Overhang angle control and optimal part orientation in topology optimization for additive manufacturing

van de Ven, Emiel; Driessen, Anton; van Keulen, Fred; Langelaar, Matthijs

Publication date
2015

Document Version
Final published version

Citation (APA)
van de Ven, E., Driessen, A., van Keulen, F., & Langelaar, M. (2015). *Overhang angle control and optimal part orientation in topology optimization for additive manufacturing*. Abstract from ESMC 2015: 9th European Solid Mechanics Conference, Madrid, Spain.

9th European Solid Mechanics Conference (ESMC 2015)
July 6 - 10, 2015, Leganés-Madrid, Spain

Overhang Angle Control and Optimal Part Orientation in Topology Optimization for Additive Manufacturing

Emiel van de Ven[1,*], Anton Driessen[1], Fred van Keulen[1], Matthijs Langelaar[1]

[1] Delft University of Technology, the Netherlands
(e.a.vandeven@student.tudelft.nl, a.m.driessen@student.tudelft.nl,
a.vankeulen@tudelft.nl, m.langelaar@tudelft.nl (corresponding author))

Key words: Topology Optimization, Additive Manufacturing, Overhang constraints, Part orientation

Additive manufacturing (AM) processes such as Selective Laser Melting (SLM) or Selective Laser Sintering (SLS) allow economic fabrication of metal components with unprecedented geometric complexity. This offers great design opportunities and particularly topology optimization is regarded as a key design technique paramount to fully benefit from the flexibility offered by AM. However, also AM processes have limitations regarding manufacturability. Notable examples directly linked to part geometry are minimum feature sizes and maximum *overhang angles* with respect to the build plate. Features sizes can be controlled in topology optimization using conventional filtering/projection techniques. For overhang angles, on the other hand, currently no fully satisfactory approach exists to limit the inclination of overhanging sections of the component to a certain specified angle [1,2]. Either considerable mass is added which reduces optimality, or regions with intermediate density are introduced that require additional interpretation. Moreover, in none of the existing approaches the *part orientation* on the build plate is considered. This is a highly influential variable that directly impacts the amount of critical overhang regions.

It is important to integrate adequate control of maximum overhang angles *directly* in the topology optimization process, because otherwise geometries will be generated that cannot be manufactured by AM without modification. The modification could consist of:

- costly manual or automated (local) redesign of critical sections,
- a well-chosen reorientation of the given part in the build chamber (but often no orientation can be found that completely eliminates the problem), or
- automated placement of sacrificial support features.

Support structures however increase material usage and build time and must be removed by conventional machining after the AM process. In adverse cases, they may not even be accessible for removal. These post-design modifications result in a final component that does not correspond with the optimized design, leading to extra costs and lowered performance. Therefore, considering the overhang angles during the design optimization is clearly preferable over applying post-design fixes.

In this contribution, we briefly review the approaches suggested in literature to limit overhang angles during the topology optimization process. Next, a novel approach is presented, where also the part orientation is include as a design variable. This gives much more design freedom to find configurations that meet the overhang criteria, with a much smaller reduction of the performance compared to the case where the part orientation is fixed *a priori*. We study and demonstrate the characteristics of this approach using a number of two-dimensional test problems. The computational cost of the method and the potential for its extension to the three-dimensional setting are also addressed.

REFERENCES

[1] A.T. Gaynor, J.K. Guest 15th AIAA/ISSMO Multidisc.Analysis and Optim. Conf. (2014) AIAA2014-2036.

[2] M. Leary *et al*., Materials and Design 63 (2014) 678-690.