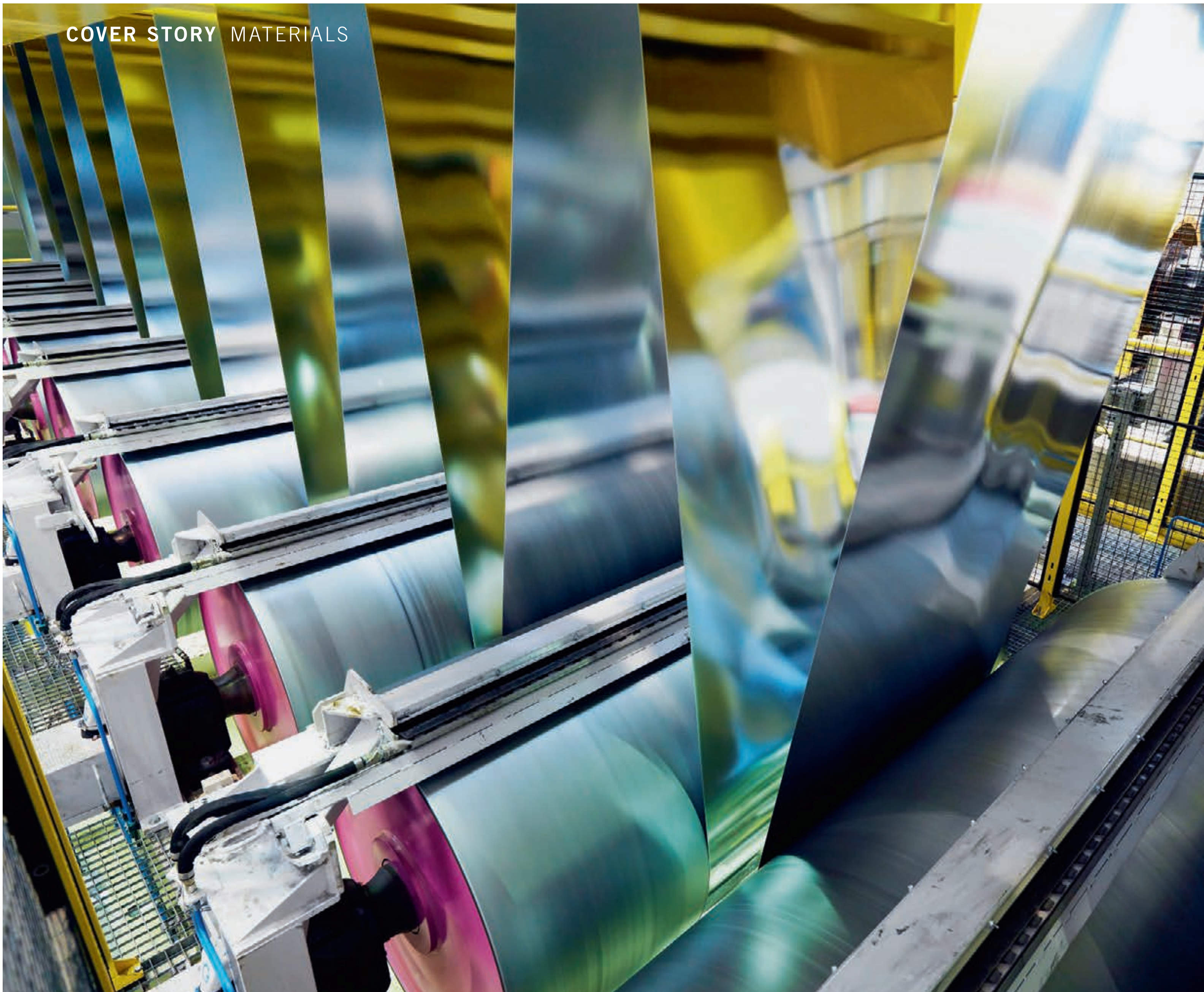
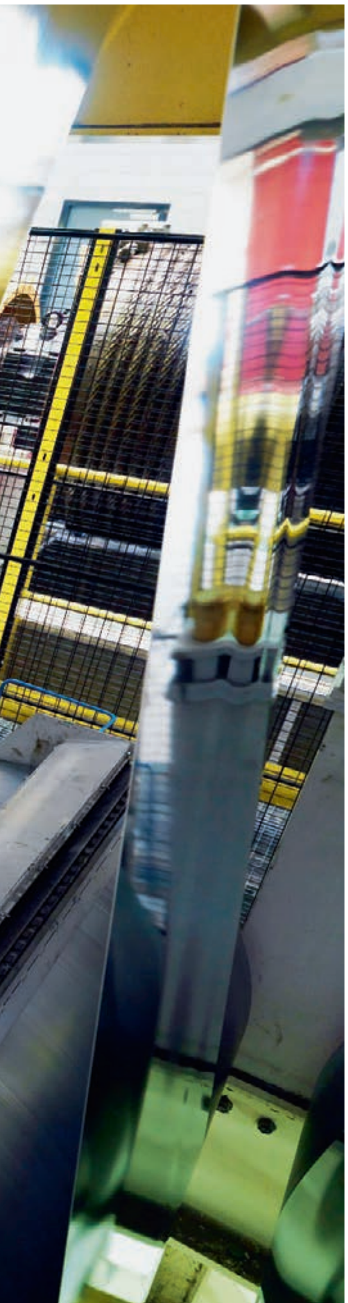


