

Effects of Particle Size Distribution on Cigarette Physical Quality

Reporter: Shen Xiaofeng

**Company: 1. Zhengzhou Tobacco Research Institute of CNTC
2. Kunming Cigarette Factory of Hongyun Tobacco (Group) Co., LTD.**



Contents

- Introduction
- Material and equipment
- Method
- Result and discussion
- Conclusions
- Acknowledgement

Zhengzhou Tobacco Research Institute, CNTC

1. Introduction

- The effects of **partial** particle size distribution (PSD) on the cigarette physical properties have been reported, and few reports regarding its effects on **stabilities** of cigarette physical properties.
- This work objective was to evaluate the effects of **integral** PSD on the cigarette physical quality (properties and their **stabilities**).

2. Material and equipment

Material

four different blends:

A contains no stem or DIET, and B, C, D contains stem, DIET or tobacco sheet.

2. *Material and equipment*

□ *Equipment*

- **Retsch AS400 shaker (mesh aperture is: 8.00, 6.70, 5.60, 4.75, 4.00, 3.35, 2.80, 2.00, 1.40 and 0.71 mm)**
- **YQ-2 shaker (mesh aperture is: 3.35, 2.50 and 1.00 mm)**
- **PL3001-S Mettler electronic balance**
- **Protos1-8 maker**
- **SODIMAT cigarette physical properties tester**
- **TEWS cigarette moisture and density tester**
- **YDX- II cigarette ends fallout tester**

Zhengzhou Tobacco Research Institute, CNTC

3. *Method*

General Procedure

- **Cut tobacco sample making**
- **Cigarette making**
- **Test**

Data Processing

- **Calculating more size ranges**
- **Grey incidence analysis**

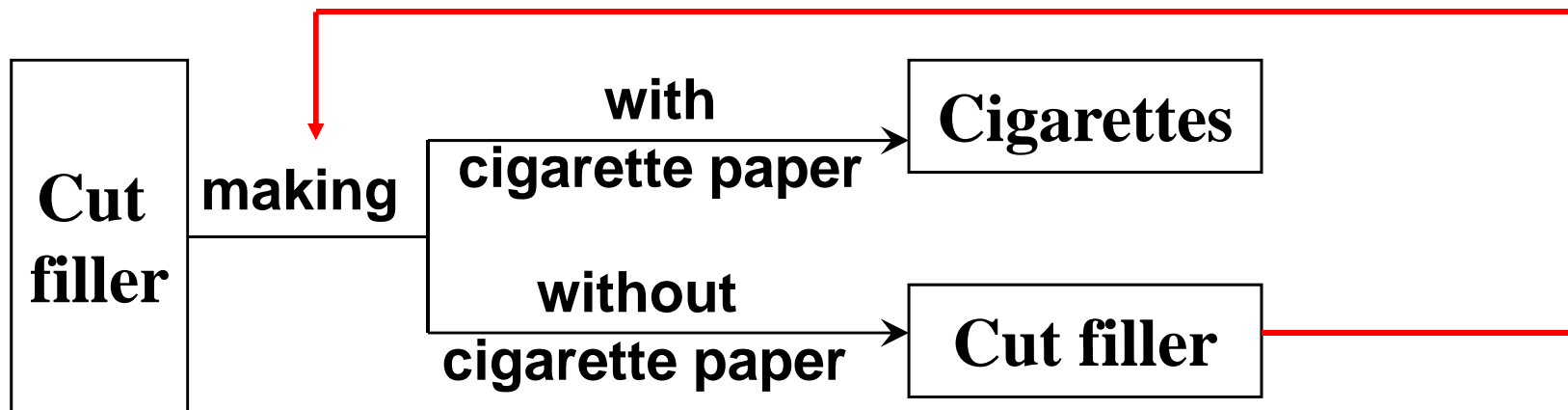
General Procedure

1) Cut tobacco sample making

- ***Blend A:*** 150 kg after-drying cut tobacco, the fractions longer than 3.35 mm (sieved by YQ-2 shaker)
- ***Blend B, C, D:*** 120 kg after-mixing cut tobacco for each kind

General Procedure

2) Cigarette making (multiple passing of a same blend)



At 1st pass, the designed value of cigarette weight was adjusted according to its hardness under the qualified loose ends

A: 6 passes
B,C,D: 4 passes

General Procedure

3) Test

- 600g cut filler was sieved by Retsch AS400 shaker
- 2000 cigarettes were used. After testing the *weight*, we picked out the cigarettes from each pass based on the average weight of all the passes to eliminate the effects of weight on the other properties. Then we measured their *density, draw resistance, hardness and ends fallout* .

