Study on Pressure Testing Method of Die-Cutting Machine Based on Micro-capsule and Image Sensor

Lin-qing JIAO, Yi-ming WANG, Shu-qin WU and Lin-hui LI
Beijing Institute of Graphic Communication
Beijing Key Laboratory of Digital Printing Equipment, China

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Abstract. For the lack of the precise measurement of the pressure value of die-cutting machine pressure detection, micro-capsule and image sensing technology are applied to the pressure testing precision of die-cutting machine in this article which puts forward two kinds of die-cutting pressure testing methods and the related tests, obtaining the die-cutting machine pressure profile. In view of the data obtained from tests, the article proposes two kinds of pressure processing methods based on micro-capsule and image sensor, considering the factors to obtain appropriate data processing method, using two methods of die-cutting pressure test to calculate the accurate numbers of die-cutting pressure, and the error range is obtained. This paper provides a new method for the pressure test of die cutting machine, and provides a new method for data processing of pressure test based on micro-encapsulation and image sensor technology.

Preface

The cutting force of die-cutting machine is difficult to determine, but very important dynamic parameters. It is the important factors that affect the die-cutting machine performance, and it is the key part to improve the work speed and stability of die-cutting machine[1]. How to accurately measure the overall pressure of die-cutting machine is a big obstacle in the face of researchers. The die-cutting machines produced in the market all have nominal die-cutting pressure, but the die-cutting pressure is not accurately tested and the reference is poor.

The domestic research status of die-cutting pressure test stays at theory, experiment and simulation[1-9], and the precise measurement of die-cutting pressure is not yet involved. Wei Yanbin[2] proposed a method of pressure analysis of flat die-cutting machine, which can calculate the maximum pressure shearing force that the mechanism can bear in the theory; Wang Qiang[3] designed the online pressure testing system by measuring the die cutting pressure indirectly through the deformation of the wall panel; Xue Chaozhi and others[4] analyzed and studied the generation mechanism and influencing factors of die-cutting pressure by combining theory with experiment.

Aiming at the precision problem and the pressure test method presented in terms of the pressure test of die-cutting machine, and the precise testing method and data processing method of die-cutting machine are put forward. Micro-capsule and image sensor technology was applied to accurate detection of die-cutting pressure. And this paper puts forward two pressure data processing methods, considering the factors to select the appropriate calculation method, using two kinds of die-cutting pressure tests to estimate the accurate value of die-cutting pressure for obtaining the error range.

Theoretical Knowledge and Experimental Methods

Pressure Testing Technology Based on Micro-encapsulation and Image Sensor

To date, in many cases, the availability of pressure data remains extremely difficult. However, the pressure testing system using the new micro-capsule and image sensor technology can obtain precise pressure value and pressure distribution diagram through just a few steps. The test system includes paper, scanner and image analysis software.
There are two types of pressure papers: double-chip made by two-layer polyester film and single-type. One layer is coated with micro-granule material (A-film), and the other layer has the color material (C-film), which is used to face each other on the coating level of the two films. A single chip has both.

When the pressure is applied, the micro-particles break down, and the color layer reacts with the color layer, then the red pressure zone appears. The micro-particle is designed to rupture under different pressures, so the color density reflects the pressure.

**The Theoretical Calculating Method for Die-Cutting Pressure**

The die-cutting pressure is transmitted and realized through the steel knife and steel wire on the die cutting plate. The magnitude of die-cutting pressure can be calculated according to the length of the incision and the line of pressure[5]. The current calculating formulation is as follows:

\[
P = K_1 \cdot L \cdot F
\]  

(1)

Among them, P is the die-cutting pressure, unit N; L is the overall length (including the incisions and pressure lines) of the die cutting, unit mm; F is the die-cutting force of the unit length incision and the pressure line, unit N/mm; K_1 is the coefficient of various adverse factors considered in production, in engineering, K_1=1.3.

The model shear force F of each material unit length is determined by test method in production. A steel knife and a steel wire with a certain length of L1 are mounted on the die cutting to cut off the cardboard or the required line marks, measuring the pressure P_{20} (general with 10 times average value of stress as a calculating basis), using the formula (2) can calculate per unit length on the die shear force F.

\[
F = P_{20} / L_1
\]  

(2)

When measuring the value of pressure P_{20}, due to the instantaneous completion of the die-cutting process, the transient testing of the die-cutting pressure is difficult and the practical application is limited.

**Die-Cutting Pressure Testing Method**

(1) Traditional method:

When the die-cutting board and gasket are not installed, four standard blocks are used, which is placed on the four corners of the moving platform. The height is equal to the thickness of the die cutting board and the plate thickness by using the standard gasket (1mm, 0.5mm, 0.3mm, 0.2mm, 0.1mm, 0.05mm). The fuse with a diameter of about 3mm and a length of about 60mm is placed respectively on the block, then the pressure is pressed once, and the compressed fuse is taken out. The thickness is measured and the pressure value is estimated. The estimated error of this method is large, and it depend on the length and shape of the fuse greatly.

