
ABSTRACT

Various types of bending process are designed as per shape and thickness of work piece. The strength of sheet metal varies with the shape due to bending. The change in shape causes the change in moment of inertia. The bending also cause change in material properties. The bending leads to strain hardening of the material. The sequence of bend and lot size also criteria in process planning. The time to change the tool and traveling time with thickness of sheet are also the criteria.

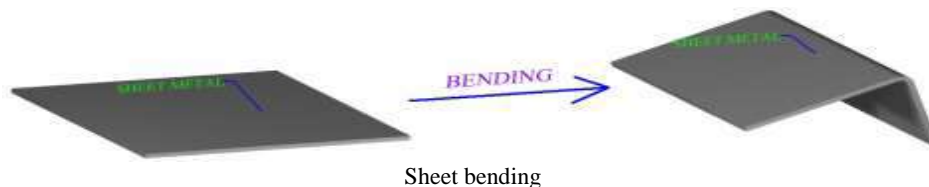
KEYWORDS: Bending process, Strain hardening, process planning, Moment of inertia.

INTRODUCTION

Bending of sheets and plates is broadly used in forming parts such as folds, flanges, etc. Bending is a forming operation in which a sheet metal is subjected to bending stress thereby a flat straight sheet is made into a curved sheet. The sheet gets plastically deformed without change in thickness. For bending Die and punch are used. If a v shaped die and punch are used, the bending is called v-bending. If the sheet is bent on the edge using a wiping die it is called edge bending. In this process, one end of the sheet is held like a cantilever using a pressure pad and the other end is deformed by a punch which moves vertically down, bending the sheet. Usually in order to obtain an angle of 90°, edge bending is done [R. Chandramouli].

Sheet Metal Bending:- In manufacturing industry, Bending of sheet metal is a common & decisive process. Sheet metal bending involves plastic deformation of the work over an axis, creating a change in the geometry of parts. Similar to other metal forming processes, bending changes the shape of the work piece, while the volume of material will remain same. However in some cases bending may reduce thickness of sheet slightly. During most of the operations, however, bending will produce no significant change in the thickness of the sheet metal. In addition to creating a aspire to geometric form, bending is sometimes used to change strength and stiffness to sheet metal, to change a part's moment of inertia, for cosmetic display and to hide the sharp edges[Nitin Singh Thakur].

Figure:- 1



Theory of bending:

In plastic bending, we ignore the thickness devaluation. Therefore, we assume that the neutral axis lies at the center of the sheet thickness. Consider a sheet of thickness t , allowed to bend so that it is twist to a radius of curvature of R .

We can assume no strain along the width and the bend angle same. Bending allowance is the arc length of the neutral axis in the bend area. It is an important design parameter. It is given by:

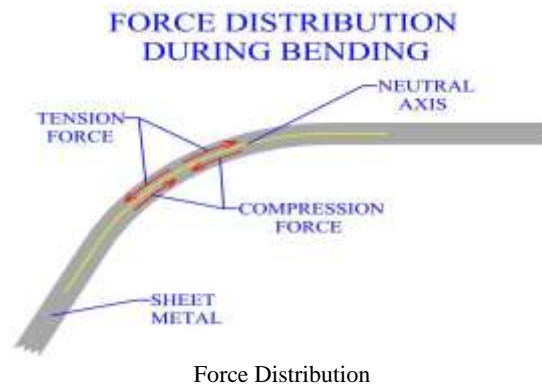
$L_b = (R+kt)$, where k is equal to 0.5, for ideal bending-neutral axis, is a constant, varies at center. $K = 0.33$ to 0.5 for $R < 2t$ or $R > 2t$ respectively. We can find the strain on outer fiber or inner fiber :

$$e = \frac{1}{(2R/t)+1}$$

In actual bending, the outer fibers span getting shrunk more than the inner fibers. This change in strain between outer and inner fibers change with decrease in radius of bending or decrease in R/t . Beyond a certain minimum R/t the tensile strain on outer fiber may increase so high that the material outside starts crashing. The particular radius at which cracks develop on the outer surface of the sheet due to bending is called minimum bend radius. It is usually given in conditions of the sheet thickness, t .

The following table gives minimum radius for some materials: [R. Chandramouli]

Figure: 2



Tables: 1

Table 1 . Minimum radius for bending [R. Chandramouli]

Material	Soft	Hardened
Aluminum alloys	0	6 t
Low carbon steel	0.5 t	4 t
Titanium alloys	2.5 t	4 t

Classification of Sheet Metal Bending Processes:- Different sheet metal processing operations are laser cutting and bending, punching, bending, incremental forming, shearing and blanking, spinning, stretch forming, deep drawing and redrawing, rubber hydro-forming and explosive forming (Groover, 2010). Bending forward a straight line is the most common among all sheet forming processes; in various ways it can be done such as forming forward the complete bend in a die, folding or flanging in special machines, or by wiping, or sliding the sheet over a radius in a die (Marciniak, 2002). The terms folding and bending are almost used in the sheet-metal industry and largely interchangeable in common argot, to be precise, the term ‘folding’ refers to sharp corners with a minimum bend radius and the term ‘bending’ refers to deflections of relatively large corner radii. Folding and bending involve the deformation of material along a straight line in two dimensions only (Timings, 2008).[Gwangwava NI*]

Process Planning for Sheet Metal Bending

Process planning for sheet metal bending involves a series of operation and activities, which consist of selection of the tool, blank length calculation, calculation of bending forces, tolerance verification on the basis of tool and part deformations, determination of a bending sequence and setup planning etc. For small and medium lot sizes, the set up time is one of the most important factors affecting the time involved in the process and thereby affecting the cost effectiveness at this manufacturing stage. Process plan optimization is vital in order to minimize the total production time. Work done in this area can be broadly classified into two divisions, single part planning and multi-part planning. De Vin et al [Dvin94], Radin and Shiptalni [Radi96] and Gupta et al. [Gupt98, Gupt99b] have illustrated automated process planning systems that bring about plans for one part at a time. However multi-part planning was not mentioned in their work. [Satyandra K. Gupta1]

Classification of Bending Machines

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most popular sheet metal. Common equipment used includes box and pan brakes, brake presses, and other specialized machine presses. Typical products that are made like this are boxes such as electrical cage and rectangular ductwork.