Data Processing

1) Calculating more size ranges

- PSD can be described as formula (1) :

$$F = 100 - 100 \exp(-ad^n) \quad (1)$$

F- cumulative fraction; **d** - mesh aperture;

a, **n** – parameters, obtained by data regression

- The fractions between any two sizes could be calculated according to formula (2):

$$f = F_1 - F_2 \quad (2)$$

Data Processing

2) Grey incidence analysis

- To analyze the contribution of several sub-factor to the main factor
- *Connection coefficient*: the measurement of the connection degree between the factors
- *Connection polarity*: the positive value means that the sub-factor **increases** the main factor and the negative value means the opposite side.

4. *Result and discussion*

- The grey incidence analysis was conducted between the calculated fractions in 13 size ranges of sample A, B, C and D (sub-factors) and the cigarette physical properties and their stabilities (main factor), calculating separately the *connection polarity* and *coefficient*.

Table 1 grey incidence analysis of sample A

Size range (mm)	Cigarette physical properties					Standard deviation			
	Weight	Cigarette density	Draw resistance	Ends fallout	Loose ends	Draw resistance	Weight	Cigarette density	Hardness
>6.70	-0.599	-0.593	-0.597	-0.581	-0.529	-0.618	0.585	0.529	0.614
5.60-6.70	-0.687	-0.681	-0.685	-0.611	-0.564	-0.680	0.645	0.618	0.681
4.75-5.60	-0.749	-0.745	-0.744	-0.643	-0.604	-0.735	0.711	0.689	0.756
4.00-4.75	-0.814	-0.810	-0.810	-0.678	-0.649	-0.802	0.798	0.761	0.856
3.35-4.00	-0.888	-0.886	-0.885	-0.708	-0.698	-0.860	0.865	0.822	0.917
2.80-3.35	-0.966	-0.966	-0.960	-0.732	-0.747	-0.911	0.872	0.833	0.884
2.50-2.80	0.974	0.972	0.972	0.750	0.781	0.910	-0.854	-0.799	-0.831
2.00-2.50	0.926	0.923	0.925	0.768	0.783	0.896	-0.836	-0.759	-0.793
1.70-2.00	0.889	0.886	0.889	0.785	0.790	0.883	-0.807	-0.729	-0.763
1.40-1.70	0.868	0.864	0.867	0.796	0.794	0.859	-0.790	-0.711	-0.745
1.00-1.40	0.849	0.845	0.845	0.807	0.794	0.835	-0.775	-0.696	-0.726
0.71-1.00	0.830	0.826	0.826	0.815	0.791	0.816	-0.758	-0.686	-0.709
<0.71	0.817	0.813	0.813	0.817	0.784	0.804	-0.744	-0.675	-0.697

Connection polarity : 2.80mm is a critical size. If fractions of the size longer than it increase, weight, density, draw resistance, ends fallout and loose ends will decrease, however, the standard deviation of weight and density increase accordingly.

Table 1 grey incidence analysis of sample A

Size range (mm)	Cigarette physical properties					Standard deviation			
	Weight	Cigarette density	Draw resistance	Ends fallout	Loose ends	Draw resistance	Weight	Cigarette density	Hardness
>6.70	-0.599	-0.593	-0.597	-0.581	-0.529	-0.618	0.585	0.529	0.614
5.60-6.70	-0.687	-0.681	-0.685	-0.611	-0.564	-0.680	0.645	0.618	0.681
4.75-5.60	-0.749	-0.745	-0.744	-0.643	-0.604	-0.735	0.711	0.689	0.756
4.00-4.75	-0.814	-0.810	-0.810	-0.678	-0.649	-0.802	0.798	0.761	0.856
3.35-4.00	-0.888	-0.886	-0.885	-0.708	-0.698	-0.860	0.865	0.822	0.917
2.80-3.35	-0.966	-0.966	-0.960	-0.732	-0.747	-0.911	0.872	0.833	0.884
2.50-2.80	0.974	0.972	0.972	0.750	0.781	0.910	-0.854	-0.799	-0.831
2.00-2.50	0.926	0.923	0.925	0.768	0.783	0.896	-0.836	-0.759	-0.793
1.70-2.00	0.889	0.886	0.889	0.785	0.790	0.883	-0.807	-0.729	-0.763
1.40-1.70	0.868	0.864	0.867	0.796	0.794	0.859	-0.790	-0.711	-0.745
1.00-1.40	0.849	0.845	0.845	0.807	0.794	0.835	-0.775	-0.696	-0.726
0.71-1.00	0.830	0.826	0.826	0.815	0.791	0.816	-0.758	-0.686	-0.709
≤0.71	0.817	0.813	0.813	0.817	0.784	0.804	-0.744	-0.675	-0.697

