Calculation of Setup Variable For Process of Bending and Rolling Operation using Analytical Approach & Finite Element Method

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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 metal sheet. A finite element model of this process was built under the ANSYS environment based on the solution of several key techniques, such as contact boundary condition treatment, material property definition, meshing technique, and so on. A mathematical model of the process of bending and rolling the thin-walled components is presented taking into account the geometrical nonlinearity. Also presented is the technique for calculating the setup variables of bending equipment, which is based on reduction of the initial differential boundary-value problem to the discrete one with the use of the finite difference method.**

***IndexTerms*— Cylindrical bending; Finite elements analysis; Residual stress.**

I. Introduction (Heading 1)

In three roller sheet bending machine sheet is bend with the help of load acting on upper roller, which is movable. 3 roller sheet bending machine mainly consist of following parts: 3 rollers (upper roller and 2 bottom rollers), motors, gears, power screw, and frame. Bending operation is done by applying load (force) with the help of upper roller, which is movable. It can be moved by adjusting the power screw manually. Two bottom rollers are fixed which acts as a support for holding the metal sheet. When upper roller moves in a clockwise direction, bottom rollers simultaneously move in anticlockwise direction. Motor is used in sheet bending machine for providing power transmission. Gear drives are used for minimize the rpm transferred from motor to the assembly (machine). Spur gears are used in 3 roller sheet bending machine. Spur gears used are made up of cast iron. Square threaded power screw is used to change the position of upper roller. This operation is totally manual. Frames is a fixed rigid support used for supporting the assembly and also prevent machine from vibrations.

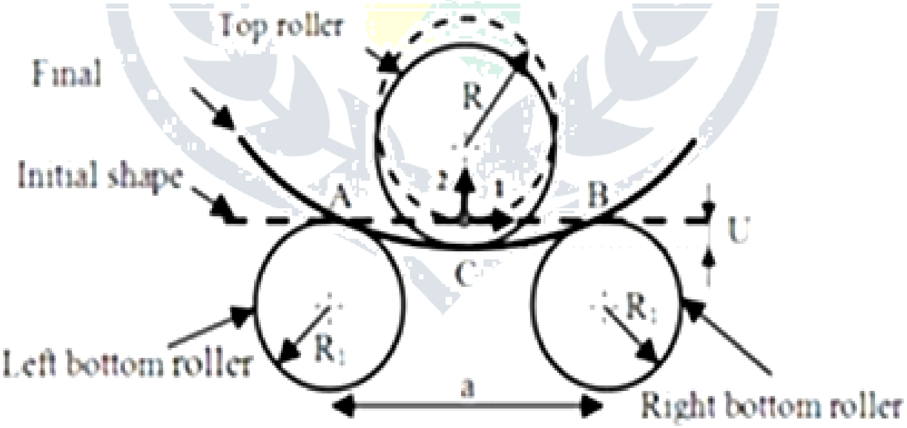

Fig. 1.Configuration of a pyramidal three-roller bending machine

II. FEM STEPS:

The analysis of a structure during its design process is accomplished by the solution of the partial differential equations which describe the given model. This involves the following three steps.

I. The description of the geometry the physical characteristics and the mesh (preprocessing)

II. The application of the finite element analysis (solution)

III. The visualization and interpretation of the results of the solution (post processing).

These three steps are quite distinct and correspond to creating, on the programming level, the three distinct modules:

i. Module to enter the data

ii. Module to perform the analysis

iii. Module to interpret and display the results.

