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Improving the appearance of 3-coat-1-bake multilayer films on automotive bodies

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A R T I C L E I N F O

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A B S T R A C T

3-coat-1-bake is a coating process which primer-surfacer, basecoat, and clearcoat sprayed on an e-coat substrate by a wet-on-wet technique. However the appearance of the 3-coat-1-bake films has been inferior to that of the conventional 2-coat-1-bake films. Therefore, 3-coat-1-bake coating process has been introduced to only economy-class automobiles. In this study, the surface unevenness is discussed as a quantitative parameter of appearance. We assumed that the surface unevenness of the 3-coat-1-bake films is mainly occurred by not only telegraphing of substrate unevenness but also telegraphing of interface unevenness between coating layers. In this paper, we verify this assumption by focusing on telegraphing of interface unevenness between coating layers and examine to reduce the surface unevenness. To reduce the surface unevenness, it is effective to decrease shrinkage of wet film and/or to minimize interface unevenness between coating layers. The surface unevenness reduced when selecting an isocyanate hardener to the basecoat instead of a melamine resin. Because selecting an isocyanate hardener decreased shrinkage of the basecoat film after loss of the macroscopic flow of the clearcoat film. The surface unevenness greatly reduced in the case of basecoat with a low Tg (glass transition temperature) acrylic resin. A low Tg acrylic resin in the basecoat promotes levelling better. Therefore, this minimized interface unevenness between the basecoat and the clearcoat layers at loss of the macroscopic flow of the clearcoat film. It is verified that to decrease shrinkage of wet film, it is effective to select isocyanate hardener. It is also verified that to minimize interface unevenness between coating layers it is effective to use acrylic resin with low Tg.

1. Introduction

Almost all automobile body is finished with coating to have attractive appearance and excellent durability. On the coating surface, there is unevenness with wide range of wavelength which was formed in the coating process. The unevenness should be small from the view point of appearance in all wavelength ranges. There have been studied the unevenness forming process in various approaches [1–3], and published many literatures dealing with paint formulation, baking/application direction (horizontal/vertical), curing chemistry, and substrate roughness [4–9] and so on.

Tachi [10] revealed two mechanisms that dominate the unevenness formation during coating process of automobile finishing as shown Figs. 1 and 2 schematically (Figs. 1 and 2 are not real as a point that the unevenness of the surface is distinct smaller than the film thickness). Fig. 1 represents schematically the first unevenness formation mechanism: randomly depositing paint droplets make both the peak areas and the valley areas locally during spraying to form the surface unevenness (hereafter termed the paint depositing mechanism). Though levelling occurs during the flash and baking process, this surface unevenness remains after baking. As levelling is more effective in longer wavelength unevenness, the paint depositing mechanism affects rather longer wavelength unevenness including the phenomenon called orange peel. Fig. 2 represents schematically the second unevenness formation mechanism: film shrinkage during flash and baking lacks uniformity locally due to variation of film thickness which leads to surface unevenness (hereafter termed the telegraphing mechanism). The telegraphing mechanism works after a certain time defined as when the levelling flow rate of the wet film falls below the shrinkage rate (hereafter termed the loss of macroscopic flow). By the time of the loss of macroscopic flow, levelling is always dominant and the surface is kept flat. The telegraphing mechanism causes all wavelength unevenness.

The conventional coating process for automobile bodies is a 2-coat-1-bake process, in which basecoat and clearcoat are sprayed using a wet-on-wet on baked primer-surfacer layer and baked together. Recently a 3-coat-1-bake process involves primer-surfacer, basecoat and clearcoat has gradually been introduced to reduce carbon dioxide

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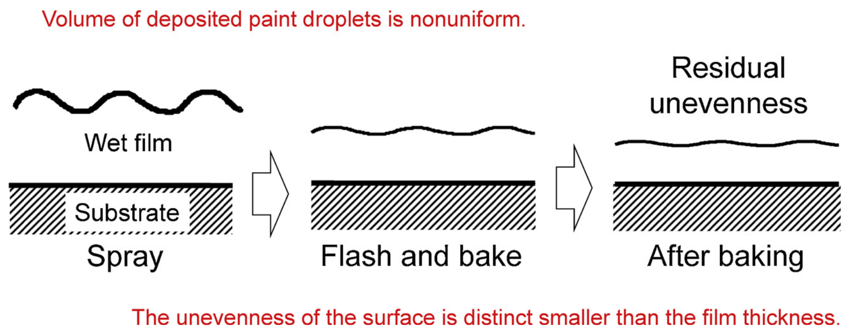

Fig. 1. Schematic representation of surface unevenness formation due to non-uniformity of the volume of depositing paint droplets.

