# Study of Scraping Guide Ways Inspection

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***Abstract*—Based on the image morphology technology and takes IEEE 1394 digital camera as the image catching tool, which is to be able to check the number of the actual contacts of each area on the box guide ways and the distribution uniformity of each area of machine. By setting from an experienced scraping technician as example, there should be around 16~24 points on the bearing surface per square inch which is considered as an acceptable level of its tolerance. The performance of tolerance of the box guide ways can be secured to ensure the precision requirement of machine. The evenly distributed lubrication on the surface of box guide ways can be assured to prolong the machine life of usage. This study can eliminate the disadvantage by the inspections with naked eyes of quality control inspectors. After practical tests, the contact points on the box guide ways can be firmly check, it will be a big amount of reduction of machine producing cost which is generated by lack of inspection by eyes and the repeat scraping job. The computerized inspection record will be great benefit for supporting after sales service**

***Index Terms*—scraping, guide ways inspection, image processing, machine tool**

## I. Introduction

The mass production of linear guide way effectively improved the production speed of traditional machines and the rapid speed of linear motion. Many machines guide ways perform high precision and low anti-resistance, while high rigidity is still required, such as bridge type grinding machine or gantry Milling machine, it can still be adopted by box guide ways. The main reason is that the linear guide way is unable to reach the thrust force and radius force, and its bearing capacity is still insufficient for large size machine. Thus, box guide way is still the main stream mechanical structure of heavy duty machine.

But the number of contacting points and surface finish acceptance of box guide way is still depends on the naked eyes of scraping technician to examine if the box guide ways are qualified, as shown in fig. 1. However, examining the contact point with naked eyes is a controversial way. To determine whether the contact points are evenly distributed and if the area of each contact point is made within the allowable range, which meets the requirements for the uniform forces exerted on the guide way surface, is a critical key factor to determine the precision and its life running time of machine. Unfortunately, inspections with naked eyes are kind of job which is time-consuming, and in general, many experienced technicians are gradually retiring while only a few people in young generation are willing to do machine scraping inspection. Although motorized scraping machines have been invented, but it is normally used on the last step for scraping only, and the guide way is still unable to be assured whether the precision of machine is qualified. There have been further researches for the theories, among which CAD/CAPP/CAM software technologies are introduced. Practically, considering the assembly after each component is completed; this design is a great advantage to meet the precision requirement and also convenient to consider the nature of scraping, improving the quality of machines [1-4]. However, it can't be assured that the life and duration of machine because the research neglected the importance of the contact point of box ways surface and the uniform lubrication. For the straightness of guide way of machine, Profile Matching Method is adopted for measurement. Despite it is helpful to the inspection of new machine and the compliance of tolerance [5,6], it is still unable to assure to maintain the precision of machine in the long term. Fundamentally, the basis is to precisely inspect the uniformity and control the area of each contact point of bearing surface. This is the most important issue, considering the quality of machine

Figure 1. Reagents on the surface of guide way

The image morphology is applied to extract the geometric features of binary images, such as noise treatment of image or intensification of object structure. The basic image morphology includes four functions as following: (1) Dilation is an algorithm in binary image to escalate or thicken objects. The way and degree of escalation are controlled by the shape of structuring element, usually it's used to fill small caves of objects or thicken lines. (2) Erosion is an algorithm in binary image which is used to shrink or thin objects. The way and


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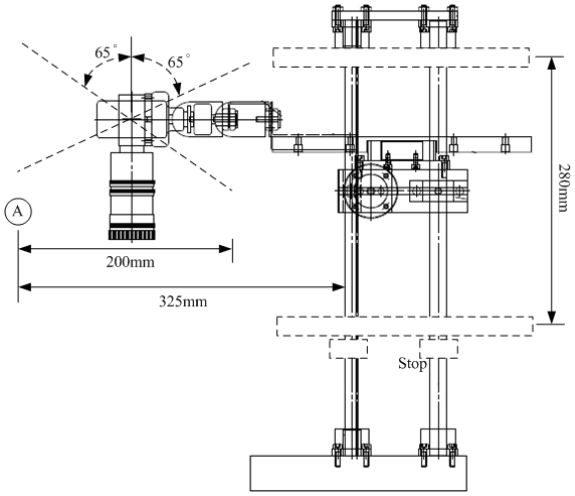
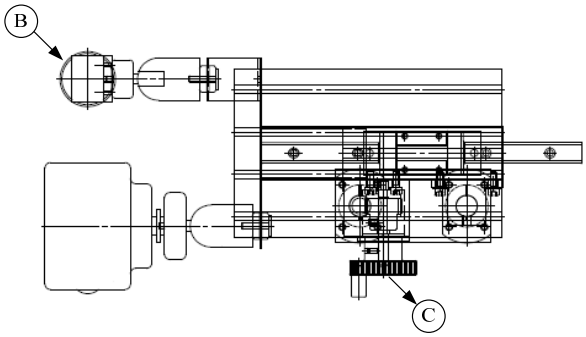
degree of shrink are also controlled by structure of physical object, usually it's used to clear noises or thin lines. (3) Morphological opening is to use erosion algorithm on image first, and then expansion algorithm is applied, usually it's used to eliminate small details in image to maintain most of the shapes of objects. (4) Morphological closing is to use expansion algorithm on image first, and then erosion algorithm, usually it's used to connect adjacent objects, fill seams, and smoothen the edges of objects [7-12].

