

Optimization-Based Analysis of Stress and Deformation in Sheet Metal Forming Using ANSYS

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Abstract:

The sheet metal forming technique is widely used in automotive industry for manufacturing of various components. The objective of current research is to investigate the effect of sheet metal design parameters on stresses and deformation generated using optimization technique. The modeling and FEA analysis is conducted using ANSYS software. The transient structural analysis is conducted to determine deformation and equivalent stress at different time intervals. The equivalent stress is observed to be minimum during bending process and reaches to maximum value at final stage. The die angle has significant effect on shear stress. The die angle has significant effect on shear stress generated on metal sheet. The shear stress is observed to minimum at 92° and maximum for 88° .

Keywords: Optimization-Based Analysis analysis, FEM, forming limit diagram, sheet metal forming process, Ansys

1. INTRODUCTION

Sheet metal forming (SMF) is one of the most fundamental and widely adopted manufacturing processes used to produce complex, high-precision components across a broad range of industries, including automotive, aerospace, electronics, and consumer goods. The growing demand for lightweight structures, improved fuel efficiency, and cost-effective mass production has further increased the importance of advanced sheet metal forming techniques. These processes enable the transformation of flat metal sheets into desired geometries through controlled plastic deformation while maintaining structural integrity and dimensional accuracy [1].

Sheet metal forming (SMF) techniques are widely used in many industries to produce final-shaped components from a workpiece. In an SMF process, a thin piece of metal sheet is stretched into a desired shape by a tool without wrinkling or excessive thinning. In the past decade, methods for forming high-strength materials with low plasticity and difficult-to-form metals have been developed for cold, warm, and hot forming conditions

[1], [2]. These advancements have significantly expanded the applicability of SMF processes, particularly in the manufacturing of high-performance and lightweight components.

The performance and quality of sheet metal forming processes are strongly influenced by several key factors, including process parameters, material properties, and tooling conditions. Process parameters such as blank holder force, punch speed, lubrication, temperature, and die geometry play a critical role in determining the final product quality. Improper selection of these parameters can lead to defects such as wrinkling, tearing, springback, and non-uniform thickness distribution. Therefore, understanding the relationship between these parameters and forming behavior is essential for achieving defect-free components.

Material characteristics also significantly affect the formability of sheet metals. Properties such as yield strength, ductility, strain hardening exponent, and anisotropy influence how a material responds to deformation. The increasing use of advanced high-strength steels (AHSS), aluminum alloys, and other lightweight materials has introduced

new challenges in forming due to their limited ductility and higher strength. As a result, innovative forming techniques and process modifications are required to improve their formability and ensure reliable production.

In recent years, optimization techniques have gained considerable attention in sheet metal forming to enhance process efficiency and product quality. Methods such as design of experiments (DOE), response surface methodology (RSM), genetic algorithms (GA), and machine learning approaches are increasingly being used to determine optimal process conditions. Additionally, the integration of numerical simulation tools, particularly finite element analysis (FEA), has enabled accurate prediction of material behavior, stress distribution, and defect formation, thereby reducing the need for costly experimental trials.

The objective of current research is to investigate the effect of sheet metal design parameters on stresses and deformation generated using optimization technique. The modeling and FEA analysis is conducted using ANSYS software.

2. METHODOLOGY

The model of sheet metal bending design is developed using sketch and extrude tool. The model is developed in ANSYS design modeler. The optimization variables are also selected at this stage.

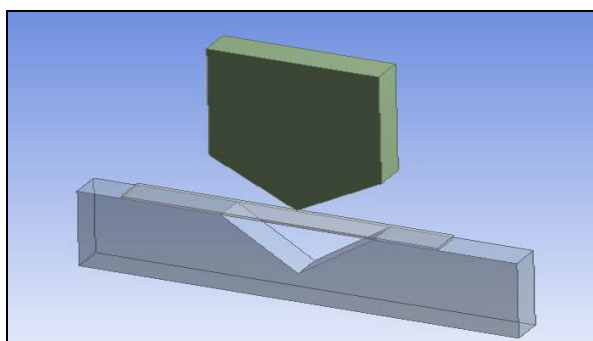


Figure 1: Model of sheet metal bending set up

The sheet metal die and punch is meshed using relevant mesh settings which include

defining mesh element size, aspect ratio. The mesh quality checks are performed and discretized model is shown in figure 2 below. The model comprises of 2187 elements and 3254 number of nodes.

