Research Article

Analysis of Preparation Conditions of Low-Temperature Curing Powder Coatings Based on Local Clustering Algorithm

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The coating industry is gradually developing towards a green and efficient direction. Powder coating has the advantages of energy saving, nonpolluting, high efficiency, and easy production automation. Its output has grown rapidly and has become one of the development directions of the coating industry. Powder coatings have expanded into new end markets with their well-known advantages. In order to analyze the preparation conditions of low-temperature curing powder coatings, this study selects low-temperature curing powder coatings and ordinary powder coatings to compare, analyzes the realization mechanism of low-temperature curing powder coatings, and uses actual cases for research and analysis. Low-temperature curing powder coatings were prepared with trimethylolpropane (TMP) as the main raw material. Using a combination of single-factor analysis and orthogonal experiments, the effects of TMP addition, curing temperature and curing time on the gloss and impact properties of coatings were studied, and a local clustering algorithm was proposed to intelligently determine the optimal coating condition. Low-temperature curing powder coatings are optimized and screened by algorithms.

1. Introduction

Powder coating is a new type of solvent-free, solid powder-based coating. Powder coatings use air as the dispersion medium for spraying, the powder is recyclable, the loss rate is small, the film is formed at once, there are few pinhole defects, it is robust and durable, and it is more environmentally friendly than other types of coatings [1]. Powder coatings are used on a large scale in many industries due to their environmentally friendly construction and excellent coating performance, and the technology is developing rapidly. However, common powder coatings have the disadvantages of high grilling temperature and long curing time, resulting in high energy consumption in practical applications, and the high curing temperature can also lead to brittle parts. In the auto parts industry, the car wheel is the main load-bearing part of the car, which requires not only sufficient mechanical strength, but also sufficient toughness to ensure its impact resistance. Reducing the curing temperature of powder coating can increase the toughness of the wheel, reduce the energy consumption of production, and achieve the purpose of energy saving and environmental protection. At present, energy-saving and environmentally friendly low-temperature curing powder coatings have also been adopted in large quantities in the field of home appliances, effectively reducing energy consumption, but the traditional low-temperature curing powder coatings leveling is not good and aluminum wheels have high requirements for the appearance of the coating, and thus cannot be sprayed on them. To realize the popularization of low-temperature powder coatings in automotive wheels, the premise is that the wheel products produced under the low-temperature powder process meet the current performance standards for automotive parts [2].

The curing of powder coatings is divided into four stages: melt, flow, gel, and cure, where the curing process determines the performance of the coating film. The curing needs to be carried out at a certain temperature, which is called the curing temperature and can be regarded as the temperature at which the chemical reaction proceeds rapidly. According
to the thermodynamic reaction mechanism, only when the molecular collision energy reaches the activation energy of the reaction can the chemical reaction take place [3]. The molecular collision energy is increased with the temperature, so increasing the temperature or reducing the activation energy of the reaction is an effective means to speed up the reaction. For low-temperature curing powder coatings, the lower the temperature, the better, so choose to reduce the activation energy is the only measure. General powder coating curing temperature is generally at 180°C to 200°C; low-temperature curing powder coating curing temperature can be lower than 160°C; and in a certain temperature range, the curing temperature of the coating is reduced by 10°C, it can save about 10% of energy. Therefore, low-temperature curing research on coatings is of great importance to save energy and reduce costs and expand their application areas [4].

