# State of the Art

## Manufacturing processes for plastic components

## with metallic surfaces

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**Scope of report:** 13 pages

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# 1 Introduction

The present report on the state of the art for the process-technical implementation of plastic components with a metallic surface was compiled within the framework of the PolyMetal project in the **Intereg V-A Slovenia-Austria 2014-2020** funding line and serves as a basis for decision-making on the most promising procedure for the prototypes to be processed in the project in order to achieve the project objective.

Metallic surfaces, handles, cladding, etc. are perceived as "more valuable" in technical applications than comparable parts made of plastic. This is mainly due to the optical and haptic properties of the different materials. The so-called "cool-touch effect" provided by metals as opposed to plastic materials plays a central role in this. This effect can be achieved either by means of thermally conductive plastic additives or, alternatively, by the use of special processing technologies that apply a more or less thin metal layer to the surface of the plastic. The advantage of the latter method is the possibility of using commercial inexpensive standard plastics and still obtaining manufactured surfaces of parts that give the impression of being made of metal. However, the combination of plastics and metals also poses difficulties due to different material properties, such as differences in thermal expansion. There are also limits to the choice of process technology due to the different processing temperatures required. For example, due to their limited heat deflection temperature, only a limited number of coating processes are suitable for plastic parts.





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# 2 Production of plastic parts with metallic surfaces

Generally speaking, there are two alternative ways of producing plastic parts with metallic surfaces. Either metal foils are back-injected with plastic in an injection moulding process, or a finished plastic part is coated with metal after production (by injection moulding or by another process). To implement these methods, several different techniques offering different advantages and disadvantages are available. Figure 1 provides a rough overview of the relevant techniques.

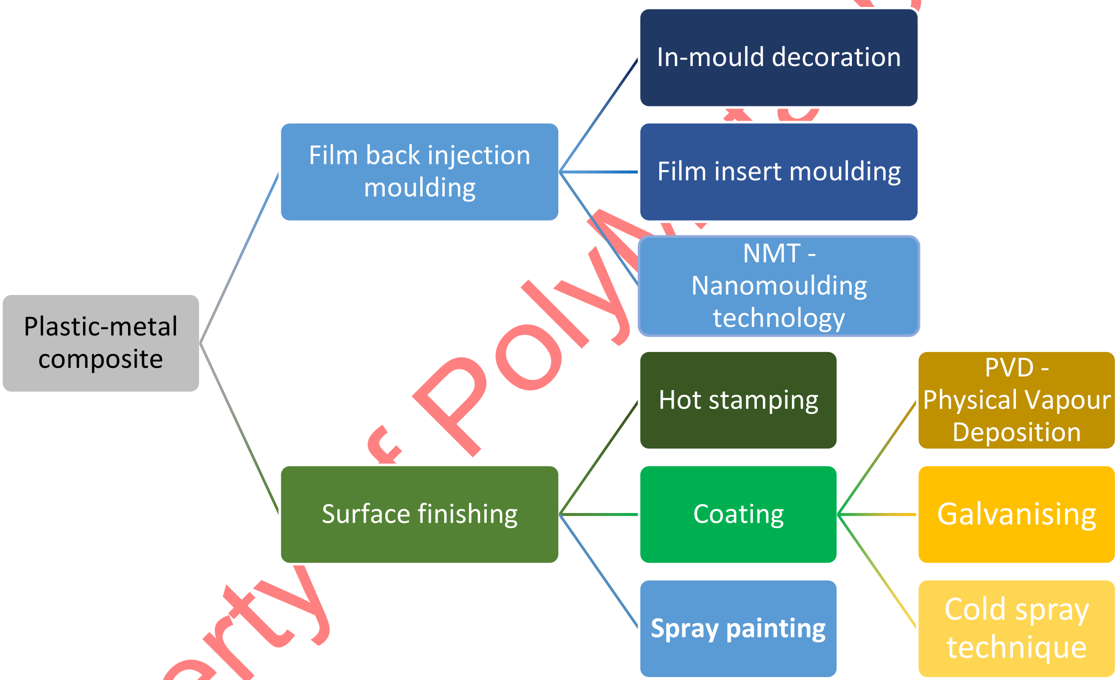


*Figure 1: Relevant techniques for the production of plastic-metal composites.*





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# 3 Methods for back injection of films

There are several different methods of processing available for back-injecting films, each with its own advantages and disadvantages. From a process technology point of view, the most uncomplicated variant is the so-called in-mould decoration (IMD) process (shown schematically in Figure 2). This technology involves the automatic placing of a continuous film in the injection mould (1), followed by the film being fixed in the mould and adjusted by means of a vacuum (2); the mould is then closed and the plastic– usually amorphous plastics such as polycarbonate (PC) or acrylonitrile-butadiene-styrene (ABS) – is injected (3). The finished plastic/metal part is then removed in a last step (4).

