# Designs through topology optimization with considerations of direct metal deposition related constraints

**V. Mishra***, **C. Ayas**†, **M. Langelaar**† **and F. van Keulen**†

* † Delft University of Technology, Mekelweg 2, 2628CD, Delft, The Netherlands
e-mail: v.mishra@tudelft.nl

## ABSTRACT

Direct Metal Deposition (DMD), an additive manufacturing variant, is a process that produces parts by simultaneously melting and depositing metal wire or powder in a sequential manner using a robotic arm. DMD is an umbrella term for processes such as Wire-Arc Additive Manufacturing (WAAM) and Laser Metal Deposition (LMD). DMD is not anymore limited to prototype development but functional parts such as ship propellers and aircraft structures can be produced in an economically effective way compared to other conventional substractive manufacturing methods.

Unique features of DMD are high material deposition rate and freedom to choose deposition paths. Deposition of material could be in any direction, plane or order. As the molten metal is deposited, it cools down rapidly and sequential deposition creates thermal gradients inside a part. These thermal gradients lead to generation of residual stresses and part distortion. Moreover, subsequent passes of heat source around a point dictates the temperature history of the point which in turn controls the microstrucutre and hence the mechanical properties. Various deposition paths, ranging from rudimentary raster patterns [1] to algorithms like Adaptive Medial Axis Transformation [2] are used. The deposition paths can be non-uniformly spaced depending on the dimensions of a design. To deposit material along non-uniformly spaced deposition paths, material deposition rate and robot travel speed are adjusted. These adjustments lead to non-homogeneous heat input along a deposition path. As a result, thermal history vary along and also, transverse to the deposition paths. It results in non-uniform microstructure in a manufactured part. To generate uniform microstructure along the deposition path, designs could be altered such that they accomodate uniformly spaced deposition paths.

Topology optimization with maximum and minimum size constraints can be used in order to control the feature size of a design. There are different methods present in the literature to impose these restrictions. However, maximum size restrictions lead to designs with many intersecting features. These intersecting features are again problematic to produce through DMD processes [3]. For instance, extra material is typically deposited at the intersections which leads to non-uniform deposition heights in a design. This leads to an increase in production time as extra deposited material has to be removed by machining after a particular number of deposition steps.

This paper considers the minimization of the intersecting features combined with feature size constraints in topology optimization. An intersection identification parameter is proposed utilizing the stress response of the design to the loading and boundary conditions of the optimization. Multiaxiality of the stress state at the intersection has been used to formulate the intersection identification parameter. The intersection parameter is integrated over the design domain and is minimized over the design domain as an extra objective function. Classical 2D compliance minimization load cases are presented as proof of concept. Furthermore, extending this method to 3D cases will be discussed.

## REFERENCES

[1] Ding, D. and Pan, Z. and Cuiuri, D. and Li, H. *A practical path planning methodology for wire and arc additive manufacturing of thin-walled structures*.(2015) Robotics and Computer-Integrated Manufacturing, 34:8–19.

[2] Ding, D. and Pan, Z. and Cuiuri, D. and Li, H. and van Duin, S. and Larkin, N. *Bead modelling and implementation of adaptive MAT path in wire and arc additive manufacturing*. (2016) Robotics and Computer-Integrated Manufacturing, 39:32–42.

[3] Mehnen, J. and Ding, J. and Lockett, H. and Kazanas, P. *Design study for wire and arc additive manufacture*. (2014) International Journal of Product Development, 19(1/2/3):2–20.