Effect of Different Puff Modes on Ash Condensation Performance of Cigarettes

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Abstract—In this paper, ISO puff (CORESTA), Canada deep puff mode and Massachusetts puff mode are used to influence the appearance, ash index and ash column deviation of cigarette in the combustion process. The experimental results show that, in different puff modes, the condensation index of cigarette has little change, indicating that the condensation effect of cigarette paper is relatively stable, and the overall performance is good, but the deviation degree of cigarette ash column changes greatly, and the average difference of the results under different lens measurement is large, especially in the Massachusetts puff mode, the average difference between lenses is up to 1.1. The mean value of the coefficient of variation of the deviation of the ash column is 50%, which shows that the deviation of each measurement is quite different.

1. INTRODUCTION
Cigarette packing ash is an important appearance form that consumers directly feel in the process of cigarette burning[1-4]. The quality of cigarette packing ash directly affects consumers' judgment on the quality of cigarette products[5-9]. Because cigarette paper plays the role of wrapping tobacco and directly participates in cigarette combustion, it has the most critical influence on cigarette ash wrapping performance. Li Guizhen et al. found that pulp, filling amount and quantity had little effect on cigarette pack ash performance, while adding soot regulator could significantly improve cigarette pack ash performance[6]. Shen Jingxuan et al. improved the ability of cigarette to pack ash on the basis of not changing the style of cigarette, so as to achieve the purpose of improving the ability of cigarette to pack ash and upgrading the grade of cigarette[7]. Zheng Han et al. combed the research on cigarette pack ash from the research progress of influencing factors of cigarette pack ash performance, the research status of relevant detection parameters and methods of cigarette pack ash, the development status of cigarette pack ash detection equipment, etc., and thought that it could be an important indicator to evaluate cigarette combustion performance, while adding soot regulator could significantly improve cigarette pack ash performance[8]. Yu Yao et al. prepared a kind of dense ash coated general anesthesia cigarette paper through the papermaking method and the proportion design of pulp. The cigarette ash prepared from this kind of cigarette paper was significantly improved, and the integrity and gray of the ash were greatly improved[9]. Zhang Ying et al. used the independently developed cigarette coagulation analysis software to put forward the parameter of the coagulation index[10], and evaluated the coagulation capacity of different brands of cigarettes, and analyzed the influence of the coagulation performance of cigarette paper on the combustion performance of cigarettes. The research shows that the calculation of the condensation index of cigarettes is simple, The response of the software is rapid. The coefficient of variation between the coagulation indexes of different brands of...
cigarettes of the same brand is small, and the differentiation of the coagulation indexes of different brands is obvious. The coagulation index of cigarettes can be used as an important index and an effective means to measure the coagulation performance of cigarettes, which can be used to evaluate the comprehensive performance of cigarettes. Cigarette paper plays an important role in the coagulation performance of cigarettes.

At the same time, in the process of cigarette smoking, the frequent ash falling and flying ash of cigarette cause the phenomenon of burning cone falling off seriously, which not only pollutes the environment, but also causes consumers and forced smokers to feel uncomfortable and disgusted with the environment, affects consumers' loyalty to the cigarette brand, and even brings some security risks[10-13]. Meanwhile, with the development of cigarette technology, the continuous improvement of consumption level and quality, consumers' requirements for cigarette quality are also constantly improving. The attention and selection of cigarette products are gradually expanded from taste, price, packaging and other aspects to more factors. The ash state after cigarette combustion is more and more valued by consumers due to its intuitiveness[14-19].

In recent years, research on cigarette pack ash has been carried out in the tobacco industry, mainly including two aspects: performance research and detection method research[20-22]. The feasibility and accuracy of the detection method is an important prerequisite for the study of cigarette ash performance[23-27]. Therefore, it is of great significance for the effective and objective measurement of cigarette combustion ash performance. At present, the measurement and expression method of cigarette pack ash usually adopts the method of quantitative characterization by comparing the crack area of burning cigarette ash column with the total area of the surface after the image of a single cigarette of the test sample is taken under the condition of static combustion, and then processed by the relevant image software. The above method, on the one hand, does not collect image data under the standard dynamic puff condition, on the other hand, in the process of image collection, only one side image of the test sample can be collected. Due to the influence of factors such as the difference of tobacco density, the end of cigarette paper clasp, and the split ash column of cigarette ash sheet, the image of cigarette ash sheet can be collected on one side It is difficult to accurately reflect the objectivity of the test sample, which causes the test result to deviate from the real value seriously.

2. EXPERIMENTAL MATERIALS AND METHODS

2.1. Experimental materials and instruments

The experimental sample is a uniform specification cigarette purchased in the market, which is measured after being balanced under temperature and humidity. 15 cigarettes are taken as a group, and the average value is taken.

In the experiment, a self-developed device for measuring the ash performance of cigarette combustion package with full vision is used, including a cigarette holder, a full vision image acquisition device, a cigarette puff system device and a processing device. The cigarette holder is used to hold cigarette, and the full vision image acquisition device includes LED light source, multiple groups of cameras, image for calculating the ash index of test sample collection, through three groups of cameras uniformly perpendicular to the smoking state of the burning cigarette, through a single cigarette three side simultaneous image acquisition mode, to achieve the three side full vision collection of the test sample burning ash column. The end of cigarette holder is connected with the pipeline of cigarette puff system to provide different puff modes. The LED light source is applied to ensure the requirements of shooting test cigarette image collection and lighting. Multiple groups of cameras should be evenly distributed on the test cigarette and kept vertical to the cigarette.

