Automotive Engineering: Plasma technology sets new quality standards for sealing motor pump housings

Corrosion protection from the plasma nozzle

When ZF TRW Automotive in Gelsenkirchen decided ten years ago to coat a safety-relevant aluminum component with atmospheric pressure plasma to improve corrosion protection, it was a world first. Today ZF TRW pretreats over one million parts a year with the environmentally friendly plasma jet technology from Steinhagen in Westphalia.

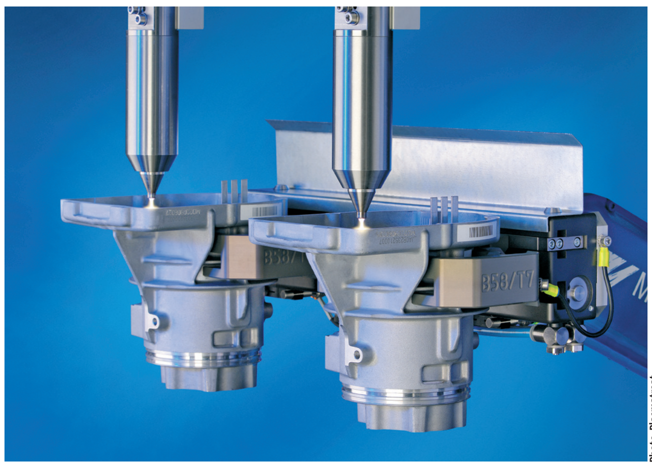

Fig. 1: ZF TRW Automotive has used atmospheric pressure plasma for ten years for the microfine cleaning and corrosion protection of safety-relevant die-cast aluminum housings

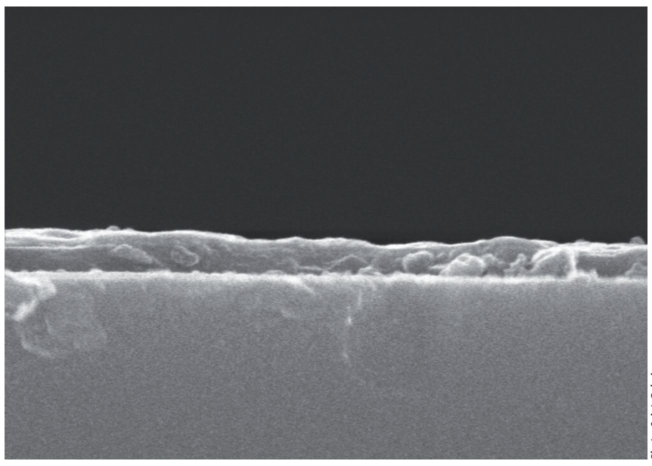

Fig. 2: The image shows a cross-section through an approx. 100-nm thick PlasmaPlus coating (SEM 50000 x magnification)

Prior to this, low pressure was the only option, but since the mid-2000s, it has been possible to produce and deposit functionalized plasma nanocoatings under atmospheric pressure. Whether for corrosion protection or adhesion promotion, as a release agent, anti-adhesion or barrier coating, the PlasmaPlus plasma polymerization technology jointly developed and patented by Plasmatreat GmbH from Steinhagen (Westphalia) and the Fraunhofer IFAM in Bremen enables users to apply functional coatings to their material surfaces without a vacuum chamber.

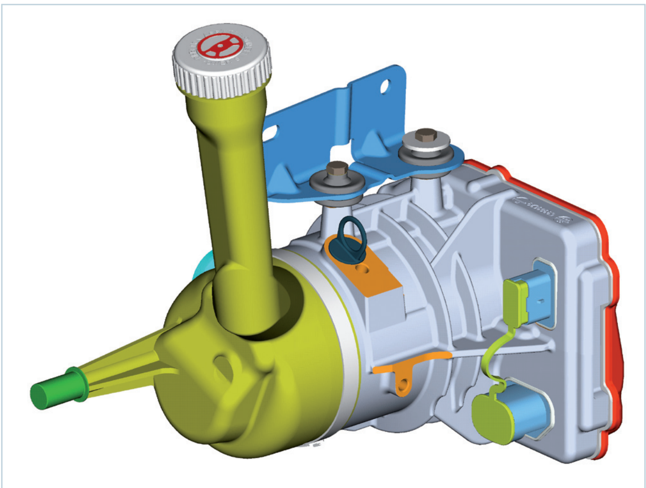

Fig. 3: A die-cast aluminum housing protects the motor pump unit. The bonded joints are pretreated with PlasmaPlus to prevent failure of the adhesive bonds due to corrosion.

