Study on Grey Benchmark Adjustment and Visual Measurement of Cigarette Combustion

Han ZHENG, Geng LI *, Hao WANG, Zhenhua YU, Ying ZHANG, Jiao XIE, Xu WANG, Tao WANG, Tingting YU, Baoshan YUE, Jianbo ZHAN
R & D Centre, China Tobacco Yunnan Industrial Co., Ltd. 650231 Kunming, China
First author: Zheng Han,zhengh@ynzy-tobacco.com
*Corresponding author: LI Geng, lig@ynzy-tobacco.com

Abstract. The color of cigarette paper and its ash after combustion is one of the most intuitive evaluations for consumers. In order to solve the problem that the judgment of machine vision is not unified and there is no standard reference, an objective and accurate method of cigarette combustion gray benchmark adjustment and visual measurement based on ceramic stick was are provided in this paper. Through multi-faceted simultaneous shooting of a single cigarette in the state of static combustion or smoking, real-time image tracking acquisition is carried out to complete multi-faceted full vision acquisition of cigarette sample combustion. The experimental results show that there are some standard deviations in the three angles, and the method of taking the mean value reflects the gray of cigarette combustion to the greatest extent. Using ceramic bar as reference to calibrate cigarette gray, real-time acquisition and data processing can accurately and objectively determine and compare the test samples, which could be applied for scientific statistics and research. The uniform lighting design of multiple LED light sources ensures the quality of the collected images.

1. Introduction
The gray of cigarette combustion refers to the ratio of the gray level of the gray area of the ash column and combustion cone after cigarette combustion to that of cigarette paper of the test cigarette samples[1-2]. The color of cigarette paper and its ash after burning is one of the most intuitive evaluation for consumers. There is no unified standard to evaluate the color characteristics of cigarette paper and its ash column, which can not be quantitatively analyzed by human sight[3-5]. As the white balance parameters of different vision machines are not unified, different machine vision judgment will be different[6,7]. Therefore, in order to get an objective evaluation of the gray value of cigarette paper and its ash column, it is necessary to adopt a gray benchmark adjustment and visual measurement method of cigarette combustion based on the ceramic stick. At present, the gray degree of cigarette combustion is mainly evaluated by the visual method of technicians, which is easily affected by the technical level, experience and subjective consciousness of the observers, thus affecting the accuracy and objectivity of the evaluation results. In addition, the visual method can not collect and digitize the real-time data of cigarette combustion, which affects scientific statistics and research. In this regard, there is no good solution to solve the above problems. In order to solve the problem that the judgment of machine vision is not unified and there is no standard reference, an objective and accurate method of cigarette combustion gray benchmark adjustment and visual measurement based on ceramic stick is provided in this paper. The image acquisition of the test sample when the cigarette is still burning or smoking is carried out. Multiple cameras are evenly
distributed around the test cigarette, and the camera lens position is perpendicular to the axial direction of the cigarette. The multi-faceted full vision acquisition of the cigarette test sample combustion gray is completed by taking multi-faceted simultaneous pictures of a single cigarette in the state of still burning or smoking and real-time image tracking acquisition.

2. Method and principle
1. The samples were pretreated according to GB/T 16447. In order to investigate the gray of cigarette combustion of different samples under specific conditions, pretreatment was carried out according to the set equilibrium conditions, or the samples were directly tested to analyze the gray difference under different conditions.

2. The ceramic rod sample was placed at the measuring position, as shown in Fig. 1. The axial direction of the cigarette placed at the measuring position is perpendicular to the camera and lighting source.

3. The gray value of the ceramic bar was set as Gray0=255, and the ceramic bar was placed at the background position of the cigarette to be tested. The camera is placed in the focus range of the lens, and 3 cameras are evenly distributed around the axis of the cigarette to be measured. A strip light source is fixed on the side of each camera, and the central line of the strip light source is consistent with and parallel to the central axis of the cigarette to be measured to make the surface of the cigarette uniform.

4. Start the software control system, lighting system, camera system, take the sample picture before burning and light the cigarette. After lighting the sample cigarette, start to collect the cigarette burning image in real time. Cigarette combustion detection can choose static combustion detection or smoking status detection. Smoking status includes ISO, FTC, Massachusetts, Canada deep smoking and other standard modes (including user-defined mode). The camera system includes multiple groups of cameras, which are evenly distributed in the direction perpendicular to the cigarette (the axial center interval is 120 degrees), so as to ensure that all sides of the cigarette can be fully collected. Camera specification is as follows, sensor size ≥ 15 mm², Pixel size ≥ 1.22 μm x 1.22 μm. The lighting system includes multiple groups of lighting sources, which are evenly distributed with the camera (the axial center interval is 120°), to ensure the uniform lighting of cigarette. Light source specification is color temperature ≥4500 K, illumination should be selected and adjusted according to the requirements of the experimental environment, and the collected image should be clear.

Fig.1 Positions of light source, camera and ceramic stick/cigarette
5. When the cigarette burns to 3 mm away from the tipping paper, the cigarette combustion image was stop collected. In the process of sample determination, the image is collected automatically by the control system every 2 s. The acquisition time interval can be customized according to the measurement requirements, and the accuracy is 0.1 s.

