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Force Analysis of Metal Sheet in Bending Operation on Sheet Bending Machine

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***Abstract*— In the three roller bending machine, the three rollers rotate. Bending can be done in both sheet metal and bars of metal. For designing a three roller bending machine, it is required to calculate the exact force for bending. Based on this force, the machine parameters and motor power are decided. Various factors that should be considered while calculating this force are material properties, width, and thickness, number of passes, bending radius, force developing mechanism and link. To analyses the force and power for motor the designer takes the help of analysis software. The cost of software for analysis is high. So there is requirement to find simple formula. In this paper the various theories regarding bending are reviewed, formulae for force and power calculation are collected and finally a case study is taken where we have put together all the results of these formulae.**

Keywords— Bending force, bend radius, material thickness and width, Number of passes.

INTRODUCTION :

Roller bending process can be used to deform a sheet or plate to hollow shapes of constant (i.e. cylindrical, elliptical) or varying cross sections like cone frustum. Cylindrical and conical shells are the basic components used for the various engineering applications like cylindrical tanks, boiler chambers, heat exchanger shells, pressure vessels, tunnels, etc. The process can be performed using many materials such as carbon and alloy steels, aluminum alloys and titanium alloys. Rolling machines with both three and four rolls are indispensible to the production of cylinders with various curvatures. The rolling process is usually performed by a three roll bending machine often called as pyramid type, because of the peculiar arrangement of the three rollers. The entire process of the roll bending may be divided into three steps: namely,

1. Positioning of blank sheet or plate.
2. Lowering of the center roller.
3. Feeding of the plate.

In the very first step, a flat blank sheet is fed into the machine by two rotating side rollers until the sheet is properly positioned. In the second step, center roller is displaced downward causes bending of the sheet. In the final step, two side rollers rotate again, so that the sheet is bent continuously.

The rolling process always began with the crucial operation of pre bending both ends of the sheet. This operation eliminated flat spots when rolling a fall cylindrical shape and ensured better closure of the seam. The success of three roller bending process heavily depends on the experience and skill of the operator.

Figure 1 shows the six stages of three roller sheet bending operation sequence for fixed bottom roller gap.

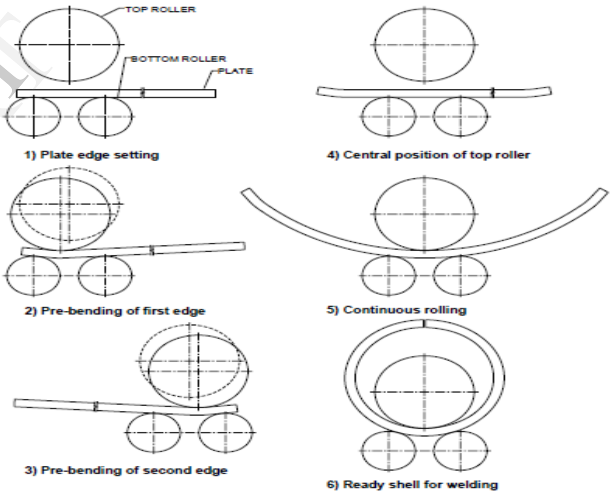

Fig. 1: Three Roller Sheet Rolling Sequence for Fixed Bottom Roller Gap

Top roller load required to bend the plate is the function of various parameters viz. sheet thickness, sheet width, sheet material property, shell diameter to be rolled, center to center distance between bottom two rollers, displacement of top roller, etc.

I. MACHINE SPECIFICATION:

Features of Three Roller Rolling Machine: The upper roll on 3-roll plate bending machine is fixed. The two ends of upper roll are controlled by PLC. The two lower roll can move up and down in arc way around fixed roller. It can finish pre-bending and rolling by feeding once. The three rollers are driving rollers. They can prevent skidding while rolling thin steel plates. Three roller rolling machine is controlled by micro-machine and has digital display. Compared with four roller plate bending machine, the structure of three roller plate rolling machine is compact and

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multiple. It is economical and practical for rolling thin and medium plates.It features clear and precise operation, high efficiency, reliability and competitiveness.
1

Specification

Among different plate bending machines, three roller plate rolling machine possesses the maximum structure and driving modes. The structure, price and application of three roller rolling machine will be different owing to the roller position change.

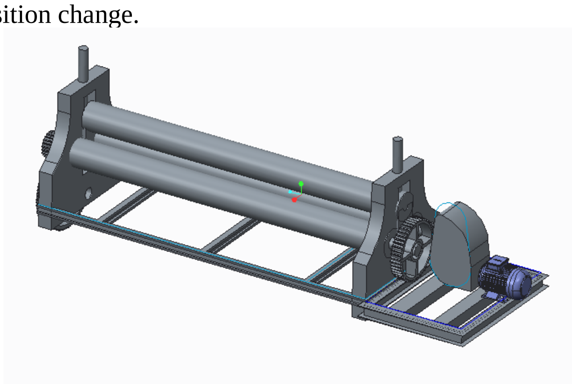

Fig 2.3 Roller sheet bending machine CAD Model.

