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ELECTROPLATING OF AM WAX MODELS FOR THE PRODUCTION OF INTERNAL STRUCTURES

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Abstract: *The collaboration between the University of Duisburg-Essen, the Fuel Cell Research Center Duisburg (ZBT) and the company Galvano-T GmbH leads to a new process combination. Here Multi-jet modeling (MJM), electro-plating and milling are consecutively utilized to produce metal parts with complex internal structures. For this purpose the MJM must be adapted according to the requirements. The support structure has to be eliminated and issues about the bonding have to be solved. As a result of this investigation test geometries show a good bonding and thus the electroplating produces defined structures. This article describes the project´s basic concept and gives some insight into current research.*
Key words: *additive manufacturing, rapid prototyping, multi-jet modeling (MJM), electroplating, electroforming*

1. INTRODUCTION

Additive Manufacturing (AM) describes manufacturing processes, whereby models are built layer by layer. Since first appearance in 1987 (Wohlers, 2011) the prior objective has been changed for a numbers of years. More and more the research is focused on Rapid Manufacturing and Rapid Tooling than on Rapid Prototyping. (Weidinger & Methner, 2005; Zäh, 2006) Together, these are the three possible applications of additive processes, listed in VDI-guideline 3404. Whilst Rapid Prototyping is used for fabrication of parts with limited functionality or selected characteristics and Rapid Manufacturing for end products, also described as production parts, Rapid Tooling is the use of additive technologies to produce tools or moulds. This possible use is subdivided in direct and indirect processes. The process chain for indirect processes is shown in Fig. 1. The additive manufactured part is used as a tool or mould for additional manufacturing steps. (The Association of German Engineers, 2009)

One potential application of an indirect process chain is currently being developed at the University of Duisburg-Essen, in cooperation with the Fuel Cell Research Center Duisburg (ZBT) and the company Galvano-T GmbH, Windeck. The approach combines the additive technology Multi-jet modeling (MJM) with electroplating. The difference to previous applications of coating procedures is that former approaches merely utilized the combination for finishing surfaces. (Wohlers, 2011) In this research, electroplating takes a leading part in the manufacturing process. The chain consists of five steps: preparing a metal base, generating the wax model, electroplating of the wax-copper-part, removal of the wax and a milling process. Equal to every Additive Manufacturing process, a CAD data is the basis. This file has to be adapted to the new combination. The next step is to print a wax structure on a prepared metal plate (in this case of research copper).

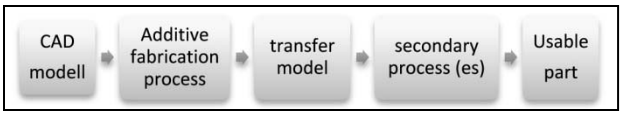


Fig. 1. Process chain for indirect processes (VDI, 2009)

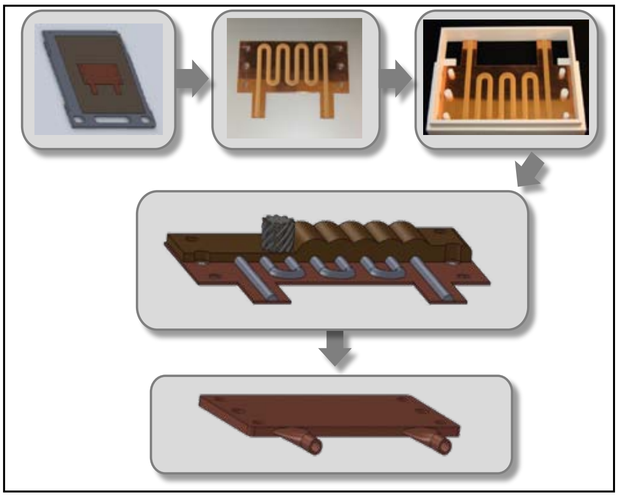


Fig. 2. Procedure of the process combination

The geometry of the copper plate has to be as close to the end geometry as possible, to minimize the reworking. Afterwards, the electroplating of the wax-copper part can begin. If a sufficient thickness of electroplated copper coating is achieved, the model can be cleaned and the wax molten out. A final milling process levels the structure and shapes the geometrically undefined junctions. The whole process combination is depicted in Fig. 2.

