

Study of High Smooth Electrodeposition Coating That Enables Primer Process-less Paint System

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ABSTRACT

A study was conducted on a high smooth electrodeposition coat that enables a 3-coat 2-bake primer process-less paint system. This study attempted to suppress the gas pinholes remaining in the deposition film before drying. The methods investigated were to suppress hydrogen gas generation by reducing the neutralizing acid concentration in the e-coat bath, and to enhance gas escape during electrodeposition by optimizing the deposition film viscosity. Application of these methods achieved a smoothness that enables a 3-coat 2-bake primer process-less paint system to secure a paint appearance equal to that provided by the current 4-coat 3-bake paint system.

1. Introduction

The purpose of automotive body paint is to secure anti-corrosion quality and color design. General automotive body paint uses a 4-coat 3-bake (4C3B) coating consisting of an electrodeposition coat (e-coat) that provides anti-corrosion functions, a primer coat that hides the surface roughness, provides chipping resistance (resistance to stone-chip paint damage) and blocks light to the e-coat, and a top coat consisting of a basecoat layer and clear layer that manifest the color design. Research based on this coat composition is proceeding for coating color design such as super-brilliant silver metallic coating⁽¹⁾, and also to achieve coat surfaces with high image clarity. Regarding high image clarity, numerous examples of technical development of coating materials aimed at increasing the coating surface smoothness have been reported since the 1980s, including the use of two primer layers, development of high-finish basecoat materials, and use of two clear coat layers^{(2), (3)}. In addition, an example has also been reported of technology that enhances the paint appearance by using steel plate that achieves high image clarity by controlling the unevenness of the ground steel plate surface⁽⁴⁾, and demands for paint appearance remain high.

On the other hand, amidst calls to prevent global warming, there are also demands to reduce CO₂ generated by the automobile production process, and development of new production technology is proceeding. A short-process paint system that integrates the primer and top coat

processes has recently been introduced for body paint and use is spreading, but there are concerns about a drop in paint appearance (image clarity). A typical measure to address this is to change the clear coating to a high smooth type, but the use of high smooth-type coatings poses cost increase issues.

Previously, the hiding of surface roughness that affects paint appearance was performed by the primer coat (25 μm to 35 μm) present between the e-coat and top coat, and the e-coat (15 μm to 20 μm), which is applied to secure anti-corrosion quality, was not subject to high demands for smoothness. However, in the 3-coat 2-bake (3C2B) primer process-less paint system, the surface roughness-hiding function of the primer is performed by the e-coat and top coat (Fig. 1).

This study investigated the smoothness of the e-coat, which had mainly provided anti-corrosion functions thus far and was not the subject of attention for its contribution

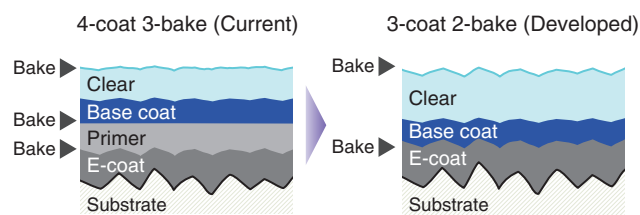


Fig. 1 Body paint structure

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to paint appearance. As a result, an e-coat smoothness was achieved that can secure a marketable paint appearance even without the use of a high smooth-type clear coating. This paper describes these details. The investigations in this study used a coat thickness of 15 μm , which is a strict condition for the e-coat thickness on outer panels that require good paint appearance.

2. Investigation of High Smooth Film Deposition Methods

The e-coat can be broadly divided into a coating resin component and a pigment component. Development of a new coating resin component affects the most important e-coat functions of anti-corrosion performance and throwing-power performance, so smoothing methods that do not involve a change in the resin component were investigated.

There are two possible methods as follows. The first method is to increase the ratio of the coating resin component that forms the coat. This reduces the ratio of the pigment component that impedes thermal flowing of the coat during drying, which enhances fluidity and makes it easier to form a smooth surface. However, enhancing the thermal fluidity brings about a drop in the melt viscosity, with the result that the coating coverage is insufficient at the edges of the coated object due to shrinkage stress during drying, making it easier for corrosion to occur (Fig. 2).

The second method is to reduce the surface conditioner, which is called an anti-crater additive. Oils and grease that could not be completely removed in the previous process or that were used in the various work processes may be adhered to the body on which e-coating is to be performed, or substances with properties that suppress thermal fluidity may be applied to maintain quality. This surface conditioner suppresses the fluidity of the coating in order to suppress the expansion of crater-shaped coat defects produced by contamination. This property conflicts with increasing the smoothness. In addition, reducing this surface conditioner not only lowers the crater resistance, but may also reduce the adhesion with the seam sealer and underbody coat.