The data in image segment for different objects is applied. There are four different common technologies for the segmentation of gray-scale image, The description as following: (a) Threshold-based segmentation which is to utilize the gray-scale statistical bar chart to figure out the suitable threshold values to segment objects from background [13-14]. (b) Boundary-based segmentation; it is to utilize the obvious variations of brightness in between object and background, which is to figure out the edges of objects [10]. (c) Region-based segmentation; it is to set the similar brightness in adjacent image with the same tag for segmentation [15]. (d) Hybrid segmentation; this is to combine all the above three methods for segmentation to achieve better segmentation. Among these, the watershed segmentation is representative [16].
Following ISO inspection standard for machine manufacturing industry, the contact point requirement of bearing surface is around 16-24 points evenly distributed in the area of one square inch. The inspection method is to apply reagents on the surface of guide way and move the scraped sliding elements back and forth on the surface which is scraped. Thus, the surface of the sliding element has obvious reagents, as shown in fig. 1, which is applicable for the quality controller to identify the number of bearing point and ensure it meets the requirement. Unlike the method with reagent that determined by naked eyes, this adopts CCD camera is to identify the sliding element, which is not applied with reagent. Though the calibration of image, it can convert the image coordinate system to the world coordinate system to further recognize the number, area, and uniformity of the bearing point within each square inch, which can be analyzed by computer.

This image analyst system is a PC-based structure, consisting of IEEE 1394 digital camera, video extraction card, and light regulator. The processes and analyses of image are completed done by LabVIEW and MATLAB of National Instrument. The transmission speed of IEEE 1394 digital camera is fast and precise, the maximum shooting speed is up to 400Mbit/s, and the parameters of camera can be adjusted by software, such as shutter speed, white balance, and gain values, etc. Figure 2 shows the mechanism drawings of the scraping guide ways inspection device. Figure 2(a) and 2(b) are the side view and top view of the scraping guide ways inspection device respectively. "B" is light regulator as shown in figure 2(b), which is used to adjust the reflective brightness on the scraped surface, it is to stabilize the algorithm for image processing. "C" is a hand wheel, which is to drive the gear rotation on the rack, so that the whole inspection platform can be moved upward and downward with a stroke distance for 280mm. Combined with the lens of range 8mm-48mm is applied, this device is able to catch the ranged view area from the farthest 500 cm2 to the nearest 230cm2. The turret design will be able to do angle adjustment for the camera and the light regulator for a range of ±65°. Even the 60°V shape guide way slope can be inspected. The linear guide way can be used to control the movement of inspection platform, both in back and forth with movable stroke for 200mm. "A" is the front edge in Figure 2(a), which meets the requirement that the inspection platform can easily move. The total movement is 325mm. This range meets most inspection requirements of guide way surface.




(a) side view




(b) top view

Figure 2. The prototype scraping inspection machine.

## II. IMAGE CALIBRATION

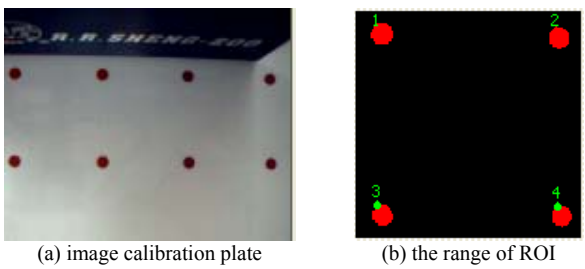
The realization of this work supposes the availability of a great number of repetitions of samples responding to the same known theoretical model. In practice, as the theoretical model is unknown, we use the Monte-Carlo method based on the generation of the data by computer according to a fixed theoretical model.

