Optik - International Journal for Light and Electron Optics 170 (2018) 82–89

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

Numerical investigation of heat current study across different platforms in SLM processed multi-layer AlSi10Mg

H.M. Khan[a,*], M.H. Dirikolu[a], E. Koç[b], Z.C. Oter[b]

[a] Department of Mechanical Engineering, Faculty of Engineering, Istanbul University, 34320 Avcilar, Istanbul, Turkey
[b] Aluminium Test, Training and Research Centre, Fatih Sultan Mehmet Vakif University, Beyoğlu, Istanbul, Turkey

ARTICLE INFO

Keywords:
Selective laser melting
Overhang surface
ANSYS
Finite element analysis
AlSi10Mg
Laser

ABSTRACT

Selective Laser Melting (SLM) of three dimensional multi-layer model is being numerically investigated using finite element method with academic ANSYS software. The temperature distribution and melt pool formation with underlying solid base, support structure and loose powder is investigated in a single scan track. The results illustrate that the melt pool depth is deepest with the loose powder base but the regions adjacent to solid surface reduces the pool depth due to improved heat dissipation. Moreover, the liquid penetration increases with the layer addition and its intensity is dependent on input specific energy. The study suggests the selection of lower specific energy in the initial layers while designing overhang surfaces, clearance etc. to prevent excess powder melting beyond the layer thickness to achieve smooth surface.

1. Introduction

Selective Laser Melting (SLM) involves intricate melt pool phenomenon that necessitates detailed assessment to accomplish preferred results [1]. As of now, numerous experimental and numerical studies have been conducted in last one decade and several distinctive features have been discovered that paved a way to regulate the process more closely than ever [2–4].

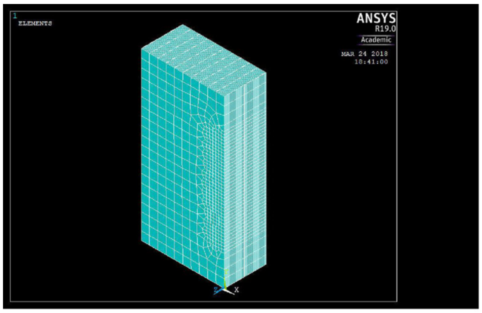
The recent embark of several giant industries in the production of 3D printing machines is expected to bring the technology to the doorstep of small to midscale companies and accessible to various Research Institutes to make a leap forward in advancement of Additive Manufacturing [5,6].

SLM is a layer wise fabrication of 3D parts using high powered laser that melts the powder readily to attain desired geometrical and physical features. The heat conduct through molten liquid melts the several layers beneath the active layer resulting in strong metal bonding [7]. However, the formation of melt pool is reliant on several other features for its size and shape. For example, the melt pool forms above the solid metal base, loose powder base, support structures or depending on location in the entire part forms differently [8–10]. Moreover, the material type, laser power, scan speed, layer thickness, scanning pattern options etc. are already known previously to results in different shape and sizes of the melt pool due to the varying heat inflow and its dissipation [11,12].

AlSi10Mg is one of the most frequently used Al alloy in several prominent industries for its excellent strength to weight ratio, high heat thermal conductivity and superior corrosion resistance that puts it ahead of other light metal alloys in several applications [13,14]. However, the additive processing of AlSi10Mg is full of challenges such as poor flowability, high affinity to oxides formation and high reflectivity that are needed to be tackled thoughtfully. Several successful studies have been conducted previously with different processing and material parameters to evaluate the microstructural and mechanical properties of processed parts to obtain

* Corresponding author.
E-mail addresses: hamaidmahmood.khan@ogr.iu.edu.tr (H.M. Khan), dirikolumh@istanbul.edu.tr (M.H. Dirikolu), ekoc@fsm.edu.tr (E. Koç), zcoter@fsm.edu.tr (Z.C. Oter).

https://doi.org/10.1016/j.ijleo.2018.05.081
Received 30 March 2018; Accepted 19 May 2018
0030-4026/



