Study on Performance Control of Intercalated Melt-Blowout Method Based on Least Nonlinear Squares

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Abstract: In this paper, the performance control of intercalated melt-blown nonwoven materials has been studied in many aspects. According to the different indexes given by the title, a model has been established to analyze the change rule of structure variables and product performance of intercalated melt-blown nonwoven materials and the influence relationship of different indexes, and the model has been verified. For the research on the change law of structural variables and product performance, we first preliminarily analyzed the change law of structural variables and product performance after intercalation through data visualization, and studied the change ratio of six indicators. The primary objective of the model is to study the dependence of the intercalation rate on the six indexes. Then we study the influence of the intercalation rate on the change ratio of the three indexes, namely porosity, compression and resilience, and filtration resistance, through correlation analysis. Studies on the relationship between process parameters and structural variables, we after data processing on multiple correlation analysis of the dependent variable and the correlation coefficient between different independent variable indicators, and then by the least squares fitting receiving distance, air velocity and thickness, porosity, compression resilience, the relationship between the use of the relationship developed predict eight parameters combination structure of the variable. Finally, we use simulation data to verify the practicability of the model and the effectiveness of the algorithm, solve the problem of intercalating melt-blown nonwovens performance control, so as to improve the efficiency of the processing and weaving system, maximize the use of resources. And analyze the advantages and disadvantages of the model, explore the significance of promotion and reference.

Keywords: Correlation Analysis; Least Square Fitting; Optimization Model; Multiple Objective Programming

1. The background of the problem

Melt-blown nonwovens have good filtration performance and are important raw materials for the production of masks. However, melt-blown nonwovens have very fine fiber and poor compression recovery elasticity. In order to improve this material, scientists created interlayer melt-blown method, which inserts polyester staple fiber and other materials into melt-blown fiber flow during the preparation of polypropylene melt-blown. The process parameters of intercalated melt-blowout process interact with each

other and determine the structural variables, which affect the final product performance. Therefore, it is of profound significance to study the relationship between process parameters and structural variables, and between structural variables and product performance in intercalating melt-blowing process, so as to help improve product quality.

2. The establishment, solution and analysis of the model

In this case, we first preliminarily analyze the change rule of structural variables and product performance after intercalation through data visualization, and then solve the change ratio through visual analysis and numerical analysis of six indexes including thickness, porosity, compression and resilience, filtration resistance, filtration efficiency and air permeability. Then, the correlation analysis is used to study whether the change ratio of six indicators and intercalation rate have an impact. Finally, the minimum nonlinear square fitting is used to analyze the influence mechanism of intercalation rate and the change ratio of several influential indicators.

2.1 Construction and analysis of correlation analysis model

Then, correlation analysis was used to study the relationship between the intercalation rate and the change ratio of the six indicators, so as to verify whether the intercalation rate had an impact on the change.

Before the correlation analysis, we need to study whether the data of each group obey the normal distribution. Pearson correlation coefficient analysis is used for indicators that meet the normal distribution, and Spearman correlation coefficient analysis is used for indicators that do not meet the normal distribution.

The skewness and kurtosis of variables were used for normality test.

It can be seen from the results that the four indexes of thickness, porosity, air permeability and filtration resistance obey normal distribution, while the other indexes do not.

2.2 Solving the correlation analysis model

Therefore, Pearson's correlation coefficient was used to analyze the correlation between thickness, porosity, air permeability and filtration resistance on intercalation rate, and Spearman's correlation coefficient was used to analyze the two indexes of compression resilience and filtration efficiency.

Pearson correlation coefficient calculation formula:

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}}$$

Spearman correlation coefficient calculation formula:

$$\rho = \frac{\sum_{i=1}^{N} (X_i - \bar{X})(Y_i - \bar{Y}))}{\sqrt{\sum_{i=1}^{N} (X_i - \bar{X})^2 \sum_{i=1}^{N} (Y_i - \bar{Y})^2}}$$

Finally, Matlab software was used to solve the problem (see the appendix for the code), and the correlation coefficients of the six indicators were obtained as follows:

Variation in thickness	Variation of porosity	Compression resilience changes	Filtration resistance variation	Filtration efficiency variation	Change in air permeability
-0.0219	-0.2152	-0.1927	0.3503	-0.0647	-0.0672

Therefore, we can get that the three indexes of thickness, filtration efficiency and air permeability have a negative correlation and weak influence on the intercalation rate, and because the absolute value of the value is small, they are relatively no influence indexes.

The influence of porosity and compressive resilience on intercalation rate is negative and weak.

The influence of filtration resistance on intercalation rate is positive and weak.