- Air bending
- Bottoming
- Coining
- Three-point bending
- Folding
- Wiping
- Rotary bending
- Roll bending
- Elastomer bending
- Jogging

Folding

In folding, clamping beams hold the longer side of the sheet. The beam rises and folds the sheet around a bend profile. The fold beam can move the sheet up or down, permitting the fabricating of parts with positive and negative bend angles. The resulting bend angle is altered by the folding angle of the beam, tool geometry, and material properties. Large sheets can be handled in this process, making the operation easily automated. There is little risk of surface damage to the sheet. [Aniruddha Kulkarni 2015]

LITERATURE REVIEW

(**M. Schenk**) Showed that folding sheets from flat sheet materials into 3D surfaces provides a way to form coated sheets with a deep relief, without stretching the base material. Manufacturing can therefore be done using only low-energy bending operations along the fold lines. (**S.B. Chikalthankar 2014**) Studied various parameters affecting spring back such as punch angle, grain direction of sheet metal material, die opening, ratio of die radius to sheet thickness, sheet thickness, punch radius, punch height, coining force, pre bend condition of strip etc. (**B. Engel 2014**). Studied the influence of the shifting of the neutral axis and the shear stress in the adhesive on the forming behavior of the metal layers is shown. And planned an optimization diagram to show the bending limits of sandwich-sheets dependent on the layer- thickness and side lengths (**Sergei Alexandrov^a 2011**). Make an analyzed the through-thickness distribution of the principal stresses and damage parameter as well as the variation of the bending moment with the radius of curvature of the concave surface are found for Swift's hardening law and one specific damage evolution law. (**Hiroshi Hamasakia^a 2014**). Performed U-bending experiments and the corresponding finite element simulations using several combinations of plastic strain reliant Young's moduli and isotropic and kinematic hardening rules were conducted (**Rüdiger U. Franz von Bock 2015**). Presents a numerical analysis for model-scale ice in which material parameters are developed that can represent: tension, compression and in-situ downward bending. The key phenomenon joining the deformation processes in bending together with those in compression and tension, proved to be the through thickness dependency of properties (**Mohammed H.**

Serror 2012). This paper represents an analytical study for the deformability of such laminate within the context of necking instability while a freestanding high-strength sheet metal subject to tension will rupture at small strain.

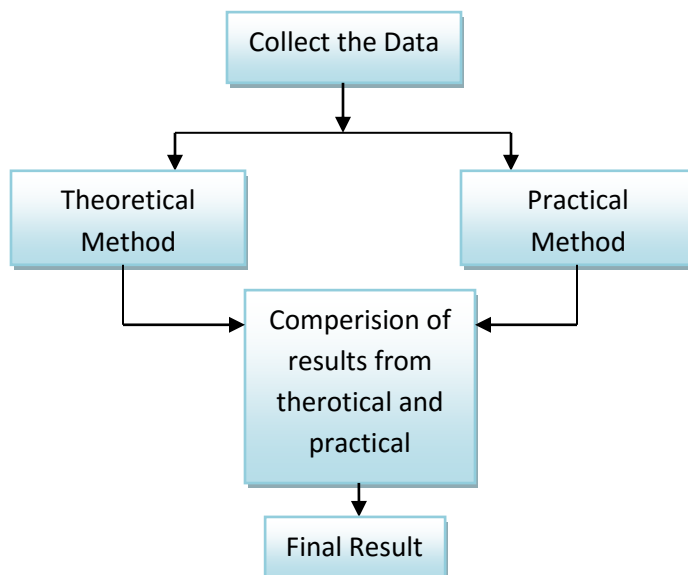
Problem Definition & Proposed Solution

- In fabrication the conventional angles are used to join the perpendicular walls or to support the structure. The cost of angle depends upon the weight of the material of angle. The angle must have bending and buckling. Strength to support the structure. To give more strength the dimension of angle is increased and hence the weight.
- In most of the prefabricated structure walls are supported and joint and consumed a lot of line to get it join with skills for alignment and check the perpendicularity. The reduction in time and ease. Can reduce the production cost.
- Different shapes of angles are used for various applications and strength. The shape affects the various types of strength.

METHODOLOGY

- Theoretical Method :-** In this method,
 1. analysis on CAE software with (ansys software 14.5)
 2. Theoretical Calculation by bending equation and buckling theorem.
 3. Find the result.
- Practical Method :-** Testing on UTM machine find the result
 1. Compression all result
 2. Simulation
 3. Final result

Proposed work Plan



In industry sheet metal is used in various structures. The sheets are given bends through different bending process. The bending imparts strength to the structure by changing moment of inertia and strain hardening. The bucking strength increases with number of folds increases as the moment of inertia increases. The bending radius selected depends upon the hardness of the material and hence the tool is selected. In mass production the tool changing time and sequence of bending are the criteria to select the lot size to make the operation profitable

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