Experimental Analysis on the Measurement of the Formation Time of Carbonless Copy Handwriting by "Fading" Gray Value Measurement Method

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Abstract. Carbon free carbon copy paper is a special writing material, which often appears in many commercial disputes and cases. The handwriting identification of carbon free carbon copy paper has often become one of the key factors in case adjudication. However, the existing handwriting inspection methods of carbon free carbon copy paper are not effective, and cannot analyze the law of the formation time of carbon free carbon copy handwriting. For this reason, this paper proposes an experimental analysis based on the "fading" gray value measurement method to determine the formation time of carbon free copy handwriting. The characteristics of solvents have an important impact on the formation of handwriting. Therefore, this paper analyzes the characteristics of the existing main pen solvents in terms of fading and copying ability. In this paper, according to the characteristics of carbonless copy characters, combined with the gray value measurement method, the calculation method is optimized. The optimized method is more suitable for the determination of the formation time of carbon free copy handwriting, and has the advantage of simplifying the calculation steps. In the specific test experiments, the relationship between extraction rate and time change, handwriting reproducibility and other items are tested. The experimental results show that the extraction rate of carbon free copy handwriting decreases rapidly with the increase of formation time, and gradually tends to be stable. In this paper, the characteristics of the solvents and colorants for pen and their influence on the formation of handwriting are analyzed. It is concluded that the types and use of solvents and colorants have an impact on the formation time of carbon free copy handwriting.

Keywords: Gray Value Measurement Method, Carbon Free Carbon Copy Paper, Handwriting Detection, Pen Solvent

1. Introduction

Carbon free carbon copy paper is a kind of chemical pressure sensitive recording paper. It has the characteristics of easy to use, clear handwriting and neat overprint. It is widely used in modern office, transaction documents and various electronic printing records. The common ones are the delivery,
withdrawal, collection and printing of bills from financial institutions [1-3]. The structure of carbonless paper can be divided into coupling (color rendering) and self-supporting (self-coloring), and most of them are coupling. The principle of replication is: under the pressure of writing tools or printers, the surface of microcapsule coating first decomposes, the packaging of colorless dye oil (colorant) moves to the second aspect, and the coating reacts color after contacting with developer. There is no writing on the front of the second layer, and so on, until the third layer [4-5].

In recent years, with the wide use of carbon free carbon copy paper in economic exchanges, there are more and more cases involving the examination of such substantive documents. On the basis of understanding the characteristics of carbon free carbon copy paper, some criminals use physical and chemical methods to eliminate and change the handwriting of carbon free copy paper [6-7]. Therefore, determining the formation time of handwriting is a common recognition problem. There are few reports about the formation time of carbonless copy handwriting in China. In this study, the "fading" gray value measurement method is used to measure the formation time of carbon free copy handwriting, and the characteristics of the formation are compared, which provides basic research data for the measurement of the formation time of carbon free copy handwriting [8-10].

This paper deeply studies the current detection methods of carbon free copy handwriting formation time in China, and understands that the existing carbon free copy handwriting formation time detection method is relatively backward, the detection result accuracy is low, and there are many deficiencies. Therefore, it is of great significance to improve the inspection method of the formation time of carbon free copy handwriting and analyze the internal law of the formation time of carbon free copy handwriting. Therefore, this paper puts forward the experimental analysis of the formation time of carbonless copy handwriting based on the "fading" gray value measurement method, hoping to improve the existing gray value measurement method to help the existing research on carbon free copy handwriting formation time. In this paper, aiming at the problems existing in the existing detection, the conventional gray value measurement method is optimized and improved to make it more suitable for the detection of carbon free copy handwriting formation time. The experimental results show that the extraction rate of carbon free copy handwriting decreases rapidly with the increase of formation time, and gradually tends to be stable. Analysis shows that the formation of carbon free copy handwriting is mainly through the pressure to squeeze the solvent in the pen, and form traces on the carbon free copy paper, so the solvent and colorant in the pen have a great impact on the formation time of the handwriting. Therefore, in the actual detection process, the influence factors of solvents and colorants should be fully considered.

2. Carbon Free Copy Paper and Handwriting Formation

2.1. Carbon Paper and Carbon Free Carbon Copy Paper
Carbon paper is a special writing material, which is often used to copy debit notes and invoices. In all kinds of economic cases and disputes, the actor or the parties often use carbon paper to forge receipts and contracts in order to avoid criminal responsibility and distort the facts. Carbon paper has the advantages of easy to use, clean hands, clear handwriting, convenient processing, especially suitable for computer printing. The new carbon paper is widely used in commercial invoice, tax, post and telecommunications industries. Carbon free copy paper is a kind of high-grade paper which uses different chemical coatings on the paper surface to produce color reaction under the action of handwriting or printing pressure to achieve the purpose of reproduction. Carbon free carbon copy paper consists of top and bottom pages. To get more copies, just insert multiple intermediate pages between the top and bottom pages.

