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Modeling and Analysis of Forming Die: A Comparative Study of Numerical and Analytical Results

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Abstract

The standard sheet metal forming technique of "deep drawing" is used to create intricate 3D components from thin sheet metals. Deep drawing is a crucial metal-forming method in many industries. Deep drawing is a complicated deformation that is influenced by process and geometrical variables. Optimization of the deep drawing process is a difficult undertaking. New deep drawing techniques are needed in industrial applications due to the complexity of fabric and textile composite geometries. Modern incremental shaping techniques seem to be particularly beneficial in this situation. The capacity to forecast the elastic spring back, the residual stresses in a draped woven fabric, and the ability to draw reasonable judgments about the incremental forming procedure have also recently evolved. In this paper, the press tool is designed and modeled in SolidWorks and Finite Element Analysis (FEA) results were calculated in ANSYS Workbench 17.1 and compared with analytical results.

Keywords

Sheet metal forming, Metal forming method, Finite element analysis, Analytical results

Introduction

A very broad variety of applications are made possible by the field of composite materials. Such materials are being used increasingly often in the automotive, medical, and aerospace industries. This rise can be attributed, in particular, to composites' advantageous weight-to-characteristic ratio. In fact, compared to these materials' density, their mechanical properties in tension/compression, out-of-plane bending, and in-plane shear [1-4] and [5-8] are rather beneficial.

Deep drawing process

To create a hollow shell, a sheet of metal is drawn in a hollow chamber known as the die using typical punching power. This method is known as deep drawing. By exerting the blank holder force, a blank holder is used to regulate and direct the flow of the blank material [9, 10]. The setup of the deep drawing technique for the current investigation is shown in figure 1.

Stresses in the deep drawing process

When stress exceeds, the material begins to follow a flow in the die cavity, is representing as flow stress. The yield criteria, which was the function of the extreme values of the stresses, or principal stresses in two perpendicular directions, theoretically examines the value of flow stress. Furthermore, residual stress in a material is a tension that doesn't result from outside pressures [11-13]. An

Figure 1: Set-up of deep drawing process in present stud.

empirical diagram called the Forming Limit Diagram is used to identifies safe area where deep drawing can be employed to prevent failures.

Typical hydro-mechanical deep drawing process

Similar to the previous section, an O-ring is utilized in the hydro-mechanical deep-drawing process to stop fluid from leaking out onto the flange when female die is substitute by fluid pressure then the punch determines the output of the workpiece. The blank holder serves the same purpose as traditional deep drawing [14]. SMG Engineering Germany was the first company to employ hydro-mechanical drawing. The hydro-mechanical drawing was created by SMG Engineering [15], who also called it active hydro-mechanical shaping. Pre-bulging, shutting the dies, and increasing the pressure are all included in it. Using this technology, large car exterior panels may be created.

In order to fill the space between the blank flange and the die, Buerk [16] employed a seal ring in his 1967 paper on hydro-mechanical drawing. It was determined that the deformation is a result of bending, stretching, and compression. Due to the fluid pressure, which rises quickly as the punch descends, an upward bead typically forms at the blank's free end. Radial and tangential strains are brought on by the upward bead in the flange region. The die's drawing radius is not crossed during the actual drawing, which allows the LDR to rise to a maximum of 3.0. For extremely high pressure, it is suggested to add a copper ring on top of the seal ring, which is constructed of wear-resistant plastic. Buerk also recommended a number of combinations, including a mixture of blanking and drawing, redesigning (second draw), reverse drawing (counter draw), and hydro-mechanical drawing.

There have been systematic investigations into the homogeneity and kinetics associated with the die-imprinting of MGs, and instances utilising the nano metal die-imprinted MG as optical components as well as mould inserts have been provided. The key findings are: Numerical comparisons of the processing uniformity among the free-imprinting as well as the die-imprinting were made by inserting parameters such as relative volatility as well as maximal difference [17].

Punch profiles and die-punch clearance, which are important components of stretch flange forming. the investigations five punch profiles in the context of aluminium alloy AA5052 using FEA calculations and testing. The effect of clearance on variables like fracture length, bending load, and strain is one of the noteworthy discoveries. It emphasises the benefits of more stepped punch profiles in reducing fracture lengths during stretch flange forming, offering insightful information for production improvement [18].

Experimentation

Theoretical analysis and numerical process simulation

The top plate, bottom plate, guiding pillar, bush, and their material qualities, as well as the dimensions of the deep drawing components, are considered in the assembly of the deep drawing process. The part materials and dimensions are listed in table 1.

Table 1: Specifications of deep drawing.

