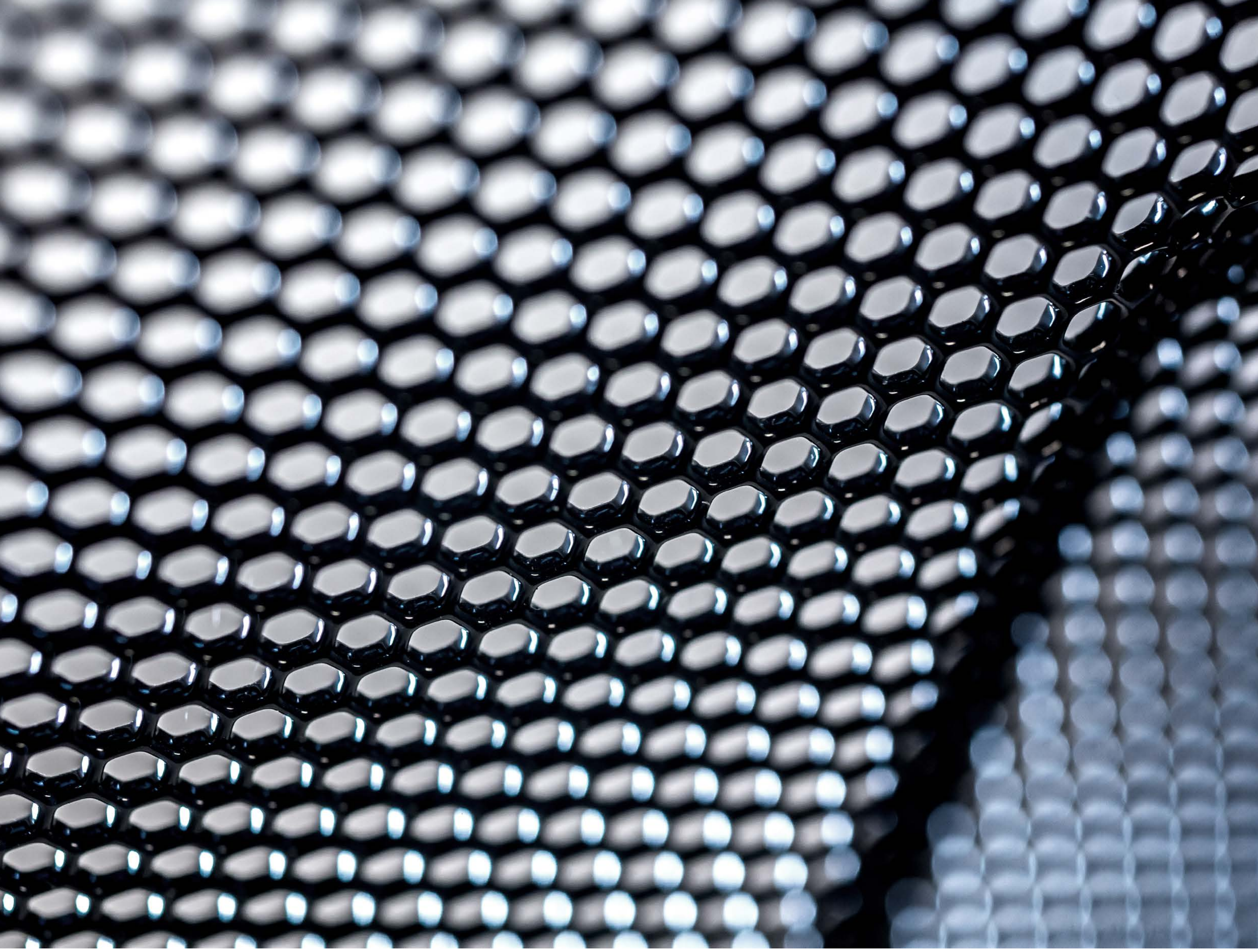

SOLVARO

WHITEPAPER

CORROSION PROTECTION FOR PERFORATED METAL COMPONENTS

CONTENT

FOREWORD

Perforated metal components are widely used in automotive technology: as ventilation grilles and engine hoods on agricultural and construction machinery, buses and trucks, they have to be able to withstand extreme stresses. To ensure that the perforated sheets can endure those stresses over the entire service life of the vehicle, high-quality, comprehensive corrosion protection with optimal edge coverage is indispensable.