The above two methods are subject to the previously described concerns.

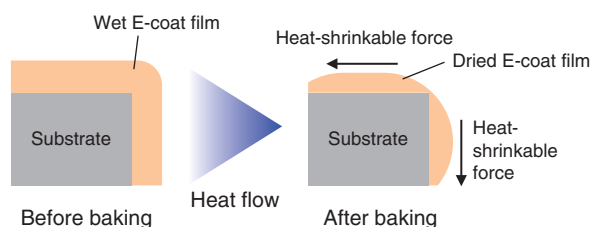
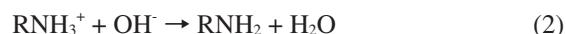


Fig. 2 Edge-covering property

Increasing the e-coat bath temperature and adding solvent are recognized as effective means of increasing the e-coat smoothness, but these detailed mechanisms have not yet been discussed. Increasing the e-coat bath temperature means that the behavior in the film deposition process is affected by the coat viscosity. Adding solvent increases the amount of solvent that transfers to the deposition film, which likewise means that the behavior in the film deposition process is affected by the coat viscosity. Hydrogen gas is produced on the steel substrate in the electrodeposition process, and this hydrogen gas escapes by passing through the film. The authors hypothesized that the increase in smoothness due to increasing the e-coat bath temperature and adding solvent is rooted in the behavior of the hydrogen gas produced during e-coat deposition. However, it was inconceivable that the hydrogen gas itself affected the film smoothness, so this study focused on the film, that is to say on the gas pinholes remaining in the film, after the hydrogen gas had escaped.

3. Reduction of Hydrogen Gas Pinholes

Equations (1) and (2) show the chemical formulas for the e-coat chemical reaction and deposition mechanism.



The water electrolysis shown in Eq. (1) occurs on the surface of the negatively charged substrate, with the result that OH radicals are generated on the steel surface. The OH radicals neutralize the acid that was suspended in the paint particles, so the paint particles lose their charge and deposit onto the steel surface as shown in Eq. (2) (Fig. 3)^{(5), (6)}. The hydrogen gas produced on the steel substrate by this electrodeposition process escapes intermittently from the film during e-coating, but traces of where the gas escaped exist as gas pinholes in the film. These gas pinholes cannot be completely repaired even in the thermal flowing process during drying, and remain as unevenness in the film surface. There are two possible methods as follows for reducing

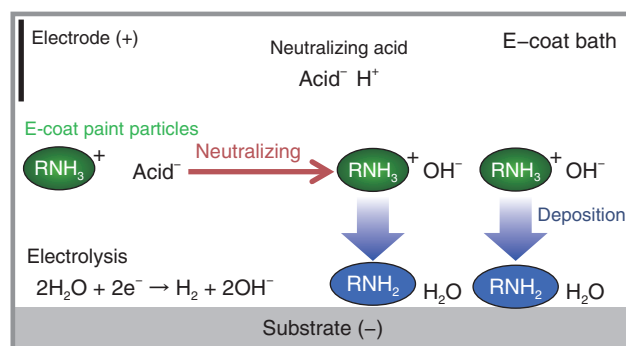


Fig. 3 Schematic image of E-coat

these hydrogen gas pinholes. The first is to increase the film deposition efficiency to reduce the amount of gas produced, and the second is to enhance the hydrogen gas escape. These two methods reduce the gas pinholes remaining in the film, so they can be expected to increase the film smoothness after drying (Fig. 4).

3.1. Increase in Deposition Efficiency

The amount of hydrogen gas is determined by the amount of electricity that flowed as shown in Eq. (1). That is to say, film deposition that uses less electricity also suppresses the amount of hydrogen gas produced. The deposition efficiency (film mass that can be deposited per unit coulomb) can be considered as an index for this purpose. Potential methods for increasing this deposition efficiency are to reduce the neutralizing acid concentration (MEQ) and to increase the solid concentration (NV) in the paint. This study attempted to reduce the MEQ. Positively charged paint particles are neutralized by acid and dispersed stably within the e-coat (Fig. 5), and the acid is then neutralized by OH radicals generated by water electrolysis. When using a high MEQ design created to stably disperse the paint particles, many OH radicals are consumed in neutralizing the acid, with the result that the amount of produced hydrogen gas increases. Therefore, it was thought that if a low MEQ design that was sufficient to neutralize the paint particles could be achieved, the film could be deposited using a smaller amount of electricity, which would reduce the amount of gas produced with the result that there would be fewer gas pinholes remaining in the deposition film and the deposition film surface roughness would increase. This study compared high MEQ design and low MEQ design deposition films, and the results showed that, as expected, the low MEQ design reduced both the hydrogen gas pinholes remaining in the deposition film and the deposition film surface roughness, and also increased the film smoothness after drying (Fig. 6). Reducing the MEQ lowers the bath stability (dispersibility), but this issue was addressed by using a new high disassociation-type neutralizing acid.

