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RAIN/LIGHT SENSOR PRODUCTION

Successful Crisis Management Due to Plasma

An adhesion problem in the manufacture of rain/light sensors used for automatic wiper control would have almost led to a breakdown in the newly installed production line of a sensor manufacturer in Baden-Württemberg.
What issues had to be addressed and how were they resolved?

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The Swabian family-owned company Weber-Formenbau is a recognized specialist for demanding multi-component injection-molded parts for the automotive, medical and electronics industries. This company produces, among others, the complex polycarbonate optics for rain/light sensors in an injection molding process on behalf of a renowned supplier to the automotive industry. The design of the rain/light sensor with housing consists of various plastic material layers which must adhere to one another, precisely and all over the surface. It goes without saying that air inclusions must be avoided under all circumstances because even tiniest air bubbles can be the cause of malfunctioning: The sensor will detect rain although the sun is shining.

Fig. 1: The Openair plasma beam strikes the polycarbonate lenses with almost ultrasonic speed. Both the microfine cleaning effect and the high degree of activation impart the plastic material with new adhesion properties.

Fig. 2: The rain/light sensor reflects incoming light beams while measuring the light refraction. Transparent LSR forms the cover layer for adhesion to the glass pane.

The principle

The operating principle of rain sensors is based on the fact that the daylight beam inciding on the windshield passes through a lens of the rain sensor and is reflected by the former (fig. 2). The reflection is

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Fig. 3: The highly complex polycarbonate optics of the sensors is produced by Weber-Formenbau in a three-component injection molding process.

Fig. 4: The PC lenses are initially overmolded with a PBT housing.

Fig. 5. Section view: Portion of the LSR coating on the left, still uncoated lenses on the right

Fig. 6: The finished injection molded sensor

detected by a photodiode which optoelectronically measures the light refraction. If the windshield is dry, the entire light is reflected relatively uniformly (total reflection) and passed on to the photodiode. Water drops or water films on the glass, however, disturb the reflection. The more the rain wets the glass surface whilst driving, the lower the light intensity measured by the diode and the stronger the pulses the sensor is sending to the automatic wiper control system.

But producing the plastic optics alone is not enough given that such a sensitive component must additionally be well protected, say enclosed, on the one hand and a cover layer for adhesion to the windshield is required on the other.

The challenge

To build the sensor components, the Esslingen-located company expanded their plastic component production areas and invested in new machinery because the complex nature of the components to be produced required multiple production steps and several injection molding machines. In a first injection molding machine, the polycarbonate lenses are produced from three components (fig. 3). With an overall length of hardly 3cm, these fiber optics cover both the sensor function for daylight and the sensor function for wetting the outer windshield with water.

After a comprehensive visual inspection of each single unit, the pre-molded parts are overmolded in the next production step with polybutylene terephthalate (PBT) (fig. 4) in a 2-component injection molding machine where the PBT

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serves as a kind of housing which laterally tightly encloses the PC optics. The viewing faces of the small PC optics remain free during this process. In the next production step, the entire PC/PBT face was supposed to be overmolded with a coating of transparent LSR (Liquid Silicone Rubber) (figs. 5 and 6). The liquid silicone rubber forms the contact face to the windshield. Since rain/light sensors are to be detachable, and therefore re-usable, in the event of windshield fracture, there was the requirement that the LSR must afford strong adhesion to the PBT housing and the PC lenses.

The adhesion problem

But exactly in this production step an unexpected adhesion problem showed up: The LSR, injected as the last component to provide adhesion to the windshield, was repelled by the surface of the polycarbonate lenses. The subsequent inspection revealed air bubbles - tiny but sufficient to affect the light refraction to such an extend that the sensor would have received an "undesired rain pulse".

"Nine hundred sensors were due to be delivered within a few weeks only, so we immediately got to work seeking the cause and a solution to the adhesion problem," recalls Elvira Postic, CEO of Weber-Formenbau and grandchild of the company founder. But neither a modification of the polycarbonate nor stronger adhering silicones brought about a remedy. It was only when Clemens Trumm, Manager Application Development Center at Momentive Performance Materials, and the University of Esslingen were consulted on an advisory basis that they realized that the lack of wettability of polycarbonate was due to the PC surface itself, and not to the LSR. The surface energy was

Fig.7: At Weber Formenbau the Plasmatreat jet has been integrated into the fully automated process.

too low. Apart from that, adhesion defects were generated by partially film-like contaminations. Trumm made the suggestion to treat the component surface with atmospheric plasma and recommended Plasmatreat, a company located in Steinhagen, Westphalia.

