Experimental and Automatic Measurement System Design of Flatness of Automatic Wallboard Cutting Surface

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Abstract. With the development of the industrialization of buildings, the demand for wallboard is increasing. The development of wallboard automatic production lines can solve the problems of low efficiency and low automation in the production process of wallboard. In the paper, the insufficient of the method that wall panel length detection in JGT169-2016 is considered, the automatic measurement system and cutting surface flatness analysis experiment is designed. Using MATLAB to filter and fit data. Optimize the cutting speed of wallboard based on LJQB-JX-600-QGJ.01 cutting machine. Through experimental analysis, better control parameters are selected for production control, and the quality of production wallboard is further improved, thereby improving the quality of the production line.

1. Introduction
While the construction industry is booming, the traditional development model is more and more difficult to meet the many needs of the industry development [1]. Under this background, the industrialization of construction has gradually developed and improved. As an important part of the industrialization of buildings, wall panels are increasing in demand with the development of the construction industry [2]. Different types of wall panels can be produced according to different production materials and different manufacturing methods [3-4].

The width and height of the wallboard forming are determined by the relevant structural parameters of the forming machine, and the accuracy of the forming length of the wallboard is related to the cutting machine control parameters. Optimizing the cutting execution speed can improve the quality and speed of the production wallboard, and thus improve the quality of the production line and the industrialization level of the building [5]. Design the automatic measurement system and data analysis method of the flatness of the cutting surface of the wallboard, and select the better speed control parameters for production control.

2. Experimental platform construction
In the process of wallboard production, the accuracy of the length of the wallboard is mainly determined by the cutting accuracy of the cutting device. In the general technical requirements of the JGT169-2016 wallboard, the wall panel length error is specified as ±5 mm [6-7]. Summarize the method of wall panel length detection in JGT169-2016, and the measurement process mainly includes two parts: point selection and length detection. The traditional measurement method has the following disadvantages: (1) In the process of length detection, the length of the wallboard is directly measured by the tape measure, and no auxiliary positioning is used. (2) The wall length measurement tool is a tape measure, and the measurement work is done manually. The measurement result is affected by the manual operation level, and the error is relatively large. (3) The wall panel length detection process
collects three sets of data, and the amount of data collected is small. (4) In the process of selecting the measuring points, the manual positioning of the points is adopted, which is cumbersome and has a large workload.

![Diagram of improved detection method.](image1)

The improved wall panel measurement method is shown in figure 1. The template is a metal material with precise dimensions. The auxiliary device is arranged with the template as the reference. The auxiliary device is parallel to the template reference surface. The distance $K$ between the two is the self-set value. The measurement aid and the wall panel detection surface, and the distance is recorded as $L$. The comparison between $K$ and $L$ can be used to evaluate the flatness of the cut surface of the wallboard. The smaller the difference between the two, the more accurate the cutting of the wallboard.

The two cutting surfaces are formed after one cutting is completed, and the detection method convert the whole wall panel detection into a single side flatness detection, that is, flatness detection is performed on a single cutting surface. The error is multiplied by 2 and is within ±5 mm, and the smaller the error, the better.

In the paper, the laser ranging module commonly used in the field of industrial ranging is used for distance detection. The module detection accuracy is 0.1mm, the measurement time is 1s when the measurement distance is 10cm, and the distance measurement module completes the distance detection after receiving the ranging instruction. The communication transmits the detected value to the upper computer, and the method reduces the operator's operation amount and improves the measurement accuracy. The distance detecting module is fixed on the uniform motion device, and the moving device carries the distance detecting module to perform distance detection on the auxiliary device. The data collecting period is 1s, and the moving speed of the uniform moving device is adjusted, and the ranging module can complete the fixed distance picking point. After the movement speed is lowered, the movement time of the detecting device becomes longer, and the number of points is increased. The hardware composition and control process of the point selection device are shown in figure 2.

