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Evaluation and Research on Cut Stem Uniformity Based on Principal Component Analysis

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Abstract. In order to improve the stability and uniformity of cut stem module quality in the process of blending cut tobacco, 15 influencing factors were selected from the two dimensions of cut stem morphology and cut stem structure, and the principal component analysis was used to establish a comprehensive evaluation model for cut stem uniformity, and the cut stem structure was characterized and evaluated by combining the cut stem width distribution interval. Five principal components are extracted according to the principle that the cumulative contribution rate is greater than 80%, and the model score coefficient is calculated according to the eigenvalue. The results showed that the principal component comprehensive score of cut stem uniformity of G01 and G05 batches was lower than that of the other three batches, and the proportion of cut stem with cut stem width>1.8mm reached more than 65%. The shape of cut stem was flake, and the cut stem uniformity was poor. The characteristic width of G02 and G03 batches of cut stem filaments is about 1.5mm, and the morphology of cut stem is filiform. The comprehensive score of 5 batches of cut stem is consistent with the analysis result of the proportion of cut stem width distribution, which indicates that the principal component analysis method can quickly and accurately evaluate the uniformity of cut stem, providing a new idea for qualitative analysis of cut stem quality.

Keywords. Structure of cut stem, Tobacco stem morphology, Principal component analysis, Uniformity evaluation

1. Introduction

As one of the important raw materials of cigarette products, cut stem has strong filling and flammability, which can improve the burning performance of cigarettes and reduce mainstream smoke emission [1-3].With the requirement of "reducing harmful components in the cigarette " in the industry and the improvement of the technological level of cut tobacco processing, the proportion of cut stem in the blending of formula cut tobacco has gradually increased [4]. However, the size of cut stem produced by the traditional process of making cut stem is relatively large, which leads to the problem of poor stability of physical indicators of cigarettes after being used in medium and fine cigarettes, limiting the application of cut stem [5]. Therefore, an index for evaluating the structure of cut stem is needed to conduct qualitative evaluation on the use and applicability of cut stem. The uniformity of cut stem is an index to comprehensively

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evaluate the quality of cut stem, which is affected by the morphology, distribution and change trend of cut stem [6].At present, there are relatively few studies on the evaluation of cut stem uniformity, mainly focusing on the following aspects: first, the cut stem morphology is divided by image recognition technology, and the cut stem morphology characterization method is established. As He [6], Zhu et al.[7] establish the model and method of cut stem morphological uniformity coefficient and evaluation by using the image method to measure and calculate the cut stem morphological index. And the morphological characteristics of lamellar to filamentous cut stem were characterized. The cut tobacco quality analysis method based on visual morphological feature detection proposed by Zhang et al.[8]. Based on visual morphological feature detection, the length of cut tobacco is calculated by using Hough transform principle of skeleton extraction, and the average measurement time of cut tobacco width uniformity is less than 11s (per 0.01 kg) and the image processing time is less than 2.5s, which can meet the requirements of online detection of large quantities of cut tobacco; Li et al.[9] uses computer vision technology to divide the distribution interval of characteristic width of cut stem and define four forms of cut stem in combination with the interval of characteristic width ratio of cut stem. Second, research was carried out on the uniformity or consistency of cut tobacco in the process of blending. For example, Qi et al.[10]used the principal component analysis method to analyze the structural changes of cut tobacco before and after blending with different types of tobacco blending machines, calculate the intercept of each quality point, and evaluate the quality difference between products; Dong et al.[11]the homogeneity in blending of microwave cut stalks was evaluated by establishing a prediction model of near infrared spectroscopy. The third is to study the quality characteristics of stem shreds prepared under different processing conditions and their impact on the quality of finished cigarettes. For example, George Fazekas[12] provided a novel technology for the processing of tobacco stems, which particles having superior bulk filling capacity, cigarette filling index and end stability, compared to the process of rolling and cutting, shredding produces; Li et al[13] studied the the effects of STS/HT + fluidized bed/drum drying on the utilization rate of cut tobacco, the mainstream smoke and sensory organs, which provided data support for improving the compatibility and component uniformity of cut tobacco and cut stem; Xia et al[14]compared the differences of chemical composition, sensory filament rate and other indexes of cut stems between conventional drying and medium and short wave infrared drying. The filling value, filament rate of cut stem dried by medium and short wave infrared drying is lower than that of conventional cut stem, but the structure of cut stem tends to be consistent, which provides data support for new infrared drying and auxiliary equipment. The above researches mainly aim at a specific index or process. Because the production process of cut stem is affected by many factors, the uniformity of blended cut stem is directly related to the width of tobacco stem, cut stem and other indicators. Integrating the information related to the structure of cut stem in the production process has an important guiding significance for the quality control of cut stem.

