Fatigue Life Manipulation

A defined arrangement of crack delay elements optimizes the life of Selective Laser Melting parts that are under fatigue loading, thus ensuring safe use in an industrial environment. For this purpose, examinations are carried out on specimens that are having different arrangements and geometries of crack delay elements and their influence on service life is tested by means of experimental and numerical methods. Fracture mechanical investigations, like influence of crack delay elements on crack initiation and crack deflection behavior are the results of this project in order to generate an optimal design for cyclically loaded components.

1. Objectives

The opportunities to optimize the fatigue behavior of additively manufactured structures are investigated in this project. Specific heat treatments, notches with different geometries on the crack path, as well as the alternating crack initiation and crack growth phases are those possible optimization measures. The service life of technical structures under fatigue loading are reduced because of various stresses, the main goal of this project is to extend the total lifetime by using sophisticated configurations of notch form, notch position and notch orientation. By varying these notch parameters, basic knowledge about crack growth behavior in SLM processed components is obtained.

Using crack growth retardation methods substantially higher fatigue life can be achieved. Here, the effect of notches on the lifetime during crack initiation and crack growth periods are taken into account. The reason for the difference in lifetime can be found in the time for crack initiation. The notches positioned on the crack path lead to a new initiation of the crack at each notch. The significantly higher number of load cycles for the reinitiation of the crack compared to the number of cycles for propagation of the crack over the distance of the notch in a specimen without notch will be used to manipulate the total lifetime.

2. Latest results

The comparison of the experimentally examined and the numerically predicted crack path for a compact tension specimen with “diamond-shaped” notches is demonstrated in Figure 20. The crack paths of both samples show a good agreement. Both, the prediction of the crack path as well as of the position of the reinitiation points are realistic. The experimental results confirm the simulation investigations and thus it is possible to predict the

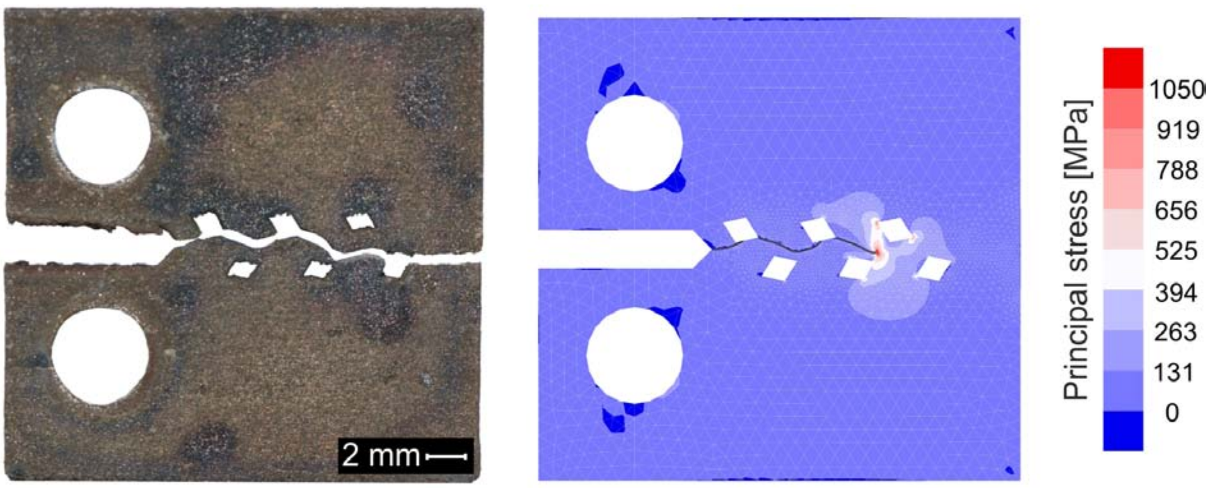

Figure 20: Comparison between experiment and simulation of the crack path of a compact tensile specimen with diamond shaped notches

crack growth behavior in additive manufactured components.

Results of investigations on notched structures show that the decrease or increase in fatigue life can be manipulated significantly by introducing notches. Taking the titanium alloy as an example, a huge lifetime extension can be achieved by using a row of notches or elongated notches. All in all the lifetime manipulation depends on notch size, notch position and on material behavior such as brittle in case of titanium alloy or ductile in case of stainless steel. By discovering optimal parameters for notch size and notch position a momentous lifetime extension can be achieved. In special cases a crack arrest is also possible. Thus, additive manufacturing offers the possibility to produce lightweight structures that have longer fatigue lifetime.

The fatigue life manipulating methods are applied to a strength and lightweight bicycle stem from the high-performance segment, Figure 21. To reduce the weight of this structure, notches are implemented. The shape of the notches is based on the earlier findings of this project. Because the stress situation is different at every point of the stem each notch shape is individually adapted to the load situation. The comparison to a commercially available stem clarifies a weight reduction of 30 % and a possible increase of the service life of this product.

3. Outlook

The future investigations in this area can be the adaptation of the main results obtained on complex, laser melted structures. The results can be targeted to redesign real parts that are under fatigue loading. These real parts should be additionally tested under actual operating loads to figure out the possible lifetime extension by using additively manufactured smart notches.

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Figure 21: Three different views of additively manufactured bicycle stem with newly introduced crack delay elements