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AM-AWARE DESIGN INTEGRATED WORKFLOW

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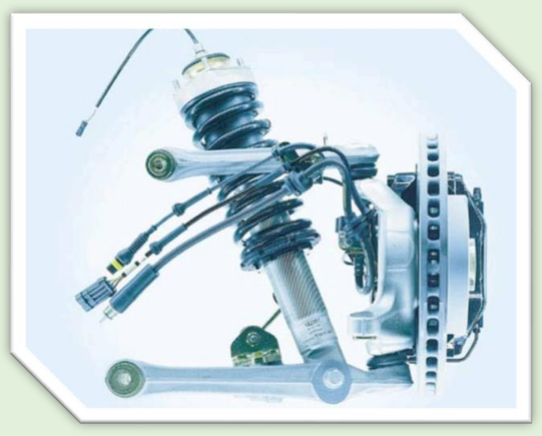
Introduction Laser Powder Bed Fusion is considered as one of the most innovative manufacturing technologies and has rapidly gained interest in industry because it allows to produce near-net-shape metal components characterized by complex geometry. Parts with geometrical characteristics driven by optimized lightweight trade-offs would be readily produced by L-PBF and when combined to adequate strength are of great interest for sectors such as automotive and aerospace. In parallel with the evolution of the AM technology, the finite element-based software provides simulation and optimization tools that allow full exploitation of 3D printing potential. The main aims of this contribution are the presentation and discussion of an integrated design workflow of a metal AM part from geometrical topological optimization to AM process simulation actual part fabrication in an industrial-grade L-PBF system using the AlSi10Mg alloy powder and structural qualification by fatigue testing of actual parts under realistic working conditions.

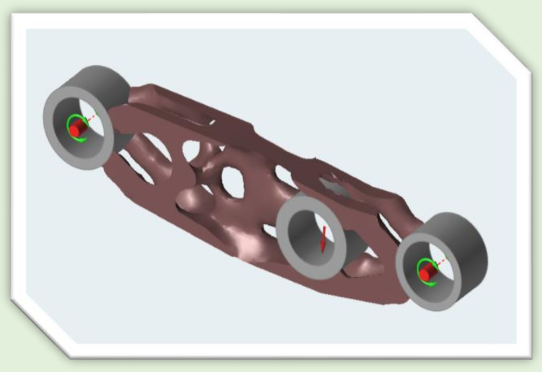
DESIGN

PART SELECTION



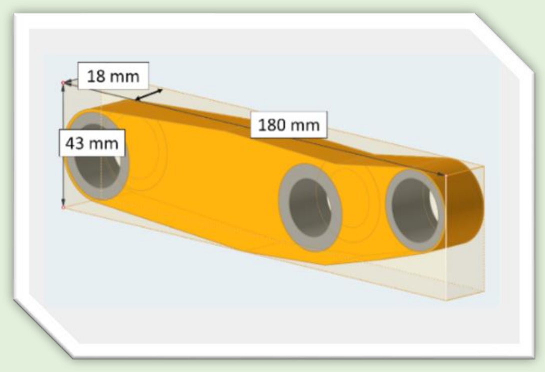
The identified component is the lower suspension arm of a car which develops a key structural function as it is connected to the chassis, to the wheel upright and the shock absorber. The scaled version of the suspension arm was selected because it is subjected to dynamic loading and therefore it requires a fatigue integrity assessment at the design stage and subsequent experimental verification.

TOPOLOGY OPTIMIZATION



Topological optimization based on SIMP-algorithm (solid isostatic material with penalization) that attributes a varying density to each element. The optimization goal is defined in terms of minimization of the mass and global maximization of the stiffness. The solution respects imposed limits and is characterized by the best stiffness-to-weight ratio.

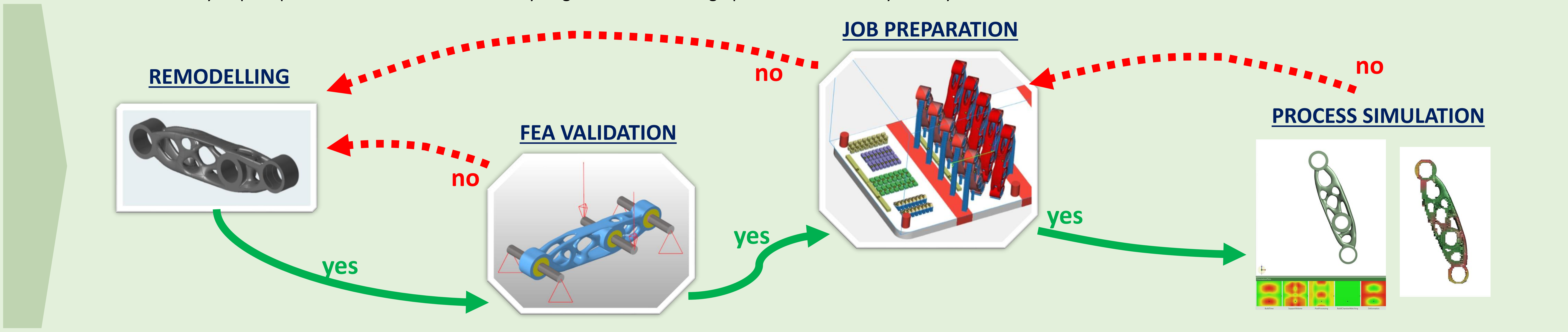
DESIGN SPACE DEFINITION



To perform optimization of the part, the geometry is divided in the "design space" where material is present but can be removed to achieve an optimal geometry, and the "non-design space", where material and geometry are fixed to guarantee necessary interfaces (bearing seats etc.), that define the boundary conditions