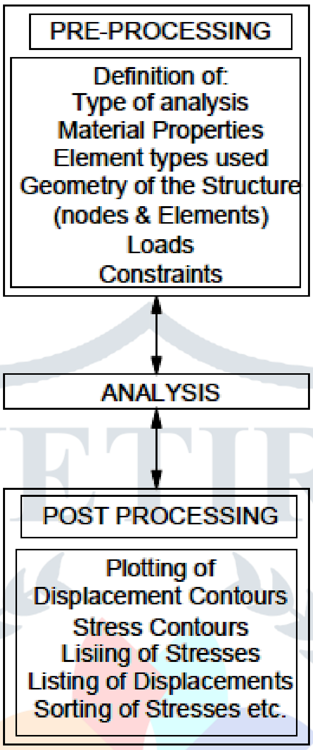

Fig 2: Steps in FEM

III. MODELING PROBLEM:

The importance of modeling and simulation in manufacturing technology is increasing due to the need for continuous reduction of development times. This necessitates the optimization of the production processes, the enhancement of product quality and a reduction of costs. The application of numerical modeling is especially resorted to in the development of new production methods and in the use of new materials. Specialized software solutions are available to optimize the design of castings (solidification analysis), welding process (resistance welding, gas metal arc welding), heat treatment and metal forming (sheet metal processing, tube bending, extrusion, rolling, drawing, forging etc).

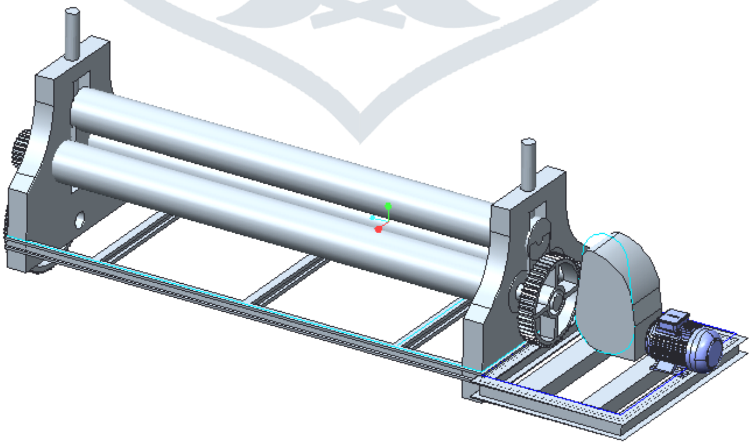

Fig 3: Assembly Modeling of 3 Roller Bending Machine

IV. MESH GENERATION

1. Click on generate cfx mesh tab in project tab.
2. Define regions for boundary condition in Cfxmesh module
3. Region In, out and wall.

4. Define control for mesh size. Mesh size in body spacing = 9
5. Define face spacing as a constant
6. Define inflation layer =5
7. Define inflation boundary on diaphragm portion.
8. Set surface proximity =yes
9. Generate surface mesh.
10. Generate volume mesh.
11. Generate .gtm file required for cfx pre.

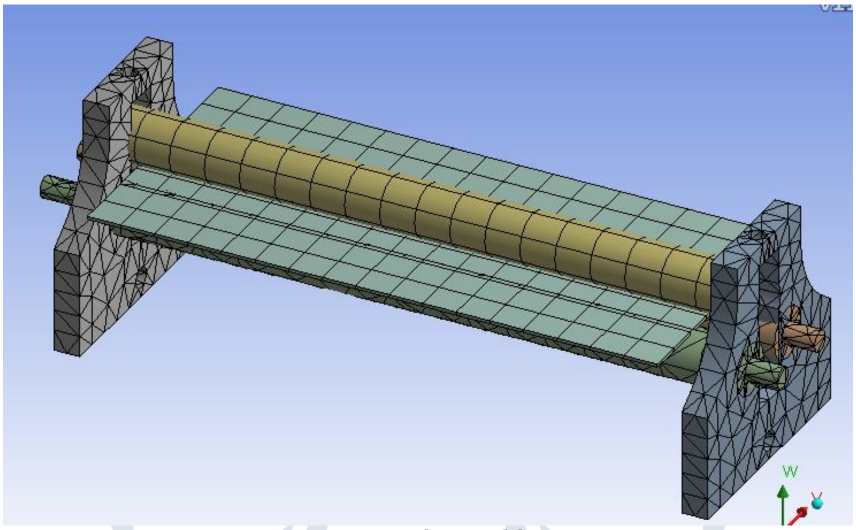

Fig 4: Meshing Model

V. DEFINING BOUNDARY CONDITIONS.

- **Loading conditions:**

1. Displacement constraint if fixed support located at both ends.
2. Moment load act on the upper roller having certain magnitude.

