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ŁUKASZ PASIECZYŃSKI*, NORBERT RADEK**

DEVELOPMENT OF POLYURETHANE PAINT WITH SPECIAL METALLIC EFFECT

OPRACOWANIE FARBY POLIURETANOWEJ O SPECJALNYM EFEKCIE METALICZNYM

A b s t r a c t

The article analyzed the problem of cloud defect in metallic paint, caused by grain arrangement during paint application on a structural element. Presents test results of coating system consist of a high solid corrosion protection primer and a two-component topcoat with a metallic gloss effect (RAL 9006) developed in our company. The paint system properties were examined after the conditioning period.

Keywords: cloud defect, polyurethane metallic paint, metallic topcoat, polyurethane special effect

S t r e s z c z e n i e

W artykule przedstawiono problem tworzenia się defektu chmurki w lakierach metalicznych spowodowanych nieodpowiednią dystrybucją pigmentu. W artykule przedstawiono wyniki systemu zawierającego podkład antykorozyjny oraz lakier nawierzchniowy z efektem metalicznym (RAL 9006) opracowany w firmie BARWA. Właściwości systemu malarskiego zostały określone po okresie kondycjonowania.

Słowa kluczowe: defekt „chmurki”, lakier metaliczny, specjalny efekt farby poliuretanowej

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* M.Sc. Eng. Łukasz Pasieczyński, Firma Handlowa BARWA Jarosław Czajkowski.

** D.Sc. Ph.D. Eng. Norbert Radek, Assoc. Prof., Centre for Laser Technologies of Metals, Faculty of Mechatronics and Machine Design, Kielce University of Technology.

1. Introduction

In order to enhance the competitiveness of vehicle appearance and to attract customers, painting systems are used with special effects. One of them is the use of metallic pigments in paint topcoats. Such pigments glamorize appearance of coatings, as well as create a protective barrier against harmful elements of the environment. Metallic effect is obtained by dispersing metallic aluminum (aluminum flakes, aluminum grain) in a coating film. The process is difficult, because the final result of the achieved metallic coating is strongly dependent on many factors, such as pigment distribution and shape, surface smoothness, pigment orientation in relation to the surface of substrate or previous layer, pigment wet ability and grain size [1, 2].

Due to the shape, aluminum pigments are divided into two basic groups: irregular flakes (cornflakes) and lenticular flakes (silverdollar). The use of various shapes of metallic pigments causes differences in gloss of coatings as well as their visual appearance (surface smoothness, the absence of protruding pigment). Irregular flakes will scatter the light more than lenticular flakes (silverdollars) which have a more rounded shape. Lenticular flakes are commonly used in industrial and automotive paints.The size of particles dispersed in the system is yet another considerable factor. The larger particles are dispersed the greater metallic effect is obtained (brilliance, sparkle effect). Smaller particles give more homogenous effect with darker coating because of the better light scattering at the edges of the particles [3].

Distribution of aluminum pigments in a coating film on the surface or in the entire volume of a resin is as important as their shape. Every type of grain distribution has both its advantages and disadvantages. The way the grain is distributed in a resin depends on the technology of preparation. Leafing pigments of high surface tension do not get wet by a resin and float onto the surface of a wet film. This effect is obtained by the use of stearic acid in the pigment production. However, in high polar systems, pigment may get wet by a resin and “drown” inside the coating, turning into a non-leafing pigment. Addition of oleic acid or dispersing agents in the production process causes such an effect. Metallic effect is obtained by light reflection on the smooth surface of aluminum flakes [1].

Reflected light may, however, refract or scatter on the flakes’ edges or micro-roughness of the pigment surface. In that case, metallic effect is the sum of light reflection and scattering. The higher the ratio of reflected light the greater and more intense effect is to be observed. Metallic effect depends on the grain distribution and therefore on the angle of reflection. Pigment orientation of pigment in a coating film is an important factor in the visual effect. The more parallel aluminum pigment flakes are arranged to the surface the greater light reflection is noticed. Poor orientation results in a cloudy appearance. The type of grain and the process of its introduction into a metallic paint have an influence on grain distribution in a resin and defects of coating appearance which may occur after application. Poor grain selection, its size and shape as well as improper mixing lead to the atrophy of metallic effect, the coating darkening or “cloud” effect which is caused by improper pigment particles distribution. A cloud is formed by agglomeration of aluminum pigment particles in a resin and is observed by darker and brighter spots or stripes on the coating.

To avoid such defect on coating, it is recommended to apply more paint layers and cross painting because each following paint layer reduces the cloud effect. However, it increases production costs.

