Weldable Corrosion-Protection Primer – Thin Film-Coated Steel Sheets for the Automotive Industry
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**Cover picture:**

The cover picture shows coils and a body in white made of steel sheet.

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1 Introduction

Corrosion-protected steel sheets for the automotive industry make a strong contribution to car safety, environmental protection, and economy:
- Corrosion protection of cavities, folds, and flanges is improved significantly and boosts the vehicle’s value. The duration of usage and the recycling intervals will be considerably prolonged.
- The vehicle’s safety, especially crash parts, remains stable during the whole period of usage. This will become even more important as the thickness of the steel sheets, for example when using high-strength steels, is steadily reduced.

Even today a high level of corrosion protection is achieved due to constructive measures and the usage of pure or alloyed zinc-coated steel sheets together with improved phosphating methods and electrodeposited (ED) paints. Further demands of the automotive industry require a progressive development of the corrosion-protection concepts aiming for:
- extension of guarantee promises
  - less rust, starting, for example, in cavities
  - minimizing corrosion attack on parts important for safety
  - avoiding cosmetic corrosion of the outer skin
- reduction of processing costs of the car manufacturer by simplifying or even avoiding manufacturing steps
- improvement of environmental sustainability

In this manner the end customers of cars benefit from properties such as longer life-time and long-time maintenance of value.

Weldable corrosion-protection primers (CPP) – i.e. thin-film coatings – in combination with metallic coatings create products with new properties. The cathodic protection of the zinc-coatings is combined with barrier effect, abrasion stability, elasticity, and the lubricant properties of organic coatings. This so called “duplex system” complies in an ideal manner with the demands of the automotive industry for steadily improved corrosion-protection concepts.

The increased application of galvanized steel sheets in the car industry has improved corrosion protection remarkably. The defects due to corrosion have been reduced significantly (Fig. 1).

2 Potentials of weldable corrosion-protection primers

An autobody sheet coated with CPP is a galvanized steel sheet with an additional one- or two-sided thin organic coating. These weldable products provide various ecological and economic benefits to the OEM:
- Increasing the corrosion protection of galvanized steel sheets, especially in areas where the car manufacturer’s corrosion-protection systems, i.e. phosphating combined with ED paints, are not or are only insufficiently able to cover the surfaces. This is especially important for cavities, flanges, and joints in the inner parts of the car where the zinc coating is extremely endangered by the contribution of humidity or sodium chloride without ventilation
- Retention of the main properties for car manufacturing, like weldability, adhesive bonding, and ED paintability
- Simplification or omission of the car manufacturer’s secondary corrosion-protection measures (like waxing and sealing). Secondary corrosion-protection measures are expensive and might deteriorate while the car is being used. When using CPP, the car production is much more flexible

![Fig. 1: Development of corrosion protection on the basis of TÜV reports](image-url)
• Increasing corrosion protection of pressed parts in the state of delivery (manufactured parts, coated on both sides with CPP, can be shipped worldwide without any further corrosion-protection measures)
• Prevention of bimetallic corrosion (contact corrosion) in combination with other metals
• Improving formability of the steel sheet due to additional lubricant effects of the CPP
• Improving adhesive bonding, generating positive impact on crash behavior and safety of vehicle

This type of CPP-coated galvanized steel sheet enables the car manufacturer to reduce the manufacturing process and to increase the warranty against rust perforation.

3 Layer composition

Substrates are electrogalvanized (EG) or hot-dip galvanized (HDG) steel sheets, one- or two-sided pre-treated and organic-coated. The thickness of the metallic coating depends on the corrosion protection demanded, usually between 5 to 7.5 µm zinc. For the pretreatment a chromate-free system is used that fulfills the EU-legislation 2000/53 (End of Life of Vehicle). Depending on the required protection effect several different CPP can be chosen. They differ in their composition especially regarding the conductivity pigments and the achievable coating thickness. State-of-the-art systems are the so-called “1st generation”. Newly developed systems for significantly higher protection have been introduced to the automotive industry and are called “2nd generation” systems. Fig. 2 shows typical compositions. The real image of CPP is shown in Fig. 3 in a cross-cut and a SEM view.
4 Processing

The application of the complete system, i.e. zinc plus CPP coating, takes place in a continuous process at the steel manufacturer. First of all the metallic coatings are applied in electrogalvanizing or in hot-dip galvanizing lines. The pretreatment of the metallic surface is usually applied in a so-called “no-rinse process” and the application of CPP by continuous roll coating follows in separate coil coating lines or directly in electrogalvanizing lines with integrated coil coaters (Fig. 4).