![Point selection hardware composition and control process.](image2)

![Experimental platform.](image3)

Based on the above analysis, the experimental platform was built to optimize the measurement methods, measurement tools, and point selection of wallboard inspection. The overall hardware
structure of the design wall panel flatness detection system is shown in figure 3. The two cutting surfaces of the wallboard are detected by the distance measuring module, and the detected values are analysed and processed by the upper computer.

3. Experimental data filtering

In the host computer, the application program and the ranging module are used to exchange information through MATLAB, and the processing of collecting data is completed.

In the process of measuring the distance of the mobile device, the moving range is consistent with the length of the wall panel, and the width of the wall panel is 600 mm. In the process of data collection, the number of recording points is $n$, the spacing between the collection points is $j$, and the starting point is just located on the edge of the cutting surface of the wallboard as the best case of the collection point. The relationship between the number of collection points and the spacing is:

$$n = \frac{600}{j} + 1$$

(1)

The step angle of step motor is 1.5°, which is set to 2 subdivision mode. The number of pulses sent by the PLC controller per second is set to $m$ by the upper computer, so the stepping motor rotates every second. The number of turns is $(m \times 1.5) / (360 \times 2)$, and the pitch of the screw device is 1.5 mm, the moving speed of the mobile device is:

$$v = m \times 3.125 \times 10^{-3}$$

(2)

The moving speed unit is mm/s, and the time interval detected by the distance measuring device is 1s, and the sampling point spacing is the product of the speed and the detection time. Therefore, the distance between the acquisition detection points is numerically equal to $v$. When the first point collected is not located at the edge of the wallboard, it is difficult to ensure the last point is accurately selected. Therefore, the last point is abandoned on the basis of ensuring that the first point is accurately located on the detection surface of the wall panel. The relationship between the number of selected points and the number of pulses set by the host computer program is:

$$n = \frac{192000}{m}$$

(3)

Set $m$ to 3200, easy to get $n$ is 60, the upper computer sorts the data, and stores the collected data into the array $S$. Next, use MATLAB to get data graph. But in the process of data collection, the data will be affected by objective factors, so the detected values cannot be directly used for the analysis of the flatness of the cut surface. Data points are plotted in the MATLAB application for preliminary observation. As shown in figure 4(a), the collected points are affected by the instability of the instrument itself and other factors that cause the measured value to exceed the drawing point of the drawing area; as shown in figure 4(b), there are small holes in the cutting surface of the wallboard. The detection point distance value changes greatly.

![Figure 4. Problems with data.](image)

Whether it is the loss of data or the large change of data, its essence is the sudden change of data. For the characteristics of the two kinds of errors, the data is processed by the limiting filter algorithm. The filtered values are stored in the array $Q$. The maximum allowable difference of the limiting filter algorithm is 1.5mm. In order to prevent the mutation of the first experimental data from affecting the accuracy of the subsequent data, the limiting filtering algorithm is improved, and the first experimental data is compared with the standard distance of 100 mm. The algorithm rules are:

When $i=0$: 
When \( i > 0 \):

\[
\begin{align*}
S_i & = |Q[i] - Q[i-1]| & \leq 1.5, Q[i] = S[i] \\
& > 1.5, Q[i] = S[i-1]
\end{align*}
\]  

(5)

As shown in figure 5, the filtered data is redrawn into graph, and the data has no phenomena such as missing or mutations.

