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Application of Zeolite Runner Exhaust Gas Treatment Technology (ADR) in Automobile Paint Shop

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Abstract: The coating production line measurement and control system is a system that uses industrial control technology to manage and control the electrical equipment of the coating workshop to realize the entire coating manufacturing process. VOC emissions from automotive paint shops are accompanied by a large amount of heat and a wide variety of VOC components. If not handled properly, it will cause serious pollution to the atmosphere. At the same time, some component gases pose a serious threat to the health of production personnel. The main purpose of this paper is to analyze and study the application of zeolite runner waste gas treatment technology in an automobile paint shops. This paper analyzes the research status of coating production lines at home and abroad and the current status of electronic coating exhaust gas treatment, and focuses on the application of zeolite runners in painting workshops. The largest factor is paint, accounting for 50.15%, followed by cleaning solvent, clear coat, and the smallest is sealant, accounting for only 0.58%.

1. Introduction

For a long time, the large energy consumption of automobile paint shops has been widely concerned. In the automobile painting workshop, various processes have the characteristics of high energy consumption and high pollution. The drying and curing process of the paint film is not only the process with the highest energy consumption in the workshop, but also the top priority of VOC emission control. According to the statistics of industry experts and scholars, the painting process accounts for 67% of the consumption of the entire automobile manufacturing process. In addition to electricity, the entire coating process also involves water, hot water, gas, and other energy sources. When the VOC content in the drying furnace is high, it must be continuously discharged to the outside world to prevent exceeding the explosion limit. The high temperature flue gas contains a large amount of flammable gas, which must be treated before it can be discharged [1].

In his research on waste disposal and automotive paint shops, Winter proposed a novel constraint programming model for real-life paint shop scheduling problems [2]. Evaluate and compare our models experimentally by performing a series of benchmark experiments using real examples in the industry. Experiments show that the decision variant of the paint shop scheduling problem is NP-complete. Aksoy improves parameters such as quality, efficiency, and performance by applying industrial robotic metal painting methods and using automated systems to achieve the environmental conditions required to ensure optimal painting quality and additional improvements throughout the research process [3]. The Yosri study focused on investigating the effectiveness of simulating this paint line using computational fluid dynamics (CFD) methods to identify airflow and turbulence patterns that may help understand particle concentration and movement in the paint line [4]. To study particle movement and concentration in this automotive paint line, six mechanical designs of ventilation systems are proposed. From here, an optimal design that meets the goal of minimizing particle concentration and its dissipation in the painted part is reasonable. Therefore, improvements such as layout arrangement and mechanical design are factors in overcoming and reducing foreign particles falling into parts during painting. The results of this study could also serve as a benchmark for the design of new automotive paint lines in the future.

With the rapid development of the industry, the waste gas generated in the manufacturing process is directly discharged into the air, and the environmental pollution is becoming increasingly serious. The state attaches great importance to the pollution control of VOCs. This paper mainly analyzes and studies the application of zeolite runner waste gas treatment technology in automobile painting workshop. This paper analyzes the research status of coating production lines at home and abroad and the current status of electronic coating waste gas treatment, and focuses on the application of zeolite runners in painting workshops. PLC control system. At the same time, in response to the current energy crisis and the national call for energy conservation and consumption reduction, the energy management of the painting workshop was analyzed and researched, and a refined energy management system was designed to help enterprises save energy and reduce consumption and improve economic benefits.

2. Research on the Application of Zeolite Runner in Paint Shop

2.1. Research Status of Coating Production Lines at Home and Abroad

Coating generally refers to the work of spraying protective and decorative layers on the workpiece. With the development of the industrial revolution, the coating production method has developed from traditional manual to modern automation, and the coating production line with a high degree of automation has been widely used in various fields of industrial production [5-6].

(1) Development status of foreign coating production lines

Foreign coating production lines were originally small workshops as production units, mainly small-scale production lines that were brushed by hand and then dried naturally. Then, through simple spraying, pre-treatment, dip spraying to purify the surface of the workpiece, electrophoretic coating to improve the oxidation resistance of the workpiece, automatic electrostatic spraying, and robotic spraying, etc., it has gradually developed into an assembly-line mass production method.