3.2. Enhancement of Hydrogen Gas Escape

Reducing the film viscosity is thought to be an effective means of enhancing gas escape within the deposition film. The film viscosity is dependent on the temperature, so it is important to reduce the viscosity within the e-coat bath temperature range.

First, the relationship between the loss elastic modulus of the deposition film and the deposition film surface

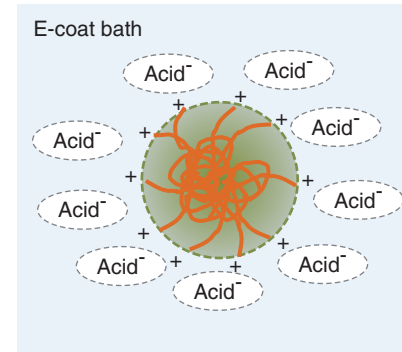


Fig. 5 Function of neutralizing acid

MEQ	High	Low
Beginning of deposition		
End of deposition		
Deposition film Ra	3.70	3.42
E-coat Ra (Dry)	0.17	0.15

Fig. 6 Cross-sectional view of wet film on high and low MEQ

	Standard	High coulomb efficiency	High gas desorption speed
Beginning of deposition			
End of deposition			
After baking			

Fig. 4 Schematic image of E-coat

roughness was investigated (Fig. 7). The loss elastic modulus is an index of deposition film viscosity, and can be used as a substitute to evaluate gas escape. The deposition film surface roughness was confirmed to decrease together with the loss elastic modulus. That is to say, enhancement of gas escape was proven to reduce surface unevenness. In addition, the deposition film surface roughness exhibited a fairly constant value at a loss elastic modulus of approximately 0.10 MPa or less. This means that there is an optimum value for this e-coat material. The solvent quantity was adjusted to achieve this optimum loss elastic modulus within the e-coat bath temperature range (26°C to 30°C). As a result, a stable deposition film surface roughness could be obtained within the entire temperature range (Fig. 8). The degree of solvent quantity adjustment was extremely small, and there was also no effect on the minimum melt viscosity during drying. This confirmed that the smoothness enhancing effect of solvent adjustment was not due to the reduction in melt viscosity during thermal flowing, and was instead a result of enhanced gas escape during film deposition, which reduced the gas pinholes.

