Corrosion Protection of the Cut Edge of Coil Coated Sheets by Application of UV-Curing Lacquers

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Introduction

In production engineering there is a demand to rationalize manufacturing processes towards shorter process chains. This can either be done by substitution of processes by more sophisticated ones or by integration of more procedures into one process step or by using new materials with advanced properties.

By using coil coated sheet metal no separate coating process will be needed after assembly. Coil coating is a process to apply organic coatings to sheet metal directly after the rolling process and before any subsequent processing. Coil coated sheet metal has found a broad variety of applications in the sheet metal industry, e.g. for household article casings or façade planking of buildings. However, the use of those materials is limited for a large extent of applications by its liability to corrosion of the cut edge which is not covered by paint[1-6]. In cases where corrosion resistance is a relevant issue usually additional steps to seal the cut edge are required. This contradicts the demand for fewer manufacturing operations.

A possible approach to this problem is to integrate a procedure that can optimize corrosion protection into the cutting process. Letting flow part of the surface coating into the cutting clearance and cover the bare cut edge, corrosion resistance can be enhanced. This directed flow of the lacquer can be achieved by using an advanced cutting process which separates the material by tensile stress instead of shear stress of conventional cutting or blanking by using enlarges cutting clearances and chamfered cutting tool geometries[7]. This method, however, does not reliably eliminate sub-coating corrosion migration completely.

By applying a corrosion inhibiting medium, e.g. UV-curing lacquer, onto the cut edge corrosion resistance can be significantly improved. To minimize process steps this application can be integrated into the cutting process. This patented (DE 10 2005 058 572.8) procedure only requires specially adapted cutting tools which provide a means of transport of the UV-curing lacquer within the tools to the cut edge of the sheet, while standard cutting presses can be used.

Application Process

In Figure 1 a sectional representation is given of an exemplary cutting tool modified for integrated application of UV-curing corrosion inhibiting agents. The cutting punch (1) has bores or grooves (2) to feed the agent to the coil coated sheet (3). The sheet is clamped between blank holder (5) and die (6). By downward movement of the punch the sheet is being cut. A chamfered geometry (7) of the punch can help the sheet’s cut edge to be covered with part of the surface coating by directed flow of the coating into the cutting clearance. After the cutting process is finished the scrap (11) can be disposed of, while via bore hole (2) and a permeable tissue, e.g. felt (4) the UV-curing lacquer is applied to the cut edge of the work piece (10) by further downward and upward movement of the punch. A UV-curing lamp (8) and associated wiring (9) could be integrated into the cutting tool. This application process has the advantages that no separate process step for sealing of the cut edge is necessary and that only zones of the work piece are treated which are liable to corrosion.

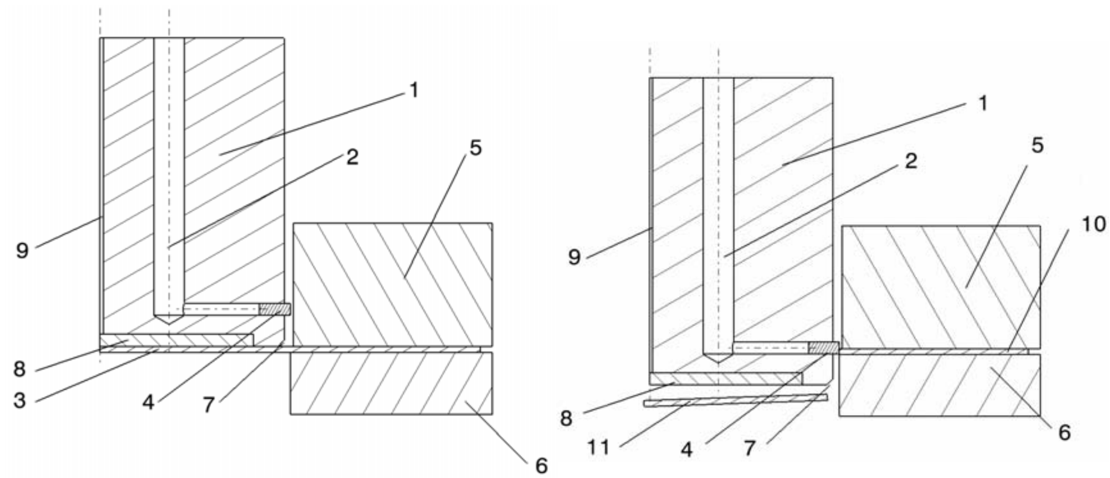

Figure 1: Cut section of integrated application of UV/curing lacquer onto the cut edge; left: before begin of cutting process; right: after cutting process before begin of lacquer application

Experiments

Application of UV-Curing Lacquers

A variety of deep drawing quality electro galvanized sheet steel (DC06 according to EN 10130) of 0.7 mm thickness with up-to-date organic coatings - one prefinished sheet with top coating for automotive appliances (four layers) and and one preprimed/prefillered (two layers) sheet to substitute cathodic dip painting - has been cut by the above described process. Different UV-curing lacquers and different felt qualities have been researched.