Clustering is one of the core tasks of machine learning. The clustering effect is highly dependent on the feature representation of the data. A good feature representation can significantly improve the clustering effect, so classical clustering algorithms use feature extraction algorithms to extract a feature representation that facilitates clustering. The feature extraction algorithm and the clustering algorithm are independent of each other, resulting in the decoupling of feature extraction and clustering algorithms. In recent years, deep neural network-based clustering algorithms have jointly optimized the feature extraction process and the clustering process, using neural networks to extract clustering-oriented feature representations. Currently, deep neural network-based clustering algorithms have proven their superiority. Therefore, a comprehensive review of the existing deep clustering algorithms and a classification of the existing deep clustering algorithms from the neural network perspective is presented. The goal of clustering is to divide similar data points into the same cluster, and different clustering algorithms are derived according to different clustering approaches [5]. Depending on the clustering approach, classical clustering methods classify typical clustering algorithms into prototype clustering, density clustering, graph clustering, and hierarchical clustering. Prototype clustering uses a set of prototypes to portray the cluster structure and determine the sample attribution by measuring the distance between the samples and the prototypes. The main goal of density clustering is to find high-density regions that are partitioned by low-density regions. The graph clustering algorithm transforms the clustering problem into a graph optimal partitioning problem by constructing an undirected weighted graph based on similarity. In practical applications, the traditional $K$-means algorithm suffers from problems such as the need to prespecify $k$-values and random selection of initial clustering centers, all of which affect the performance of $K$-means [6]. In order to solve these problems, many variants of the $K$-means algorithm have been generated. The author gives a brief overview of traditional $K$-means, points out its problems, summarizes improvements in the determination of the number of clusters, initialization of clusters, similarity measures, and sensitivity to noise and outliers, and finally gives further research directions. The $K$-means algorithm is currently the simplest and most popular clustering algorithm within various subject areas. A large number of scholars continue to publish research on this algorithm every year to find a general method, and the task proves to be difficult to accomplish in practice. The ease of implementation, efficiency, and simplicity are the main reasons for the popularity of this algorithm. In practice, the traditional $K$-means algorithm has some drawbacks, such as the $k$-value needs to be specified in advance, the initial clustering centers are chosen randomly, and the algorithm is very sensitive to outliers and noise, which affect the final performance of the $K$-means algorithm. In order to solve these difficulties, many $K$-means improvement algorithms have appeared. In the era of big data, as data access becomes more convenient, applications such as data analysis and computer vision need to deal with larger and larger amounts of data and higher complexity of data structures. Facing these new challenges, traditional clustering algorithms are increasingly unable to meet the demand [7].

In this study, based on the existing experiments of various properties of low-temperature powder coatings, the influence of different condition factors on the preparation of low-temperature curing powder coatings was studied, and a series of standard tests and a series of feasibility studies on the application of low-temperature curing powder coatings were conducted by investigating the durable properties of powder coatings, construction process of low-temperature powder coatings, coating film properties, coating film balance block adhesion properties, and so on. Based on the existing formulations, the introduction of trimethylolpropane (TMP) monomer instead of part of neopentyl glycol, at the same time because it has three active functional groups, can effectively improve the reaction activity of polyester, so that polyester has excellent branching degree, greatly improve the activity of the end carboxyl group, which makes polyester resin in the premise of maintaining the original excellent performance, but also to meet the low-temperature curing conditions. This article aims at the effects of trimethylolpropane content, curing temperature and curing time on gloss and impact resistance of powder coatings, and proposes a local clustering algorithm, which is used to intelligently select the optimal formulation of outdoor-type low-temperature curing polyester resin from the three conditions. This paper is arranged as, in section 2; we described the related work of our research article. In section 3, we described a proposed method, and in section 4, we gave results and experiment of our research and at the end in section 5, we gave the conclusion of our research.

2. Related Works

In this section, we will discuss how we prepared powder coating formulation, as well as clustering algorithm.

2.1. Powder Coating Formulation Research. The low-temperature curing of powder coatings is achieved by increasing the reactivity of the resin and curing agent. Selection of
suitable accelerator to achieve low-temperature curing of powder coatings. The choice of synthetic resin epoxy resin with reactive epoxy group, the reactivity of its group with the size of the resin molecular weight and resin structure and there are differences [8], powder coating resin has the following characteristics: the molecular weight of the resin is small, but the glass transition temperature is higher than lowing characteristics: the molecular weight of the resin is small, but the glass transition temperature is higher than 50°C, the resin is brittle, at room temperature is easy to mechanical crushing to get the required particle size, and the powder at room temperature is not easy to slump. Resin in the powder coating curing temperature, low melt viscosity, easy to level to get a relatively thin and flat coating film. There are many varieties of resin, mixed with different melting point, viscosity, and epoxy value of resin, can be adjusted to get the required technical index of resin and made into different needs of powder coatings. The resin has good dispersion of color and filler, and good powder matching of different curing agents (or cross-resin), which can configure different nature of coating varieties. Resin with good electrostatic properties and melt leveling, good adaptability to different construction methods. Epoxy phenolic resin is a kind of composite phenolic epoxy resin with both bisphenol a phenolic component and phenol phenolic component in the resin molecular structure. From the chemical structure, this resin has a high density, corrosion resistance, good film hardness, good wear resistance and other characteristics, selected as the main raw material for low-temperature curing powder coatings [9].

