Powder Coatings for Corrosion Protection

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Summary: Powder coatings found a wider use in corrosion protection of steel structure. In Europe very often double-layer systems are used, based on an adhesion promoting epoxy (EP) primer and a weathering stable top coat, mostly polyester (SP) sometimes EP/SP-hybrid powders. An interesting development is the use of zinc filled EP powders as primer to offer a cathodic protection to the steel surface. Powder systems with and without zinc were compared to proved coating systems based on liquid paint materials, where powder coating systems showed results comparable to these systems. Besides many advantages of powder coatings for corrosion protection there are still some problems. The workshops carring out the powder coating have to be in control of the surface pretreatment like chromating, but especially phosphating and the work with the chromate-free pretreatment methods for galvanized steel. As always in the field of corrosion protection it is the surface pretreatment and preparation which determines the quality of the whole coating system decisively. This problem can be solved by appropriate working. In some years the problem with the general maintenance of powder coatings after weathering and ageing will be actual. This problem should be solved because of the homogeneous coatings on larger areas. Of importance will be the adhesion on the old coating and the appearance of the maintenance coating. The touch up of smaller parts as transport damages will be much more difficult in order to the appearance.

Keywords: corrosion protection; powder coatings; surface preparation; surface pretreatment; zinc (rich) primer; adhesion; maintenance

1 Introduction

Some years ago powder coatings were typically known for all kinds of industrial finishing. But in the recent years more and more steel constructions, or parts of them, for the field of heavy corrosion protection are powder coated. The main causes for this trend to powder coatings in corrosion protection are the following:

- The demand of solvent minimization can be reached in an optimum way by using powder coatings.
- For reasons of quality assurance and cost reduction the trend to shop coating can be found generally for all kinds of steel structures.

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- The equipment of several workshops have reached dimensions that enables them for also surface preparation and powder application of large structural elements.
- Special methods for surface preparation were designed for powder coating.
- Powder systems were developed especially for corrosion protection.

Due to this trend there have been carried out several investigations on corrosion protection systems based on powder coatings, i.e. influence of surface preparation and pretreatment as well as different types of powder coatings. The results are compared to proved coating systems based on liquid paint materials.

2 EN ISO 12944

The basic European standard EN ISO 12944 „Corrosion protection of steel structures by protective paint systems" describes in part 1 the paint systems to be used according to this standard. It is also mentioned that powder coatings are excluded from this standard. This means in fact that there is in the moment no standard for the use of powder coatings in the field of corrosion protection. Since now there are only guidelines (Normally nationally but not internationally used.) which are originated from industrial finishing like GSB and Qualicoat. In Germany powder coatings are laid down in a common guideline of several federations working in the field of corrosion protection. But this guideline only deals with metal-plus-paint systems ("Verbänderichtlinie Duplexsysteme"). But as powder coatings found a wider use in the field of corrosion protection of steel parts this situation has to be thought over.

3 Surface preparation

Surface preparation plays an important role for the effectivness of corrosion protection. Besides typical methods from the field of corrosion protection like blasting and sweeping there is work on methods known from industrial finishing like chromating and phosphating. Also chrome-(IV)-free preparation methods are of high interest. For this reason the methods of industrial finishing and corrosion protection have to be optimized now. This offers chances, but may contain also a lot of problems. Investigations on the influence of the type of surface preparation on corrosion protection with powder coatings were carried out.

The momentary situation with different surface preparations and pretreatments for powder coatings can be described by the following table.

Table 1. Surface preparation and pretreatment for powder coatings in corrosion protection

substrate	surface preparation	surface pretreatment	coating	remarks
steel	blasting Sa 2½		epoxy (zinc) polyester	Sa 2½ assures in all cases good results
		phosphating	epoxy polyester	phosphating + zinc filled epoxy primer doesn't work
galvanized steel	sweep blasting		polyester (epoxy)	only roughening, not removing
		chromating	polyester (epoxy)	excellent effectivness, but: Cr(VI) is cancerogen
		phosphating	polyester (epoxy)	several methods with different results, may causes problems
		chromate-free	polyester (epoxy)	basis: (Ti,Zr)F, promising developments

4 Testing of powder coatings

In Europe very often double-layer systems are used, based on an adhesion promoting epoxy (EP) primer and a weathering stable top coat, mostly polyester (SP) sometimes EP/SP-hybrid powders. An interesting development is the use of zinc filled EP powders as primer to offer a cathodic protection to the steel surface. But due to application the amount of zinc in the prime powder is significantly less than in typical liquid based primers, so that an active (cathodic) action is not really assured. Powder systems with and without zinc were compared to proved coating systems based on liquid paint materials, where powder coating systems showed results comparable to these systems.