2. Experimental

The designed paint system includes epoxy primer with a high solid content and a two--component polyurethane paint with a high metallic gloss effect. Epoxy provides very good adhesion to steel due to the multitude of functional groups in the polymer molecule and corrosion resistance. The topcoat paint RAL 9006 is designed by F.H. Barwa laboratory. The coating was applied with SATA spray guns with 1.3-1.4 nozzle on steel. Before the application, the surface of steel was polished with a 240-grit sandpaper. Next, the epoxy primer was applied and heated at 60° Celsius for 60 min. The two layers of topcoat paint were applied wet-on-wet with a good hiding power. There was a 10-minute break between painting of the two layers in order to let the thinners evaporate from the coating. The prepared samples were conditioned at 23 degrees Celsius and 50% humidity for minimum 7 days in order to perform tests on dry coating.

3. Results and discussion

The paint is easy applicable. It can be applied as simply as an ordinary polyurethane topcoat without the necessity of cross painting or spraying to minimize the cloud defect. Additionally, RAL 9006 topcoat has much thicker grain and its metallic effect is similar to the base coat system. This paint system also enables repair of a paint surface damaged by external factors (e.g. brushing, scratching) with low production cost and within a short period of time. As a proof, a part of the sample was polished with a P400-grit sandpaper and polyurethane coating was re-applied in the abrasion place. No defects were observed in the coating.

Metallic effect depends on many factors and each factor has a direct effect on the final coating. For this reason, metallic effect measurement requires several techniques: tint and color saturation, gloss, brightness and hiding power or DOI (distinctiveness of image). It causes improvement in gloss, brightness and color saturation. A flop is another measured parameter. It is a change in brightness depending on the observation angle. It is especially noticeable on a car mask and car bumper.

The DOI parameter is responsible for the clarity of reflecting objects that surround the coating (trees, buildings, other cars). Market dictates high demands on paint coatings with metallic effect. They should be high gloss, bright with visible metallic effect and have high DOI and flop coefficient at the same time. After the formulation, the properties of the product were examined. Table 1 shows the results of the following tests performed on the liquid paint: density, solid content, flow time, drying time. Values given in Table 1 were obtained on a ready to use product (with added hardener and thinner).

Cured coating was also tested for mechanical properties, corrosion and humidity resistance. After the conditioning period had finished, the thickness of dry coating was tested by the magnetic induction method and adhesion tests were performed by the cross cut method and pull-off test. The hardness of cured coating was measured by Koenig pendulum. The corrosion resistance test was performed in the salt spray chamber according to PN--EN ISO 9227 at 35°C using 5% saline solution. The tests in the humidity chamber were conducted according to PN-EN ISO 6270-2 with following parameters of the chamber inside: humidity 100% and temperature 40°C. The summary tests results are presented in Table 2.

Table 1

Properties of liquid product ready to use

Test	**Standard**	**Result**
Density [g/cm^3]	PN-EN ISO 2811-1	0,95
Solid content by mass [%]	PN-EN ISO 3251	57
Solid content by volume [%] (calculation method)	Technical procedure	54
Flow time cup Ford4 [s]	PN-EN ISO 2431	26
Drying time at 60°C [h]	–	2
Color RAL	–	9006

Table 2

Selected properties of dry coating applied on steel

Test	**Standard**	**Result**	
Thickness [μm]	PN-EN ISO 2808	121,9	
Cross cut	PN-EN ISO 2409	No change	
Adhesion [MPa]	PN-EN ISO 4624	4,96	
Hardness, Koenig pendulum [s]	PN-EN ISO 1522	105	
Corrosion resistance test [1000 h]	PN-EN ISO 9227	No change	
Humidity resistance test [1000 h]	PN-EN ISO 6270-2	No change	
Gloss [gloss unit]	PN-EN ISO 2813	20°	67,2
		60°	94,2
		85°	90,9

The next test of resistance to aggressive environmental conditions (corrosion and moisture) were finished and assessed after 1000 hours of exposure. The result revealed no changes in the tested coatings (no blistering, cracking, corrosion or thread-like corrosion). 1000 hours is a minimum time for a coating to be resistant to environmental effects. However, this time could be extended when aluminum is used as a substrate instead of steel.

The paint could be applied by the wet on wet method or on the surface of a dry sanded primer. Two layers should be applied to obtain entire paint coverage. Our product does not cause a cloud effect but creates an uniform varnish layer on the element. During the evaporation of solvents we can observe the grain which spreads across the entire surface within the next two or three minutes. In the next test, the two samples were prepared with and without a cloud defect. Each sample had a grid with a similar surface area. The surface of the samples was examined by a spectrophotometer (with six different angles –15°, 15°, 25°, 45°, 75°, 110°) to determine the change of the color by measuring $L^*a^*b^*$ parameter. The results are shown in Figs. 1 and 2.