Principal component analysis is to try to combine the original indicators into a new set of unrelated comprehensive indicators to replace the original indicators, which can solve the problem of indicator interaction and the conflict between the scores of individual characteristic compounds. It is mainly used in quality evaluation, feature extraction, image processing and classification [15-17]. In the cigarette industry, It has been applied in the evaluation and control of cigarette raw material quality, cigarette formula, cigarette sensory evaluation and other aspects [18]. This study is mainly aimed at the multi index representation of cut stem uniformity evaluation after flavoring. With the help of the principal component analysis method, the cut stem uniformity evaluation model combining the stem structure of incoming tobacco and cut stem structure was established. Combined with the characterization of cut stem width distribution interval, the accuracy of cut stem uniformity evaluation was achieved, providing technical support for the fine control of cut stem making; At the same time, through the evaluation of cut stem structure uniformity, feedback the control of stem making process index parameters, which has practical guiding significance for the improvement of cigarette processing and stem product process.

2. Materials and Methods

2.1. Materials and Instruments

Test materials: general stem and general cut stem (provided by Zhangjiakou Cigarette Factory)

Test instruments: TPI150 - II tobacco digital projector (Anhui Institute of Optics and Precision Machinery, Chinese Academy of Sciences), RetschAS400 sieve (Germany Retsch Company), 3002/02 electronic balance (sensitivity 0.01g, Switzerland METTLER-TOLEDO Company)

2.2. Test Method

2.2.1 Sample Preparation

General stem sampling: randomly select 20 batches of incoming tobacco stems for sampling. According to the production sequence number (S1- S20), randomly select 1000g ± 100g samples from the incoming packed stems. Manually select the stems and stems containing tobacco stems from the stems. Weigh and record with an electronic balance with a sensitivity of 0.1g. Select stems with a length of more than 20mm, weigh and record.

General cut stem sampling: corresponding to 20 batches of incoming tobacco stem sampling, sample general cut stem at the outlet of stem flavoring. After the production is stable, sample 5 times for each batch, with a sampling interval of 1 min and a sampling volume of 400g. Reduce the sample to (100.0g ± 10.0g) for testing by quartering method.

2.2.2 Tobacco Stem Shape Detection

According to the "Cigarette Process Specifications" (new edition), including the method of measuring the stem turning rate, the stem turning rate and long stem rate of the sample are calculated as follows: $g_i = \frac{g_i}{g} \times 100\%$

In the formula: g_i- stem percentage or long stem percentage (%);

g_i- weight of tobacco stem and stem containing tobacco stem (g) or weight of long stem with a length more than 20cm (g);

g -- total weight of sample (g).

2.2.3 Determination of Cut Stem Structure

The structure of cut stem was determined according to the national standard YCT351-2010 Determination of Shredded Tobacco Fragmentation in Coiling Process. Retsch AS400 sieve was used to screen according to the size of screen aperture. The screen aperture includes: 8.00mm, 6.70mm, 5.60mm, 4.75mm, 4.00mm, 3.35mm, 2.80mm, 2.00mm, 1.40mm and 0.71mm;Operating parameters: screening duration: 4 min, speed: 230 r/min, screening mode: clockwise - counterclockwise - clockwise - counterclockwise (change the direction of the screener every 1 min), then weigh the weight of the upper stem of each layer of screen mesh, use the least square method to fit the stem size distribution equation, and obtain the characteristic size (1) and uniformity coefficient (2).