The used UV-curing lacquers were paintable multi-metal welding primers, usually used prior to topcoating in coil coating lines. They differed in viscosity: 2,000 mPas and ca. 7,000 mPas.

The employed tissues were wool felts of different thickness and density: 1 mm - 0.28 kg/dm^3; 2 mm - 0.22 kg/dm^3; 2 mm - 0.36 kg/dm^3; 2 mm - 0.40 kg/dm^3.

The curing was done by a 400 W UV-curing metal halide lamp with an intensity of about 225 mW/cm^2 for about 20 s each for top and bottom side of the sheet.

Corrosion Tests

According to DIN 50021- SS salt spray tests have been performed with a 5% NaCl-solution at a temperature of 35 °C to verify the suitability of the integrated application of UV-curing lacquers for improving corrosion resistance. Selected specimens (conventionally cut and cut by the above described process) were subjected to six cycles of this test, accumulating to a test duration of 144 hours. After washing and drying the specimens have been photographed and the depth of sub-coating corrosion migration was measured. For this, coating loosened by corrosion had been removed with a knife.

Results and Discussion

In polished cut images it could be observed that thin layers of UV-curing coatings can reliably and reproducibly be applied onto the cut edge by the above described process, cf. Figure 2.

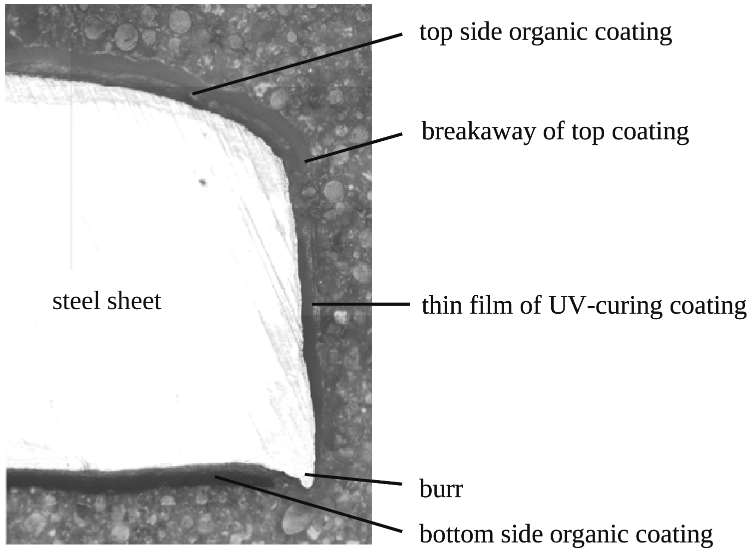

Figure 2: Polished cut image of cut edge of coil coated sheet steel covered by UV-curing lacquer

Corrosion tests proved that the described process is capable of preventing corrosion migration at the cut edge (Figure 3) on the top side of the sheet. By sealing the bare cut edge with the UV-coating corrosive media cannot attack the steel substrate.

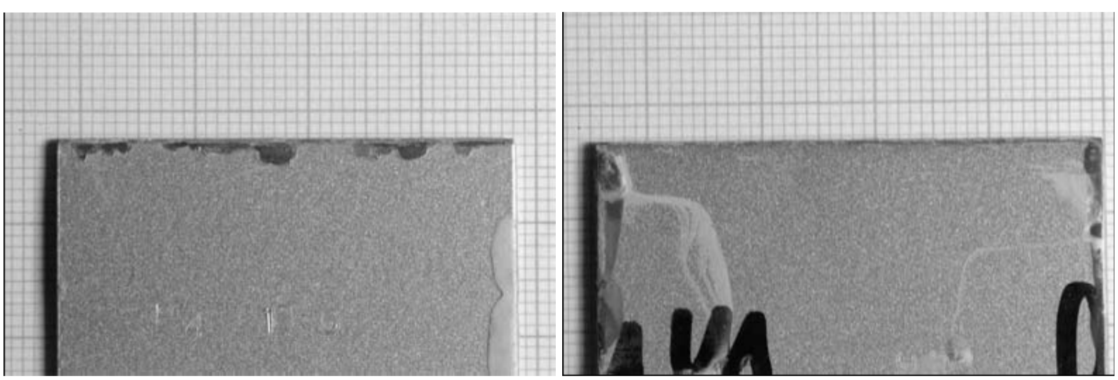

Figure 3: Evaluation of sub-coating corrosion migration, left: high progression of corrosion (no application of UV-curing coating onto cut edge), right: no progression of corrosion (cut edge treated with UV-curing lacquer)

As seen in Figure 4 using a cutting process as described by Hoffmann[7] can reduce sub-coating corrosion migration compared to standard cutting parameters, especially on the top side of the sheet. However, far better results on the top side can be yielded when using a cutting process with integrated application of a UV-curing corrosion inhibiting agent, cf. Figure 5. Only with one felt quality with insufficient permeability for the lacquer corrosion did occur on the top side.

