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Determination of Effects of Primer Surfacer Properties on the Automotive Coating Appearances by DOE

S. Bastani[*1], A. R. Massoumi[2], P. Qodsi[3], A. Karbasi[3]

[1] Assistant Professor, Department of Surface Coatings and Corrosion, Institute for Color Science and Technology, P.O.Box: 16765-654, Tehran, Iran

[2] MSc., IranKhodro Co., Paintshop, Tehran-Iran

[3] MSc., Department of Polymer and Color Engineering, Amirkabir University of Technology, P.O.Box: 15914-4413,Tehran, Iran.

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ABSTRACT

In general, the evaluation of automotive coatings appearances favors (is considered preferentially) more than chemical and physical properties. Therefore, its improvement is most required. Studying appearance by means of QMS-BP technique, in which it measures some of the most important coating appearance factors, such as: the specular gloss, distinctness of image (DOI) and orange peel. In this article the influence of variation in the primer properties, such as thickness, roughness and gloss on the appearance of final coating system for two different primer types was studied. Results showed that increase in specular gloss would cause the intensification of NAP (Niveau d'Aspect Peinture) values, while increase in thickness and roughness would decrease it. Prog. Color Colorants Coat. 2(2009), 79-86. © Institute for Color Science and Technology.

1. Introduction

The current global economy has increased international competition. It has forced many manufacturers to improve their products quality. The appearance measurements are implemented to determine quality and compatibility of variety of products from textiles to automotive finishes.The scope, methods, instruments and standards for measuring of appearance must be precise and reproducible due to the international market requirments.

The appearance of an object is the results of a complex interaction of the incident light on the object, the optical characteristics of the object and human perception (Figure 1). In multilayer coatings, such as automotive coating, the topcoat appearance will be affected by the properties of each layer. Gloss and surface texture of each layer are the major parameters, which define topcoat appearance.

*Corresponding author: bastani@icrc.ac.ir

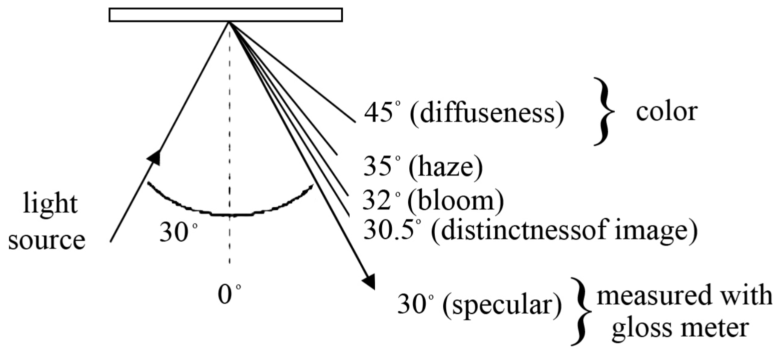

Figure 1: Measuring the topcoat appearance attributes.

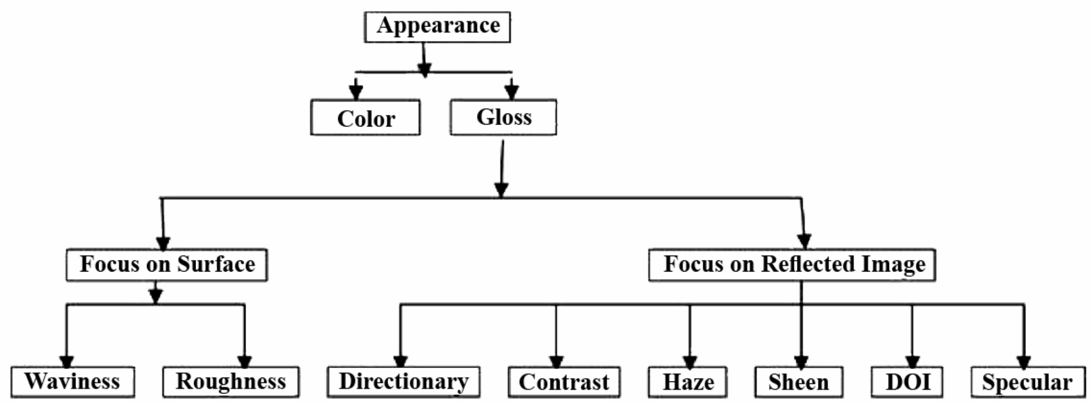

Figure 2: Varius types of gloss.

