# PROCESSING RELATIONSHIPS OF HYBRID POLYMER-METAL COMPOSITES IN THE INJECTION MOULDING PROCESS

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Introduction

- Manufacturing a hybrid composite structure often is a two-stage process.
  - Two-step process is labour-intensive and time-consuming in contrast to a one-step process.
- The target of combining metal and plastic parts is to reduce the total weight and to generate desired properties.
- In this work the realisation of the bonding between metal and polymer parts in one step by using the injection moulding process is analysed.
  - To define the technical process limits, different materials are produced in several test series, while varying the parameters melting temperature, holding pressure and mould temperature.

### **Experimental**

- **Materials** 
  - Amorphous thermoplastic, PA12 Grilamid TR 60
  - Aluminium, EN AW-1050A
  - Technicoll 9110 as coating material
- Different manufacturing parameters, Tab. 1
  - Melting temperature (290 350 °C)
  - Mould temperature (60-100 °C)
  - Holding pressure (300 650 °C)
- Test Methods
  - Shear edge test and a test sample, Fig. 1
  - **Optical analyses** Macroscope (Leica Wild M 420) Microscope (Leica DMRE) Scanning electron microscope (Zeiss)

Table 1: Manufacturing parameters of the samples.															
Sample	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
Melting temperature / °C	290	290	290	290	290	350	350	350	350	350	320	320	320	320	320
Mould temperature / °C	60	100	60	100	80	60	100	80	80	80	60	100	60	100	80
Holding pressure / bar	300	300	650	650	475	475	475	300	650	475	300	300	650	650	475



Figure 1: a) Shear Edge test machine [1] and b) mounted test sample.

[1] K. Weidenmann, L. Baumgärtner, B. Haspel, Materials Science Forum 2015, 825–826.



### **Results after the shear edge test**

- Figure 2: adhesive connection between polymer and metal changes between the area near and distant from the sprue
  - Increasing shear strength with increasing melting temperature
  - Sample A14 has the highest shear strength
- Figure 3: force-displacement-curve of three samples near and distant from the sprue
  - fracture behaviour: ductile / brittle







## **Results of the optical analysis**

#### Figure 4:

- (a) Polarised, macroscopic analysis of a shear edge sample with residues of polymer arrears on the aluminium surface
- (b) Microscopic analysis of the interface with a crack structure inside the polymer like a drop-shaped structure

#### Figure 5:

- (a) Filamentary material structures inside the crack
- (b) Different structure areas, which cannot be analysed with EDX

Figure 4: (a) Macroscopic analysis of a shear edge sample, (b) microscopic analysis of the interface [2].



Figure 5: (a) Scanning electron microscope analysis of a fissure, (b) the material transition [2]

2500 µm





### **Discussion and conclusion**

- Melting temperature, holding pressure and mould temperature have an influence on the shear strength of the hybrid.
  - A higher manufacturing temperature of the whole tool results in higher shear strength.
  - The final shear strength of 3.4 MPa is low in contrast to literature values of 17 MPa [3].
- Beside the manufacturing parameters, the interface between the parts and the polymer melt path influence the final production of the hybrid.
  - The polymer promoter influences the final product in form of the drop shaped structure. If the interface of the shear edge sample has many drop-shaped structures, no ductile slipping occurs but the sample fails brittle.
  - Other forms of surface treatments, like pin microstructures, realise better shear strengths [3].
  - With increasing length of the melt path lower shear strengths were established. The adhesion coating that was used is activated by a rise in temperature and the polymer cool down time depends on the melt path after the mould injection
  - The process-structure-property relationships of hybrid polymer-metal composites can be modified during the injection moulding process

[3] E. Saborowski, A. Dittes, P. Steinert, T. Lindner, I. Scharf, A. Schubert, T. Lampke, Materials (Basel) 2019, 18.



# **THANKS FOR YOUR ATTENTION!**

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