2.2. Principle of Handwriting Formation in Carbonless Copy
According to the different color developing methods, carbonless copy paper can be divided into coupling type and self-loading type (SC paper). The coupling carbonless copy paper includes paper loading (CB paper) and paper unloading (CF paper). The coupled carbonless copy paper must be used
together. Self-contained carbon free carbon copy paper becomes upper, middle and lower layers, which can be colored automatically and is mostly used for printing. Several layers of microcapsules were coated on the back of CB paper. The microcapsules mainly contained dyes. When writing the first page, write by pressure, break CB microcapsule or fluidized bed paper, make dye flow, and achieve the purpose of writing when color reaction occurs. SC paper is coated with microcapsules containing dye and developer at the same time on the front side of base paper, which can be used separately without matching.

3. Comparative Analysis of Paper Copy Ability after Different Solvents Fading

Solvent is one of the factors that make the pen writing. When the solvent is added to the pen, the solvent will stay on the paper under the pressure during the writing process. At present, different functional pens use different solvents, and the composition of solvents has an important impact on the formation time of writing. In order to further study the formation time of different carbon free carbon copy paper handwriting, it is necessary to study the fading and copying ability of the mainstream pen solvent in the market. In general, the identification of handwriting formation time will involve the copying of solvent after paper fading. Therefore, it is necessary to study the copying ability of solvent after fading. In this paper, the fading time and the characteristics of the fading ability of 11 kinds of pen solvents are summarized, as shown in Table 1.

**Table 1. Characteristics of 11 main pen solvents**

| Organic solvents | Fading time | Characteristics of fading replication ability |
|------------------|-------------|---------------------------------------------|
| Ethanol          | <5min       | Slow color development, dark color          |
| Ethyl acetate    | <5min       | No color rendering                          |
| N-butyl acetate  | <5min       | Slow color development, light color         |
| Dimethyl formyl  | <5min       | No color rendering                          |
| Amine            | <5min       | No color rendering                          |
| Benzene          | <5min       | Fast color rendering, dark color            |
| Toluene          | <5min       | Fast color rendering, dark color            |
| Xylene           | <5min       | Fast color rendering, dark color            |
| Acetone          | <5min       | No color rendering                          |
| Chloroform       | <5min       | Slow color development, dark color          |
| Tianna water     | <5min       | No color rendering                          |

4. Discussion

4.1. Materials and Methods

(1) Instruments and conditions
Micro spectrophotometer, measurement method: reflection, sampling spectral range: 400-800nm; sampling area: 1200 µm²; objective lens: 20 ×.

(2) Reagents
Methanol, ethanol, acetonitrile, ethyl benzoate, m-methyl phenol, o-methyl phenol, etc.

(3) Sample preparation
The black signature pen is purchased from the market, and the Chenguang brand sample is used as the experimental sample. The sample pen is the most commonly used neutral signature pen in the market. At regular intervals, draw a straight line on the carbon free carbon copy paper with a signature pen, and record the sample preparation time. The interval between word preparation and sample preparation should be shorter. The samples were stored at room temperature (18-26 °C) and protected from light.

(4) Sample extraction
The handwriting of the sample formed on the same day was 2.5cm. The weak extract was extracted for 15min, 25min, 35min, and the strong extract was extracted for 25min, 35min, 50min, 65min and
The gray value of the extracted solution was measured and analyzed, and the extraction time was determined by comparing the analysis results.

4.2. Analysis of Experimental Results

(1) The relationship between extraction rate and time

According to the experimental results, the extraction rate of solvent in handwriting ink was calculated. Results the extraction rate was taken as the ordinate and the relative formation time of handwriting as the abscissa. The curve of the extraction rate of glycerol and glycol in handwriting samples with time is shown in Figure 1. It can be found that the total change trend of the extraction rate is: with the increase of the relative formation time of handwriting, the extraction rate gradually decreases. Specifically, within 5 months, with the increase of handwriting formation time, the extraction rate decreased rapidly, and changed slowly from 5 months to 10 months, and tended to balance after 10 months.

![Figure 1. Comparison between extraction rate and time](image)

(2) Reproducibility

The sample handwriting was divided into five parts, and the same length (2.5cm) handwriting was extracted under the same conditions, and then the gray value was measured and analyzed. The maximum relative standard deviation of the method is about 3%, which indicates that the method has good reproducibility. The results of sample determination are shown in Figure 2. The analysis shows that most of the solvents are easy to volatilize when the handwriting is in contact with the air, and the content of the solvent will change with the change of the writing time. Therefore, the relative formation time of the carbon free copy paper handwriting can be determined according to the content of the solvent in the handwriting.
4.3. Method of Measuring Fading Gray Value

Gray value measurement method is to record the light wave before and after deformation by complementary metal oxide semiconductor, which is faded twice before and after deformation. In the reconstruction process, the interference fringes between the two light waves are used to understand the change of light waves, and then the deformation of the object is analyzed when the fading is twice.

