TITLE: 3D Printed Steel Tooling and Dies for High Volume Part Production

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ABSTRACT

The benefits of 3D printing can be leveraged to manufacture tooling and dies with novel designs and conformal cooling that extend tooling and die lifetime and accelerate production. Realizing this benefit is challenging however as wrought tool steels cannot be easily printed using certain metal 3D printing methods, including laser powder bed fusion (PBF). Formetrix has developed a steel specifically for PBF that can be used to easily print tooling and dies with promising properties, including high hardness and toughness. In this paper, we will present the limitations in using traditional wrought tool steels in 3D PBF printing and the need to design new alloys specifically for 3D printing in this market. After comparing the properties of Formetrix alloys to industry standard tool steels, we will review specific case studies involving aluminum die casting, hot stamping, and compression forming to demonstrate how these new materials perform in high volume part production environments.

INTRODUCTION AND MOTIVATION

Additive manufacturing, or 3D printing, is the process of building a volume of material layer-by-layer. The benefits of this compared to traditional subtractive machining are too numerous to name and explore here, but of particular interest for tooling and dies is the ability to achieve near net shapes, form complex geometries, and incorporate conformal cooling. Doing so can enable innovation for new product designs and improve production efficiencies, indirectly reducing waste and costs.

Realizing the benefits of additive manufacturing in tooling and die is only possible if the right combination of printing process and material are available. Laser powder bed fusion (PBF) is one of the preferred metal additive manufacturing process for tooling and dies because it can generate parts that have near 100% density, high spatial precision for fine features and smooth surfaces, and superior properties compared to other additive processes. In PBF, a layer of powder is deposited in a two-dimensional plane where it is melted by a laser in select locations to become part of the piece being "printed". This process is repeated layer-by-layer until the desired piece is fully formed.

Conventional wrought tool steels, such as H13, M2, and D2, however, are challenging to print by PBF without gross cracking. To print H13 without cracking, for example, the printing must be done at elevated temperatures, which increases costs and production times as well as reduces consistency within and between parts. Even when these strategies for printing H13 are used, large parts, which are often the case for tooling and die, are still vulnerable to cracking during printing due to their size. Furthermore, PBF additively manufactured tool steels exhibit nominally no ductility or toughness.

In response to these limitations associated with PBF of tool steels, maraging steels, such as 18Ni300 or M300, and precipitation hardening stainless steels, such as 17-4 PH, have been deployed as substitutes in additive manufacturing tooling and dies by PBF. Although both M300 and 17-4 PH can be reliably printed crack-free using PBF at near room temperatures, the maximum achievable hardness of 17-4 PH is insufficient for most industrial tooling and die applications and the toughness and ductility of M300 at peak hardness are nearly zero despite the hardness and strength being sufficient (1; 2). Furthermore, M300 requires an aging heat treatment of several hours after printing to achieve similar properties as traditional tool steels (2). Adding this extra step increases the overall fabrication time and costs. Also, many maraging steels, including M300, rely on cobalt, which is being considered as toxic by some