- **Material Properties:**

TABLE 3
Model > Geometry > Parts

Object Name	Part 1	Part 2	Part 3	Part 4	Part 5
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Material	Structural Steel				Aluminum Alloy
Stiffness Behavior	Flexible				
Nonlinear Material Effects	Yes				
Bounding Box					
Length X	1150. mm		250. mm		1230.5 mm
Length Y	1100. mm		250. mm		15. mm
Length Z	125. mm		3553.3 mm		2747.3 mm
Properties					
Volume	1.0598e+008 mm³		1.5779e+008 mm³		5.0708e+007 mm³
Mass	831.95 kg		1238.7 kg		140.46 kg
Centroid X	-3.7552e-002 mm	-3.7553e-002 mm	-175. mm	175. mm	105.6 mm
Centroid Y	243.85 mm	243.84 mm	338.47 mm		456.6 mm
Centroid Z	62.476 mm	3087.5 mm	1566.9 mm		1500. mm
Moment of Inertia Ip1	7.8428e+007 kg·mm²		1.0664e+009 kg·mm²		8.835e+007 kg·mm²
Moment of Inertia Ip2	8.3462e+007 kg·mm²		1.0664e+009 kg·mm²		1.0607e+008 kg·mm²
Moment of Inertia Ip3	1.5971e+008 kg·mm²		9.2988e+006 kg·mm²		1.7726e+007 kg·mm²
Statistics					
Nodes	1436	1425	893	928	1080
Elements	598	593	361	373	136

Table 1.1 Bill of Material (Aluminum Alloy sheet)

- **Solution step**
  Solve the problem by click on start run

1.5 Postprocessor

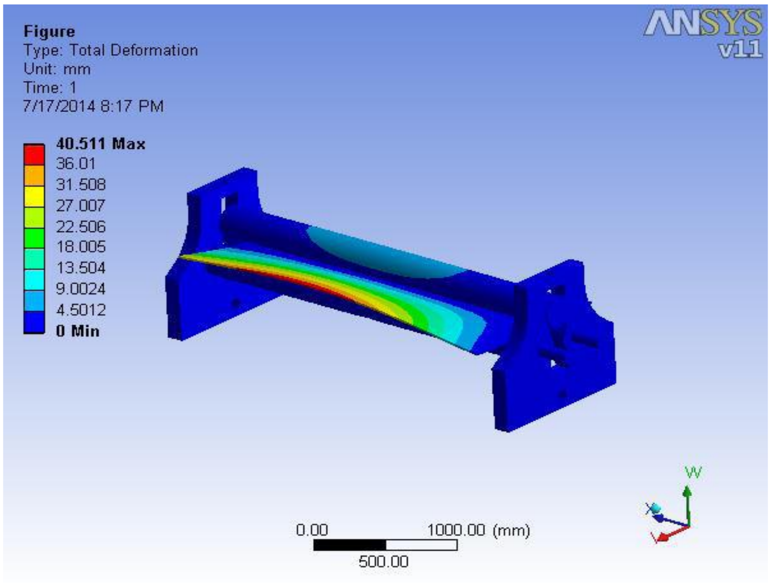

Fig 5: Total Deformation of metal sheet (Aluminum alloy)

