Bending Analysis of Steel Plates on 3D Roller Bending Machine

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Abstract - Sheet metal bending processes are some of the most commonly used industrial manufacturing operations. The development and optimization of these processes are time consuming and costly. Therefore, finite element simulations may aid the design and quality assurance of sheet metal products. In the present study, a commercial finite element package was used to analyze the three-roller bending of a steel sheet. Now, the problem is we cannot predict Maximum displacement of top roller without endangering crack formation in plate so that we need to investigate effect of top roller position on maximum stress and residual stresses in the formed sheet and also find Maximum displacement of top roller allowed without endangering crack formation in plate. Here our objective is to design three roll pyramidal bending machine for given sheet thickness range. To Conduct Dynamic FEA analysis using ANSYS to validate maximum stress –strain produced in the sheet by given top roller position. Find Maximum displacement of top roller allowed without endangering crack formation in work piece.

Key Words: Electric Wheelchair, Head Motion, Eye blink Monitoring, Automation System.

1. INTRODUCTION

3-roller pyramidal configuration bending machine is widely used in heavy engineering applications for the manufacturing of cylindrical tanks, bending of spring, shell of boiler and heat exchangers, turbines, pressure vessel, towers, reactors, etc. Top roller load required to bend the sheet is the function of various parameters such as, thickness of plate, width, diameter of the shell to be rolled, properties of plate material and gap between the bottom rollers etc. Machine capacity has limitation by size and shape of motor of 3-roll bending machine motor. Machine consists of two bottom rollers and a one top roller as shown in Fig.1.1. Sheet metal plates are rolled without reduction in thickness to get the desired cylindrical shape. The plate undergoes plastic deformation and this is cold forming process due to that it has higher dimensional accuracy. The elements used in the construction 3-roll bending machine are as shaft, bearings, lead screw, gear, levers and frame.
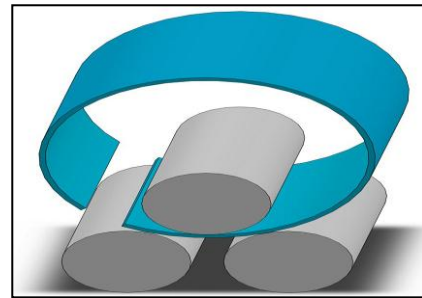
Fig -1: Three Roll Bending Machine

3-roller pyramidal configuration bending process has four stages are as follows,

(1) Static bending (2) Forward rolling

(3) Backward rolling and (4) Unloading of the work piece.

Firstly, the metal sheet is kept between top roller and bottom rollers and gives the vertical displacement to the top roller to get the required bending. In second stage the bottom rollers are driven by hand lever in forward direction to get the roll bending of the plate. We also use motor for the rotating of bottom rollers. Similarly for getting better dimensional accuracy of the final shape the rollers are driven in backward direction. The bent sheet is unloaded by raising the top roller. The process is performed using many materials such like aluminium alloys, carbon and alloy steels. In Roll bending machines having3-roll bending process is useful for the manufacturing of cylindrical shapes and with the help of this machine we obtained different radius of curvatures without crack formation in plate. The bending machine is helpful for bending plates of various materials such as Carbon alloy steel, aluminium alloy steel etc.

This type of process is also widely used for manufacturing a variety of products for various types of industries such as, asymmetrical cones, semi-finished products. Moreover, 3-roll bending process is beginning to be taken useful consideration by industries for manufacturing large, thick parts like the thick, conically shaped of wind tower or the crown of Francis turbine runner. Some Francis turbine runners installed in the dam basement of a hydraulic power plant are 10 meters in diameter, and 5 meters in height, while plate thickness can exceed 100 millimeters. Roll bending process is the plastic

deformation of a metal that uses a set of rolls to bend flat plates or sheets into variety of shapes such as conical or ovals, cylindrical. 3 roll bending is a continuous three-point bending process with negligible change in plate thickness.

Several number of processes can be involve for the manufacturing processes of such big parts welding, casting etc., but few number of processes delivers the final product within a optimum time and at competitive cost. From these options, the roll bending process, which causes plastic deformation of a sheet or plate around a linear axis of the roll with very little or no change in sheet or plate thickness, is considered as an favorable alternative.

