TFT-LCD-G6 Screening Test and Optimization of Vibration Separator in Glass Substrate Production Line

Ping WEI
Anhui Technical College of Mechanical and Electrical Engineering, Wuhu, China

Keywords: Screening capacity, Vibration analysis, Glass quality.

Abstract. This paper mainly expounds the experimental conditions of TFT-LCD-G6 generation glass substrate equipment, and solves the problem of screening ability analysis and optimization by field debugging. Vibration analysis of floor slab with 5.5 meters elevation caused by the operation of vibration screening machine in different installation modes of equipment reduces the influence on the weighing accuracy of small materials in the batching system, and solves the major hidden danger of the proportion of raw materials in actual production and the problem of affecting the quality of finished glass.

Preface

In the TFT-LCD-G6 generation glass substrate industry, the mixture ratio is the source of glass substrate production. The so-called mixture is made by mixing alumina, boron oxide, barium nitrate, strontium nitrate and other raw materials and broken glass (particle size less than 0.3mm) with mixer. Among them, the glass crushing with a mass ratio of 30% in the mixture acts as flux, which can make the raw materials melt rapidly in glass furnace, so as to achieve the purpose of energy saving, consumption reduction, homogenization and clarification of glass liquid. It can be seen from this that the broken glass meeting the specifications and sizes plays an important role in the production of mixtures and glass.

Composition of Batching System

The batching system is divided into main batching system and broken glass system. 1) Operation flow of main batching system: input raw materials and broken glass into raw material silos and broken glass silos and weigh them accurately, convey them to mixer through screw feeder, mix and mix raw materials evenly, and transport them to kiln for use; 2) Operation flow of broken glass system: according to the size required by customers, meet the quality requirements. Fine glass, corner material and waste glass produced after horizontal and vertical cutting are crushed by hammer crusher and transported by bucket elevator or belt conveyor to vibration screening machine to screen out broken glass whose particle size meets the requirements (particle size is less than 0.3mm) and put into the main batching process; broken glass whose particle size is more than 0.3mm is put into the main batching process. Glass transport back to the crusher continues to break.

Installation and Debugging of Vibration Screening Machine

Glass crushing plays an important role in the G6 generation glass substrate industry. Continuous batch screening of glass crushing can meet production requirements, particle size is a certain amount. The installation, commissioning and normal operation of vibration screening machine is extremely important. At present, there are two ways to install vibration screening machine: one is that the vibration screening machine is installed on the platform composed of I-beam steel on the first floor (elevation 1.5 meters); the other is that the vibration screening machine is installed on the second floor (elevation 5.5 meters). The above two installation modes are determined by different glass breaking process and glass breaking conveyor.
Effectiveness

Vibration intensity of floor is detected by vibration detector when the frequency of vibration motor of vibration screen is 50 Hz, 48 Hz, 46 Hz, 44 Hz, 42 Hz and 40 Hz. The measured data are shown in Table 1.

Table 1. Data measurement table.

<table>
<thead>
<tr>
<th>Frequency (HZ)</th>
<th>Distance from the center of the screen</th>
<th>Screening machine position along load-bearing beam distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.2m 1m 2m 5m</td>
<td>0.5m 1m 2m 5m</td>
</tr>
<tr>
<td>50</td>
<td>5.8 5.6 4.8 1.1</td>
<td>4.5 4 3.3 0.9</td>
</tr>
<tr>
<td>48</td>
<td>4.5 4 3.4 0.7</td>
<td>3.2 2.9 2.4 0.6</td>
</tr>
<tr>
<td>46</td>
<td>2.4 2.2 1.7 0.4</td>
<td>1.8 1.6 1.2 0.4</td>
</tr>
<tr>
<td>44</td>
<td>1.7 1.5 1.3 0.3</td>
<td>1.3 1.2 1 0.2</td>
</tr>
<tr>
<td>42</td>
<td>1.2 1.2 1 0.3</td>
<td>1 0.9 0.8 0.2</td>
</tr>
<tr>
<td>40</td>
<td>0.9 0.8 0.7 0.1</td>
<td>0.7 0.7 0.6 0.1</td>
</tr>
</tbody>
</table>

