Investigation of automotive primer and basecoat paint surface's adhesion by solid particle erosion

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Investigation of Automotive Primer and Basecoat Paint Surface's Adhesion by Solid Particle Erosion

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Abstract. Millions of cars are sold around the world and tons of paint are used for these cars. Since the car paint industry is alive in this way, new developments in the paint sector have been taking place every day. It is important to determine how these developments affect paint erosion. Solid particle erosion wear is a subject that keeps its update for car paints and it always needs to be investigated in detail. The target of this experimental study is to investigate solid particle erosion behavior of a commercial acrylic/melamine primer surface and basecoat of automotive paint. As a erodent, silica particles having a weight of 1 to 5 kg were used. Tests were performed at 30º and 90º impact angle and particle velocity 23 m s^{-1}. With this work, an idea about the adhesion of the car paint coatings to the material surface was obtained.

1. INTRODUCTION

The car painting industry has undergone incredible changes by way of materials and processes development following the general progress of manufacturing technology from the start of the twentieth century until today [1]. Also the coating technology in automotive paint system has improved rapidly. First half of the twentieth century all coating steps were executed manually. After mass production system, automated coating systems were introduced. In 1940s after mass production system there were need faster drying and curing in automotive paint system. So in this time enamels began to be used. But enamels had limited availability. That's why it had to give way to synthetic chemicals. Cross-linking in paint became the latest technology. So that all the preparations like cleaning, sanding, repairing, and so on required for car paint in one day can be made.

Over time the number of coatings applied to car paints fell to four or five (figure 1). The function of these layers were corrosion protection for the primers, smoothness and chip resistance for the primer surfacers (which are often applied at the front ends and exposed areas in two layers), and color and weather resistance for the final top-coat layer. In the 1950s the process of applying the primer changed to dip coating, a more automated process, but a hazardous one owing to the solvent emission of the solvent-borne paints. Explosions and fire hazards then forced automotive manufacturers to introduce either waterborne paints or electrodeposition paints. The latter, which were introduced during the late 1960s, are more efficient in terms of material transfer as well as throwing power that is necessary for improved corrosion protection of the inner parts of the car body [1].

These developments in the paint sector have resulted in the emergence of paints that are more resistant to corrosion and retain their longer-lasting brightness.

Furthermore, raw material development in the pigment section, with improved flake pigments based on aluminum and new interference pigments that change color depending on the angle in which they are viewed, has resulted in enhanced brilliance and color effects of automotive coatings [2].

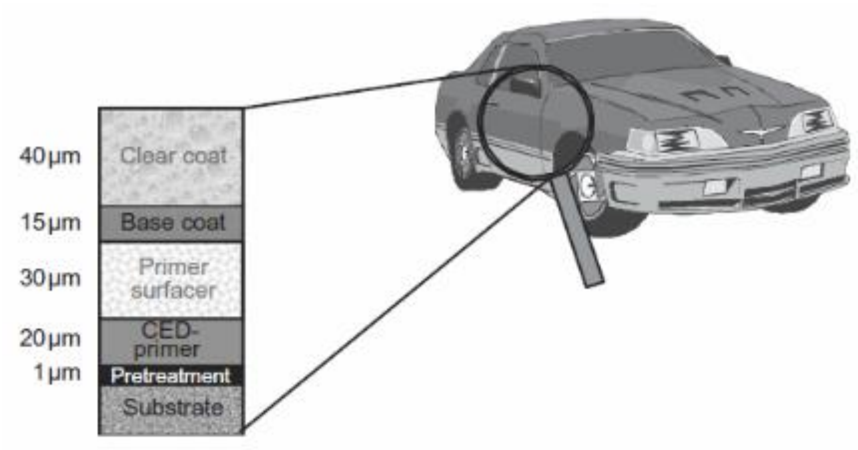

FIGURE 1. Scheme of the multilayer coating of cars [1].