Distribution equation of stem size:

$$F(\mathrm{x}) = 100e^{(-aq^{p})} \tag{1}$$

Find a, p and substitute them into the equation:

$$d = e^{\left[\frac{\ln(\ln 2) - \ln a}{p}\right]} \tag{2}$$

In the formula, F(x) - cumulative mass fraction of stem wire on each sieve screen,%;
a -- Characteristic size of cut stem;
p -- uniformity coefficient of cut stem distribution;
q -- screen aperture, mm.

2.2.4 Measurement of Cut Stem Width

According to the requirements of ISO20193:2019 Determination of Cut Tobacco Width of Tobacco and Tobacco Products, 20 cut stems were randomly selected from 50g cut stem and pasted on the sample holder in turn. After the sample was placed, it was immediately put on the tobacco digital projector for testing. The test results of single cut stem width were recorded to the nearest 0.01mm. Each sample was repeated three times.

2.2.5 Regional Distribution of Cut Stem Width

Based on the morphological characterization method of cut stem proposed in the literature[6、9], the characteristic width of cut stem: filiform (0.6~1.2mm), near filiform (0.9~1.5mm), near flake (1.2~1.8mm) and flake (>1.8mm), the size distribution and proportion of cut stem width were statistically analyzed.

2.3. Construction of Principal Component Analysis and Evaluation System for Cut Stem Uniformity

2.3.1 Indicator Selection

Due to the inconsistency of the length and short of the incoming tobacco stems, the stem thickness and the percentage of stem turning in the production line of cut stem making, the morphological difference of cut stem is large and the uniformity is inconsistent. The uniformity of cut stem is a method to comprehensively evaluate the quality of cut stem, which mainly shows the morphological and appearance characteristics of cut stem. It is affected by the shape of incoming tobacco stem, the technology of making cut stem, process parameters and other factors, and there is a certain correlation between various indicators. In view of the current production process, the production equipment parameters and process standards are relatively fixed. Two major indicators of tobacco stem shape and cut stem structure were selected for specific evaluation system construction, while， tobacco stem shape include: A_1 stem turning rate,A_2:long stem rate; cut stem structure include: B_1:>8.00mm, B_2:6.70~8.00mm, B_3:5.60~6.70mm, B_4:4.75~5.60mm, B_5:4.00~4.75mm, B_6:3.35~4.00mm, B_7:2.80~3.35mm, B_8:2.00~2.80mm, B_9:1.40~2.00mm, B_{10}:0.71~1.40mm, B_{11}:<0.71mm, B_{12}feature size, B_{13} uniformity coefficient.

2.3.2 Research Method

The cut stem structure is one of the important indicators of the cut stem quality. The cut stem structure before cutting the stem is closely related to the cut stem uniformity in the production process. The cut stem form (long stem rate, stem turning rate) and cut stem structure (L_1:>8.00mm, L_2: 6.70~8.00mm, L_3:5.60~6.70mm, L_4:4.75~5.60mm, L_5:4.00~4.75mm, L_6:3.35~4.00mm, L_7: 2.80~3.35mm, L_8:2.00~2.80mm, 15 index factors such as L_9:1.40~2.00mm, L_{10}:0.71~1.40mm, L_{11}:<0.71mm, uniformity coefficient, characteristic size), and there is a certain correlation between the long stem rate, stem turn rate, and each size of cut stem structure. In order to reduce the correlation between indexes, reduce the workload of data analysis, and better evaluate the cut stem uniformity. The principal component evaluation model is constructed according to the classified cut stem uniformity evaluation system. The specific analysis process is as follows:

(1) Standardization of sample data

The form index of tobacco stem and the size of cut stem are the proportion (%) of each observation index respectively, and the characteristic size represents the specific size value (mm). There are dimensional and order of magnitude differences between the indexes. The original data set is standardized into a data set with mean value of 0, variance of 1 and close to the standard normal distribution through dimensionless standardization. Calculation formula (3):

$$x^* = \frac{x-u}{\sigma} \quad (3)$$

Where, x: original data, m: mean value, s: standard deviation

(2) Extract main components

The original data is expressed as an n*p matrix, whose corresponding eigenvalue λi is the main component variance contribution, and the orthogonalized unit eigenvector a_i is the variance contribution rate, $a_i = \frac{\lambda_i}{\sum_{i=1}^{p} \lambda_i}$

When the cumulative contribution rate $\sum a_i$ >At 80%, it is considered that the information is sufficient to reflect the original variables; The size of a_i indicates the ability of the principal component to respond to information, and the principal component can be extracted according to its value.

(3) Build evaluation model

According to the principle of determining the principal components: the characteristic value is greater than 1 and the number of principal components is less than the number of original analysis indicators, m indicator variables are selected as the principal components to replace the original p indicators, so that m principal components can be comprehensively analyzed, a comprehensive evaluation function F of cut stem uniformity can be created, and the comprehensive value of cut stem uniformity of each batch can be calculated and sorted. The evaluation function is shown as follows:

$$\mathrm{F_i} = (a_{11} + a_{12} + a_{13} + \ldots\ldots a_{1n}) \times X_1 \times Z_1 + (a_{21} + a_{22} + a_{23} + \ldots\ldots a_{2n}) \times X_2 \times Z_2 \\ \ldots\ldots + (a_{p1} + a_{p2} + a_{p3} + \ldots\ldots a_{pn}) \times X_p \times Z_m$$

Where: a_{11}, a_{12}, a_{13},......,A_{pn} is the component score coefficient; Z_1, Z_2, Z_3,...,Z_m is the contribution rate of extracted variance; Let $X=(X_1, X_2,...,X_p)$ is a P-dimensional random variable, X_1, X_2, X_3......respectively represent the indexes of cut stem uniformity: tobacco stem morphology indicators and cut stem structure indicators, m is the number of main components, $m<p$.

3. Results and Discussion

3.1. Principal Component Analysis Model for Cut Stem Uniformity Evaluation

3.1.1 Establish the Evaluation Model

Pearson correlation analysis was carried out for the indicators selected in 1.3.1. The results of correlation analysis showed that: L4: 4.75~5.60mm and L1:>8.00mm, L8: 2.00~2.80mm were extremely significantly negatively correlated (P<0.01), and were extremely significantly positively correlated with the uniformity coefficient and characteristic size (P<0.05). The cut stem turning rate and L7: 2.80~3.35mm were significantly positively correlated (P<0.01). The characteristic size and L9: 1.40~2.00mm,L10: 0.71-1.40mm were significantly negatively correlated (P<0.01), significantly positively correlated with the uniformity coefficient (P<0.01), and significantly correlated with L11:<0.71mm (P<0.05), indicating that there was a certain correlation between cut stem morphology and cut stem structure. Using SPSS software to conduct principal component analysis, select the principal components whose eigenvalues are greater than 1, and finally determine the number of principal components of the cut stem uniformity evaluation model to be 5 (Table 1), the variance contribution rates are 30.894%, 22.208%, 12.878%, 12.282%, 7.770%, and the cumulative variance contribution rate is 86.032% (>80%), which can represent most of the information of the data. Therefore, the first five common factors F1, F2, F3, F4,F5 were selected as new variable to reflect the level of cut stem uniformity.

Table 1. Correlation matrix eigenvalues and cumulative contribution rates of principal components.

Component	Initial characteristic value a			Extract sum of squares load		
	Total	% of variance	Cumulative%	Total	% of variance	Cumulative%
1	4.634	30.894	30.894	4.634	30.894	30.894

2	3.331	22.208	53.102	3.331	22.208	53.102
3	1.932	12.878	65.98	1.932	12.878	65.98
4	1.842	12.282	78.262	1.842	12.282	78.262
5	1.165	7.77	86.032	1.165	7.77	86.032

Table 2. Component coefficient matrix of principal components.

