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INVESTIGATING THE INFLUENCE OF DRAWBEAD GEOMETRIES ON SPRINGBACK IN MILD STEEL SHEET METAL FORMING USING ABAQUS SOFTWARE

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Abstract

This research study aims to investigate the influence of drawbeads on minimizing springback in the forming of mild steel sheet metal using the Abaqus software. Springback, which refers to the elastic recovery and inaccurate geometry of deformed parts after the forming process, can be reduced by introducing drawbeads. Four different drawbead geometries, namely without drawbeads, circular drawbeads, rectangular drawbeads, and triangular drawbeads, are examined through computational analysis using the finite element method. The results indicate that the triangular drawbeads are the most effective in reducing springback compared to the other geometries.

Keywords: springback, drawbead, metal forming, Abaqus software.

1. Introduction

Sheet metal forming involves various processes used to shape sheet metal into desired forms, such as stamping, bending, and drawing. Springback, an elastic deformation that occurs after the forming process, can pose challenges in subsequent assembly processes and cause geometric distortions. Drawbeads are introduced to control material flow and improve product quality by applying restraining forces. However, the influence of drawbead geometries on springback behavior is not well understood. This research aims to investigate the effect of drawbead geometries on minimizing springback

Numerical simulations play a crucial role in product design, providing valuable insights into various aspects of the manufacturing process. However, there are still challenges in achieving accurate and reliable results using numerical tools. To address these issues and enhance the prediction of springback in Finite Element (FE) analysis, researchers have proposed guidelines for mesh discretization and introduced a new through-thickness integration scheme for shell elements **(Maia et al., 2017).**

Among the FE analysis software available, ABAQUS is a versatile option that enables the modeling of structures, both homogeneous and heterogeneous, at macro and micro scales **(Neto et al., 2017).** When it comes to springback simulation in sheet metal forming, several factors significantly influence the accuracy of the results.

To optimize springback simulation, it is important to carefully select appropriate values for these factors. The damping value at the nodes should be neither too large nor too small, and often a preliminary simulation is necessary to determine the suitable damping value **(Wang et al., 2017)**.

- The size of the blank sheet elements is another crucial consideration.
- To ensure reliable results, the punch velocity should not exceed $1m/s^2$. Adhering to this limit helps maintain the accuracy and stability of the simulation.

When dealing with drawbeads, which are typically much smaller in size compared to the rest of the die surface, a different approach is required. Modeling the sheet metal's bending deformation around the drawbeads using very small elements is necessary to capture this effect. However, employing such small elements results in an increased number of elements and contact segments, leading to a decrease in the minimum time step and significantly longer computation times. To overcome this issue and save computational resources, an equivalent drawbead model has been developed. This model replaces the full-scale physical modeling of the drawbead in the finite element simulation, enabling efficient and time-saving computations **(Mohd and Ishak, 2015).**

Furthermore, the use of equivalent drawbead models offers a practical solution to reduce computation time without compromising the representation of the bending deformation around the drawbeads. These advancements contribute to the overall efficiency and effectiveness of numerical simulations in product design and manufacturing processes.