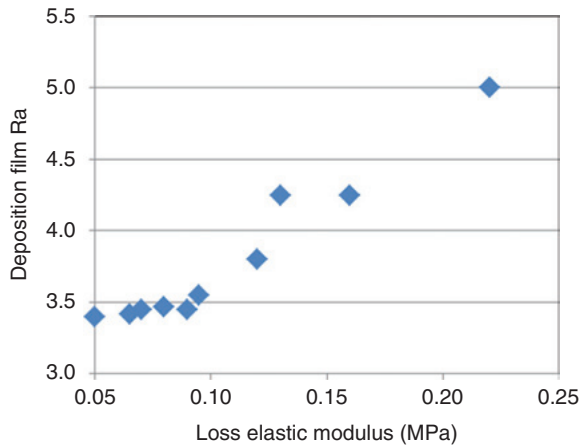


Fig. 7 Relationship between loss elastic modulus and deposition film Ra

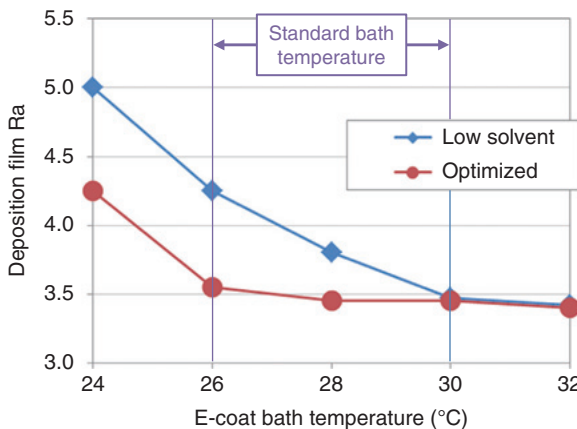


Fig. 8 E-coat bath temperature and deposition film Ra

4. Setting the Target

Next, the relationship between the paint appearance and the e-coat smoothness was investigated to determine the target value for the surface roughness-hiding function to be performed by the e-coat in the 3C2B primer process-less paint system. The correlation between the paint appearance index and the three cutoff regions of 0.8 mm, 2.5 mm and 0.8 mm to 8.0 mm was investigated using Ra (arithmetic mean estimation) as the e-coat smoothness index. The curve obtained by cutting off the waviness components longer than the prescribed wavelength from the film profile curve is called the roughness curve, and this wavelength is called the cutoff value. The results showed that the paint appearance index and surface roughness (cutoff 2.5) exhibit a high correlation (Fig. 9). Therefore, the film smoothness that can achieve the paint appearance target was set at $Ra \leq 0.25$ (cutoff 2.5), compared to the current $Ra \leq 0.30$ (cutoff 2.5) (Fig. 10).

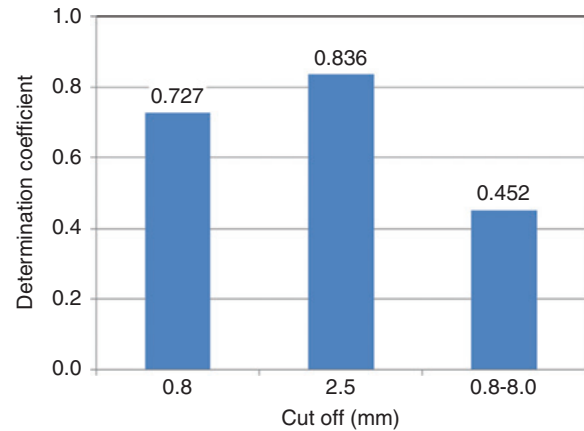


Fig. 9 Determination coefficient with paint appearance index and cut off values

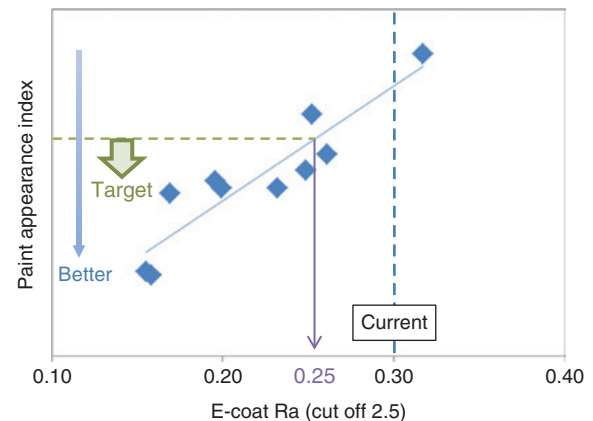


Fig. 10 Paint appearance and E-coat Ra

5. Verification of Effects

The effects were verified using an e-coat that employs the methods investigated in this study and steel sheets with different surface roughness (Fig. 11). The results were better than those for conventional materials within the control range of steel sheet surface roughness and secured a smoothness that satisfied the target value of $Ra \leq 0.25$ (cutoff 2.5).

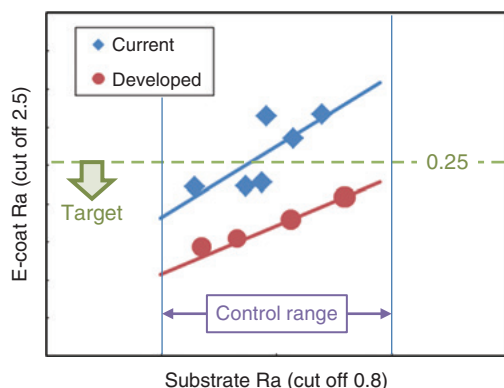


Fig. 11 E-coat Ra and substrate Ra

6. Conclusion

The e-coat smoothness can be increased to a level that supports the 3C2B primer process-less paint system by use of the following methods that reduce gas pinholes in the deposition film.

- (1) The MEQ in the coat was reduced to reduce the amount of hydrogen gas produced.
- (2) Gas pinholes were reduced by optimizing the deposition film viscosity to enhance gas escape within the deposition film.

An e-coat was developed by combining knowledge on how to increase smoothness obtained through this study with high throwing-power performance. Efforts are underway to promote the successive application of this e-coat to 3C2B primer process-less paint systems that require e-coat smoothness and to Honda's body painting lines.

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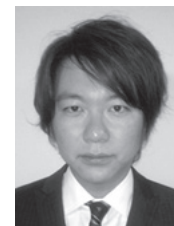
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