Analysis of Factors Influencing the Resistance of a Type of Air Filter Paper Based on SPSS

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Abstract: The thicknesses, basis weights and resistances of a type of filter paper randomly sampled were tested by experiment. The statistical analysis of the test data was carried out by multiple linear regression analysis of the statistical software SPSS19.0. The conclusion were as follows: when the paper had a basis weight variation from 55.2 g/m² to 59.8g/m² and a thickness variation from 0.385mm to 0.406mm, α=0.05, basis weight variation on resistance existed significant influence, the regression equation was Δp=2.551w, correlation coefficient R²=0.83; thickness variation on resistance did not exist significant influence.

1. Introduction

The air filter paper can remove the toxic and harmful aerosol particles by using its porous structure formed by the fine, soft and interlacing fibers, so as to purify the air. When air filter paper is used as personal protective materials, it is usually used for anti-mite masks, gas masks, etc [1]. When used as collective protective materials, it is usually used in air filters for air conditioning systems, clean workshops, and civil air defense fortifications [2,3]. The filter resistance of air filter paper is inevitably an important indicator due to the respiratory resistance of the person wearing a mask and the intake resistance of the air filter.

For air filter paper, its resistance is related to many of its structural parameters. Papermaking process limitations often result in structural heterogeneities among different points on the same type of air filter paper, then resulting in uneven resistance. Therefore, it is necessary to carry out research on air filter paper, find out the cause of resistance variation, and try to provide reference for the control of resistance uniformity in papermaking process, and further support the development of paper industry technology [4-6].

2. Data Acquisition

Variable Determination. The factors influencing the resistance of air filter paper are extremely complicated. The resistance of air filter paper is calculated as follows:

Δp=A1L. 

In the formula (1), Δp represents resistance, Pa; L represents thickness, cm; A1 represents a constant related to the fiber structure of air filter paper, air viscosity and gas flow rate. When A1 is constant, the resistance increases linearly with the increase of the thickness; when the thickness,
viscosity of the air, the specific velocity of the air flow are constant, the resistance is related to the fiber structure of the air filter paper, and the basis weight (i.e., the mass per unit area of the paper, also called the surface density) is a parameter that expresses the fiber structure of air filter paper. When the fiber density (paper basis weight) increases, the amount of fibers contained in per unit volume of the air filter paper increases. When the airflow passes through the air filter paper, there are more obstacles in per unit volume, the pressure drop loss increases, and the resistance increases [7,8].

Therefore, this paper selects thickness and basis weight of air filter paper as the independent variables, and studies their correlation with the dependent variable resistance.

**Data Test.** On a certain type of air filter paper, 25 circular paper sheets of d=6 cm were randomly cut with tweezers, and the thickness, the basis weight and the resistance were measured for each circular paper. The thicknesses of the air filter papers were tested by a thickness meter, and each round paper took three points for testing and then averaged; the round papers were weighed by an electronic balance, and the weight was divided by the area to obtain a basis weight value; the resistances of the air filter papers were measured by an inclined-tube micro-manometer, the velocity of the airflow was 0.32L/min/cm², the effective test area was 28 cm². The resulting 25 sets of test data was listed in Table 1.

| Serial number | Thickness [mm] | Basisweight [g/m²] | Resistance [Pa] |
|---------------|----------------|---------------------|-----------------|
| 1             | 0.385          | 57.9                | 157             |
| 2             | 0.386          | 55.2                | 151             |
| 3             | 0.387          | 56.5                | 153             |
| 4             | 0.388          | 55.2                | 147             |
| 5             | 0.389          | 58.4                | 155             |
| 6             | 0.390          | 59.0                | 157             |
| 7             | 0.391          | 56.7                | 154             |
| 8             | 0.391          | 58.7                | 156             |
| 9             | 0.392          | 57.7                | 158             |
| 10            | 0.393          | 55.7                | 148             |
| 11            | 0.394          | 59.7                | 161             |
| 12            | 0.395          | 55.6                | 147             |
| 13            | 0.395          | 56.2                | 153             |
| 14            | 0.395          | 59.1                | 160             |
| 15            | 0.396          | 56.8                | 155             |
| 16            | 0.396          | 57.5                | 155             |
| 17            | 0.396          | 58.1                | 159             |
| 18            | 0.397          | 57.4                | 158             |
| 19            | 0.397          | 56.9                | 156             |
| 20            | 0.397          | 55.4                | 151             |
| 21            | 0.398          | 57.3                | 154             |
| 22            | 0.398          | 59.8                | 161             |
| 23            | 0.406          | 56.8                | 154             |
| 24            | 0.406          | 58.0                | 157             |
| 25            | 0.406          | 59.6                | 162             |
It can be seen from Table 1 that the air filter papers had a thickness of 0.385 – 0.406 mm, a basis weight of 55.2 – 59.8 g/m², and a resistance distribution of 147 – 162 Pa.

