# Adhesive and Corrosion Properties of Laser Molten Fe-alloy Moulds for Polymer Processing

**The insertion of cooling channels into injection molding tools leads to a faster cooling rate of the manufactured polymer parts and therefore to a decrease in the production time. These cooling channels are perfused by a cooling liquid consisting of tap water, biocides and other inhibitors and chlorides. To avoid corrosion as far as possible, different laser melting alloys were tested for their mechanical, corrosive and adhesive properties. The tensile strength of all alloys fulfills the minimum requirements for the use in injection moulds. As recommendation the results showed that either all parts that are electrolytically and electrically connected has to be constructed of Corrax (which shows the best corrosion performance due to the high Cr-content) or if this is not possible Orvar (conventionally molded as building platform) should be combined with H13 (laser sintered as injection molding tool) as otherwise galvanic corrosion would lead to a preferential corrosion of metal parts with reduced Cr-content.**

## 1. Objectives

The insertion of cooling channels into injection molding tools leads to a faster cooling rate of the manufactured polymer parts and therefore to a decrease in the production time. These cooling channels are perfused by a cooling liquid consisting of tap water, biocides and other inhibitors and chlorides. During the cooling process the temperature varies in a wide range, affecting the solubility of oxygen. For high temperatures (here typically about 90 °C) close to the center of the injection molding tool the oxygen solubility is low but for low temperatures (here typically between 25 °C and 40 °C) the oxygen solubility is high. In combination with the aggressive components of the cooling liquid the corrosive attack to the injection molding tool leads to a malfunction. This effect is supported by enlarged surfaces and imaginable skip zones caused by incompletely molten alloy particles in the cooling channels from the selective laser sintering process, which is the only manufacturing method to form such injection molding tool with cooling channels.

To avoid the corrosion as far as possible, different laser melting alloys were tested for their mechanical, corrosive and adhesive properties: standard MS1 alloy (X3NiCoMoTi 18-9-5, high Ni-concentrations), alloy H13 and conventionally moulded Orvar (ca. 5%Cr + Mo, medium Cr-concentrations), and alloy Corrax (X3CrNiMoAl 12-9, high Ni- and Cr-concentrations).

## 2. Procedure

Polished and unpolished samples were tested by means of FE-SEM, EBSD, Raman spectroscopy, XPS and EDX to characterize the surface changes; XRD and TEM to characterize the crystallinity of the bulk material; tensile tests to characterize the mechanical properties and electrochemical investigations to characterize the corrosion properties.

## 3 Latest results

The mechanical and microstructural properties of the Corrax and MS1 alloy exhibit an isotropic and homogenous behavior for the as built condition. But a heattreatment (aging) is needed for both materials to increase the tensile strength and hardness. Directly, after SLM processing of H13, retained austenite was found within the microstructure. During the tensile test a part of the retained austenite was transformed in the ferrite matrix which indicates a TRIP effect. The mechanical properties are strongly anisotropic according to the tensile tests as well as after a heat-treatment. The ultimate tensile strength of H13 after and before a heat-treatment fulfills the minimum requirements for the use in injection moulds.

The Corrax alloy showed the highest chromium concentrations on both surfaces (polished and unpolished). Possible Cr-oxide layers after contact to the electrolyte on the polished sample led to the conclusion that a passive Cr-layer in analogy to the well-known healing effect of Cr was formed. The Corrax alloy showed the highest impedance values (~10^5 Ohm x·cm^2) on both surfaces (polished and unpolished) in comparison to the other samples (Orvar, H13, MS1).

The impedance values for polished H13 samples (laser sintered) were close to the values of Corrax. On the unpolished H13 samples the impedance values were at about ~10^4 Ohm x·cm^2. The Orvar alloy (conventionally molded) showed smaller impedance values of about ~3·10^3-5·10^3 Ohm· x cm^2. It can be assumed that a passive layer on H13 (laser sintered), caused by chromate, was build.

For the MS1 alloy the impedance values were similar to those of the Orvar alloy. The corrosion potential E_Corr was slightly more anodic than for H13/Orvar with similar corrosion current densities i_Corr.

With regard to contact corrosion between the material of the building platform and the molding tool, only materials with the same composition should be combined when they are in electric and electrolytic connection.

As recommendation the results showed that either all parts that are electrolytically and electrically connected has to be constructed of Corrax (which shows the best corrosion performance due to the high Cr-content) or if this is not possible Orvar (conventionally molded as building platform) should be combined with H13 (laser sintered as injection molding tool) as otherwise galvanic corrosion would lead to a preferential corrosion of metal parts with reduced Cr-content.

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