Appearance attributes of an object are roughly derived into chromatic and geometric attributes. The chromatic attributes are those that vary from the spectral distribution of the reflected light (color).The geometric attributes are those that vary from the spatial or angular distribution of the reflected light (gloss) [1].

Gloss is the ability of reflecting a large fraction of light in one direction compared to those of all other directions. Gloss is the best property to compare visual aspect of coatings [2], which is divided into two general categories depending on the method of measurement (Figure 2). The human eyes usually focus on the surface and determine different surface textures such as orange peel and surface roughness. The eyes also focus on the reflected image and detect the surface attributes such as specular gloss, DOI and haze. As the result, the mirror-like surface is determined [3, 4].

Specular (mirror-like) gloss is the most considerable appearance attributes of topcoats which equals the ratio of reflected light at the specular angle to the incident light beam angle. No full-satisfactory method for the measuring gloss is available; however, the reflected beam can be measured in the specular angle [2].

One of the methods of appearance measurement, which is used nowadays in automotive industries, is the employment of QMS-BP that estimates the NAP value. In fact the NAP (Niveau d'Aspect Peinture) value which is almost equal to the human perception of an automotive coating appearance, is the result of different parameters, such as gloss, DOI and orange peel taken from 26 different points of a car exteriority[5].

Paint is applied on the body after three surface treatments. The first stage acts against corrosion, then a gray layer called electrocoat is applied on the sheet of metal to suppress the surface large amplitude deformations. Another primer gray layer improves the leveling of the surface and protects it against loose chips. The electrocoat and the primer layers are separately baked. The paint coating is composed of a 15-18 µm layer of colored paint called basecoat, and a 35-45µm layer of transparent varnish, which is also called clearcoat. The clearcoat is a protective layer against weathering. It also carries on the surface leveling and gives gloss property to the surface .The basecoat and clearcoat are baked simultaneously with an intermediate firing [6].

Primer layer with different surface texture, such as: orange peel, roughness and gloss are important parameters in determining quality of the appearance.

Based on the Orchard equation used for leveling, by increasing the coating thickness, the amplitude will decrease (Figure 3). It will be more level, and the surface will become smooth. Increased uniformity will result in better leveling of the basecoat (BC)/Clearcoat (CC) layer and better appearance [7].

$$\ln(\frac{a_0}{a}) = \frac{16 * \pi^4 * \gamma * h^3}{3 * \lambda^4} \int \frac{1}{\eta} dt \quad (1)$$

Increased primer layer roughness will cause surface non-uniformity and loss of gloss. Relation between gloss and surface roughness can be stated as following:

$$R_F = R_\circ \exp[-(4\pi\sigma / \lambda)^2] + 32R_\circ / m^2(\pi\sigma / \lambda)^4 (\Delta\theta)^2 \quad (2)$$

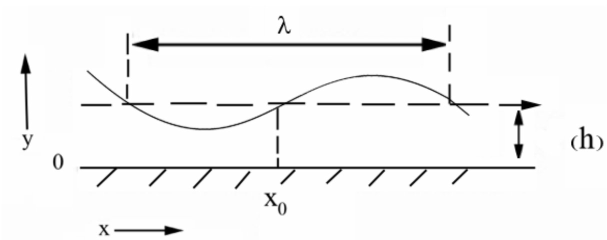

Figure 3: Orchard equation and the waviness of coating surface.

Where R_0 is the reflectance from a corresponding smooth surface, σ is the root mean square roughness, λ is the wavelength of the incident radiation, m is the mean gradient of the surface and $\Delta\theta$ is the solid angle of measurement. In relation to this equation, the first term is the specular and the second is the diffuse reflectance [8].

2. Experimental

Materials

Black primers surfacer of Goharfam Co. and Gamathinner Co. were applied for the experiments. Dupont's anodic ED coating for application ED layer and the metallic black basecoat of Goharfam Co. and clearcoat of Sudeh Co. for BC/CC Layers were also used.

Sample Preparation

13 plates were used for QMS-BP test for each experiment. Eight plates were used for vertical points and five plates for horizontal ones. Each sample was degreased and phosphated (like car exterior condition) and then AED layer was applied on it. Different values of roughness were reached using emeries with different emering numbers ranged from 60 to 3000. In real conditoins, different values of roughness are appeared due to the non-uniform ratio of resin to pigment amounts in ED film at different vertical and horizontal points.