Fig -1: Example of Roll Bending Process Product

1.2. LITERATURE REVIEW

1. Federal It is not known when the first roll bending machine was introduced in the industry, but a similar machine was already operated in 1828. In the year 1840 a few years later after the invention of the machine Sir William Fairbairn a shipbuilder, built plate bending rolls to make boilers and other products made of iron and steel plates. Steam engine was used to power the roll bending machine during the Industrial revolution, Between the late 19th and mid-20th centuries, the core technology of the roll bending machines was handheld. Various patents relating to such machines were found in these times. Steam engines were replaced by individual electric motors as power source. Servomechanisms and then hydraulic motors were applied to control the paths of the roll bending machine since the 1950's. Thus we get more accurate products from roll bending machine. Nowadays, many different types of roll bending machines have been developed over the last few decades to adapt to various forming production specifications. The roll bending machines can be classified into two major types in the market: a three-roll model (including pyramidal and asymmetrical models) and a four-roll model. Various researchers have worked for the development of mathematical models for 3-roll bending process.

M. K. Chudasama and H. K. Raval(2012) [1], conducted a study of analytical model for prediction of force during 3-roller multi-pass conical bending and its experimental verification. They found that conical sections and shells are produced using 3-roller conical bending machine. In this bending process, the blank is given static bending by loading the blank over the bottom rollers and down the top roller. The rollers are rotated due to that getting roll bending action. Static bending of the plates requires much larger force and it is possible by multiple stages to lower down the value of required force [Gajjar et. al., 2008]. The total deflection of the top roller required are splits in steps to get the Multipass bending. The machine is designed by taking base of maximum reaction forces during bending. In this research paper an analytical model is proposed for prediction of bending force during the multiple pass three roller conical bending.

Zen Zemin Fu et.al (2013) [3], in which they stated that the 3-roll bending forming of sheet metal is an useful and flexible manufacturing process due to its simple configuration. This process is suitable for forming large sheet parts with complicated, curved faces. Most researches on roll bending forming of large plates are mainly based on experiments and explain the process through macroscopic metal deformation. An analytical model and ABAQUS finite element model are proposed in this paper for investigating the 3-roll bending forming process. A accurate relationship between the downward inner roller displacement and the desired spring back radius of the bent plate is yielded by both analytical and finite element approaches, which all agree well with experiments.

Himanshu V et.al, published a paper named "Bendability analysis for bending of C-Mn steel plates on heavy duty 3-roller bending machine" in 2007 which states, Bendability is constrained by maximum top roller load imparting capacity of the machine. Maximum load is encountered during the edge pre-bending stage of roller bending. Capacity of 3-roller plate bending machine is specified by maximum thickness and minimum shell diameter combinations that can be pre-bend for given plate material of maximum width. Commercially available plate width or width of the plate that can be accommodated on machine decides the maximum rolling width.

A. H. Gandhi et.al (2008) [5], described the work proposed an analytical and empirical model to estimate the top roller position explicitly as a function of desired radius of curvature for three-roller cylindrical bending of plates, considering the contact point shift at the bottom roller plate interfaces. Effect of initial strain and change of material properties during deformation is neglected. Top roller positions for loaded radius of curvature are plotted for a certain set of data for centre distance between bottom rollers and bottom roller radius.

2. Theoretical Analysis

The various machine elements used in the construction three roll bending machine are explain below
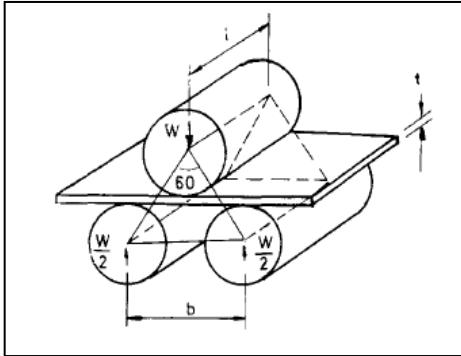
2.1 Shaft Design:

Fig -3: Design of Shaft

i) Material properties of the shaft [11]

Max stress	400-500 N/mm2

Depending up on ruling section

Yield stress	310-440N/mm2

Depending up on ruling section

0.2% proof stress	280-420 N/mm2

Depending up on ruling section

Elongation	10-15% min

One of the important design parameters for the three rolls is the folding pressure that comes into play during bending. Consider three rolls disposed with its axes at the corners of an isosceles triangle, as shown in Fig. 3.1. The bending moment to which the plate is subjected to is given by,

$$M = \frac{Wb}{4}$$

Where W is the load exerted by the central (top) roll and b is the distance between the lateral rolls. A rigorous study of the plastic behavior of cold rolling is given in Ref. [1]. Reasonable estimate one can proceed as follows. If the plates were to deform at the point of contact, the bending moment can be equal to the plastic moments of resistance of the plate.
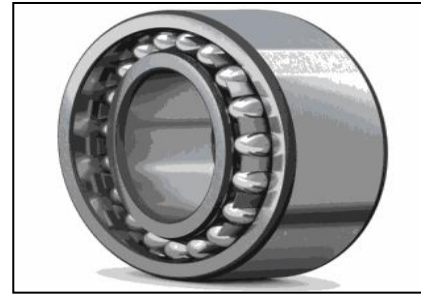
2.2 Bearing