The vibration detection and evaluation criteria are based on ISO2372 machine vibration classification table 2, and the relationship curve between floor vibration intensity and frequency of vibration motor. As shown in Figure 1:

Table 2. ISO2372 Machine Vibration Classification Table

<table>
<thead>
<tr>
<th>Vibrational Intensity</th>
<th>0.28 0.45 0.71 1.12 1.8 2.8 4.5 7.1 11.2 18 28 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>good good good Satisfied Satisfied Dissatisfied Dissatisfied Not allow Not allow Not allow Not allow</td>
</tr>
<tr>
<td>II</td>
<td>good good good good Satisfied Satisfied Dissatisfied Dissatisfied Not allow Not allow Not allow Not allow</td>
</tr>
<tr>
<td>III</td>
<td>good good good good Dissatisfied Satisfied Dissatisfied Dissatisfied Not allow Not allow Not allow Not allow</td>
</tr>
<tr>
<td>IV</td>
<td>good good good good good Satisfied Satisfied Dissatisfied Dissatisfied Dissatisfied Not allow Not allow Not allow</td>
</tr>
</tbody>
</table>

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Figure 1. Relation curve between vibration intensity and frequency of vibration motor.

Summary

Through the summary table of measured data and the curve table of the relationship between the floor vibration intensity and the frequency of vibration motor, it can be seen that the floor vibration intensity decreases from 1.7mm/s to 0.2mm/s along the center of the vibration screen to the load-bearing beam when the vibration motor frequency is 44HZ under the premise of meeting the production demand. Check the vibration detection and evaluation of standard medium machine, vibration intensity is less than 1.8mm/s, which belongs to the good.

Through the above experimental measures, not only safety problems to solve the vibration of floor extension to run the vibration screen caused by the security risks to a minimum, but also eliminates the vibration sieving machine operation accurate weighing batching system to shake the floor no problem.

Reference


Development of a Four-axis Laser Measuring System for Turbine Blade Profile

Yun-yong CHENG¹,*, Wen-guang YE¹, Jun-jie LI¹ and Kai TANG²

¹School of Mechanical Engineering, Northwestern Polytechnical University, Xi’an, Shaanxi, China 710072
²School of Mechanical Engineering, Hong Kong University of Science and Technology, Hong Kong

*Corresponding author

Keywords: Turbine blade profile, Laser measurement, Sensor calibration, Point cloud stitching.

Abstract. Aiming at the acquirement of the turbine blade profile data with both high accuracy and efficiency, a non-contact measuring system based on line-laser displacement sensor and four-axis numerical-control platform has been developed. This article mainly describes the presented solution of the calibration of the laser axis and the rotation axis. With this solution, a measurement data merging algorithm was designed and applied to generate the blade profile from a set of multi-view point clouds. At the end of the article, an experiment was performed to verify the efficiency and accuracy of the system.

Introduction

The shape of the turbine blade surface has a decisive influence on the performance of the aero engine. As a key part of the aero engine, the turbine blade must have a high level of shape accuracy and surface integrity to meet the requirements of safety and high-performance of the aero engine. Therefore, an accurate detection and evaluation of the blade surface become an important guarantee to the manufacturing quality of the turbine blade¹², while the traditional ways such as template profile method, automatic draw-curve method and electric sense method has been unable to handle the issue³.

Currently the CMM is the most widely used method of measuring the turbine blade⁴, which provides a quite high level of accuracy. However, a theoretic CAD model is needed to conduct a strict measuring trace planning to make a correct compensation for the probe radius⁵. That process will take a lot of time and still cannot solve the problem of the compensation on the high-curvature surface. The laser measuring can quickly acquire high-density point cloud data, which can solve the problems with both high quality and efficiency⁶⁷.