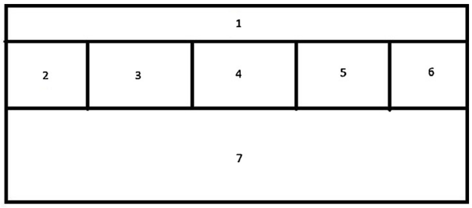


Fig. 1. (a) FE Model, (b) Solid, powder Regions layout in a schematic model.

attainable results [15–18]. However, the amount of work reported on critical overhang geometries with AlSi10Mg is quite limited and largely centered on trial and error basis or user's experience [13,19]. The present study is focused on the formation of dross in the initial layers of overhang geometries with and without support structures in terms of melt pool shape and to proposed a solution through numerical approach in handling processing parameters at such critical junctions.

The numerical study of melt pool formation has also been extensively explored using different finite element approaches on various metal alloys, polymers, composites etc. [20,21]. The formation of melt pool in a single track, multi-track or multi-layer study has revealed varying heat flow analysis different for different materials with or without support structures [22–24]. Some recent studies have also covered the FEM models of AlSi10Mg where the alloy melt pool shape and thermal gradient at the subsequent built of multi-layer structure is evaluated [3,25]. The current study will be focused on heat dissipation in structures built on solid base, support structures and loosely placed powder base as well as at the crossover of the aforementioned regions.

2. Numerical model

2.1. Finite element set-up

The finite element study was performed on ANSYS thermal transient model. AlSi10Mg was chosen for thermal study where the heat flow analysis in powder layer with solid substrate, powder base or underlying support structure as well as the heat flow at the junction of solid-powder interface in overhang geometries are evaluated. The Finite element model of a simple cubical geometry chosen for the analysis is shown in Fig. 1(a). The region of laser impact is finely meshed to better capture the variation in heat flow whereas the rest of the region is meshed coarsely. The ANSYS 19.0 student copy is chosen for the analysis which is provided with limited meshing capability having maximum of 32k nodes or elements.

The solution domain consists of symmetric cubical model of size 1.8 mm * 0.9 mm * 0.45 mm (L*W*H). The laser scanning is taken along the Y-direction having only single scan track while Z-direction is taken along the building direction. The entire 3D model is divided into 7 sections comprising of solid body, support structure and powder base apart from the top active powder layers and the underlying solid platform as shown schematically in Fig. 1(b). The active powder layer denoted by region 1 is where the high powered laser scans the top surface and the heat formed flows though it into the regions 3,4 and 5 respectively as the laser progress towards the end of the model along the Y-direction. The region 1 is further divided into 3 layers sequentially built over time. The platform denotes by region 7 will be used as heat sink. In order to capture the real scenario, the regions 2 and 6 denotes the surrounding powder region around the model to capture the heat dissipation at part ends. In this simulation, the model is meshed with 23,184 nodes and 20,700 elements using Solid70 element type.

2.2. Heat flow equation

The high powered laser is the only source of heat energy in SLM process that melts the powder particles into one single unit. The formation of liquid pool in any dense specimen extends well below the active powder layer to bind the underneath layers to form a uniform solid structure and its shape is strongly dependent on processing parameters, material parameters, the parts geometrical features as well as the layer position. The major mode of heat flow in the model is govern through conduction, convection and radiation and is expressed as follows;

$$k\frac{\partial T}{\partial \eta} - Q + h_c(T - T_0) + \sigma\varepsilon(T^4 - {T_0}^4) \tag{1}$$

The ambient temperature, T_0 in the chamber is set at 303 K. The other nomenclature includes thermal conductivities 'k' of either loose powder or solidified part are all temperature dependent. 'Q' represents the inflow of heat due to moving laser source, η is a spatial vector of powder surface, h_c is the convective heat coefficient, σ is the Stefan Boltzmann constant and ε is the emissivity of the powder AlSi10Mg.