High Performance – Low VOC-Content: Innovative and trend-setting coating systems for industrial applications

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Summary: This paper describes low VOC coating systems successfully implemented and operating in two industrial branches.
For Light Alloy Wheels, the innovative coating process comprises ecofriendly chromium-free surface pre-treatment, epoxy polyester powder primer, water-borne base coat and acrylate powder clear coat.
The coating process as an example for agricultural machinery includes iron phosphatizing surface pre-treatment for steel substrates; the coating system itself consists of a water-borne stove-type dip priming operation (for all objects). Finish coat type (Plant I):
2-component water-borne PUR top coat; (Plant II): TGIC-free polyester powder top coat.
These new coating systems have proved successful in existing series production. All technical requirements and the provisions of the VOC Regulations are fully complied with.

1. Introduction

Up to this day, the wide use of ecofriendly coatings has been limited to large-series applications such as car body coating using EC, water-based fillers and water-borne base coats, or to industrial painting applications e. g. for radiator coating with one or only a few colour shades, lighting fixtures or high-bay storage and retrieval systems with EC and / or powder coatings.

As yet, more than 2/3 of the industrial paints are being used with a substantially high portion of organic solvents.

In 1999, the European Community passed the guideline 1999/13/EC that regulates the limitation of emissions of volatile organic compounds (VOC) which usually arise in the painting process. In Germany, this guideline came into force on August, 2001 as Ordinance named 31.BimSchV, i.e. Federal Emission Protection Law; now this regulation operates in all member countries of the European Community.

In order to comply with this regulation, it is necessary to either use expensive exhaust gas treatment processes (thermal post-combustion) or to generally implement low emission coating systems. From November 1, 2004, the emission limits will be applicable to new, and from November 1, 2007, to old coating facilities.

In the varied and heterogeneous field of industrial coatings with a great number of different substrates, a wide variety of parts and colour shades and gradations, individual and custom-

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ised requirements to the coating, there are presently only a few applications using environmentally acceptable paints. Although there exist in many fields of application suitable low-VOC-product technologies.[1)]

This hesitant approach to the implementation of low emission coating systems can be explained by various reasons: Any product change-over entails modifications to the current equipment or machinery, hence it is a matter of investment costs; additional costs are incurred in the surface pre-treatment, since low emission water-borne powder and

EC-systems are more sensitive to the given surface finish, and quite often there are higher material costs involved.

There is, however, already a considerable number of manufacturers of industrial goods, whose business philosophy already considers and includes environmentally friendly manufacturing and coating processes. Such new technology has been used successfully and without detriment to performance. And, what is worth mentioning, these companies anticipated the new legal regulation.

This paper deals with series coating presenting to this effect two examples of such coating used in major branches of industry, where the painting and surface pre-treatment operations have been changed-over to ecofriendly, low emission products and methods. It has to be stressed that the coatings have met all requirements and the provisions of the VOC Regulations have equally been complied with.

2. Coating of Light Alloy Wheels by Components Suppliers to Automotive Industry

Today, light allow wheels are not at all regarded as the typical outfit of sports cars. In a great number of new cars they are already fitted as standard equipment. The reasons for their increasing use are reduced weight, excellent running properties and the sportive elegant appearance of the cars equipped with such wheels. Light alloy wheels are aluminium die-cast items. Features such as their pretentious, attractive exterior (gloss, metal effects, styling) and the long-term protection against corrosion, aggressive agents, loose Chipping's, adverse weather conditions, etc.) are produced by a multi-layer effect paint. World-wide, about a 100 millions light alloy wheels are produced per year.

2.1 Description of the Overall Process / Objects

The standard coating process for light alloy wheels starts with the following stages of treatment: alkaline degreasing, etching and followed by a - usually yellow - chromatising process. Together with the subsequent powder priming, this treatment provides very good adhesion and corrosion resistance. On principle, for standard wheels the top coat is applied in two steps: Metallic base coat and clear coat.

The usual 40 to 70 °C hot wheels are sprayed with the high solid metallic base coat which, in turn, is then, after a short flash-off time, overpainted wet-in-wet with a high solid clear coat. The two coat layers are then baked, cooled down and the wheel is then packed for shipment. Following is the description of an innovative and particularly ecofriendly process already used in series production:

2.2 Surface Pre-treatment

In this application case, we have as surface treatment an innovative metal-free conversion process.[2)]

The process includes the following phases:

- Alkaline degreasing – Etching – Rinsing with deionised water
- Chemical treatment; a transparent layer is formed (free from chrome)
- Rinsing with deionised water
- Retained water drying

The conversion layer obtained by this process provides very good corrosion protection and paint adhesion results

2.3 Application of Priming Coat

The powder priming coat is applied by electrostatic charging with corona process. This results in a uniform coating layer and high coating efficiency along with good adhesion to the substrate and excellent corrosion protection. The viscoelastic consistency of this coating provides protection against mechanical damages.

