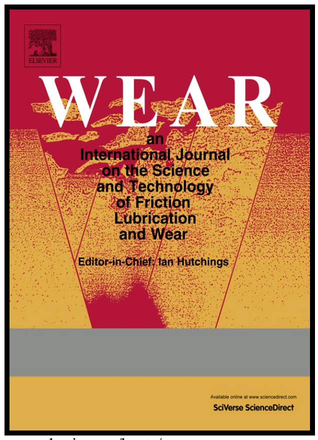
Author's Accepted Manuscript



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PII: S0043-1648(18)30069-3
DOI: https://doi.org/10.1016/j.wear.2018.04.006
Reference: WEA102398

To appear in: *Wear*

Received date: 12 January 2018
Revised date: 9 April 2018
Accepted date: 9 April 2018

The effects of temperature on friction and wear mechanisms during direct press hardening of Al-Si coated ultra-high strength steel

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Abstract

Direct press hardening is a non-isothermal sheet metal forming method which combines forming and heat treatment in a single process. However, due to the high temperatures during the forming phase, tool wear is severe and friction is high. In this paper, hot strip draw tests are utilised to assess the influence of the forming temperature on the coefficient of friction (COF) and active wear mechanisms during sliding of Al-Si coated Press Hardening Steel (PHS) strip in contact with uncoated tools under typical hot forming process conditions.
The COF is found to be temperature dependent during initial sliding against a virgin tool surface. Whereas, for 10 consecutive strip draws, COF is only temperature dependent for the first samples over the temperature range from 400^{o}C to 750 ºC. This would be due to the tribolayers which form in the tool-sheet contact during the test series. Conversely, the wear mechanisms active in this temperature range are temperature dependant: at higher temperatures (> 600 ºC) an area of severe abrasive wear is found that precedes a thick layer of compaction galling while at lower temperatures, (< 600 ºC) adhesive wear is dominant. Furthermore, the results show that particles leading to compaction galling are predominantly generated from the Al-Si coating and their size depends on temperature and are related to the fracture of the Al-Si coating.

Keywords: hot stamping; wear; friction; temperature effects; Al-Si coating; press hardening steel

Introduction

Direct press hardening is a process widely used to produce structural automotive parts that have complex shapes. In direct press hardening, the sheet is heated in a furnace (900-950 ºC), transported to a forming press where it is formed at high temperatures (typically 700-750 ºC) and directly quenched. In this way, good formability can be combined with high strength and low spring back. However, due to forming at high temperatures, the friction is high and the tool wear is severe [1-6].

The main wear mechanism observed in industrial tools is adhesive wear by material transfer from the Al-Si coating to the tools [1-3]. In laboratory setups, the material transfer of the sheet coating to the tool have been investigated in detail. High temperature pin on disc tests [2,4-11], strip drawing over radii [12-13], cup deep drawing [14], and flat strip draw tests [15-19] have all been used to investigate the wear mechanisms during press hardening. Pelcastre, et al. [4], Prakash, et al. [20], Vilaseca, et al. [3], Venema, et al. [19] and Pujante, et al. [1] make distinction between compaction galling and normal load adhesive wear. In compaction galling, wear debris accumulate easily within valleys of the surface or surface defects. These entrapped debris form compactions of the hard intermetallics of Al-Si mixed with oxidised debris from the coating/tool during sliding. The transfer layer (formed by adhesive and compaction galling) acts as an obstacle for wear debris to move out of the contact. The accumulation and later compaction of the wear particles result in more severe