



ORGANIZATION OF QUALITY CONTROL OF PAINT COATINGS ON BODY SURFACES IN THE AUTOMOTIVE INDUSTRY

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Abstract

The article analyzed key issues in the automotive industry regarding paint quality, aesthetic appeal, corrosion resistance, and longevity of vehicles. It has been studied that achieving consistent and high-quality painting work requires combining advanced technologies and rigorous quality control processes throughout the painting process. Furthermore, the article examines various aspects of car paint quality control, focusing on key stages such as surface preparation, paint application, paint drying, and final inspection. Issues, methods, and methodologies related to ensuring the durability, appearance, and performance of paint are also discussed.

Keywords: Sealant, automotive industry, primer, quality control, Ishikawa diagram, IoT sensors, paint and varnish layer.

Introduction

The process of painting passenger cars is of great importance in the automotive industry. This process affects not only the aesthetic appearance of the vehicle but also the quality of the coating, which ensures its long-term service life. Quality control of the paint and varnish layer is carried out taking into account the quality of materials, technological processes, and environmental conditions [1]. This article analyzes the main quality issues arising during the car body painting process, as well as modern technologies used to identify and eliminate them. The painting process not only improves the vehicle's appearance but also increases its corrosion resistance and

ensures long-term service. The process of painting the car body using modern technologies is crucial for achieving high-quality results, ensuring the car remains in excellent condition for a long period. Modern technologies, including artificial intelligence (AI), IoT systems, and machine learning (ML) methods, further enhance the painting process. AI systems allow for the automatic detection of paint layer color, luster, surface defects, and thickness. IoT sensors help monitor paint viscosity and other parameters in real time.

Main part

In automotive plants, the painting process is carried out in stages based on a specific algorithm. Quality control and careful process management are necessary at every stage [2]. Below are the main stages of the car body painting process (Fig. 1).

Cleaning stage: At this stage, the car body is thoroughly cleaned of dirt, dust, oil, and other contaminants. This is necessary to ensure the surface is clean and the paint adheres well, ensuring a high-quality coating.

Priming stage: At this stage, apply a primer layer that ensures better adhesion of the paint to the body surface and improves the durability of the coating. This layer also protects the body from corrosion. After priming, the surface is usually left to dry before applying the next layer.

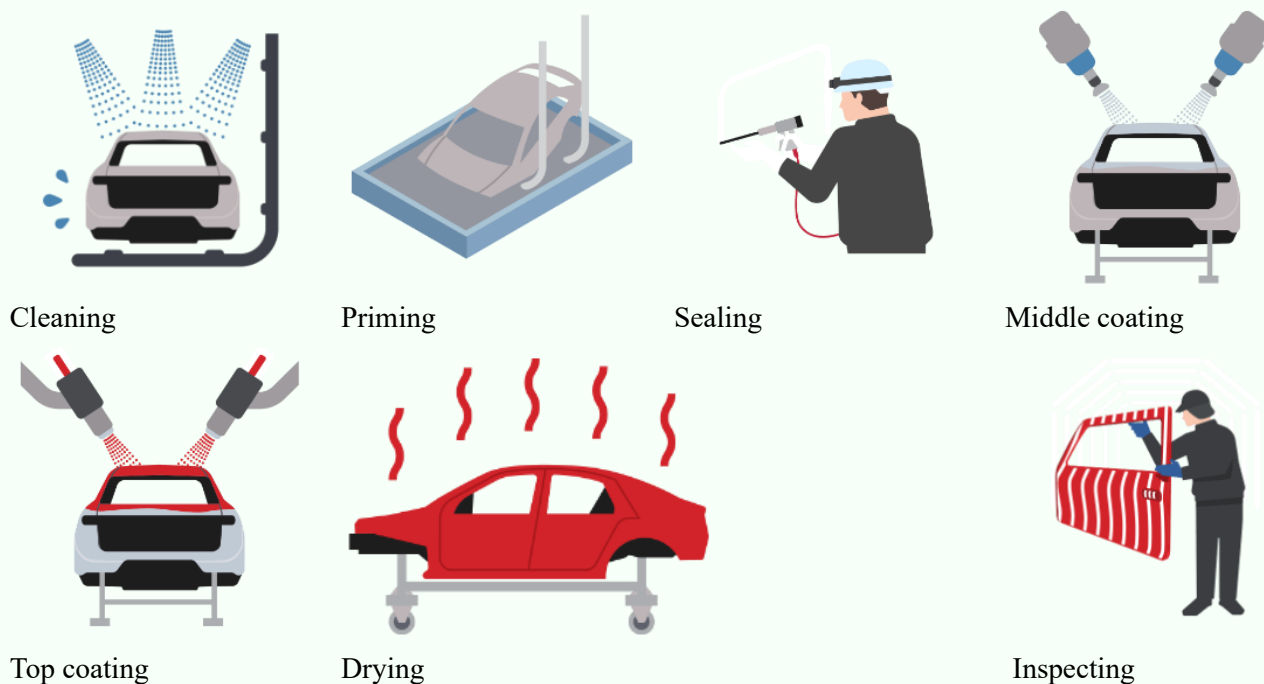


Figure 1. The main stages of the car body painting process.