It involve the study of present 3 roller sheet bending machine.. In this we will first identify the mechanical element will find out the dimension of the machine component from vidarbha Industry.

Fig 3.3 roller sheet bending machine form vidharbha Industry

II.RESEARCH METHODOLOGY

1. Productivity analysis of manually operated and power operated sheet bending machine
2. Modelling of metal sheet bending machine.
3. Simulation of sheet metal bending machine with different materials.
4. Forces analysis of metal sheet by analytical method.
5. Bending force analysis of metals sheet during bending operation by software approach .
6. Productivity analysis of manually operated and power operated sheet bending machine
7. Modelling of metal sheet bending machine.
8. Simulation of sheet metal bending machine with different materials.
9. Forces analysis of metal sheet by analytical method.

Bending force analysis of metals sheet during bending operation by software approach .

II. DESIGN ANALYSIS OF MACHINE

Calculations Of Gear Drive:

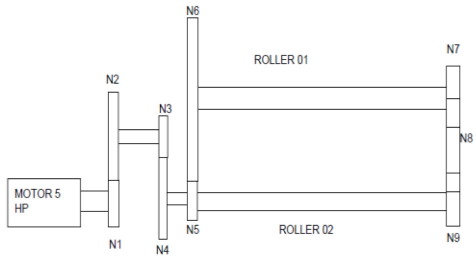

Fig 4.Power Transmission System for rolling machine

1) FOR DRIVE 1 :-

i) $Pd_1 = Pr \times K_1$

Where, Pd = Design power

Pr = Rated power

K1 = Load Factor, table XVI – 2, D.D. Book

there are 5% power losses

Pr = 0746 × 5 × 0.95

[Motor used of 5HP]

Pr = 3.5435 KW

Pd_1 = 3.5435 1.2

[load factor K1 = 1.25for medium shocks]

Pd_1 = 4.4293 KW

ii)Tooth load (Ft) =

where Vp – Pitch line velocity

Vp = rw

= d/2×2×N1

Vp = 1093.27 m/s

Ft = Pd_1/Vp

F_t = 4.051 N

Module , m = = =6.470 mm

where , d = Pitch diameter

T = No. of teeth

iii)Dynamic load, (F_d) =

Where,

C = Deformation factor , table XVI – D.D. book

e = Error in profile mm fig. 16. 1 D.D. book

b = Face width of gears

$$\therefore Fd = 4.051 + \frac{21 \times 1093.27 \left[5900 \times 0.068 \times 75 \right]}{21 \times 1093.27 + \sqrt{\left(5900 \times 0.068 \times 75 \right) + 4.051}}$$

F_d = 29872.41 N.

We know thatF_d = 29872.41 N.

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}$$

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$$\frac{N_2}{2900} = \frac{17}{23}$$

(N_1=2900)

N_2 = 2143.4 rpm

IV.DESIGN FOR 3 ROLLER SHEET BENDING MACHINE

Calculation of load & stress acting on the sheet

W = 4EI/ RL

Where,

E = Modulus of elasticity of compression

I = Moment of inertia of sheet.

R = Radius of curvature

L = Length of sheet

FOR STAINLESS STEEL

a) t_1=5mm

b =1250 mm

L =3466mm

i) W_1 = 4EI / RL

E = 196 x 10^3MPa or N.mm^2

$$I = \frac{bh^3}{12}$$

R = Radius of curvature

L = Length of sheet.n

$$W_1 = \frac{4 \times 196 \times 10^3 \times 1250 \times 5^3}{550 \times 3466 \times 12}$$

W_1 = 5355.05 N

ii) Bending shress.

$$\sigma_{b1} = \frac{MY}{I}$$

M = Bending moment

Y = Perpendicular distance of the neutral cassis

$$\sigma b = \frac{5355.05 \times 625 \times 2.5 \times 12}{1250 \times 5^3}$$

σ_{b1} = 642.60 N/mm^2

iii) Deflection of sheet at mid span to obtain required radius of curvature -

$$\delta_1 = \frac{W\ell^3}{48EI}$$

$$= \frac{5355.05 \times 3466^3 \times 12}{48 \times 196 \times 10^3 \times 1250 \times 5^3}$$

$\boldsymbol{\delta_1 = 26.909mm}$

b) for t_2 = 10mm

$$\text{i)}\ W_2 = \frac{41 \times 961 \times 10^3 \times 1250 \times 10^3}{550 \times 3466 \times 12}$$