6. The camera was applied to adjust the ratio of gray value Gray₁ of the ceramic bar after white balance and the gray value Gray₀ set before adjustment, thus, the calibration conversion coefficient η, the average gray value of the cigarette and the gray column part of the collected cigarette image is calculated to obtain the cigarette combustion gray H. The gray of cigarette combustion is the ratio of gray level of gray column and combustion cone to gray level of cigarette paper H=Gray₂/Gray₅ × 100%. For the H₀ evaluation of the same batch of cigarette samples, after box sampling according to the moisture content test of GB / T 5606.1, the average value of 10 cigarette samples was taken as the gray H₅ of the batch. In the process of measuring the gray value of sample cigarettes, the color RGB is converted into Gray, using the famous psychological formula Gray=R*0.299+G*0.587+B*0.114.

7. The parameters of camera white balance are set, and the proportion is set according to the ratio of 1 / R: 1 / G: 1 / B according to the R, G and B values of the detection ceramic rod. The RGB values of the detected objects are the average values within the range of the measured objects. The ratio of gray value Gray₁ detected by the ceramic bar after adjusting the white balance of the camera and the gray value Gray₀ set before adjusting is taken as the calibration conversion coefficient η.

8. According to the measurement requirements, the image acquisition data in different combustion length ranges are selected. The gray values of multiple cameras in the selection range are H₁, H₂... Hₙ, which are the weighted average values of the real-time data collected from multiple sides of the test samples. The gray values of the test cigarette samples are calculated according to H₀=1/n Σₙ=₁ (H₁ + H₂ + ⋯ + Hₙ).

Pixel precision refers to the actual distance of each pixel. In the same condition, the smaller the pixel precision is, the higher the image quality is, which can reduce the misjudgment at the critical point of the image. In the visual image detection, it is an important condition to meet the pixel accuracy requirements of the collected image. The pixel accuracy (unit: mm/Pixel) is calculated according to Eq.(1).

\[
\text{Pixel accuracy} = \frac{W_1}{H} = \frac{W_2}{V}; \quad (1)
\]

Where, \(W_1\) -- field height of vision camera device, \(W_2\) -- field width of vision camera device, \(H\) -- image vertical resolution, \(V\) -- image horizontal resolution.

3. Experimental

3.1. Samples
24.0 mm circumference and 84.0 mm length of conventional cigarette are taken as test samples.

3.2. Configuration
Control system: analysis software: FZ-PanDA (OMRON Co.,Ltd., Japan), image processing software: AV5171B human-machine interface (self-developed); Lighting system: JL-LR-100X30 (Jiali Co.,Ltd., China); Camera system: camera model: FH-SC04 (OMRON Co.,Ltd., Japan), lens model: 3Z4S-LE (OMRON Co.,Ltd., Japan); Calibrator: ceramic rod.

3.3. Environmental
Test temperature is 22 ± 2 ℃ and the relative humidity is 60 ± 5% .

3.4. Testing and adjustment
① Place the test cigarette with diameter D at the detection point, adjust the shooting parameters of the visual camera device, and confirm that the image area of the collected cigarette is clear, as shown in Fig. 2.
Capture the cigarette image, and use the windows drawing software or other image processing software to obtain the number of vertical pixels of the image corresponding to the cigarette diameter shown in the red line of Fig.3.

According to Eq. (2), the pixel accuracy of the Fig. 3 is calculated, which is used as the pixel accuracy of the gray image of cigarette combustion under the above conditions.

\[
\text{Pixel accuracy} = \frac{D}{P}
\]  

Where, \(D\) is the diameter and width of test cigarette (unit: mm), and \(P\) is the number of vertical pixels corresponding to the cigarette diameter (unit: Pixel).

3.5. Calculation
On the man-machine interface, the gray column area of the image before and after acquisition was detected and processed by the software. The gray value \(H_0\) of cigarette combustion is calculated as follows, 3 groups of cameras can be selected in the implementation example, and the gray in the selected range is \(H_1, H_2, H_3\), which are the weighted average values of the real-time data collected from 3 sides of the test sample. The gray value of test cigarette samples was calculated according to

\[
H_0 = \frac{(H_1 + H_2 + H_3)}{3}
\]

4. Results and discussion
According to Table 1, there are some standard deviation in three angles. The single angle test of cigarette combustion gray and visual judgment can not fully reflect the characteristics of cigarette combustion gray. The way of taking average value reflects the cigarette combustion gray to the greatest extent, which is a more effective method to determine cigarette gray and visual measurement, and is suitable for promotion in subsequent measurement.
Table 1 Measuring gray value difference and standard deviation of different angles