(2) Accurate testing method:

Plan A: Use the rubber sheet (size) to simulate normal die-cutting motion, place the paper fine pressure on the moving platform, take a sheet of paper and place the pressure paper on the paper for testing. During the test, we used the dial indicator to measure the deformation in the middle of the operating side panel, and the pressure test was performed at the time of the deformation of 0.10mm, 0.20mm, and 0.30mm; the pressure paper is LW type.

Plan B: Place the standard pad on the four corners of the platform and place the pressure paper on the standard pad for the single die-cutting stress test. During the test, we used the dial indicator to measure the deformation in the middle of the operating side panel, and the pressure test was performed at the time of the deformation of 0.10mm, 0.20mm, and 0.30mm. The pressure paper is HH5 type.
Die Cutting Pressure Direct Test Method

The Testing Process
1. Cut the pressure paper into the desired size.
2. Put the pressure paper between the pressure surfaces to be measured.
3. Apply conventional operating pressure.
4. Take out the pressure paper and check the pressure and pressure distribution.
5. Use the scanner to read color sensitive paper.
6. The fpd-8010e software was used for analysis.
7. The analyzed data are processed twice.

Experimental Conditions and Instruments
The pressure experiment in the temperature of 30 °C and humidity under 65%. The pressure test was carried out on 1060 models produced by a company.

Fuji stress test system is used in the test, which consists of Fuji pressure test paper, EPSON, V300 scanner and Fuji fpd-8010e pressure analysis system software. The pressure test papers used in this test, named the thin film sensor (collectively called "pressure paper"), are LW type and HHS type.

<table>
<thead>
<tr>
<th>Table 1. Detailed parameters of pressure paper.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: LW HHS</td>
</tr>
<tr>
<td>Measuring range (MPa)</td>
</tr>
<tr>
<td>2.5-10</td>
</tr>
<tr>
<td>130-300</td>
</tr>
<tr>
<td>Accuracy ±10%</td>
</tr>
<tr>
<td>Recommended temperature</td>
</tr>
<tr>
<td>25°C-35°C</td>
</tr>
<tr>
<td>15°C-30°C</td>
</tr>
<tr>
<td>Recommended humidity</td>
</tr>
<tr>
<td>35%RH-80%RH</td>
</tr>
<tr>
<td>35%RH-70%RH</td>
</tr>
<tr>
<td>Thickness single: ca.110um double - slice: A-film: ca.90um C-film: ca.90um</td>
</tr>
</tbody>
</table>

Data Processing Method
The data measured by the paper is processed, and the basic principle of data processing is to estimate the overall pressure by using the linear relationship between pressure and pressure area. In the process of data processing put forward 5 kinds of calculation methods, which were considered in the 5th kind of method to calculate the various aspects, including the pressure sensitive paper color not part of the influence factors such as pressure, pressure sensitive paper contact area, the calculation is more accurate and reliable.
Method 1

The pressure area and the load measured by the single-tensioned paper are estimated as a whole and the average is calculated. Depending on the test method, the calculation method is different. For test Plan A, the pressure area in the test process is the whole paper area, and the overall pressure is estimated by the data measured on the sheet film.

For test Plan B, the pressure area in the test process is the area of the four small piece of the standard block, with a single film can be measured by the data to estimate the pressure of four standard block, is the whole pressure.

The formula is as follows

\[ M = \frac{1}{n} \sum_{j=1}^{n} \frac{F_j S_j}{9800 S_y} \quad (3) \]

\( M \) represents the die-cutting pressure, and the unit is ton T; \( N \) is the number of pressure paper, \( F_i \) represents the load of the ith pressure paper, and the unit is n; The compressive area measured by \( S \) is the unit mm; \( S \) contact for up and down the platform contact area, for the test Plan A, the area of the contact area of the whole paper, \( S_y = 595 \times 800 = 47600 \) mm, for the test Plan B, the area of the contact area of four standard block, \( S_y = 4 \times 32 \times 100 = 12800 \) mm.