2.2. Measurement method of cigarette ash condensation index

The test results of determining the performance of cigarette combustion package are specifically characterized by cigarette combustion condensation index, which is the proportion of the area of the
unblemished part of the ash column to the overall area after cigarette combustion, and is calculated according to formula (1),

\[
AI = (1 - \frac{S_r}{S_t}) \times 100\%
\]  

where, AI - tuff index, Sr - crack area of ash column, St - overall area of ash column. The higher the agglomerating index is, the better the performance of cigarette samples is.

2.3. Measurement method of deviation degree of cigarette ash column
In the process of cigarette combustion, the ash wrapped by cigarette paper will deviate from the original vertical cigarette at a certain angle. Therefore, this paper defines the combustion deviation angle \( \alpha \) as follows,

\[
\alpha = \frac{180}{\pi} \times \left\{ \frac{\pi}{2} - \cos^{-1}\left(\frac{x}{y}\right) \right\}
\]

Where, \( x \) is the length of BD segment, \( y \) is the length of BC segment.

According to the combustion picture, the correlation distance of different smoke after combustion is measured, and the deviation angle is calculated according to the formula.

3. RESULTS AND DISCUSSION

3.1. Comparative analysis of three groups of camera pictures
It can be seen from Figure 1 that different cameras take different pictures of smoke burning due to different shooting angles, and the indexes calculated according to the pictures are different, such as the ash condensation index, the width of carbon line and the ash holding rate. The traditional test method only uses one-sided photo taking method, which cannot completely reflect the ash condensation index of smoke.

3.2. Comparative analysis of the condensation index under different puff modes
It can be seen from the experimental data that the average value of camera 3# is the closest to the average value of the three cameras. Under different puff modes, the condensation index of cigarette has little change, indicating that the condensation effect of cigarette paper is relatively stable and the overall performance is better. The mean value of ISO puff mode is the lowest of 93.4, while that of deep puff in Canada is slightly higher, 94.4, and that of Massachusetts is the highest, 94.9. In the ISO puff mode, the maximum value is 95.7, the minimum value is 90.0, the coefficient of variation is 0.9%, in the Canada deep puff mode, the maximum value is 96.5, the minimum value is 90.8, the coefficient of variation is 1.1%, in the Massachusetts puff mode, the maximum value is 97.2, the minimum value is 92.7, and the coefficient of variation is 0.7%.

Figure 1. Comparison of the appearance of cigarette agglomerate by three side photography
TABLE 1. COMPARISON OF ASH COLUMN DEVIATION UNDER DIFFERENT PUFF MODES

| Puff mode       | ISO puff | Canada deep puff | Massachusetts puff |
|-----------------|----------|------------------|--------------------|
| Camera 1#       | 93.6     | 93.6             | 94.8               |
| Camera 2#       | 93.3     | 95.1             | 95.1               |
| Camera 3#       | 93.4     | 94.4             | 94.8               |
| Max value       | 95.7     | 96.5             | 97.2               |
| Min value       | 90.0     | 90.8             | 92.7               |
| Total average   | 93.4     | 94.4             | 94.9               |
| CV average (%)  | 0.9      | 1.1              | 0.7                |

3.3. Comparative analysis of deviation degree of ash column under different puff modes

It can be seen from the experimental data that the deviation degree of the cigarette's ash column changes greatly in different puff modes, and the mean value of the results varies greatly in different lens measurements, especially in the Massachusetts puff mode, the mean value difference between lenses is up to 1.1. The minimum value of the three puff modes is 0, but the maximum value is different. In ISO puff mode, the maximum value is 19.7, in Canada puff mode, the maximum value is 11.9, in Massachusetts puff mode, the maximum value is 7.7. It is particularly noteworthy that the mean value of the variation coefficient of the deviation degree of the ash column reaches 50%, which indicates that the variation of the deviation degree of each measurement is particularly large, and the deviation degree directly determines the probability of the accidental falling of the ash in the actions such as popping the ash in the process of smoking the cigarette. It is worth further in-depth study. It is necessary to comprehensively measure the performance of the cigarette ash performance.

TABLE 2. COMPARISON OF ASH COLUMN DEVIATION UNDER DIFFERENT PUFF MODES

| Puff mode       | ISO puff | Canada deep puff | Massachusetts puff |
|-----------------|----------|------------------|--------------------|
| Camera 1#       | 3.6      | 5.0              | 4.3                |
| Camera 2#       | 4.5      | 5.2              | 3.2                |
| Camera 3#       | 4.5      | 4.7              | 4.1                |
| Max value       | 19.7     | 11.9             | 7.7                |
| Min value       | 0        | 0                | 0                  |
| Total average   | 4.2      | 5.0              | 3.9                |
| CV average (%)  | 53.2     | 49.2             | 53.5               |

4. CONCLUSION

Different cameras take different pictures of smoke burning due to different shooting angles, and the indexes calculated according to the pictures are different, such as the ash condensation index, the width of carbon line and the ash holding rate. The traditional test method only uses one-sided photo method, which can not completely reflect the ash condensation index of smoke. Among the three shots, the closest to the average value is the average data of camera 3#. Under different puff modes, the condensation index of cigarette has little change, indicating that the condensation effect of cigarette paper is relatively stable and the overall performance is better. Under different puff modes, the deviation degree of cigarette ash column changes greatly, and the mean value of the results under different puff mode varies greatly, especially under the Massachusetts puff mode, the mean value difference between lenses is up to 1.1. The mean value of the coefficient of variation of the degree of deviation of the ash column is 50%, which shows that the variation of the degree of deviation of each measurement is very large.

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