Application of the Coating

Hand spray gun was used for spraying the primer surfacer and expected thicknesses with the tolerance ±3µm were obtained. All plates were cured in a furnace in the same conditions. For application of the basecoat and clearcoat each series of plates was stuck on the car body for simulating the same conditions.

Design of Experiments (DOE)

Three levels for studying gloss, thickness of primer surfacer and roughness of ED layer were chosen, and as it is stated before two kinds of black primers were applied. Different values of parameters have shown in Table 1.

The experiments were designed using the Minitab software and ten experiments were chosen for studying the effects of the primer surfacer properties. The results are shown in Table 2.

Table 1: Presenting different values of parameters.

Parameters \ Level	Level 1	Level 2	Level 3
Thickness (µm)	20	35	50
Gloss(60°)	80	60	40
ED Roughness (Horizontal-Vertical)	0.25-0.4	0.37-0.6	0.5-1
Primer Surfacer's Supplier	Goharfam	Gamathinner	

Table 2: Thickness, gloss and ED roughness tests results for various conditions.

Level \ Parameters	Supplier	Thickness (µm)	Gloss (60°)	ED Roughness (Horizontal-Vertical)
1	Gamathinner	50	40	0.25-0.4
2	Goharfam	20	80	0.5-1
3	Goharfam	50	40	0.5-1
4	Gamathinner	20	80	0.25-0.4
5	Gamathinner	20	40	0.5-1
6	Goharfam	50	80	0.25-0.4
7	Goharfam	20	40	0.25-0.4
8	Gamathinner	50	80	0.5-1
9	Goharfam	35	60	0.37-0.6
10	Gamathinner	35	60	0.37-0.6

Measurement of primer surfacer properties

Thickness Measurement: The thickness of the ED coated plate was measured before and after primer application based on ASTM B433 standard using Electrophysik Mini Test4100 instrument

Gloss Measurement: The gloss of primer surfacer layer was measured at the angle of 60 degree based on ASTM D563 standard using Micro Tri-gloss Instrument.

Roughness Measurement: The surface roughness of each sample was measured using Surface Roughness Tester TR100 at the wavelength of 0.25 mm.

Measurement of Appearance

QMS-BP Test: The test designed by Autospect Co., was used, in order to measure the coating appearance and to determine the NAP values for each series.

Measurement of the appearance is based on focusing onto reflective images. This instrument can determine the

NAP values for different points of the car exterior by measuring the gloss, distinctness of image (DOI) and orange peel of 26 different points on car body.

Distinctness of image (DOI) and Orange peel Measurement: Wave scan DOI instrument manufactured by BYK-Gardner Co. was used to determine DOI and orange peel of the topcoat of each sample. Wavelength below 1 mm was used to measure the DOI. The tension value was measured with the wavelengths of 0.3- 12 mm for determining orange peel.

3. Results and discussion

The measurements show that series 4, 9 and 10 have the higher NAP value, and series 2, 3, 5, 8 with high roughness values have the lower NAP value. Results of measuring DOI and orange peel show that for the maximum values of NAP (in series 6, 9, 10), DOI's are maximum (Figure 4).

