An Investigation on the Impact of Density on Electrical and Mechanical Properties of Pure Copper in Binder-Assisted, Sinter-Based Additive Manufacturing

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ABSTRACT

Pure copper exhibits high thermal conductivity, high electrical conductivity, and good mechanical properties. These properties make pure copper an excellent material choice for many thermal and electrical applications such as heat exchangers and electrical devices.

The development of pure copper in additive manufacturing (AM) has been of great interest. This is mainly due to design limitation in conventional manufacturing methods, and recent advances in AM that have enabled the production of topologically intricate parts with internal features.

This work presents the additive manufacturing of pure copper parts via Intelligent Layering™ which is a binder-assisted, sinter-based additive manufacturing technology with subtractive elements. A variety of test coupons were additively manufactured and subsequently, processed by hot isostatic pressing (HIP). The coupons were tested for density, electrical conductivity, and mechanical properties. The microstructures and porosity of the sintered parts were also studied.

INTRODUCTION

The use of copper has been prevalent throughout civilization and was found to be one of the first metals in history to be extracted and worked by humans [1]. At room temperature, pure copper has a thermal conductivity (k) value of 401 $W.m^{-1}.K^{-1}$, the highest of any non-precious metals, making it ideal for use in thermal management applications [2]. Similarly, copper also exhibits excellent electrical conductivity (σ) of 102% IACS (59.6 MS/m at room temperature), making it a fundamental material in electronic devices and electrical wiring [2]. Mechanically, copper is ductile and malleable, allowing it to be shaped and formed easily into wires, piping or sheet metal. Copper is also almost completely recyclable, reducing the need to mine new ore and minimizing waste. In addition, copper also has its niche properties such as it being antibacterial allowing the use in select healthcare and food processing applications.

Pure copper has increasingly been used in both binder jetting and powder bed fusion metal AM [3]. Copper is commonly manufactured by traditional methods, but AM has a unique advantage of producing complex internal geometries and consolidating several parts in an assembly into one part. By pairing copper's thermal conductivity with complex geometries enabled by additive manufacturing, pure copper AM finds a use-case in specialized heat dissipation applications (prominently heat exchangers and rocket engines with specially designed cooling channels) and electrical contacts.