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Experimental Study on Die Shoulder Patterning Method (DSPM) To Reduce Springback of U-bending Hat-Shape Part

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ABSTRACT: In the sheet metal industry, such as car door pillars, U-bending is becoming more common. However, when extracting sheet metal from fixtures, the springback phenomenon often occurs, resulting in a change in product efficacy, waste of material, and an increase in production costs. As a result, minimising springback in sheet metal bending is critical for maintaining tight geometric tolerances in the deformed component. Experiments and simulations have been used by several researchers to investigate and predict the occurrence of springback. Regardless, no studies on the application of die shoulder patterning to reduce springback in hat-shaped parts have been conducted. The hat-shaped component is deformed in this paper using a new develop forming process, which has been tested and validated using new finite element prediction. As predicted, die shoulder patterning dominates springback sensitivity, with hat-shaped parts having a lower springback due to a larger contact region. Springback is greatly reduced in AISI 1030 due to the optimised sliding tension between the die shoulder and the blank board.

Keywords: *Springback; U-bending; Patterning*

1. INTRODUCTION

Sheet metal U-bending is becoming more common in the production of beams and car fenders. [1-2]. Most manufacturers agreed that this forming method is the simplest and effective for producing hat-shaped pieces. It also aids mass production because it could produce the same commodity at a high rate at a low cost while maintaining high quality. However, since manufacturers rely on different sheet metals, such as low-carbon steel, the springback phenomenon has become an increasing concern for them. After removing the final part from the fixture grips, sheet metal is likely to have experience returning it to its original shape. The springback phenomenon is known as the elastically driven changes in the shape of a part after it has been released after the forming phase.

A numerical prediction based on fundamental theories or assumptions of engineering beams in U-bending is one of the solutions in previous springback behaviour investigation. They use modification of the tool curves for bending of sheet metal under minimal tension [3]. On the other hand, these assumptions can only be implemented for small-springback in pure bending case. In past study, there are fewer investigation carrying out carefully and professionally managed experiments of springback under practical forming conditions (i.e., involving bending and unloading simultaneously with applied friction and sliding over the tooling) [4]. Other researchers focus on material indirect realistic experiments such as stretch-bend tests or tensile tests; nonetheless, these tests are not meant for final parts in large scale productions [5]. Over the years, surface patterning has been widely recognized to play a crucial role in engineering components' structural integrity [6]. A. Godi designed a new typology of patterned surfaces using the axial sliding technique (AST) has successfully reduced up to half of the frictional forces at normal loads compared to no patterned surfaces. They claimed it improved the components' performance, such as carrying a systematic load and offering extra-lubrication valley [7]. However, their micro-patterned AST only suitable for rod-type components and not applicable to hat-shaped components. This research introduced a new method of springback improvements using a set of an insert that was patterned on the corner shoulder act as the die shoulder to produce the best final hat-shaped parts in U-bending.

2. METHODOLOGY

2.1 Die Shoulder Patterning Method (DSPM)

A novel die surface patterning technique (DSPM) to improve the structural integrity of hat-shaped components is introduced as shown in Figure 1 in which the die insert was designed with a rib pattern.

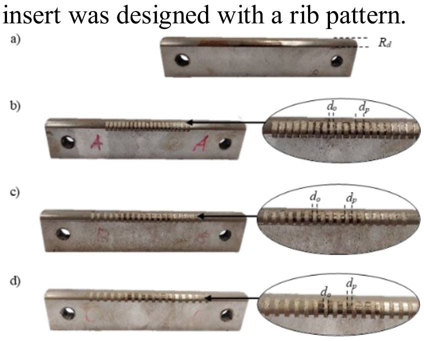

Figure 1: The die inserts with DSPM a) no pattern, b) P1, c) P2, d) P3

Four different type of DSPM is designed as tabulated in Table 1. A set of DSPM with no treated treatment made as standard designed to differentiate between DSPM and non-DSPM. Three set of pattern is differentiate by radius pattern, rib size and pitch distance. For each experiment, a set of pattern were clamped inside the body of dies and three blanks were formed into hat-shaped parts. The U-bending process was conducted using a hydraulic press machine, and the parameters were selected based on previous studies and availability. Afterward, the measurement analysis of formed hat-shaped was investigated using coordinate measuring machine (CMM) to reveal the nature of the springback after removal from the fixtures grips.

