ISSN 2616-5767 Vol.7, Issue 5: 14-18, DOI: 10.25236/AJETS.2024.070503

Application of Accelerated Light Aging Test in the Quality Evaluation of Automotive Coatings

Qianyao Xiang

China Automotive Engineering Research Institute Co., Ltd., Chongqing, China

Abstract: *The object of this paper is to study the application of accelerated light aging tests in the quality evaluation of automotive coatings. Experimental materials for automotive coatings were prepared, and a xenon lamp weathering tester was used to simulate conditions such as natural light exposure. The aging degree and performance changes of the samples under simulated conditions were analyzed. A 2000-hour aging test was conducted on specific automotive coating samples under highly simulated actual working conditions. The gloss loss did not exceed 3%, the color difference △E was ≤3.0, the maximum thickness variation was less than 2μm, and the adhesion met relevant requirements. After the accelerated light aging test, the gloss stability of the automotive coating samples was strong; the fading phenomenon was not significant; the wear degree was low. It indicated that the selected automotive coating samples were of good quality and met the needs of practical production applications.*

Keywords: *light aging; test; application; accelerated; quality evaluation; automotive coating*

1. Introduction

With the rapid advancement of automotive industry technology and the continuous upgrading of consumer demand, automotive body coatings, as a key aspect of vehicle appearance and protection, have become a crucial factor in market competition due to their performance and quality[1-2]. Automotive body coatings not only bear the responsibility of showcasing the vehicle's unique design and superior quality but also face complex and variable environmental challenges such as intense sunlight, extreme temperature fluctuations, high humidity, and corrosive substances. Prolonged exposure to these environmental factors can easily lead to coating aging, manifested in color fading, surface cracking, chalking, and peeling, which severely compromises the vehicle's aesthetics, durability, and market value.

To ensure that automotive coatings can withstand the test of time and maintain consumer rights and satisfaction, this study introduces the application of accelerated light aging tests in the quality evaluation of automotive coatings[3]. By simulating the combined effects of key aging factors such as light, temperature, and humidity in the natural environment, accelerated light aging tests can replicate the performance degradation process that coatings may undergo during long-term outdoor exposure in a relatively short period. This provides automotive manufacturers and coating suppliers with an efficient and reliable means of quality evaluation. This testing method not only helps identify the weak points of coating materials, guiding formula optimization and process improvement but also ensures that every new car meets the predetermined durability standards before entering the market. This, in turn, enhances the product's market competitiveness, extends the vehicle's service life, and improves the consumer's driving experience and satisfaction. Therefore, promoting and deepening the application of accelerated light aging tests in the quality evaluation of automotive coatings is of great significance for advancing the high-quality development of the automotive industry.

2. Experimental Materials and Preparation

2.1 Preparation of Automotive Coating Experimental Materials

To ensure the smooth implementation of the experiment, representative standard test coating samples were obtained from an automotive manufacturer. The selected samples are consistent with the coating materials actually used on the production line[4]. The technical parameters of the automotive coating samples are shown in Table 1.

ISSN 2616-5767 Vol.7, Issue 5: 14-18, DOI: 10.25236/AJETS.2024.070503

Table 1. Technical Parameters of Automotive Coating Samples

No.	Item	Parameter
1	Coating Color	Orange
2	Coating Type	Non-metallic paint
3	Coating Thickness (Total)	96.1μm (Primer 24.6μm + Base coat 28.2μm + Clear coat 43.3μm)
4	Initial Gloss (%)	97.8
5	Expected Weatherability	Designed for a lifespan of over 10 years
6	Substrate Type	PP+EPDM-T20
7	Coating Adhesion	0 grade (No detachment within the grid)

Upon receiving the coating samples from the automotive manufacturer, a visual inspection was conducted to ensure there were no defects such as scratches or contamination. The sample identification numbers, production dates, and other relevant information were recorded. Following the above steps, the preparation of the experimental samples for this study was completed.

