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Abrasion resistance of camouflage coating systems

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Abstract

The aim of this article is to evaluate the abrasion resistance of camouflage coating systems according to the D4060-10 standard using the Taber Abraser. The method is a standard test for assessing the resistance of coatings to mechanical wear by simulating the abrasion process that occurs during exploitation. The abrasion resistance of camouflage coatings is crucial, especially in the context of military applications. Camouflage coatings are used on military vehicles, equipment and devices to ensure their ability to camouflage in various environments. High abrasion resistance ensures that the camouflage pattern does not wear out quickly, which is important for effective camouflage. The study analyzed three different coating camouflage systems that were subjected to a test to determine their durability and effectiveness under conditions of intensive abrasion. The results obtained allowed for a comparison of the resistance of these systems. The obtained data provide valuable information for further development of camouflage coating systems with increased abrasion resistance, which is of great importance for military and industrial applications.

Keywords: camouflage, coatings system, abrasion, military equipment and vehicles

1. Introduction

Polymer coatings are part of the system: surroundings – coating – substrate. Coating protects the substrate against the destructive influence of operating environment factors. In many cases, the coating determines the safe operation of a technical facility. Polymer coatings are applied to various types of substrates such as metals, wood, concrete, plastics, ceramics in order to protect the substrate against the effects of external factors (mechanical, chemical, environmental, thermal and others) and to give these substrates appropriate decorative and specific properties depending on destination. In most applications, the main purpose of polymer coatings is to protect the substrate against corrosion. The coatings are intended to significantly extend the service life of the protected substrate. Due to their different purposes, they have various structures (Radek, 2023). Figure 1 shows the structure of a typical two-layer coating system.

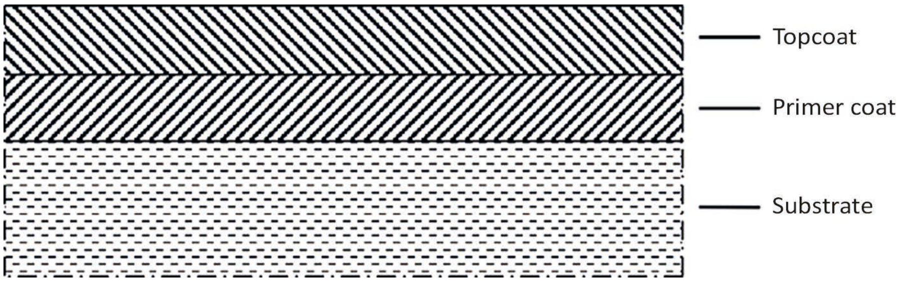

Fig. 1. Typical coating system

The mechanical durability of coating system is important for coated products. One of the most important properties is abrasion resistance, especially for military equipment. Abrasive wear notably contributes to the damage to protective coatings on military vehicles and equipment during service time. Coating systems for military equipment usually consist of a primer coat and a topcoat. The latter coat is exposed to the environment and subjected to abrasive wear. For outside areas, typical the topcoats are based on polyurethane. This is basically because of their good resistance against ultraviolet light and their high color stability. Primer coats are almost entirely made of epoxy as the base polymer. Epoxies provide a good adhesion, corrosion protection including barrier resistance, but they are not resistant to ultraviolet light and deteriorate once the protective topcoat is damaged or abraded. Therefore, the resistance of topcoats against abrasive wear is an important lifetime parameter for corrosion protection and special properties like camouflage. Abrasion resistance may be defined generally as the ability of a material to withstand mechanical action, such as rubbing, scraping, or erosion, that tends progressively to remove material from its surface (Sward, 1972; Suzuki, 1999; Momber, 2021; Rossi, 2009).

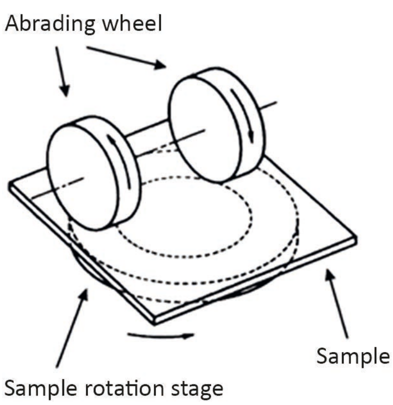

Fig. 2. Principle of Taber abrasion test (Sward, 1972)

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One of the methods of measuring abrasion is the method using rotating wheels and an example is Taber abraser test. This is one of the best known and most widely specified methods of measuring abrasion or wear, yet it lacks interlaboratory reproducibility, as pointed up in ASTM D4060-10. In the abrasion test procedure coating system is applied at uniform thickness to the plane, rigid panel. After curing coatings system is abraded by rotating the panel under weighted abrasive wheels. Figure 2 shows the principle of Taber test.

