INVESTIGATION OF THE EFFECT OF RESIDUAL STRESSES AND ROUGHNESS OF ADDITIVE MANUFACTURED COMPONENTS ON THE COATABILITY AND FATIGUE STRENGTH OF THE COMPOSITE SYSTEM

To achieve the performance of conventionally manufactured components, additively manufactured components have to fulfill at least the same requirements. This includes the possibility of functionalized surfaces with coatings and of being able to realize a sufficient fatigue strength of the overall system (component/coating). In the present project, therefore, the effects of residual stress and surface roughness, known as the restriction of the SLM process, on the coatability are fundamentally examined and the dynamic strength of the overall system is considered.

PROJECT OVERVIEW

DURATION

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Objectiv

This project investigates the effects of residual stresses and surface roughness of additively manufactured components on the coatability and fatigue properties of the composite system (= coated component). The materials 316L and IN718 are analysed. In this context, the aim of these investigations is to achieve a qualitative statement regarding the effects of residual stresses and roughness on the coatability. This includes the determination of the adhesion strength of the coating as well as the generation of coating optimized SLM- and post-processing parameters, which guarantee a gap- and pore-free bond with high cohesion and adhesion. Further goals are the determination of the fatigue strength, the identification of failure mechanisms as well as the crack origin. Therefore, a fundamental understanding of both, the process and the combination of the advantages of both process steps to substitute further process steps, such as metal-cutting surface treatments, is mandatory. Based on a better understanding of the process, the quality of the additive components should also be optimized to such an extent that at least the level of conventional cast or forged components is reached.

Approach

First, for the manufacturing of the samples a parameter adaption is carried out. Subsequently, established sample geometries for fatigue tests (dog bone samples for room temperature and cylinder samples for 650 °C) are produced. The investigation of the manufacturing parameters ensures definable sample properties with a negligible porosity for a robust process and reproducible mechanical properties. After the production, all samples are examined regarding roughness, residual stress and porosity. This is followed by a pre-treatment using grinding or corundum blasting with a subsequent additional characterization of the roughness and residual stresses. The effects of the respective pretreatment methods on the surface are measured and correlated. Untreated samples (with and without heat treatment) are carried along as reference. Furthermore, half of the samples are coated via atmospheric plasma spraying using Al_2O_3 as coating material. The coating is performed at the Institute of Materials Engineering (TU Dortmund).

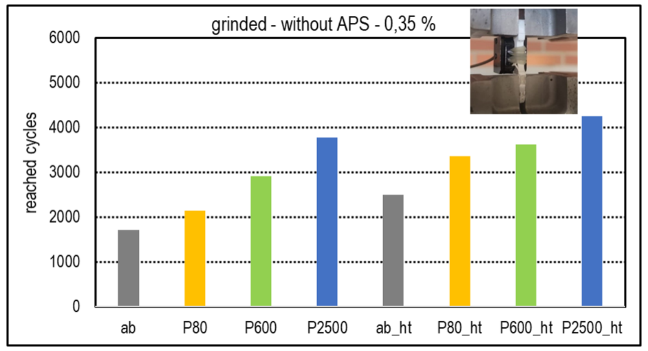

FIGURE 1 Low cycle fatigue strength of grinded, un-coated 316L samples without coating at a strain amplitude of 0.35%

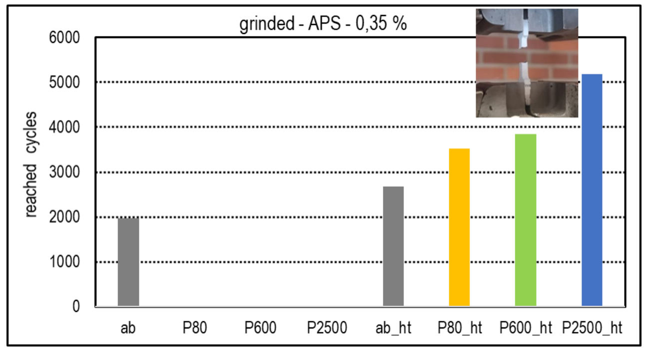

FIGURE 2 Low cycle fatigue strength of grinded 316L samples with a Al_2O_3 coating at a strain amplitude of 0.35 %

Afterwards, the porosity is quantitatively measured by micro-CT and image analysis. The final step of the investigations is the implementation of low cycle fatigue tests with different total strain amplitudes (0.35 %; 0.50 % and 0.80 %) and the characterization of the fracture surface, crack initiation and crack spread.

Results

In order to investigate the influence of the different pre- and post-treatments (grinding, blasting, heat treatment and coating) on the low cycle fatigue, fatigue tests are carried out. Here, the additively manufactured 316L samples (different states) are fatigued at a total strain amplitude of 0.35 %, a strain rate of $6*10^{-3}$ s-1 and at R = -1 at room temperature. Figure 1 shows the low cycle strength of grinded 316L specimens (different states) without coating at a strain amplitude of 0.35 %. Based on the results it can be seen that grinding with a finer grain size leads to a better surface quality, and therefore to better fatigue properties. Furthermore, it can be seen that heat-treated samples exhibit the same tendencies, but with higher numbers of cycles. This can be explained by the fact, that the performed heat treatment reduces residual stresses, which are known to have a negative effect on the fatigue behaviour. Figure 2 summarizes the low cycle strength of grinded 316L samples (different states) with Al_2O_3 coating at a strain amplitude of 0.35 %. The results reveal that an additional Al_2O_3 coating ensures a further increase of the low cycle strength. This trend does not apply to the heat-treated samples for the layer adhesion in this state is too low. It can be assumed that the residual stress condition has a negative effect on the adhesion.

Outlook

The restrictions currently present in the SLM process, such as porosity, residual stresses and surface roughness, are to be minimized based on the investigations carried out in this project. Therfore, a general improvement in fatigue life for 316L and Inconel 718 SLM components is achieved. Furthermore, a correlation between the adhesion of different coating materials and the different coating processes regarding their influence on the short-term fatigue of SLM components is addressed in the final period of the research project. The results are then correlated with post-treatment methods, like coating processes and the material pairing, with the aim to specify a critical criterion for adhesion. This approach is very important because a coating, allows non-corrosion resistant materials to be coated with a corrosion resistant material or for example to make it wear resistant.