In the image plane, the unit seen used to represent the image element is in pixel. To realize the size in the image plane, it needs to calibrate images to convert the image coordinate system to the world coordinate system. In this

experiment, a calibration plate is distributed with points in various colors. The interval of each point is within one inch. Thus, every 4 points is circled one square inch. Figure 3(a) shows the image calibration plate. Figure 3(b) shows the range of figure 3(a) Region of Interest (ROI) and convert to HSI color space. This can easily extract red, which is more saturated. HSI color space illustration is shown as figure 4. HSI color space represents colors with Hue, Saturation, and Intensity. Hue indicates the wave length of the light reflected from object. Different wave lengths represent different colors. In HSI color space, Hue indicates the object color, such as $H = 0°$ represents red, $H = 120°$ represents green, $H = 240°$ represents blue. Saturation indicates the sharpness of color. When S=0, it is the location of center point. S value is closer to the point of center, the color is lighter, such as light blue, light red, light green, and so on. The closer to the edge, the color is darker, such as dark blue, dark red, dark green, and so on. Intensity indicates the relative shading in the grey-scale image. $I = 0$ represents as dark (black). $I = 1$ represents as bright (white).

Thus, the red points can be extracted as the higher saturated values which are reserved. This study selects the range of saturation within 200~255. The data of red points is shown as table 1. The mass center and the area of red point 1 are located at (17.2, 16.6) and 154 pixels respectively, red point 2 are located at (135, 17.2) and 149 pixels, red point 3 are located at (17.4, 135.5) and 152 pixels, red point 4 are located at (136.7, 136.1) and 150 pixels. As shown in table 1, even though the sizes of the four points are the same, the results obtained in the image plane are a little bit different. The reasons are as following; 1. The distortion caused by the camera itself, 2. The difference of saturation happened due to uneven lighting. The maximum difference of red point is 5 pixels, which is negligible since there is almost no influence. The distances of red points can be obtained from following equation. X=118.5, Y=118.9, each point is the length of the image plane in 1 inch. Thus, the region of interest (ROI) to check the scarping image is an area with 119 pixels long and 119 pixels width.

$$X = \frac{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} + \sqrt{(x_4 - x_3)^2 + (y_4 - y_3)^2}}{2}$$
$$Y = \frac{\sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2} + \sqrt{(x_4 - x_2)^2 + (y_4 - y_2)^2}}{2} \quad (1)$$




(a) image calibration plate (b) the range of ROI

Figure 3. Image calibration plate

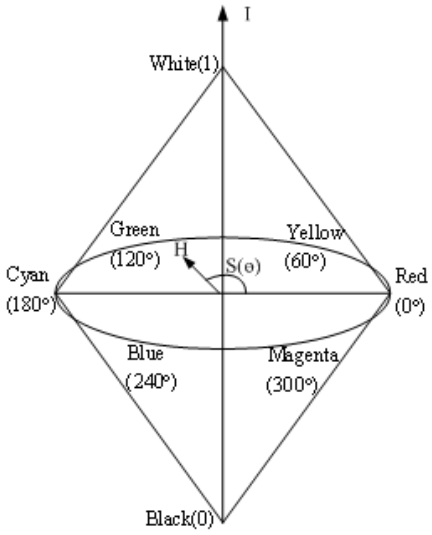



Figure 4. HSI color space

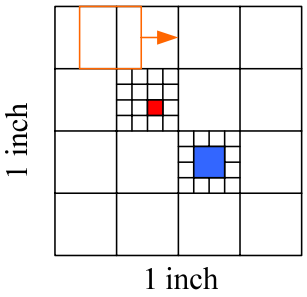



Figure 5. Scanning images method

TABLE1
IMAGE DATA OF CALIBRATION PLATE (UNIT: PIXEL)

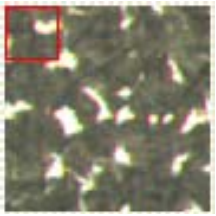
| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Center of Mass X | 17.2 | 135 | 17.4 | 136.7 |
| Center of Mass Y | 16.6 | 17.2 | 135.5 | 136.1 |
| Area | 154 | 149 | 152 | 150 |