ZINC-MAGNESIUM COATED HOT DIP GALVANISED STEEL

Car corrosion performance has been improved continuously in recent years. Therefore, today's consumers expect extremely durable steel components in their vehicles. With MagiZinc, Tata Steel has developed a new generation of hot dip galvanised steel that has a thinner coating to help save weight on vehicle bodies. At the same time, it resolves lightweight design and manufacturing challenges of conventional coatings, such as tool pollution and galling behaviour.



AUTHORS

DR. NITTE VAN LANDSCHOOT
is Business Development Manager Automotive at Tata Steel Product Marketing Automotive in IJmuiden (Netherlands).

CHIEL DANE
is Principal Scientist Applications & Engineering at Tata Steel RD & T in IJmuiden (Netherlands).

ROB BLEEKER
is Senior Researcher Metallic Coated Strip at Tata Steel RD & T in IJmuiden (Netherlands).

DR. MARGOT VLOT
is Principal Scientist Metallic Coated Strip at Tata Steel RD & T in IJmuiden (Netherlands).

MOTIVATION

Since the introduction of zinc coatings on steel in the automotive industry, the corrosion performance of cars has been significantly increased. Zinc applied during galvanising protects the steel by providing a physical barrier, as well as cathodic corrosion protection for the underlying steel. However, the tribology of conventional zinc coatings still poses problems for car manufacturers in the press shop.

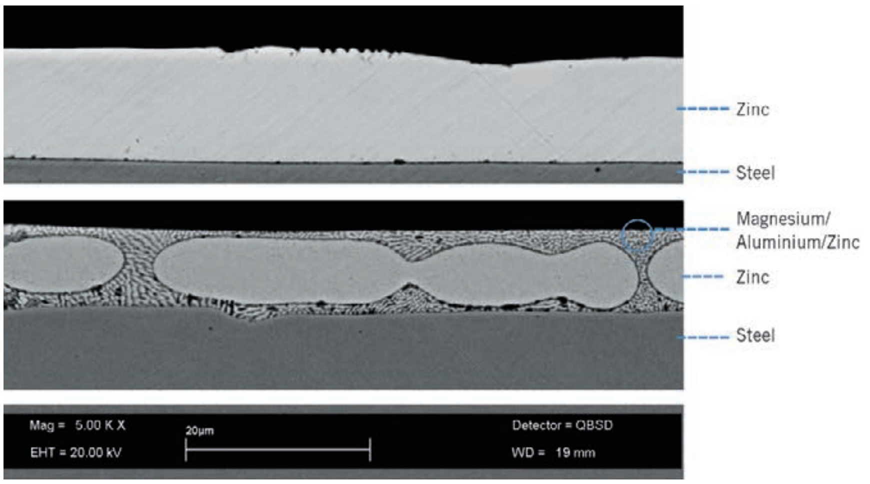
Furthermore, due to the need for thinner, weight-saving coatings, and with the aim of conserving limited natural resources, the industry itself has a significant interest in the reduction of the amount of zinc used. For this reason, Tata Steel has developed a new alloyed zinc coating that aims to fulfil these requirements. The objective was to find a new coating with improved corrosion protection that can be used on existing galvanising lines and that can be applied smoothly in the manufacturing processes currently used by the automotive industry. The new coating is to be utilised in all non-exposed parts of the car but should also boast the potential for external applications in the car body.

