

Reviewer #3

General Comment

The authors deal with the question of the fatigue behavior of auxetic structures, which is a relevant for additive manufacturing. For this purpose, a numerical model is analyzed for five auxetic structures in different states. The paper makes a valuable contribution in the field of additive fabrication of auxetic structures and contributes to a further scientific development of this topic. The introduction and the problem are described in a comprehensible way and references are given to an appropriate extent and actuality.

Comment #1:

The reviewer suggests to use the term "Laser Powder Bed Fusion" (LPBF/L-PBF) as a general term in the contribution for describing the process - instead of SLM. For example, in 3.1 the use of a EOSINT M270 is mentioned, however, EOS itself refers to their metal processes as DMLS and not SLM. SLM Solutions on the other hand registered "SLM" for their process. The reviewer is of the opinion that any commercially protected terms should be avoided to ensure clarity.

Response:

In the manuscript, the term SLM is replaced with the term DMLS, which, as mentioned, corresponds to the EOSINT M270 system.

Comment #2:

The reviewer finds the title (and first sentence in the Abstract) somewhat misleading, as it does not indicate that it is essentially a numerical analysis. The reader might come to the conclusion that auxetic structures are physically produced and analysed accordingly. It is suggested to clarify this by including "numerical analysis" already in the title and in the beginning of the abstract.

Response:

Authors agree with the reviewer. Therefore, the Title of the manuscript was revised:

["Computational fatigue analysis of auxetic cellular structures made of DMLS AlSi10Mg alloy"](#)

The Abstract of the revised manuscript is also changed. The beginning of the Abstract now reads as:

[In this study, computational fatigue analysis of topology optimised auxetic cellular structures made of Direct Metal Laser Sintering DMLS AlSi10Mg alloy is presented.](#)

Comment #3:

The authors are encouraged to check if graphics with a higher resolution can be used, some of them seem a bit pixelated.

Response:

All Figures were modified to a higher resolution.

Comment #4:

Selection of Optimized Auxetic Cellular Structure

Figure 1 gives the reader a good and compact insight into the behavior of auxetic structures. Reference is made to the possibilities of additive manufacturing and the fact that there is a high degree of freedom in the design of cellular structures which cannot be realized otherwise.

My understanding is that the topology optimized structures originate from Ref. 65. However, under 2.2. paragraph 3: The wording "The drawback of this procedure" in connection with "...the following smoothing procedure was applied..." implies that here original scientific investigations follow which are based on a given state of the science: Please clarify whether these are completely results from reference 65 (Borovinšek) or whether the execution of the smoothing procedure is an original component of the investigations for this publication. Against this background, it should also be more clearly stated whether topology 1-5 originates from Ref. 65 or were developed in the context of this publication.

Response:

The results of the previous study by Borovinšek et al. [65] are sharp-edged topologies. From that study, five sharp-edged topologies were taken. Then the smoothing procedure was developed for this research (it is an original component of this publication) and applied to the five selected topologies to get the topologies in Figure 3. The last paragraph of Chapter 2.2 was revised accordingly:

The drawback of this procedure is that the resulting optimal topologies of the quarter cell models are sharp-edged since their topology consists of square-shaped parameter regions (Figure 2a). Sharp edges of the structure result in stress concentrations under load and do not allow a direct application of the obtained topologies from [65]. To study the fatigue behaviour of the obtained topologies, a geometry smoothing procedure was developed for this investigation. It was applied to reduce the number of possible stress concentration regions. The smoothing procedure consists of the following five steps:

1. Selection of the topology from the Pareto front (Figure 2a, dark grey area).
2. Determination of the medial axis of the topology.
3. Simplification of the medial axis to straight lines between the line connection points (Figure 2b, red lines).

4. Thickening of the simplified medial axis to obtain the geometry; the horizontal and vertical lines retained their thickness, while a new thickness was defined to the oblique lines of the medial axis. The thickness of these lines was set to such a value that the topology area remained the same (Figure 2b, light grey area).
5. All remaining sharp corners were rounded using an equal fillet radius R (Figure 2c).