Fig -4: SKF Ball Bearing

We use the bearing here in its most general sense. Whenever two parts have relative motion, they constitute a bearing by definition, regardless of their shape. Usually, lubrication is needed in any bearing to reduce friction and remove heat. Bearings can roll or slide or do both simultaneously. A plain bearing is formed by any two materials rubbing on one another, whether a sleeve around a shaft. In a plain bearing, one of the moving parts usually will be steel or cast iron or other structural material in order to achieve the required hardness. Transmission shafts, links, and pins are in this type. The parts that move against will usually be made of a bearing material such as bronze, Babbitt, or a nonmetallic polymer. A thrust bearing supports axial load.
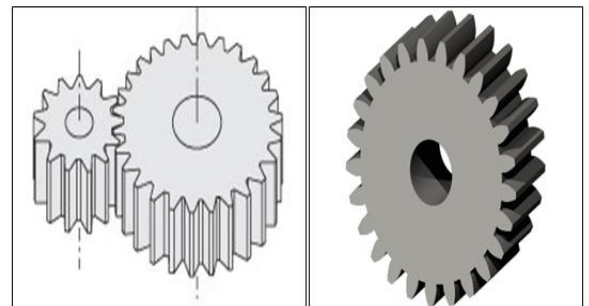
2.3 Gear:

Fig -5: Spur Gear

Spur gears are used to transmit torque and angular velocity in a wide variety of applications. There is also a wide variety of gear types. The simplest type of gear, the spur gear, designed to operate on parallel shaft and having teeth parallel to shaft axis. Other gear types likes helical, bevel, and worm can accommodate nonparallel shafts. Early gears were most likely made of wood and other easily worked materials, their teeth merely being pegs inserted in a wheel. It was not until the industrial revolution that machines demanded and manufacturing techniques allowed the formation of gears as we now know them with specially shaped into a metal disk.

2.4 Lead Screw:

The circuit The Selection of material for screw and Plane carbon steel Nut at Caste Iron. The lead screw is used for adjusting the upward roller from both the sides for getting the various type carve shape of metal sheet it is mounted on both the side of the upper shaft through the frame .When the nut engages the thread, theoretically all the thread in engagement should share the load. In actual, inaccuracies in the thread spacing cause virtually all the load can be taken by the first pair of thread. Thus the conservative approach in calculate the thread stress is to assume the worst case of one thread pair is taking all the   load equally or the other extreme case is to assume that all the engaged threads gives the load equally.
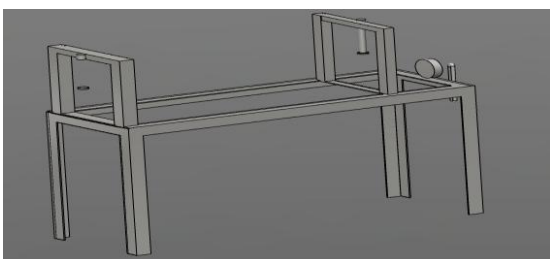
2.5. Lever:
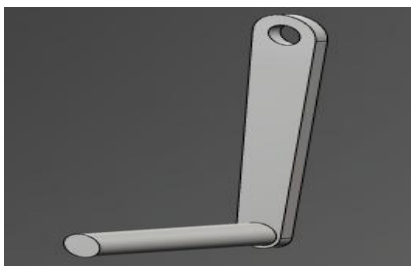
Fig -6: Lever

Our machine is manually operated so the hand lever is used for operating or revolving. It is directly connected by the shaft. The lever is most important in the hand operated sheet bending machine. It is connected to the gear. When lever is move from rotary than two shaft rotated in same direction.

2.5. Frame:

Fig -7: Frame

The frame is made up by cast iron angle. Dimension of frame =area = (length x bright x height)

Specification:

  Material = Mild Steel

  Length $\times$ width = 850$\times$350 mm.

3. Experimental Analysis:

3.1. Frame:

The experimental set up consists of 3 roller bending machine with helical groove on the rollers, groove is provided for ensure the path for strain gauges mounted on the plate to pass without being rolled and results of the strain observation on plate while rolling are not strangled. Strain gauges are located on the plate at the time of testing to read the strain values during rolling process. The connection of strain gauges is given to digital multimeter for measurement of strain by using the formula of change in resistance per unit original resistance.The top roller is given vertical displacement with the help of lead screw arrangement to get the required bending andbottom rollers are driven by using hand lever.