Abrasion resistance is calculated as loss in weight at a specified number of abrasion cycles or as loss in weight per cycle or as number of abrasion cycles required to remove a unit amount of coating thickness (ASTM D4060-10).

2. Materials and treatment parameters

The test samples were made of DC01 alloy steel measuring 150 mm × 100 mm × 1 mm. The surfaces of the steel samples were prepared as follows: washed with XPA10006 remover, sanded with a rotary grinder with P80 sandpaper and washed with XPA10006 remover. SATA guns with nozzles and a Blowtherm spray booth were used to apply the coating systems. Camouflage coating systems were applied to the prepared steel samples using the pneumatic spray method in three variants:

1. Two-layer coating system (SP1): BP450-100/N primer, BW400-6031 camouflage coat.
2. Two-layer coating system (SP2): BP450-100/N primer, BW400-6031 camouflage coat + carbon nanotube modification.
3. Two-layer coating system (SP3): BP450-100/N primer, BW400-6031 camouflage coat + glass microsphere modification.

Coating systems were heated at 60°C for 60 minutes. The samples prepared in this way were aged for 21 days at room temperature.

The abrasion test was carried out on the DT-523 Rotary Abrasion Tester (model: AN 141 523). Calibrase type discs (CS-17) were used for the test – flexible wheels made of rubber containing abrasive material in the form of aluminum oxide particles. Every 500 cycles, the abrasive discs were regenerated using the S-11 abrasive disc. A 1000 g weight was used for each arm. Each sample was weighed before the test and the thickness of the coating system was measured. The thickness was measured after every 500 abrasion cycles. When the first coating (topcoat) of the system was removed, the sample was weighed. The sample was also weighed when the whole coating system was completely removed from the sample. Figure 3 shows used rotary abrasion tester.

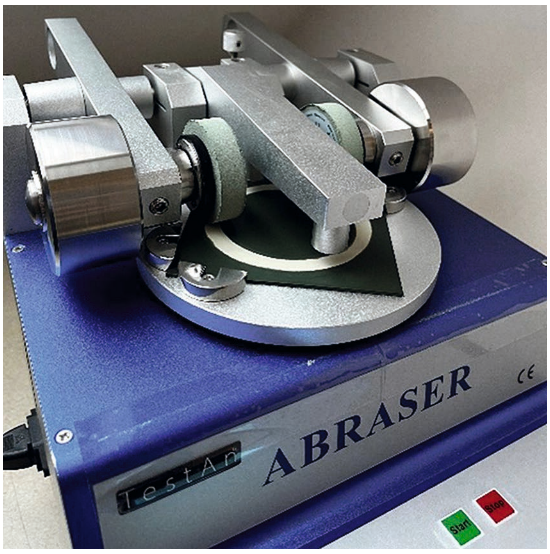

Fig. 3. DT-523 Rotary Abrasion Tester

Figure 4 shows the appearance of samples with SP1, SP2, SP3 coating systems applied after the abrasion test.

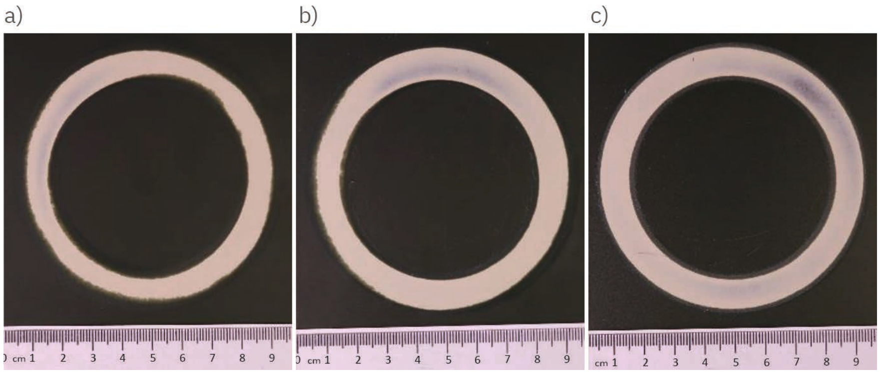

Fig. 4. Coating system after Taber test. a) SP1, b) SP2, c) SP3

3. Results and discussion

The abrasion resistance test conducted using the Taber Abraser device allowed us to determine the durability of three camouflage coating systems in the context of mechanical wear. Figure 5 shows the change in the thickness of coating systems depending on the number of abrasion cycles on the Taber tester. The presented curves have an inflection point resulting from the difference in abrasion resistance of the primer and topcoat included in the coating system.