Along with these developments experienced in the paint sector, major developments have been observed in the paint spray method. Because of the latest developments in wet-on-wet coating technology, coating machines, automated cleaning processes, and modern paints, the time taken today for the coating process, including pretreatment, can be as short as 8 hours for a car body leaving the body shop and entering the assembly line [3].

While these developments were experienced in the car painting sector, the materials used in the cars changed to a great extent. Initially, only steel material was used, but now aluminum, magnesium and plastic materials have begun to take its place. The main effect of using these materials is that they are cheap, light and well-formed.

There has been an increasing trend, recently, towards researches on solid particle erosion wear; one of the types of surface damages where eroding particles of different dimensional sizes under various impact velocities and impingement angles, strike and affect top surfaces of materials thereby leading to material losses and functional variations [4,5].

Damage to paint surfaces by solid particle erosion, when wear is caused by discrete solid particles striking the surface, is of great concern to both automobile and paint manufacturers, and there is a general need for an improved understanding of the factors controlling the erosive durability of paint coatings used in automotive applications [6]. It has even been claimed that appropriate testing and test methods could play a more important part in future coating technology than resins and paint formulations [7].

For any erosive wear situation, process parameters such as the particle impact velocity, the angle of particle impact relative to the surface and the particle size are expected to have a significant effect on the wear rate of the material under investigation [8]. This paper reports the attachability of the typical commercial car paint coatings to the material surface with solid particle erosion testing.

2. EXPERIMENTAL SETUP AND PROCEDURE

2.1 The Solid Particle Erosion Test

The solid particle erosion tests were carried out on a specially designed “gas-blast” apparatus in which dry and pressurized air was applied to the test sample surface of the impingement particles and the ASTM G76-95 standard test method in which the wear condition was investigated was used [9]. The impact velocity and angle of the erosive particle can be changed as desired in this test tool. Pressurized air were adjusted with a pressure regulator and controlled from a manometer. Since the nozzle is perpendicular to the sample, the erosion scar on the coating can be easily seen. In all experiments, angular silica sand (SiO_2) with a diameter 200-400 μm were used as an erodent.

Impact velocity of erosive particles was fixed to 23 ms^{-1} and the impact angle was changed from 30° to 90°. Double disc method was used for determination of the impact velocity [10] and adjustment of the impact angle was achieved by rotating the sample holder relative to the axis of the nozzle. Also erodent particle kilogram changed from 1 kg to 5 kg. All tests were performed at room temperature. The erodent particle sizes were determined by sieving. The sizes chosen represent the typical range of airborne particles that would be expected to be encountered in automotive practice, excluding large stones that might be thrown up from another vehicle's tyres [6].

2.2 Materials

In the tests, galvanized sheet metal in car bodies was used. Dimensions of used metals was 30x40x1 mm. Three sets of samples were prepared for the tests. Each sample group consists of ten samples. Erodent impact angle of 30° and 90° were equally applied to half of ten samples. Also, at each angle tests were performed with erodent masses in weights ranging from one kilogram to five kilograms. The first sample group is made of uncoated galvanized sheet metal. For second sample group, only the primary coating was applied. For the third sample group both the primary coating and base coating were done. In the primary coating, primerfiller (Baslac 20-24) was mixed with the hardener (Polaron, e-Fast hardener) in a ratio of 4:1. In the basecoat, acrylic basecoat was mixed with the acrylic reducer (Polaron, T 8-18) in a ratio of 2:1. The factors and levels are summarized in Table 1. All coatings were made by hand spray method in the industrial environment at room temperature. Prior to the erosion wear test and after, all samples were weighed with a compact analytical balance (A&D HR-250AZ). After erosion tests all samples were photographed and made image processing to obtain erosion scar.

TABLE 1. Test parameters.