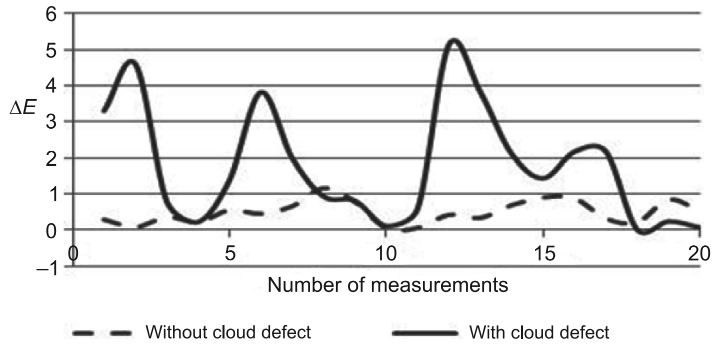

Fig. 1. Color difference for angle 25°

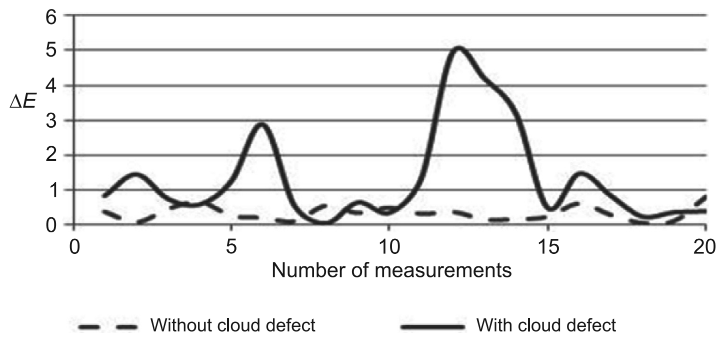

Fig. 2. Color difference for angle 45°

Figures 1 and 2 present a comparison of color difference (ΔE) for samples with and without a cloud defect in the two of six selected angles (25° and 45°). The sample with a cloud defect has a significantly higher value of the ΔE parameter than the sample without such a defect.

ΔE (1) parameter equals:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \tag{1}$$

The values of Δa and Δb parameters do not exceed 0.5 for the sample with a cloud defect, although the change in color is well observed. In this case, the ΔL parameter (brightness parameter) explains the effect. The ΔL parameter gives some information about brightness in a given point and its fluctuations are caused by a cloud defect that is irregular distribution of grains in the resin. The study on spectrophotometer for 8° angle deviation from the perpendicular axis to the tested surface was finished with the ΔE parameter not exceeding 1.0 for the sample without the cloud defect. A scratch test was conducted to test the adhesion of the coatings. Adhesion tests were conducted by means of the REVETEST instrument (CSEM, Switzerland). The measurements were performed at the load increase rate of 49 N/min, table feed rate of 10 mm/min and scratch length of 10 mm. A special

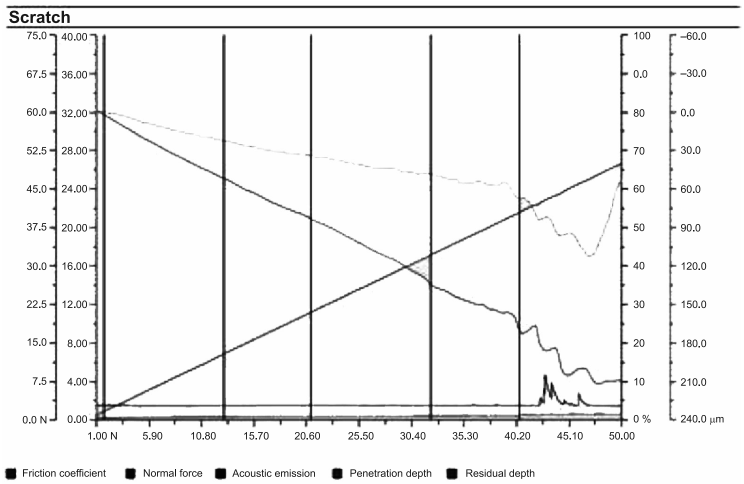

Fig. 3. Result of scratch tests of metallic coating adhesion

Rockwell diamond cone indenter with a corner radius of 50 μm, was used to scratch the samples at a gradually increasing normal load. The information about cracking or peeling of the layers was obtained based on the measurements of material resistance (tangential force) and the registration of acoustic emission signals. The lowest normal force causing a loss of adhesion of the coating to the substrate is called a critical force and is assumed to be the measure of adhesion. The value of critical force was 42 N, the result of the scratch test is shown in Fig. 3.

4. Summary

Low production costs due to an easy application, the same as for ordinary polyurethane varnish. Cross painting or application of a thin finishing layer is not required. Metallic effect is obtained without losing high gloss. It is comparable to double layer systems.

No cloud defect and the entire coverage of primer is achieved when the paint is applied in two layers.

Good resistance of a finished product to aggressive environmental factors and good adhesion to steel.

Possibility to repair local damaged areas (scratches) without losing the surface appearance and metallic effect.

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