W_2 = 42840.40 N

ii) Bending shress. $\sigma_{b2} = \frac{MY}{I}$

$$\sigma_{b_2} = \frac{42840.40 \times 625 \times 5 \times 12}{1250 \times 10^3}$$

σb_2 = 1285.21 N/mm^2

$$\text{iii)}\ \delta_2 = \frac{W\ell^3}{48EI}$$

$$= \frac{42840.4 \times 3466^3 \times 12}{48 \times 196 \times 10^3 \times 1250 \times 10^3}$$

δ_2 = 31.279 mm

c) for t_3 = 15mm

$$\text{i)}\ W_3 = \frac{4 \times 169 \times 10^3 \times 1250 \times 15^3}{550 \times 3466 \times 12}$$

W_3 = 144586 N

$$\text{ii)}\ \sigma b_3 = \frac{144586 \times 625 \times 7.5 \times 12}{1250 \times 15^3 \times 12}$$

σb_3 = 1927.81 N/mm^2

iii) δ_3=Wl^3/$_{48EI}$

$$= \frac{144586 \times 3466^3 \times 12}{48 \times 196MU^3 \times 1250 \times 15^3}$$

δ_3=29.873 mm

d) t_4 = 20mm

$$\text{i)}\ W_4 = \frac{4 \times 196 \times 10^3 \times 1250 \times 20^3}{550 \times 3466 \times 12}$$

W_4 = 342723.51 N

$$\text{ii)}\ \sigma b_4 = \frac{342723.51 \times 625 \times 10 \times 12}{1250 \times 20^3}$$

σb_4 = 2570.42 N/mm^2

$$\text{iii)}\ \delta_4 = \frac{342723.51 \times 3466^3 \times 12}{48 \times 196 \times 10^3 \times 1250 \times 20^3}$$

δ_4 =26.231 mm

e)t_5 = 25mm

$$\text{i)}\ W_4 = \frac{4 \times 196 \times 10^3 \times 1250 \times 25^3}{550 \times 3466 \times 12}$$

W_5 = 669381. 34 N

$$\text{ii)}\ \sigma b_5 = \frac{669381.3 \times 625 \times 12.5 \times 12}{1250 \times 25^3}$$

$$\text{iii)}\ \delta_5 = \frac{669381.3 \times 3466^3 \times 12}{48 \times 196 \times 10^3 \times 1250 \times 25^3}$$

δ_5 = 22.54 mm

Materials are used for force analysis are as follows

1. Aluminum alloy
2. Copper alloy
3. Stainless steel
4. Gray cast iron
5. Magnesium alloy

Thickness of sheet used practically varies from 5mm to 25 mm. The experimental performed on sheet having dimensions (1250 x 3466) mm . The power gained by upper roller through different gear drive system and this load is applied on the sheet. A sheet passes through between the upper and lower roller the sheet goes

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bend. This process is continue till the required result is obtained.

The stress induced on the sheet is calculated by the analytically as well as virtually using analysis software.

For virtual analysis CAD MODEL is generated in creo parametric 2.0 and converted into iges format and call into the ANSYS workbench for structural analysis.

V. RESULTS

For thickness 5mm:

Sr.No	Material	Analytical		Standard Deviation (σ)
t = 5 mm		Stress (N/mm^2)	Deformation (mm)	
01	Aluminum Alloy	237.69	32.872	
02	Copper Alloy	655.71	31.908	0.689
03	Gray Cast Iron	327.85	29.067	
04	Magnesium Alloy	149.43	35.899	
05	Stainless Steel	642.63	26.909	

Table No.1: Analytical Calculation

VI. CONCLUSION:

After performing actual experiment force calculation and fem analysis on metal sheet at different materials, we conclude that the force which required for bending the sheet is found by virtually it is tested in terms of factor of safety as well as material safety while bending operation.

On the basis of the results and its analysis, following conclusion can be drawn. From the result's analysis for constant radius of curvature (R) ,constant dimensions by changing the material, load(W) increases as the value of modulus of elasticity(E) increases ie Load is directly proportional to the modulus of elasticity. From the result's analysis and calculations we can conclude that for same material keeping dimensions constant change in radius of curvature(R) changes the value of load(W) .As radius of curvature(R) increases the load(W) value also increases. From the result's analysis and calculations , for same radius of curvature (R) and material if thickness varies from 5 mm to 25 mm ,it directly affects the value of load(W) ie. Load increases as the thickness changes in increasing order. Required surface finish of cylinder or any circular product is directly affected by skilled labour as they lowered the top roller with the help of power screw in some extent.

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