Yet the coating of perforated sheets is a science unto itself. Burr formation during perforation promotes the edge-thinning effect, which in turn significantly compromises the quality of the surface coating. The results and evaluation of coating processes are not comparable to solid sheets and are not sufficient for complex perforations with thin bridges. To ensure adequate coating with optimal edge coverage, metal component specialist Solvaro joined forces with partners from the field of surface technology to develop an advanced, multi-step, comprehensive process that extends from the material selection to the surface technology. The results are promising: the well thought out process makes it possible to strike the perfect balance between the competing interests of sufficient layer thickness for high corrosion resistance and the best possible air circulation. The high-quality coating of perforated sheets gives the end user a longer service life combined with optimal air circulation and attractive design.

OPTIMAL CORROSION PROTECTION IS A QUALITY FACTOR FOR PERFORATED SHEETS

As ventilation grilles and engine hoods for agricultural and construction machinery, buses and trucks, perforated components have to fulfill multiple requirements at once. In addition to the criteria of air circulation, robustness and aesthetics, rust protection is also a top priority: Ventilation grilles and engine hoods are permanently exposed to extreme influences due to their exposed position at the front of the vehicle. Rain, ice and snow attack the perforated sheet; dust and dirt particles settle on the thin bridges of the prefilter; and flying rocks test the mechanical strength of the perforated metal component. To withstand these stresses over the long-term, corrosion protection with sufficient thickness and optimal edge coverage is indispensable.

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PERFORATED SHEETS MUST ENSURE OPTIMAL AIR CIRCULATION BECAUSE ENGINE COOLING HAS A SIGNIFICANT IMPACT ON FUEL CONSUMPTION.

Maximum air circulation is required for engine cooling

One important characteristic of perforated sheets is air circulation. The powerful engines of agricultural and construction machinery, buses and trucks are continuously supplied with cooling air through the small holes in the perforated sheet metal. Perforated sheets must ensure optimal air circulation because engine cooling has a significant impact on fuel consumption.

The free cross-section of a perforated component can be up to

80 %

This requirement is in fundamental contradiction with the desired prefilter effect, as illustrated by the example of an Hv 6–6.7 perforated sheet (hole width 6 mm/hole pitch 6.7 mm). The free cross-section A0 with this perforation is 80%, which achieves excellent air circulation. However, the high air circulation rate is inevitably associated with a lower prefilter effect.

From the vehicle manufacturers' point of view, adequate engine cooling is also indispensable with regard to emissions limits. Air circulation therefore plays a central role for the coating of perforated metal components: Improper coating can quickly cause holes to clog and affect air circulation.

Over 2,800 individual standards for perforated metal components

The requirements for the coating of metal components are extremely diverse, and this is also reflected in the technical standards. Today, developers of perforated metal components are confronted with over 2,800 individual standards – the spectrum ranges from DIN, EN and ISO standards to customer standards and special quality assurance specifications. Anyone wishing to find their way through the jungle of standards will first have to filter the list of requirements. It quickly becomes clear that many of the customer-specific standards refer to solid material and are therefore unsuitable for the coating of perforated components. The challenge, then, is to optimally adapt the coating system to the customer's requirements and then translate that from solid material to perforated metal.

Technical challenges in coating perforated sheets

Coating holes and edges on perforated metal components is a tricky undertaking. A hexagonally perforated component with a hole width of 2 mm and a hole pitch of 2.5 mm (Hv 2–2.5) has 184,000 holes per square meter – the bridges are accordingly thin, with a thickness of just 0.5 mm. This illustrative example makes it immediately clear that the perforated sheet has different surface characteristics than a solid sheet.

