Copper Heat Sinks: Design and Fabrication via Sinter Based Material Extrusion (MEX) 3D Printing

Kameswara Pavan Kumar Ajjarapu[1], Saleh Khanjar[1], Julio Izquierdo[1], Sundar V. Atre[1], Kunal H. Kate[1]

[1]Materials Innovation Guild, University of Louisville, Louisville, KY 40208

ABSTRACT

Copper heat sinks, especially for electronic applications, are typically manufactured using conventional techniques such as bonding, forging, folding, skiving, or machining. Such heat sinks tend to have simple fin/pin structures, partly attributed to the limitations of conventional processing technologies. In this work, we utilize topology optimization to overcome challenges in transforming decade-old traditional sink of heat design using the sinter-based material extrusion (MEX) 3D printing process. In this work, we developed a >90wt.% copper powder-filled polymer filaments to fabricate thermally efficient heat sink designs that were MEX 3D printed and subsequently processed to remove polymer (debinding) and sintered to achieve dense copper parts. It was identified that thick and thin features in heat sinks tend to debound at different rates due to the differences in surface area and amount of binder material that needs to be removed. Although this differential behavior poses challenges with retaining part integrity post debinding and sintering, it can be overcome using techniques such as topology optimization. Therefore, this study looks at understanding the structure-material property relationships behind 3D printing copper heat sinks by MEX-3D printing process by implementing topology-optimized designs that were tested for their thermal efficiency using simulation and experiments.

1 Introduction

A large segment of metal parts that are manufactured for consumer-based products are fabricated using traditional manufacturing processes (typically metal injection molding, casting, or machining). Extensive research has been conducted on such processing techniques and their influence on the structure and properties of final parts. However, such traditional manufacturing techniques suffer from limitations on design freedom. Heat sinks for electronic applications is one good example of consumer-based products that suffers from design constrains for to limitations on how they are conventionally manufactured. Inspite of multiple traditional manufacturing techniques such as bonding, folding, skiving, or machining, being used to fabricate these heat sinks, they still look similar in design as seen in **Figure 1(a)**. Therefore, a need for advanced manufacturing technologies such as additive manufacturing (AM) to manufacture a variety of metallic components was emphasized [1–5].

The ability to form very complex geometries that cannot be manufactured using traditional manufacturing techniques provides a new dimension for additive manufacturing to produce lightweight geometries that match or exceed the properties of geometries produced with conventional manufacturing processes [6–8].. Such design techniques like topology optimization, generative design, and lattice design have been utilized often for different AM techniques like L-PBF, SLA and binder jetting [9–11] but not for metal fused filament fabrication. Of the multiple AM technologies capable of manufacturing complex parts, material extrusion (MEX) is the most economical process as the cost of the machine/equipment, feedstock materials, and overall processing is relatively lower than other AM processes [4,5]. **Figure 1(b)** shows a typical MEX process overview where copper powder and polymeric binder are compounded and then extruded to produce filaments for 3D printing via fused filament fabrication (FFF) before debinding and sintering.