3D Printed Powder Compaction Tools

S.Sundar Sriram
Sundram Fasteners Limited
Hosur, India 635109

Kalathur S. Narasimhan
P2P Technologies, New Jersey

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ABSTRACT

3D printed powder compaction tools made from high carbon alloyed ferrous powders have been successfully developed using Laser Powder Bed Fusion (LPBF). These compaction punches, used in powder metallurgy (PM) applications, are printed to near-theoretical densities and exhibit excellent mechanical integrity, remaining crack-free despite their high carbon and alloy content. The LPBF process enables rapid and cost-effective tooling development for both prototype and serial production of PM parts. The additive nature of the process ensures high raw material (RM) utilization rates, making it highly sustainable. Performance evaluations at standard compaction pressures up to 900 MPa confirm that the 3D printed punches are suitable for compacting a wide range of powder metal parts.

1. INTRODUCTION

The evolution of additive manufacturing (AM) has revolutionized the design and manufacturing of metallic components, offering significant advantages in terms of geometric complexity, material efficiency, and production agility. Among the various AM technologies, Laser Powder Bed Fusion (LPBF) has emerged as a particularly effective technique for manufacturing high-performance metal parts with near-net-shape accuracy and near-theoretical densities. This capability makes LPBF highly attractive for applications where dimensional precision and mechanical integrity are critical.

In the field of powder metallurgy (PM), the compaction of metal powders into green bodies using high pressures is a foundational step in the manufacturing of structural components. Traditionally, this process depends on precision-machined metal punches and dies, which are often costly and time-intensive to produce, particularly when accommodating design changes or developing new geometries.

Recent advances in 3D printing of tooling, specifically using LPBF with high-carbon alloyed ferrous powders, present a transformative opportunity for the PM industry. Additive manufacturing enables the manufacturing of compaction tooling with enhanced design flexibility, reduced lead times, and high degree of raw material utilization.

This study investigates the development of 3D printed powder compaction tools, with a primary focus on punches manufactured via LPBF. Emphasis is placed on evaluating their structural integrity, performance under typical PM compaction conditions, and feasibility for serial production. The work aims to demonstrate the potential of AM-based tooling to accelerate product development cycles and enhance manufacturing efficiency in the powder metallurgy sector.