Epoxy-polyester-powder coat (hybrid)-type
primer; FREOPOX powdercoat EKK

- Stoving conditions: 220°C/ 30 min.
- Film thickness: 80-100 µm

This type of powdercoat features excellent levelling properties, which is the prerequisite for the formation of the metallic effect expected from the subsequent base coat. Furthermore, this powder primer has a very good degassing effect as it is pervious to gas escaping from die-cast components.

2.4 Base Coat

Due to the application of the base coat, the powder-coated wheels are given an aluminium-metallic appearance. Today, there is an increased demand by consumers for light metallic colour hues. Such effects are produced by the specific making up of the coating system, on the one side, and by special aluminium pigments with variation of the particle size. The results range from very fine, light to coarse-grained sparkling effects.

The latest technological development are chromium-like, reflecting metallic effects.

Conventional, solvent-borne, acrylic-melamine-based systems show solids contents ranging:

- from 17 to 25 (% by wt.) medium solids VOC-value 800 – 700 g/l
- from 25 to 35 (% by wt.) high solids VOC-value 700 – 625 g/l

The application is usually by electrostatic high rotation bell or disc, and/or by high volume low pressure (HVLP) spraying. Both application methods provide a minimum of over spray. In conventional wheel coating, the base coat is applied using the wet-on-wet technique and then, after some minutes flash-off time, re-coated with clear coat and stoved jointly with the latter. The application described in our example uses a base coat conforming to the latest technology, that is the water-borne technology:

-acrylate-melamine low-bake system FREIOTHERM Hydro Base coat

-solids content: 25 % by weight.

-organic solvents: 12 % by wt. VOC-value: 375 g/l

Prior to applying the base coat, the wheels are heated up to 90°C using infrared radiators in the preheating zone.

Application:

-high rotation bells, 40.000 rpm; 80 kV and automatic HVLP sprayers

-Environmental conditions: Temperature: 23-25° C; rel. humidity of the air: 55-65 %

-Stoving conditions: 130° C / 15-20 min

-Dry film thickness: 15µm

2.5 Clear Coat

The clear coat protects the metallic-base coat from colour changes and corrosion. It features excellent levelling and provides the metallic layer with gloss, thus protecting it from the influences of weather, thawing salt, fuels and other factors. Due to these stringent requirements only high-performance acrylate-based stoving systems are used. Conventional wheel coating processes use high solid clearcoats whose solids content is about 50 % by weight. As is the case with base coats, the application of clearcoats is by electrostatic high rotation bells and / or the HVLP method using the wet-on-wet-technique and stoving them together with the base coat.

The clear coat used for the present application reflects the latest state of the art:

Acrylate powder clear coat. The clear coat system is characterised by outstanding properties such as high gloss, high brilliance, levelling, good weather resistance.

The powder clear coat is applied by electrostatic charging by a corona process.

-Stoving Conditions: 190°C/25 –35 min (object temperature)

-Film thickness: 60µm

-Total film thickness of the multilayer coating system: 150-170µm

2.6 Requirements to the Coatings and Test Results / Performance

Requirement	Test Method	Requirement / Spec.	Results
Adhesion	Cross-cut test DIN EN ISO 2409	Gt 0 - 1	Gt 0
Corrosion test	CASS test DIN 50021 / 53167	240 h wb <= 1 mm	wb < 1 mm
Corrosion test	Salt spray test DIN 50021/53167	1000 h wb <= 1 mm	wb < 1 mm
Humidity test	Condensation water DIN 50019/53209	1000 h m0/g0	m0/g0
Chemical resistance	VDA 621-412	Resistance against various media	Tests passed
Weathering resis-tance	Accelerated weathering test VDA 621-429/430 QUV (313nm)	1000 h Gloss retention 20° angle: 90%	Tests passed (Fig. 1, 2)