The process is based on the Openair-Plasma technology developed by Plasmatreat in 1995 and now used in virtually all sectors of industry throughout the world. The jet technology cleans surfaces to a microfine level and activates them with the aim of significantly improving their wettability and adhesive characteristics in preparation for downstream processes such as bonding, painting or printing. With in-line and robotic capabilities, the jet systems are designed for use in continuous, fully automated production processes (Fig. 1).

A precursor in the form of an organosilicon compound is added to the plasma generated in the nozzle to produce the plasma coating. Due to high-energy excitation within the plasma, this compound is fragmented and deposited on the surface in the form of a vitreous coating (Fig. 2). The chemical composition can be varied according to the application to ensure that optimum results are obtained for any given material. The application is area-selective, which means that the coating precisely targets the predefined areas. The dry process is environmentally friendly, reliable and reproducible. In 2007 a global player in the automotive supply sector was the first company to use the technology for series production on an industrial scale.

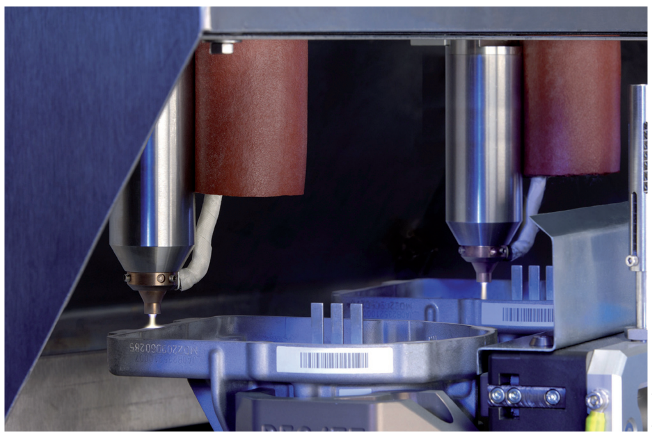

Fig. 5: Corrosion protection from the plasma nozzle: The coating is applied with millimeter precision to the exact areas where surface functionalization is required.

Subsequent integration into the process chain

Provided that the quality requirements for new developments are fully specified from the start, they can be implemented using well-established technical solutions in accordance with the corresponding influencing parameters. However, it is significantly more difficult if customer requirements change at a later stage of the project when the global process chains are already in place.

TRW Automotive GmbH in Gelsenkirchen, now part of ZF Friedrichshafen AG, was faced with just such a challenge ten years ago. A well-known car manufacturer subsequently demanded a higher level of corrosion resistance for the die-cast aluminum housings of its motor pump assemblies. These units are safety-relevant components used in the power steering systems (Fig. 3) and must satisfy extremely strict requirements for environmental stability, such as resistance to corrosion, thermal resistivity and spray water. Mechanical, and above all, corrosive stresses that the component is exposed to during its lifetime should not cause the bonded joints to fail, as this would mean that the electric motor and electronic components would no longer be protected. The original process, which involved spraying a fluoropolymer-based corrosion inhibitor manually onto the bonded joint from the outside after glueing, was no longer adequate since the car manufacturer now demanded a far more rigorous long-term corrosion protection test.

In such cases, it is often impossible to integrate well-established technical solutions into the existing process chain, or only by implementing major changes with corresponding high investment costs. Moreover, changes in production processes which involve alterations to the plant result in production downtimes. To make the component more resistant to environmental influences, there were three traditional options available: upgrading the material, anodizing or passivation. As a fourth option, low-pressure plasma coating, and finally, a fifth option – the first industrial series application of a newly developed corrosion protection from the plasma nozzle.

When weighing up the pros and cons of the different pretreatment processes, ZF TRW Automotive worked on a process of elimination and eventually came to the following conclusion: The first four options had one thing in common; they were very expensive. Furthermore, upgrading the material and anodization would entail extensive product validations. In addition, all the processes apart from low-pressure plasma would have to be integrated into the process chain in such a way that quality would be in the hands of external global suppliers. Carrying out quality-control on finished components in the as-supplied condition would be extremely complex and would significantly reduce process reliability. Only one pretreatment method remained: The new plasma coating technology from Plasmatreat. A comparatively low-cost method which not only satisfied all requirements for immediate integration into the existing production line, but offered other benefits as well.