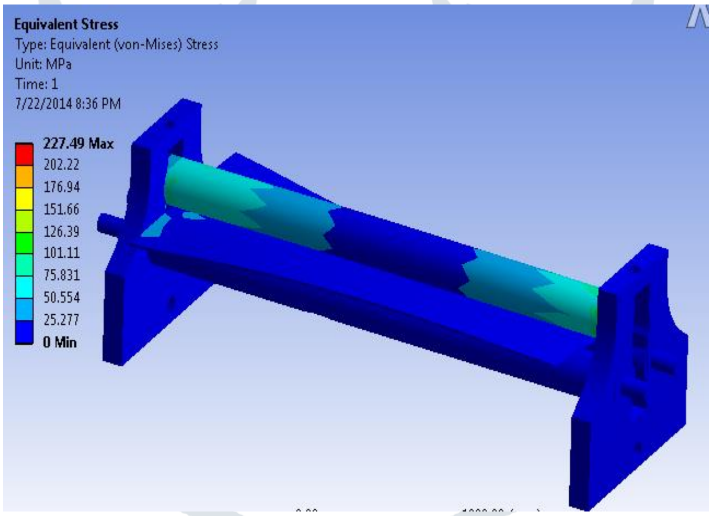

Fig 6: Equivalent Stress on metal sheet or roller (Aluminum alloy)

VI. RESULT & DISCUSSION :

After performing all the calculations and analysis done in ansys we get number of results. These results are changing according to the material and according to the loading condition and finally depend upon the thickness of the sheet.

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 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.

The results obtained are :

For thickness 5mm:

Sr.No	Material	Analytical		By using Software		Standard Deviation (σ)
t = 5 mm		Stress (N/mm^2)	δ (mm)	Stress (N/mm^2)	δ (mm)	
01	Aluminum Alloy	237.69	32.872	227.49	40.511	0.689
02	Copper Alloy	655.71	31.908	632.38	38.207	
03	Gray Cast Iron	327.85	29.067	358.02	37.532	
04	Magnesium Alloy	149.43	35.899	161.79	42.949	
05	Stainless Steel	642.63	26.909	621.7	33.941	

TableNo.1.2 Comparison between Analytical Calculations and Software Calculations

Where, $\delta = \text{Deformation}$

For thickness 10 mm:

Sr.No	Material	Analytical	
t = 10 mm		Stress (N/mm^2)	Deformation (mm)
01	Aluminum Alloy	475.39	37.248
02	Copper Alloy	1311.44	32.437
03	Gray Cast Iron	655.719	33.454
04	Magnesium Alloy	299	38.213
05	Stainless Steel	1285.21	31.279

TableNo.1.3 Analytical Calculations

VII. 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:

1) 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.
2) 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.

Sr.No	Material	Analytical		By using Software		Standard Deviation (σ)
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Tableno.1.4 Comparison Between Analytical Calculations And Software Calculations

Following table shows results of the analysis calculated manually and by using software which is developed. By varying thicknesses, load simultaneously and keeping modulus of elasticity, radius of curvature constant for same material results obtained are as follows. Following parameters are kept constant. If you assume that error between the deformations evaluated by the software and manually is assumed to follow normal distribution then, it can be estimated that if deformation estimated by the software is δ then, in 99.97 % of the cases deformation estimated by manually will lie in the range δ ±3σ, where value of sigma (σ) is 0.689 mm.

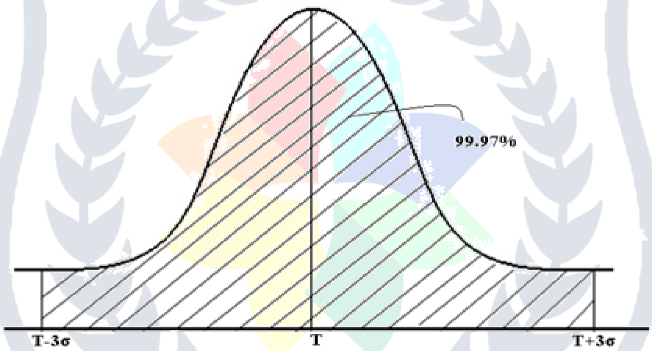

Fig 7: Normal Distribution Diagram

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