In coating these components, the uncontrolled formation of burrs during the perforation of the sheet metal poses a particular challenge. The uncontrolled burr created in the fracture zone on the punch exit side makes the subsequent coating process more difficult because the surface tension forces the applied coating back towards the flat surfaces at the edges of the perforation. This effect is called edge thinning and results in a thinner coating on the edges of the perforated sheet than on flat surfaces. Due to the insufficient coating thickness, the component is susceptible to corrosion in later practical use and cannot meet the requirements for corrosion protection.

In the prior process of edge rounding, it is therefore important to minimise edge thinning though suitable measures. This makes it possible to achieve uniform application of the coating with optmised edge coverage.

With a thickness of just

0,5 mm,

the bridges are accordingly thin.

WHAT IS EDGE THINNING?

Edge thinning is a physical effect that occurs when coating surfaces and causes reduced coating thickness at the edges. The curved surface in the edge area produces a surface tension that displaces the paint toward the flat surfaces. This significantly reduces the thickness of the coating in the area of the edge, which can lead to cracking of the coating or, in extreme cases, even dewetting. Near the edge, on the other hand, the layer thickness can increase to the point of forming a bead.

STEP-BY-STEP PROCESS FOR MAXIMUM SERVICE LIFE

In contrast to a solid sheet, a perforated sheet consists entirely of edges – coating processes for solid sheets reach their limits here and cannot guarantee sufficient coverage of the edges. From the coating technology perspective, it is therefore important to take a comprehensive view of the product life cycle. Each production step is considered in terms of its impact on the coating process – from material selection to the final coating. This holistic approach makes it possible to achieve an optimal coating result for the end user. As an experienced specialist in surface technology, Solvaro has developed an advanced, multi-stage and comprehensive process that meets the exacting coating requirements for perforated metal components in almost every respect.

1st

STEP –

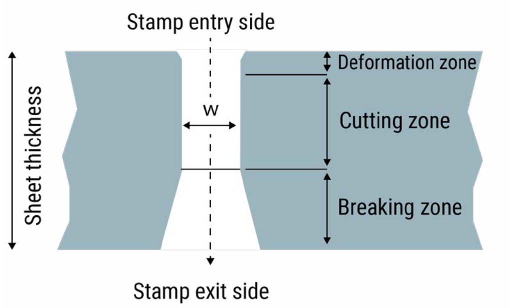
Perforation

Perforating metal sheets involves the use of a punching tool that cuts through the sheet from the punch entry side to the punch exit side. The sheet can be divided into three zones: the deformation zone, the cutting zone and the fracture zone. The fracture zone refers to the area where the metal breaks out in the final phase of perforation. Unevenness and burrs inevitably occur here.

From a manufacturing perspective, it is important in the first step to influence the effect of burr formation through good tool grinding. Burrs promote the physical effect of edge thinning and make it more difficult to achieve optimal edge coverage during subsequent coating.

Solvaro counteracts burr formation with a special, in-house grinding process with which the punches of the hexagonal tools are regularly machined. This enables the company to maintain hole quality and ensure clean and precise perforation: the result is sharp edges that can then be rounded off in a controlled manner.

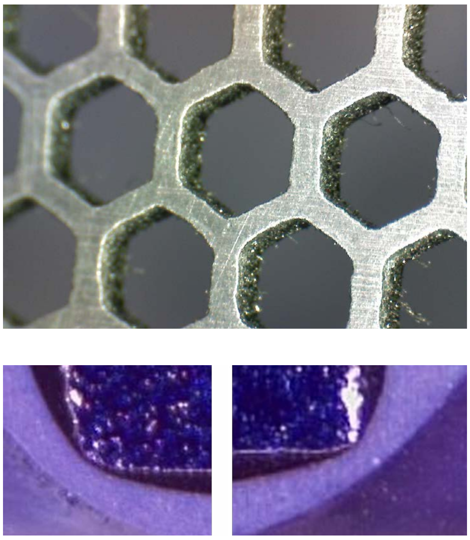
Grinding the tools at fixed intervals ensures hole quality.