Accelerated weathering - QUV-Test (B313)
Retention of gloss

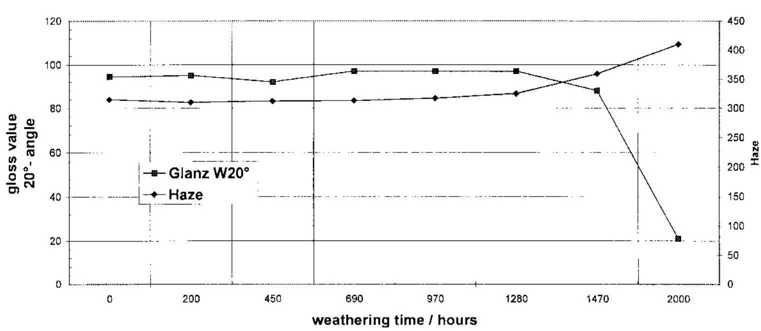

Figure 1. Light alloy wheel coating system(conventional): QUV-test results: Epoxy polyester powder primer/ High solid base coat/high solid clear coat

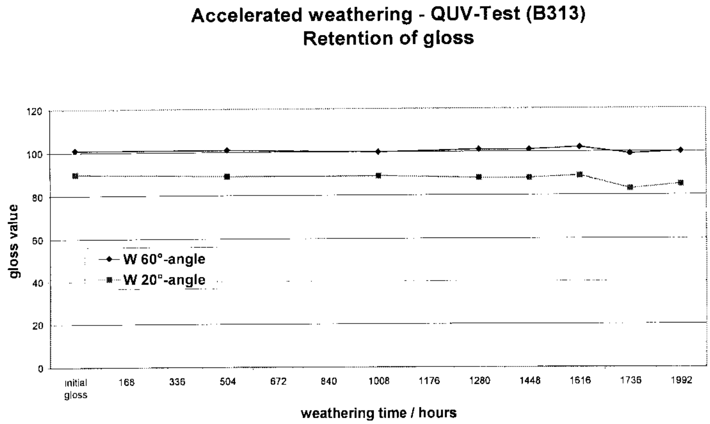

Figure 2. Light alloy wheel coating system (new): QUV-test results: Epoxy polyester powder/water-borne base coat/acrylate powder clear coat

These results show that the new coating system fulfils all requirements.

2.7 Balance of Solvents used in Previous / New Process

Below is a comparison of the quantity of solvents saved with water-based base coats and powder clear coats against conventional coatings:

Based on a yearly production rate of 2 million wheels, the balance of solvents is as follows:

	Conventional Base coat / clear coat	**Water-borne Base coat / powder clear coat**
Solvents content in base coat:	38.000kg	6.700kg
Solvents content in clear coat:	40.000kg	0kg
Total amount of organic solvents	**78.000**	**6.700kg**

The new coating structure entails a drastic reduction of organic solvents – more than 90%.

3. Coating Systems for Agricultural Machines

In agricultural machines industry steel is the most common material. Unlike the coating of light allow wheels, there is no standard coating process in this field of application. Depending on where the machines are intended to be used, there are coating systems suited to such purpose. The majority of these coating systems are, however, still solvent-borne. Therefore, also

in this market segment the VOC Regulations give rise to reconsider the coatings systems with the intention to minimise emission values without impairment of performance.
The large number of coating systems operating in this field can be roughly classified by their corrosion protective capability and the required weather resistance

a) Low to medium requirements to corrosion protection and weather resistance

Surface pre-treatment	:	solvent degrease or blasting
Primer	:	air-drying alkyd or acrylate systems
Top coat	:	air-drying alkyd or acrylate systems

b) Medium to high requirements

Surface pre-treatment	:	blasting and/or iron phosphatizing
Primer	:	2-comp.- epoxy system
Top coat	:	2-comp.-acrylate or polyester – isocyanate (PUR) system

c) Very high requirements

Surface pre-treatment	:	zinc phosphatizing
Primer	:	KTL
Top coat	:	2-comp.-acrylate-isocyanate(PUR) system

3.1 Description of the Overall Process / Objects

The example representative for this field of use describes the painting process for soil tilling machines (plows) at **Plant I** and harvesting machines (grass / hay) at **Plant II** (new) using a water-borne 2 –layer coating system, in the first case, and, in the second case, a mixed-structured water-based primer and powder top coat-system characterized by the high performance requirements. Both plants use the same sort of priming coat. For equipment-specific reasons, the top coat technologies used at the two plants are different.

3.2 Surface Pre-treatment

Both plants use a standard iron phosphatizing spray process.

