Optimization of Design Parameter of Constant Blank Thickness by Varying Friction Coefficient Using Explicit FEA on Deep Drawing Process of A Cylindrical Plate

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Abstract— Customarily, most metal forming systems have been tried tentatively utilizing experimentation or observational strategies, which are costly and tedious methodologies as dies, blank holders and punches need to be manufactured. By making utilization of finite element analysis the forecast of punch force, the blank holder force, the thickness distribution through sections of the metal and the lubrication requirements can be determined. This can altogether reduce the manufacturing costs. However during deep drawing process the design parameters have a significant effect on the quality of the drawn part. In this a 3D finite element model is developed for the deep drawing process of a cylindrical plate. Then the influences of design parameters including die shoulder radius, punch nose radius, Sheet metal thickness and coefficient of friction on the process are investigated by simulation. From the simulations the thickness distribution and thinning of the blank with respect to the die design parameters can be predicted. Furthermore, with numerical simulation, working parameters can be optimized without expensive shop trials

Index Terms— Dies, Blank Holder, Punches, Finite Element Model

I. INTRODUCTION
Deep drawing is a process which is used to produce cups, shells, boxes and similar parts from metal blank using the principle in which the blank material is radically drawn into the forming die by the movement of the punch. It is thus a shape transformation process with material retention. A simple drawing operation is shown in fig 1.1. A round blank is first cut from flat stock. The blank is then placed in the draw die, where the punch pushes the blank through the die. On the return stock the cup is stick with punch, to avoid this blank holder is used. Generally, a drawing operation is referred to as shallow drawing when the depth of cup is less than the diameter of cup and drawing of cup is deeper than half its diameter then it is called deep drawing.

II. OBJECTIVE AND METHODOLOGY

2.1. Objective
The objective of this paper is to perform explicit dynamic analysis on blank material for manufacturing a cylindrical shell part, by varying different parameters like die shoulder radius, punch nose radius, Sheet metal thickness and coefficient of friction with respect to blank thickness.

2.2. Methodology
- In this paper the first step is to design a 3D model (assembly) of die, punch, blank material with thickness and a blank holder.
- Next, the total assembly is converted into .xt file format which is than imported into Ansys workbench to perform explicit dynamic analysis.
- First, providing all the initial steps are performed like applying material properties, contact between two surfaces are applied by changing the blank thickness the analysis will be performed.
- Now, by selecting the particular blank thickness by varying coefficient of friction the analysis is performed and at last selecting the best process.
- Next, by selecting the particular blank thickness and coefficient of friction by varying die shoulder radius the analysis is performed and at last selecting the best process.
- Now, from the best process by varying the punch radius with similar contact the analysis is performed and at last selecting the best process.
- Now all the results are tabulated and a graph is plotted by selecting the parameter with blank thickness with respect to results
III. MODELLING

Table 1: The Geometry was modeled by using the following dimensions and all are in mm

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punch radius ( r_p )</td>
<td>56</td>
</tr>
<tr>
<td>Punch nose radius</td>
<td>4</td>
</tr>
<tr>
<td>Height of the punch</td>
<td>67.7</td>
</tr>
<tr>
<td>Die radius ( r_d )</td>
<td>57.7</td>
</tr>
<tr>
<td>Die shoulder radius</td>
<td>6</td>
</tr>
<tr>
<td>Blank diameter ( r_j )</td>
<td>224</td>
</tr>
<tr>
<td>Blank thickness ( t )</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 2: Model of Die

Figure 3: 3D Model of Punch

Figure 4: 3D Model of Blank

Figure 5: The figure shows the final isometric view of assembly

IV. ANALYSIS BY USING EXPLICIT DYNAMICS IN ANSYS WORK BENCH

The Implicit and Explicit are two types of approach methods to solve the finite elemental problem. The implicit finite elemental analysis approach is useful in solving the problems where which time dependency of the solution is not an important factor [e.g. static structural, harmonic, modal analysis etc.] whereas the Explicit Dynamics approach is helpful in solving higher deformation time dependent problems such like as Crash, Blast, Impact, deep drawing, drop test etc.

4.1. Explicit Dynamics

Explicit Dynamics is used to perform analysis for high-speed impact simulation i.e. like collision of two objects. It is also used to perform drop test simulation analysis i.e. when an object falls down from a certain height onto floor with some gravity. A time dependence integration method is used in Explicit Dynamics analysis system.
Once the meshing of the geometry is completed the next step is to provide the initial conditions like (initial velocity, Angular velocity), this settings are varied for different problems. In analysis setting, time step must be defined time dependently.