S. No.	Part name	Material	Dimensions (in mm)
1	Top plate	Structural Steel	Cross section area: 250 mm x 150 mm, Thickness: 30 mm, Stroke length: 90 mm, Stroke diameter: 50 mm
2	Bottom plate	Structural Steel	Cross section area: 250 mm x 150 mm, Thickness: 30 mm
3	Guide pillar	Structural Steel	Diameter: 25 mm, Length: 198 mm
4	Bushes	Structural Steel	Diameter: 40 mm, Length: 60 mm

FEA method

The deep drawing machine's design and modeling have all been examined during this examination procedure. We have taken into account the top plate, bottom plate, guiding pillar, and bushes when designing this technique. This deep drawing material is examined using ANSYS Workbench 17.1, a computer-aided drafting program. In order to avoid practical issues, it is crucial to do the analysis. Since doing so realistically is too expensive, it is advised to carry out a study prior to manufacture.

For the bottom and top plates as well as the guiding pillar and bushes in this analysis method, structural steel is employed as the tool material. Table 2 listed the material characteristics of the modeled pieces.

Theoretical stress calculation

Bottom plate

Stress can be calculated from the following relation:

$$\text{Stress, } \sigma = \frac{Force}{Area} \tag{1}$$

Table 2: Material properties of structural steel.

Properties	Value	Units
Elastic modulus	1.14×10^5	MPa
Density	4.5	g/cm^3
Poisson's ratio	0.33	-

$$\sigma = \frac{1000N}{150 \text{ mm x } 250 \text{ mm}} MPa$$

$$\sigma = 0.0267 MPa$$

Top plate

Stress can be calculated from the following relation:

$$\text{Stress, } \sigma \; \frac{Force}{Area}$$

$$\sigma = \frac{1000N}{150 \text{ mm x } 250 \text{ mm}} MPa$$

$$\sigma = 0.0267 MPa$$

Guide pillar

Stress can be calculated from the following relation:

$$\text{Stress, } \sigma = \frac{Force}{Area}$$

$$\sigma = \frac{F}{\pi \text{ x } D \text{ x } L} MPa$$

$$\sigma = \frac{1000N}{\pi \text{ x } 30 \text{ x } 198} MPa$$

$$\sigma = 0.064 MPa$$

Bushes

Stress can be calculated from the following relation:

$$\text{Stress, } \sigma = \frac{Force}{Area}$$

$$\sigma = \frac{1000N}{\pi \text{ x } 40 \text{ x } 60} MPa$$

$$\sigma = 0.132 MPa$$

Results and Discussion

The deep drawing analysis procedures, designs, and modeling were examined using CAD software (ANSYS 17.1) as well as the analytical process. By following the procedures above, we were able to find the stress values of deep drawing's numerical and analytical results, respectively. Table 3 presents the comparison of stress in ANSYS results and calculated results. Figure 2 presents the analysis of the deep drawing.

Table 3: Comparison of stress in ANSYS results and calculated results.

S. No.	Description	ANSYS results (MPa)	Analytical results (MPa)
1.	Top plate	0.021	0.0267
2.	Bottom plate	0.017	0.0267
3.	Guide pillar	0.058	0.064
4.	Bushes	0.107	0.132

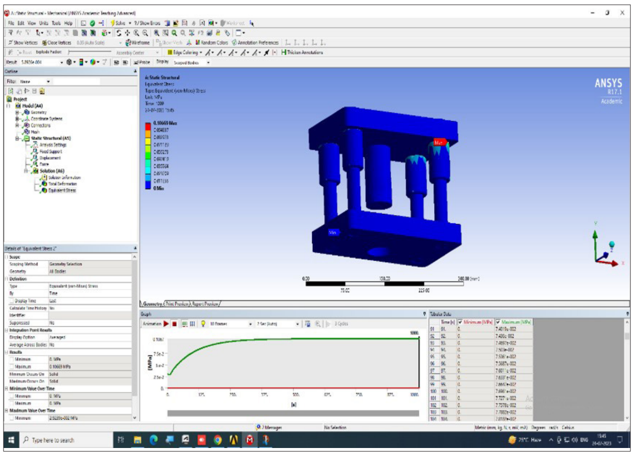

Figure 2: Analysis of the deep drawing.

Conclusion

In this study, the use of SolidWorks was essential for producing precise models of deep drawing. Because structural steel has good material qualities and ensures representative research, it was chosen as the material for the models. We verified the precision of our simulations using ANSYS for FEA. The accuracy and dependability of the computational technique were demonstrated by comparing the FEA findings with analytical values. The results of our study highlight the value of FEA in determining how the stress distribution in a deep drawing created is distributed. It is a crucial tool for structural analysis since it is more affordable than physical testing. We were able to learn more about how deep drawing behaved in various situations because of the inclusion of FEA in our research. This in-depth comprehension enhances the design process and improves the quality of the finished product. The use of FEA in conjunction with analytical techniques showed that it may be a reliable and effective replacement for stress analysis, particularly in intricate engineering applications like deep drawing. Our study confirms the reliability of FEA as a virtual testing tool with a careful modeling and analytical methodology, enabling engineers to make knowledgeable judgments in a resource-efficient manner. Confidence in the implementation of FEA for various industrial projects is increased by the effective confirmation of analytical data. This opens the door for FEA to be used more widely in engineering practices.

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None.

Conflict of Interest

None.

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