Description of System

As show in figure.1, this system consists of two parts: the four-axis numerical-control mobile platform and the line-laser displacement sensor. The returned data from the grating ruler of the mobile platform is used to build a universally environmental coordinate system and to transform the point data in the coordinate system of the sensor into the environmental coordinate system. Then using the feature of the sensor’s data, accurate calibrations of the sensor coordinate system and the rotation axis of the environmental coordinate system will be executed with the software.
(1) The working principle of the system

The laser displacement sensor in the system utilizes the optical triangulation method and can get 625 points data at once when the corresponding function is called. Though the accuracy of a single point is 10-20μm, lower than the CMM method, the rebuilt surface still can be made precise through a right construction method. The best working distance of the sensor is within X(-12.5mm, 12.5mm) and Z(90mm, 115mm).

As show in figure 2, there are two coordinate systems-the sensor coordinate system (Cs)(Xs, Zs), and the environmental coordinate system (Ce)(Xe, Ye, Ze, Ae), in which the Ce data comes from the grating ruler of the mobile platform. The basic process of data acquirement is as follow:

- Calibrate the position and direction of the Cs in the Ce using a specially designed measuring process which can figure out the pose deviation of the system precisely;
- Figure out the position and the direction of the rotating axis A in the Ce.
- Execute a multi-view measurement of the part on the rotating platform. And with the calibration result, the data will be transformed from the 2D data in the Cs to the absolute 3D data in the Ce.
- Joint the multi-view data point clouds into a single-view data point cloud with the calibration results of the rotating axis A and the value of current angle returned by the grating ruler.

(2) Methods of the system

i. The calibration of the pose deviation of the Cs in the Ce

Given the fact that the assemblage between the sensor and the mobile platform is designed to be easily disassembled and that even the smallest deviation during the assembling can cause an obvious error in the process of jointing. So the calibration of the Cs in the Ce is critical to the final accuracy of the system.

The measuring coordinate system of the sensor is a 2D system with axes of X and Z. For the convenience of the data transforming between the Cs and the Ce, the vectors of the axes in the Cs must be perpendicular to the corresponding axes in the Ce. The assemblage of the sensor depends on the fitting between 2 planes of the platform and sensor only, so it can be assumed that the majority of the assembly error comes from the level deviation of the main laser direction (Z axis), which becomes the target parameter of this calibration process.

An iterative triangulation method is developed to figure out the deviation of the main laser direction, which is as shown in the following figure:
A. Initial condition: double $\Psi_0 = \pi/2$

B. Measure the current line profile and correct it with $\Psi$

C. find the intersection between the optical axis and the line

D. move backward by the distance of a along X axis

E. figure out $\Psi$ based on the geometric relationships in this chart

Meet the accuracy requirement

Save and exit

Suppose $\Psi = \Psi$

Yes

Yes

Figure 3. Iterative triangulation method for the calibration of the laser axis.

This method using simple triangulation method, can figure out the angle deviation precisely after multiple iterative processes. And the result will be used in the next step of data transformation between two coordinate systems.

ii. The calibration of the rotating axis A and the jointing of multi-view data

To achieve the reconstruction of the point cloud, this system adopts a multi-view data rotating jointing method based on the angle data returned by the mobile platform.

This system utilizes the method of measuring a master ball in different angle of the rotating platform and acquiring the sphere centers using least square fitting method, and with the position data of the centers figures out the direction vector of the rotating axis and the center of the rotation system.