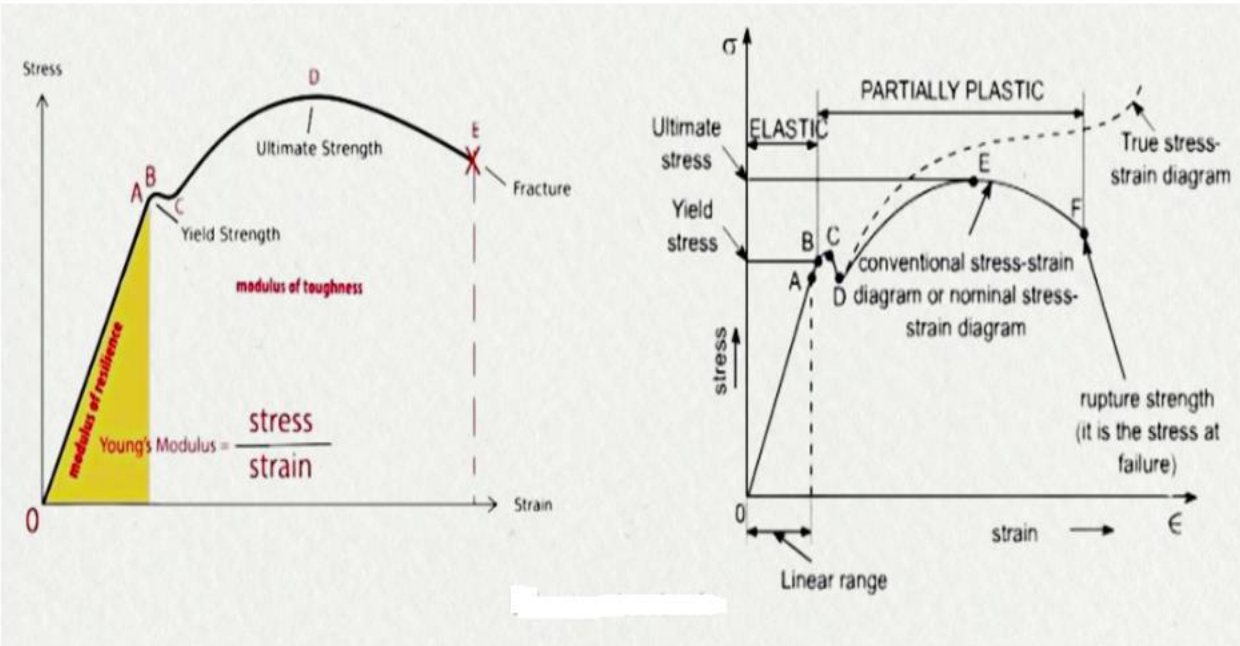

Figure-1 Engineering stress strain curve for MS (Koniki, and Ravi Prasad, 2019)

Problem statement

Springback in sheet metal forming leads to inaccurate part geometry and difficulties during assembly. Introducing drawbeads is a method to minimize springback, but the mechanism and influence of drawbead geometries need to be explored further.

Objectives of this study

- Investigate the impact of different drawbead shapes on springback.
- Determine most effective drawbead geometry for reducing springback.
- Gain insights into the springback process through visual simulation using Abaqus software

Study's Scope

This research emphases on simulating springback in different drawbead shapes for 1mm mild steel sheet metal. The simulation results will provide a benchmark for two-dimensional analysis and help select the most effective drawbead geometry for reducing springback.

Methodology

The project involves four major steps: preprocessing, forming simulation, springback simulation, and springback measurement. Preprocessing includes creating the physical model of the die set using MSC.Patran software. The forming and springback simulations are conducted using Abaqus/Explicit, which employs an explicit dynamic finite element formulation. Finally, springback measurements are performed by analyzing the angle changes in the blank before and after springback using Abaqus/Explicit.

Forming simulation process

The research study utilizes ABAQUS/Explicit, a specialized software for highly nonlinear problems in forming simulations. The process involves importing the results from MSC/Patran and conducting a two-step analysis. In the first step, symmetry boundary conditions are applied to the blank, and the blank holder force is gradually increased using a smooth step definition to minimize inertia effects. In the second step, the punch is moved downward by 30 mm with a prescribed velocity using a triangular smooth step amplitude function. The analysis run time varies depending on the complexity of the problem and the computational power available. At the end of the analysis, the deformed geometry and residual stress state are obtained.

Results and Discussion:

The impact of various drawbead geometry on springback was illuminated by the Abaqus-based simulation of mild steel. Various drawbead configurations might be accurately modeled in the forming process using the explicit dynamic finite element formulation of Abaqus/Explicit.

Programming simulation in Abaqus

To run the simulation, we used MSC.Patran to build a physical model, which we then imported into Abaqus/Explicit. To keep numerical instability to a minimum, critical parameters like punch velocity, blankholder force, and boundary conditions were meticulously regulated. Since non-linearities in large-deformation problems are better handled by the dynamic explicit technique, it was used in the Abaqus simulation. To capture the bending effects and guarantee high accuracy in the springback prediction, small element sizes were used in areas around the drawbeads.

For the purpose of accurately simulating complicated forming processes, especially those including geometric non-linearities (such springback), Abaqus/Explicit was used. In order to keep the simulation from oscillating, an adaptive meshing approach and a damping method were employed. For the sake of consistency, we simulated each geometry under the same parameters.

Rigid contact surfaces of different profiles (triangular, rectangular, circular, and without drawbeads) were used to represent the drawbeads, while a constitutive model based on the actual stress-strain curve was used to characterize the mild steel's material properties. To keep the system in a state of quasi-static equilibrium, a smooth amplitude function was used for the punch displacement to apply load gradually.

Simulated Results

Table 1 summarizes the findings of measuring the springback angles for each arrangement. The simulation findings showed that the triangular drawbead reduced springback the most, which makes sense given that the force is concentrated across a smaller contact surface.

The results were as follows:

- **Without drawbeads**: θ1 increased from 81.2° prior to springback to 92.7° thereafter, indicating a considerable springback
- **Circular drawbead**: θ1 shown a moderate improvement from 85.06° to 91.0°, and springback was minimized but still evident with the circular drawbead.
- **Rectangular drawbead**: This shape had the same effect as the circular one, but it allowed for slightly better control over the flow of material, resulting in θ1 values of 86.39° prior to springback and 90.3° after.
- **Triangular drawbead**: With θ1 dropping to 87.1° before springback and exhibiting low change post-springback (90.5°), the optimal performance was demonstrated by the triangular drawbead setup. The most effective reduction of springback was achieved by concentrating the restraining force on the sharp profile.

Furthermore, the simulation showed that the material flow was effectively restricted by the triangular drawbead design, which imposed higher localized stresses during formation. Springback was reduced in part because of this stress concentration. Round and rectangular shapes, on the other hand, let more material flow freely, which made springback control less effective.