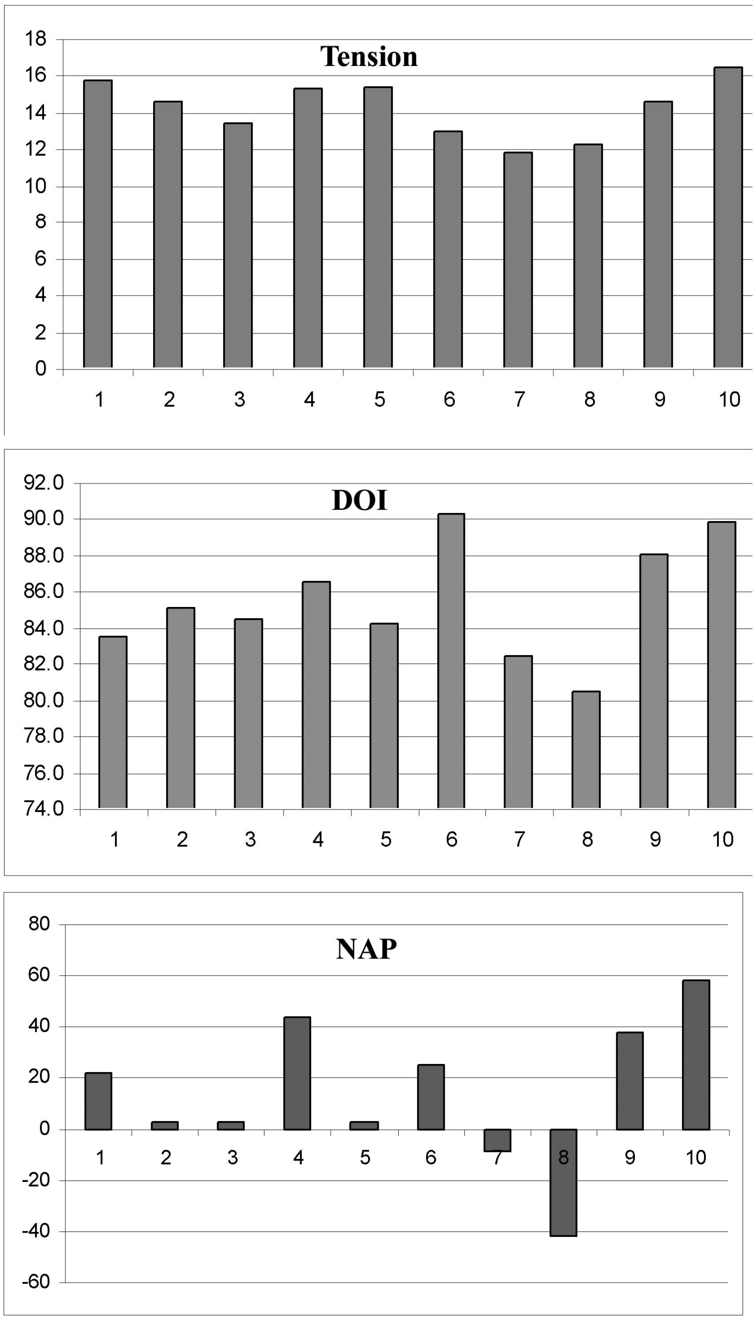

Figure 4: Tension, DOI and NAP values of 10 systems.

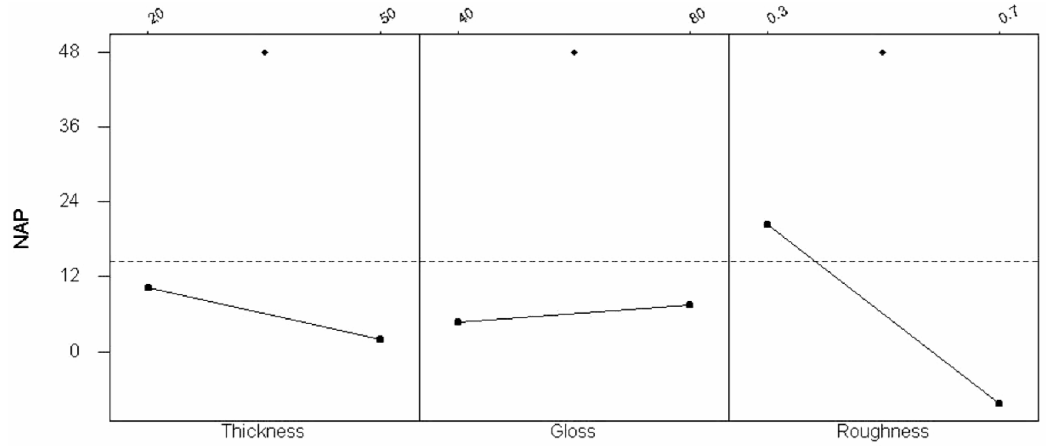

Figure 5: The effect of parameters on the NAP values.

