Fatigue Behavior of FDM and LS Parts

In practice, the knowledge of the fatigue properties, in addition to the static material properties, is crucial for a reliable component design. Many components are not only statically loaded, but also dynamically loaded in the area of application, such as a fastener on an airplane. Therefore, the fatigue behavior of Fused Deposition Modeling (FDM) parts manufactured with Ultem 1010 and Ultem 9085 as well as Laser Sintering (LS) parts manufactured with Polyamide (PA) 12 are analyzed in this project. Furthermore, chemical surface treatment can be used for surface smoothing of additive manufactured polymer parts. The influence of the chemical surface treatment on the mechanical properties will be analyzed in static and dynamic tests.

1. Objectives

This project will deliver valuable information regarding fatigue and creep data of different additively manufactured polymers. For FDM parts, improvement of fatigue properties by process parameter optimization will be carried out.

2. Procedure

The dynamic strength values in the form of S-N curves are initially determined for FDM components made from the materials Ultem 1010 and Ultem 9085. LS components made out of the material PA 12 (Type PA 2200). Due to a general good fatigue behavior of Polyamide, fatigue tests will concentrate on stiffness respectively possible length increase of specimens during the tests. For the LS parts an EOS P 396 and for FDM parts a Stratasys Fortus 400 mc machine is used.

Besides the detection of S-N curves the fracture of Ultem 1010 and Ultem 9085 specimens will be analyzed. Therefore, microscopy pictures will be taken. The aim of this analysis is a specific variation of process parameters with regard to improve the fatigue behavior. This improvement will be performed for both Ultem materials as well as for X, Y and Z orientation of the specimens. The classification in different built orientations in necessary, because the layer wise building process leads to anisotropic mechanical properties (cf. Figure 18). Afterwards, additional S-N curves for parts with optimized process parameters will be carried out.

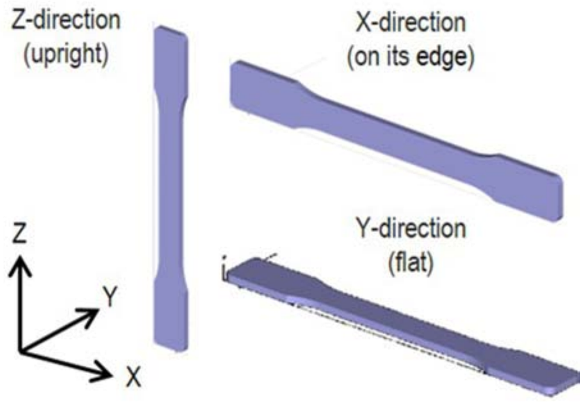

Figure 18: Build orientation tensile bars

In addition to the dynamic characteristics, the FDM materials are also analyzed on the basis of long-term creep tests, in which the failure time is determined for different load levels. The creep tests will be performed at room temperature in standard atmosphere.

The use of components as final products generally places a great demand on the appearance. For this purpose, previous projects at the DMRC have analyzed possibilities for chemical surface treatments for the materials listed above. Chemical methods have the advantage of an effective leveling of the most rough and wavy surfaces from additively manufactured products. Another focus of this project is to analyze the influence of the chemicals on the dynamic strength values and creep properties.

3. Latest results

The dynamic testing of polymers is connected to some specific features, due to the polymer-specific material behavior. For metallic materials, higher test speeds of 100 Hz, for example, are used to achieve a high number of load cycles in a short time on the test bench. Due to internal friction of the molecules, thermoplastic polymers have the ability to reach the softening temperature because of the simultaneous poor thermal conduction properties and low temperature resistance at high test frequencies. This leads to an early failure of the test specimens. Thus, dynamic testing of polymer components with significantly reduced testing frequency should be carried out, resulting in a significant increase of the test duration. The S-N curves are prepared for swelling loads with a constant minimum stress. Here it is possible to use standard tensile bars. Figure 19 shows the fatigue behavior for Ultem 9085, tested with a frequency of 5 Hz.

For Ultem 9085, chemical treatment shows no influence on mechanical properties, given that the treatment time is not too long. Due to a smoother surface, the chemical treatment may have positive influences on fatigue. First fatigue tests of Ultem 9085 specimens do not confirm this theory. Internal notches in the specimen seem to exert a significant influence on lifetime, especially with cyclic loads.

4. Outlook

Temporarily long term influence on mechanical properties are unknown for the used chemicals. Therefore, long term tests will be performed, while specimens will be treated and stored for a minimum of one year.

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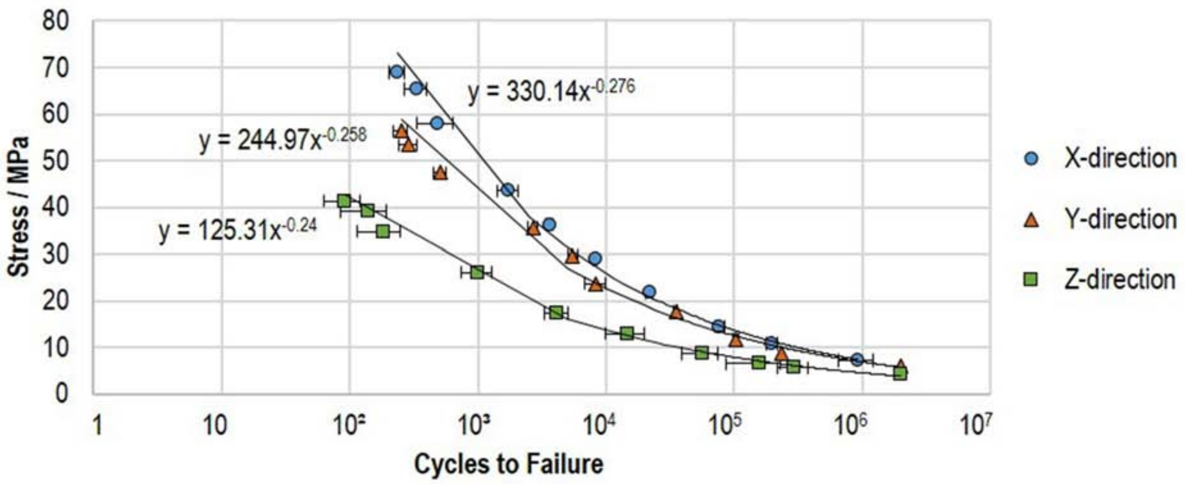

Figure 19: S-N curve for untreated Ultem 9085