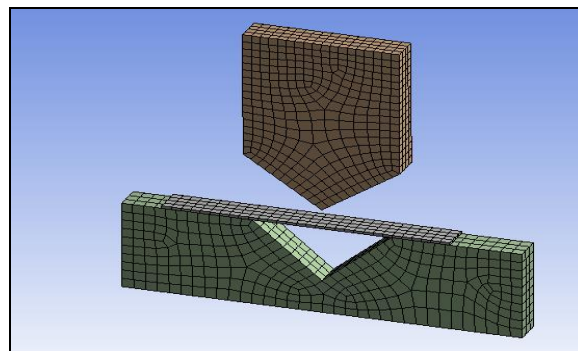


Figure 2: Meshed model of sheet metal

The transient structural analysis conditions are defined with end time of .01secs. The loads and boundary condition for structural analysis are defined as shown in figure 3. The bottom face of die is applied with fixed support and punch is applied with initial velocity.

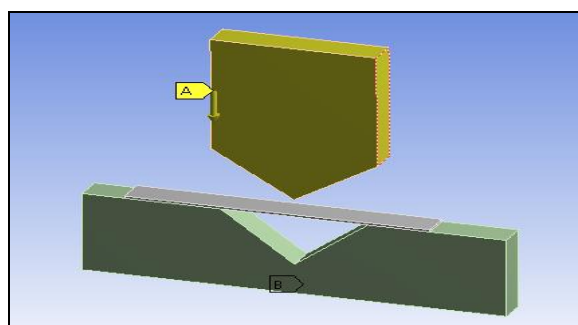


Figure 3: Applied loads and boundary conditions

The transient structural analysis is conducted using sparse matrix iterative solver to determine nodal values of displacement and stresses. The results obtained from nodes are interpolated for entire element edge length and is computed for all time intervals.

3. RESULTS AND DISCUSSION

The deformation plot is obtained from transient structural analysis and is determined for different time intervals.

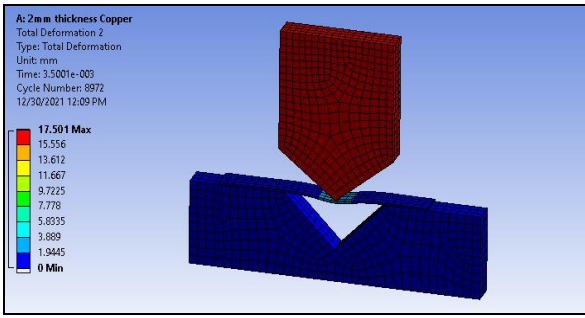


Figure 4: Deformation plot at .0035secs

At .0035secs, the punch makes initial contact with metal sheet. The magnitude of deformation at this instance is more than 15.55mm. The deformation increases with time.

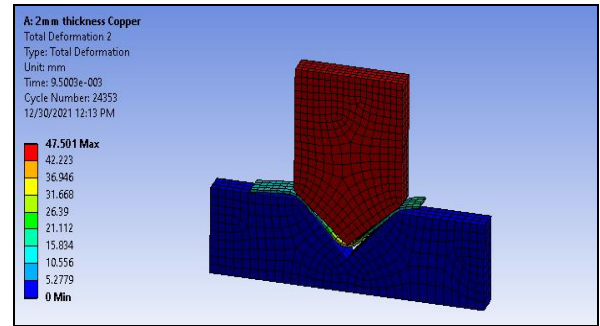


Figure 7: Deformation plot at .0095secs

At .0095secs, the bending of metal sheet takes place as shown in figure 7 above. The magnitude of deformation at this instance is more than 42.223mm. The complete bending of metal sheet takes at this step.

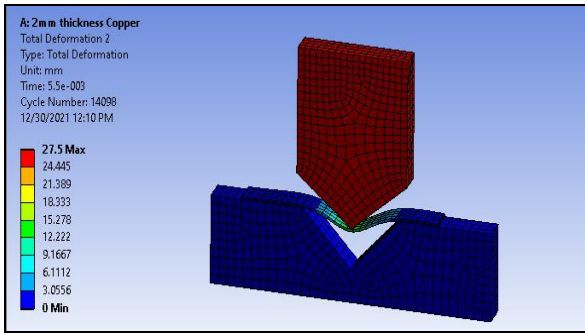


Figure 5: Deformation plot at .0055secs

At .0055secs, the bending of metal sheet takes place as shown in figure 5 above. The magnitude of deformation at this instance is more than 24.44mm. The deformation increases with time.

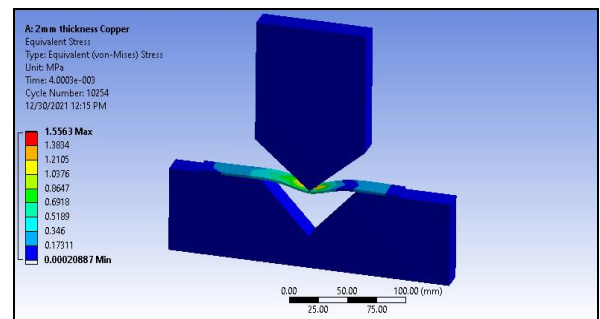


Figure 8: Equivalent stress plot at .004secs

The equivalent stress plot is generated for sheet metal forming process at .004 secs as shown in figure 8 above. The equivalent stress obtained at this time interval is more than 1.38MPa. The equivalent stress is higher when punch makes 1st contact with metal sheet.

