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POLIMERY

Acrylic polyurethane coatings durability under outdoor weathering in an industrial area

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Abstract: In this work, weathering performance and durability of a commercial automotive acrylic polyurethane topcoat samples exposed at a natural testing station in an industrial atmosphere (Police, Poland) were studied. After a 16-month outdoor aging process, surface morphology and general appearance of the clearcoat were investigated by means of optical and scanning electron microscopes, an optical profilometer and by a glossmeter. For further investigation of the samples surfaces chemistry X-ray photo-electron spectroscopy (XPS) and Fourier transform infrared spectroscopy (FTIR) were utilized. Test results showed that the outdoor exposure changed the appearance of the acrylic polyurethane topcoat surface because protuberant spots of various sizes were observed. Quantitative profilometric analysis indicated an apparent increase of surfaces roughness, however, no signs of chemical degradation of the studied topcoat were revealed by XPS and FTIR analyses. Finally, it was apparent that the surface protuberances observed after the ageing test resulted by atmospheric deposits consisting mainly of oxygen, calcium, phosphorus, iron, and silicon compounds and elemental carbon. Additionally, it was revealed that a detailed cleaning process of the clearcoat surfaces may remove the detected contaminants.

Keywords: automotive coating, acrylic polyurethane coating, industrial area, outdoor weathering, FTIR, XPS.

Trwałość akrylowych powłok poliuretanowych w warunkach atmosferycznych na zewnątrz w obszarze przemysłowym

Streszczenie: W niniejszej pracy zbadano trwałość próbek komercyjnej akrylowo-poliuretanowej nawierzchniowej powłoki samochodowej w trakcie ich ekspozycji w atmosferze przemysłowej zakładów chemicznych (Police, Polska). Morfologię powierzchni i ogólny wygląd powłok lakierowych (po 16 miesiącach testu) zbadano za pomocą mikroskopu optycznego i skaningowego mikroskopu elektronowego, profilometru optycznego oraz połyskomierza. Do badań składu i struktury chemicznej powierzchni wymalowań wykorzystano rentgenowską spektroskopię fotoelektronów (XPS) oraz spektroskopię w podczerwieni z transformacją Fouriera (FTIR). Ekspozycja w atmosferze przemysłowej zmieniła wygląd powierzchni powłok gdyż zaobserwowano wypukłe plamy o różnej wielkości. Dodatkowo, ilościo-

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wa analiza profilometryczna wykazała wyraźny wzrost chropowatości powierzchni, chociaż wyniki badań metodami XPS i FTIR nie wykazały żadnych oznak chemicznej degradacji testowanych próbek. Ostatecznie okazało się, że wypukłości obserwowane na powierzchniach starzonych powłok były osadami atmosferycznymi składającymi się głównie ze związków tlenu, wapnia, fosforu, żelaza, krzemu oraz węgla. Dodatkowo wykazano, że dokładne umycie powierzchni powłok powoduje usunięcie wspomnianych zanieczyszczeń.

Słowa kluczowe: powłoka samochodowa, akrylowa powłoka poliuretanowa, obszar przemysłowy, test starzenia na zewnątrz, FTIR, XPS.

Automotive industry is one of the primary users of acrylic coatings, which are known for their aesthetic appearance, long-term weathering durability, good chemical, and mechanical resistance [1–3].

Outdoor durability of multilayer automotive coating systems depends mainly on properties of their outermost layers known as topcoats. Today, clear topcoats ("klars") based on 2K acrylic polyurethane compositions are dominant technology in Original Equipment Manufacturer (OEM) and refinish automotive coatings in Europe and they are also widely used globally [4-5]. These clearcoats with urethane cross links (resulting from a reaction of OH groups of an acrylic polyol with polyisocyanate) offer improved resistance against UV light degradation and environmental effects.

Nonetheless, acrylic clear topcoats as other protective coatings may degrade over time and lose their functional properties as a result of exposure to environmentally destructive factors such as UV, temperature, oxygen, humidity, road salt, air pollutants, microorganisms and wide range of other natural agents including bird droppings, tree gums and even dragonfly eggs [2, 6–14].

In order to evaluate coating quality and service lifetime accelerated laboratory tests and outdoor exposure in natural weathering conditions are performed. Many different accelerated tests like QUV weathering, thermal cycling, aging in cabinets with salt spray, humidity or SO_2 atmospheres and acid etching tests are commonly used to simulate various environmental influences [3, 8, 15–17].

Despite many efforts made on improvement of conventional accelerated tests such as climate alternating tests or simulation of acid rain, the problem of getting of acceptable correlation between laboratory and outdoor exposures still exists. Therefore, natural exposure in various locations (different climate and pollution level) combined with analytical techniques for early detection of chemical changes in coating materials are considered as the most reliable method for evaluating the weathering behavior of exterior coatings. However, long exposure times (minimum one year) are required in order to obtain representational data due to changes of meteorological conditions throughout the year [18].

Although outdoor weathering aging of automotive acrylic coatings are carried out in many various locations including sites with humid and warm conditions (*e.g.* Florida, south coast of France), dry and hot conditions (*e.g.* Arizona, Australia) [3, 8, 19–20] and urban environments (*e.g.* Radom, Poland) [7, 21], natural exposure tests in industrial areas are still limited; thus, there is a lack of information about durability and degradation behavior of acrylic polyurethane coatings in atmospheres commonly considered as harsh environments.

In this work, the aging behaviour of automotive commercial coating systems exposed to specific industrial environment was studied. Changes in surface topography and morphology of an acrylic polyurethane topcoat layers and their general appearance were monitored by optical and scanning electron microscopes, an optical profilometer and by a gloss reflectometer. The alternations of chemical structure after exposure were analysed by two complementary techniques: X-ray photoelectron spectroscopy (XPS) and Fourier transform infrared spectroscopy (FTIR). Special emphasis was given to distinguish between surface contamination and possible destruction of the tested acrylic polyurethane clear topcoat.

EXPERIMENTAL PART

Sample preparation

The automotive industrial three-layer coating system (i.e. primer, basecoat, and clear topcoat; Spectral Coating Technology, Novol, Poland) was applied by an air spray wet-on-wet technique on blast cleaned steel panels (76 × 152 × 0.8 mm) in a professional car paint workshop. The samples were prepared in two versions using silver and black color basecoat compositions. Specific chemical composition of the topcoat is unknown, however, it is based on a hydroxyacrylic copolymer and an isocyanate hardener (HDI, hexamethylene diisocyanate). Thicknesses of the dry coating were 65±10 μm (after conditioning at room temperature for 21 days). Before their outdoor exposure, the edge of the coated panels were protected using an anticorrosive vinyl paint.

Outdoor weathering exposure

Outdoor exposure test was performed according to internal factory standards for 16 months (from May 2019 to September 2020) at an industrial area near fertilizer and inorganic chemicals plants of the Grupa Azoty