Table 1 Design of die shoulder patterning

Pattern	Type	Radius corner, R_d (mm)	Rib size, d_o (mm)	Pitch distance, d_p (mm)
No Pattern	Null	5	0	0
P1	Vertically	5	2	0.2
P2	Vertically	5	2	0.4
P3	Vertically	5	2	1

3. RESULT AND DISCUSSION

The measurement of springback in this work consisted of one region at flange-wall of $\theta_{I,L}$ which were satisfactorily analysed as shown in Figure 2. To better comprehend the DSPM, an eccentric analysis of the flange shape and longitudinal strain distribution along the top and bottom portions of the twelve forming structures was summarized. The parameters used was the blank width, w in millimeters and press holding time, t in second as tabulated in Table 2. All the angle obtained were compared to the optimum springback angle of hat-shaped parts of 90˚ after removing from the fixtures.

According to the angle obtained at $\theta_{I,L}$, the non-DSPM has the highest angle of 95.258˚ during 1s of press holding time which was the furthest from the optimum angle needed. To add, the non-DSPM also has the lowest angle of 84.743˚ during 3s for hat-shaped width of 20 mm. The absence of die patterning was one of the contributing elements to this result. As a result, the non-DSPM was rejected because it lacked sufficient contact area, particularly in the flange-wall areas, throughout the press holding time intervals required to achieve the ideal springback angles. Meanwhile, the obtained angle for P1, P2 and P3 were close to the optimum angle needed throughout the experiments due to the pattern involved as it gives less wall friction and larger contact area during U-bending process.

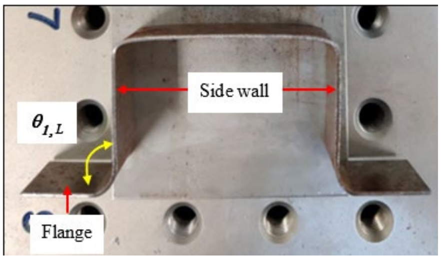

Figure 2: Springback measurement of hat-shaped part

Table 2 Springback measurement data for $\theta_{I,L}$.

Type of DSPM	Set of Experiment	Blank width, w	Angle obtained at flange-wall of $\theta_{I,L}$ — Press holding time, t: 1s	3s	5s
Non-DSPM	1	20	95.258	84.743	89.232
	2	25	86.593	90.89	91.742
	3	30	91.948	91.562	90.612
P1	1	20	92.322	92.28	91.231
	2	25	90.879	91.744	92.099
	3	30	91.287	89.835	90.343
P2	1	20	91.712	91.243	91.195
	2	25	89.543	90.623	91.204
	3	30	90.204	90.973	90.917
P3	1	20	91.829	91.061	91.001
	2	25	91.349	90.917	90.567
	3	30	90.715	90.238	91.033

4. CONCLUSION

In conclusion, the obtained measurement variables for all DSPM models (P1, P2, and P3) had significant effects on springback characteristics except for the non-DSPM. P2 was chosen as the best DSPM with a R_d of 5 mm, d_o of 2 mm and d_p of 0.4 mm because P2 successfully minimised the springback angle as the contact area and sliding stress between the die shoulder and surface of the blank were optimised for AISI 1030 blanks. To sum up, one of hypotheses accepted was the longer the press holding time used, the closer the angle to the optimum springback angle as the sliding stress is reduced. For future research, different DSPM shall be considered to enhance further the springback of U-bending.

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