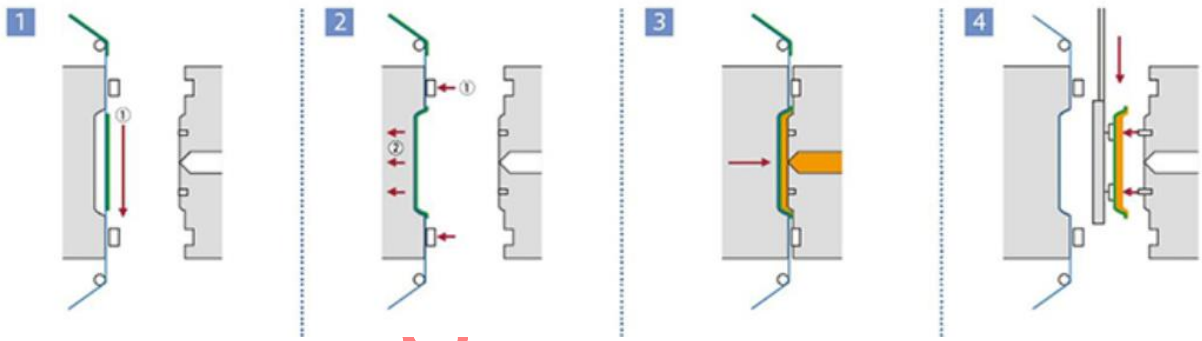


*Figure 2: Schematic sequence of the in-mould decoration process. (www.nissha.com)*

This technology will, as a rule, require no or only minor post-processing of the composite component, which renders this production method comparatively efficient in terms of cycle times and costs. The most significant disadvantage of this method results from the limited elasticity of the films used. Since these films can only be stretched to a very limited extent, a production of markedly three-dimensional components is not possible. Attempts to do so would lead to the tearing of the films, sharp edges and corners would cause holes in the films und the end result would be an irregular surface of doubtful quality. Furthermore, the construction of suitable tools (parting planes, injection points, etc.) is somewhat more complex than in the case of conventional injection moulds, since a poorly designed tool can lead to wrinkling or tearing of the film.





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Variants of this process are now also being offered in which the film is heated inside the tool between steps 1 and 2, to allow greater flexibility and plasticity of the films. Another variant of the method permits the film to be positioned on two sides of the plastic component. Solutions for the IMD process are offered by numerous tool makers, injection moulders and machine builders. Engineering solutions are implemented, inter alia, by Engel Austria GmbH (Schwertberg, Austria) or Krauss Maffei Technologies GmbH (Munich, Germany).

In film insert moulding (FIM), the film to be back-injected is not automatically uncoiled from a roll and positioned in the mould, but first pre-formed in a thermoforming process to fit the subsequent component geometry. This is then positioned in the mould of the injection moulding machine after cutting and punching. The commonly used plastics are the same as in the IML (In Mold Labeling) process; for high-quality parts, polyamide 12 (PA12) may be used. Although the FIM approach is more complex and requires longer cycle times, it allows the production of components with a more pronounced three-dimensionality than it is possible to achieve by the IMD method.

Nanomoulding technology is a process that serves to improve the bond between plastic component and metal foil. Due to the different properties (including thermal expansion, etc.) of different materials and to adhesion problems in the case of some material combinations, this issue is an important factor in the production of high-quality composite parts. To achieve improved adhesion between metal and plastic, the metal foils are pre-treated before they come into contact with the plastic in the injection moulding process. This pre-treatment comprises a total of four steps in which the film is immersed in different chemical baths. These chemicals allow a strong bond between the plastic and the film which cannot be broken even by heavy mechanical stress.



The disadvantage of these technologies lies in the fact that the films used are usually very thin, which makes sense in terms of processability and costs, but will not usually create a cool-touch effect. With the IMD and FIM processes, however, it would be possible, in view of the thickness of the films, to use filled, thermally conductive plastics to enable a higher heat transfer.