In addition, in the optical measurement of the smooth surface, the reflection of the surface has a vital and negative effect on the imaging of the profile, causing the outlier points, which is almost inevitable for the parts with high complexity. Those outlier points can gather and form a dense cluster attach to the real surface of the part and some of those clusters can be fitted to be smooth curve. In the calibration process of the rotating axis, it will lead to an erroneous fitting result and cause huge deviation in the jointing process. This system solved the outlier problem in the calibration process through the iterative least square fitting method, which is, after each fitting process, the points with a deviation higher than the threshold will be deleted, afterwards new fitting process will be conducted on and on until no point has to be removed.

After the acquisition of calibration result, the multi-view measurement of the part can be processed. With the angle of each view and the parameters of the rotating axis, the jointing process begins. And the expression is as below:

$$M'_i = M_i$$

$$\begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
-X & -Y & -Z & 1
\end{bmatrix}$$

$$\begin{bmatrix}
x^2(1 - c) + c \\
x y(1 - c) - z s \\
x z(1 - c) + y s \\
0 \\
0 \\
0 \\
0 \\
1
\end{bmatrix}$$

$$\begin{bmatrix}
x y(1 - c) + z s \\
(1 - c) + x s \\
y z(1 - c) + c \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}$$

After jointing the data of each view, a restored point cloud is generated.
Error Analysis

Except for the error of the laser displacement sensor itself, there are several other sources of the error: the error of the mobile platform, including the deviation of the direction of the axes, the verticality and the vibration of the axes; the error during the calibration of the Cs in the Ce, including the non-level deviation of the laser axis; the error during the jointing, including the deviation during the calibration process of the rotating axis and the error of the value of angle returned by the rotating platform; and the specular reflection of the surface under certain inspecting angle also leads to emerge of the false measurement. Aiming at those sources of error, improvement can be made on the moving system and the extraction and the removing of the outlier points.

Experiment and Conclusion

Since the CMM can be more precise in the single point acquisition, it can be a relatively reliable reference to the result of the laser measuring system.

A turbine blade is measured with this system and the CMM method separately to verify the validity and accuracy of the laser measuring system. The results of the two methods is respectively shown in the figure.4 (a) and figure.4 (b). The data then is imported to UG and used to conduct a spline fitting. With the curve sections, we utilize the deviation detection module in UG to conduct analysis of the accuracy.

![Figure 4. Comparison of results from different measurement methods.](image)

The result of analysis is shown in the table below:

<table>
<thead>
<tr>
<th>Number of points</th>
<th>Number of points</th>
<th>%</th>
<th>Histogram of the deviation distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>≥Min [μm]</code></td>
<td><code>&lt;Max [μm]</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-25</td>
<td>-20</td>
<td>21</td>
<td>1.12%</td>
</tr>
<tr>
<td>-20</td>
<td>-15</td>
<td>35</td>
<td>1.87%</td>
</tr>
<tr>
<td>-15</td>
<td>-10</td>
<td>62</td>
<td>3.31%</td>
</tr>
<tr>
<td>-10</td>
<td>-5</td>
<td>297</td>
<td>15.84%</td>
</tr>
<tr>
<td>-5</td>
<td>5</td>
<td>400</td>
<td>21.33%</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>508</td>
<td>27.09%</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>328</td>
<td>17.49%</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
<td>114</td>
<td>6.08%</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
<td>70</td>
<td>3.73%</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
<td>40</td>
<td>2.13%</td>
</tr>
</tbody>
</table>

This table indicates that 81% of the deviations are restricted within 10μm and 96% within 20μm when taking the CMM data as reference. It proves both the high accuracy in a large scale of the measurement and the efficiency of the system.

According to the result, the efficient measurement and fast jointing of the point cloud data has been achieved with high accuracy. But during the measuring process, there still are many outlier points caused by the specular reflection in certain inspecting direction. These points can form a smooth curve attach to the surface of the part called non-isolated outlier points and be hard to recognize and remove. The next improvement should solve this problem with the method of majority voting detection of the outlier points, which divides the point cloud into regular point clusters and irregular point clusters, and isolates the non-isolated point clusters through a vote among the regular points.
Acknowledgement
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References
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