(2) Development status of domestic coating production lines

The construction of the coating production line in my country started late. Due to the relatively weak economic and industrial foundation, the initial production line was used foreign acquaintances, and the workpieces were brushed by hand. With the accumulation of industrial construction and reform and development, it gradually developed into a the production method of industrial automation. The construction of the early production line was relatively simple in structure. With the development of technology, the tank body was gradually replaced by the tank body made of glass fiber reinforced plastic. The more advanced production lines are mainly concentrated in coastal areas and other areas, and compared with the current coating, the requirements for coating at that time were mainly anti-corrosion. With the development of my country's economy and technology, and continuous exchanges and cooperation with foreign scientific research institutions, great progress has been made in the design technology of coating production lines. As well as the development and wide application of spraying robot technology in recent years, it represents that my country's coating production line is moving towards a new historical period.

2.2. Current Situation of Electronic Coating Waste Gas Treatment

According to the characteristics of coating exhaust gas, the treatment can be divided into two parts, pretreatment and VOC treatment [7-8].

(1) Preprocessing

The pretreatment mainly deals with the paint mist particles carried in the spraying exhaust gas. The paint mist particles in the exhaust gas are small, the viscosity is large, and it is easy to adhere. To avoid blockage and damage to the subsequent treatment equipment, the exhaust gas needs to be pre-treated.

At present, the commonly used paint mist treatment technologies can be divided into two categories, dry and wet. The wet treatment method uses water or solvent to absorb the particles and organic matter in the paint mist according to the principle of similar compatibility; dry filtration separates the particles from the exhaust gas through material fiber interception to improve the filtration efficiency.

Compared with wet treatment, dry filtration has the advantages of no sewage and no change in air humidity. However, dry filtration generates waste filter material, increasing consumables and operating costs. In addition to dry filtration and wet washing, paint mist can also be regarded as ordinary dust, and the traditional dust removal method can be used to select the corresponding dust removal equipment according to the characteristics of different paint mists.

There are many types of filtration processes, but the treatment of paint mist by coating exhaust gas is still a difficult problem. Different coating industries use different types of coatings, and there are certain differences in the properties of paint mist. You should formulate an effective treatment plan and select the corresponding equipment according to your own situation and the experience of technicians.

(2) VOCs treatment

Coating exhaust gas has the characteristics of large air volume and low concentration. In engineering, the combined process of destructive method and non-destructive methods is often used. First, the adsorption process such as activated carbon is used to concentrate the large air volume and low concentration exhaust gas, and the high concentration and small air volume generated after desorption. The exhaust gas is treated by thermal oxidation methods such as catalysis or incineration, and the VOCs are treated after coating the exhaust gas to remove particulate matter [9-10].

2.3. Zeolite Runner

In order for the runner to have the above functions, the material of zeolite is essential, and the zeolite runner should be selected from three aspects:

(1) High zeolite content

Zeolites with high content rate can more easily adsorb VOCs.

(2) The hydrophobicity of zeolite should be good

To judge whether the adsorption performance of the zeolite runner meets the standard, in addition to the size of the adsorption area of the zeolite itself, it is also necessary to detect the hydrophobic performance. Good hydrophobicity is beneficial to the adsorption of zeolite. In the case of high humidity of exhaust gas, it is easy to detect the hydrophobicity of zeolite. Zeolite with poor hydrophobicity may cause the surface of zeolite to block and reduce the adsorption efficiency of zeolite.

(3) The desorption efficiency of zeolite is higher

As can be seen from Figure 1. In addition to adsorption, desorption of zeolite is also essential. The combination of the two can reflect whether the purification effect of zeolite runner on VOCs is efficient. Zeolite cannot be completely desorbed in the desorption zone, which will affect the adsorption efficiency of zeolite for a long time, and affect the service life of zeolite. Zeolite is resistant to high temperatures, and the corresponding desorption temperature must reach a certain level to make it desorb. After the runner turns to the adsorption area, the cycle of adsorption-desorption-cooling ends [11-12].

