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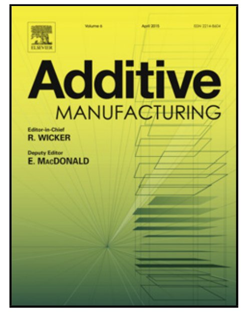

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Authors: Shukri Afazov, Willem A.D. Denmark, Borja Lazaro Toralles, Adam Holloway, Anas Yaghi

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Distortion Prediction and Compensation in Selective Laser Melting

Shukri Afazov*, Willem AD Denmark, Borja Lazaro Toralles, Adam Holloway, Anas Yaghi

Digital Engineering – Design & Simulation, Manufacturing Technology Centre (MTC), Pilot Way, Ansty Park, Coventry, CV7 9JU, UK

**corresponding author: shukri.afazov@the-mtc.org*

Abstract

This paper presents a new approach for modelling additive layer manufacturing at component scale. The approach is applied to powder-bed selective laser melting (SLM) and validated, where the mechanical behaviour of macro-scale industrial components has been predicted and compared with experimental results. The novelty of the approach is based on using a calibrated analytical thermal model to derive functions that are implemented in a structural finite element analysis (FEA). The computational time for a complete analysis has been reduced from many days to less than three hours for a 3D blade component with a height of 80mm. The induced distortion in SLM has been compensated for by modifying the initial geometry using FE predicted distortion. A newly developed distortion compensation method, based on optical 3D scan measurements, has also been implemented. The two distortion compensation methods have been experimentally validated. In summary, the research presented in this paper shows that the mitigation of distortion in SLM is now possible on industrial macro-scale components.

Keywords: *additive layer manufacture, selective laser melting, distortion prediction, distortion compensation, finite element modelling, optical 3D scan measurements*

1. Introduction

Powder-bed additive layer manufacturing (ALM) processes, such as selective laser melting (SLM) and electron beam melting (EBM), allow increased design freedom to produce components with complex 3D shapes. This is one of the biggest advantages of ALM compared to other traditional manufacturing processes, such as casting and machining. Many industries are looking at ALM as a future technology that can enable the production of lightweight components. In relation to this, existing components have been redesigned for ALM using topology optimisation techniques [1]. There are, however, challenges in ALM which need to be addressed and overcome in the near future. Some of these challenges are: management of residual stresses and distortion, material defects such as porosity and micro cracks, design of support structures and their removal, predictability of life, post-processing of ALM parts, powder management, equipment reliability and repeatability, high volume production rates, build rates and associated costs, etc. This paper addresses the distortion management challenge.

Distortion in AM has been predicted in the past. Some researchers have adopted the ‘classical welding modelling approach’ using the FE method. This method consists of applying a mathematically modelled heat source into a coupled thermo-mechanical FEA as described in [2]. Ding [3] summarised some of the FE techniques adopted to model additive manufacturing processes including: (i) material activation using element birth techniques or controlling the material properties to represent elements which are active but have a passive role, also referred to as “quiet elements (QE)”; (ii) using a combination of solid and shell elements; (iii) substructuring approaches; and (iv) remeshing approaches. All these FE modelling techniques have their limitations when it comes to