The choice of curing agent thermosetting powder coatings must be added to the curing agent. The curing agent reacts with the resin to form a film; therefore, the curing agent of low-temperature powder coatings should have good reactivity. Polyester and anionic catalytic curing agent compound curing agent, can ensure that the powder coating has a faster reaction rate, can be used as a low-temperature curing powder coating epoxy resin curing agent. The pigment and filler used in powder coatings require chemically inactive pigments and fillers, which do not react chemically with other components in the manufacturing and storage of powder coatings, and have good stability to heat and light, and the pigments and fillers used in general solvent-based coatings that can meet the aforementioned conditions can be used. In the low-temperature curing powder coatings, pigments titanium white, iron red, mica iron oxide, cadmium red, cadmium yellow, carbon black, phthalocyanine blue, phthalocyanine green, and ultramarine can be used. The fillers that can be used are precipitated barium sulfate, light body calcium carbonate, talc, kaolin, precipitated silica, mica powder, and quartz powder. Light body calcium carbonate was used in this test [10].

The selection of additives needs to be based on the principle of improving the leveling and edge coverage of the coating film. Adding a small amount of petroleum resin and paraffin wax in low-temperature curing powder coating is good. The coating formulation debugging and screening selected different ratios of resin and curing agent to determine the gelatin time, using the paint film impact tester to test its impact strength at room temperature results are shown in Table 1.

With the increase in the amount of curing agent, the gelatin time is shortened, but the amount of curing agent is too high or too low, all make the impact strength decrease, the reason is that too little curing agent, incomplete curing, slow reaction; too much curing agent, will make the chain growth of the addition polymerization reaction is blocked, the molecular weight decreases, so that the impact strength decreases. In order to ensure the strength performance of powder coatings, the basic composition of 100 parts of resin and 30 parts of curing agent is selected; the amount of pigment, filler, and additives is determined according to experience and test, and low-temperature curing powder coating samples are obtained. The best formulation of low-temperature curing powder coatings is shown in Table 2.

2.2. Clustering Algorithm. Cluster analysis is gradually developed along with the development of science in the fields of statistics, computer science, and artificial intelligence, and for this reason, any greater research progress in these fields is bound to promote the rapid development of cluster analysis algorithms. For example, the development of artificial neural networks and support vector machines in the field of machine learning has led to the development of neural network-based clustering methods and kernel clustering methods. At present, deep learning based on artificial neural networks will also drive the further development of clustering analysis methods. So far, clustering research and its application areas have been very extensive, so this paper mainly focuses on the clustering analysis algorithm as the main object and discusses the whole process of clustering analysis. Cluster analysis is a more rigorous process of data analysis. The whole process of cluster analysis is shown in Figure 1, starting from the data source of the clustering object to the knowledge archive of the clustering results [11], which mainly includes four parts of research, namely, feature selection or transformation, clustering algorithm selection or design, evaluation of clustering results, and physical analysis of clustering results.

Clustering algorithms can generally be used in division-based, density-based, grid-based, and constraint-based ways to perform classification. However, in the context of the Big Data era, with the increasing amount of data and its increasingly diverse data forms, clustering algorithms are more widely used; at the same time, higher requirements are placed on the algorithms themselves. Clustering algorithms are divided into two categories: small data clustering and big data clustering. Small data clustering mainly reflects the basic idea of clustering, while the idea of big data clustering is mainly reflected in the concept, architecture, and other aspects, as for the specific implementation of the underlying clustering algorithm; in fact, there is no essential difference with the small data clustering algorithm. In other words, the specific implementation algorithm of big data clustering still uses small data clustering techniques. This paper reclassifies the clustering algorithms so far and reviews two types of algorithms, small data clustering, and big data clustering, respectively [12], and classifies the traditional division-based, density-based, and grid-based algorithms as a unified
division-based clustering algorithm. The core idea of big data clustering is to deal with the relationship between computational complexity and computational cost, and scalability and speed. Therefore, the focus of big data clustering algorithms is to improve the scalability and execution speed of algorithms at the cost of minimizing the quality of clustering. Big data clustering is divided into three categories such as distributed clustering, parallel clustering, and high-dimensional clustering [13]. Among them, parallel clustering and distributed clustering algorithms, need to be executed in a cluster of computers; therefore, these two algorithms are collectively called multicomputer clustering [14]. The hardware architecture of multicomputer clustering is shown in Figure 2.

