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Contact Pressure Profiles in Axisymmetric Compression Considering Friction and Geometrical Factors

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Abstract

Contact pressures in open die forging of axisymmetric parts are mainly influenced by friction and billet geometry through the shape factor. In this work, a FE model has been developed for analyzing the compression of axisymmetric billets, assuming different friction conditions and shape factors of the workpiece in order to evaluate the contact pressures behaviour under compression and to determine general trends. A constant friction factor law is assumed, *m*, and the shape factor is determined as the ratio between the height of the workpiece and its diameter, *H/D*. Additionally, results are compared with those obtained by the SM method to validate the numerical model. The results presented in this paper demonstrate that the area of highest wear is located in different positions depending on the original geometry of the workpiece, so this information could be considered as a useful guidance when designing dies in more complex compression processes as well as in other recent related processes such as multi-material forming.

Keywords: forging; upsetting; axisymmetric; friction factor; shape factor; contact pressure; Finite Element Method

1. Introduction

Metal forming industry is well known by an efficient material utilization, excellent final material properties and high production rates. In the last decades, investigations have been focused in the development of new processes

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which can overcome some of the limitations and/or disadvantages of conventional ones. In fact, some of them are developed by combining some of these conventional techniques. Some recent examples are localized Incremental Forging (LIF) processes [1], which are based in the application of incremental forces in order to globally form the workpiece; there is also a growing interest in covering the gap of knowledge mainly concerning design criteria of multi material forming processes and its simulation [2]. Thus, to improve the knowledge in these new processes, it is advisable to get detailed information about the conventional ones through analysis tools. Different analytical techniques have been developed in order to study metal forming processes. Early methods are based on simple theoretical foundations, where only geometrical considerations and stress distributions are considered. Some examples are the Slab Method (SM), also called Sachs' Method [3], and the Upper Bound Theorem (UBT) [4]. Nowadays, analytical methods such as SM and UBT are commonly used to validate FEM results. Since decades, the Finite Element Method (FEM) has been established as an indispensable tool for metal forming analysis [5]. This numerical method is a powerful technique that takes into account the three main contributions to the total energy required (homogeneous deformation, friction and distortion). By using FEM it is possible to study at the same time the influence of several technological factors; although the effect of friction in metal forming processes has been analyzed since years [6-8], lastly some focus on the friction influence is being observed [9-12]. In compression of solid billets between parallel flat dies, the complexity of non-uniform deformation is not only represented by barrelling phenomenon due to friction [13] but also by the fact that a part of the initially free surface comes into contact with the platen during compression, phenomenon called folding [14]. The mode of deformation is also influenced by the billet geometry, measured by the shape factor [15]. The main aim of this work is to evaluate these phenomena for a best knowledge of the die-workpiece interface behaviour by means of contact pressure profiles. The influence of friction and shape factors on contact pressures is analyzed, which is important to investigate or understand in order to identify general trends of contact pressures under compressive conditions. This knowledge is directly related to some recent developments based on forming by compression, such as multi-material forming and can be also of guidance when more complex geometries has to be form, as in the case of impression-die forging. The knowledge of maximum contact pressures location can be helpful in order to predict die wear and subsequent die failure.

2. Methodology

2.1. Definition of cases

Contact pressure distributions for different geometries are going to be obtained under different friction conditions, defined by the so called friction factor. The different cases that are submitted to finite element analysis are shown in Table 1. The case codes denote how each FE model is named for an easy identification.

Table 1. Technological factors and case codes.

Case code	Diameter *D* (mm)	Height *H* (mm)	Friction factor *m*	Case code	Diameter *D* (mm)	Height *H* (mm)	Friction factor *m*
G1.0	10	3	0	G4.0	10	10	0.0
G1.1			0.1	G4.1			0.1
G1.2			0.2	G4.2			0.2
G1.3			0.5	G4.3			0.5
G2.0	10	5	0.0	G5.0	10	20	0.0
G2.1			0.1	G5.1			0.1
G2.2			0.2	G5.2			0.2
G2.3			0.5	G5.3			0.5
G3.0	10	7	0.0				
G3.1			0.1				
G3.2			0.2				
G3.3			0.5				