Sealing stage: This stage involves sealing the seams and joints of the body to prevent moisture and air penetration. Hermetic sealing helps ensure the coating is uniform across the body surface and increases its durability.

Middle coating stage: This stage involves applying a paint that determines the color of the vehicle's middle coating or main coating. This layer is often applied in several stages to ensure a uniform coating. Each layer must be dried before applying the next one.

Top coating stage: This stage applies a top coating (lacquer or transparent film) over the base coating to create a glossy coating and protect it from external factors such as ultraviolet rays, scratches, and chemicals. This layer adds brightness and color depth to the car.

Drying stage: This stage is important to take time to dry the coating after each stage of application. For this purpose, natural drying or special ovens or infrared drying systems are used. To achieve a high-quality result, it is important to provide sufficient drying time for each layer.

Inspection stage: This stage is the final stage and consists of a full inspection of the quality of the painting work. The thickness of the coating, color uniformity, presence of defects, and surface contamination are checked. If any malfunctions are detected, they are rectified, and the machine is ready for delivery to the customer.

These steps are a guarantee of obtaining a high-quality and durable coating that ensures not only an aesthetic appearance but also protection from external influences [6]. Identifying and eliminating surface defects that occur during the car body painting process is a crucial stage. In this regard, the Ishikawa diagram (cause-effect diagram) helps to systematically analyze the factors that lead to defects. Below is an Ishikawa diagram with the main factors, compiled to analyze the causes of particles (dust, hairs, metal residues, etc.) occurring in the paint layer (Fig. 2):

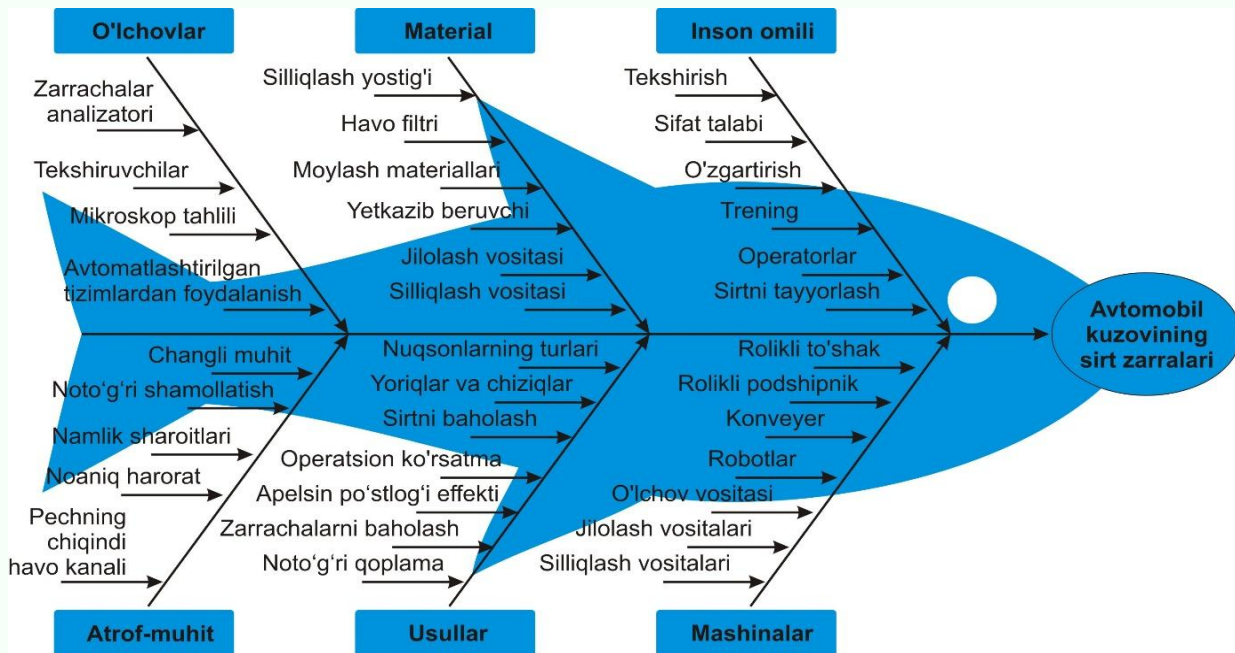


Figure 2. Methods for eliminating surface defects in the car body during the painting process (The Ishikawa diagram was prepared to study the causes of surface particles).