INTEGRATED DESIGN ITERATION

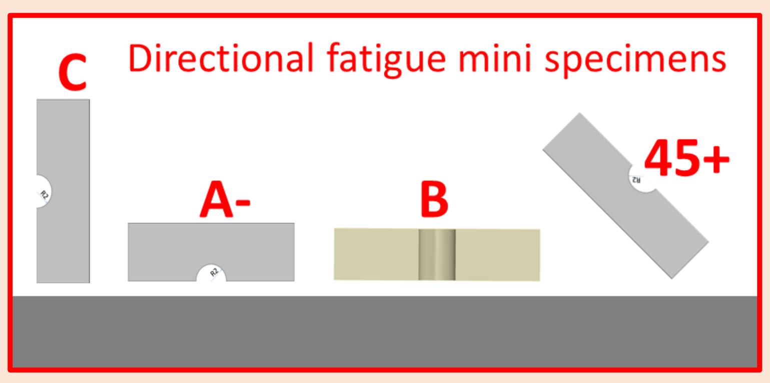
Validation of the reconstructed and optimized part geometry requires repeated finite element analyses (FEA) to iteratively identify possible critical points and local model refinement; requirements related to DfAM rules should be considered during modeling. The job preparation requires specifical knowledge and experience to define the correct position and successful results. Numerical process simulation allows to forecast distribution and magnitude of residual stresses and part deformation upon fabrication and after release from the build plate. If some zones are identified as critical in terms of manufacturability or post-process intervention is necessary to go back to the design phase and iteratively modify the model.



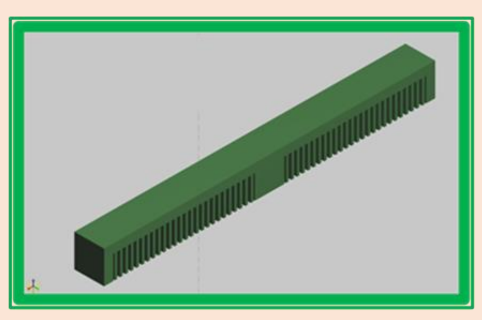
PRODUCTION

The job was built from the AlSi10Mg alloy in a SLM500 system (SLM Solution GmbH - Germany) using printing parameters defined by the expert technology partner Beam-It.

Optimized suspension arms printed according to two different orientations to investigate the differences introduces by dissimilar surface direction and supports position.



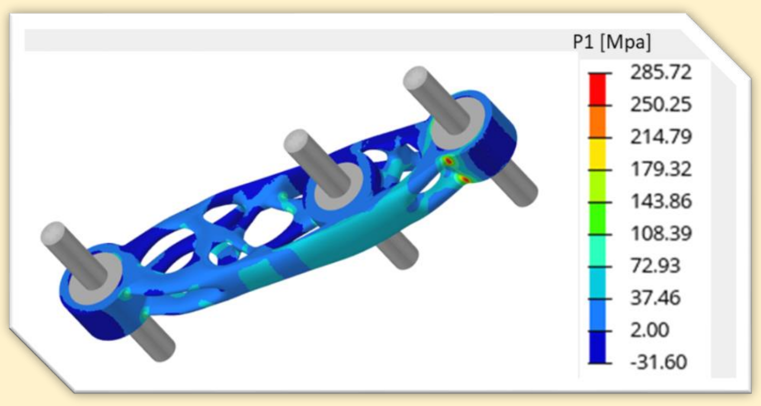
Miniaturized specimens divided into four different orientations produced to evaluate effect of build direction on fatigue performance of the material and to generate fatigue data useful for the part qualification phase.

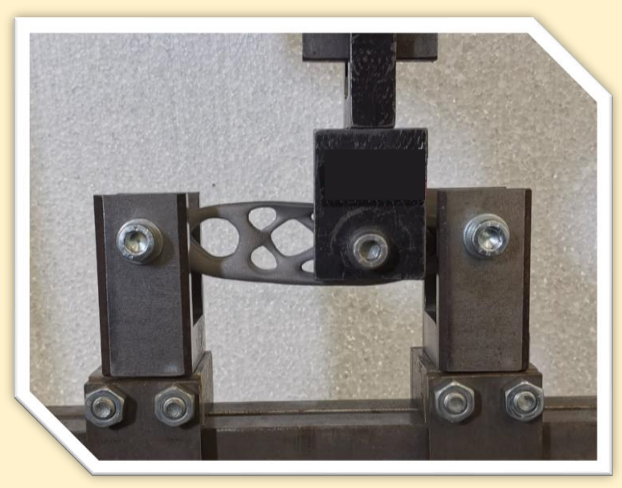


Process Calibration specimen for evaluation of inherent strains.

QUALIFICATION

The fatigue performance is a crucial aspect to be taken in consideration for part design and manufacturing process qualification. The behaviour evaluated from numerical simulation of the model and the experimental results completed on the real part must be proven consistent performing laboratory tests to correlate collected results. Dynamic loading has been applied to optimized lower arms to determine their actual fatigue strength. The fatigue data of as-built AlSi10Mg alloy were obtained using the miniature specimens.





Conclusions

An integrated design workflow of a metal AM part followed by actual part fabrication and testing is required for the structural integrity assessment of the additively manufactured part. Design of components to be produced by L-PBF is an iterative process involving topological optimization, CAD remodeling, FE analysis, part orientation analysis and PBF process simulation prior to actual part production. Prediction of fatigue response of optimized L-PBF part benefited requires extensive modeling and simulation activities and ad-hoc material testing.

Acknowledgements

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