9th International Conference on Hot Sheet Metal Forming of High-Performance Steel — CHS² 2024
27–29 May 2024, Nashville, Tenn., USA
10.33313/512/B0202

High-Temperature Friction and Wear of Hot Stamping Tool Materials Produced by Laser Metal Deposition

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Abstract

Additive manufacturing (AM) offers new possibilities in terms of product design and material tailoring. Thanks to the many advancements in AM in recent years, high-end applications have now become a reality. One potential field is the production of dies for hot stamping using this novel manufacturing route. AM can be used to produce tools with complex cooling channels that would be impossible to obtain with conventional manufacturing. Furthermore, tool refurbishing can be locally tackled with specific AM techniques such as laser metal deposition (LMD). Several works have shown the feasibility of producing fully dense and homogeneous AM parts of high-performance steel by combining process optimization and post-AM heat treatments. However, tribological studies on AM produced tools are still limited, particularly in the context of hot forming. Thus, the aim of this work is to increase the knowledge on the friction and wear behavior of LMD tool materials in hot stamping conditions. A high temperature strip drawing tribometer was used to perform sliding tests of tool steel samples produced by LMD. Two LMD materials were investigated: a hot-work tool steel and a conceptual high-hardness tool material. The counter-body was AlSi-coated boron steel strip. Workpiece test temperatures were 600°C and 700°C. All tribotests at 700°C resulted in AlSi-coating rupture, resulting in higher and more unstable friction. The wear mechanisms observed for LMD tool steel were a combination of abrasive and adhesive wear. At 700°C, these mechanisms were more severe. The high-hardness LMD tool material showed minimal signs of abrasive wear; material transfer was more spread-out, thinner, and patchier compared to the other LMD material. The LMD process itself did not seem to have either a positive or a negative effect on the tribological behavior of the tool materials.

Keywords: high temperature tribology; additive manufacturing; laser-metal-deposition; friction and wear mechanisms; hot stamping

1 Introduction

The advancements in additive manufacturing (AM) of metallic materials, particularly iron-based alloys, is opening the possibilities of using this technology in more demanding applications. In the past, AM was frequently limited to only producing prototypes (for years, *rapid prototyping* was used a synonym for AM) due to the several defects associated with the technology. However, today many of the issues related to metallic AM products have been overcome in one way or another. Porosity has been greatly reduced (or even virtually eliminated in certain processes) through the optimization of processes parameters [1]. Anisotropy and residual stresses can be reduced with post-AM heat treatments [2]. Thus, there is a growing interest in applying AM parts in more advanced applications, one of them being the production of dies for hot stamping processes. AM opens up the possibility of tailoring local properties, producing complex geometries (e.g., conformal cooling channels) and locally refurbishing the tool surface. Different AM processes have their unique advantages: selective laser melting (SLM) is ideal for achieving conformal cooling channels with minimum materials defects, as well as better manufacturing accuracy; laser metal deposition (LMD) would be the choice if depositing a new layer of tool material when refurbishing a die [3].

Yet even though there are several works reporting the advances in AM tool materials from a processing optimization and materials characterization point of view, there are few works pertaining the tribological behavior of materials produced by these manufacturing processes. This is especially important in the case of hot stamping tribology, since during interaction with workpiece material, the dies inevitably are exposed to both abrasive and adhesive wear [4,5]. Thus, the aim of this study is to