3. Proposed Methods

In this part, we will discuss the main martial an instrument, powder coating synthesis steps.

Preparation of powder coating and at the end, we will describe the local clustering algorithm.

3.1. Main Raw Materials and Instruments. Raw materials used are as follows: neopentyl glycol, TMP, terephthalic acid, isophthalic acid, no outlying oxide, antioxidant, triglycidyl isocyanurate (TGIC), titanium dioxide, barium sulfate, and leveling agent. Instruments used are as follows: magnetic stirring stainless-steel reactor, gapless twin-screw extruder, electric constant temperature drying oven, rotary vane vacuum pump, coating film thickness gauge, gloss meter, electrostatic spraying equipment, and paint film impactor.

3.2. Powder Coating Synthesis Steps. Synthesize the intermediate of end-hydroxy polyester resin by adding neopentyl glycol, TMP, terephthalic acid, catalyst nonoutlying oxide, and so on into the 5-liter reactor according to the formula. Start to warm up slowly; wait until neopentyl glycol starts to melt, turn on the stirring device and connect the condensate, stirring speed slowly rise to 60 to 75 rpm, evenly warm up to 180°C and then keep warm for 1 h, 180°C to 220°C to 5°C/h, 220°C to 240°C to 10°C/h, to 240°C and then keep warm for 1 h, take sample to measure, acid value viscosity qualified, that is to get polyester intermediates. Acidification of polyester intermediates about 225°C to 228°C cast antioxidants, cool down to 210°C, add adipic acid, isophthalic acid, maintain the temperature, acidification, to 10°C/h ramp up to 240°C insulation until the acid value, viscosity qualified, vacuum decompression for 2 h, while tracking the acid value and viscosity, and remove the resin cooling.

3.3. Preparation of Powder Coating

(1) Weigh the polyester resin, TGIC, titanium dioxide, barium sulfate, and leveling agent according to the formula, mix well, wait for the gapless twin-screw extruder to reach the set temperature, turn on the cooling water line, adjust the feeding speed to 30 Hz and the screw to 40 Hz, then pour the sample into the twin-screw extruder to extrude the pressed sheet.

(2) Extruded into the piece of the sample after cooling in the crusher crushed into powder, with 180 mesh sample sieve out the powder. Open the electrostatic spraying equipment, take a spare metal plate with an air gun blowing clean hung on the iron frame of electrostatic spraying equipment, the powder will be poured into the gun and start spraying, spraying hands from the plate surface about 200 mm, moving up and down at a uniform speed to ensure the uniformity of the film. Back and forth about five times, and then take off the sprayed board into the electric thermostat blast drying oven baking curing.

(3) After curing, take out the board to cool, use the coating thickness gauge to measure the thickness of the board, use the gloss meter to measure the gloss, use the paint film impactor to impact the board (positive and negative), and finally conclude the board.

3.4. Local Clustering Algorithm. K-means algorithm mainly follows the idea of “things are clustered together and people are divided into groups”, which clusters a given data set into k relevant clusters according to the distance between samples and makes the distance between data points in each cluster as small as possible and makes the distance between clusters as large as possible. If expressed as a data expression, the relevant calculations and definitions of the K-means algorithm are as follows:

<table>
<thead>
<tr>
<th>Table 1: Powder properties of different ratios.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportioning (mass fraction, %)</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Curing temperature (°C)</td>
</tr>
<tr>
<td>Gelation time (s)</td>
</tr>
<tr>
<td>Stamping strength (N cm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Low-temperature curing epoxy powder ingredients formula.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of raw materials</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Epoxy resin</td>
</tr>
<tr>
<td>Compound curing agent</td>
</tr>
<tr>
<td>Face filler</td>
</tr>
<tr>
<td>Auxiliary agent</td>
</tr>
</tbody>
</table>

Mathematical Problems in Engineering
The data set to be clustered is \( S = (x_1, x_2, \ldots, x_n) \), and the \( k \) clusters of clustering centers are divided into \( C_1, C_2, \ldots, C_K \).

\[
d(x_i, x_j) = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2 + \cdots + (x_{ip} - x_{jp})^2}. \tag{1}
\]