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# 4 Techniques for surface finishing of plastic parts

Hot stamping, coating and spray painting of plastic parts takes place after the production of the component in a separate process step. In hot stamping, a film is applied to the plastic part in a process comparable to that of the IMD method. This is not done as part of the production process of the component, however, but – as with all refining methods – in a separate subsequent step (Figure 3), which complicates the coating process and, from an economic point of view, must be considered as a disadvantage. The advantages over the IMD process consist in greater freedom with regard to material selection and component geometry. The films used are usually thinner than those used in the IMD or FIM process, which means that filler particles may show or push through the film, which has a negative effect on the surface feel and appearance of the components. The suppliers of complete solutions for the hot stamping process (process technology and metal foil) include Leonhard Kurz Foundation & Co KG (Fürth, Germany) and MADAG AG (Fahrweid, Switzerland). As an alternative to this technology. there are different coating techniques available for surface finishing.



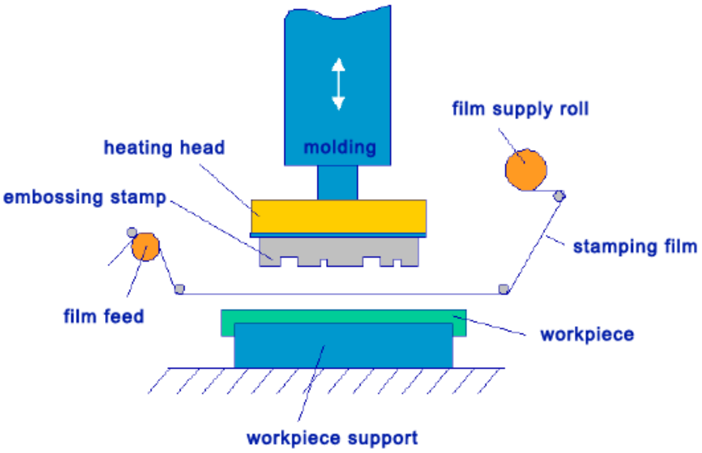


*Figure 3: Schematic representation of the hot stamping process (www.mid-tronic.de)*

For the selection of a suitable coating process for plastic parts for which a cool-touch effect is desired, two parameters are of central importance: the temperature at which the component is to be coated and the achievable layer thickness. As may be seen in



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Figure 4, the coating temperature severely limits the choice of available coating techniques for plastics.

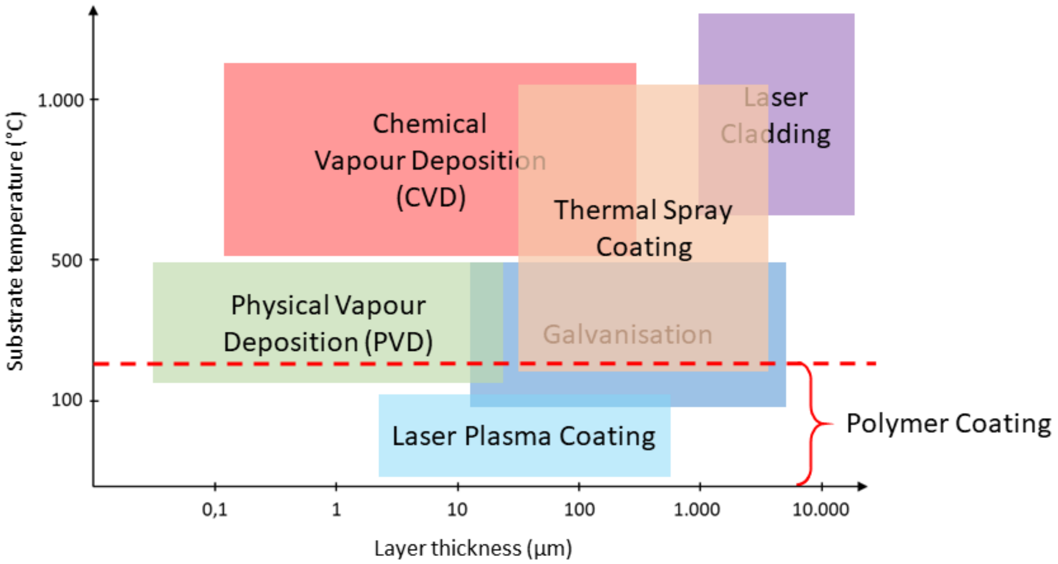


*Figure 4: Process temperatures and achievable layer thicknesses of different coating technologies. (www.plasma-innovations.com)*

In view of the temperature sensitivity of plastics, CVD and laser cladding must be ruled out completely; as regards thermal spray coating methods, only the so-called cold spray technique can be considered an option. As already mentioned, a certain layer thickness is of great importance if a cool-touch effect is to be achieved.