## III. IMAGE ANALYSIS

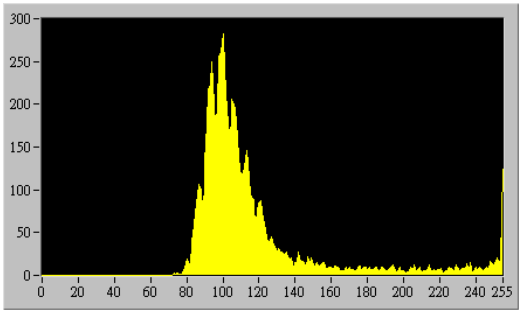
Through the image calibration, the size of one square inch can be obtained in the image plane, which is assigned as ROI of image, and the image in ROI is calculated if complying with the requirement of scraping. Several questions will be encountered when determined with images; such as (1) it is difficult to have identical size at crest, due to manually scraping these days; (2) In the area of each square inch, there are many incomplete

points around the edges. To solve the questions, the contact of 16 points in each square inch is set as standard. Therefore, 1/16 of 1 square inch is used as a mask for scanning images. Meanwhile, convolution algorithm is used with images. The size of the scraping crest should be larger than 1/16 and smaller than 1/4 of mask, as shown in Figure 5. If there is no crest found in the convolution algorithm, it is determined as disqualified. The disqualified area will be marked for reference.

This study uses threshold segmentation to segment the disqualified scraping area. Threshold segmentation is a method to find the suitable critical values through histogram. Figure 6(a) shows the original image of scraping, and the red frame is a scanning area with 1/16 square inch. The scanning procedure is started from left to right and from top to bottom. Figure 6(b) shows the histogram of the scraping image. The numbers of the brightness values with 100 are the maximum quantity in the image while the image for looking for the reflective surface in Figure 6(a) can be found, which shows that the brightness value is a little bit high.



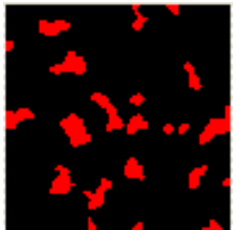
(a) original image



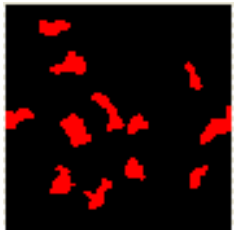

(b) histogram of scraping image

Figure 6. Image processing by histogram

Therefore, Threshold is set between 100 and 255. The binary image as shown in Figure 7(a) is obtained. Figure 7(a) shows the most crests that need scraping which can be segmented with Threshold segmentation. However, there are still some tiny noises that must be filtered out. And the effective crest size defined above, in the image of 119×119 images in this experiment, it is defined to be between the value of 55 and 221. Therefore, the crest which is not within this range will be deemed as noises and filtered out. Figure 7(b) shows the result that the noises are cleared



(a) threshold segmentation result



(b) noises removed result

Figure 7. Threshold segmentation result

Through the image processing procedures as mentioned in above, the crests in scraping image can be segmented. Next, the whole image is checked with the 1/16 square inch area which is set as described above. The method is to carry out convolution algorithm through this area with image. And the searched area where is disqualified will be marked as 1. Set the image of m×n as f, and mask T is value of matrix m×m = 1. The calculation of equation convolution can be given as following equation and the result is shown in Figure8(a).

$$f'(x,y)=\sum_{i=0}^{m-1}\sum_{j=0}^{m-1}T(i,j)f\left(x+i-\frac{m-1}{2},y+j-\frac{m-1}{2}\right)=T*f(x,y)$$

(x=0,1,…,M-1; y=0,1,…,N-1; i=0,1,…,m-1;j=0,1,…,m-1)

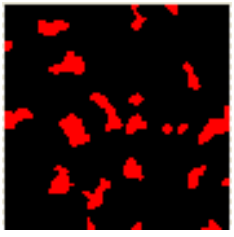
$$\begin{cases}T*f(x,y)\le 0, & f'(x,y)=1\\ T*f(x,y)>0, & f'(x,y)=0\end{cases} \quad (2)$$

The image $f'$ is a binary image. The position marked with "1", which represent the location that is determined by mask "T" as disqualified. The image $f'$ is convolution through morphology with another mask "G". All the disqualified area can be extracted as following equation. Figure8(b) shows the result of convolution. It can clearly confirm that the disqualified areas are located.