Connection coefficient: The closer to a given size, the bigger the connection coefficient is. For different physical properties and stabilities, this size is different.

Table 2 grey incidence analysis of sample B

Size range (mm)	Cigarette physical properties						Standard deviation		
	Weight	Cigarette density	Draw resistance	Hardness	Ends fallout	Loose ends	Weight	Cigarette density	Draw resistance
>6.70	-0.579	-0.582	-0.577	0.574	-0.597	-0.567	0.575	0.580	0.618
5.60-6.70	-0.624	-0.627	-0.630	0.633	-0.618	-0.582	0.650	0.628	0.667
4.75-5.60	-0.676	-0.679	-0.681	0.688	-0.651	-0.618	0.766	0.689	0.717
4.00-4.75	-0.743	-0.747	-0.746	0.759	-0.688	-0.660	0.813	0.770	0.732
3.35-4.00	-0.820	-0.823	-0.819	0.842	-0.726	-0.705	0.793	0.865	0.760
2.80-3.35	-0.894	-0.896	-0.895	0.915	-0.762	-0.748	0.754	0.923	0.805
2.50-2.80	-0.944	-0.947	-0.950	0.956	-0.787	-0.780	0.718	0.932	0.855
2.00-2.50	0.965	0.969	0.991	-0.946	0.812	0.813	-0.698	-0.895	-0.867
1.70-2.00	0.928	0.934	0.940	-0.895	0.837	0.846	-0.688	-0.865	-0.851
1.40-1.70	0.892	0.898	0.905	-0.862	0.855	0.871	-0.661	-0.833	-0.836
1.00-1.40	0.859	0.865	0.872	-0.831	0.876	0.901	-0.634	-0.803	-0.822
0.71-1.00	0.833	0.838	0.846	-0.807	0.896	0.930	-0.613	-0.779	-0.813
<0.71	0.817	0.823	0.831	-0.792	0.911	0.942	-0.600	-0.765	-0.809

Table 3 grey incidence analysis of sample C

Size range (mm)	Cigarette physical properties						Standard deviation		
	Weight	Cigarette density	Draw resistance	Hardness	Ends fallout	Loose ends	Weight	Cigarette density	Draw resistance
>6.70	-0.614	-0.553	-0.555	0.562	-0.717	-0.494	0.511	0.548	0.622
5.60-6.70	-0.688	-0.623	-0.623	0.638	-0.617	-0.555	0.599	0.629	0.708
4.75-5.60	-0.760	-0.702	-0.698	0.723	-0.665	-0.591	0.696	0.722	0.761
4.00-4.75	-0.833	-0.787	-0.779	0.818	-0.712	-0.625	0.809	0.828	0.807
3.35-4.00	-0.904	-0.875	-0.861	0.918	-0.757	-0.654	0.873	0.939	0.836
2.80-3.35	-0.968	-0.957	-0.937	0.978	-0.796	-0.678	0.887	0.911	0.865
2.50-2.80	0.978	0.971	0.987	-0.948	0.822	0.694	-0.849	-0.899	-0.859
2.00-2.50	0.956	0.943	0.971	-0.915	0.837	0.708	-0.824	-0.876	-0.844
1.70-2.00	0.930	0.909	0.939	-0.882	0.846	0.720	-0.807	-0.852	-0.825
1.40-1.70	0.914	0.889	0.918	-0.862	0.851	0.727	-0.800	-0.833	-0.815
1.00-1.40	0.901	0.873	0.902	-0.847	0.853	0.734	-0.796	-0.817	-0.808
0.71-1.00	0.895	0.865	0.893	-0.838	0.852	0.737	-0.799	-0.808	-0.805
<0.71	0.896	0.865	0.894	-0.839	0.848	0.737	-0.806	-0.808	-0.807