2.2 Experimental Instruments and Equipment

To detect the aging degree of the automotive coatings, a xenon arc weathering tester was selected as the main equipment for this experiment. The technical parameters of this equipment were set as shown in Table 2[5].

Table 2. Equipment Technical Parameters

No.	Item	Parameter
1	Brand and Model	Atlas Ci4000
2	Light Source	Xenon Lamp
3	Filter	Daylight Filter
4	Wavelength (nm)	300~400
5	Irradiance (W/m²)	60±2
6	Chamber Air Temperature (℃)	38±3
7	Black Panel Temperature (℃)	65±3
8	Relative Humidity (%)	60~70
9	Operation Mode	Continuous Illumination
10	Spray Cycle	Spray Time: (18±0.5) min, Interval Between Sprays: (102±0.5) min

The technical parameters of the instruments and equipment were adjusted to ensure they met the actual testing requirements.

2.3 Artificial Accelerated Light Aging Test Method

After completing the preparations mentioned above, the testing conditions were set according to the testing standards[5], ensuring the accuracy and repeatability of the results.

Representative automotive coating samples were selected, ensuring the surfaces were free of scratches and contamination. The initial state of the samples, including parameters like color and gloss, was recorded[6]. The samples were then mounted on the sample holder in the testing equipment, ensuring they were evenly exposed to the light source without any shadowed areas.

The xenon arc weathering tester was activated, and the light aging process was carried out under the preset testing conditions. It was essential to maintain a stable internal environment within the equipment during testing to prevent fluctuations in temperature, humidity, and irradiance from affecting the results. Throughout the test, samples were periodically (every 144 hours) removed to visually inspect any appearance changes. A gloss meter and a spectrophotometer were used to measure and record changes in performance parameters (gloss and color). The data collected before and after the test were compared and analyzed to assess the degree of aging and performance changes of the automotive coatings under simulated light exposure conditions[7].

ISSN 2616-5767 Vol.7, Issue 5: 14-18, DOI: 10.25236/AJETS.2024.070503

3. Results and Discussion

3.1 Gloss Loss Analysis

Gloss loss is an indicator of the reduction in surface gloss under specific conditions (e.g., light exposure, high temperatures). In fields such as coatings and materials science, calculating gloss loss is crucial for evaluating coating quality and material durability. Therefore, gloss loss was selected as a key indicator for assessing automotive coating quality. The formula for calculating gloss loss is as follows:

$$S = \frac{s - s_1}{s} \times 100\% \tag{1}$$

Where: S is automotive coating gloss loss; s is the gloss measurement before aging (measured using a gloss meter); s_1 is the gloss measurement after aging. Gloss measurements at a 60° angle were taken every 144 hours, with samples being tested until 2000 hours. The results were plotted as shown in Figure 1.

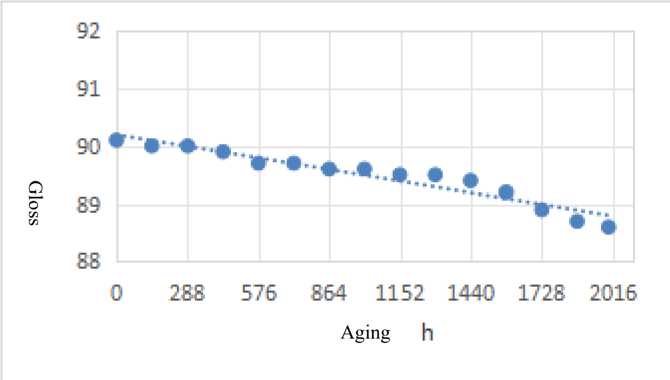

Figure 1. Gloss Variation of Automotive Coating in Artificial Accelerated Light Aging Test

From the analysis of the experimental results shown in Figure 1, it can be observed that the automotive coating underwent a continuous 2000-hour test under highly simulated real-world conditions using the artificial accelerated light aging tester. During this period, the coating demonstrated exceptional performance, with gloss loss not exceeding 3%, a value below the industry's typical threshold.