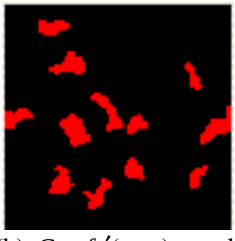
$$f''(x,y)=\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}G(i,j)f\left(x+i-\frac{n-1}{2},y+j-\frac{n-1}{2}\right)=G*f'(x,y)$$

(x=0,1,…,M-1; y=0,1,…,N-1; i=0,1,…,n-1;j=0,1,…,n-1)

$$\begin{cases}G*f'(x,y)\ge 1, & f''(x,y)=1\\ G*f'(x,y)<1, & f''(x,y)=0\end{cases} \quad (3)$$



((a) $T*f(x,y)$ result



(b) $G*f'(x,y)$ result

Figure 8. Convolution result

## IV. EXPERIMENT

Figure 9 shows the prototype of scraping guide ways inspection device. The design of the stand can be varied along with the range of movement where the inspected items are stored and different angles may be applied. The tripods with various lengths can be replaced. The fixture of camera can be adjusted upward or downward with travel distance 280mm, which is to obtain the best focus range. This fixture can be also moved forward or backward for a range of 200mm, which meet the request of purpose for wide range of inspection.

Figure 9. Prototype of scraping guide ways inspection device

Figure 10 shows the result of processing scraping image. To illustrate the fact of each shot, the detail is described as following:

(1) Figure10 (a1) is the first original scraping image. Through the image processing method as described above, first point can be found that the brightness is larger than 100 with Threshold segmentation. The results are shown in figure 10 (a2), there are 21 scraping points found. However, the sizes of the points are different. All the points are either too big or too small which is deemed to be ineffective crest. Thus, through the sieve of effective crests, Figure 10 (a3) is obtained. The effective crests are 10 points. The image is format with convolution algorithm with 1/16 square inch mask. The disqualified location will be marked as 1. The red part as shown in Figure 10(a4) those are all the marked locations. The image shows in Figure 10(a4) is format with convolution algorithm. The purpose is to spread the points marked as 1 to areas, as shown in figure 9(a5). Eventually, the disqualified areas are marked in figure 10(a3). The inspectors can find which one is the disqualified area, as shown in figure 10 (a6). From the results, there are a number of 10 points of scraping contact, which is not meet the requirement. As for the uniformity inspection, apparently, there are four areas disqualified.

(2) Figure10(b1) shows the second scraping original image. Through Threshold segmentation, 19 scraping points can be found. The result is as shown in Figure 10(b2). Through the procedure, the sieve of effective crest, Figure10(b3) is obtained. The effective crests are 13 points. Through twice of convolution algorithms, the disqualified locations are marked, and the points are spread to different areas, shown as Figure 10(b4) and figure 9(b5). Eventually, the disqualified areas are marked in 10(b3). The inspectors can find which one is the disqualified area. The result is shown as Figure 10(b6). It's confirmed that the number of scraping contact point is only 13 points, which is not meet the requirement. As for the uniformity inspection, it is obviously found that a large area is disqualified.

(3). Figure 10(c1) shows the third scraping original image. Through Threshold segmentation, 24 scraping points can be found, among which 12 points are effective crests. And the results as shown in Figure 10(c6), the number of scraping contact point is only 12 points, which does not meet the requirement, too. As for the uniformity inspection, it is obviously found that 3 large areas are disqualified.

(4). Figure 10(d1) shows the fourth scraping original image. Through Threshold segmentation, 19 scraping points are found, among which there are 14 points which is effective crests. From the result as shown in Figure 10(d6), the number of scraping contact point is 14 points, which does not meet the requirement. As for the uniformity inspection, it is obviously found that an area is disqualified.

(5). Figure 10(e1) shows the fifth scraping original image. Through Threshold segmentation, 16 scraping points are found, among which there are 10 points which is effective crests. From the result in Figure 10(e6), the number of scraping contact point is 10 points, which does not meet the requirement. As for the uniformity inspection, it is obviously found that 3 areas are disqualified.

