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Design of process parameters in wiping Z-bending process using statistical analysis technique

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Abstract

With the more severe requirement for the wiping Z-bent parts, in recent years, the high dimension precision is required. The major forming problem of spring-back is the main barrier faced in product quality upgrading in the precision bent parts. With the various process parameters, including bend angle, material thickness, tool radius, web height and workpiece length, these resulted in the processing difficulty in the control of spring-back feature. However, these process parameter designs for controlling the spring-back characteristic has not been researched yet. In this study, therefore, the effects of these process parameters were investigated by using the finite element method (FEM) simulation. In addition, the process parameter design was also examined by using the combination of the FEM simulation, and statistical analysis technique to determine the degree of importance of each process parameter. The experiments were carried out to validate the FEM simulation results. The results elucidated that the material thickness, bend angle and tool radius have a major influence on spring-back characteristic, respectively.

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Keywords: Z-bending; Spring-back; Analysis of variance (ANOVA); Finite element method

1. Introduction

In many industrial fields such as an automotive industry and a housing-utensil industry, by using a die, a bending process is widely employed to form curved shapes in sheet-metal parts. In recent years, the more severe requirements of high dimension precision for the industrial sheet-metal parts are required. The spring-back is the principal forming problem faced in product quality upgrading in the precision bent parts. In the past, most researches

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of bending process were carried out to develop with the different ways for achieving the precision bent parts via the finite element method (FEM) and experimental analysis [1-5]. However, almost all of the past researches were performed the L-, V-, and U-bending processes [1-5]. Only a few researches were done on the Z-bending process [6, 7]. Therefore, it resulted in a lack of some understanding for the improving this Z-bending process to achieve the precise bent parts. In the present research, to have much more understanding of Z-bending process, a wiping Z-bending process being one type of Z-bending process was investigated. The FEM was used as a tool for investigating the effects of process parameters on spring-back characteristics and obtaining the spring-back characteristics as well as the laboratory experiments were performed to validate the FEM simulation results. Next, by using the combination of the FEM simulation and statistical analysis technique, the process parameter was also examined to determine the degree of importance of each process parameter. As the results, the statistical analysis results are able to specify the process parameters that markedly influence the spring-back characteristic and yield information about the degree of importance of each process parameter on the wiping Z-bending process. The results elucidated that the material thickness, bend angle and tool radius have a major influence on spring-back characteristic, respectively.

2. FEM-simulation and experimental procedures

In the present research, as shown in Fig. 1, the investigated model of wiping Z-bending process was illustrated and the measured bend angles in the Z-shape parts was also depicted. Next, Table 1 lists the details of this model and the process parameter conditions. A two-dimensional plane strain was applied. The two-dimensional, implicit, quasi-static finite element method of a commercial analytical code, DEFORM-2D, was used for the FEM simulation. The punch, die, and blank holder were set as rigid types and the workpiece material was set as an elasto-plastic type. The rectangular elements approximately 4,000 elements were generated on workpiece material. The aluminum A1100-O (JIS) was used as workpiece material in the present research and its properties were taken from tensile test data [3, 7].

To examine the degree of importance of process parameters in relation to the spring-back characteristic, as listed in Table 1, the three levels of the five parameters, including bend angle, material thickness, tool radius, web height and workpiece length were applied. In the present research, owing to the lower bend radius was set by the tool radius (R_p) and material thickness (t), the investigation of it was neglected. On the basis of the central composite design technique, the experimental design was performed and the 43 experiments, in total, were carried out as listed in Table 2. The Analysis of variance (ANOVA) technique was also applied to illustrate the degree of importance of each parameter that markedly influenced the spring-back characteristic, as depicted in the equation (1)

$$\%\ Contributions = [SeqSS_{treatment} / SS_{total}] \times 100 \qquad \ldots\ldots (1)$$

Where $\%Contributions$, $SS_{treatment}$ and SS_{total} represent the degree of importance of each parameter, the treatment sum of squares and the total sum of squares, respectively.

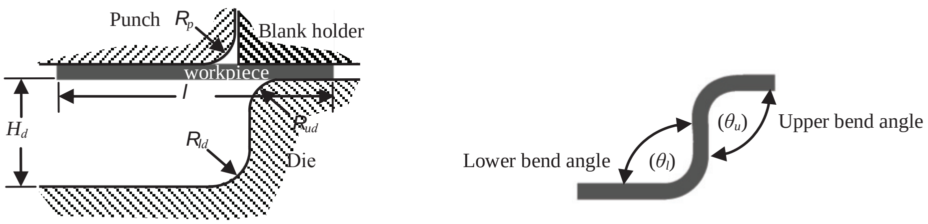

Fig. 1. FEM simulation model and measured bend angles.