This data not only visually confirms the strong resistance of the automotive coating sample to light aging but also highlights the scientific nature of its material formulation and the excellence of its manufacturing process. Despite the harsh testing conditions, the coating maintained a high level of gloss stability, clearly indicating its high quality.

This proves that the automotive coating sample excels in light aging resistance and is of high quality, fully meeting the complex and variable practical application requirements. Whether exposed to sunlight during daily driving or subjected to long-term parking under extreme climatic conditions, the coating effectively protects the car's surface, delays the aging process, and keeps the vehicle's appearance as bright as new.

3.2 Color Change Analysis

Color change is a critical indicator of coating quality. Stable color helps maintain the vehicle's appearance and enhances consumer recognition of its quality. A spectrophotometer was used to directly measure the color parameters of the samples before and after aging, including L* (lightness), a* (red-green value), and b* (yellow-blue value). The color difference (ΔE) was calculated to quantitatively assess the degree of color change. A larger ΔE value indicates more significant color change. The ΔE calculation formula is as follows:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \tag{2}$$

Where: △L is the difference in lightness before and after aging; △a is the difference in red-green

ISSN 2616-5767 Vol.7, Issue 5: 14-18, DOI: 10.25236/AJETS.2024.070503

value before and after aging; △b is the difference in yellow-blue value before and after aging.

During the light aging test of the automotive coating, color measurements were taken every 144 hours, with samples being analyzed until 2000 hours. The results were plotted as shown in Figure 2.

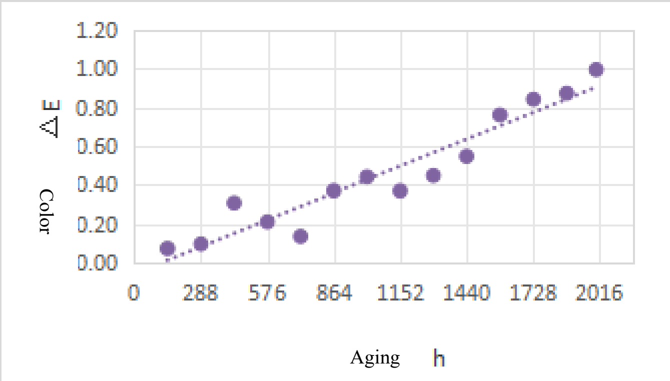

Figure 2. Color Difference Variation of Automotive Coating in Artificial Accelerated Light Aging Test

In the CIELAB color space, L reflects changes in lightness, while a and b* represent shifts in the red-green and yellow-blue directions, respectively. The experimental results indicate that as aging time increased, the color difference (ΔE) gradually increased. In the early stages of aging, the growth of ΔE was relatively slow, whereas in the later stages, it accelerated.

3.3 Wear Degree Analysis

After evaluating the gloss and color difference of the coating, the wear degree of the automotive coating was assessed before and after the artificial accelerated light aging test. The thickness change of the coating before and after the simulated aging test was measured accurately to quantify the wear degree.

In the artificial accelerated light aging test, the automotive coating was subjected to simulated extreme light conditions to rapidly mimic the effects of prolonged natural exposure. Before and after the test, the coating thickness was measured precisely using an ultrasonic thickness gauge. This change directly reflects the physical wear and chemical degradation of the coating due to light exposure and high temperatures. If the test results show minimal or no significant change in coating thickness, it indicates that the coating has excellent wear resistance and light aging performance. Such a coating can effectively withstand environmental erosion, maintaining its original protective function and aesthetic appearance, thereby extending the vehicle's service life and appearance quality.

Conversely, if the coating thickness significantly decreases, it suggests that the coating has experienced considerable wear during the light aging test, which may lead to increased surface roughness, reduced gloss, and potentially impact the overall protective performance of the coating.