Sample groups	**Number of samples**	**Primary coating**	**Basecoat**	**Erodent velocity (m/s)**	**Impact angle (°C)**	**Erodent weight (kg)**
First	10	No coating		23	30-90°C	1-5 kg
Second	10	Primefiller + hardener		23	30-90°C	1-5 kg
Third	10	Primefiller + hardener	acrylic basecoat + reducer	23	30-90°C	1-5 kg

3. RESULTS

Solid particle erosion depends on many factors. The size, speed and shape of erodent particles, value of impact angle are the most important factors affecting erosion wear mechanism. The paints on the automotive parts are very much exposed to solid particle erosion, especially when they are stabilized or on village roads. In this study, it is aimed to examine the adhesion of paint layers with solid particle erosion experiments.

3.1 Effect of Impingement Angle and Erodent Weight on Erosion Damage

Figure 2 shows weight loss of three sample groups according to erodent weight at 30° impingement angle. As seen in the graphic, the first sample group (no coating) has been the least erosion wear. Because there is no coating in this sample group and galvanized steel is more durable to erosive wear. Actually painting car parts makes these parts less durable to solid particle erosion. In the second and third sample groups, very close solid particle erosions occurred. This is an expected situation.

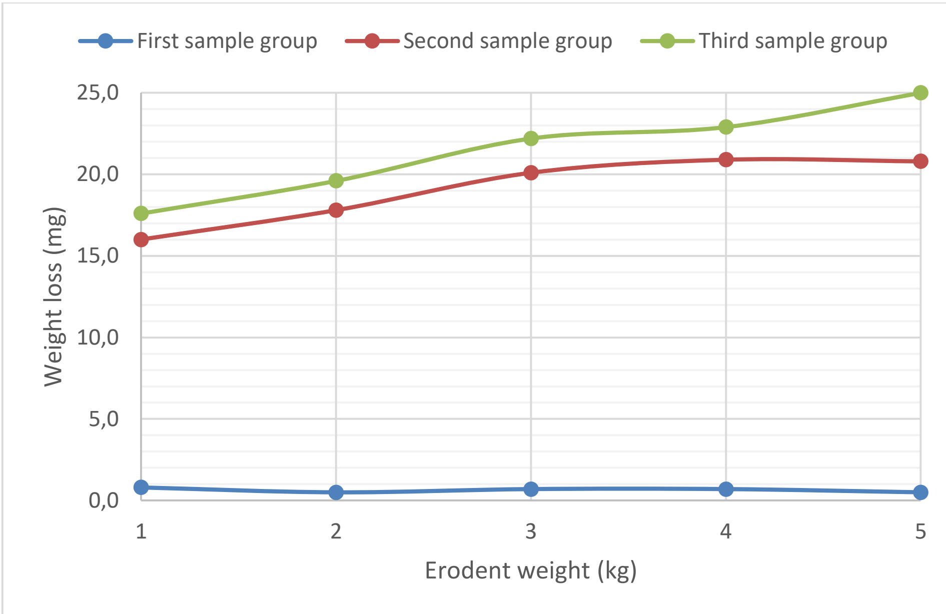

FIGURE 2. Solid particle erosion rate at 30° angle

Figure 3 gives the rate of erosion at the angle of 90 degrees. It is seen from graph that when a 1 kg weight of erodent was used to first sample group, there was a small degree of incubation. Incubation is the accumulation of erosive particles on the sample surface due to the impingement of erosive particles perpendicular to the surface of the sample and the increase of the weight of the sample in the test result. In the first sample group, after the weight of the erosive weighing 1 kg, the sample no longer had the incubation effect and the surface of the sample began to wear. The graphs of the second and third sample groups differ from the first graph according to the weight of the erosive particles. In the third sample group, the increase in the erosion rate was parallel to the increase in the erosive particle weight, whereas in the second sample group, the erosion wear rate decreased due to the accumulation of the erosive particles on the surface of the target material after a certain weight of the erosive particle.