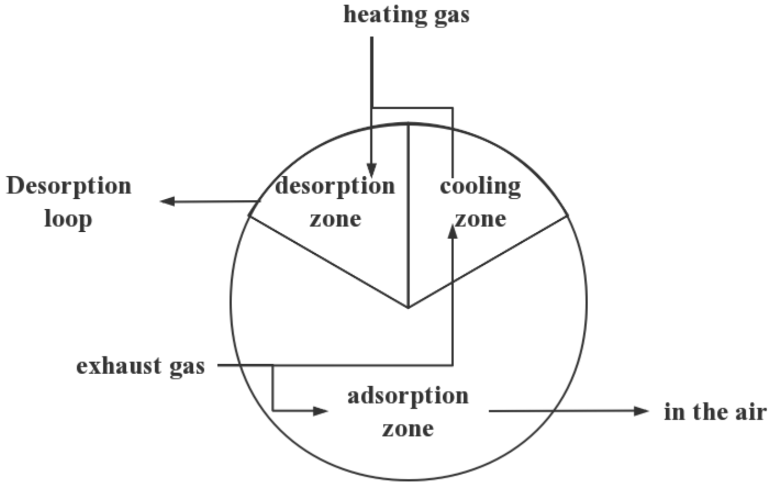

Figure 1: Zeolite Runner Demonstration Area

2.4 Analysis Method of Reaction Kinetics

To understand the catalytic reaction mechanism, the reaction kinetics are discussed. At present, the commonly used reaction kinetic models include series kinetic model (PRL), redox model (MVK), and Arrhenius equation. The reaction rate r of the organic matter with the catalyst is the characteristic parameter for obtaining the kinetic parameters, and the calculation formula is shown in Formula 1.

$$r = \frac{F}{V} x \tag{1}$$

In the formula, F is the molar flow rate of organic matter, mol/s; V is the catalyst volume, cm^3; x is the conversion rate of organic matter obtained by the formula, %.

(1) PRL model

Because the oxygen concentration is much larger than the organic matter concentration, and the change in the experiment is negligible, the PRL model can be abbreviated as Equation 2.

$$r_i = k' c_i^n \tag{2}$$

Where k is the approximated reaction rate constant, s-1.

When using the PRL model for fitting, to obtain the value of the reaction order n and the reaction rate constant k, the abscissa in the fitting graph is represented by the logarithm of the molar concentration of organic matter injection, lnc, and the ordinate is the reaction rate at the corresponding temperature and concentration. Logarithmic lnr representation. According to the intercept and slope of the fitted straight line, the series n and the reaction rate constant k are obtained, and the curve is expressed as formula 3.

$$\ln r = \ln k + n \ln c \tag{3}$$

(2) MVK model

The MVK model divides the catalytic reaction into two parts: reduction reaction and oxidation reaction, and it is considered that the two processes of VOCs reduction catalyst and oxygen oxidation catalyst alternately occur on the surface of the catalyst. Because the oxygen concentration is much greater than the organic matter concentration, it can be regarded as a constant, 8.44×10-6mol/cm3, and the formula can be simplified to 4 forms.

$$\frac{1}{r} = a + \frac{1}{k_i c_i} \tag{4}$$

When using the MVK model to analyze the organic matter, the abscissa is represented by the reciprocal 1/c of the molar concentration of the organic substance injected, and the ordinate is represented by the reciprocal 1/r of the reaction rate at the corresponding temperature and concentration. According to the intercept and slope of the fitted line, take the surface oxidation reaction rate constant k_o and the surface reduction rate constant k_r.

3. Application of Zeolite Wheel in Paint Shop

3.1. The Main Hardware Components of the Electrical Control System

The main structure of the electrical control system is composed of controllers, frequency converters, monitoring equipment, and testing equipment, and each group of equipment has its irreplaceable role. Here, the functions and roles of each group of hardware devices will be explained first.

(1) Controller

Since this equipment is an indispensable product in the factory and plays a decisive role in the production environment of the entire product, it is easy to operate and easy to judge faults in actual use. Based on the above factors, the core controller of the control system adopts Mitsubishi Automation company's Q series PLC. Q series is a medium and large-scale PLC developed on the basis of A series. Its high performance, high speed, and miniaturization of modules can be more effectively used in discrete control and motion control.