DEVELOPMENT OF MAGIZINC

The development of a new coating starts with the investigation of different alloys. Small amounts of titanium, copper, manganese, chromium and magnesium are alloyed and put on steel panels in a hot dip simulator. This procedure forms the basis for the systematic analysis of the properties of the new alloys in respect of their corrosion and galling behaviour in a small-scale environment. Initial results concerning the corrosion performance of the various coating alloys come from a salt spray test (ASTM B-117), in which the corrosion process at intentionally damaged areas of the steel panels is accelerated. Performance is measured by the time it takes for red rust to appear, indicating that the zinc protection has ended.

None of the elements added to the zinc alloy gives a result as favourable as that of magnesium. Small amounts, as low as 0.5 %, provide two to four times longer corrosion protection than the standard zinc alloy. Microstructural analyses of the new coating versus regular coatings show that magnesium forms an eutectic structure (lamellae) with zinc in between the dendritic crystals of pure zinc, ❶. Due to the presence of magnesium, corrosion protection layers form faster, are more compact and deposit on areas where the steel is unprotected. This prevents the steel from reacting with oxygen [1, 2, 3]. The microstructure also results in a harder surface that is slightly more brittle than pure zinc coatings, but remains bonded to the steel even after extreme bends, as concluded in T-bend tests (DIN EN 13523-7) [4].

After a suitable coating composition was derived empirically, the behaviour of the new zinc coating had to be tested in the industrial galvanising process. During hot dip simulation, it was found that the addition of magnesium to the zinc bath leads to the formation of an oxide crust on the liquid metal. The crust reduces the subsequent adhesion and corrosion protection performance of the steel due to the inclusion of oxygen molecules. This effect is solved by adding aluminium to the alloy, at least equalling the level of magnesium, which at the same time offers the possibility of further improvements in cor-



❶ Cross-section of microstructures: pure zinc coating (above), MagiZinc coating (below)

rosion protection. Based on these findings, sheet metal galvanising was tested in a real production environment in a pilot line facility at the Centre for Research in Metallurgy in the Belgian city of Liège. The best balance between adhesion quality, corrosion performance and cost was determined for an alloy containing 1.6 % aluminium and 1.6 % magnesium, and it is called MagiZinc.

MAGIZINC IN THE MANUFACTURING PROCESS

A new coating should be processable in a similar way to regular zinc coatings for the different production steps in the car manufacturing process; the coating should at least perform equally but preferably better during forming of parts during pressing, assembly and painting. Therefore, tests examined the behaviour of the new material with regard to the following parameters:

: friction and formability
: joining
: paint adhesion
: corrosion.

These tests showed that MagiZinc particularly improves the abrasion behaviour between the metal, lubricant and tooling.

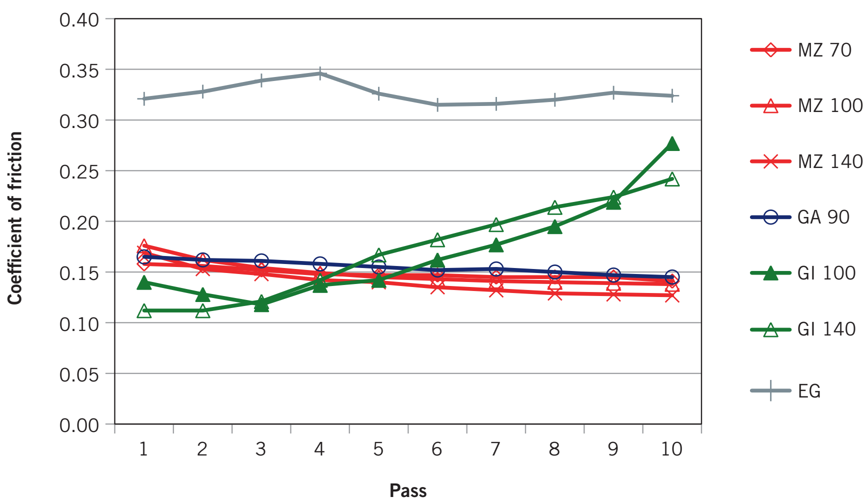
During these tests, MagiZinc coatings in different thicknesses (MZ 70, MZ 100, MZ 140) were compared to currently used hot dip galvanised (GI 100, G 140) and galvannealed (GA 90) coatings, as well as electro galvanised (EG) for automotive applications. The tests were based on common standards used by car manufacturers and on German norms and standards.