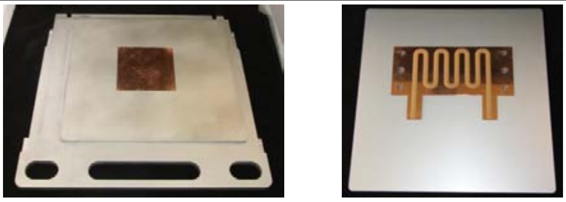
The main field of application, at least in this project, is the fuel cell technology. There are many components which are responsible for guiding liquid media. The new process combination prevents seal issues and will be presumably less expensive than the manufacturing by beam melting, which was used in a previous project. (***, 2009)

2. ADAPTION OF THE MULTI-JET MODELING

Multi-jet modeling is an additive process, in which a molten material is deposited through droplet based printing heads. The used system, 3D Systems´ Thermojet, was introduced in 1999 and the implemented print head contains 352 nozzles. The layer thickness amounts to 0.04 mm. As in any molten material system, normally a support structure is required to support overhang and to simplify the removal of the part. (Gibson et al., 2010; Chua et al., 2003) The Thermojet generates this structure by itself. The main difference between the regular use of this technology and its application in this research project is the omission of the described supports. The part has to be printed directly on the metal base structure.

At the attempt of manipulating the software to eliminate the support structure, an option in the maintenance tool is detected which enables the choice of an arbitrary start layer. After the analysis of the Thermojet log files, the last support layer is determined in layer number 125. By defining the start layer to this value, the construction process starts immediately with the main part.

Fig. 3. Adhesion problems without support structures



a b

Fig. 4. Constructed platform with different adapters

Another fact is mentioned by studying the log files. In general build processes, the build platform does not lower for the first 20 layers of the support structure and does so by 0.02 mm for the next 11 layers. This procedure effects a reduction between the nozzles and the platform, respectively the layer printed before. Instead of building the support structure, in the modified process the part is built directly with the first layer, therefore these steps have a direct influence on the accuracy of the produced wax structure. Due to the possibility to deactivate this behavior, the problem is solved and the accuracy is secured.

By printing the first test pieces, the necessity of the support structures and the varied lowering of the platform are made clear. The adhesion of the wax part is not assured. Fig. 3 shows an example for this defect.

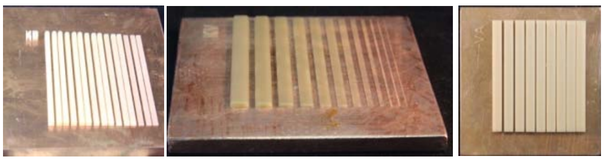
Pretreatments of the copper base plates do not achieve any success, but finally the start of the process on preheated copper plates, the post heating and the slow cooling down of the copper wax part carry out promising results. Experiments with different temperatures point out 55 °C as an attached value.

In order to simplify the process, a customization of the Thermojet platform is realized. The regular platform is just a plane surface. By sticking the copper plates on it, there is always an element of uncertainty in the process. Therefore a new platform with a placeholder for different adapters is constructed. The various adapters create an adequate flexibility in the project. They enable the operation with different types of copper plates for test geometries and components. Fig. 4 a. shows the constructed platform with an adapter for a test plate (80x80 mm), Fig. 4 b. pictures the adapter for heat exchangers used in fuel cell technology with a printed copper part.

3. PROCESS LIMITS AND POSSIBILITIES

With these solid process conditions, ensured by modification of the process, first test geometries expose some existing limits and possibilities. Therefore different test geometries are built. Fig. 5 shows the geometries cw (a: constant wide), cp (b: constant proportion of cross section) and vd (c: variable distance).

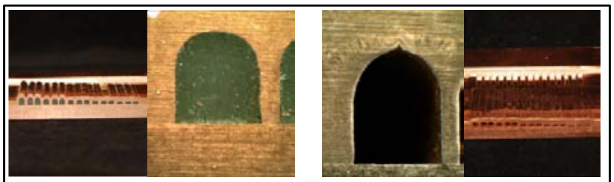
Basically, none of the test geometries points out limitations, which affects the main planned application of the process combination. For the application in this project the smallest possible cross section is too small for guiding liquid media, so it is not restricted by the MJM process.



a b c

Fig. 5. Test geometries

4. ELECTROPLATED STRUCTURES



a b

Fig. 6. Electroplated test geometries

The first electroplated structures produce good results. As shown in Fig. 6, two different approaches are realized. A. shows an activated structure, which means an electrical start layer is spread on the wax structure. In Fig. 6 b. this layer is lacking. Both approaches yield homogeneous results. In b, a small gap is shown at the top of the structure, but it is too small to influence the fluid flow. Nevertheless, alternative b is preferred, because of more rework and consumption of material in case a.

5. CONCLUSION

After the positive realization of the main idea, some components are produced by the project´s process chain. The next steps, some of which were already carried out are the implementation of reactive pallets in the fluid flow by sticking them into wax structures and printing a cover on it or the production of more filigree structures.

6. ACKNOWLEDGEMENTS

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