In the following figures two types of powder coatings with different amounts of zinc dust in the primer are shown in transverse sections. As comparison a transverse section of a typical zinc rich primer based on liquid paint materials is also added.

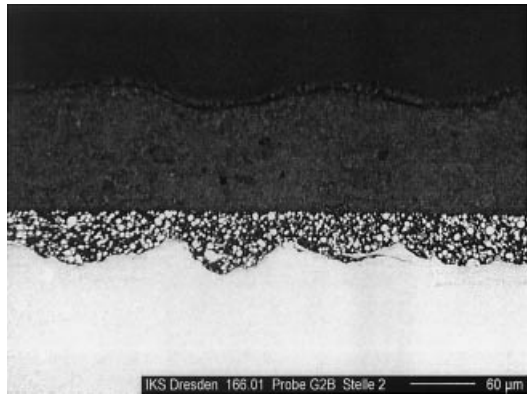

Figure. 1. EP-powder prime coat (zinc dust containing) EP/SP-powder top coat

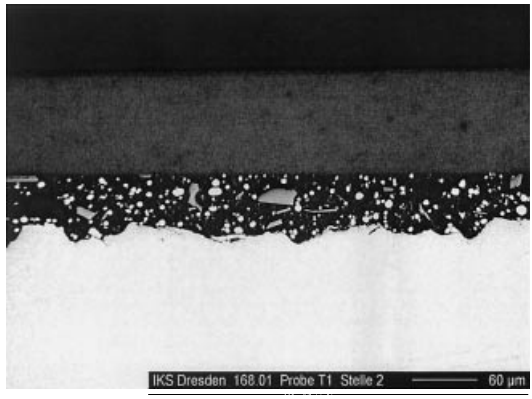

Figure 2. EP-powder prime coat (zinc dust containing) EP/SP-powder top coat

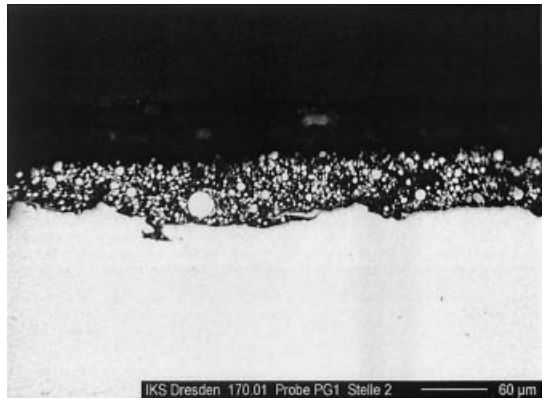

Figure 3. EP-zinc rich primer PUR-top coat

As example for the corrosion protection properties of powder coatings some test samples after salt spray test according to ISO 7253 for the duration of 1440h (i.e. category C5-I long according to EN ISO 12944-6) are shown in the following figure.

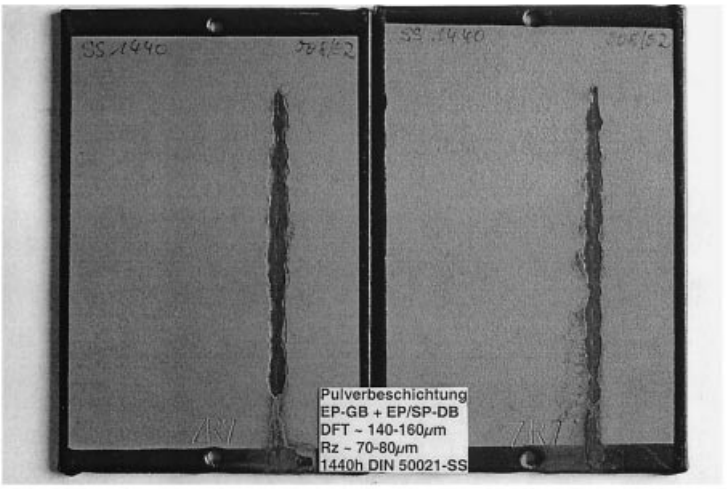

Figure 4. Powder Coating after 1440h salt spray test (ISO 7253)

Some results for loading and testing of powder coatings for corrosion protection are summerized in the following two tables.