Variable	Component				
	1	2	3	4	5
Long stem rate	-0.349	0.521	0.211	-0.007	-0.340
Stem turning rate	-0.225	-0.354	0.636	0.360	0.457
L1	0.479	0.13	0.263	0.651	-0.344
L2	-0.134	0.641	0.373	0.457	0.330
L3	0.283	0.833	0.257	0.041	-0.097
L4	-0.905	0.039	0.205	-0.304	0.134
L5	0.061	-0.664	-0.259	0.557	0.048
L6	0.293	0.181	-0.524	0.014	0.708
L7	0.245	0.659	-0.62	0.016	-0.086
L8	0.648	0.159	-0.221	0.542	0.010
L9	0.551	-0.711	0.27	0.021	-0.158
L10	0.749	-0.252	0.267	-0.479	0.054
L11	0.644	0.287	0.415	-0.134	0.166
Uniformity coefficient	-0.796	-0.381	-0.251	0.313	-0.138
Feature size	-0.913	0.286	0.109	0.187	0.027

Extraction method: principal component analysis.
A Extract 5 components

It can be seen from Table 2 that the load of principal component 1 is higher on indicators such as L_4:4.75~5.60mm,L_8:2.00~2.80mm, L_9:1.40~2.00mm, L_{10}: 0.71~1.40mm, L_{11}:<0.71mm, uniformity coefficient and feature size, which are negatively correlated with L4: 4.75~5.60mm, uniformity coefficient and feature size; The load of principal component 2 was higher on the index of long stem rate, L_2: 6.70~8.00mm, L_3:5.60~6.70mm, L_5: 4.00~4.75mm, L_7:2.80~3.35mm, L_9:1.40~2.00mm, and was negatively correlated with L_5: 4.00~4.75mm, L_9: 1.40~2.00mm;The load of principal component 3 is higher on the index of stem percentage, L_6:3.35~4.00mm;Principal component 4 has higher load on L_1:>8.00mm, L_5:4.00~4.75mm, L_8: 2.00~2.80mm;The load of principal component 5 is higher on the index of stem percentage and L6: 3.35~4.00mm.The five principal component information includes 15 indicators that affect the uniformity of cut stem, which can be used as a new variable to reflect the uniformity level of cut stem.

According to the principal component coefficient method, the comprehensive evaluation model of cut stem uniformity is obtained. The principal component equations (4) are:

$$F1=-0.16X_1-0.10X_2+0.22X_3-0.06X_4+0.13X_5-0.42X_6+0.03X_7+0.14X_8+0.11X_9+0.30X_{10}+0.26X_{11}+0.35X_{12}+0.30X_{13}-0.37X_{14}-0.42X_{15}$$

$$F2=-0.29X_1-0.19X_2+0.07X_3+0.35X_4+0.46X_5+0.02X_6-0.36X_7+0.10X_8+0.36X_9+0.09X_{10}-0.39X_{11}-0.14X_{12}+0.16X_{13}-0.21X_{14}+0.16X_{15}$$

$$F3=0.15X_1+0.46X_2+0.19X_3+0.27X_4+0.18X_5+0.15X_6-0.19X_7-0.38X_8-0.45X_9-0.16X_{10}+0.19X_{11}+0.19X_{12}+0.30X_{13}-0.18X_{14}+0.08X_{15}$$

$$F4=-0.01X_1+0.27X_2+0.48X_3+0.34X_4+0.03X_5-0.22X_6+0.41X_7+0.01X_8+0.01X_9+0.40X_{10}+0.02X_{11}-0.35X_{12}-0.10X_{13}+0.23X_{14}+0.14X_{15}$$

$$F5=-0.32X_1+0.42X_2-0.32X_3+0.31X_4-0.09X_5+0.12X_6+0.04X_7+0.66X_8-0.08X_9+0.01X_{10}-0.15X_{11}+0.05X_{12}+0.15X_{13}-0.13X_{14}+0.03X_{15} \quad (4)$$