The results are summarized as follows:

No impact indicator	Weak impact index of negative correlation	Weak impact indicator of positive correlation
Thickness	Porosity	Filtration resistance
Filtration efficiency	Resilience of compression	
Permeability		

That is, the intercalation rate is affected by the change ratio of porosity, compressive resilience and filtration resistance.

3. Study on the relationship between process parameters and structural variables

In ontology, we after data processing on multiple correlation analysis of the dependent variable and the correlation coefficient between different independent variable indicators, and then by the least squares fitting receiving distance, air velocity and thickness, porosity, compression resilience, the relationship between the use of the relationship developed to predict eight parameters combination structure variables.

3.1 Complex correlation analysis

In order to determine the correlation coefficient between each index in the structural variable and the process parameters of the independent variable, a model of $x_1, x_2, ..., x_k$, By calculating the simple correlation coefficient between the linear combination and the dependent variable as the variable y and, $x_1, x_2, ..., x_k$. And the complex correlation coefficient between. The specific calculation process is as follows:

In the first step, use y to pair, $x_1, x_2, ..., x_k$, make the regression, obtain:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \cdots \hat{\beta}_k X_k$$

In the second step, the simple correlation coefficient is calculated as y and. $x_1, x_2, ..., x_k$. And the complex correlation coefficient between. The calculation formula of the complex correlation coefficient is:

The complex correlation coefficients between process parameters and structural variables are obtained as follows:

Thickness	Porosity	Compression rebound rate
0.988	0.934	0.52

Therefore, the process parameters are related to the three indexes of thickness, porosity and compression rebound rate of the structural variables.

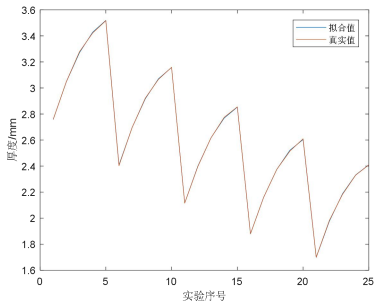
3.2 Minimum nonlinear square fitting model to solve variable relationships

Next, we use least nonlinear squares to fit the relationship between process parameters and structural variables.

Fitting relationship between thickness and process parameters

$$y_1 = -2.9791 - 0.0193x_1 + 0.0083x_2 + 0.0011x_1^2$$

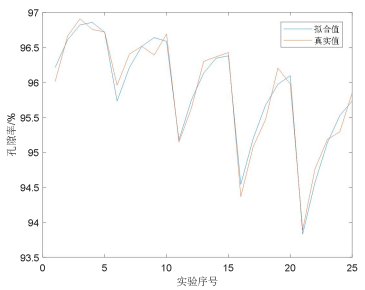
A rendering of the fitting



Fitting relationship between porosity and process parameters

$$y_2 = 75.0643 + 0.3520x_1 + 0.0260x_2 - 0.0015x_1^2 - 0.0002x_1x_2$$

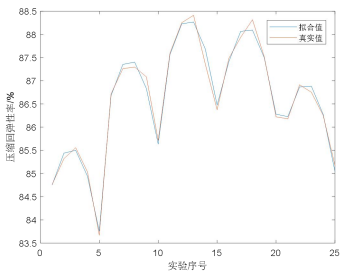
A rendering of the fitting



Fitting relationship between compression rebound rate and process parameters

$$y_3 = 43.9098 + 1.1533x_1 + 0.0589x_2 - 0.0208x_1^2$$

A rendering of the fitting



It can be seen from the fitting effect diagram that the fitting effect is good.

3.3 Predict the structural variables of eight process parameter combinations

The combination of eight process parameters was substituted into the above model, and the following structural variable results were predicted:

Acceptance distance (cm)	Hot air speed (r/min)	Thickness (mm)	Porosity (%)	Compression resilience (%)
38	850	2.7642	96.2677	86.0667
33	950	2.6889	96.2263	87.9287
28	1150	2.7132	96.2632	87.2060
23	1250	2.5347	95.9726	85.0645
38	1250	3.3879	96.5536	83.8039
33	1150	2.9944	96.5446	86.7742
28	950	2.4139	95.7696	88.3836
23	850	1.9486	94.6345	87.4660

4. Innovation and promotion of the model

Our minimum nonlinear ls model is established on the basis of correlation analysis, provide for the problem of study on the relationship between the variables related to verify whether the variable relationship between again to solve the train of thought, establish the method of the model and the number of thinking to solve a variety of categories or index change problems, has certain prediction, in the subject will help us to predict the eight kinds of craft A structure variable that combines parameters. This model has certain promotion and reference significance, for example, it can also be applied to storage strategy, process manufacturing and capital circulation and so on.

However, our model also has some shortcomings, that is, in the process of regression of least nonlinear square fitting, the correlation of regression cannot pass all the regression data points. This shortcoming can be compensated by drawing the fitting effect to observe and adjust.

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