Cold plasma

The Openair plasma process patented by Plasmatreat as early as in 1995 is known to be based on a nozzle principle (fig. 7) working under normal atmospheric conditions. The intensity of cold plasma is so high that processing speeds of several 100 m/min can be achieved. The typical rise in temperature of the plastic surface is less than 30°C during treatment. The system is characterized by a triple effect: It activates the surface by targeted oxidation processes, discharges the surface at the same time and brings about a microfine cleaning effect. Thanks to the specific nozzle configuration, the treatment space around the substrate surface virtually remains electrically neutral.

Activation of the surfaces

When the atmospheric pressure plasma beam strikes a plastic surface, oxygen- and nitrogen-containing functional groups are attached to the mostly nonpolar polymer matrix so that the surface is invisibly modified. This effect becomes possible by the energy-rich radicals, ions, atoms and molecular fragments existing in the plasma and releasing their energy to the surface of the material being treated, thus initiating chemical reactions. The produced functional hydroxyl, carbonyl, carboxyl and ether groups - but also the oxygen compounds of nitrogen - enter into partly very solid chemical bonds with adhesives and paints and thus help improve adhesion.

Surface energy

Surface energy (mJ/m²) is known to be the amount of energy required for breaking up chemical bonds when producing new material surfaces. It is the most important measure for assessing the probable adhesion of an adhesive layer or a surface coating. Nonpolar plastic materials have a low surface energy, usually between < 28 mJ/m² and 40 mJ/m². But experience has shown that good prerequisites for adhesion are first achieved with surface energies greater than 38 ... 42 mJ/m². With a plasma treatment, however, the surface energy is significantly increased due to the formation of polar groups, such as hydroxyl functions, on the surface. During this process, not only the wettability with a given paint or adhesive is improved, but also the creation of a covalent bond, which is a very stable atomic bond, is made possible on the surface.

For liquids, the surface energy is equal to the surface tension, and each liquid, each paint, each adhesive has its own inherent tension. Secure adhesion of a coating is conditional on the surface energy of the solid material being greater than the surface tension (mN/m) of the liquid adhesive. Trials at Plasmatreat have demonstrated that energy values of over 72 mJ/m2 are achievable with Openair plasma pretreatment.

The solution

The injection molder was left with exactly as little as five days up to the delivery of flawless components. Plasmatreat, after having carried out the fault analysis, immediately conducted a test run on 100 components. After the treatment the components were returned to Esslingen without delay for getting overmolded with LSR. The optical inspection left no room for interpretation: Not a single air inclusion was recorded, the silicone adhered perfectly to the polycarbonate. The next day a further eight hundred components were subjected to the same pretreatment - with the same positive result.

In order to enable direct component treatment in the tray, the injection molder was supplied with a rental plasma system on day after. At the same time a plant concept for initially offline component treatment was developed due to the fact that the desired integration of the plasma plant did not appear to be realizable since all processing sides in the injection molding machine had already been occupied. A situation that, according to Joachim Schüßler, Head of Sales at Plasmatreat, is encountered quite frequently: "A new process does not work properly against expectations, and our technology is to provide remedy with inline pretreatment. When looking at the new machine we often find that there is no space left for installing the system.“

Integration of the plasma system

In the case of Weber-Formenbau, an integration solution was, however, found in collaboration with KIKI-Automations and the injection molding machine manufacturer Arburg. The machine was converted accordingly in the area of the machine base. The plasma nozzle now enters the tool from downwards from the machine bed - rather than from upwards as usual. There are two cavities which are moved by means of a rotary unit. The overmolding process of the PC optics with PBT is performed in the upper cavity. After rotation, the already overmolded components contained in the lower cavity are treated with plasma using a pneumatic motion system. Thereafter, the silicone is injected. The inline process only takes a few seconds. The xy motion system positioned in the machine base is moved into the working range of the tool. A plasma nozzle can thereby move over the adhesion area and activate the surface of the PC optics for long-time stable adhesion to LSR.

Conclusion

This application example shows that manufacturers would be well advised to consider the option of automated pretreatment of plastic surfaces right from the start when planning a new production line since the permanent optimization of materials can substantially modify their composition and, as a consequence, their adhesion properties. In the case of the Esslingen-located sensor manufacturer, it was not only possible to completely eliminate the unexpectedly arisen adhesion problem but also to considerably reduce the scrap rate. Besides its high effectiveness, the Plasmatreat technique excels above all by its safety and reproducibility in the production process. Conventional pretreatment methods such as cleaning with wet chemicals or mechanical methods can be completely replaced, harmful emissions avoided and production steps saved by this plasma technique. Weber-Formenbau records a monthly production rate of about 120,000 rain/light sensors to date and has meanwhile put a third plasma plant from Steinhagen into operation.

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