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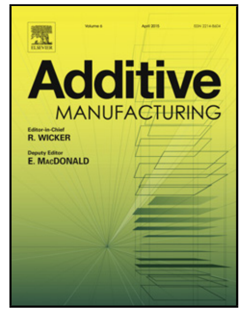

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Author: Richard J. Williams Catrin M. Davies Paul A. Hooper

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A Pragmatic Part Scale Model for Residual Stress and Distortion Prediction in Powder Bed Fusion

Richard J. Williams, Catrin M. Davies, Paul A. Hooper

Department of Mechanical Engineering, Imperial College London, SW7 2AZ, UK

Abstract

Parts manufactured by laser powder bed fusion contain significant residual stress. This stress causes failures during the build process, distorts parts and limits in-service performance. A pragmatic finite element model of the build process is introduced here to predict residual stress in a computationally efficient manner. The part is divided into coarse sections which activate at the melting temperature in an order that imitates the build process. Temperature and stress in the part are calculated using a sequentially coupled thermomechanical analysis with temperature dependent material properties. The model is validated against two sets of experimental measurements: the first from a bridge component made from 316L stainless steel and the second from a cuboidal component made from Inconel 718. For the bridge component the simulated distortion is within 5% of the experimental measurement when modelled with a section height of 0.8 mm. This is 16 times larger than the 50 μm layer height in the experimental part. For the cuboid component the simulated distortion is within 10% of experimental measurement with a section height 10 times larger than the experiment layer height. These results show that simulation of every layer in the build process is not required to obtain accurate results, reducing computational effort and enabling the prediction of residual stress in larger components.

Keywords: residual stress prediction; powder bed fusion; distortion; process modelling; selective laser melting

1. Introduction

In powder bed fusion (PBF) a moving localised heat source melts metal powder to manufacture three dimensional components. Thermal gradients are created by the heat source and conduction through previously melted layers. The material expands and contracts as it is thermally cycled and this leads to residual stress. The residual stress can cause geometric distortion, resulting in the scrappage of parts if they are outside dimensional tolerances. In extreme cases cracking and other failures can occur during the build process itself [1]. In-service performance of a component is also often compromised by the presence of residual stress.

Email address: paul.hooper@imperial.ac.uk (Paul A. Hooper)

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