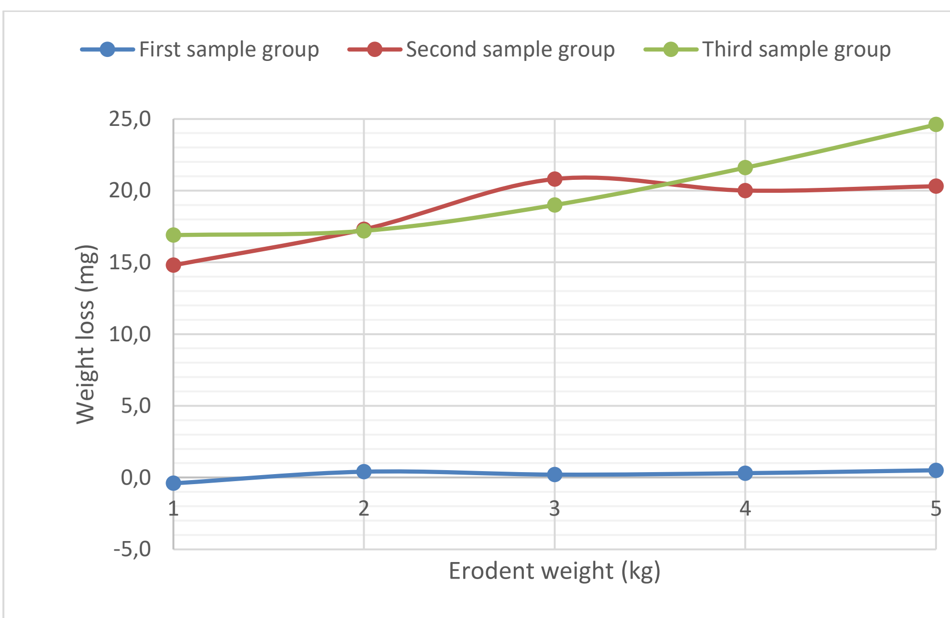

FIGURE 3. Solid particle erosion at 90° angle

It can be seen from two figure (Figure 2 and Figure3) that the second and third sample groups shows similarly erosive weight loss according to the erosive particle weight. However, it is considered that the number of layers of the third sample group is higher and the rate of solid particle erosion is also higher. This can be explained by the strong attachability between the primary coating and the secondary coating. The most weight loss on all figures is usually at a 30º angle. This is ductile material behavior. Slope of all graphs are different because there is no correlation between erodent weight and angle.

3.2 Erosion Scar Diameter Results

Figure 4 and 5 shows the photographs of multi-layer erosion scars in the industrially sprayed automotive steel part. From these photographs the erosion scar is clearly visible. The size of the erosion scar varies according to the coating made. The diameter of these erosion scars formed by image processing method is determined. Then these diameters are compared with each other. As it seen in the photographs, coating were worn and erosive particles contacted the main material surfaces.

