ln(pinholes + 1), a) results of still images of cover samples, b) results of images from moving cover strips.

Discussion

The goal of this project was to develop a method to evaluate the moisture resistance of module covers with a light transmission image inspection system. The results were not promising, with the R^2 between ln(number of pinholes + 1) and water penetration being 0.47 and 0.23 for still samples and moving strips respectively. The moderate association found in the still sample testcould have been, as the need is to determine when covers will fail to perform, rather than actually predicting penetration rates. However, for the results on moving strips (closer to the real condition when doing inspection on a full size module cover), the regression model is inadequate to determine the condition of cover strip. The problem is not just the low correlation, but the number of instances where there are large amounts of water penetrating with no pinholes present. While there were a few cover strips where the water penetration was less than expected based on identified pinholes, the great majority of the strips had higher penetration than expected, particularly when few pinholes were found, This frequent occurrence indicated that pathways for water penetration existed other than the direct path that would allow light to be detected as pinholes. Further investigation was required to explain this phenomenon, which has significant implication for the current inspection methods used in industry, as well as the attempt at automated inspection.

Considering the different situations of the two tests, for the still image samples, the rainfall simulation applied water to the whole region of the sample For the strip samples, only selected locations on the strip were sampled for the moisture penetration. Another fact is that while selecting and cutting the small samples from the cover was done manually on a light table, and may have resulted in a bias toward areas with more visible pinholes. Further examination has shown that the decay of the coating on the covers allows the water to circuitously penetrate through the space between the woven tapes of the cover fabric, but light can not go through.

The tested samples included different types, woven, film and vinyl covers. The cases where predicted water penetration was lower than the actual water penetrations usually happened on the woven covers, for the other two types of covers, the number of pinholes and water penetrations had a higher correlation. Figure 5 shows the images from a woven cover where 5(a) is a normal reflected light image in which the degraded cover layer can be seen , 5(b) is the cover with back lighting and 5(c) is the binary image after automatically threshold selecting. The coating was obviously decayed and peeled off; however, the back lit visual inspection showed no pinholes on the cover. This kind of situation happened on a portion of woven covers, but not all of them. Depends on the condition of the cover, some coating will be decayed and cracked while other regions are intact. Figure 6shows a cover section that with a high water penetration that does result in pinholes in the binary image. Under the back lit situation (figure 6(b)), some white spots can be seen in the grey level image. The greater agreement between predicted and actual water penetration suggests that for this type of covers, direct paths through pinholes are the major channels of water penetration instead of indirect paths between cracked coating and fibers.

Figure 5. a) A small region of a module cover, b) the same region with back light applied, c) binary image after automatically pinhole detection.

Figure 6. a) A small region of a module cover, b) the same region with back light applied, c) binary image after automatically pinhole detection (pinholes are present, although they may not be visible due to image resolution).

Conclusions

This research found that the light transmission image inspection method can accurately determined the moisture resistance of film and vinyl module covers, but was not reliable for woven, coated covers. For these covers, the condition of the moisture barrier coating affects the moisture resistance but this form of defect can not be examined by a light transmission image inspection system. A method of imaging that can determine the coating condition is needed in addition to or as a replacement for light transmission imaging.

For current module cover inspecting operation, visual inspection of covers for pinholes is not reliable as a sole determinant of cover quality. The coating condition should be also examined. Flaking or broken coating does suggest the loss of moisture resistance and would be a reason for discarding the cover, even without visible pinholes.

Acknowledgements

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