From the results as mentioned above, it's realized that all disqualified numbers of bearing points and the areas can be clearly found. This is also verified the methods for image processing adopted in this research have excellent effects. Figure 11 shows the human machine interface. The image on the left is the original image caught by camera. The red frame in the photo is the scanning area of 1/16 square inch. Through the image processing methods as described above, the image on the right is obtained. When the area of disqualified block is 0, and the number of effective contact point is between 16~24, it is determined as qualified, and the OK indicator will be lit up. On the contrary, if one of the conditions does not meet, it is determined as disqualified, and NG indicator will be lit up. Through the information of coordinate and area, the locations and the sizes of all points can be found. The smallest one is at point (11.68, 7.24) with area of 2.56 $mm^2$; the largest one is at point (17.84, 7.87) with area of 6.14 $mm^2$. As shown in Figure 11, which shows the analysis result of Figure10(e6). This research takes the inspection item as an example to input LabView system for analysis. From the analysis report, it can be found that the area of disqualified block is 297.392 $mm^2$, and the effective contact points are only 10 points, which does not meet the standard. Thus, the result is determined

as NG. Figure 11 shows that X and Y mark the coordinate location of the inspected point respectively. The area of the inspected point is calculated by computer. Meanwhile, the qualification can be determined by checking if this area is larger than the set area.

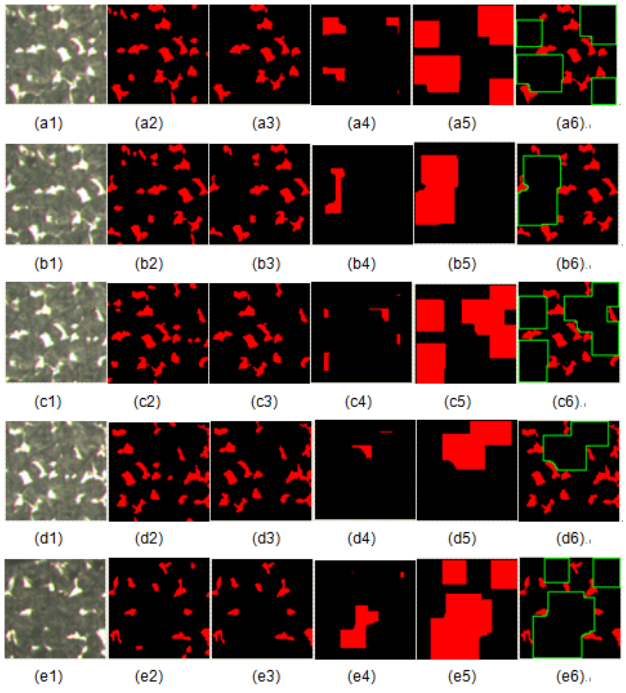



Figure 10. Result of processing scraping image

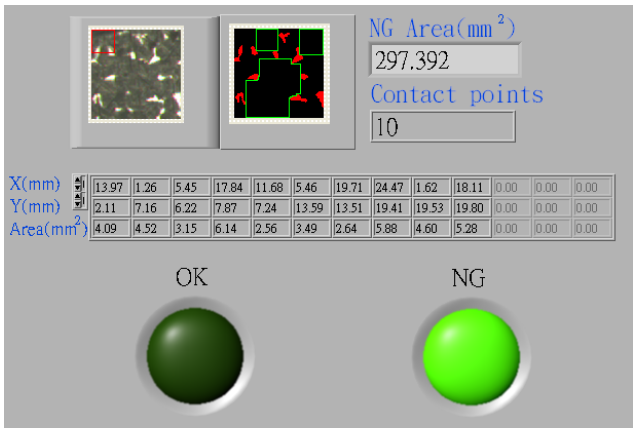



Figure 11. LabView system analysis report

## V. Conclusion

The scraping guide ways inspection device can accurately inspect the contact points of the guide way of machine, as concluded as the following:

The study can accurately inspect the contact points of the sliding surface on the guide ways with optical methods to ensure the precision and quantity of contact point of guide way.

The digitized inspection data are obtained. In addition to the number of contact points and the uniformity, the area of each point can be calculated to eliminate the possible errors by determinations with naked eyes.

The eyes inspection mistakes can be avoided and prevent the time wasting from the assembly of machine, which is to be dismantled to improve the production margin.

## Acknowledgment

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From 1977-1979, he was serving in his family company, there are mainly in producing metal cutting machines, including Turning machine and Planning Mills. He then found his own company in 1980, as a trading house and specally in marketing CNC metal working machines, and to increase the quality and service, he decided to start the production plant of CNC metal turning machines and CNC machining centers in 1996, main markets are N.A and European market, very successfully introduce his own brand into this market. He is now only the shareholder of his company, no more running the business daily basis.