The structure within the control level adopts the internationally common ladder diagram structure, which is more intuitive and effective to grasp the logic of the program.

(2) Inverter

There are three parts in the system for frequency conversion control, adsorption fan, desorption fan, and runner motor. Taking into account the state of the equipment site, the adsorption fan adopts multi-speed control, the desorption fan adjusts the motor frequency according to the state of on-site debugging, and finally outputs at a fixed frequency, and the runner motor runs at a constant speed. The actual processing effect on the spot adjusts the frequency and changes the motor speed.

(3) Monitoring equipment

There is only one monitoring device in this system: the touch screen.

(4) Testing equipment

1) Adsorption mechanism

Including pressure sensor, micro differential pressure switch, runner differential pressure switch, etc.

2) Desorption mechanism

Including pressure sensor, desorption outlet, temperature sensor, desorption inlet temperature sensor, desorption regulating valve, ventilation regulating valve, flammable alarm, etc.

3) Catalytic combustion mechanism

Including burner inlet temperature sensor, burner outlet temperature sensor, natural gas regulating valve, burner ignition detection, natural gas low pressure switch, natural gas high pressure switch, ignition solenoid valve.

4) Other

Heat exchanger outlet temperature sensor, etc.

3.2. Requirements for Work Instructions

Write equipment operation work instructions according to the system template requirements;

The important parameters of ADR operation that must be covered are: such as incinerator temperature and desorption temperature;

There must be a record of switching on and off to ensure that the running time of the ADR can be traced back;

There are replacement records of filter cotton, etc., and the replacement time cannot be during production or solvent cleaning;

There are records of solvent cleaning personnel entering and leaving to ensure that the ADR is in a normal disposal state during solvent cleaning;

There are records of equipment inspection, and the frequency of inspection is not less than 1 time per shift;

There is a record of handover of hazardous waste filter cotton to ensure compliance of hazardous waste disposal;

All operating records are archived for more than 5 years;

All record sheet attachments are attached to the work instruction.

3.3. Requirements for Inspection Record Sheet

The frequency of inspection is not less than 1 time/shift;

All parameters appearing in the inspection record table need to be marked with the parameter range in the inspection table. The value must be recorded during inspection;

Inspection Record Coverage Content

(1) Incinerator temperature and desorption temperature;

(2) Status of the incinerator body;

(3) The pressure difference of the ADR runner;

(4) Fan frequency (affects the pressure difference of the adsorption wheel)

(5) Differential pressure of filter cotton

(6) Bypass (closed, the air valve maintains negative pressure)

(7) Air duct (complete)

(8) Overall status (smooth operation)

(9) It is not allowed to manually turn on the ADR device at any time;

(10) When the ADR fails, the bypass will be automatically opened for the sake of equipment safety.

3.4. Requirements for Equipment Operation Records

Every time the machine is turned on and off, the time of turning on and turning off must be recorded in detail;

When cleaning with solvents, the entry time and completion time of the cleaners must be clearly recorded;

The frequency of inspection is not less than 1 time/shift;

The start time and end time of filter cotton replacement must be clearly recorded;

The hazardous waste filter cotton replaced each time has a workshop/operator handover record, which corresponds to the time and amount of replacement;

All timings match the ADR switching timings and no self-contradictory situations can arise.

4. Application Analysis of Zeolite Runner in Paint Shop

4.1. Exhaust Emission Standards

While focusing on the rectification of various industries, the corresponding exhaust emission standards are also gradually improving. Taking electronic painting as an example, the national and local levels have issued corresponding standards to stipulate their VOC emission limits. The emission limits of non-methane hydrocarbons (NMHC) stipulated in the relevant standards in the past five years are listed in Table 1. If there are special emission limits, the special emission limit standards are used.

Table 1: VOC emission standards for related electronic coating exhaust gas in the past five years

level	Standard Specification	Emission limit (mg/m^3)
National standard	"Electronic Industry Pollutant Emission Standards" (second draft)	100
local standard	1	50
	2	60
	3	30
	4	60
	5	60
	6	50
	7	20

From the changes in emission limits in the past five years, it can be seen that the control standards for industrial VOCs are becoming increasingly strict, and VOCs have become the key direction of air pollution control. Catalytic oxidation and incineration technology is currently the treatment technology with the highest treatment efficiency, accounting for about 28% of the domestic market and 41% of the global market.