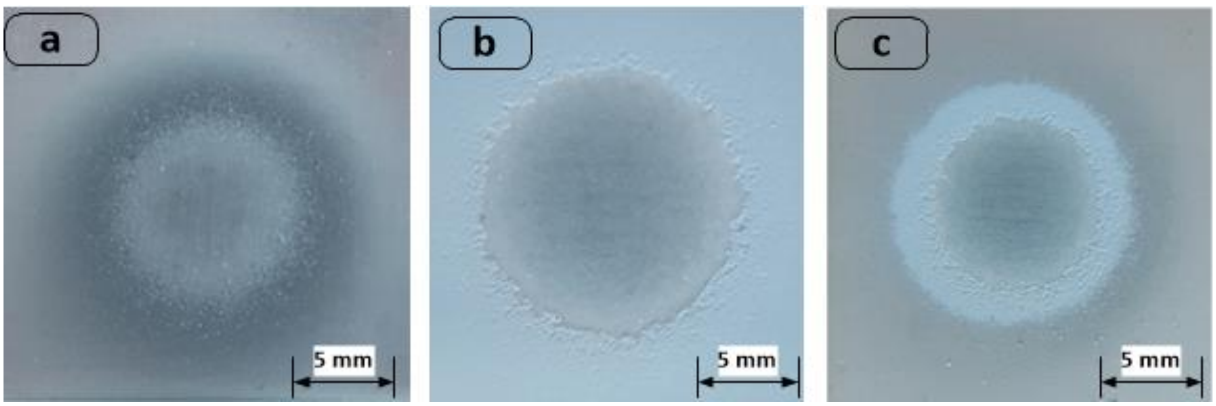

FIGURE 4. Erosion scar photographs of automobile paint system at 30°impact angle a) first sample group b) second sample group c) third sample group

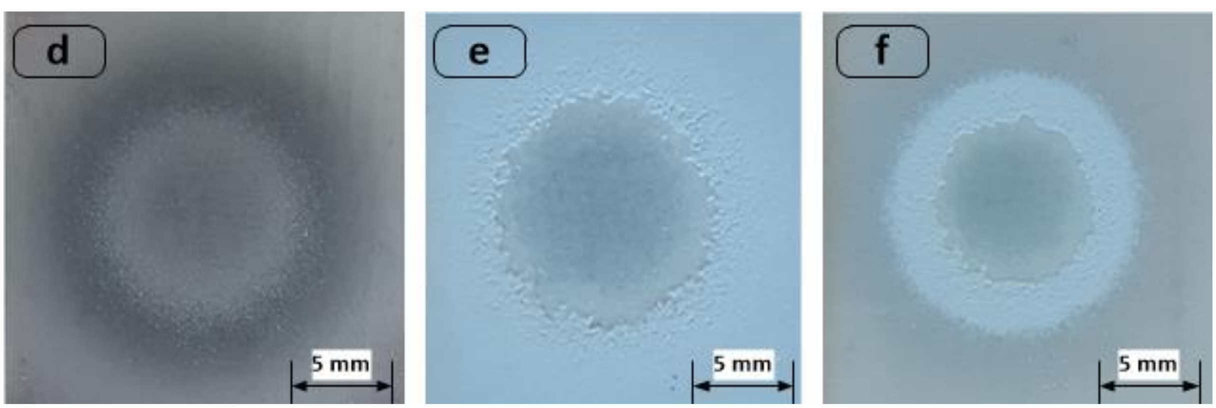

FIGURE 5. Erosion scar photographs of automobile paint system at 90°impact angle a) first sample group b) second sample group c) third sample group

Figures 6 and 7 show the erosion scar diameters according to the erodent weights of the three sample groups. When looking at these graphs, the maximum erosion scar diameter reached 30° impact angle. The particles that hit the surface at an angle of 30° did not accumulate on the surface but flowed away, causing more erosion wear. In general, the second sample group had a greater erosion scar diameter when compared between sample groups. In the second sample group, there are only primefillers and hardeners. This shows that these coatings do not adhere too much to the surface of the base material and wear out more quickly. Although the third sample group had a two-layer coating, the erosion scar diameter remained lower. This may indicate that a strong adhesion between the second and third group of samples. Also, the fact that there is no liner connection between the graphs in different erodent weights shows that there is no correlation between erodent weight and erosion scar diameter.

