Quality research of paintwork of Volkswagen Tuareg car body elements

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Abstract. Appearance is one of the criteria forming the aesthetic perception of a particular vehicle. However, the appearance of the car is a factor determining the consumers’ opinion about the brand of the car. Many vehicles during their operation for many different reasons undergo repair and restoration operations. As a rule, repairing body elements the paintwork is performed, the quality of which and the observance of technologies and standards during work ultimately determine the durability of the paintwork. The quality of the paintwork, the presence of damage, fragments of destruction is one of the essential aspects that interest consumers in the secondary market. The article presents the results of a study of the paintwork quality of the Volkswagen Tuareg car body elements; the presence of defects is identified, the causes of their occurrence are detected.

1. Introduction

The color quality of the car body has become the main aesthetic factor affecting the process of buying a car [1]. Vehicle manufacturers, recognizing the demand of the market, focus on aesthetics, environmental protection, and the quality of the paint applied to the car. The color and quality of the paint largely determine the decision of the buyer [2]. Growing customer expectations regarding the appearance of cars are forcing car paint shops to scrutinize car bodies. Currently, qualified workers visually inspect each car body for the identification and elimination of paint defects. However, people can neither detect nor judge defects objectively and reliably for a more extended period [3].

The complicated and broad requirements that the exterior of the car must comply with prompted BMW to make the technological leap from liquid, transparent coating to powder coating capabilities. A transparent coating creates an unsurpassed gloss effect, and a transparent coating on a powder basis makes the surface of the car even shinier [4].

According to the current classification of coatings for industrial products by their appearance, decorative coatings for cars are class I–II coatings (out of seven regulated). Decorative coatings have two different contact surfaces: one contact surface is with the external environment (usually gaseous or liquid); the other contact medium is with a solid or substrate.

Decorative coatings are films bonded by adhesive forces to a hard surface. The structure of the decorative coating of the car consists of several layers.

Phosphating the metal obtains the first layer. Phosphating is the processing of metal by exclusive means based on phosphate salts, as a result of which a protective film appears on the surface among the options for protecting the metal from corrosion by phosphating, the most known phosphating...
primer. Hydroabrasive phosphating and chemical treatment of metal are also applied. In addition to protecting the metal, the film provides increased adhesion of the metal to the coating materials.

The second layer is soil, which is the base of the entire coating. The purpose of the second layer:
- provide adhesion of the decorative coating to the substrate;
- protect the substrate from the effects of destructive factors;
- protect the subsequent layers of the coating from the effects of the substrate (for example, alkalis or plasticizer made of plastic).

The third layer is the base coat. The purpose of the third layer:
- strengthen the protective functions of the primer layer;
- ensure the alignment of the soil and the substrate;
- maximize the properties of the coating (light reflection, color, diffusion inhibition);
- increase the protective properties of the coating to mechanical stress.

The last (top) layer is varnish (if necessary). The purpose of the fourth layer:
- basic protection against the effects of the atmosphere (UV radiation, precipitation, air humidity), chemical agents (acids, alkalis, aggressive gases) and solvents (liquid motor fuel);
- solutions to functional problems (decorative, optical, electrical, and other properties).

The decorative coating, initially, laid down specific properties established by the manufacturer. The car operation leads to its aging, the accumulation of damage, and destruction due to interaction with the environment. As a result, defects appear in the product.

According to the requirements of GOST 9.311-87, corrosion lesions are determined with the naked eye with visual acuity of 1.0-0.8, with normal color sensation at a distance of 25 cm from the controlled surface with a sample illumination of at least 300 lux.

There is a possibility to establish the type of corrosion damage by using a magnifying glass or other optical means, for example, a microscope.

2. Research Objectives
1. To identify the presence of a car Volkswagen Tuareg defects in the decorative coating of moldings.
2. If there are defects in the decorative coating of the moldings of the Volkswagen Touareg car, identify the cause of their occurrence.

3. Materials and methods
   The object of research is a Volkswagen Tuareg passenger car, 2016 model year.
   Research equipment and tools:
   - Camera SONY Cyber-shot 14.1 megapixels.
   - Magnifier with eight magnification.
   - ET-11P feeler gage.
   - Digital microscope Digital microscope 500.
   - Transparent mesh, area 1 dm².
   - Ruler.