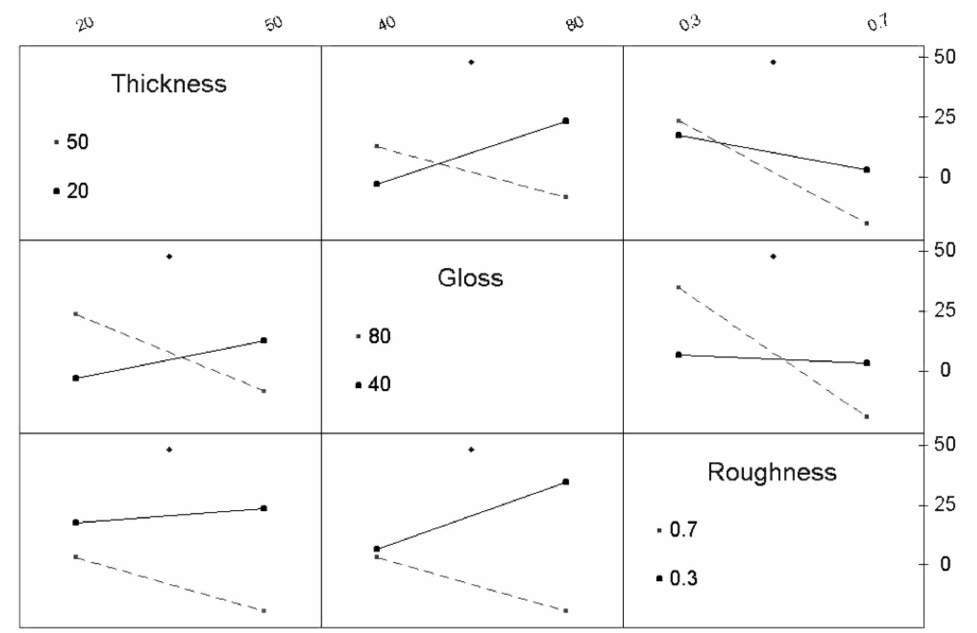

Figure 6: The effect of parameter Interaction on the Nap value.

Figure 5 shows the effect of different parameters on the NAP value (the roughness values are the average of the car exterior). The NAP values fell sharply when the roughness of ED increases. The ability of primer for coating the surface declines while the surface roughness of ED layer increases and the primer will transfer the surface profile to the next layer, so that the surface of the primer will become rough and cause a reduction in the NAP values. In addition, the NAP values increase when the primer layer glossiness increases, because the surface of the coat will be smoother, and application of the next layer on the smooth surface will cause greater NAP values. Results of the interaction between gloss and roughness shows that only in high values of gloss, NAP values are dependent on the ED layer roughness and in low values of gloss, the roughness has low effect on the NAP value. By amplification in the primer glossiness, NAP values will become more sensitive to the roughness of under layer, because the profile of the under layer will transfer and effect the NAP values.

Results also show that the decrease in the thickness of coating will cause reduction in the NAP values. However, the interaction between roughness and thickness shows that the transfer of surface profile will be equal at low roughnesses, and effects on NAP values will be negligible. At high values of roughness, the NAP sharply decreases, while the increasing the thickness, since even at high thicknesses, the primer cannot cover highly rough surfaces so the surface profile will transfer (Figure 6).

Results of interaction between gloss and thicknesses in Figure 7 show that only in low thicknesses, increase in the gloss causes rise in the NAP value .But in the high thicknesses, it will reverse, and the NAP decreases when the gloss increases.

Figure 8 shows the relation between NAP and different parameters interaction.

The effect of all parameters on the NAP values can be predicted by the following equation obtained from the regression of data, where the Block is related to the type of primer.

$$\begin{aligned} NAP &= 6.12 - 2.5 \times Block \\ &- 4.13 \times Thickness + 1.37 \times Gloss - 14.38 \times Roughness \\ &- 11.88 \times Thickness \times Gloss \\ &- 7.13 \times Thickness \times Roughness \\ &- 12.63 \times Gloss \times Roughness \end{aligned}$$

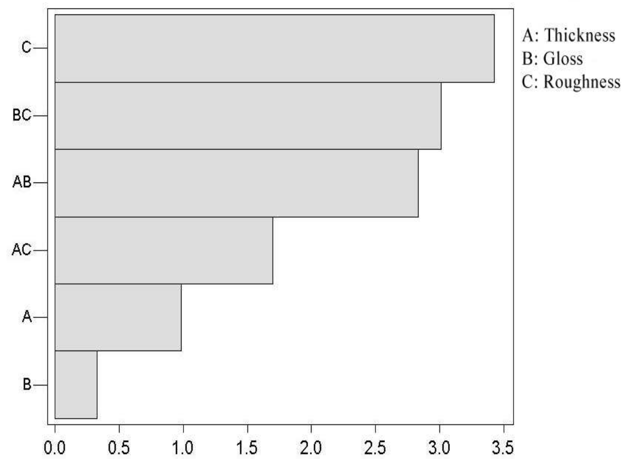

Figure 7: The interaction between gloss, thickness and roughness.