Taking the variance contribution rate of each principal component as the weight coefficient, the comprehensive evaluation model of cut stem uniformity is obtained:

$$F = \frac{30.894\%}{86.032\%} * F1 + \frac{22.208\%}{86.032\%} * F2 + \frac{12.878\%}{86.032\%} * F3 + \frac{12.282\%}{86.032\%} * F4 + \frac{7.77\%}{86.032\%} * F5 \quad (5)$$

Bring equation (4) into equation (5) to get the final evaluation equation (6) of cut stem uniformity:

$$F=0.008*X_1+0.049*X_2+0.143*X_3+0.158*X_4+0.163*X_5-0.124*X_6-0.042*X_7+0.068*X_8+0.053*X_9+0.142*X_{10}+0.008*X_{11}+0.062*X_{12}+0.166*X_{13}-0.165*X_{14}-0.067*X_{15} \quad (6)$$

3.1.2 Application of Cut Stem Uniformity Evaluation

Randomly select 5 batches of cut stem produced by the stem production line, and use the above model to evaluate the uniformity. Measure the rate of long stem and broken stem of the incoming tobacco stem, screen and measure the structure of cut stem, calculate the comprehensive score of the principal components of the uniformity of cut stem after each batch of flavoring, and evaluate the uniformity of cut stem according to the scores. The results are shown in Table 3, the comprehensive score of cut stem uniformity of the five batches is as follows: G02>G04>G03>G05>G01. The scores of G01 and G05 batches are lower, and the cut stem uniformity of G01 and G05 batches is lower than that of other batches, which means that the stem uniformity of G01 and G05 batches after flavoring is worse than that of G02, G03 and G04 batches. According to the morphology of the incoming tobacco stem and the structure of cut stem, it can be seen that the characteristic size of the cut stem of G01 batch and G05 batch is significantly higher than other batches, indicating that the score evaluation of the evaluation model is consistent with the cut stem morphology.

Table 3. Comprehensive scores of main components of cut stem uniformity.

Batch	Principal component 1 score	Principal component 2 score	Principal component 3 score	Principal component 4 score	Principal component 5 score	F value
G01	-2.990	0.090	0.003	1.311	-0.376	-0.930
G02	-2.503	-0.031	-0.104	1.386	-0.414	-0.762
G03	-2.498	-0.058	-0.104	1.399	-0.404	-0.764
G04	-2.484	-0.062	-0.117	1.404	-0.422	-0.763
G05	-2.734	0.083	-0.022	1.311	-0.369	-0.810

3.2. Results of Cut Stem Width Measurement

The measurement results of cut stem width showed that most of the cut stem morphology produced by the traditional process are flakes, and there is a problem of poor uniformity in cigarette blending. Therefore, the cut stem width should be as close to the leaf width as possible. The width of cut stem after flavoring in batches G01~G05 was measured by TPI150 - II tobacco digital projector, and the proportion of cut stem width of each size was calculated. The results (Figure 1) show that the proportion of cut stem width in G01 batch is the largest (nearly 70%) in the range of>1.8mm, and its characteristic width is also the highest. The cut stem morphology is mostly lamellar, and its uniformity is relatively poor; The proportion of G04 and G05 batches>1.8mm is the largest (50-65%), followed by 0.9~1.2mm and 1.2~1.5mm in width. The shape of stem filament is nearly lamellar, with general uniformity; The proportion of cut stem width 0.6~0.9mm, 0.9~1.2mm, 1.2~1.5mm, 1.5~1.8mm and>1.8mm in batches G02 and G03 is relatively uniform. The cut stem morphology is filiform and the cut stem is relatively uniform. The proportion distribution of cut stem width and cut stem uniformity are consistent with the order obtained by principal component analysis, which indicates that the principal component evaluation model of cut stem uniformity is suitable for the current cut stem production mode, and the accuracy of the model is good.