In the PVD process, very thin metal layers are applied to a component in a vacuum chamber. In this process, atoms are released from a cathode by bombardment with high-energy ions. These released atoms pass into a gas phase and are transferred to the component to be coated by an applied voltage or a magnetic field. This method can also be used to create different multilayer coatings. One of the advantages of this technique is that, in contrast to galvanisation, it is possible to dispense with the use of environmentally harmful chemicals, which, among other things, has a positive effect on the operating costs and also eliminates the disposal costs for these substances. The disadvantage is that the surfaces to be coated must be very smooth, which renders the use of filled thermoplastics in the carrier component rather inadvisable. PVD processes are offered, among others, by Nanogate SE (Quirschied-Göttlborn, Germany) and Benseler Beschichtungen Bayern GmbH & Co KG (Bogen, Germany). An inline PVD solution integrated into the injection moulding process is offered by Varioplast Konrad Däbritz GmbH (Ötisheim, Germany).

When galvanising plastic parts - as well as when galvanising metals - electricity is passed through an electrolytic bath. The metal that is being used for coating is located at the anode, while the component to be coated is placed at the cathode. From the cathode (*Verbrauchskathode*), ions are released by the current and subsequently deposited on the surface of the component. Layer thickness can be influenced by the strength of the current. On an industrial scale, either direct metallisation (Futuron process) or a conventional process sequence with electroless metallisation activated by pickling as the first metallic process stage are used in the galvanisation of plastics. This method is mainly used for decorative applications. According to Friedrich Keim Kunststoffbearbeitung und -veredlung GmbH (Werdohl, Germany), the layer thicknesses that are achievable in this way permit the production of visually appealing surfaces of filled plastics up to a moderate filler content (glass fibre content of up to about 30%) by means of galvanising. Due to the variability of the layer thicknesses, it is even possible to achieve a cool-touch effect. The plastics commonly used for coating are ABS, PC, ABS/PC blends, PA6, PA66, mineral- and glass fibre-filled or impact-modified polyamides (Friedrich Keim Kunststoffbearbeitung und -veredlung GmbH), or partly aromatic polyamides (Galvaplast AG, Pratteln, Switzerland).

When using the cold spray coating method, a metal powder is shot at a component through a heated gas at very high (supersonic) speed. The high impact velocity of the powder makes it possible for a firmly adhering metal layer to form on the component even without previously melting the metal. However, this method is not widely used commercially and is only implementable or useful within certain limits (possible material combinations, costs, etc.).

Other methods, still relatively new and therefore not widely used, include in-mould metal spraying, which involves a metal layer sprayed into the injection mould which is then deposited on the plastic as it is injected and continues to adhere to the component when it is demoulded, and laser plasma coating in which the metallic layer is transferred





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to the component surface by means of a plasma jet. This process is a modification of thermal spray coatings.

Spray painting is used in a wide range of applications for metal parts and in the consumer electronics industry to colour plastic injection moldings and is good alternative for manufacturing metallic-sporting designs. The majority of spray painting is manually operated. The sprayed material generally has one or more of following functions: filler, primer, colour, decoration and protection. Glossy, rich and intense colour finish is achieved with multilayered base coat, top coat with or without clear on top. Spray coatings are built up in thin layers. Usually 2 components solvent based, water – borne or UV lacquer/paints are used. Compared with long-established metal-effect lacquers, some companies (e.g. Mankiewicz Gebr. & Co., Hamburg, Germany and Peter Lacke GmbH, Hiddenhausen, Germany) have developed new materials, like chrome substitute lacquers, etc., which create full-surface chrome look with mirror or vanishing effects.





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# 5 Summary

To be able to achieve a "cool-touch" effect on a plastic component, a certain thermal conductivity (on the surface of the component) is required. There are different techniques for the production or processing of components available for increasing the very low thermal conductivity of plastics and also giving them a metallic surface feel.

For larger numbers of geometrically simpler - actually approximately two-dimensional - components, **methods involving the back-injection** of films will be more suitable. These methods are, as a rule, comparatively easy to implement. Since only minor preliminary or post-processing will be required, depending on the method used and/or the component geometry, the cycle times and per-piece costs will be relatively low. The disadvantages associated with these methods include restrictions with regard to component geometry and processable film thicknesses. If the films are too thin, sufficient heat transport will not be possible and the desired metallic feel will not be achieved. Although heat transport can be increased by thermally conductive fillers in the plastic carrier, an excessive filler content in combination with too thin a film can result in optically and haptically inadequate surfaces. Furthermore, there must be sufficient adhesion between plastic and metal to prevent subsequent detachment of the film from the component. To prevent this, so-called nanomoulding technology, which provides excellent adhesion between the film and the polymer, may be helpful.