FRICTION AND FORMABILITY

During the forming process, conventional zinc-coated steels frequently affect the process stability and component quality through the abrasion of zinc flakes and galling. Degraded material and maintenance costs, as well as delays through tool cleaning, lead to high total costs for manufacturers. Tata Steel studied the coating properties in different collaborations and developed its own philosophy and tests to improve the galling of zinc from the metal perspective. ❷ shows the behaviour of MagiZinc compared to GI, GA, as well as EG in the Linear Friction Test from Renault. This test was used primarily to study and to improve the coating properties further. The test measures the increase in friction and material damage caused by adhesion of zinc flakes. A flat strip is clamped into a freshly polished tool and is rolled ten times at room temperature using defined amounts of lubricant. Compared to the other coatings, MagiZinc shows nearly no adhesive transfer of zinc particles to the tools caused by adhesion, thus reducing galling significantly.

WELDING AND JOINING

Adhesive bonding and spot-welding are two of the most important means of connecting metal parts in the car manufacturing process. The performance of these joints will be affected by the type of metallic coating. To compare the adhesive bonding performance of MagiZinc to GI and GA, lap-shear strength and failure modes are determined for different adhesives, different base materials and different ageing conditions in a lap-shear test according to German standard VDEh Sep 1160. In general, the adhesive bonding properties of MagiZinc are comparable to GI and GA. Only for adhesives with very high tensile strength (> 25 MPa) does MagiZinc tend towards higher adhesive failures. These differences diminish after ageing. During spot welding of zinc-coated steels, the copper electrode will be slowly polluted and damaged by contact with the zinc after many welds and needs to be replaced or dressed in order to avoid sub-standard welds. Both



❷ Linear Friction Test results show the development of friction and material damage due to the adhesion of zinc on the tools the welding range and electrode life were determined for MagiZinc and compared to GI, with similar performance results for both.

PAINT ADHESION

After forming and assembly of the parts, the car body is phosphated, electrochemically dip painted and covered by a topcoat layer to achieve a sophisticated organic coating system protecting the full BIW and giving it an appealing appearance. The zinc coating has to be compatible with all of these process steps. The most important criterion is that the paint system adheres to the zinc coating to reduce the risk of corrosion of damaged or stone-chipped areas. In order to test the properties of MagiZinc, scratches were applied to the test panels. After putting the panels in a conditioned wet atmosphere, or immersing them in water, the coating adhesion was tested and no differences were found between sheets coated with MagiZinc and conventional galvanised sheets. Therefore, the paint adhesion of the new alloy meets the standards required by the automotive industry.