| No. C/mm | Camera | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | Average |
|----------|--------|------|------|------|------|------|------|------|------|------|-------|---------|
| 1        | 24     | 1#   | 107.4| 125.1| 106.6| 103.9| 122.4| 112.5| 100.8| 114.2| 113.7| 110.6   | 111.72  |
|          |        | 2#   | 113.6| 107.7| 115.1| 125.8| 104.2| 105.6| 111.5| 116.6| 117.5| 107.5   | 112.05  |
|          |        | 3#   | 104.7| 118.9| 102.6| 119.2| 114.8| 96.6 | 100.1| 111.0| 106.9| 120.1   | 109.49  |
|          |        | SD   | 4.5  | 8.9  | 6.4  | 11.2 | 9.1  | 8.0  | 6.4  | 2.8  | 3.8  | 4.9  | 6.6     |
|          |        | Average | 108.6| 117.3| 108.1| 116.3| 113.8| 104.9| 113.9| 109.4| 114.5| 111.0  | 111.09  |
| 2        | 20     | 1#   | 117.3| 106.8| 111.0| 109.0| 117.3| 97.9 | 121.1| 117.6| 120.1| 106.0   | 112.41  |
|          |        | 2#   | 109.4| 122.5| 113.5| 118.9| 114.0| 116.6| 114.7| 114.9| 114.6| 113.0   | 115.21  |
|          |        | 3#   | 116.5| 115.8| 108.9| 107.9| 105.8| 104.1| 107.8| 126.6| 118.2| 98.9    | 111.05  |
|          |        | SD   | 4.3  | 7.9  | 2.3  | 6.0  | 5.9  | 9.5  | 6.6  | 6.1  | 2.8  | 7.1    | 5.85    |
|          |        | Average | 114.4| 115.0| 111.1| 111.9| 112.4| 106.2| 114.5| 119.7| 117.7| 106.0   | 112.89  |
| 3        | 17     | 1#   | 127.4| 133.0| 124.7| 122.7| 118.8| 122.6| 114.6| 126.4| 122.8| 122.5   | 123.55  |
|          |        | 2#   | 123.3| 105.7| 109.7| 120.2| 115.9| 116.0| 116.2| 132.2| 118.6| 119.3   | 117.71  |
|          |        | 3#   | 134.4| 120.3| 131.5| 117.1| 130.7| 123.4| 116.2| 120.4| 129.1| 130.2   | 125.33  |
|          |        | SD   | 5.6  | 13.7 | 11.1 | 2.8  | 7.8  | 4.1  | 0.9  | 5.9  | 5.3  | 5.6    | 6.28    |
|          |        | Average | 128.3| 119.7| 122.0| 120.0| 121.8| 120.7| 115.7| 126.3| 123.5| 124.0   | 122.2   |

As shown in Fig.4, for the sample cigarettes, the images of the three different test surfaces are different, the images are clear and the quality is good. Therefore, it is necessary to collect the full visual data of the sample in real time with multiple groups of cameras.

Fig.4 Combustion of the same cigarette at three different angles

The measurement of cigarette combustion gray is easily affected by the technical level, experience and subjective consciousness of observers, which affects the accuracy and objectivity of evaluation results. For different visual detection machines, the purpose of calibrating the gray scale with a unified reference object is accomplished. By calibrating the gray scale of cigarettes with a ceramic rod as a reference, real-time collection and digitization, the invention can accurately and objectively judge and compare the test samples. Multiple groups of cameras realize the full vision image data acquisition of the test samples, avoiding the one-sided collected image due to the limited shooting angle, which cannot measure the gray of the sample accurately. Multiple groups of LED light sources provide uniform illumination on multiple sides to ensure the quality of collected figures.

5. Conclusion
1. There is a certain standard deviation in the three angles, and the way of taking the mean value truly reflects the gray of cigarette combustion to the greatest extent.
2. The ceramic rod was taken as the reference to calibrate the cigarette gray, which could collect and digitize in real time, judge and compare the test samples accurately and objectively, and the data could be used for further scientific statistics and research.
3. Multiple groups of LED light sources and multi-faceted uniform lighting design ensure the quality of collected figures during cigarette combustion.
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References
[1] ZHENG H, WANG H, ZHAN J, et al. Effect of Different Puff Modes on Ash Condensation Performance of Cigarettes[J]. Journal of Physics Conference Series, 2020, 1676:012026.
[2] ZHANG Y, ZHAN J B, MIAO M M, et al. Evaluation and Analysis of Ash Condensation Performance of Cigarette Paper [J]. China Pulp & Paper 2017, 36(7): 44-47.
[3] LI G, DING H Y, SUN J, et al. Study on Improvement of Cigarette Ash Packing Effect [J]. China Pulp & Paper, 2012, 31(8): 32-34.
[4] SHEN J X, SUN J, XIAO W Y, et al. The Effect of Additives on Cigarette Ash Wrapping [J]. China Pulp & Paper Industry, 2012, 33(14): 23-25.
[5] MU L, HUI J Q, FENG Y H, et al. A Method to Determine the Grayness Value of Cigarette Ash [J]. Tobacco Science & Technology, 2018, 51(7): 67-72.
[6] ZHENG H, ZHANG Y, Wang H, et al. Research Progress and Application of Low Ignition Propensity Cigarette Paper [J]. China Pulp & Paper 2017, 36(9): 78-81.
[7] ZHENG H, ZHAN J B, WANG H, et al. Analysis on Research Progress of Cigarette Ash Condensation Properties [J]. The Journal of New Industrialization, 2018, 8(11): 93-97.