3. Analysis Methods

Multivariate statistical analysis studies how to effectively organize and analyze data that is randomly affected and to infer or predict the problem under investigation, then help us grasp the characteristics and changing rules of the event as a whole. In many real problems, the relationship among variables is complicated, it is difficult to give an accurate quantitative, but it can be seen from the data that there is a correlative relationship. Linear regression analysis is a mathematical statistics method for dealing with variable correlation. It assumes a linear relationship between the dependent variable and the independent variables, and uses a certain linear regression model to fit the data of the dependent variable and the independent variables. The regression equation is obtained by determining the model parameters, and then the correlation between the variables can be analyzed by this regression equation \[ \text{[9,10]} \]. Now we need to study the relationship between the variations of thickness and basis weight and resistance of a certain type of air filter paper, so we use multiple linear regression to solve.

The regression analysis based on the optimal combination of multiple independent variables to predict the dependent variable is called multiple regression. Assume the number of independent variables influencing the dependent variable Y is p, and record independent variables as \( x_1, x_2, \ldots x_p \), record the partial regression coefficients of the variables as \( \beta_1, \beta_2, \ldots \beta_p \), then the model for multiple linear regression analysis is:

\[
Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \epsilon.
\]  

Among them, \( \epsilon \sim N (0, \sigma^2) \), it must meet the four hypotheses including normality, unbiasedness, homoskedasticity, and independence, and independent variables \( x_1, x_2, \ldots x_p \) must satisfy the assumption that there is no multicollinearity. When building a multiple linear regression model, if there is a linear correlation between two or more independent variables, multiple collinearity will occur. If the tolerance is less than 0.1, the variance expansion factor VIF (reciprocal of the tolerance) is greater than 10, indicating that the data has multiple collinearity \[ \text{[11]} \].

At the same time, it is necessary to test the significance of the linear relationship between the dependent variable and the independent variables, in other words, to test the validity of the multiple linear regression equation. Regression analysis method is used to determine the degree of correlation of various factors. The correlation coefficient R² is generally used to evaluate the correlation degree or the effect of fitting. \( 0 \leq R^2 \leq 1 \), the closer R² is to 1, the higher the correlation and stronger the significance is; the closer to 0, the lower the correlation and weaker the significance is, which means that the variables outside the model are more effective \[ \text{[12]} \]. Using the statistic F \( (F = \text{Regression Mean Square / Residual Mean Square}) \), the significance of the entire regression equation can be tested, and the statistic t \( (t = \text{partial regression coefficient / standard error of regression coefficient}) \) can be used to test the regression coefficient \[ \text{[13]} \]. According to the significance level of \( \alpha=0.05 \), when the probability P value of the F statistic or t statistic is less than 0.05, the significance test can be passed, the equation or the regression coefficient has statistical significance; otherwise, it cannot pass significance test, equation or regression coefficient was not statistically significant.

SPSS (Statistical Package for the Social Science), the sociological statistical software package is one of the most famous statistical softwares in the world and is widely used in various fields of social sciences and natural sciences. The software package is rigorous in theory, and its statistical analysis functions are complete which cover almost all statistical analysis functions from descriptive statistics, exploratory data analysis to multivariate analysis. It has been gradually popularized in China.

4. Analysis Process

The test data was subjected to multiple linear regression analysis of SPSS. The analysis results are shown in Table 2 to Table 6 and Figure 1 to Figure 3.

Table 2 shows the way in which the independent variables enter the model. Two independent variables including thickness and basis weight are forced into the regression model.
Table 2 Input/Remove variables

| Model | Input variable     | Variable removed | Method |
|-------|-------------------|-----------------|--------|
| 1     | Thickness, basis weight \(^b\) | .               | Enter  |

a. dependent variable: resistance;  
b. all requested variables have been entered.

Table 3 shows that the correlation coefficient \(R^2=0.828\), indicating that there is a close linear correlation between the dependent variable resistance and the selected two independent variables. At the same time, it can be seen that the Durbin-Watson test value is 1.838. Generally speaking, the Durbin-Watson test value is from 0 to 4, the closer to 2, the more likely the observations are independent of each other. That is, the observations of multiple linear regression in this study are independent of each other.