4. Results and discussions
   Surface treatment plays an essential role in the perception of product quality and is the first that a potential buyer sees. Today, the final body repair of cars and trucks must inevitably provide the required surface quality. Defects that occur in the paint shop, such as dust particles, are eliminated by manual grinding/polishing, which leads to other types of defects when the last polishing step is performed incorrectly or is not completed [5]. With the improvement of painting techniques in the automotive industry on car bodies, it is possible to achieve high-quality paints with high gloss, clear images, and deep orange peel. In this case, another defect, called the “metal texture effect,” is becoming increasingly crucial for the appearance of the paint [6]. The automatic detection of small defects (up to 0.2 mm in diameter) on the surfaces of the car body after the painting process is
Currently one of the most severe problems of quality control in the automotive industry. Although several systems have been developed over the past decade to solve this problem, as far as we know, they were focused exclusively on flat surfaces and were unable to inspect other parts of the surfaces, namely style lines, edges, and corners, as well as deep concavities [7].

The inspection of the vehicle was on the premises of the technic zone in the daytime, with artificial lighting.

In the presence of the car owner, a specialist checked the decorative coating of moldings condition and the paintwork of the car body.

During a visual inspection found:

- the decorative molding on the right front fender has a chrome finish;
- the decorative molding on the right front door has a chrome finish;
- the decorative molding on the right rear door has a chrome finish;
- the decorative trim (top) on the rear bumper has a chrome finish;
- the decorative trim (lower) on the rear bumper has a chrome finish;
- the decorative molding on the left rear door has a chrome finish;
- the decorative molding on the left front door has a chrome finish;
- the decorative molding on the left front wing has a chrome finish;
- the thickness of the car paintwork is in the range of 177 to 348 microns.

Analysis of measurements of the thickness of the paintwork suggests that the tailgate was repainted.

Measurements of the thickness of the tailgate are in the range from 305 to 348 microns. The remaining ferromagnetic elements of the body are in the factory color. The thickness of the paint coating is in the range from 177 to 271 microns. The thickness of the factory paint should be in the range from 140 to 180 microns. The large values of the thickness of the paintwork are explained by the fact that a protective coating (presumably quartz) is additionally applied to the body. The state of the paintwork evidences the fact of applying a protective layer after preliminary washing and approval of the car owner.

An external inspection of the decorative coating (front and rear door and front wing moldings) was performed, including using a Digital microscope 500 electron microscope. As a result of the inspection, it was found that on all the elements mentioned above of the car body there are local areas of coating destruction on which the substance was formed gray to brown, similar in appearance to corrosion products. Following GOST 28246-2006, these areas of destruction are classified as "metal corrosion".

According to the methodology proposed in GOST 9.311-87, the area of the destroyed coating is determined using the following steps: on the surface to be evaluated, experts apply a plate of transparent material with a mesh or wire mesh applied to it (the side of the square can be 10 mm or another, which depends on the size of the samples and areas of destroyed areas) or draw a rectangular shape and calculate its area.

Assessment of the molding of the front left wing led to the determination of the following types of corrosion damage:

- A – surface tarnishing (non-removable translucent film) on 20% of the surface;
- G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 3% of the surface;
- D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 2% of the surface;
- K – corrosion of the base metal (spots and dots) on 1% of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 20 + 0.8 \times 3 + 1 \times 2 + 1 \times 1 = 8.4\%. \]

Assessment of the molding of the front left door led to the determination of the following types of corrosion damage:
A – surface tarnishing (non-removable translucent film) on 20 % of the surface;
G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 2 % of the surface;
D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 4 % of the surface;
E – corrosion of the sublayer (spots and dots) on 1 % of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 20 + 0.8 \times 2 + 1 \times 2 + 1 \times 1 = 10.6 \% . \]

Assessment of the rear left door molding led to the identification of the following types of corrosion damage:
A – surface tarnishing (non-removable translucent film) on 20 % of the surface;
G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 2 % of the surface;
D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 2 % of the surface;
K – corrosion of the base metal (spots and dots) on 1 % of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 20 + 0.8 \times 2 + 1 \times 1 = 8.6 \% . \]