coating system	cutting clearance	tool chamfer geometry	depth of sub-coating corrosion migration [mm]	
			top side	bottom side
preprimed/prefillered	10%	0°	1.80	0.24
preprimed/prefillered	30%	0.72 x 60°	1.16	0.27
preprimed/prefillered	30%	1.2 x 30°	1.21	0.01
preprimed/prefillered	10%	1.2 x 60°	1.85	0.02
preprimed/prefillered	20%	1.2 x 60°	1.49	1.31
preprimed/prefillered	30%	1.2 x 60°	1.33	0.42
preprimed/prefillered	40%	1.2 x 60°	0.67	0.22
preprimed/prefillered	60%	1.2 x 60°	0.78	0.12

Figure 4: Depth of sub-coating corrosion migration when using enlarged cutting clearance and chamfered punch

coating system	lacquer viscosity [mPas]	felt quality [mm] - [kg/dm³]	depth of sub-coating corrosion migration [mm]	
			top side	bottom side
4-layer top coating	2,000	2 - 0.36	0.00	0.00
preprimed/prefillered	2,000	1 - 0.28	0.00	0.48
preprimed/prefillered	2,000	1 - 0.28	0.00	0.00
preprimed/prefillered	2,000	2 - 0.22	0.00	0.05
preprimed/prefillered	2,000	2 - 0.22	0.00	0.10
preprimed/prefillered	2,000	2 - 0.22	0.00	0.07
preprimed/prefillered	2,000	2 - 0.36	0.09	1.12
preprimed/prefillered	2,000	2 - 0.36	0.11	0.59
preprimed/prefillered	2,000	2 - 0.36	0.15	0.60
preprimed/prefillered	2,000	2 - 0,40	0.00	0.02
preprimed/prefillered	2,000	2 - 0,40	0.00	0.09
preprimed/prefillered	2,000	2 - 0,40	0.00	0.26
preprimed/prefillered	7,000	2 - 0.22	0.00	0.00
preprimed/prefillered	7,000	2 - 0.22	0.00	0.35
preprimed/prefillered	7,000	2 - 0.22	0.00	0.50
preprimed/prefillered	7,000	2 - 0.22	0.00	0.01

Figure 5: Depth of sub-coating corrosion migration when using cutting process with integrated application of UV-curing corrosion inhibiting agent

Yet, as Figure 4 and Figure 5 show, neither the cutting process described by Hoffmann[7] nor the process of the integrated application of UV-curing lacquer can clearly reduce corrosion on the bottom side of the sheet. This is caused by the burr formation during the cutting process. The burr has bad influences to corrosion protection because of low adhesiveness of the coating in the burr zone.

Conclusions and Future Work

It could be shown that a cutting process with an integrated application of a UV-curing lacquer can be used to inhibit corrosion of the cut edge of coil coating sheet metal. A variety of corrosion inhibiting agents of different viscosity and different permeable tissues, e.g. wool felts, for transporting the agent to the cut edge can be used. The described process can be used to protect the cut edge of sheets with different coating systems. Complete corrosion inhibition can be achieved for the top side of the sheet, while the bottom side - where the burr forms during the cutting - in most cases still shows the same or only a slightly reduced amount of corrosion migration. Future work will concentrate on solving this remaining corrosion problem dependably.

Acknowledgements

The author would like to express his gratitude for the support of the mentioned project by DaimlerChrysler AG, voestalpine AG for providing coil coated sheet, Chemetall GmbH for providing the UV-curing lacquers and Dymax for providing the UV-curing lamp.

References

1 W. Trabelsi, L. Dhouibi, E. Triki, M. Ferreira, M. Montemor, *An electrochemical and analytical assessment on the early corrosion behaviour of galvanised steel pretreated with aminosilanes*, Surface and Coatings Technology 192/2-3, 2005, 284-290.

2 D. Wolfhard, C. Filthaut, I. Rogner, B. Schinkinger, *Organically precoated steel sheets for automotive production*, ThyssenKrupp techforum, Dec. 2003, 14-19.

3 S. Lyon, R. Howard, I. Zin, *Electrochemical cell study of cut edge corrosion inhibition on coil coated steel sheet*, Transactions of the Institute of Metal Finishing 80/2, 2002, 64-66.

4 S. Lyon, R. Howard, J. Scantlebury, *Kinetic mechanisms for cut edge corrosion of coil coated architectural cladding*, British Corrosion Journal 37/3, 2002, 214-216.

5 R. Leggat, S. Taylor, *Effect of micron scale surface deformation on the corrosion behavior of coil-coated aluminum alloy 5182*, Corrosion 55/10, Houston, 1999, 984-990.

6 I. Dehri, R. Howard, S. Lyon, *Local electrochemical impedance at the cut-edge of coil-coated galvanized steel after corrosion testing*, Corrosion Science 41/1, 1999, 141-154.

7 H. Hoffmann, R. Petry: *Optimized Corrosion Protection of the Cut Edge of Coil Coated Sheets by an Advanced Cutting Process*, 16th International Corrosion Conference, Beijing, September 2005