Table 3 Model summary

| Model | R  | R square | Adjusted r square | Standard estimated error | Durbin-Watson |
|-------|----|----------|-------------------|--------------------------|---------------|
| 1     | .910\(^a\) | .828    | .813              | 1.797                    | 1.838         |

a. predictor variables: (constant), thickness, basisweight;  
b. dependent variable: resistance.

As can be seen from Table 4, the test statistic F value of the model is 53.035, and the significance level P value is 0.000. According to the significance level of \(\alpha=0.05\), the model is significant overall. It can also be seen that the regression coefficient of at least one independent variable is not zero, indicating that the established regression model is statistically significant (\(\alpha=0.05\)).

Table 4 Anova

| Model | Sum of square | Degree of freedom | Mean square | F          | Significant |
|-------|---------------|-------------------|-------------|------------|-------------|
| 1     | return residual total | 342.353           | 2           | 171.176    | 53.035      | .000\(^b\) |
|       |                | 71.007            | 22          | 3.228      |             |             |
|       |                | 413.360           | 24          |            |             |             |

a. dependent variable: resistance;  
b. predictor: (constant), thickness, basis weight.

Table 5 gives the regression coefficients, t-test results, and collinearity test results in the regression model. The tolerance value is 0.941, which is greater than 0.1, indicating that there is no multicollinearity in the data. The t values are -0.874, 9.622, and 1.235 respectively, and the P values are 0.392, 0.000, and 0.230 respectively. According to the significance level of \(\alpha=0.05\), the analysis shows that there is a significant linear relationship between the basis weight and the resistance, no significant linear relationship between thickness and resistance, and the constant term cannot pass the significance test and should not be included in the equation. Therefore, the established multiple regression equation is:

\[
\Delta p = 2.551w. \tag{3}
\]

In the formula (2), \(\Delta p\) represents resistance, Pa; \(w\) represents basis weight, g / m\(^2\).
Table 5 Coefficienta

| Model        | Non-standardized coefficient | Standard coefficient | t  | Significant | Collinear statistics |
|--------------|------------------------------|----------------------|----|-------------|----------------------|
| Basis weight | -.23.360                     | 26.727               | -.874 | .392        | .941                 | 1.062                |
| Thickness    | .2551                        | .265                 | .876 | 9.622       | .000                 | .941                 | 1.062                |
| (Constant)   | -23.360                      | 26.727               | -.874 | .392        | .941                 | 1.062                |

a. dependent variable: resistance.

It can be seen from Table 6 that the absolute value of the normalized residual has a maximum value of 1.482, which does not exceed the default value of 3, indicating the result has no abnormality, that is, the residual satisfies the unbiasedness.

Table 6 Residual statisticsa

|                        | Minimum value | Maximum value (x) | Average value | Standard deviation | Digital |
|------------------------|--------------|------------------|--------------|--------------------|---------|
| Predictive value       | 148.83       | 161.68           | 155.16       | 3.777              | 25      |
| Standard predicted value | -1.676     | 1.727            | .000         | 1.000              | 25      |
| Residual               | -3.583       | 2.662            | .000         | 1.720              | 25      |
| Standard residual      | -1.994       | 1.482            | .000         | .957               | 25      |

a. dependent variable: resistance

Figure 1 is a cumulative probability plot of model normalized residuals. It can be seen from Figure 1 that the distribution of each point is close to the diagonal, indicating that the cumulative residual probability of observation fits normal distribution. Figure 2 is a scatter plot of the regression residuals, where the points are evenly distributed, indicating that the data conforms to the equal variance.

Figure 1 Cumulative probability plot of normalized residuals
5. Summary
Based on the relevant research results, this paper combed out the factors influencing the resistance of air filter paper (including thickness and basis weight), and extracted 25 samples of a certain type of air filter paper by randomly sampling to conduct experimental tests, applied multivariate regression analysis method in SPSS 19.0 software to analyze the test data. The conclusion were as follows: when the basis weights varied from 55.2 g/m² to 59.8 g/m², the thicknesses varied from 0.385 mm to 0.406 mm, α=0.05, basis weight variation had a significant effect on resistance, and its regression equation was Δp = 2.551w, correlation coefficient R² = 0.83; thickness variation had no significant effect on resistance.

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