Assessment of the front right wing molding led to the determination of the following types of corrosion damage:
A – surface tarnishing (non-removable translucent film) on 20 % of the surface;
G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 1 % of the surface;
D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 2 % of the surface;
E – corrosion of the sublayer (spots and dots) on 1 % of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 20 + 0.8 \times 1 + 1 \times 2 = 7.8 \% . \]

Assessment of the front right door molding led to the determination of the following types of corrosion damage:
A – surface tarnishing (non-removable translucent film) on 20 % of the surface;
G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 2 % of the surface;
D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 2 % of the surface;
K – corrosion of the base metal (spots and dots) on 2 % of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 20 + 0.8 \times 2 + 1 \times 2 + 2 \times 1 = 9.6 \% . \]

Assessment of the rear right door molding led to the determination of the following types of corrosion damage:
A – surface tarnishing (non-removable translucent film) on 15 % of the surface;
G – corrosion of the coating with the formation of oxide-like products (unremovable dark spots and spots) on 2 % of the surface;
D – corrosion of the coating with the formation of salt-like products (gray spots and dots) on 2 % of the surface;
K – corrosion of the base metal (spots and dots) on 1 % of the surface.

\[ S_{decorative\ coating} = \sum_{i=1}^{N} K_i \times S_i = 0.2 \times 15 + 0.8 \times 2 + 1 \times 1 = 7.6 \% . \]
Assessment of the upper lining on the rear bumper led to the determination of the following types of lesions:

Peeling (expansion) of the decorative coating under chrome on an area of 3%.

Evaluating the lower lining on the rear bumper led to the identification of the peeling (expansion) of the decorative coating under chrome on an area of 2%.

Determine the estimated score:

- Decorative properties of the coating moldings – AD 4.
- Decorative overlays of a back bumper – HELL 5.

By the value of the area of corrosion damage to the base metal (2%), we determine the estimated score of the protective properties of the coating – AZ 6.

For types of destruction of protective properties, if necessary, it is allowed to put in brackets the designation of the size of a typical defect.

The study found that the decorative body moldings of the Volkswagen Tuareg car have the following groups of damage (defects) of the coating:

- Fading of the coating surface.
- Corrosion of the coating with the formation of oxide-like products.
- Corrosion of the coating to form salt-like products
- Corrosion of the base metal.
- Peeling (swelling) of the coating.

A detailed analysis of damage with magnification up to 500 times (using an electron microscope) allows us to unequivocally state that these defects occurred both with damage to the decorative layer (Fig. 1, 2), and without mechanical damage (Fig. 3).

**Figure 1.** Image of the enlarged image of the destruction of the molding on the left side
Figure 2. Image of an enlarged image of the destruction of the molding on the right side.

Figure 3. Image of an enlarged image of the destruction of the molding on the right side.
The expansion (peeling) of the decorative coating on the upper and lower plates of the rear bumper (Fig. 2, Fig. 3) has no visible damage from mechanical stress, and was formed as a result of insufficient adhesion, which is seen when comparing with how mechanical damage is reflected in the grill radiator (Fig. 4).

It should be noted that the decorative moldings on the door frames do not have similar damage, although they were in the same operating conditions.

The decorative coating has defects, including without external mechanical damage; however, not all compared decorative elements have characteristic defects. Given this fact, we can make an unambiguous conclusion that the defects of moldings (destruction of the decorative layer) on the right front wing, right front door, right rear door, left rear door, left front door, left front wing, on the rear bumper overlays as a result of a violation of the coating technology.

5. Conclusion

The car Volkswagen Touareg, there are defects in the decorative coating of moldings namely; tarnishing of the surface of the coating, corrosion of the coating with the formation of oxide-like and salt-like products, corrosion of the sublayer and base metal, delamination of the coating (expansion).

Manufacturing defects have moldings; front right-wing, right front door, right rear door, left the rear door, left the front door, left front wing, and upper and lower rear bumper trim.

Defects in the decorative coating of moldings and linings for the rear bumper of a Volkswagen Tuareg car were formed as a result of a violation of the coating technology.

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