Design and Analysis of Sheet Metal Bending Machine

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Abstract—Nowadays, the world is focusing more towards automation. Each and every work of human is reduced by machine, but few areas of manufacturing such as electrical panels, trolleys, chimneys etc the usage of bending machines requires high cost and need skilled labour to operate it. So this project is aimed to design and modify die and punch for range of angles and thickness to reduce time, cost and effort without altering accuracy of the bend. Hydraulic sheet bending machine consist of hydraulic jack, bending die, punch, fixture. The present work includes the modelling and simulation (stress analysis) of hydraulic operated sheet metal bending machine subjected to load. This necessitates the optimization of production processes, and enhancement of product quality. The modelling is done using SOLIDWORKS software and stress analysis is carried out using advanced fem tool ANSYS.

Key words: Design, modification, hydraulic, bending, die, punch, ANSYS, SOLIDWORKS

1. INTRODUCTION

Bending is a metal forming process in which a force is applied to a piece of sheet metal causing bending of it to an angle and forming the desired shape. Bending is typically performed on a machine called a press brake which can be manually or automatically operated. A press brake contains an upper tool called the punch and a lower tool called the die. The sheet metal is located between them. In automatic press brake the punch is forced into the sheet under the power of a hydraulic jack. The bend angle is determined by the depth which the punch forces the sheet into the die. Precisely, this depth is controlled to achieve the desired bend angle.

FIG.1 V-BENDING OPERATION
Bending is a process by which metal can be deformed by plastically deforming the material and changing its shape. The material is stressed beyond the yield strength but below the ultimate tensile strength. The surface area of the material does not change much. Bending usually refers to deformation about one axis. In engineering mechanics, bending (also known as flexure) characterizes the behavior of a slender structural elements subjected to an external load applied perpendicularly to a longitudinal axis of the element. The structural element is assumed to be such that at least one of its dimensions is a small fraction, typically 1/10 or less, of the other two. When the length is considerably longer than the width and the thickness, the element is called a beam. For example, a closet rod sagging under the weight of clothes on clothes hangers is an example of a beam experiencing bending. On the other hand, a shell is a structure of any geometric form where the length and the width are of the same order of magnitude but the thickness of the structure (known as the ‘wall’) is considerably smaller. A large diameter, but thin-walled, short tube supported at its ends and loaded laterally is an example of a shell experiencing bending. In the absence of a qualifier, the term bending is ambiguous because bending can occur locally in all objects. To make the usage of the term more precise, engineers refer to the bending of rods, the bending of beams, the bending of plates, the bending of shells and so on[1].

2. LITERATURE REVIEW

1. S. M. Bapat and DessaiYusufali(2014) have investigated on the design and optimization of a 30 ton hydraulic forming press machine. The work done in this paper shows that analysis of the frame structure in terms of its material, geometry and stressed induced in it. Metal forming is one of the manufacturing processes which are almost chip less. In this paper they focused on the causes of structural failure problem in the machine because hydraulic press continuously deals with the stress that may be compressive or tensile for that press machine always works under impact load condition and because of impact load the hydraulic press always experienced continuous stress .it is studied that different components of the machine are subjected to different types of loading condition and are analyzed by using FEM tool ANSYS. Weight optimization of press frame and upper head is done, which in turn reduces in thickness of the frame structure and material[6].

2. Pedro G. Coelhoaet al. (2005) conducted a study on structural analysis and optimization of hydraulic press brakes . It has been found that the source of deflection parallelism errors and minimize them through a structural optimization methodology. Based on the model of the bending process in press brake defined by Timoshenko theory of beams, it has been not possible to design a machine that achieved uniform Bending angles for every bending length because no optimal shapes or dimensions of the bed and ram that leads to parallel deflections for all bending lengths. To achieve uniform bending angles for every bending length work piece bending errors have been derived by considering for all the
influence of shape, dimensions and initial deformation of the machine structural components, shape optimization, dimensional optimization has been performed and to decrease the bending error optimal initial deformation was performed[5].

3.CALCULATIONS

A. BENDING FORCE CALCULATIONS FOR SHEET:

Sample Calculations for sheet having thickness 4mm and bend angle 90°

Bending Allowances is given by:

\[
BA = \alpha_i (IR + t*b)
\]

BA=Bending allowance
IR=inner radius=5mm
\(t=4\)mm
\(\alpha_i =\)Bending angle (rad)

\(b=0.33\) for \(IR<2t\) & \(b=0.5\) for \(IR>2t\)

E.g. \(BA = \frac{(90/360) * 2*3.142(5+0.33*4)}{3} = 9.9218\)mm.

The maximum bend force is given by:

\[
F_{max} = \frac{(k*UTS*L*t^2)}{W}
\]

Where, UTS is ultimate tensile strength of the material,

\(W\) is die opening width
\(K\) takes values between \(1.2\) for \(W=16*t\) & \(1.33\) for \(W=8*t\) for v-die bending.