Depending on the individual coating system, the cross-linking of the organic coating takes place at temperatures of approx. 250 °C PMT (Peak Metal Temperature) or at approx. 160 °C for bake-hardening steel grades.

The application in a roll-coating process ensures extremely regular, non-porous coatings with thin layers and high efficiency. By coating on-site at the steel manufacturer, its long-term experience in coil coating ensures increased emphasis on ecological aspects.

5 Characteristics

5.1 Properties for usage

5.1.1 Surface

In order to protect cavities, folds, and welded flanges against corrosion, CPP are usually applied on the inner side of outer skin parts and on both sides of inner body parts.

The topographic structure of a skin-passed surface of the steel sheet will not be leveled by the CPP coating. The organic-coated surface has a higher number of peaks but the same roughness as an electrogalvanized surface.

5.1.2 Alkaline resistance

As body shells will be degreased before entering the painting section, the alkaline resistance of CPP is important – even when strongly formed.

Laboratory tests with cups showed that in different alkaline baths the CPP remains stable even with a pH value of 13. Therefore, the car manufacturer’s degreasing process needs no changes or adjustments.

5.1.3 Corrosion protection

Due to process-specific differences in the car manufacturer’s painting section, it is more complicated to reach and paint the cavities of folds and flanges compared to the unformed parts of the body.

The additional CPP on the steel sheet increases the resistance to corrosion in the cavities and protects effectively against rust perforations, especially where the surface of the body has not been sufficiently coated or phosphated. Cavities that are too narrow or non-accessible for the ED coating, air bubbles which cannot escape as well as folds and flanges are typical examples. Usually these parts of the body in white are protected with so-called secondary corrosion-protection measures, such as waxing and sealing. When using CPP, these secondary measures can be reduced significantly or even omitted completely (Fig. 5).

The pigmentation of CPP is designed to high electrical conductivity, enabling a standard ED paint thickness. The adherence of the ED paint is identical to that on electrogalvanized surfaces.

Corrosion tests with flanges, pressed parts, or with cups or extremely formed parts show 3–4 times better resistance to corrosion in the
different testing conditions (e.g. VDA 621-415) or in accelerated outdoor exposure tests (e.g. VDA 621-414) (Fig. 6). When using newly developed CPP it is possible to double the resistance to corrosion (i.e. a 6–8 times better behavior compared to metallic coating).

Further information concerning corrosion tests can be found in the brochure “Accelerated corrosion tests of corrosion-protection systems on steel sheet for the automotive industry,” Stahl und Eisen 121 (2001) No. 6.

5.2 Processability

5.2.1 Formability behavior

The good lubricant properties of organic coatings generate an excellent deep drawing behavior. The forming behavior shows advantages...
compared to electrogalvanized steel sheet due to a better coefficient of friction and abrasion:
- Avoidance of direct contact between zinc coating and the tool’s surface due to the organic matrix of the CPP (zinc normally tends towards cold welding with the tool’s surface)
- The microstructure of the organic coating is an excellent substrate for lubricants. Ultimate forming possibilities can be reached by additional oiling with a standard corrosion-protection lubricant, superior to conventional electrogalvanized or prephosphated steel sheets without CPP

Fig. 7 shows the comparison of the forming behavior (working range deep drawing) of electrogalvanized steel sheet with and without the use of CPP (in oiled status).

Due to improved tribological conditions, CPP-coated material shows in comparison to conventional zinc-coated surfaces a widening of the working range and a shift of the maximum drawing ratio to higher values.

