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Novel extrusion punch design for elimination of punch ejection load and enhanced lubrication

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Abstract

The extreme surface expansion and pressures observed during the backward cup extrusion process can adversely affect the surface of the work-piece and diminish the life of the punches. To reduce or eliminate punch ejection load and galling commonly encountered in the backward extrusion process, a punch system composed of a main body punch and a punch nose insert is proposed. The nose insert is both an elastic strain field generator to facilitate punch removal and a gateway for lubricant transport. The preliminary test results have shown a marked reduction in both galling and the load required to eject the punch.

Keywords: Galling; Lubrication; Punch ejection load; Punch design

1. Introduction

The dies and punches in metal forming operations can be subject to mechanical, thermal, chemical, and tribological loads. These loads influence tool failure and the integrity of the part formed. Some of the challenges in employing forming operations to produce defect-free products are tool wear and adhesion of the deformed material to the die/punch surface, commonly referred to as galling. Galling can develop rapidly or gradually, depending on the nature of the loads exhibited at the tool/work-piece interface, tool surface roughness, mutual solubility of die-work-piece contact surfaces, etc. With repeated forming cycles, successive buildup of material on the tool can significantly shorten its life.

Metal forming processes rely on lubricant to reduce the high frictional forces at the tool-work-piece interface, which in turn lessens the probability of galling. Lubricants employed by the forging industry include conversion coatings, mineral oils with a myriad of additives, and several types of solid lubricants [1,2]. For severe cold forging of steel and of aluminum products, which exhibit high interface pressure and larger surface expansion, a conversion coating is necessary to ensure that the lubricant film does not break down [3]. The zinc phosphate-based conversion coating has been the industry standard for the last 80 years for the cold forging of steel, and aluminum fluoride is a common conversion coating for the forging of aluminum products [4]. The conversion coating adheres to the billet by chemical reactions that create a pre-coat on the base metal and bonds well with various lubricants, such as metal soaps and extrusion oils. Due to its strong bond to the part surface, the conversion coating is able to prevent the lubricant from being pushed away from the part surface when subjected to high loads [5].

Although many of these lubricants have been used for decades, they either are composed of harmful materials or are produced or applied using processes that cause harm. In the case of zinc phosphate and aluminum fluoride coatings, the process of applying them to the work-piece creates a heavy metal sludge that is difficult to dispose of and poses a risk to workers [4–6]. The phosphorus, chlorine, and sulfur additives used in the various mineral oils

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can be difficult to dispose of and handle. This is due to harmful byproducts, such as dioxins, and the possibility of the dispersal of the additives or their byproducts into the atmosphere, which requires specialized ventilation systems in the plant [7].

The demand for environmentally friendly lubricants has prompted the development of less toxic lubricant as an alternative to conversion coatings. These lubricants include MEC HOMAT, DAIDO Aqua-Lub, and SISU Chem [6,8]. Some of these lubricants have been shown effective, particularly for non-severe and medium forging operations. Another approach to addressing issues related to adhesive and abrasive wear of forming tools is modification of the tool surfaces to enhance tribological performance. Physical vapor deposition (PVD), chemical vapor deposition (CVD), and diamond like coating (DCL) are among the coating variants that have been introduced in the last decade [9–11]. For example, nitrided-type coatings have been found to perform well for dies used for aluminum alloy forging, whereas plasma nitriding and vanadium nitriding have shown to reduce galling in titanium forgings [12,13]. In a cold heading experiment to study the performance of PVD and CVD coatings of TiN on an AISI M2 tool, the CVD coated tool exhibited superior performance, whereas the PVD coating began chipping after rather few operations, leading to excessive friction. The billet material used was 34Cr4 steel. The better adherence of the CVD coating improved performance significantly [14].