Method 2

This method considers that the pressure value not in the measurement range is linear with the measurement efficiency, and the pressure value in the measurement range is not estimated. Calculation steps are as follows, first calculate the load of a single pressure sensitive paper, not within the scope of the measuring part (void) pressure \( P_{min} \), namely the pressure sensitive paper measurement range of the minimum and efficient product, this is because, in fact, no discoloration of pressure is not been able to achieve the minimum pressure, pressure sensitive paper can change color is invalid part stress size and efficient linear relationship. The formula is as follows.

\[ M_i = \frac{\left[ (1 - \eta_i) S \eta_i P_{min} + F_i \right] \cdot S_j}{9800 S_y} \quad (4) \]

Calculate the total die cutting pressure.

\[ M = \frac{\sum_{i=1}^{n} M_i}{n S_j} \quad \Rightarrow \quad \sum_{i=1}^{n} S_j M_i = S_j M \]

\[ M = \sum_{i=1}^{n} M_i \quad (5) \]

Found in data processing, the two kinds of calculation methods, comprehensive consideration, the method may consider comprehensively in the several calculation methods, estimating process is rigorous, the test results more accurate, have certain reference value. The following test data are calculated using calculation method 2.

**Calculation Results and Comparison**

The test Plan A was tested three times, and the test sequence was divided into A-1, A-2 and A-3. In turn, the deformation amount of the wall panel is 0.15mm, 0.20mm and 0.25mm. See from pressure sensitive paper color of color deepened gradually with the increase of pressure, uneven distribution of color, no color or color in the middle of a shallow, the lower right corner place color is deeper, to determine the position of the up and down the platform stress concentration around, the larger stress concentration, the lower right corner place that uneven pressure distribution of the platform.
The test Plan B was tested three times, and the test sequence was divided into B-1, B-2, B-3. The following data:

Figure 5. Color chart of pressure after pressure.

Figure 6. B-1-0.15mm Pressure distribution after scanning.
Data summary analysis

Table 2. Summary of stress test data.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Deformation (mm)</th>
<th>type</th>
<th>Method 1 (Ton)</th>
<th>Method 2 (Ton)</th>
<th>Method 3 (Ton)</th>
<th>Method 4 (Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>0.20</td>
<td>LW</td>
<td>121.43</td>
<td>-</td>
<td>151.33</td>
<td>102.65</td>
</tr>
<tr>
<td>A-2</td>
<td>0.25</td>
<td>LW</td>
<td>146.62</td>
<td>-</td>
<td>180.53</td>
<td>150.86</td>
</tr>
<tr>
<td>A-3</td>
<td>0.30</td>
<td>LW</td>
<td>171.82</td>
<td>-</td>
<td>203.61</td>
<td>184.73</td>
</tr>
<tr>
<td>B-1</td>
<td>0.15</td>
<td>HHS</td>
<td>147.56</td>
<td>28.20</td>
<td>161.72</td>
<td>51.04</td>
</tr>
<tr>
<td>B-2</td>
<td>0.20</td>
<td>HHS</td>
<td>154.80</td>
<td>75.45</td>
<td>185.91</td>
<td>108.91</td>
</tr>
<tr>
<td>B-3</td>
<td>0.25</td>
<td>HHS</td>
<td>162.64</td>
<td>123.28</td>
<td>215.00</td>
<td>160.42</td>
</tr>
<tr>
<td>B-4</td>
<td>0.30</td>
<td>HHS</td>
<td>183.27</td>
<td>166.38</td>
<td>225.08</td>
<td>198.74</td>
</tr>
</tbody>
</table>

Table 3. Summary of stress test data.

<table>
<thead>
<tr>
<th>Plan</th>
<th>0.15mm</th>
<th>0.20mm</th>
<th>0.25mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan A</td>
<td>102.65</td>
<td>150.86</td>
<td>184.73</td>
</tr>
<tr>
<td>Plan B</td>
<td>108.91</td>
<td>160.42</td>
<td>198.74</td>
</tr>
<tr>
<td>Average</td>
<td>105.78</td>
<td>155.64</td>
<td>191.74</td>
</tr>
<tr>
<td>Increment</td>
<td>54.38</td>
<td>49.86</td>
<td>36.1</td>
</tr>
<tr>
<td>Error</td>
<td>3.0%</td>
<td>3.1%</td>
<td>3.7%</td>
</tr>
</tbody>
</table>

Through the data in the table, it can be found that the data obtained by the two test methods is relatively close, and the average and error rate can be calculated as shown in table 2, and the data can be used as reference for technical personnel.

When the deformation of the upper platform is 0.25mm, the die cutting pressure value is 191.74 tons (about 200 tons). The data in Tab. 3 is reliable, which can provide data support for the design of pressure measurement system of die-cutting machine according to the relationship between the deformation amount of the upper platform and the pressure.

Conclusion

Through the use of microcapsules and image sensor technology, used in the die cutting machine pressure test, put forward two kinds of die cutting pressure test method, gained the exact number, and puts forward two kinds of stress testing based on the technology of microcapsule and image sensor data processing method, by comparing the obtained the suitable data processing method, get precise and reliable numbers. At the same time, the data processing method can provide a new way of thinking for the workers who use microcapsule and image sensing technology to test the pressure.

Acknowledgements

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