E.g. \(F_{max} = \frac{(1.33*450*600*4^2)}{(8*4)} = 179550\) N

=18.3028 tonne

Table 1. Bending Force values

<table>
<thead>
<tr>
<th>BENDING ANGLE((\alpha_i)) (degree)</th>
<th>SHEET THICKNESS(t) (mm)</th>
<th>BENDING ALLOWANCE((BA)) (mm)</th>
<th>BENDING FORCE((F_{max})) (tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>0.8</td>
<td>5.6548</td>
<td>3.6605</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
<td>6.2837</td>
<td>9.1514</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
<td>6.2832</td>
<td>13.7271</td>
</tr>
</tbody>
</table>
B. STRESS CALCULATIONS:

For Punch

Material used - EN8(080M40)

\( S_u = 580 \text{ MPa} \) & \( S_y = 480 \text{ MPa} \)

Using FOS = 1.5

UTS is ultimate tensile strength = \( \frac{S_y}{FOS} = \frac{480}{1.5} = 320 \text{ MPa} \)

Stress in punch (\( \sigma_{punch} \)) = \( \frac{F_{max}}{\text{Minimum Punch area}} \)

\[ \begin{align*}
60 & \quad 4 & \quad 6.6323 & \quad 18.3028 \\
90 & \quad 0.8 & \quad 8.4829 & \quad 3.6605 \\
90 & \quad 2 & \quad 9.4247 & \quad 9.1514 \\
90 & \quad 3 & \quad 9.4248 & \quad 13.7271 \\
90 & \quad 4 & \quad 9.9218 & \quad 18.3028 \\
120 & \quad 0.8 & \quad 11.3097 & \quad 3.6605 \\
120 & \quad 2 & \quad 12.5763 & \quad 9.1514 \\
120 & \quad 3 & \quad 12.5445 & \quad 13.7271 \\
120 & \quad 4 & \quad 13.2365 & \quad 18.3028 \\
\end{align*} \]

Therefore, punch is safe.

For Die

Stress (\( \sigma_{die} \)) = \( \frac{F_{max}}{\text{Minimum die area}} \)

\[ \begin{align*}
60 & \quad 4 & \quad 6.6323 & \quad 18.3028 \\
90 & \quad 0.8 & \quad 8.4829 & \quad 3.6605 \\
90 & \quad 2 & \quad 9.4247 & \quad 9.1514 \\
90 & \quad 3 & \quad 9.4248 & \quad 13.7271 \\
90 & \quad 4 & \quad 9.9218 & \quad 18.3028 \\
120 & \quad 0.8 & \quad 11.3097 & \quad 3.6605 \\
120 & \quad 2 & \quad 12.5763 & \quad 9.1514 \\
120 & \quad 3 & \quad 12.5445 & \quad 13.7271 \\
120 & \quad 4 & \quad 13.2365 & \quad 18.3028 \\
\end{align*} \]

\[ \frac{(20*9810)}{(32*600)} = 10.22 \text{ MPa} < 320 \text{ MPa} \]

Therefore, Die is safe.
4. NUMERICAL ANALYSIS

**Design of Die & Punch:**

Die is used for bending the sheet at required angle. Angles of die are decided based on requirement in industries. Model of the die is designed using CAD having angles 60, 90 and 120 degrees with length as 600mm.

Punch is used to force the sheet in die cavity. Model of the die is designed using CAD having angles 60, 90, and 120 with length as 600mm. Punch is designed such as there will be no need to change the whole assembly, it just has to be rotated for required angle which reduces time and effort as well; which also satisfies the objective of our project.

**ANALYSIS OF COMPONENTS USING FEA SOFTWARE:**

After designing and modeling, the components are analyzed. Punch and die analysis is carried under computer aided software to ensure that the design is safe. Punch and die are the parts which undergo repeated loads in bending machine, which is expensive too. It is very essential to carry out the analysis in order to prevent practical tryouts. Tryouts are always costly and also time consuming, instead if parts are analyzed using computer aided engineering software it provides an opportunity to improve the design of the part prior to manufacturing. Hence based on the analysis result necessary material or geometrical changes are incorporated.

**Die Analysis:**

![Stress distribution in Die](image)
Analysis of die is done using ANSYS software. Die was constrained at bottom face and 20 tonne of force was applied on above V face as it is max force on die. Above figure indicates that Equivalent (VonMises) stresses generated in die is having maximum value as 19.984 MPa and this value is much less than yield stress value in the die which is 320 MPa. Therefore, die is safe.

Punch Analysis:

![Stress distribution in punch](image)

Fig. 6. Stress distribution in punch.

Analysis of punch is done using ANSYS software. Punch was constrained at upper rectangular surface and 20 tonne of force was applied on V face as it is max force on punch. Above figure indicates that Equivalent (Von Mises) stresses generated in punch is having maximum value as 44.969 Mpa and this value is much less than yield stress value which is 320 Mpa. Therefore, punch is safe.

Difference between analytical value and calculated values of results in punch and die is because the shape of die and punch is complicated and design formulae and empirical relations are not available to calculate stress and deformation in such shapes thus we are using analysis software and basic design formulae, which are not accurate, to estimate the stress and deformation in such shapes. Thus, there is difference in calculated and analytical values of result.

**FINAL ASSEMBLY**

![Assembly](image)

Fig 7. Assembly
5. CONCLUSION

The work presented here focuses on design of hydraulic sheet bending machine. As per design and calculations this sheet bending machine will be able to bend sheet of angles 60, 90 and 120 having thickness 0.8 to 4mm. As the machine provides different angle and thickness bend, can be used in small industries. This machine reduces time required for bending various angle and thickness sheets. As size of machine is compact and die has various angles and thickness bending capacity it reduces the cost of machine. Space required for machine is also small. Hydraulic jack makes machine’s working easy and accurate.

6. REFERENCES

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