Table 4 grey incidence analysis of sample D

Size range (mm)	Cigarette physical properties						Standard deviation		
	Weight	Cigarette density	Draw resistance	Hardness	Ends fallout	Loose ends	Weight	Cigarette density	Draw resistance
>6.70	-0.552	-0.544	-0.544	0.541	-0.603	-0.577	0.506	0.537	-0.620
5.60-6.70	-0.622	-0.613	-0.613	0.612	-0.658	-0.576	0.631	0.620	-0.698
4.75-5.60	-0.697	-0.688	-0.687	0.690	-0.705	-0.626	0.733	0.712	-0.719
4.00-4.75	-0.780	-0.771	-0.769	0.778	-0.752	-0.677	0.757	0.817	-0.745
3.35-4.00	-0.869	-0.860	-0.856	0.873	-0.796	-0.727	0.748	0.894	-0.785
2.80-3.35	-0.942	-0.937	-0.926	0.947	-0.835	-0.772	0.756	0.902	-0.849
2.50-2.80	0.978	0.970	0.964	-0.949	0.862	0.805	-0.716	-0.877	0.878
2.00-2.50	0.945	0.947	0.953	-0.900	0.888	0.837	-0.692	-0.840	0.853
1.70-2.00	0.898	0.900	0.905	-0.856	0.912	0.867	-0.678	-0.799	0.828
1.40-1.70	0.871	0.873	0.877	-0.830	0.929	0.889	-0.672	-0.775	0.815
1.00-1.40	0.847	0.848	0.851	-0.807	0.947	0.913	-0.664	-0.753	0.804
0.71-1.00	0.830	0.831	0.834	-0.791	0.962	0.933	-0.649	-0.738	0.797
<0.71	0.822	0.823	0.825	-0.784	0.970	0.945	-0.641	-0.731	0.795

Comprehensive analysis of *connection polarity*

The critical size is different for the four blends.

For blend A, C, D, it is 2.80mm.

For blend B, it is 2.50mm.

Table 5 Comprehensive analysis of *connection coefficient*

Parameters		Given size(mm)				Size range of greatest influence (mm)			
		A	B	C	D	A	B	C	D
Cigarette physical properties	Weight	2.80	2.50	2.80		2.50-2.80	2.00-2.50	2.50-2.80	
	Cigarette density			2.80				2.50-2.80	
	Draw resistance			2.80				2.50-2.80	
	Ends fallout	0.71		1.40	0.71	<0.71		1.00-1.40	<0.71
Loose ends	1.40	0.71	1.00	1.00-1.40		<0.71	0.71-1.00		
Standard deviation	Weight	3.35	4.75	3.35	4.75	2.80-3.35	4.00-4.75	2.80-3.35	4.00-4.75
	Cigarette density		2.80	4.00	3.35		2.50-2.80	3.35-4.00	2.80-3.35
	Draw resistance		2.50	3.35	2.80		2.00-2.50	2.80-3.35	2.50-2.80

The critical size is different for the four blends.

The size in the range of 2.00-4.75mm will affect greatly the weight, density, draw resistance and their stability, and the size smaller than 1.40mm affects greatly on ends fallout and loose ends.

5. Conclusions

- 1) There was a critical size(2.80&2.50mm) for the *connection polarity*. If the fractions above this size increase, weight ,density, draw resistance, ends fallout and loose ends decreased, however, the stabilities of weight and density got worse.**

5. Conclusions

- 2) There was a maximum connection coefficient between particle size and cigarette physical quality. The closer to a given size, the greater the connection coefficient was. For different cigarette physical properties the size was different. Cigarette physical quality was greatly influenced by particle size in a given range.**

5. Conclusions

- 3) To manufacture a cigarette of good physical quality demands the majority of cut filler to fall in a given size range (**2.00-4.75mm**) and minimize the fraction of shorter strands (**less than 1.40mm**).

6. Acknowledgement

- My supervisors: Luo Dengshan & Du Jinsong**
- Hongyun Tobacco Group, Yunnan, China**
- Longyan Cigarette Factory, Fujian, China**

Zhengzhou Tobacco Research Institute, CNTC

Thanks for Your Attention!