The value processed by the limiting filter algorithm can be used to analyse the flatness of the wallboard cutting surface, and the processed distance measurement value is stored in the array \( Q \). The variables \( a \) and \( b \) are set to save the maximum and minimum values of the array, and \( a \) and \( b \) are obtained by cyclically comparing the array \( Q \). The acquisition principle is shown in figure 6.

\[
e = 2 \times \max \{|a - 100|, |b - 100|\}
\]  

(6)

4. Experimental data analysis

The standard deviation analysis is performed on the collected data as a whole, and the standard deviation can reflect the degree of dispersion of the measured distance values, which is used as the evaluation standard \( Z \) for the flatness of the side wall of the wallboard.

\[
Z = \frac{1}{n} \sum_{i=0}^{n} (Q[i] - 10)^2
\]  

(7)

Based on the above data acquisition and processing flow, the cutting speed is selected to be 30mm/s, and the 120mm thickness wallboard is cut. The collected data is processed by the limiting filter algorithm and then plotted. The figure 7 changes as normal, without large change.
Figure 7. Thickness 120mm cutting speed 30mm/s point collection.
Substituting the obtained experimental data into equation (7) and performing flatness analysis and solving, the results are shown in table 1:

| Wall panel specifications(mm) | Cutting speed(mm/s) | Z(mm) | e(mm) |
|-------------------------------|---------------------|-------|-------|
| 120                           | 30                  | 0.35  | 1.1   |

The cutting speed was adjusted to calculate the flatness of the cutting surface of the wallboard and the maximum cutting error at different cutting speeds. Five experiments were performed on the same cutting speed, and the statistical values were averaged.

As the cutting speed is increased, the flatness of the cutting surface of the wallboard becomes larger, and the changing trend is shown in figure 8. When the cutting speed is slow, the flatness of the cutting surface of the wallboard is small, and the quality of the cutting surface is high. When the cutting speed exceeds 35mm/s, the flatness value of the wallboard increases obviously. When the cutting speed exceeds 50mm/s, the flatness of the cutting is sharp large, and the quality of the cut surface of the wallboard is low.

As the cutting speed increases, the maximum variation trend of wallboard cutting d-value is shown in figure 9. The cutting speed and the cutting d-value basically conform to the quadratic fitting relationship, and the corresponding fitting equation is:

\[
y_2 = 0.0028x_2^2 - 0.11x_2 + 1.9
\]  

(8)

The maximum cutting speed of 5mm is brought into the equation (8) to obtain the theoretical maximum cutting speed of 58mm/s, and the theoretical maximum cutting speed is reduced by 5 as the maximum cutting speed. Experiment based on the independently developed LJQB-JX-600-QGJ.01
cutting machine [7]. When cutting 120mm thick wallboard, the maximum cutting speed is 53mm/s, the wallboard width is 600mm, and the fastest cutting time is 11.3s. The maximum speed of LJQB construction waste wall panel extrusion molding machine is 3.35 m/min, the length of synchronous motion section is 1800mm, and the fastest cutting time is 32s. The appropriate cutting speed range is 30mm/s~40mm/s, the cutting quality is high in this range, and the corresponding cutting time is 15s~20s.

According to the above process, the experimental analysis of other thickness wall panels can be used to obtain the fastest cutting speed and suitable speed range for the LJQB-JX-600-QGJ.01 cutting machine when cutting different thickness wall panels. According to the thickness of the wallboard, the wallboard number is 90mm, 120mm, 150mm, and 180mm.

The cutting standards based on data analysis are shown in table 2:

| Wall panel thickness specification (mm) | Fastest cutting speed (mm/s) | Suitable speed range (mm/s) |
|----------------------------------------|-----------------------------|-----------------------------|
| 90                                     | 57                          | 30~45                        |
| 120                                    | 53                          | 30~40                        |
| 150                                    | 51                          | 30~40                        |
| 180                                    | 48                          | 30~40                        |

5. Conclusion
In this paper, from the general manual of the lightweight wall panel, the experimental design is carried out on the many parameters of the wallboard. The wallboard flatness test is designed based on the wallboard length requirement. The influence of the cutting speed on the cutting length of the wallboard is analysed. The analysis has established a cutting speed standard based on the company's independent research and development of cutting machines. Based on the experimental analysis of this paper, the optimization of the production line control parameters can effectively improve the quality of the wallboard.

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