2nd STEP –

Deburring

The second step – deburring – aims to reduce the effect of edge thinning by rounding the edges uniformly. Rounding the edges reduces the surface tension, resulting in more uniform and thicker coating in the area of the edges. Solvaro applies a multi-stage method in which all holes are optimally rounded all the way around. The company thereby achieves the highest possible process reliability over millions of holes and ensures that the quality of the punch exit side is approximately the same as the quality of the punch entry side.



Viewed under the microscope, the sheet metal that has undergone a multi-step rounding process (picture above) shows sufficient layer thicknesses at the edges after coating.

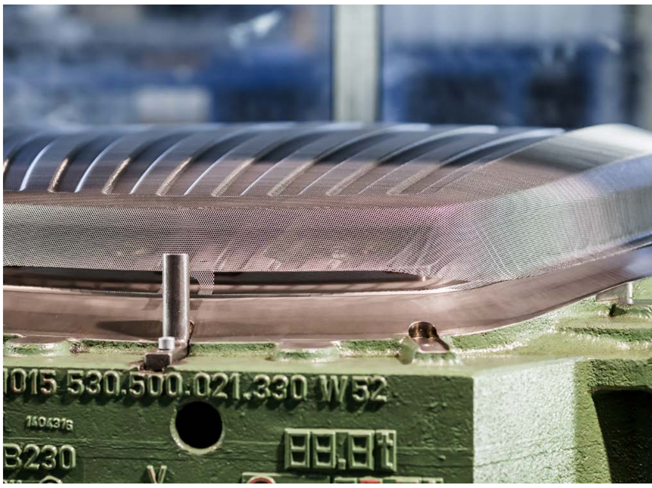
3rd STEP –

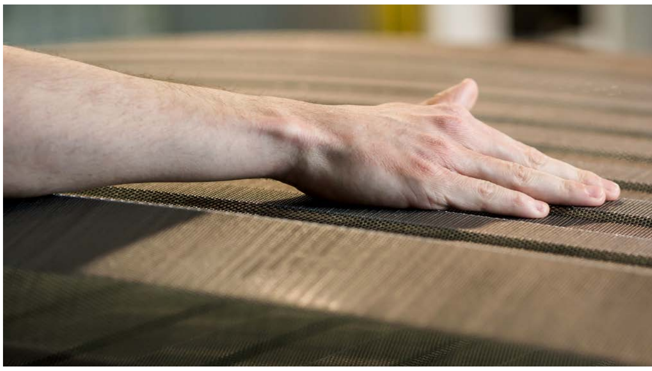
Forming

Today's commercial vehicles must meet the highest standards in terms of design and aesthetics. This applies in particular to engine hoods, which are directly in the field of vision on the front of the vehicle. The perforated metal component is shaped by deep drawing, an intermediate step that has an influence on the overall process.

The challenge: due to the perforated structure, simulations of the maximum deformation are not possible. The amount of data to be calculated is simply too large due to the large number of holes – the numerical simulation of springback, for example, cannot be performed. If there is no information about the maximum deformation available, deformation of the honeycomb structure, and in the worst case cracking of the bridges, can occur. This damage has a direct impact on the coating quality, and deformed holes also compromise the appearance of the component.

For the forming of perforated metal components, Solvaro relies on time-tested experience rather than calculations: The expertise gained though many years of practical experience allows the company to make plausible assumptions for the relevant deep-drawing parameters in advance based on comparable components. The parameters have to be defined individually for each design and range from the choice of the base material, the type of perforation (Hv-Rv) and the hole size to the drawing radii, the stamping depth and the stamping distances and angles. Solvaro advises its customers on these aspects at an early stage in the project and thus avoids component damage caused by the forming process.





A wealth of experience enables deep drawing without bridge cracking or deformations in the visible area.

4th STEP –

Pretreatment

Pretreatment of the perforated sheet creates a conversion layer through the use of phosphating. Thanks to its microporous structure, this layer ensures that the material can optimally absorb subsequent coatings. The conversion layer also counteracts rust penetration at damaged spots in the coating.

