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Research Group Additiv Manufacturing

Hybrid Manufacturing of Carbon Fiber Reinforced PEEK

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Introduction

The interactions between additive and subtractive processes have not been studied in detail and pose a challenge in the layout of post-machining processes and fixture design. Process parameters and clamping force are shown to have a deleterious effect on the surface accuracy of the resulting part and the machinability of such components.

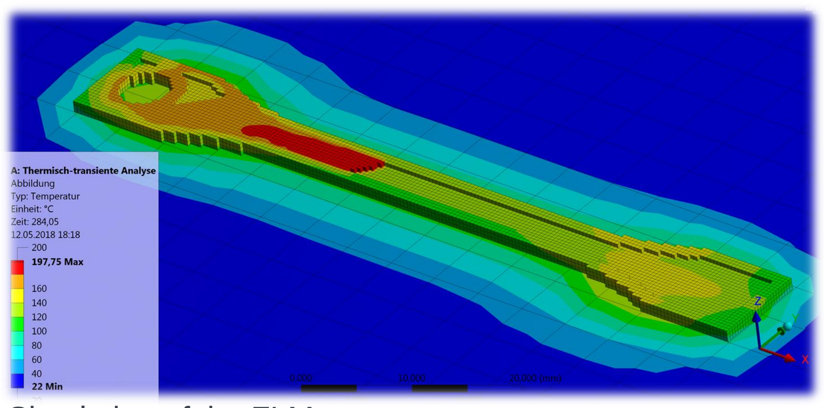
One of the major disadvantages of the here used FLM process is the limited form accuracy and often required support structures. As material carbon fiber (CF) reinforced polyether ether ketone (PEEK) was used in this investigation.

To achieve desired accuracy in shape and dimension as well as surface quality, sophisticated subtractive manufacturing is required.

Methodology and Simulation Method

To optimize AM process parameters and clamping forces a numerical simulation is required to lower the overall effort of testing.

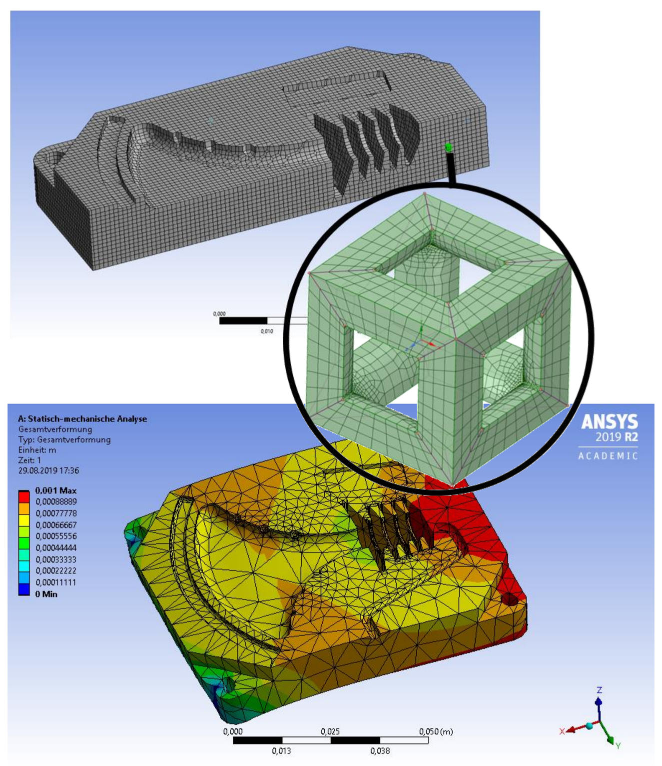
In order to predict the possible deformations caused by the FLM process, a transient thermal and a sequential structural numerical simulation with the Software packages of ANSYS was carried out. This analysis is required for the calculation of thermally induced internal stress and the associated distortion in manufactured components.