Comment #5:

Fatigue Analysis

Table 1 should, according to the text, include general process data. However, besides a minimum layer thickness, no process data is included. In my understanding, this would be e.g. scan speed, hatch distance, platform temperature, laser powder etc. or at least volume energy density. Surface roughness and density are process outcomes. Additional question with respect to "minimum layer thickness": this wording implies a variation in layer thickness towards a larger thickness for the experiments. But this does not seem to be the case, please leave out "minimum".

Response:

Authors agree with the reviewer that some additional information's (scan speed, hatch distance, platform temperature, etc.) are missing in Table 1. However, test specimens used in this study were produced by an external manufacturer using the EOSINT-M-270 system. All information the authors have received from the manufacturer are presented in Table 1 except the [volume rate 4.8 mm²/s](#) (related to the standard processing parameters according to the EOSINT-M-270 system), which was added to the revised Table 1.

Comment #6:

Fatigue Analysis

Please provide information, how the polishing of your flat tensile specimen was done and how the surface roughness is after polishing (e.g. add information to Table 1).

Response:

The surfaces roughness of as-built and cleaned specimens is given in Table 1. The specimens used for the tensile tests have been fabricated by the DMLS technology using the EOSINT-M-270 system [without additional polishing](#). The text before Table 1 was revised accordingly.

Comment #7:

Fatigue Analysis

Figure 5 provides a micrograph and the occurrence of pores are mentioned in the text. The authors do not use or discuss the occurrence of the pores further. This is necessary, however, because pores

in laser-additive manufactured components have a significant influence on fatigue behaviour, especially in dynamic conditions, which is the main topic of the paper. If the occurrence of pores in the real component cannot be considered in the numerical model due to its complexity, this should be mentioned and also stated in the discussion as a possible source of error when specifying fatigue cycles. Here your approach, the use of the Universal Slopes, should be mentioned and briefly described. So, the assumption is, pores are in the part but their impact in dynamic conditions is considered within the Universal Slope method? This should also be stated early on.

Response:

Authors agree with the reviewer's comment. Therefore, the following paragraph is added in the Conclusions of the revised manuscript:

The fatigue life in this study was obtained using the simplified Universal Slope method, where the material parameters were determined by quasi-static tensile tests considering the partly porous structure of analysed DMLS AlSi10Mg alloy (Figure 5). For a more accurate determination of fatigue life of real components made of DMLS AlSi10Mg alloy, the comprehensive Low Cycle Fatigue (LCF) tests should be performed to determine the appropriate LCF-material properties, where the influence of pores will be considered in detail. Once the LCF-material parameters are known, the standardised strain life approach could be used for the subsequent fatigue analysis.

Comment #8:

Fatigue Analysis

Line 198/199: Would you please explain why there is a scaling factor of 11. Is this for an improved visualization in Fig. 8?

Response:

The scaling factor is just for improved visualisation of the results. The following statement is added to the revised version of the manuscript:

Resulting displacement was scaled by the factor 11 for better visualisation of all structures.

Comment #9:

Discussion

The authors' finding that small but also large radii have a negative influence is indeed interesting. The authors name a general application scenario for each topology-optimized unit cell, which is a valuable aid for scientific investigations based on this for an application-specific unit cell design. The discussion is overall comprehensive and addresses the essential aspects. However, it would also be desirable to consider possible sources of error in the numerical analysis. Here I am coming back to the pores and the Universal Slope method. How valid is this approach and in consequence how valid are the specifically mentioned life cycles? Your analysis is based on the mechanics of two flat

tensile specimen - how do the individual results of those specimen differ? How pronounced is their standard deviation, are those results a valid basis to work with?

Response:

It is true that only two specimens were tested to determine the material parameters presented in Fig. 6 and Table 2. However, the measured quasi-static stress-strain responses were almost the same for both specimens and are also in a good agreement if compared to the experimental results from other researchers [67]. This explanation is added in Section 3.1 of the revised manuscript.

Comment #10:

Conclusion

line 342: Here and with reference to Fig. 5 you mention pores, but you do not consider or discuss them. This should definitely be addressed.

Response:

See Response to Comment #7.

Comment #11:

Conclusion

line 346: Please add a reference in 3.1 / Table 2 to results of other researchers if you mention the comparability of your results.

Response:

The reference [67] has been added in Section 3.1.