Problem (Effect): The presence of particles (dust, hairs, debris) on the surface of the paint. The main categories and reasons for the Ishikawa diagram are:

Human factor (workers, operators): improper clothing (anti-static clothing); non-compliance with personal hygiene requirements; insufficient inspection of the bodywork before painting; negligence during cleaning.

Equipment: contamination of paint chamber filters; insufficient filtration in the air pressure system; failure of antistatic systems; spraying wet air instead of dry air.

Substances (materials): contamination of the paint itself; improper storage of coating materials; paint that has not undergone proper filtration; residues of abrasive substances left before painting.

Method (process): improper cleaning of the surface before painting; improper airflow during the painting process; continuation of painting with dust on the surface; reduction of the body cleaning process.

Environment: excessive dust in the painting chamber; malfunction of the ventilation system; frequent opening of door shutters in front of the painting zone; variability in humidity or temperature.



Disposal recommendations: regular inspection of filters and ventilation systems; monitoring of workers' compliance with hygiene and dress code rules; filtration and storage of paint and coating materials in a clean place; surface cleaning using antistatic methods before the painting process; regular cleaning and maintenance of the painting chamber. Quality control during car painting ensures not only the appearance but also the durability, corrosion resistance, and other physical properties of the coating. High-quality painting helps the car stay in good condition for a long time.[3]

The composition of common defects in the painting process: surface defects (dust, air bubbles, "orange peel") – 38–42%; uneven coating thickness – 22–25%; color mismatch – 15–18%; defects in the drying process – 10–12%; cracks or spots in the varnish layer – 5–7%.

Painting technologies used in modern automakers: robotic painting systems - 85-90%; manual painting techniques (privatized or small-scale production) - 10-15% [4].

Share of quality control methods: visual inspection and light assessment - 60%; thickness measurement (ultrasonic, magnetic, or X-ray spectroscopy) - 25%; Automated detection systems using AI and cameras account for 15% [5].

Life expectancy of the paint layer (depending on the environment): accordingly, a high-quality paint layer degrades within 5-7 years - 80%; UV (Ultraviolet-Ultraviolet) and chemical-resistant coatings last up to 10 years - up to 20%.

Impact of environmental factors (based on ISO 12944): the risk of poor quality in the absence of temperature and humidity control is more than 40%; the risk of defects in the absence of ventilation and dust control is 30-35% [7].

Many tests and methods are used to identify problems such as "orange peel" (orange peel effect) that occur during painting. Spectrometric methods, such as XRF (X-Ray Fluorescence), are used to measure paint thickness. Additionally, washing tests, chemical resistance tests, and stress tests are conducted to verify the durability and corrosion resistance of the paint layer.

Conclusion

During the car body painting process, monitoring the quality of the paint and varnish layer is considered one of the crucial factors in ensuring the product's aesthetic properties, corrosion resistance, and operational reliability. The research results confirmed that the comprehensive organization of quality control at all stages of



painting technology significantly affects the quality of the final product. As a result of the analysis, it was established that the main portion of defects encountered during the painting process consists of surface defects (38-42%), uneven coating thickness (22-25%), color inconsistency (15-18%), and defects during the drying process (10-12%). It was also substantiated that the deviation of factors such as temperature, humidity, and dust content in the production environment from standard values leads to a decrease in coating quality and an increase in the probability of defects.

The scientific novelty of the research is explained by the systematic classification of factors affecting the quality of the paint layer, as well as the proposal of an approach to the comprehensive assessment of the causes of defects based on the Ishikawa diagram. This approach allows for the identification of relationships between the human factor, equipment condition, material quality, technological parameters, and the production environment during the quality control process. Furthermore, the impact of real-time monitoring based on artificial intelligence, machine vision, and IoT sensors on quality indicators has been scientifically substantiated. The practical significance of the research lies in the fact that the developed recommendations and analytical approaches serve to reduce paint layer defects, ensure uniform coating thickness, optimize technological processes, and increase the efficiency of quality control at automotive enterprises.

As a result, it is possible to reduce production costs, reduce the share of defective products and increase the competitiveness of finished products. It was also determined that the use of robotic systems, artificial intelligence-based inspection tools, and IoT technologies in painting processes is a promising direction for the digitalization of quality control. In the future, the development of mathematical models for defect prediction, the creation of intelligent diagnostic systems for assessing the quality of the paint layer, and the study of paint line management based on Digital Twin technology are of great scientific and practical importance.

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