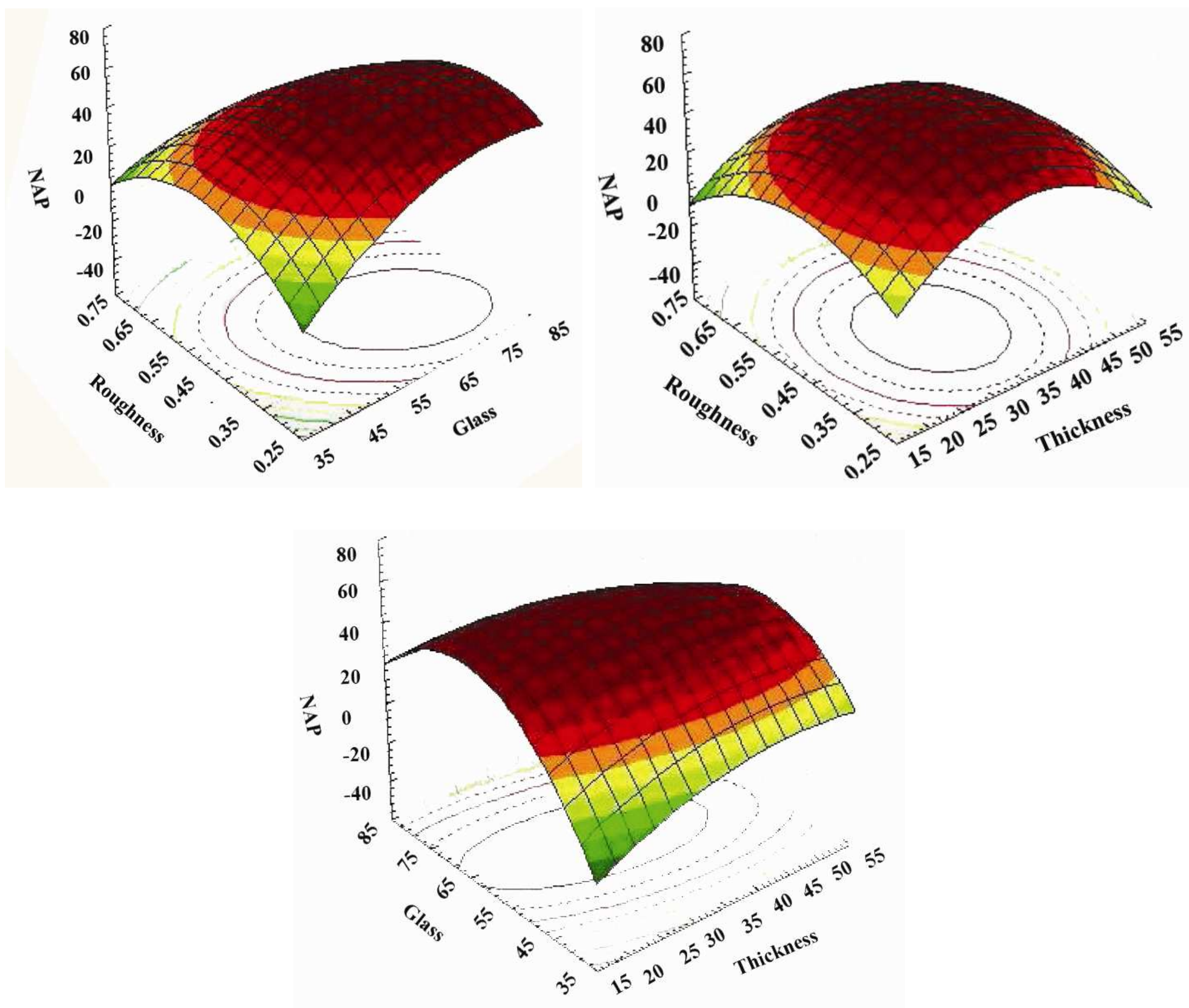

Figure 8: The relation between NAP and different parameters interaction.

4. Conclusions

The obtained results show that the roughness of ED layer is the most vital parameter in quality determination of the appearance and the NAP value. The NAP value was increased by decreasing ED layer roughness.

On the other hand, optimization between the gloss and thicknesses of the primer will cause increases in the NAP values.

Acknowledgment

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