4.2. Status Quo of Energy Utilization and Environment in Automobile Coating Industry

Automobile manufacturing mainly includes stamping, welding, painting, and final assembly according to the process, and the painting workshop is the link with the most complicated technology and the strictest process control, and it is also the link with high emission and high energy consumption. 70% of the energy consumption in the vehicle manufacturing process is used in the painting workshop. The energy consumption of each process in the painting workshop is shown in Table 2.

Table 2: Energy consumption of each process in the painting workshop

process	PT-ED	PVC	Surface coating	Top coating	Wax
Proportion	17.12%	6.02%	29.81%	38.14%	5.03%

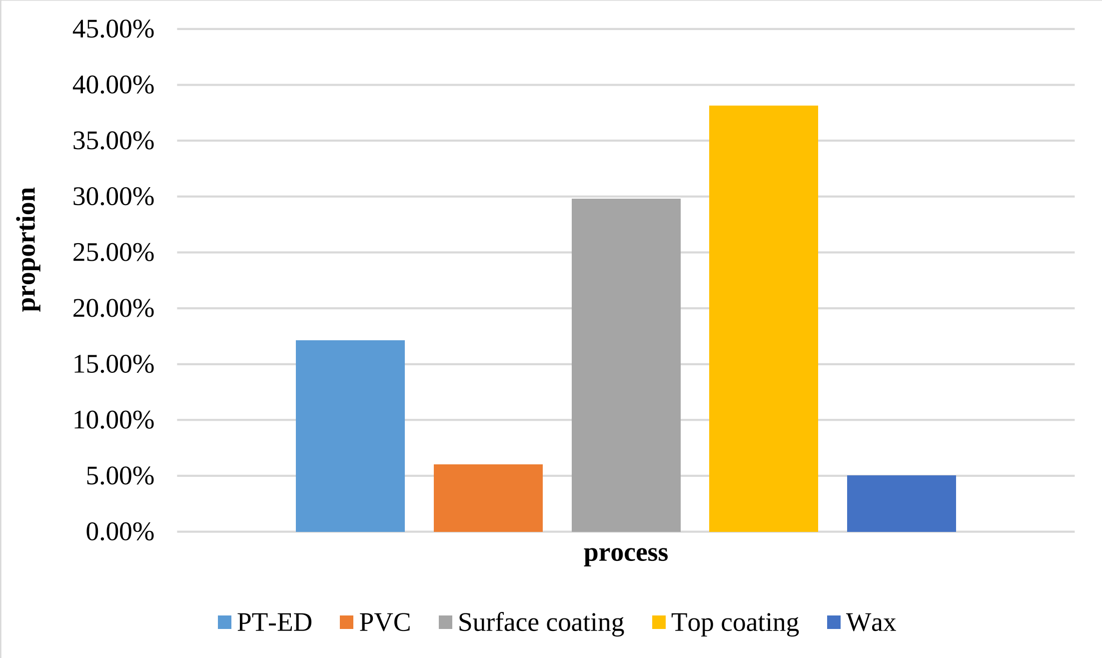

Figure 2: Energy consumption analysis of each process in the painting workshop

As can be seen from Figure 2, among many process station equipment, PT-ED, middle coating and top coating have the highest energy consumption, and among these processes, the energy consumption of the drying air conditioning system is the largest, and the drying process air conditioning system consumes the most energy. The power consumption of the paint shop is basically 50% to 60% of the total power consumption of the entire painting workshop.

4.3 Source and Characteristics of Exhaust Gas in Automobile Paint Shop

VOC waste gas mainly occurs in electrophoresis, sealants, middle coating, paint, varnish, and other related processes. The proportion of VOC volatilization in each process is shown in Table 3. Due to the complexity of the entire coating process and the long duration of the process, the impact, there are many factors on VOC concentration, which are briefly listed in Table 4.