Simulation of the FLM process

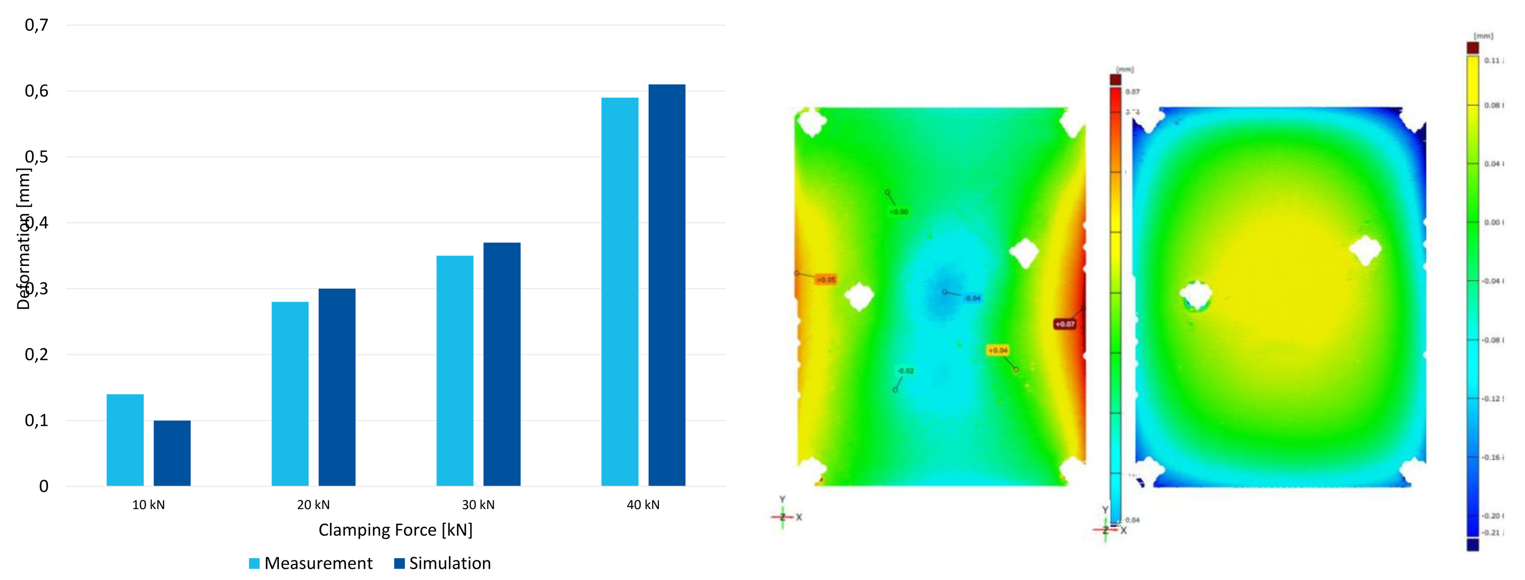
Fixture Design

Additively manufactured components often pose hollow and mesh like structure in the inside to save material. The use case component was manufactured with a rectilinear infill-pattern, an infill rate of 40% and a wall thickness of 2 mm. For the FEM calculation of the clamping forces a material homogenization approach is used to save calculation resources. With this anisotropic, thermal variant and density variant material the use case component can be simulated by means of mechanical deformation during clamping. For evaluation, the produced component was clamped with four different power levels:



Simulation of the clamping induced deformation

10 kN, 20 kN, 30 kN and 40 kN. The behavior of the component was examined during clamping and relaxing.