3.3 Application of Priming Coat

The application described in this example uses a water-borne dip primer (FREIOPLAST Hydro-primer) based on a polyacrylate dispersion with a very low VOC-value of 25 g/l

(1.5 % by weight organic solvents). This priming system provides good adhesion and corrosion protection on steel and allows overspraying with 2-comp. PUR systems as well as with powder top coat systems. It features very good intercoat adhesion to liquid and powder top coats.

This primer is applied by dipping, a process that is very efficient and shows optimum results also with geometrically complicated parts.

After a flash-off time of 15 min. the primer is stoved for 30 min. at 75 – 80°C object temperature. Dry film thickness: 20-30 µm.

3.4 Top Coat Variants

At plant I, this primer system is overpainted with a 2-comp. PUR top coat and, at plant II, with a powder top coat. The components painted at different plants and with different coating technologies are all assembled at one place. Consequently, it is necessary that the top coats of the visible parts of such component harmonise with each other in their optical properties (colour hue, gloss, metamerism).

3.4.1 2-Component PUR Top Coat

Plant I uses a water-borne 2-comp. acrylate-isocyanate (PUR) top coat:(EFDEDUR 2K-Hydro-top coat).

Application process: The parent paint is homogeneously mixed with the hardener using a two-component mixer unit. The coating system is applied by air-mix spray guns.

After a flash off time at room temperature for 30 min., the coating is forcedly dried at 70°C object temperature for 1 hour.

After this, the coat is sufficiently hard for assembly. This coat system is characterised by its application safety[3)] (blistering limit at more than 80 µm dry film thickness), which is important for complicated geometries where overpaintings are quite possible (dft >>60 µm) and its high weather resistance (see the following test results).

Technical data of the water-borne 2-comp. PUR top coat (RAL 3020)
(EFDEDUR –2K-Hydro top coat); all data based on spraying consistency.

Solids content	50% by wt.
Potlife	4 h
Gloss 60° angle	86
Organic solvents content	11,3% by wt.
VOC-value	228 g/l
Blistering limit	> 80µm

3.4.2 Powder Top Coat

Plant II uses a TGIC-free polyester powder top coat (FREIOTHERM powder coating) with good mechanical and weathering resistance. Gloss 60° value: 85. The application process is triboelectric charge by automatic guns.

-Stoving conditions: 180 °C/10 min. (object temperature).

-DFT of powder coat: 60-80µm; total film thickness: 100-120µm

3.5 Requirements to the Coatings and Test Results (Performance)

The following test results show that the new coating systems fulfils all requirements (see following table and fig. 3,4,5).

Requirement	**Test method**	**Requirement Specification**	**Results with PUR-top coat**	**Results with Powder topcoat**
Adhesion	Cross-cut test DIN EN ISO 2409	Gt 0 – 1	Gt 0	Gt 0
Indentation	Erichsen indentation DIN 53156	> 3 mm	6 mm	> 3 mm
Corrosion test	Salt spray test DIN 50021/53167	240 h wb <= 2 mm	wb < 1mm	wb 1 mm
Humidity test	Condensation water DIN 50019/DIN 53209	240 h m0/g0	m0/g0	m0/g0
Weathering Resistance	QUV 313 nm	gloss retention GSB Powder top coat:300h : 50% PUR top coat: 1.000h : 50%	90 %	70%

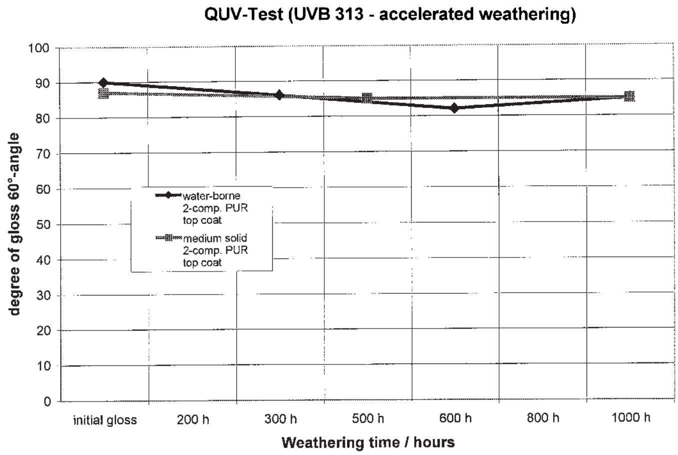

Figure 3. Comparison of weather resistance medium solid-2-comp.-PUR top coat with water-borne-2-comp.-PUR-top coat (plant I) by QUV-test