Table 3: The proportion of VOC volatilization in each coating of the process

process	proportion
electrophoresis	5.27%
sealant	0.58%
Medium coating	15.57%
color paint	50.15%
clear coat	13.84%
cleaning solvent	14.58%

As can be seen from Figure 3, the largest factor affecting the VOC concentration is paint, accounting for 50.15%, followed by intermediate coating, cleaning solvent, varnish, and the smallest is sealant, accounting for only 0.58%.

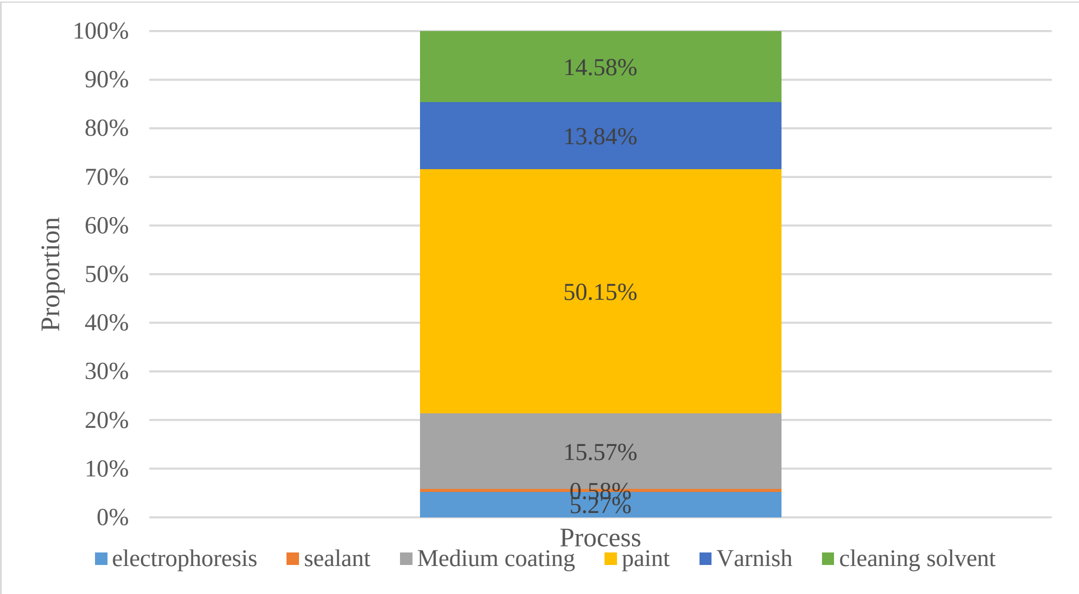

Figure 3: Analysis of the proportion of VOC volatilization in each coating of the process

Table 4: Main influencing factors of VOC concentration

process	Influencing factors	Description of the reasons for the impact
electrophoresis	1 Whether there is excess film thickness	1 film thickness with high excess VOC emissions
sealant	2 The amount of supplementary solvent added is too much	2 There are many solvents, high volatility, and high VOC emissions
Middle coat, paint, varnish	3 The temperature of the electrophoresis bath is too high	3 High temperature, fast solvent evaporation

Analysis of the above table shows that in the actual project operation management, production capacity, production efficiency, and effective operation management have a great impact on the control of VOC concentration. It is necessary to decompose and strictly control each element layer by layer to reduce the concentration of VOC.

5. Conclusions

The energy saving and consumption reduction work of coating technology needs to apply more practical engineering experience to actual projects, strengthen the technical force at the basic level, and then ensure the completion of the planning goals. During the application process, a large amount of energy saving and reducing discharge technical knowledge and experience, reduce consumption and emission reduction in the automobile industry, make efforts to protect the environment in which we live, and make efforts to enhance the international core competitiveness of the automobile manufacturing industry. As my country's economic construction and social development move towards the strategic track of vigorously developing a circular economy and building a conservation-oriented society, the requirements for energy-saving and emission-reduction levels in automobile painting workshops are becoming increasingly stringent. It is hoped that the preliminary research on energy saving and emission reduction in automobile painting workshops in this paper can lay some foundations for future research in this field. With the continuous prominence of energy and environmental problems in the automotive industry, there will be increasingly research in this field in the theoretical and practical circles, and there is a long way to go to improve the level of energy conservation and emission reduction in automotive painting workshops.

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