The current study is aimed at addressing tribological issues pertaining to backward extrusion processes, with a focus on extrusion punch design. We first examine the mechanics of the backward cup extrusion process, which is characterized by a two-stroke operation cycle: a forward punch stroke to extrude the material and a backward stroke to eject the punch from the extruded part. During both the forward and backward strokes, the punch nose boundaries are subjected to high interface pressure. Thus, to prevent galling, the lubricant film should be intact during both strokes. In other words, if the lubricant is depleted (thinned out) on the internal formed walls of the cup, galling will occur as the punch is retracted from the extruded part. It should be noted that there is substantial pressure acting at the interface between the land of the punch and the cup wall during ejection. This pressure emanates from the compressive elastic strain fields on the extruded part as well as the elastic strain field from the die casing. The objective of this study is therefore to (i) establish a new class of cup extrusion punch, in which the elastic displacement field around the punch nose is manipulated such that during the backward stroke, the punch ejection load is eliminated; and (ii) establish a punch system in which lubricant is transported to the punch-work-piece interface.

2. Conceptual design

The two main areas that will be addressed by the proposed punch design are (i) improving the ejection of the punch so as to reduce galling and improve the part surface, and (ii) providing a lubrication transport mechanism that can satisfy even the area that has the highest surface expansion. In order to accomplish this, the punch will be treated as two parts: the main body and a nose insert. The nose insert has dual purposes: to manipulate the elastic displacement field within the nose punch and to serve as a vessel to transport lubricant to the interface.

In order to eliminate the ejection load, the punch system should have the ability to expand during the forward stroke and contract during the backward stroke. By introducing a conical-type insert as shown in Fig. 1a, the punch nose outer rim can be elastically stretched to OD + δ. This is possible because as the nose of the punch makes contact with the punch body on a conical taper, the forming forces will cause the nose insert to slide a small amount into the punch body. When the extrusion stroke is completed and the load on the punch drops to zero, the punch will deflect back elastically to its original shape, as depicted in Fig. 1(b). If the process is designed such that the elastic deflection of the punch is greater than the spring back in the material, the punch can be pulled from the part with no resistance. This could completely eliminate damage to the part caused by the ejection of the punch.

In order to supply lubricant to the interface, the nose insert can be fabricated with several micro channels that will allow the pressurized lubricant to be transported to the interface, as shown in Fig. 2. We will call this an inter-

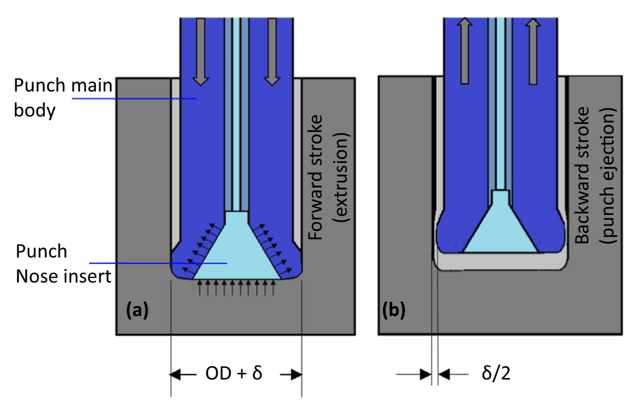

Fig. 1. Elimination of punch ejection load by manipulating elastic displacement field at the punch nose.

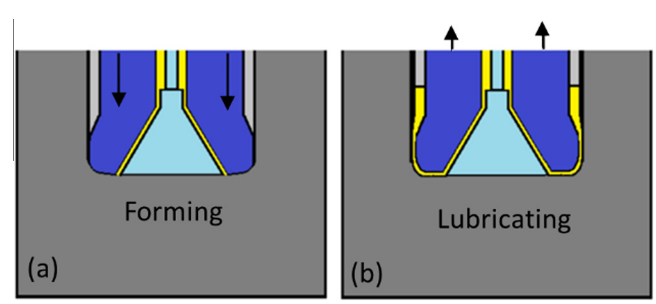

Fig. 2. Intermittent extrusion to supply fluid at the inteface.