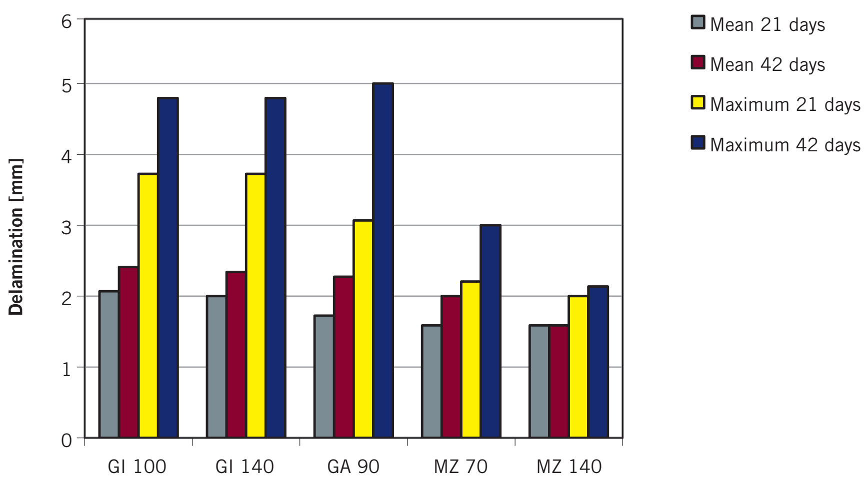
CORROSION

Before full-scale line trails were performed in a real production environment, it was important to evaluate the corrosion protection effect of MagiZinc on critical areas such as scratches, cut edges or flanges at the bottom of a door. Material performance during high humidity or the impact of deicing salt was tested. Two types of corrosion test designs were applied to study cosmetic corrosion and perforation corrosion particularly at flanges. For the former, so-called cyclic corrosion tests were used to examine paint delaminating at scratches, stone-chipped areas and cut edges. Tata Steel used Renault's ECC1 D172028 (for 21 and 42 day cycles) and the German VDA612-415 standard test for 20 week cycles. Results on cosmetic corrosion are shown in ❸ and ❹. A glass flange crevice test designed by Volvo (STD 423-0014) was used to simulate perforation corrosion that takes place in invisible areas, such as seams, where corrosion will only be detected when full perforation has already occurred, for example at flanges on the bottom of a door. Results for perforation corrosion can be found in ❺. A comparison between MagiZinc and GI and GA is documented in ③, ④ and ⑤. MagiZinc clearly shows delayed steel corrosion (red rust) and less delamination of the paint system along scratches and cut edges [5].

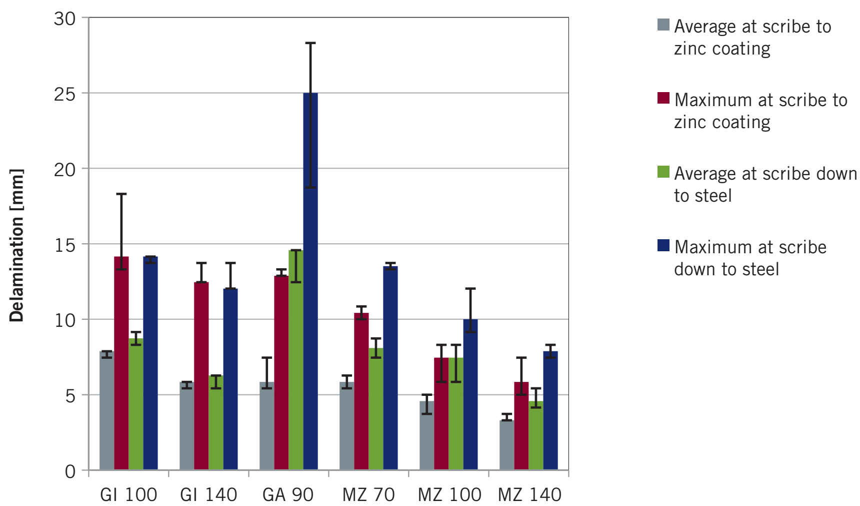
TRIALS IN A REAL PRODUCTION ENVIRONMENT

One of the first full-scale trials was conducted at BMW. A MagiZinc coated fender and different structural reinforcement parts were produced in close collaboration. The first full-scale forming, joining and painting of these parts gave the possibility to evaluate MagiZinc as integral part of a body-in-white. BMW processed the material in the same manner as their series-production material. No changes were made to the weld settings and to the stamping operation. The material was painted as part of the body-in-white and no deviations were observed. The paint appearance of the outer skin parts has not been in the focus of BMW.

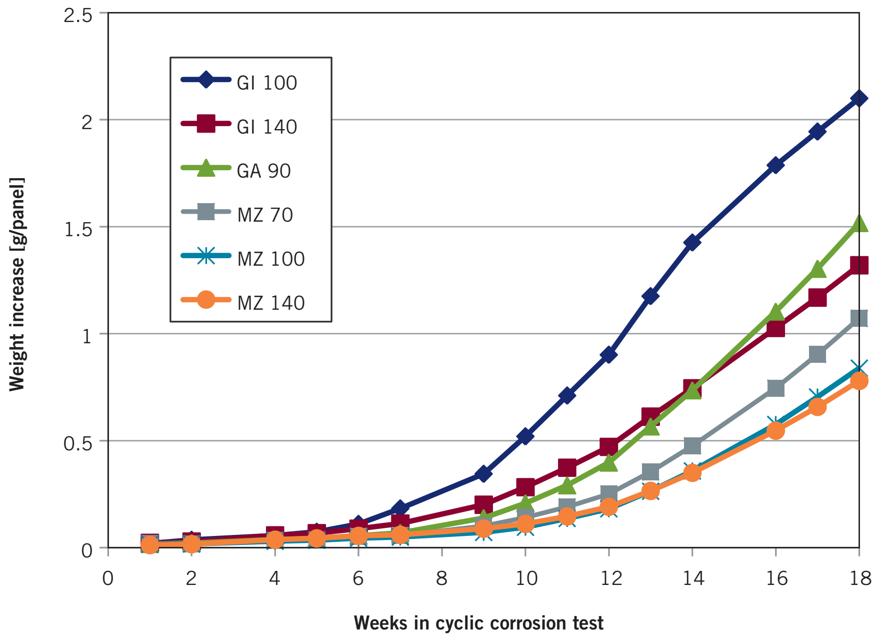
The parts were built into a corrosion test vehicle. The company tested MagiZinc Auto (5 µm layer) on one fender and their series-production product Z100 (7 µm layer) on the other, allowing for a good comparison. The MagiZinc product shows minimal cosmetic corrosion (paint delamination) compared to the series-production material in the applied accelerated corrsion test, clearly showing the benefit of the material, even with a thinner zinc layer.