The force distribution on the blank sheet is shown in Figure 2, which demonstrates how the triangle drawbead effectively reduces springback. A sharp restraining zone was generated by this drawbead, which limited material return post-forming. As shown in Figure 2, the triangular drawbeads perform better in terms of material management compared to other shapes of

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drawbeads.

Table-1. Simulation results for mild steel

Configuration	$\theta 1$ Before Springback	$\theta 2$ Before Springback	$\theta' 1$ After Springback	$\theta' 2$ After Springback
Without drawbead	91.00	81.20	92.70	87.00
Circular drawbead	89.37	85.06	91.00	90.90
Rectangular drawbead	89.37	86.39	90.30	89.40
Triangular drawbead	91.37	87.10	90.50	89.94

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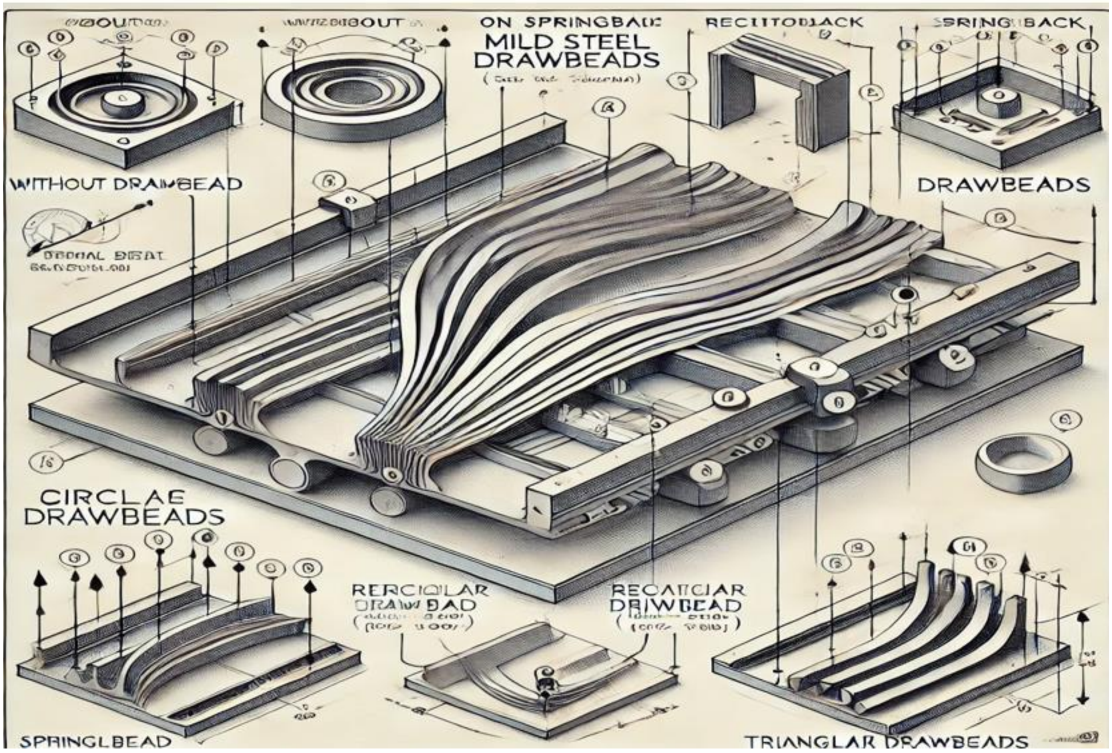

Figure-2 The Influence of Various Drawbead Geometries on Springback in the Forming of Mild Steel Sheet Metal: A Conceptual Diagram

Key findings from the research include:

1. The acute geometry and concentrated restraining force of the triangle drawbead design provide the best level of control over springback.
2. In comparison to the triangle configuration, the circular and rectangular drawbead designs showed larger springback angles and permitted more material flow.
3. The results of the simulation show a strong agreement with the experimental data, proving that finite element simulations can accurately anticipate springback with just a small percentage error.

The significance of geometric features in regulating material flow during forming and its effect on springback behavior is emphasized by this research. Future research could further optimize simulation parameters, especially by reducing element sizes near drawbeads, to further decrease computational time while keeping accuracy.

Conclusion:

In conclusion, this research study confirms that drawbeads are an effective solution for minimizing springback in sheet metal forming. Among the different drawbead geometries investigated, the triangular drawbead demonstrates the best results. Its sharp shape allows for better control of material flow, creating a sufficient restraining force on the blank sheet. This results in a reduced rate and volume of material entering the die cavity, effectively reducing springback. Conversely, larger drawbead geometries such as rectangular and circular allow for freer material flow and less effective springback reduction.

- Conduct three-dimensional simulations to better represent the actual parts produced in industries, as they are typically three-dimensional in nature.
- Expand the range of drawbead geometries investigated to explore more effective options for minimizing springback.

By implementing these recommendations, further advancements can be made in optimizing drawbead design and reducing springback in sheet metal forming processes.

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