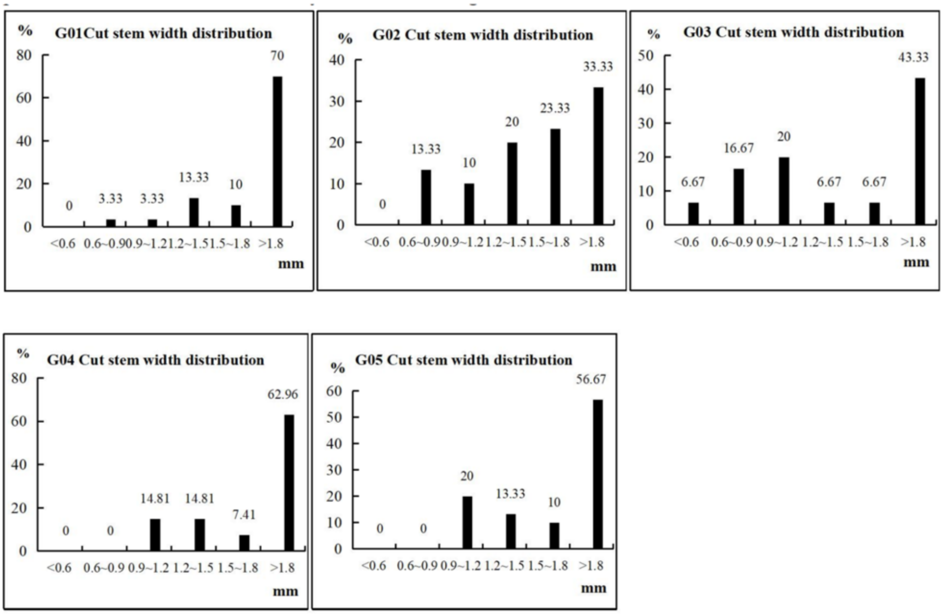

Figure 1. Results of cut stem width measurement and width distribution range in each batch.

4. Conclusion

In the production process of cut stem, the cut stem after flavoring will be directly applied to the subsequent blending process. The morphology of cut stem is affected by the length, thickness and processing parameters of the tobacco stem. The produced cut stem can be divided into broken, filiform, near filiform, near flake and flake. The width of flake cut stem is large, and the gap between the width of flake cut stem and that of leaf cut stem is obvious. If the width is uneven, the distribution of cut stem in cut tobacco will be unstable, and then affect the stability of the quality of finished cigarettes. By exploring the impact of the incoming tobacco stem shape, cut stem structure and size and other indicators on the cut stem uniformity in the production process of cut stem, multiple impact indicators were reduced to a few evaluation indicators, and the cut stem uniformity impact indicators were reduced from 15 to 5, reducing the workload. From the cut stem uniformity principal component evaluation model and the cut stem width distribution interval and proportion, the following conclusions were obtained: When the proportion of cut stem width>1.8mm is the largest, more than 50%, the whole morphology of cut stem presents flake shape,and the uniformity is poor. When the proportion of cut stem width distribution>1.8mm is less than 50%, and the sum of 1.2~1.5mm and 1.5~1.8mm proportions is greater than the proportion of>1.8mm, the whole morphology of cut stem presents filamentous, and its uniformity is good. When the cut stem width is distributed in six width ranges, and 0.6~0.9mm, 0.9~1.2mm proportion exceeds 1.2~1.5mm, the whole morphology of cut stem presents nearly filamentous, the distribution uniformity is general. To sum up, the established principal component evaluation model for cut stem uniformity is accurate and reliable, and can achieve quantitative and qualitative analysis of cut stem uniformity. Focusing on the goal of cut stem uniformity evaluation and optimization, the principal component analysis method can be used as a detection method for cigarette enterprises to control the processing quality of cut stem, and has practical significance for improving the cut stem uniformity in the blending batches.

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