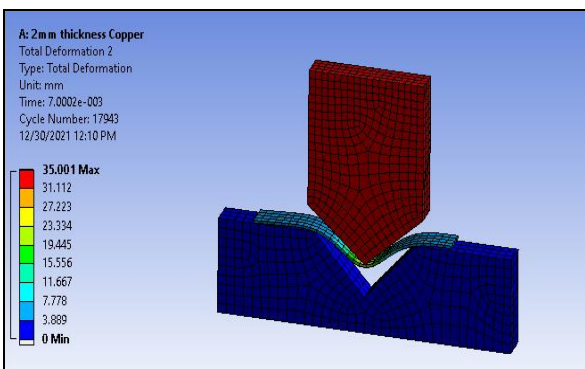


Figure 6: Deformation plot at .007secs

At .007secs, the bending of metal sheet takes place as shown in figure 6 above. The magnitude of deformation at this instance is more than 31.112mm. The deformation increases with time.

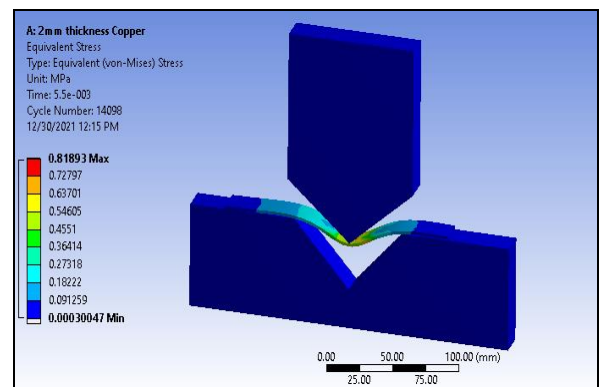


Figure 9: Equivalent stress plot at .0055secs

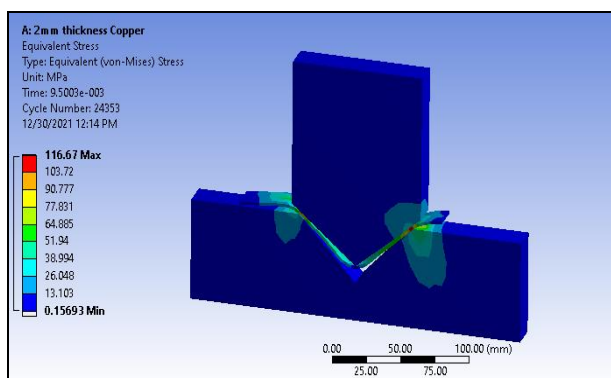


Figure 10: Equivalent stress plot at .0095secs

The equivalent stress plot is generated for .0055secs and .0095 secs after simulation start as shown in figure 9 and figure 10 above. The equivalent stress generated on metal sheet is high with magnitude of more than .63MPa at .0055secs. The equivalent stress is lower till the sheet metal deforms under load from punch. But, when the punch is in its final position (complete deformation) the metal sheet makes contact with corner edges of die and equivalent stress is maximum. The maximum equivalent stress obtained from the analysis is more than 103.7MPa.

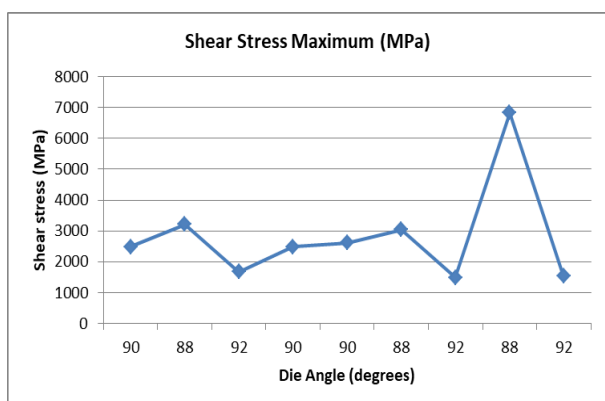


Figure 11: Shear stress vs die angle

The variation of shear stress with respect to die angle is investigated using optimization technique and is shown in figure 11 above. The die angle has significant effect on shear stress generated on metal sheet. The shear stress is observed to minimum at 92° and maximum for 88° .

4. CONCLUSION

The structural behavior of sheet metal bending process can be evaluated using techniques of Finite Element Method. The equivalent stress is observed to be minimum during bending process and reaches to maximum value at final stage. The die angle has significant effect on shear stress. The die angle has significant effect on shear stress generated on metal sheet. The shear stress is observed to minimum at 92° and maximum for 88° .

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