Plasma coatings in series production

In early 2007 ZF TRW began series production of the motor pump housing using its first plasma unit – equipped with both Openair-Plasma and PlasmaPlus nozzles. The new system was integrated into the final assembly process with little effort and without disrupting production. No new validations were required. The results of the required corrosion protection tests even exceeded the expectations of this new process. "With Plasmatreat's plasma-polymer coating we managed to virtually double the level of corrosion protection", reports Gottfried Kühn, production manager at the Gelsenkirchen plant. The corrosion test involved a SWAAT test (Sea Water Acetic Acid Test) combined with a cyclic corrosion test (CCT). The time taken until penetration occurred (appearance of the first signs of corrosion inside the housing) increased by around 50%. Even at 750 hours, the plasma-treated housing showed no signs of leakage.

"With components of this type", says Lukas Buske, Automotive Powertrain Project Manager at Plasmatreat, "there is always a risk that moisture will migrate beneath the seal if they are left unprotected. The corrosion protection provided by our coatings is particularly effective with the aluminum alloys used in the automotive industry (Fig. 4) and satisfies the requirements of DIN EN ISO 9227." The PlasmaPlus coating forms a covalent bond with the metal to ensure optimum protection against moisture ingress. Recently conducted salt-spray tests show that - depending on the alloy and seal configuration - with this coating, the components can withstand even 960 hours of exposure before failure. At the same time, the plasma-polymer coating provides an excellent adhesive substrate for both liquid seals – such as the Loctite adhesive used by TRW – and solid seals, e.g. EPDM.

A total of four robot-controlled plasma nozzles are integrated into the highly automated unit, two for cleaning and two for coating. In a first step the adhesive surfaces, always of two components, simultaneously undergo microfine cleaning with Openair-Plasma. This process releases the energy present in the surface of the metal which has been overlaid by contaminants to ensure uniform wettability and reliable adhesion. This step is followed immediately by a second step in which the cleaned surfaces are nano-coated using the PlasmaPlus process before subsequent application of the adhesive.

In addition to its in-line capability, the special advantage that PlasmaPlus technology has compared with the above-mentioned coating methods is its area-selective application. Unlike dip baths or vacuum chambers, it is not necessary to coat the entire component no matter what its size, but only the areas which actually need functionalizing (Fig. 5). And the process is fast: As Production Manager Kühn reports, the cycle time for the complete treatment of each component is just 30 seconds. The housing can be further processed immediately after treatment.

Plasma sets new quality standards

The Gelsenkirchen plant now operates three plasma units with a total of ten plasma nozzles in a three-shift system five days a week. Investment and maintenance costs are low, and the units take up very little space. The Steinhagen technology is used to pretreat over one million parts a year with a corrosion-proof coating. Whilst the motor pump housings coated with atmospheric-pressure plasma were originally destined mainly for passenger cars, today they are used predominantly in light trucks and transporters manufactured by major carmakers such as Renault, Mercedes and Fiat, as well as midsize crossover SUVs for Porsche. Corrosion protection from the plasma nozzle has proved successful all the way down the line. But that's not all: Bertram Schwanitz, development engineer at the ZF TRW Tech Center Düsseldorf, emphasizes that the use of Plasmatreat coating technology in die-cast aluminum housings has set new quality standards.

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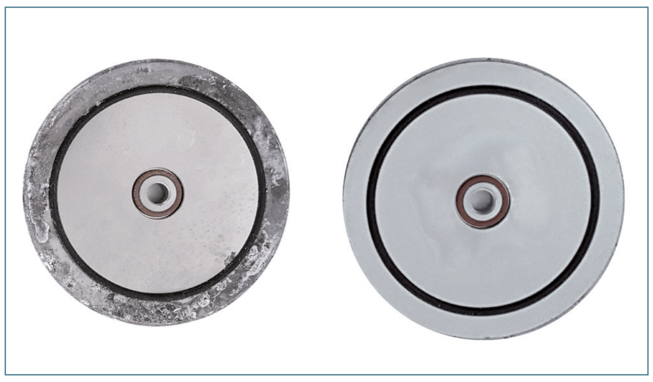

Fig. 4: Comparison: On the left, an uncoated die-cast aluminum test specimen AlSi12(Fe) after a 720-hour salt-spray test, and on the right, an identical specimen coated in the PlasmaPlus process.