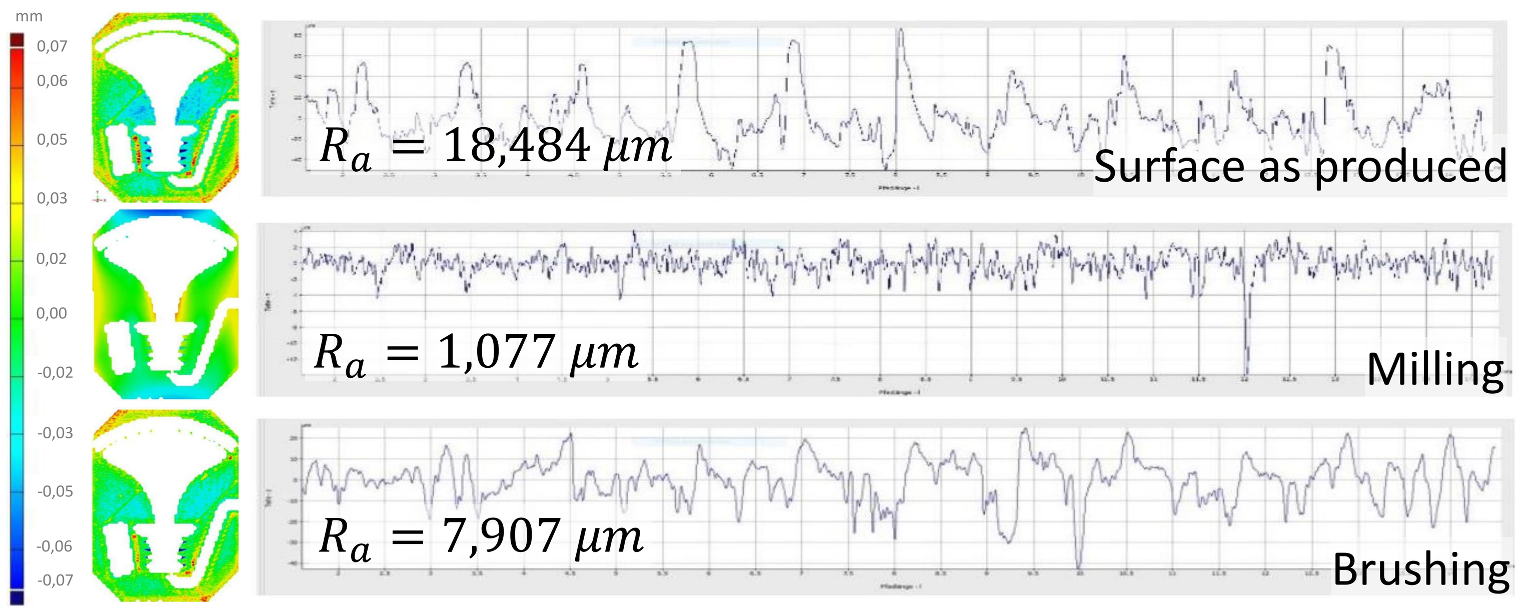


Influence of the clamping force on the deformation of the specimen measured at the upper surface

Subtractive manufacturing

To improve the roughness, the upper surface was machined. The tool used was a face milling head (diameter 100 mm) with six cutting edges.

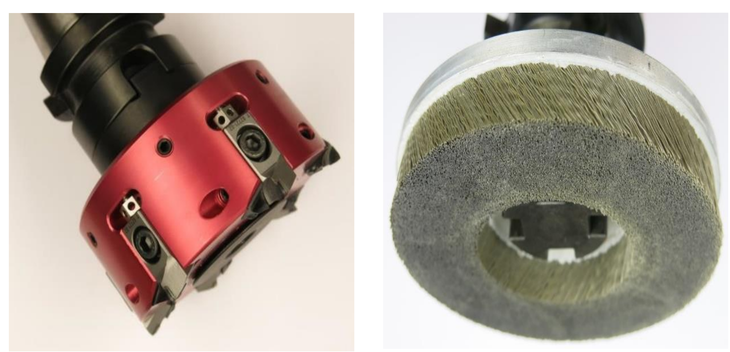
Polycrystalline diamond sheaths (PCD cutting edges) were selected and used for the milling of PEEK-CF. It was found that at a high cutting speed of vc = 7.85 m / min and high speed n > 1,500 / min improves the surface finish quality significantly. Moreover, compared to the printed components, there were only minimal differences between different areas. Thus, it can be concluded that the higher feed rate when milling additively manufactured PEEK CF components has a positive effect on process reliability.

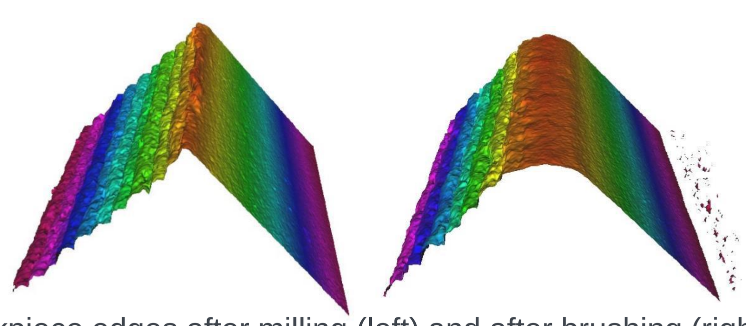


Workpiece surfaces before (upper),after milling (middle) and after brushing (lower)

The machined surfaces were re-examined for surface roughness and flatness after the milling process. The roughness profile before machining shows many large peaks with a center height of 40 - 60 µm. After the milling process, the measured profile looks heavily smoothed, the maximum profile height being 3 - 5 µm. The mean 2D roughness fell from Ra = 13.6 µm to Ra = 1.2 µm.

In Order to further improve surface quality a disc-type brush was used, also with a diameter of 100mm. The silicon carbide bristles of the brush have a grain size of 35 microns. During the literature search no qualitative processing parameters were found for the processing of PEEK CF30 with a technical brush. Therefore, a small series of experiments was carried out to find out tendencies for the best processing parameters, while the cutting speed was varied and the feed kept constant. The infeed depth of 0.5 mm was the same as in the milling process. The best result was provided with the feed rate of vf = 0.32 m / min and speed of n = 1,250 / min as cutting parameters.





Workpiece edges after milling (left) and after brushing (right)

Clamped workpiece after brushing

If a high-precision geometry is to be achieved, the milling process can be used successfully for post-processing. The milling process creates sharp edges with a very small radius, while brushing creates softer edges with a larger radius and clearer rounding.

In comparison between milling and brushing it can be said that milling results in a better average roughness. The flatness of the overall surface is better when brushing, since there is hardly any deformation through clamping because of the lower forces in the process.

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