Based on this standard, measurement points were selected on the automotive coating samples to measure the thickness at these points before and after the artificial accelerated light aging test. The results are shown in Table 3.

Table 3. Thickness Variation of Automotive Coating Before and After Artificial Accelerated Light Aging Test

Measurement Point	Thickness After Test (μm)	Thickness Before Test (μm)
1	95.8	96.1
2	95.7	96.1
3	95.9	96.1
4	95.8	96.1
5	95.9	96.1
6	95.3	96.1
7	95.5	96.1
8	95.2	96.1
9	96.0	96.1
10	95.5	96.1

The data in Table 3 indicates that ten representative measurement points were selected for the experiment to comprehensively assess the thickness change of the automotive coating after undergoing the artificial accelerated light aging test. Before the test, the coating thickness at all measurement points was consistent, demonstrating a high level of surface uniformity and ensuring consistency of the initial experimental conditions. This eliminates potential errors due to surface unevenness or defects.

Following this, the samples were placed in the artificial accelerated light aging test device to simulate prolonged exposure to extreme light conditions. Although this testing method accelerates the aging process, it effectively reveals the durability and stability of the coating in practical use. After the test, the coating thickness at each point was measured again and compared with the initial values. The results showed a slight decrease in coating thickness, with the maximum variation being less than 2 μm. This minimal change in coating thickness under simulated extreme light conditions suggests that the automotive coating's wear degree is low, indicating high-quality coating performance.

4. Conclusion

To effectively assess the light aging resistance of automotive coatings and shorten the validation period for new materials and processes, artificial accelerated light aging testing has emerged. This method simulates natural light conditions using xenon lamps to accelerate the aging process of coatings, thereby mimicking long-term aging in a shorter time. Artificial accelerated light aging testing offers advantages such as controllable test conditions, high reproducibility, and a shorter test cycle, making it widely used in evaluating automotive coating quality. Through this testing, manufacturers can quickly identify potential defects in coating materials, optimize coating formulations and application processes, and enhance the durability and aging resistance of coatings. This paper introduces the application of artificial accelerated light aging testing and designs quality assessment methods for automotive coatings from the perspectives of gloss loss and wear degree. With ongoing technological advancements and improvements in testing methods, this testing will play an increasingly important role in the quality assessment of automotive coatings.

References

[1] Cheng Ge, Ma Xudong, Cao Lingling. Review of testing methods for weather resistance and light resistance of automobile interior and exterior decoration [J]. Shanghai Coatings, 2022,(06):48-55.

[2] Cheng Xianwei, Liu Yawen, Guan Jinping, et al. Preparation and flame retardant properties of biomass-phytic acid modified polyurethane coated nylon 6 fabric [J]. Journal of Textile, 2024, 45 (06): 120-126.

[3] Hu Shuwei, Qi Tong Baihui, Zhou Mingyang, et al. Reliability evaluation and quality improvement of nuclear fuel cladding coating preparation based on analytic hierarchy process [J]. China Equipment Engineering, 2024, (11): 230-232.

[4] Zhou Guozheng, Jiang Yu, Liang Jun, et al. Study on the comb filtering effect of reflected ultrasound at the coating interface and its combination with quality imaging testing [J]. Vibration and Impact, 2024, 43 (09): 234-240.

[5] State Administration for Market Regulation, National Standardization Administration Commission. GB/T 16422.2 - 2022 Plastics laboratory light source exposure test methods Part 2: Xenon arc lamps [S] 2022 -04-15.

[6] Han Ming'en, Li Shangfeng, Zhao Guangrui, et al. Quality control of fused bonded epoxy (FBE) powder coating on pipelines of Aramco project [J]. Coating and Protection, 2024, 45 (04): 13-18.

[7] Wang Lei, Wang Zhitao, Liu Deyang, et al. Reason analysis and solution measures for failure of solvent-free coating for newly built pressure vessels during winter construction [J]. Modern Coatings and Painting, 2024, 27 (01): 32-36.