The time steps include:
- Initial time step
- Minimum time steps
- Maximum time step
- Time step safety factor

4.2. Methodology Adopted In Ansys Part
This analysis was carried out by using Explicit Dynamics module in Ansys Workbench. As the analysis is highly non-linear the time integration method will be used explicitly which is very efficient for each time step but the run time would be too enormous to be accepted.

4.3. Selecting the Suitable Analysis Part
In the Ansys toolbox the explicit dynamics is selected and the required engineering data, geometry, model and setup is created and then the software is made to run for the solution.

4.4. Selecting the Engineering data
After selecting the explicit dynamics first Engineering data should be provided for what type of material is using for different components. In the project the blank was designed with the Aluminium alloy material properties and remaining die & punch are been done with structural steel.
The geometry was modeled in Unigraphics. The deep drawing process setup contains Die, Blank holder, Punch & Blank. All the parts are drawn in solid body and the blank is drawn with some thickness. Geometry was divided in two equal parts and there by symmetry was assigned to the setup. The material assigned for blank is Aluminium alloy and the remaining parts are all structural steel.

### 4.5. Material Properties

The material assigned for blank is ‘Aluminium Alloy-6061’ with given material properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of Elasticity (E)</td>
<td>7.1E10 Pa</td>
</tr>
<tr>
<td>Poisson’s Ratio ((\nu))</td>
<td>0.33</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
<td>310 MPa</td>
</tr>
<tr>
<td>Shear Stress (K)</td>
<td>207.5 N/mm²</td>
</tr>
<tr>
<td>Maximum Allowable Stress</td>
<td>300 N/mm²</td>
</tr>
<tr>
<td>Yield strength</td>
<td>276 N/mm²</td>
</tr>
</tbody>
</table>

### 4.6. Calculations used in Analysis Process

The following calculations were performed to find out the required parameters in the Analysis Process:

1. **Blank holding Force** \(F_h\): Firstly the blank holding force \(F_h\) will be calculated from the given formula:

\[
F_h = 0.015*3.14*Y*((D_b)^2-(D_p+(2.2*t)+(2*R_d))^2)
\]

2. **Drawing Force**: Drawing force is to be calculated by the following equation:

\[
D_R = D_b/D_p; \quad F_D = 3.14*t*U_T*S*(D_R-0.7)
\]
V. ANALYSIS BY VARYING FRICTION COEFFICIENT

5.1. Plate Thickness 3mm And With Adding Friction Coefficient 0.15.

Figure 10: Total deformation of 3mm blank

Figure 11: Directional deformation of 3mm blank

Figure 12: Von misses stress of 3mm blank.

Figure 13: Shear stress of 3mm blank.

5.2. Plate Thickness 3mm And With Adding Friction Coefficient 0.20.

Figure 14: Total deformation of 3mm blank.

Figure 15: Directional deformation of 3mm blank.
5.3. Plate Thickness 3mm And With Adding Friction Coefficient 0.25.
5.4. Plate Thickness 3mm And With Adding Friction Coefficient 0.30.

![Figure 22: Total deformation of 3mm blank](image1)

![Figure 23: Directional deformation of 3mm blank](image2)

![Figure 24: Von misses stress of 3mm blank](image3)

![Figure 25: Shear stress of 3mm blank](image4)

VI. RESULTS & CONCLUSION

Table 4: Comparison of Blank Thickness with Friction Coefficient

<table>
<thead>
<tr>
<th>Type of parameter</th>
<th>Blank thickness (mm)</th>
<th>Friction Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Total deformation (mm)</td>
<td>3</td>
<td>2.76</td>
</tr>
<tr>
<td>Directional deformation (mm)</td>
<td>3</td>
<td>0.78</td>
</tr>
<tr>
<td>(z axis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Von misses stress (Mpa)</td>
<td>3</td>
<td>174.05</td>
</tr>
<tr>
<td>Shear stress (Mpa)</td>
<td>3</td>
<td>85.29</td>
</tr>
<tr>
<td>Factor of safety</td>
<td>3</td>
<td>1.58</td>
</tr>
</tbody>
</table>

From the above table by comparing von misses stress and total deformation by considering a peak value with the blank thickness with 3mm the results is 0.2 friction coefficient is considered. The von misses stress are in allowable limit for all the friction coefficient among that the friction coefficient 0.2 is considered as a peak result for von misses stress which is 175 MPa and total deformation is 2.76 mm. So, from the results and comparison we can say that deliabrely the blank with 3mm thickness and friction coefficient 0.2 will be sustained better.
A graph is drawn by comparing all the parameters

Graph 1: comparing total deformation and directional deformation thickness 3mm and with friction coefficient

Graph 2: comparing von misses stress and shear stress for blank thickness 3mm and with friction coefficient

REFERENCES