A distinction is made between iron phosphating and zinc phosphating. Some OEMs allow both processes in their standards, while others favor iron phosphating. However, zinc phosphate coatings are superior to iron phosphate coatings in terms of their protective effect, which is why this variant is used as standard at Solvaro for coating perforated metal components.

A test has shown that zinc phosphating (picture on top) achieves a much better result than iron phosphating

5th STEP –

Cathodic dip coating

Cathodic dip coating (CDC) is an electrochemical process designed for coating the full surface of complex shapes and structures. The workpiece is immersed in an electrically conductive, water-based paint bath. By applying a DC voltage between an external electrode and the material to be coated via the conductive bath, the binder is neutralised and the paint is deposited. This forms a closed, adhesive coating film on the workpiece.

Customer standards specify a thickness of 15 to 20 µm for the coating. This specification is usually intended for solid sheet metal and is absolutely adequate for that – but in the case of perforated sheet metal, often only a fraction of the CDC paint applied reaches the cut edges due to the edge thinning effect. Solvaro has therefore defined a higher layer thickness (>25 µm) on the basis of extensive tests with specialist partners and a scientific institute. This standard ensures that all functions of the perforated sheet are retained and optimal air circulation is guaranteed.

>25 µm

coating thicknesses in line with SOLVARO's in-house coating standard

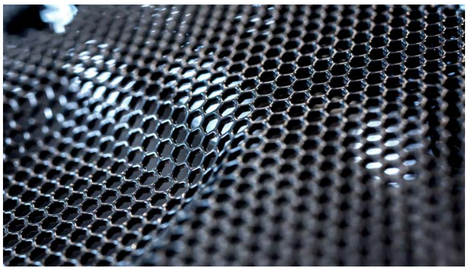
6th STEP –

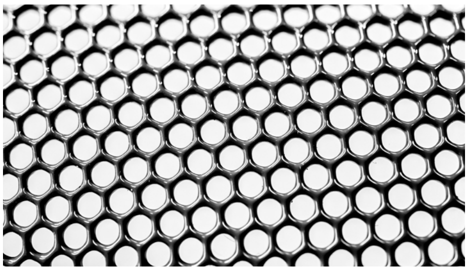
Powder coating

Powder coating gives the perforated sheet high UV resistance with a final top coat and enhances its appearance. This process step is carried out in close consultation with the customer – which usually specifies the desired powder manufacturer and the powder's color and gloss level. Applying the powder coating requires experience and expertise as well as intuition. The challenge: if too much paint is applied, the holes can become clogged and impede the air circulation, which is very important for engine cooling. In addition, clogged holes are also recognisable as visual defects. If, by contrast, not enough paint is applied, the CDC coating will show through on the component due to edge thinning.

Solvaro has tested new powder compositions with coating technology experts to find the optimal solution for perforated components. One of the more promising ways to reduce edge thinning is a targeted increase of the viscosity of the coating material. Lowering the surface tension also helps the coating to spread better at the edges.

Uniform application of paint, including on the edges, results in visually and functionally optimal rust protection

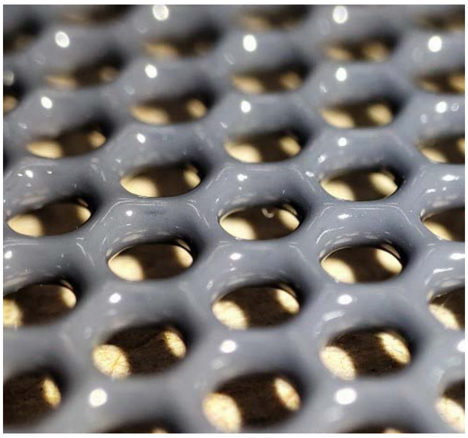




QUALITY ASSURANCE FOR COATING PERFORATED METAL COMPONENTS

In considering quality assurance for the coating of perforated metal components, it must be taken into account that some standards for solid material are not appropriate for perforated sheets. The reason for this is that the results obtained with solid material are not comparable to those obtained with perforated sheets.