Fig -8: Frame

3.1. Experimental Procedure:

Firstly strain gauge is mounted on the plateand plate is kept between the top roller and bottom rollers but at the time of placing the plate we have necessity to take care of position of strain gauge and that is in front of helical groove provided on roller.

2. Strain gauge connections is given to multimeter and take multimeter is in resistance mode and record the original resistance.
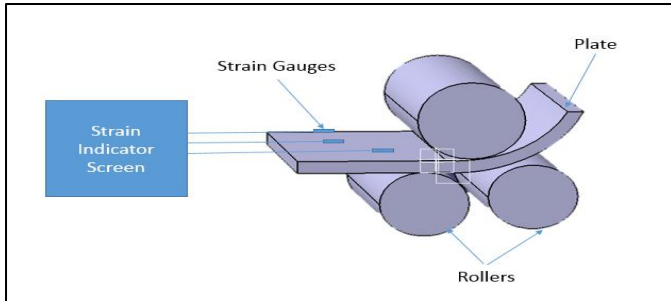
3. As we know that strain is the ratio of change in dimension per unit original dimension. Here we conduct the strain based study so we take ratio of change in resistance per unit original resistance and get strain value at each displacement.

4. The top roller is given displacement as within the range of 1 to 10 mm to get the required bending andbottom rollers are driven by using hand lever in forward direction for bending of plate. Similarly rollers are driven in backward direction to get better accuracy to the final shape. By raising the top roller the bent sheet is then unloaded.

5. For each Vertical displacement of top roller record the values of change in resistance and calculate the respective values of strain.

6. Generally plane rollers will be used to roll the plate to the shape. Maximum possible deflection of the roller is simulated using FEA. Same needs the validation as a proof of correctness of the results as one cannot rely on only FEA to predict the accurate results.
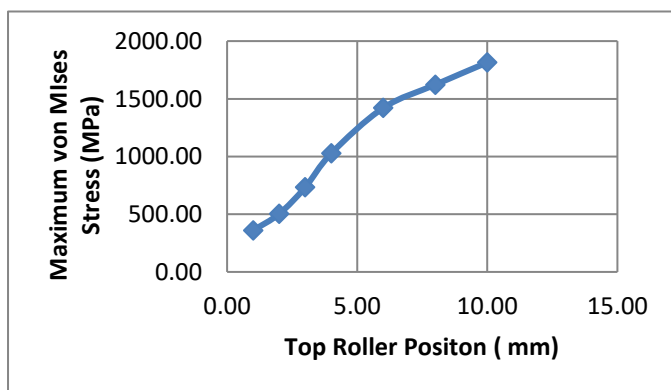

Fig -9: Schematic Block diagram for testing on three roller bending machine

4. Result & Discussion:

This chapter is concerned with both the results of the Theoretical and experimental verification. Comparison of theoretical result is made with experimental verification. It includes, Maximum displacement of top roller allowed without endangering crack formation in work piece is observed as 10 mm from FEA results. From Finite element analysis and testing results comparison strain values are in conformance with each other having maximum variation in valuesare 8.38 % which validates the FEA results. Maximum von Mises Stress found in work piece while 10 mm displacement of top roller is 1815MPa which is up to the ultimate tensile strength of the SSNL Material. Variation of maximum von Misses Stress in the plate with respect to change in top roller position as shown in graph 10 from table1

Fig -10: Displacement of top roller position V/s Maximum von Mises Stress.

Displacement (mm)	Strain		% Error
	Analysis	Testing	
1.00	0.07500	0.071	5.33%
2.00	0.16221	0.153	5.68%
3.00	0.31856	0.302	5.20%
4.00	0.50579	0.491	2.92%
6.00	0.75637	0.741	2.03%
8.00	0.88413	0.824	6.80%
10.00	1.0052	0.921	8.38%

Table 1 : Comparison of Analytical result & theoretical Result

CONCLUSION

We have calculated the diameter of the roller required for bending maximum of 2 mm thickness sheet is 30 mm. With given configuration of 30 mm roller diameter with 54 mm roller distance we can bend 1.5 mm SS plate up to roller position of 10 mm without any cracks on the sheet metal. Maximum displacement of top roller allowed without endangering crack formation in work piece is observed as 10 mm from FEA results. Strain values observed in FEA and testing are pretty much in conformance which validates the FEA model. Valuable prediction of maximum stress, spring back effect and strain values is generated for different top rollers positions while bending 1.5 mm thick SS plate using this three roller bending machine.

ACKNOWLEDGEMENT

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