Table 2. Powder coatings on blasted steel (R_z: approx. 45µm), weathering for 1 year with an additional loading in a salt spray chamber acc. to ISO 7253

System	No. of coats	DFT / µm	1 year weathering					
			blistering	rust	W_b / mm	adhesion / MPa	fracture face	hatch cut
1	2	120	0	Ri 0	0,5	7,2 ± 0,7	100C/Y	0/1
2		135	0	Ri 0	0	19,6 ± 4,6	100C/Y	0/0
3	1	90	0	Ri 0	0,5	5,7 ± 0,6	100B/Y	0/0
4		90	0	Ri 0	0	13,7 ± 1,5	100B/Y	0/0
			additional 720 h salt spray test					
			blistering	rust	W_b / mm	U_D / mm	hatch cut	
1	2	120	0	Ri 0	1,3	1,3	0/0	
2		135	0	Ri 0	1,4	2,2	0/0	
3	1	90	0	Ri 0	1,3	4,4	0/0	
4		90	0	Ri 0	1,4	3,8	0/0	

Table 3. Comparison of corrosion protection systems based on liquid and powder paint materials (steel blasted to Sa 2½ acc. to EN ISO 12944-4)

Coating system		liquid based		powder based	
		EP zinc EP mica PUR mica	EP zincphosphate EP mica PUR mica	EP zinc SP	EP SP
	DFT / µm	240	240	200	200
ISO 7253 1440h (C5-I long)	W_b / mm	0,9	1,4	1,9	1,8
	adhesion / MPa	8,0 ± 0,1	6,1 ± 2,3	> 3,4 ± 1,2	> 2,5 ± 0,1
	fracture face	70D, 30D/Y	50D, 50D/Y	20C, 80C/Y	20C, 80C/Y
	hatch cut	0	1	0	0
ISO 6270 720h (C5-I long)	adhesion / MPa	6,3 ± 2,5	4,4 ± 0,4	11,4 ± 4,3	11,0 ± 3,1
	fracture face	80D, 20D/Y	90D, 10D/Y	30C, 70C/Y	50C, 50C/Y
	hatch cut	0-1	0-1	0	0

In table 4 some results on different surface preparation methods for galvanized steel before powder coating are shown. In all the four cases the same powder coating (SP top coat, 80µm) was applied.

Table 4. Comparison of different surface preparation methods

preparation / pretreatment		sweeping	chromating	phosphating I	phosphating II
ISO 6270	blistering	0	0	1/1	0
	hatch cut	0-1	0	3	0-1
cyclic VDA-test	blistering	2/1	2/1	2/1	2/1
	U_D / mm	2,7	2,4	3,8	2,7
	hatch cut	0-1	1	0-1	0
ΔT-test	blistering	0	0	3/3	0
	hatch cut	0-1	0	3	0

The tables verify the good performance of powder coatings in corrosion protection. The values of proved coating systems based on liquid paint materials are reached. But table 4 also shows that different phosphating methods for galvanized steel lead to different, and not always good, results. It can be concluded that intensive controlling (bath temperature, concentrations etc) is necessary to obtain good results with phosphating as surface pretreatment for powder coatings in corrosion protection.

5 Outlook and problems

Besides all the shown advantages of powder coatings for corrosion protection there will be also some problems. The workshops carring out the powder coating have to be in control of the surface pretreatment like chromating, but espescially phosphating and the work with the chromate-free pretreatment methods for galvanized steel. As always in the field of corrosion protection it is the surface pretreatment and preparation which determines the quality of the whole coating system decisively. This problem can be solved by appropriate working.

Somehow more complicated is the development of maintenance strategies for powder coatings in corrosion protection. Very actual is the touch up of transport and erection damages - surely there can´t be stoved on site. But there is an intensive search for solutions, sometimes dilettante, sometimes in very interesting and unusual ways.

In a similar way there will be a problem with the general maintenance of powder coatings after weathering and ageing. It should be also worked on solutions for that. These will be realised in a easier way, because there will be homogeneous coatings an larger areas. The important thing will be the adhesion on the old coating and the appearance of the maintenance coating. The touch up of smaller parts as transport damages will be much more difficult in order to the appearance.

Nevertheless, powder coatings are an interesting and high-grade alternativ for initial coating in corrosion protection.