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# Process parameter design of spring-back and spring-go in V-bending process using Taguchi technique

Sutasn Thipprakmas *, Wiriyakorn Phanitwong

*Department of Tool and Materials Engineering, King Mongkut's University of Technology Thonburi, Thailand*

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ABSTRACT

Bent parts of complex shapes with high precision are increasingly required. To achieve a high precision of parts, especially the required bending angle, a suitable design of process parameters is strictly considered. In this study, process parameters of bending angle, material thickness and punch radius were investigated. The finite element method (FEM), in association with the Taguchi and the analysis of variance (ANOVA) techniques, was carried out to investigate the degree of importance of process parameters in V-bending process. The results revealed that the degree of importance of process parameters in V-bending process depended on the spring-back and spring-go. The material thickness has a major influence on the spring-back. In contrast, in the case of spring-go, the bending angle has a major influence and closely followed by the material thickness. In addition to predicting the degree of importance of process parameters by the combination of the FEM simulation, the Taguchi technique, and the ANOVA technique, by facilitating an improvement in the quality of the required bending angle was strictly considered by optimization of these process parameters corresponding with the spring-back and spring-go.



## 1. Introduction

Formation of high-precision sheet metal is one of the main objectives in many manufacturing industries. It plays a significant role in automotive industries, electronics industries, and housing-utensil industries. To fabricate the curved parts in the production of various items, with an economical set-up and enormous range of parts of complex sizes and shapes could be fabricated; the sheet metal V-bending process is commonly applied. Accuracy in the dimension of bent parts, especially the bending angle, is of utmost importance. In past researches, numerous finite element method (FEM) simulation and experimental works were conducted in understanding the bending feature [1–22]. However, the spring-back was studied in most of these researches. For examples, Zang et al. [1] studied the constitutive model for spring-back prediction in which the change of Young's modulus with plastic deformation is considered. Leu and Hsieh [2] investigated the influence of the coining force on spring-back reduction in V-die bending process. Wang et al. [3] studied the spring-back control of sheet metal air bending process. Tekaslan et al. [4] determined the spring-back of stainless steel sheet metal in V-bending dies. Meinders et al. [5] studied spring-back prediction and optimization using the numerical analysis. Kim and Koc [6] investigated the spring-back characteristics of aluminum sheet metal alloys in warm forming conditions using the numerical method. Yu [7] investigated the variation of elastic modulus during plastic deformation and its influence on spring-back. Kazan et al. [8] predicted spring-back in wipe-bending process of sheet metal using neural network. Ozturk et al. [9] investigated the tensile and spring-back behaviour of advanced steel of high strength (DP600) at warm temperatures. Parsa et al. [10] studied the spring-back of double curved aluminum/polypropylene/aluminum sandwich sheet by using FEM simulation and experiments. Panthi et al. [11] studied the spring-back prediction of sheet metal bending process by using FEM. It is not only the occurrence of spring-back but also the occurrence of spring-go that has effect on the bending angle. In recent years, the spring-go has also been conducted to understand the bending feature as well as to achieve accuracy of the bending angle. Thipprakmas et al. [12–14] investigated the spring-go phenomenon, as well as the effects of punch height and the ratio of punch to workpiece length. Bakhshi-Jooybari et al. [15] studied the spring-back and spring-go of CK67 steel sheet in V-die and U-die bending processes.

With the bending process, there are various process parameters with different adjustment levels, which may affect the spring-back and spring-go as well as the bending angle. Although many researches have been conducted, the process parameter design for controlling the spring-back and spring-go has not been researched yet. In this study, therefore, the Taguchi and the analysis of variance

* Corresponding author. Address: 126 Prachautit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand. Tel.: +66 24709218; fax: +66 28729080.
*E-mail addresses:* sutasn.thi@kmutt.ac.th, sutasn@gmail.com (S. Thipprakmas).

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