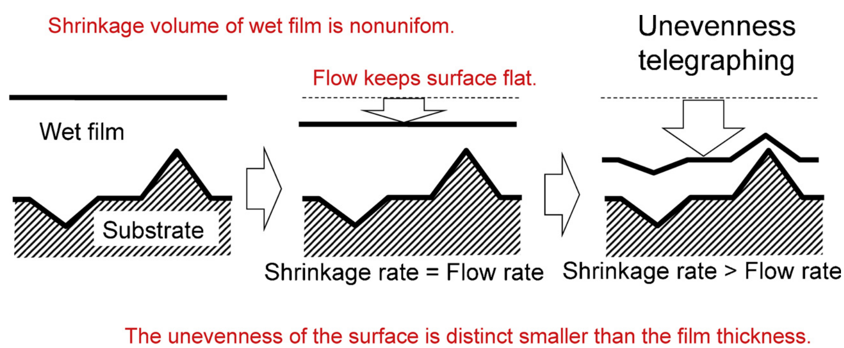

Fig. 2. Schematic representation of surface unevenness formation by non-uniform shrinkage of the wet film.

emissions through the reduction of baking energy consumption. The appearance of 3-coat-1-bake coating is generally inferior to that of 2-coat-1-bake coating because of the large unevenness so that the application of 3-coat-1-bake process has been limited to economy-class automobiles. Therefore, revealing the mechanism that increases unevenness in 3-coat-1-bake process will be expected to give the solution to improve the appearance of the 3-coat-1-bake coatings to expand its application to luxury-class automobiles.

We assumed that the mechanism producing the unevenness in the 3-coat-1-bake coatings is essentially same as the 1-coat-1-bake coatings. In this paper we verify this assumption. The principle of the telegraphing mechanism can be expanded as shrinkage transmission from uneven interface to top surface. The uneven interfaces are substrate surface, interface primer-surfacer and basecoat layers, and interface between basecoat and clearcoat layers. Fig. 3 represents schematically this principle. In this paper, focusing on interfaces between these coating layers, the mechanism of the unevenness formation and improvement policy for paint composition was studied.

2. Material and methods

2.1. Paint preparation

2.1.1. Waterborne primer-surfacer

Two acrylic emulsions with a glass transition temperature (Tg) of 20 °C and −20 °C, named as AcEm-1 and AcEm-2 were prepared by emulsion copolymerization for a waterborne primer-surfacer. Here, Tg is a calculated value from following Fox equation by using a Tg of acrylic homo-polymers:

$$1/Tg\ (K) = w_1/Tg_{(1)} + w_2/Tg_{(2)} \cdot\ \cdot\ \cdot + w_n/Tg_{(n)}$$

where w_1, w_2, w_n are weight percent of acrylic monomers, $Tg_{(1)}$, $Tg_{(2)}$, $Tg_{(n)}$ are Tg (K) of acrylic homo-polymers [11]. The copolymerization was performed in a 2 L, 4-neck flask equipped with a mechanical stirrer, a temperature control system, an inlet for feeding the pre-emulsion, an inlet for feeding the initiator solution, and a reflux condenser. The flask was first charged with 1107.0 g of distilled water and 6.8 g of Latemul PD 104 (Kao Chemical), acting as a surfactant. This mixture was subsequently heated to 80 °C under a nitrogen atmosphere, after which the pre-emulsion and initiator solutions were added simultaneously over 3 h at 80 °C. The pre-emulsion was a mixture of 607.5 g of various

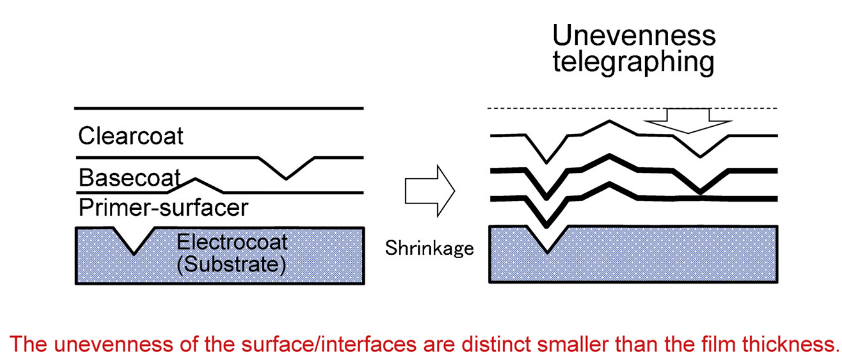

Fig. 3. Schematic representation of unevenness telegraphing via the shrinkage of a multilayer coating.