The data set to be clustered is \( S = (x_1, x_2, \ldots, x_n) \), and the \( k \) clusters of clustering centers are divided into \( C_1, C_2, \ldots, C_K \).

\[
\text{Mendist}(s) = \frac{2}{n(n-1)} \sum_{i\neq j, i=1}^{n} d(x_i, x_j). \tag{2}
\]

(1) The \( K \)-means algorithm most commonly used to calculate the distance metric between two sample objects is the Euclidean distance, defined as follows: in the equation, \( x_i = (x_{i1}, x_{i2}, \ldots, x_{ip}) \), \( x_j = (x_{j1}, x_{j2}, \ldots, x_{jp}) \), \( x_i \) and \( x_j \) denote two \( p \)-dimensional attributes of the data object, respectively.

(2) Calculate the average distance of all sample points, the formula is as follows: In the formula, \( n \) is the total number of sample objects in the data set, and \( d(x_i, x_j) \) is the Euclidean distance of sample points \( x_i \) and \( x_j \).

(3) The most commonly used objective function is the squared error criterion function, which is defined as follows:

\[
E = \sum_{i=1}^{k} \sum_{j \in N_i} \|x_j - c_i\|^2, \tag{3}
\]

where \( N_i \) denotes the set of the \( i \)th cluster, \( c_i \) denotes the center of the \( i \)th cluster, and \( E \) denotes the sum of squares of the Euclidean distances of all data sample objects and the cluster centers it belongs to. The ultimate goal is to minimize the squared error \( E \). It is not easy to find the minimum value of \( E \) directly, which is an NP-hard problem, so only heuristic iterative methods can be used. The data set \( S \) with \( n \) objects and the number of clusters \( k \) to be divided are input, and the clustering results that meet the convergence of the objective evaluation function, that is, \( k \) clusters, are output. The basic process of the \( K \)-means clustering algorithm is as follows: initialize the clustering centers, randomly select \( k \) data objects from the data set \( S \) as the initial cluster centroids for the first clustering; assign each data object to be clustered to a unique cluster set; recalculate the cluster means according to the clustering. The cluster mean is recalculated based on the clustering result, and the new mean is used as the cluster center of each cluster; the cycle is repeated iteratively until all the objects in the clusters are stable and no more changes occur.
The $K$-means clustering algorithm requires the user to specify three parameters, that is, the number of clusters $k$, cluster initialization, and the distance metric. Usually, the effect of clustering is largely limited by the choice of $k$-value, and although there is no strict mathematical formula for the choice of $k$-value, there are some heuristics. The number of clusters $k$ can be dynamically adjusted by merging and splitting clusters according to predefined thresholds. Determining the number of clusters has been one of the difficulties in clustering problems, and most of the problems of determining the number of clusters can be transformed into a model selection problem. Another basis for cluster number selection is Bayesian information criterion and Akaike information criterion, based on the characteristics of exponential function, weight adjustment, paranoid term, and the basic idea of the elbow method, by introducing the concept of contour coefficient and by calculating alternatively, a fitness function is constructed to evaluate the degree of classification, which can reduce the number of classifications while improving the tightness and dispersion.

Initialization of clusters different initialized clusters will yield different clustering effects. As the $K$-means algorithm only converges to local minima, the final clustering may only yield a local optimal solution, but not a global optimal solution. One way to overcome the local minima is to use several different initial partitions and choose the partition with the smallest squared error, given the value of $k$. However, there is no general and effective method to determine the initial partitions, and the center of mass will change with different initial partitions, which may eventually produce only locally optimal solutions. However, this iterative optimization method does not guarantee convergence to the global optimum. Although global optimal solutions can be found by simulated annealing and genetic algorithms, they require expensive computational costs. Therefore, the $K$-means algorithm uses the Canopy algorithm to initialize the cluster centers of the $K$-means algorithm, which solves the problem that the traditional $K$-means algorithm tends to fall into the local optimal solution due to the uncertainty of the initial centroid. The clustering effect is stable, and the number of iterations is low.

