# Leveraging Design for Additive Manufacturing to Remedy Low Internal Porosity in Metal Powder Binder Jetting

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**Abstract:** Metal binder jetting additive manufacturing (BJAM) is a scalable AM technology capable of producing highly complex metallic parts. However, the high porosity and propensity for distortion of sintered parts is an ongoing technological limitation which must be addressed. Previous work with water-atomized 4405 low-alloy steel has suggested a correlation between internal porosity of BJAM parts and the localized reducing potential during sintering, wherein higher porosity is observed at the core of a part due to poor gas flow and subsequent trapping of reduction by-products at these locations. In this study, we propose addressing core porosity using a design-driven approach, with incipient investigations of gas flow rate effects. The feasibility of printing gas flow channels within low-alloy steel parts and their effects on core porosity was investigated. To this effect, solid body blocks were manufactured alongside hybrid lattice/solid blocks, each encapsulating near-shape transverse rupture strength (TRS) specimens in their solid regions. High-resolution computer tomography (CT) and optical microscopy were used to elucidate the efficacy of enhanced gas flow through the lattice architecture vs. solid block in mitigating entrapped porosity in the gage section of specimens. Additionally, low-resolution CT elucidated the influence of the solid-lattice boundary interface on geometric fidelity of specimens, while the mechanical performance of relevant specimen classes was evaluated by TRS. Lastly, the effects of varying gas flow rate on specimen densification were quantified as an initial feasibility study.

## 1 Introduction

### *1.1 Metal binder jetting additive manufacturing*

Binder jetting additive manufacturing (BJAM) is a three-dimensional printing technology which utilizes a liquid-based adhesive called a 'binder' to selectively adhere powder particles in a powder bed, under ambient conditions [1, 2, 3, 4]. The manufacturing process begins with a CAD model which has been digitally segmented into printable cross-sections (layers). In metal BJAM, a thin layer of metal powder is spread on a build bed, onto which binder is selectively jetted to loosely adhere powder particles [1, 2, 3, 4]. This process is repeated to stack and selectively bond together subsequent layers, until the CAD model is reproduced as a geometry. Once printing is complete, all as-printed parts undergo a low temperature (~180 $^{o}$C, binder-dependent) curing cycle before all excess (unbound) powder is removed during a depowdering step [1, 2, 3]. These as-printed—or 'green'—parts retain their shape if delicately handled but remain fragile and are of low density (typically ~40-60%) [1, 2, 3]. Green parts are consolidated via an additional two-step heat treatment, where the cured binder is first pyrolyzed at a moderate temperature (typically 400-500 $^{o}$C, binder-dependent), followed by single- or multi-step sintering at high temperatures to densify and strengthen the part [1, 2, 3, 4].