❸ Scribe delamination in ECC1 cyclic corrosion test with average and maximum values after 21 and 42 day cycles



❹ Average and maximum scribe delamination values after 20 weeks, with scratches down to the zinc coating and scratches down to the steel substrate



❺ Weight gain of panel by red rust during glass flange test (Volvo design)

On the basis of the friction and galling tests performed in the laboratory, scientists expected MagiZinc to suffer less from tool pollution, allowing a smoother press performance. A real press trial at another German OEM was performed to evaluate this. During the trial, it was observed that when MagiZinc replaces normal zinc coatings, the press tool indeed shows 25 % lower pollution, indicating that the press can run for longer periods before the line needs to be stopped and cleaned. Crucial for this more stable stamping production is the more stable friction coefficient of Magi-Zinc compared to that of normal coatings.

OUTLOOK

Current weight reduction trends require better corrosion protection against perforation and better galling performance, as the risk for perforation corrosion increases with thinner, higher strength steel sheets. The higher corrosion resistance and improved galling behaviour of MagiZinc show clear advantages over conventional steel zinc for these new high-strength steel grades and facilitate their introduction in new cars. In this context, the introduction of MagiZinc coatings can be expected, starting with structural components. In time, these new zinc alloys can replace conventional zinc coatings on outer body panels. Successful trials at OEMs have already demonstrated these potential applications.

CONCLUSION

The development and introduction of a new metallic coating is a long process that has been carried out by Tata Steel in close collaboration with the OEMs. Material properties have to be balanced to fit the requirements of both the production process of the steel maker and the subsequent manufacturing and assembly processes of the automotive industry. With MagiZinc, Tata Steel has developed a new generation of hot dip galvanised steels that reduce production costs due to their improved behaviour in the press shop. Together with the improved corrosion protection and thinner layers, this coating system will replace currently used zinc alloys in the long term, thus contributing to the reduction in zinc consumption.

REFERENCES

[1] Hosking, N. C.; Ström, M. A.; Shipway, P. H.; Rudd, C. D.: Corrosion Resistance of Zinc-Magnesium Coated Steel. In: Corrosion Science (2007), No. 49, pp. 3669 – 3695
[2] Prosek, T.; Larché, N.; Vlot, M.; Goodwin, F.; Thierry, D.: Corrosion Performance of Zn–Al–Mg Coatings in Open and Confined Zones in Conditions Simulating Automotive Applications. In: Materials and Corrosion (2010), No. 61, pp. 412 – 420
[3] Volovitch, P.; Vu, T. N.; Allély, C.; Abdel Aal, A.; Ogle, K.: Understanding Corrosion via Corrosion Product Characterization: II. Role of Alloying Elements in Improving the Corrosion Resistance of Zn–Al–Mg Coatings on Steel. In: Corrosion Science (2011), No. 53, p. 2437 – 2445
[4] Dane, C.; Carless, L.; Vlot, M.; Toose M.: Tribologische Vorteile im Presswerk. In: Bauteile der Zukunft, Methoden und Prozesse, Tagungsband T31 des 30. EFB-Kolloquiums Blechverarbeitung 2010 am 2. und 3. März in Bad Boll (2010), pp. 203 – 218
[5] Vlot, M.; van Landschoot, N.; Bleeker, R.: ZnAlMg Coatings Versus Galvannealed. In: Galvatech 2011 Proceedings (2011)