The forming working range is to be understood as the area in which a part can be formed without any defects such as wrinkles or cracks. Because of these good lubricant properties, even difficult parts can be formed easily. The processing of high-strength steels benefits from this advantage, too.

5.2.2 Joining behavior

5.2.2.1 Welding
Steel sheets coated with CPP can be welded with all common welding processes, such as spot welding, laser welding, stud and projection welding, and MAG welding (Fig. 8).

The high amount of conductive pigments within the CPP enables the electrical current to pass through the organic coating when using spot welding. Within the specified limits for pretreatment and primer coating, the resistance between the electrodes and the primer coatings is sufficiently low.

In numerous trials, the spot welding behavior of CPP were analyzed by controlling the spot weld’s diameter of minimum $4\sqrt{t}$ ($t$ = thickness of steel substrate) and the absence of any flashes and threads. The result proved the spot-weldability of CPP-coated steel sheets.

Fig. 7: Workspace “deep drawing” of electrogalvanized steel sheets with and without corrosion-protection primer (exemplary for 1st generation)

Fig. 8: Steel sheet with weldable corrosion-protection primer – laser welding
Glueability / energy consumption before aging and after aging (10 weeks VDA 621-415) on coated with ED paints electrogalvanized steel sheet.

**Fig. 9:** Tensile shear strength and energy consumption before and after alternating climate test (VDA 621-415), corrosion-protection primer on electrogalvanized steel sheet.
For the spot welding of conductive pigmented organic-coated material the minimum diameter of the spot weld is achieved at a lower welding current compared to non-organic-coated surfaces. The suitable parameters for the welding current depend on the metallic and CPP coating (one- or two-sided).

A high potential for optimizing the electrode lifetime can be achieved by adjusting the setting range of the welding current, the type of the electrodes, the welding control, and the kind of current used.

When using fusion welding at high temperatures in the welding zone, the CPP will be affected, even at a greater distance from the welding zone. Alternative welding methods like plasma and laser welding can minimize this adverse effect.

It is mandatory to exhaust welding fumes in the same way that it is necessary for electrogalvanized material, fulfilling appropriate requirements on safety at work.

In case of overlapping laser welding, a sufficient gap between the steel sheets has to be ensured, to provide a welding seam free of cracks and pores.

### 5.2.2.2 Adhesive bonding

As is typical for organic coatings CPP offer improved adhesive power and stability in comparison to conventional electrogalvanized surfaces. The common sealants and adhesives used in the automotive industry can be applied for achieving good bonds. The excellent corrosion-protection characteristics of CPP contributes especially to the joining area because of reduced creepage. Tensile shear strength and energy consumption remain at a high level. The permanent stability of the adhesive bonding ensures a high crash safety even after corrosive strain (Fig. 9).

### 6 Validation of weldable corrosion-protection primers

In a working group for steel and surface at the Stahlinstitut VDEh, a data sheet consisting of six parts has been published. It covers the relevant analysis and testing methods in standardized forms to minimize the testing efforts for the automotive and the steel industry.

This Stahl-Eisen-Prüfblatt 1160 “Evaluation of Weldable Corrosion-Protection Primers for the Automotive Industry” consists of the following parts:
- Corrosion Performance (part 1; 1st issue 06.2004)
- Measurement of Coating Weight (part 2; 1st issue 06.2004)
- Adhesion Behavior (part 3; 1st issue 11.2005)
- Peel-Off Behavior (part 4; 1st issue 01.2005)
- Adhesive Bonding Properties (part 5; 1st issue 01.2005)
- Suitability for Electrodeposition Painting (part 6; 1st issue 11.2005)
- Procedure for quantitative Determination of Welding Fumes from Resistance Spot Welding (part 7; 1st issue 09.2008)
- Tool Wear Behavior (part 8; in preparation)

### Explanations

TÜV: Abbreviation for “Technischer Überwachungsverein”; private organization with technical inspection authority

VDA: Verband der Automobilindustrie e. V. (VDA); German Association of the Automotive Industry