Another possibility is offered by the different **finishing processes**. These involve the production of a plastic component (e. g. by injection moulding) to which, in a second step, a coating is applied. These procedures are more complex logistically and therefore more expensive. As in the case of the back-injection of films, hot stamping procedures involve the application of a metal foil to the component. This method also allows the coating of somewhat more complex and/or more pronouncedly three-dimensional components. As regards geometry and film thickness, however, the possibilities offered by the hot stamping method are also somewhat limited.

For particularly complex components, classical coating processes such as galvanisation, PVD or thermospraying offer the most suitable options. The choice of





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applicable methods is limited from the outset by the temperatures required for coating (e.g. PVD up to 50C), since plastics can only withstand comparatively low temperatures being dimensionally stable. Another criterion is the realisable layer thickness. Here again, the primary concern is to remove a sufficient amount of heat to suggest a cold surface. The use of thermally conductive fillers in the polymer is a possibility, but, depending on the method used and the degree of filling, this method, too, can result in undesirable surface defects or adhesion problems in the coating.

If a "cool-touch effect" without a metallically finished surface is desired, either by the use of a film or by coating, a highly filled system will have to be used. Such technologies will, however, present great challenges. First of all, the processing of plastics with very high proportions of fillers is complex because the flow behaviour of the material will change dramatically. Furthermore, the fillers used are usually abrasive, resulting in rapid wear and tear of the equipment used, which means that maintenance will be required at very short intervals. It should also be remembered that thermally conductive fillers (usually metal powders) are not entirely safe because of possible dust explosions during their processing. Highly filled plastic components will, as a rule, appear dull and grey (depending on the filler used). To obtain a visually and haptically pleasing surface, each component must be individually ground and polished after production. This approach is therefore highly complex and not economically feasible for mass production. In addition, high levels of fillers lead to embrittlement of the plastic material. This can result in components that are likely to break when subjected to even quite low mechanical stresses.





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# 6 Appendix

*Table 1:* Currently available standard technologies for the production of plastic components with metallic surfaces

| Technology | Process chain | | Layer thickness | Advantages | Disadvantages | Supplyer (selction) | Costs | | Limits | Project potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre treatment | Post treatment | | | | | Small quantity | Large quantity | | Gorenje | Intra-lighting |
| **In-Mould-Decoration** | Not necessary | Usually not necessary | Depending on material and component geometry, but rather low | Easy to implement in terms of process technology, widespread: Numerous suppliers of such systems | No significant three-dimensionality, limited geometry, "coated" only on one side | *Processing:*<br>**Engel Austria GmbH**, Schwertberg<br>**Wittmann Battenfeld GmbH**, Kottingbrunn<br>**Krauss Maffei Technologies GmbH**, München<br>*Films:*<br>**ISOSPORT Verbundbauteile GmbH**, Eisenstadt<br>**Baier GmbH + Co KG**, Rudersberg (D)<br>**ITW CER85**, Oyonnax (F) | | | 1. Limit layer thickness -> λ, surface quality<br>2. Component shape -> film deformation<br>3. Film material -> λ, surface quality<br>4. Filling degree carrier material -> λ, surface quality, adhesion | NO: Not a big potential because of the 3D Structure -> Cold Touch need more thickness | NO |
| **Film-Insert-Moulding** | Thermoforming and cutting of the film | Usually not necessary | Depending on material and component geometry, but rather low | Higher geometry flexibility than In-mould decotation | More complex than in-mould decoration, higher cycle times | *Processing:*<br>**Engel Austria GmbH,** Schwertberg<br>**Wittmann Battenfeld GmbH**, Kottingbrunn<br>**Krauss Maffei Technologies GmbH**, München<br>*Films:*<br>**ISOSPORT Verbundbauteile GmbH**, Eisenstadt<br>**Baier GmbH + Co KG**, Rudersberg (D) **ITW CER85**, Oyonnax (F) | | | 1. Limit layer thickness -> λ, surface quality<br>2. Component shape -> film deformation<br>3. Film material -> λ, surface quality<br>4. Filling degree carrier material -> λ, surface quality, adhesion | NO: Potential is higher but not for the actual project | NO |
| **Nanomolding technology** | pre treatment of the film | | Depending on material and component geometry, but rather low | Strongly improved adhesion between metal film and polymeric substrate | Possibility of using filled polymers as carriers with improved thermal conductivity needs to be investigated | **Taisei Plas Co Ltd.**, Kiyosu City (JP) | | | Material combinations | NO: The strong bonding between substrate and coating is not needed but for special need in future interesting | NO |
| **Hot stamping** | Two separate process steps: Production of the uncoated component by means of available production technologies (e.g. injection moulding) and subsequent application of the (metallic) film | | Usually very thin films | More freedom in material selection and component geometry than with In-mould-decoration or Film-inersert-moulding | Low heat transfer due to low layer thicknesses, unsightly surfaces with filled polymer substrates | **Leonhard Kurz Stiftung & Co KG**, Fürth, **3DHS coating process**; **MADAG AG**, Fahrweid (CH) | | | 1. Limit layer thickness -> λ, surface quality<br>2. Film material -> λ, surface quality, adhesion<br>3. Filling degree carrier material -> λ, surface quality, adhesion | NO: Technologie has potential but overall 1-4 are strongly depending on the Part geometry | NO |





