10.33313/512/A1001

Reducing Material Transfer in Hot Stamping of Aluminum via the Synergy Between Self-Lubricating Claddings and High Temperature Lubricants

Leonardo Pelcastre[1], Jens Hardell[1], Manel Rodriguez Ripoll[2]

Abstract

The hot stamping process for aluminium alloys has gained significant traction in recent years due to its potential for light-weighting in automotive components. However, achieving high-quality stamped parts with complex geometries requires precise control over surface interactions between the tooling and the workpiece. This study delves into the combined role of coatings and lubricants for optimizing the tribological interaction in the hot stamping process for aluminium alloys, with particular emphasis on the synergistic effects observed when employing a self-lubricating laser cladding in combination with a graphite containing high temperature lubricant. Three surface conditions were studied: an uncoated hot work tool steel, a laser deposited NiCrSiB cladding, and the same cladding containing lubricious aggregates of Ag/MoS_2. All surfaces were manually ground to a surface roughness Sa 0.3-0.4 µm. A commercially available graphite-based lubricant was applied on the surface of the tools prior to the tribological tests. Strip-drawing tribological tests with an Al alloy strip temperature of 300 °C revealed a significant contrast between coated and uncoated tool steels. Uncoated tool steels exhibited early lubricant failure, as seen by occurrence of aluminium adhesion, regardless of testing condition or amount of lubricant used. The cladding without the lubricious aggregates increased the distance before failure by 85%, and by 200% when the lubricious phases were present in the cladding. Similar behaviour was observed for the cladding containing Ag/MoS2 when sliding at 50 mm/s and 100 mm/s. At room temperature, similar behaviour was observed for the uncoated and coated tool steels, but in this case, the average coefficient of friction (CoF) was higher (0.24) compared to the tests at higher temperature (0.15). This work highlights the potential of coatings and lubricants in optimising the hot stamping process for aluminium alloys. The observed synergy between a self-lubricating cladding and a graphite containing lubricant presents a promising solution for friction control, wear minimisation, and reduction of tool maintenance in hot stamping of aluminium alloys.

1 Introduction

Hot forming processes enable automotive OEMs to exploit the light-weighting potential offered by high-strength aluminium alloys [1]. A variety of elevated temperature tribosystems in dry and lubricated conditions using hot work tool steels and an array of PVD coatings have been discussed, highlighting the challenges associated to aluminium forming [2]. Although investigated by different research groups, new materials, lubricants, and surface modification techniques are continuously developed, giving rise to knowledge gaps. For example, the use of different lubricants has been studied where the focus is to explore lubricants that can operate over a wide range of temperatures and their effectivity in minimizing material transfer. Ghiotti et al. [3] conducted hot strip drawing tests on lubricants containing graphite, molybdenum-disulphide, and boron-nitride reporting that graphite-based formulation provided stable lubricity between 300-500°C. Novel lubricant formulations such as electrostatically dispersed solid lubricants are still being evaluated for the hot forming of aluminium alloys [4]. The use of surface engineering techniques to improve the tribological behaviour has also been explored, with mixed results depending on what lubricants are used. Some PVD coatings have shown promising results in terms of friction control [5], whereas others show same or worse behaviour compared to untreated tool steels. There is a clear gap concerning surface engineering processes that can be used for alleviating wear and control friction. In this work, the aim is to evaluate and compare the frictional and wear behaviour of laser claddings with and without self-lubricating phases, in conjunction with commercial forming lubricants, and