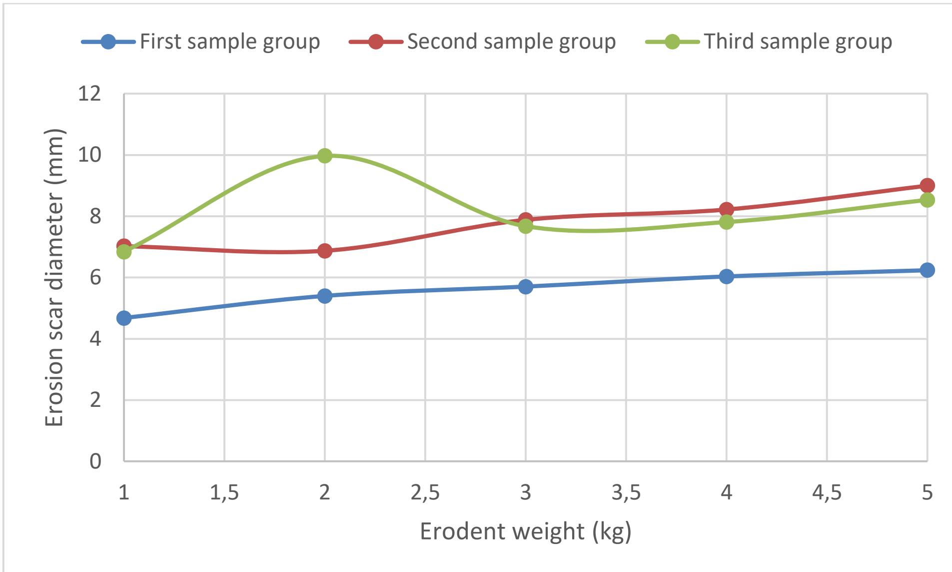

FIGURE 6. Comparison erosive scar diameter of three sample groups according to erodent weight at 30° impact angle

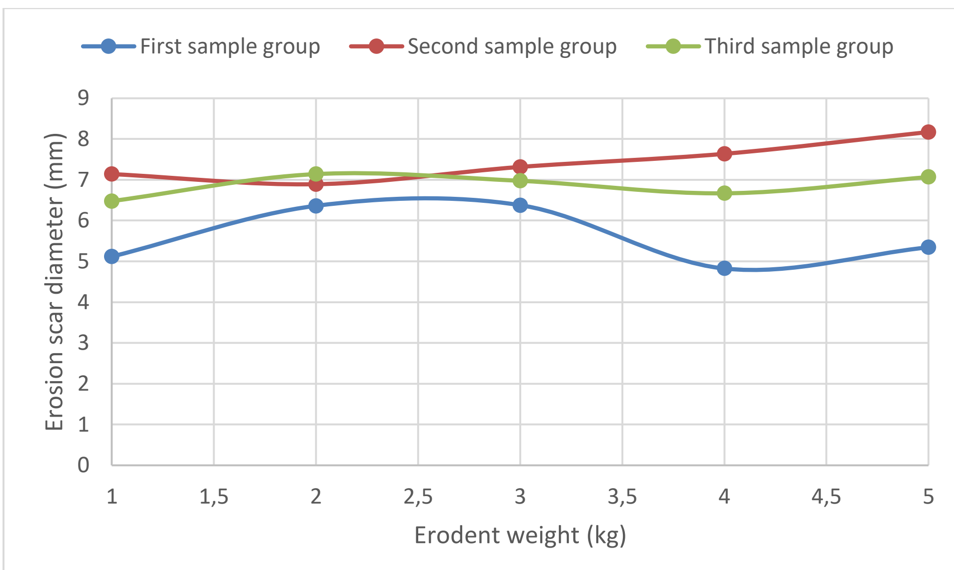

FIGURE 7. Comparison erosive scar diameter of three sample groups according to erodent weight at 90° impact angle

4. CONCLUSIONS

In this study, acrylic / melamine primer surface and basecoat of automotive paint systems were subjected to solid particle erosion wear tests. As a result of solid particle erosion tests, wear quantities of surface coatings and erosion scar diameters formed at the wear surface were calculated. The maximum wear was at 30° and was in the third sample group. Although the third sample group had a two-layer coating, the erosion wear did not double as compared to the second sample group which had a single layer coating. It has been found that there was a weak adhesion between the second sample group which had a single layer coating and the surface of the base material and there was a high adhesion between the second and third sample groups. The largest diameter of the erosion scar was found in the second sample group and at the 30° impact angle. As a result, the layered structure of automotive paint systems needs to be examined in more detail.

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