The $K$-means algorithm often uses Euclidean distance to measure the distance between points and cluster centers, and the performance of the algorithm can be better by improving the similarity measurement algorithm. $K$-means is very sensitive to noise and outliers, even if an object is far from the cluster center, it will still be classified into clusters and the cluster shape will change. $K$-means algorithm based on distance and sample weights, which uses dimensionally weighted Euclidean distance to measure the distance between data points within a cluster, solving the problem that the traditional $K$-means algorithm tends to fall into local optimum due to the randomness of selecting the initial cluster centroids and the $k$-value needs to be determined manually.

4. Experiments and Results

This section explains and analyzes the experimental results using the proposed methods and techniques. We first discuss the single-factor experiments, and then the numerical results of these experiments are analyzed in comparative manner.

4.1. Single-Factor Experiments. Single-factor experiments were conducted with TMP content, curing time and curing temperature as the influencing factors, and gloss as the index. Gloss as an indication may effectively convey the degree of influence while also facilitating the study of TMP's effect on coating film gloss. Varied TMP content polyester is added, creating powder according to the formulation and sprayed and cured at $160^\circ{C}$ for 10 minutes. To investigate the effect of TMP content on gloss of coating film, the gloss of coating film was significantly reduced after adding TMP, which improved its performance, but at the addition of 25%, it led to a decrease in gloss, only because the excess TMP made the viscosity in the powder coating system increased, causing orange peel on the coating surface, so the gloss also decreased significantly.

The effect of temperature on the gloss of the coating film was investigated by adding TMP 10% polyester resin, according to the formula made of powder after spraying, curing time of 15 min. With the increase in temperature, although the gloss of the coating film does not affect much, but it is still decreased. This is because the temperature increases, the surface of the coating film is prone to yellowing phenomenon, affecting the gloss.

The effect of time on the gloss of the coating film was investigated by adding TMP 10% polyester resin, making the powder according to the formula and then spraying it at a curing temperature of $150^\circ{C}$. The effect of time on the gloss of the coating film was investigated. The effect of time on the gloss of the coating film is small, but as the baking time increases, the surface of the coating film is continuously oxidized and its gloss decreases.

4.2. Single-Factor Experiments. The experimental results of iteration are shown in Figure 3.

Three factors clustering experiments were conducted with TMP content (A), curing temperature (B), and curing time (C) as three factors and gloss as an index. The $K$-means model was trained, and its convergence curve will be Figure 3, and the experimental results are shown in Table 3.

From the results of the extreme difference analysis in Table 3, it can be seen that the greatest degree of influence of the three factors on the glossiness is the trimethylolpropane content, and the influence of curing time and curing temperature is the same. The gloss level from experiment 1 to experiment 6 is greater than 90, which meets the normal demand. The best orthogonal test film-forming conditions for A2B1C2, that is, trimethylolpropane content at 10%, curing temperature at $150^\circ{C}$, curing time of 15 min coating film gloss performance to 98, the optimal conditions.
5. Conclusion

Powder coating application technology has received active attention in the situation of increasing attention to environmental protection, and extensive and in-depth research has been carried out both at home and abroad. The application of powder coating technology on heat-sensitive materials at low temperatures, the application in the field of coil coating in the way of assembly line operation and the use of ultraviolet curing to achieve rapid curing, get excellent leveling, decorative aspects have been significantly improved. In this paper, by studying the clustering algorithm and conducting clustering experiments on three factors to seek low-temperature curing research on powder coatings in compliance with the specified index, the following conclusions can be drawn. (1) The addition of TMP will cause the gloss of the coating film to decrease; (2) The curing time of powder coatings at different temperatures is different, and the curing temperature is high then the curing time is short; (3) When increasing the TMP content by 10%, the curing temperature can be shortened to 150°C, effectively reducing the temperature to about 20°C; (4) When the TMP content is zero, although the gloss of the paint film is high, the flexibility of the paint film is poor, and the recoil force is poor. The gloss performance of the paint film with a TMP content of 10% is good; (5) In the premise of ensuring the alcohol acid ratio, the appropriate increase in the content of trimethylolpropane can effectively improve the flexibility of polyester resin system and improve the impact resistance of the coating; (6) After experimental research results, the coating formulation of trimethylolpropane content at 10%, curing temperature of 150°C, and curing time of 15 min shows the best performance. Comprehensive conclusion, by changing the raw material components selected polyester resin coating formulations with low-temperature curing performance, which has the excellent performance of the original coating formulation but also greatly reduces energy consumption and has a good application value.
Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

Declares that he has no conflict of interest.

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References