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| Technology | Process chain | | Layer thickness | Advantages | Disadvantages | Supplyer (selction) | Costs | | Limits | Project potential | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre treatment | Post treatment | | | | | Small quantity | Large quantity | | Gorenje | Intra-lighting |
| **Galvanisation** | Two separate process steps: Production of the uncoated component by means of available production technologies (e.g. injection moulding) and subsequent application of the metal layer | | ~10 µm to >1000 µm | High flexibility in component geometry, moderately filled polymers can be coated (depending on the thickness of the coating), the achievable layer thicknesses allow a "cool-touch effect" | Use of environmentally harmful chemicals necessary | *Processing (Metals, pre treatment):* **Atotech Deutschland GmbH**, Berlin<br>*All-in-one provider*<br>**Friedrich Keim Kunststoffbearbeitung und -vereldlung GmbH**, Werdohl (D)<br>**Karl Simon Gmbh & Co KG**, Aichhalden (D), **Fischer Oberflächentechnologie GmbH**, Katzeneknbogen (D)<br>*Galvanization:*<br>**Galvaplast AG,** Pratteln (CH) | | | 1. Environment -> use of questionable materials<br>2. Layer thickness -> factor time<br>3. Filling degree -> high filling degrees lead to bad surface (optics, haptics) | NO: ABS Limitation (Special grades) !! Cr6 to Cr3!!! Using ABS is a portential! | NO |
| **Coldspray-technology** | Two separate process steps: Production of the uncoated component by means of available production technologies (e.g. injection moulding) and subsequent application of the metal layer | | ~30 µm to >1000 µm | High flexibility in component geometry, the achievable layer thicknesses allow for a "cool-touch effect | Not commercially widespread | **TLBS GmbH**, Wien | | | Not commercially widespread -> costs and possible restrictions to be clarified | NO: Extrem good adhesion and shiny smooth surface! hard to match a good color! | NO |
| **Spray painting** | Pretreatment of the surfaces to be painted | Usually not necessary | ~5 µm up to 25 µm per work step | Material independent, widespread. Suitable for flat and structured components. Large variety of colours according to RAL, NCS, PANTONE colour system -> metallic look | Technological process and materials have to be in accordance with environmental legislation. | **Numerous suppliers of such systems available.**<br>**For chrome optik** ("Chromersatzlacke") relevant Supplier: **Mankiewicz Gebr. & Co.**, Hamburg (D); **Peter Lacke GmbH**, Hiddenhausen D) | | | Material combinations | YES, possible solution for highly filled polymers | NO |
| **Highly filled polymers** | | Complex polishing of the component necessary | Bulk | Production in conventional injection moulding process, 3D printing, casting process | Poor workability, high wear on the system and on the tool, no polishing poor surface quality (matt grey and rough), poor mechanical properties of components | *Materials* **Various material suppliers**<br>*Prodiction:*<br>**Compounding companies** | | | 1. Surface quality -> haptics, optics<br>2. Filling degree -> embrittlement, price, processability, weight<br>3. Costs -> expensive fillers, high wear, complex finishing of each individual part | YES: (to check with post-painting if necessary) | YES: Minimum filler degree to reach propertie |

| | |
|---|---|
| | Low costs |
| | Mean costs |
| | High costs |





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