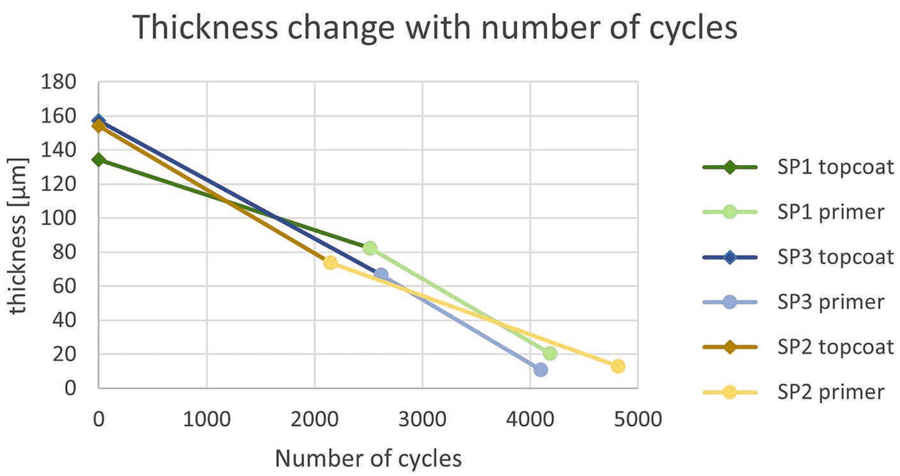

Fig. 5. Thickness change with number of cycles

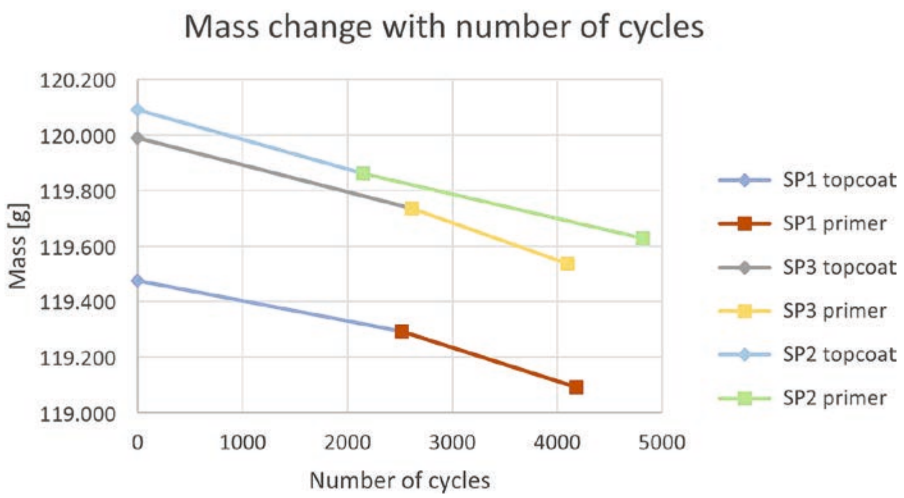

Fig. 6. Weight change with number of cycles

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Analyzing the obtained results, it can be stated that the coating without modification is the most resistant to Taber abrasion test, this is related to the fact that it was characterized by the smallest loss of thickness in relation to the number of abrasion cycles.

Figure 6 presents the weight loss of the tested coating system depending on the number of cycles.

The average mass loss per cycle for the entire coating system is presented in Table 1.

Table 1. The average mass loss per cycle for the entire coating system

Parameters \ Systems	SP1	SP2	SP3
Weight loss [mg]	384	463	455
Weight loss per 1 cycle [mg]	0.092	0.096	0.111

The lowest mass loss per 1 abrasion cycle was obtained for the unmodified SP1 coating system. This is significant because it indicates its highest resistance to mechanical wear compared to the other tested systems. The SP2 coating system shows a slightly higher mass loss compared to SP1, which suggests that it is less resistant to abrasion. Although the difference in mass loss between SP1 and SP2 is minimal, it may affect the long-term durability of the coating in difficult operating conditions. The highest mass loss per 1 abrasion cycle was shown by the SP3 coating system, which indicates that it is the most susceptible to mechanical wear among the analyzed coating systems. The results of the abrasion resistance tests of camouflage coatings are crucial for military equipment used in difficult combat conditions. The equipment is exposed to various external factors, such as sand, mud, stones, bushes and tree branches, which can lead to rapid coating wear. Choosing coatings with high resistance to mechanical wear, such as the SP1 coating system, ensures long service life of equipment and equipment without the need for frequent re-coating of the camouflage coating. This is particularly important in combat conditions, where repair or maintenance options are limited or even impossible. Equipment that can be used longer in the field reduces maintenance and repair costs and increases operational capacity.

4. Summary

The applied modification of the masking coating system using carbon nanotubes or glass microspheres had a negative impact on the abrasion resistance of the masking coating system. The best abrasion resistance was characteristic of the unmodified coating system, while the system modified with glass microspheres obtained the lowest abrasion resistance in the tests. In the next stage, hardness should be checked as another property influencing the operational durability of camouflage coating systems.

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