The best example of this phenomenon is the salt spray test according to DIN EN ISO 9227. This standardised test is used to evaluate the corrosion protection effect and is based on spraying the coated component with a salt solution under standardised conditions in a test chamber. At the end of the test period, any signs of corrosion are evaluated, with a focus on important factors such as the rust grade and corrosion penetration. The problem becomes apparent in the evaluation, which is not possible with all current standards of DIN EN ISO 4628 for a fully perforated part without an edge and frame. Solvaro has carried out extensive tests in close cooperation with the Institut für Oberflächentechnik (Institute for Surface Technology) Schwäbisch Gmünd. The result: DIN EN ISO 4628.3, which deals with rust grades on surfaces, delivers useful results. However, due to the large number of cut and punched edges, the requirements must differentiate between solid material (Ri0) and perforated components (e.g. Ri1).



The coated components are subjected to a quality inspection suitable for perforated sheets.

From the metal component specialist's perspective, however, it is much more important to meet the requirements of the market with a reliable process than to achieve maximum values in tests under laboratory conditions.

Solvaro therefore consistently bases its standards on the quality criteria demanded by the market and defines requirements for surface technology in its in-house standard.

In addition to corrosion resistance testing, the standard also includes a number of test methods as well as other standardised procedures that increase process reliability, including:

- **Gloss-level measurement according** to DIN EN ISO 2813
- **Adhesion test according** to DIN EN ISO 2409 "cross-cut"
- **Boil test** to check the pretreatment
- **Elasticity test** according to DIN EN ISO 1519 "mandrel bend test"
- **Coating thickness test** according to DIN EN ISO 2178, DIN EN ISO 2360
- **OEM specifications** for defect rates (PPM – "parts per million")
- **Sampling test** AQL according to DIN EN ISO 2859 "inspection by attributes"

> SOLVARO WAS INVOLVED AT AN EARLY STAGE AND WAS ABLE TO CONTRIBUTE ITS EXPERTISE FROM THE DEVELOPMENT PHASE ONWARD

CORROSION PROTECTION IN PRACTICE – THE FENDT 1000 VARIO

The Fendt 1000 Vario sets new standards as the most powerful tractor series from Fendt. The large tractor is available with an output of up to 517 HP and optimally translates its power with imposing tires, an intelligent ballasting and tire pressure assistant and variable all-wheel drive.

Together with the customer, Solvaro took up the challenge of developing an engine cover with particularly high air circulation for the Fendt 1000 Vario. The focus was on ensuring effective rust protection while also implementing a striking design with deep-drawn sections. Functionality was another key focus: the engine cover not only had to be extremely robust, but also had to meet the high requirements in terms of air circulation, waste heat transfer, filter effect and weight.

Solvaro was involved in the project from the very beginning and was able to contribute its expertise from the development phase onward. Thanks to its comprehensive consulting and development services, it was able to fulfill the technical requirements across the board.

The joint development work focused primarily on the following technical areas:

- Selection of a **suitable** raw material
- Determination of the **optimal hole shape and width** to enable the largest possible open area while maintaining robustness, attractive design and durable coating
- Determination of **perforation areas, hole geometry**
- Implementation of the **striking design** with deep-drawn sections based on the custom development and test work
- Carrying out **product-specific tests** and further development of the best possible coating in cooperation with the coating experts at the Institut für Oberflächentechnik (Institute for Surface Technology) Schwäbisch Gmünd

OPTIMAL CORROSION PROTECTION THROUGH EXPERTISE AND DEVELOPMENT

Experience shows that a proactive approach and continuous development in close collaboration with the customer are the keys to optimal rust protection for perforated metal components. From the perspective of the end user – the farmer or freight forwarder, for example – the longer component service life results in long-term cost savings.

From a surface engineering perspective, the compatibility of rust protection, functionality and design are key considerations when it comes to coating perforated metal components. Minimising edge thinning is of particular importance here. Based on the diverse range of market and customer requirements, Solvaro has succeeded in developing its own in-house standard that meets the high demands in every respect.

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