DEVELOPMENT AND OPTIMIZATION OF ADDITIVELY MANUFACTURED TOOL COMPONENTS FOR A HIGH-SPEED FORMING PROCESS

This project is about the ability to use AM components for forming processes. Innovative rupture discs shall be produced with a high-speed forming process called HGU (German: "Hochgeschwindigkeitsumformung – HGU). The challenge is to ensure a stable application even with small nominal sizes of the rupture discs. A significant innovation is the insertion of predetermined breaking points by secondary features in the forming process. These shall be implemented in a thermoplastic FDM die. Therefore, the development of a tool system with additively manufactured components (die and plunger) is planned for the production of innovative rupture discs. This will combine the advantages of a quasi-static and high-speed forming process in an innovative, efficient and unique tool system.

PROJECT OVERVIEW

DURATION

08/2016 – 08/2019

PARTNER

- Poynting GmbH
- Rembe GmbH
- Kunststofftechnik Paderborn (KTP)

FUNDED BY

- Federal Ministry of Economic Affairs and Energy (BMWI)
- Central Innovation Programme for SMEs (ZIM)

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ZIM Zentrales Innovationsprogramm Mittelstand

Objectives

The field of application of rupture discs as pressure protection elements is limited due to the restricted geometry as well as the inflexible production (Figure 1). A challenge of the application of very small nominal diameters (of the rupture disc) combined with a low pressure range, is the reliable and stable operation in terms of the response behavior. Furthermore, many process steps are required for the manufacturing of these types of rupture discs. The aim of the project is to develop a new rupture disc (Rembe GmbH) with a small diameter, which shows a very good response behavior even at very low pressures. A significant innovation is the implementation of secondary design features as weakening geometries. These should be integrated as metallic inserts into a thermoplastic die manufactured with Fused Deposition Modeling (FDM). The aim is a defined weakening of the material during the forming process, for this a suitable forming process is necessary. Fine geometries of the required quality can be achieved by means of a high-speed forming processes (Poynting GmbH).

Procedure

Within the HGU a short-term but very strong electromagnetic field is generated that accelerates the plunger. The acceleration takes place in the direction of the workpiece and the plunger strikes on a forming medium which generates a pulsed pressure state. This pressure ensures that the sheet metal is formed in the die. The plunger must have a very high conductivity with high strength and low mass at the same time.

The research focus is on an additively manufactured die using the FDM process. The aim is to produce thermoplastic dies which can bear the mechanical loads of the HGU process. The big advantage of complex component design through AM should be exploited in this project to produce innovative rupture discs in the considered forming process. For this purpose, the materials Polycarbonate (PC) and Ultem 9085 (blend of PEI and PC) were investigated, since both materials offer good mechanical properties with regard to the compressive strength. Another aim for the material selection is the achievable layer thickness in the FDM process. PC can be processed with a minimum layer thickness of 0.127 mm (Ultem 9085 only with 0.254 mm), which leads to a higher geometrical accuracy and better surface finish without post-processing. Another process characteristic is to be used for the forming process: the porosity of the FDM structure. The idea is to use the porosity for venting the forming process. The filament deposition and the layer-by-layer principle lead to process-related porosity in the structure (see Figure 2).

Latest results

The process-related porosity is analyzed by using computed tomography (CT). For this purpose, specimens are manufactured with different materials, orientations and toolpath parameters. Investigations have shown that the parameter "air gap" has the highest influence on the porosity and that it can be used to change the porosity in a defined manner. The lowest porosity results from a negative air gap of -5 % and amounts 3.74 % for the material Ultem 9085 (cf. Figure 3). To determine the correlation between porosity and venting, an air permeability test setup was developed. FDM samples were tested with 10 bar air pressure and the pressure drop was measured over time. The results from this test can be used to develop a certain area in a FDM part which should have a defined air permeability. This function integration can have an additional value to FDM components. To ensure a good quality of the final FDM part, some design and manufacturing-related restrictions must be observed, so that 18 applicable design rules have emerged.

Furthermore, this project develops surface treatment methods to improve the surface roughness of PC and Ultem 9085 parts. The forming process can lead to a mapping of the typical FDM structure into the sheet-metal workpiece. Therefore, chemical surface smoothing methods are developed and analyzed to reduce the roughness of the complex freeform surfaces of FDM dies.

FIGURE 1 Rupture disc (Reverse Acting Rupture Disc KUB® by Rembe)

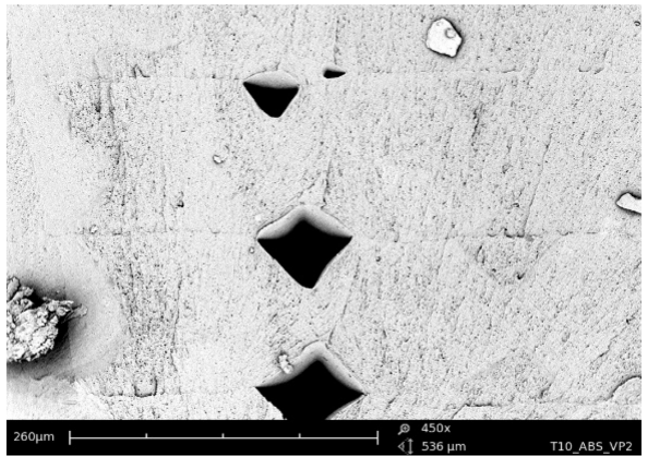

FIGURE 2 SEM-Image of a FDM structure shows process-related porosity

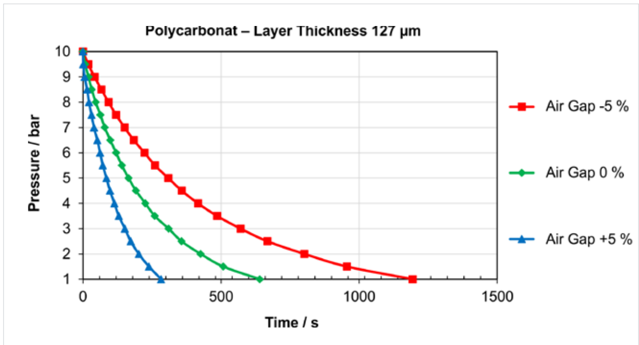

FIGURE 3 Influence of the air gap on the pressure time behaviour