Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 149 (2016) 56 – 61

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Manufacturing Engineering and Materials, ICMEM 2016, 6-10 June 2016, Nový Smokovec, Slovakia

Effects of Holding Force on the Springback Behavior of Annealed Aluminum Plates

Muhammed Emin Erdin[a,]*, Alper Atmaca[b]

[a]*Hitit University, Çevre Yolu Bulvarı No: 8, Çorum 19030, Turkey*
[b]*Hitit University, Samsun Caddesi No: 99 Çorum 19169, Turkey*

Abstract

Typical V-bending process was performed to investigate the effects of holding force on springback behavior of 1050-H14 aluminum alloy plates annealed at 120 °C for 20 minutes. Tests were conducted on a universal testing machine with 60° V-bending mold. Various holding forces (2.25 kN which is slightly higher than the required force for bending operation, 5 kN, 10 kN and 15 kN) were applied at the end of the bending processes to investigate the hardening effect on springback values. The test results showed that annealing decreases springback values in all anisotropy directions. It is also clear from the test data that application of holding force has a significant affirmative effect on springback values.

Keywords: V-bending; springback; annealing; holding force

1. Introduction

Plastic forming of metal sheets/plates has a wide application area in industry. Bending is one of the most widely used sheet metal forming processes [1, 2], especially for aluminum components [3]. Common products obtained by bending are hoods of automotive and aerospace vehicles, wheelhouse panels, machine housings, pressure vessels, medical equipment, etc. [4]. Plastic forming of sheet metals is affected by a combination of various process and material parameters such as punch velocity, force, mold and material geometry, anisotropy, chemical composition of the material, heat treatment, etc. [5]. Mechanical properties such as strain hardening exponent, strain rate sensitivity exponent and texture also have significant effect on formability [6]. Springback is an important phenomenon in sheet forming operations, which occurs after removing the applied loads from the deformed sheet due to the elastic recovery in the workpart [7]. It is possible to reduce springback in bending operations by compressing the material between the punch and the die [8]. It is difficult to predict springback of the bent workpart analytically in a bending operation. Determination of springback by trial and error technique is costly and time consuming method [4]. Precise prediction of springback is very important for the design of forming tools and quality of the product [7, 9, 10]. At this point, experimental investigation have been mostly used to determine the springback behavior of bent specimens [2].

Number of researchers have investigated the springback behavior in bending operations over the past several decades. Bakhshi-Jooybari et *al.* [11] investigated the effects of sheet thickness, punch tip radius and sheet anisotropy on the springback of CK67 steel sheet in V-bending and U-bending processes by experiments and computer simulations. Bahloul et *al.* [8] examined the effects of geometry parameters in bending operations by finite element (FE) analysis to predict the punch load and stress distribution. Panthi and Ramakrishnan [12] proposed an analytical model based on strain and deformation energy to predict springback of metal sheets such as copper, aluminum and steel in arc bending. Sharad and Nandedkar [13] predicted springback steel sheets by using FE analysis, for various die radii, sheet thicknesses, R/t ratios and strength coefficients. Nasrollahi and

* Corresponding author. Tel.: +90-533-711-1384; fax: +90-364-227-4535.
E-mail address: eminerdin@hitit.edu.tr

doi:10.1016/j.proeng.2016.06.638

Arezoo [5] studied the springback in sheet metal components with holes on the bending area using experimental measurements, FE method and neural networks to understand the influence of process variables such as hole type, number of holes, the ratio of hole width to sheet width, die radius and pad force on springback behavior. Panthi et *al.* [14] used FE method to determine the effects of geometry and material properties, and friction on the springback in bending operations. Chan et *al.* [15] specified the significant effects of mold tip and lip radius, and bending angle on springback behavior according to the results of the performed FE analyses. As clear from literature review, most of the former studies were conducted via FE analyses. Furthermore, effect of holding force applied at the end of the process has not remarked detailedly. In the present study, typical V-bending tests were performed on a universal testing machine to investigate the effects of holding force on springback behavior of 1050-H14 aluminum alloy plates annealed at 120 ^oC for 20 minutes by comparing with standard (not annealed) counterparts. Various holding forces were applied at the end of the bending operations to determine the effect of hardening on springback values.

Nomenclature

C, K	strength coefficients
E	elasticity (Young's) modulus
HB	Brinell hardness
L	length
m	strain rate sensitivity exponent
n	strain hardening exponent
R	mould tip radius
r	mould lip radius
r_n	normal anisotropy/mean plastic strain ratio
T	temperature
T_m	melting temperature
t	thickness
w	width
β	bending angle
ε	strain
$\acute{\varepsilon}$	strain rate
υ	Poisson's ratio
ρ	density
σ_y	yield strength
σ_y	ultimate tensile strength

2. Theoretical Background

As all metal forming processes, V-bending is an elastoplastic deformation operation as schematized in Fig. 1. Before the yielding of the workpart, deformation is elastic. Thus, elastic part of the deformation returns after the bending load is removed due to elastic recovery which leads to springback.

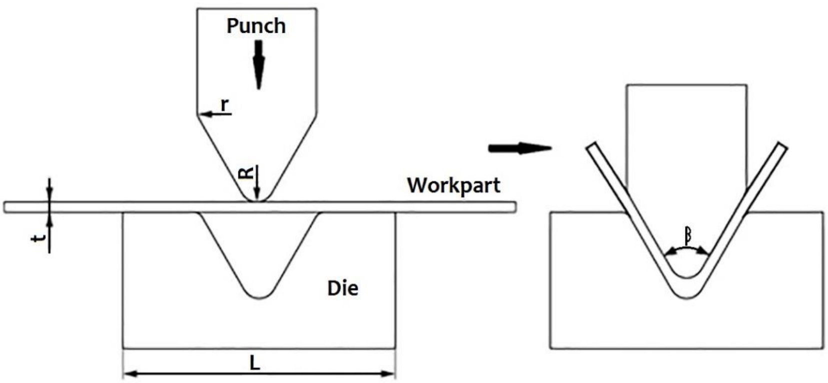

Fig. 1. Schematic drawing of V-bending process.