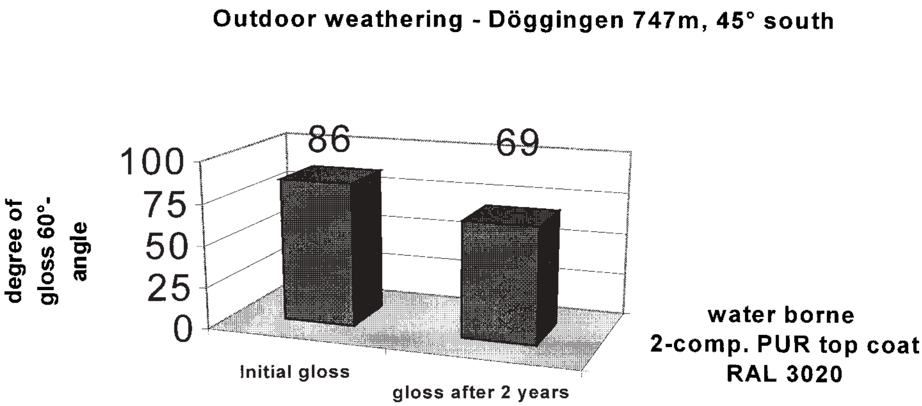

Figure 4. Outdoor weathering test of coating system plant I with water-borne top coat.

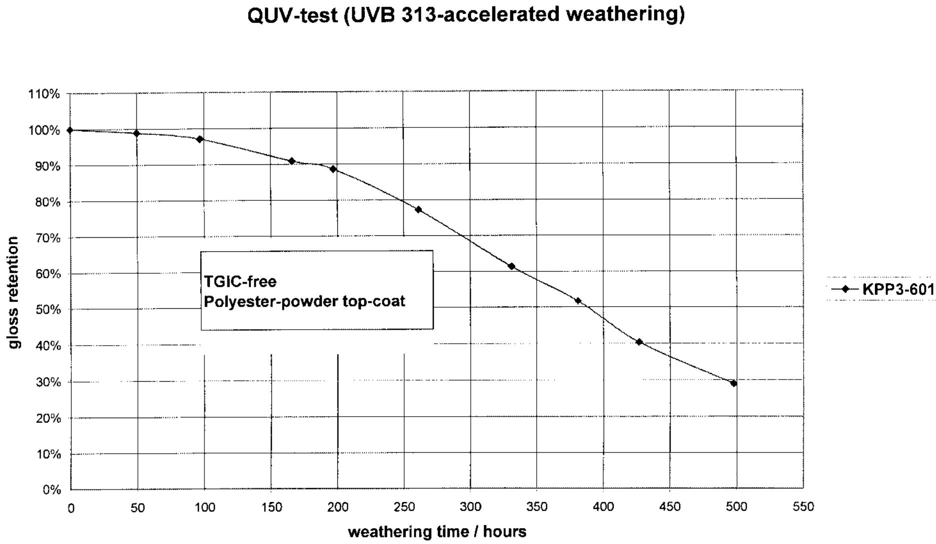

Figure 5. Weather resistance of the coating system plant II with powder top coat. QUV-test.

3.6. Balance of solvents used in previous and new coating process

Based on the same yearly production rate of machines, the balance of organic solvents as follows:

	Alkyde-primer/PUR medium solid top coat	Water-based primer/PUR Powder top coat
Primer coat	18.000kg	450 kg
Top coats	24.000kg	3.750 kg
Total amount of organic solvents:	**42.000kg**	**4.180 kg**

The new coating processes entail a drastic reduction of organic solvents – about 90 %.

4. Summary

This paper describes low VOC coating systems successfully implemented and operating in series production at two important branches of industry. It is shown that these new coatings do not only meet all requirements placed so far on conventional systems but even surpass them to a certain extent.

In the area of Light Alloy Wheels, the innovative coating process comprises ecofriendly chromium-free surface pre-treatment, epoxy polyester powder primer, water-borne base coat and acrylate powder clear coat.

The coating process for agricultural machinery includes iron phosphatizing surface pre-treatment for steel substrates; the coating system itself consists of a water-borne stove-type dip priming operation (for all objects). Finish coat type (Plant I): 2-component water-borne PUR top coat; Plant II: TGIC-free polyester powder top coat. Both coating systems provide good corrosion and weathering resistance.

These new coating systems have proved successful in existing series production. All technical requirements and the provisions of the VOC Regulations are fully complied with. Compared to previous systems, the coating technology described here entails drastic reduction of solvents and, by minimising emissions, it helps protect the environment.

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