The phase difference $\Delta \phi$ is expressed as:

$$\Delta \phi = \frac{2\pi}{\lambda} \left[ \sqrt{SA + AV} - \sqrt{SA + AV} \right]$$  \hspace{1cm} (1)

Since the deformation is very small, it can be considered that the deformation direction is perpendicular to the surface:

$$\Delta \phi = \frac{2\pi}{\lambda} \left(2\overline{AA}\right)$$  \hspace{1cm} (2)

The optical path difference $2\overline{AA}$ is expressed as $2\Delta L$, and the above formula is rewritten as follows:

$$\Delta \phi = \frac{2\pi}{\lambda} 2\Delta L$$  \hspace{1cm} (3)

Where $\Delta L$ is the out of plane deformation.

The bright fringe Series $N$ corresponds to the phase change

$$\Delta \phi = \frac{N\lambda}{2}$$  \hspace{1cm} (4)

From the above discussion, it can be seen that the phase difference reflects the shape variable, and the light intensity can be expressed by the gray value. This is the theoretical basis of the method used in this paper.

4.4. Solvents and Colorants

Solvent is the volatile component of pen in the writing process. The purpose of adding solvent is to make the colorant dissolve in the ink and make the colorant pass through the ball and ball smoothly.
Generally, the solvent with strong permeability and obvious wetting effect will play a better role in writing. Therefore, the solvent of signature pen is mainly organic alcohol, and the commonly used solvents are diethylene glycol and ethylene glycol. In order to improve solubility and writing quality, most manufacturers use mixed solvent method. This method can overcome the shortcomings of ink drying caused by too fast evaporation speed when the pen head is sealed. At the same time, it can also overcome the shortcomings of slow evaporation speed leading to handwriting drying and easy diffusion.

The main colorants are carbon black and dyes, while blue pens usually use dyes directly. In the process of writing, the dye is diazoniized to diazonium salt, which is coupled with aniline. The dye in the ink mainly acts as a colorant. After the handwriting is written on the paper, the dye components are fixed on the paper by adsorption. Because the particle radius of dye is very small, it is easy to enter the gap of paper fiber, so the ink of signature pen is very wear-resistant and has a long storage time. Dye is sensitive to light and easy to produce photochemical reaction. This feature can be used to recognize the relative formation time of handwriting.

4.5. Determination of Chemical Regression Facts
Whether the handwriting cleanliness of carbonless copy paper is normal is an effective standard to judge whether the chemical degradation occurs.

1) After the removal of benzene, xylene and other reagents, the carbon free carbon copy paper still has the fading ability. This may be related to the mechanism of chemical regression, that is, chemical reagents only dissolve the chromogenic substances produced by the color reaction, but also dissolve the unreduced substances.

2) Due to the different production process of carbon free carbon copy paper, different manufacturers use different color reagents, and the reactions produced by different reagents will be different. Even if the same coupler reacts with different developer, the color can be dark or light. Therefore, it is better to use CB, CFB and CF paper of the same type and batch from the same manufacturer for testing. The test results also need to be combined with the results of other indicators, such as color rendering speed.

5. Conclusions
In this paper, in the experimental analysis of the "fading" gray value measurement method to determine the formation time of carbon free copy handwriting, the main measurement methods of carbon free copy handwriting formation time in China are deeply studied. The analysis shows that the current detection method of carbon free copy handwriting formation time in China is too backward and the detection accuracy is not high enough to effectively analyze the formation time law of carbon free copy handwriting. At present, the main research direction in this field is to reform and innovate the method of the formation time of carbon free copy handwriting. The improved method based on the "fading" gray value measurement method proposed in this paper, to a certain extent, makes up for the shortcomings of traditional detection, and plays a positive role in improving the detection ability of carbon free copy handwriting formation time in China. In this paper, the existing gray value measurement method is optimized and improved. By simplifying the calculation steps, the accuracy of calculation is improved, so that the gray value measurement method is more suitable for the current non carbon copy handwriting formation time requirements. As a special material, carbon free carbon copy paper is widely used in commercial activities. In commercial cases, the detection of carbon free copy handwriting often plays a key role in the final trial results. Therefore, it is of great significance for the development of this field to strengthen the research on the formation time of carbon free copy handwriting in China, and the research in this paper has achieved ideal results and made a contribution to the research in this field.

Acknowledgements
This work was supported by Scientific research project of Shandong University of political science and law (2018Z02B).
This work was supported by Program for Young Innovative Research Team in Shan Dong University of Political Science and Law

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