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Identification of Parameters to Evaluate Roller Bending Process: A Review

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Abstract: This paper describes a comprehensive review of major published research work performed on three as well as four roller bending process. Based on the literature, further research scope is identified. The present literature reveals that there is a further scope to model the three roller bending process in a generalized and simplest form includes various parameters viz geometrical, process, and material parameters, which will help to produce sheet metal parts to precise shape with smooth surface finish and good dimensional accuracy.
Keywords: Bending, mathematical model, material properties, steel, rolling, alloys, cylindrical

I. INTRODUCTION

Roll bending or Roll forming is one of the metal forming processes in which a long, straight metal strip is passed through a set of rollers to transform it into desired curved cross-sectional profile. The plates to be bent are cut for required shape and size. Roll bending is a continuous forming process, produces higher dimensional accuracy of the finished products without loss of material. Cylindrical, conical, elliptical, oval shells are widely used in process industries like power plants, food processing, dairy equipment manufacturing, etc. Various products like cylindrical tanks, drums, boilers, pressure vessels, tunnels, containers, chimneys, towers, structural components are manufactured using roller bending process. Many different types of roller bending machines have been developed over the past few decades. The existing roller bending machines are mainly classified as three-roller and four-roller bending machines. Two types of three-roller bending machines, pinch-type (Asymmetrical) and pyramidal (Symmetrical) were initially developed for forming the boiler shells. Though roller bending is widely used in metal forming industries, its process is quite complex to understand. Normal practice of the roller bending still heavily depends upon experience and skill of operators. There have been several efforts made so far to develop mathematical models to understand the mechanics of bending process.

II. LITERATURE REVIEW ON ROLLING PROCESS

Over the last few decades, many research work are reported on three and four roller bending process, mostly discusses mechanics of the process through different analytical models. Hua [14] commented that it is difficult to achieve a single mathematical model that takes into account all the complexities of the bending process. A realistic simplification is thus necessary. Thus, various mathematical models are developed depending on assumptions made and factors considered. Several literatures are summarized as below.

N. E. Hansen and O. Jannerup [1] reported the geometrical analysis of single pass elastic – plastic bending of beams on the three roller bending machine by assuming triangular moment bending force and bending moment was based on the contact point shift between the plate and top roll from the vertical centerline of the top roll.

D. E. Hardt et al [2] described closed loop shape control of the three roller bending process. The presented scheme accomplishes the shape control by measuring the loaded shape, the loaded moment and effective beam rigidity of the material in real time. A series of experiments were performed to test this scheme by bending thin sheets of different materials to constant radii, specifying only the desired radius. Yang and Shima [3] discussed the distribution of curvature and bending moment in accordance with the displacement and rotation of the rolls by simulating the deformation of work piece with U-shaped cross-section in a three-roller bending process. They reported the relationship between the position of the rolls and the final curvature of the work piece by iterative method. The simulated results were compared with experimental results and the accuracy of the simulation was confirmed.

A. H. Gandhi et al [4] 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. Top roller positions for loaded radius of curvature are plotted for a certain set of data for center distance between bottom rollers and bottom roller radius. Method of least square and method of differential correction is applied to the generated data, and unified correlation is developed for the top roller position, which is verified with the experiments on the pyramid type three roller plate bending machine.

H.V.Gajjar et al [5] introduced bend ability analysis of heavy duty 3 roller plate bending machine. Various input parameters like plate thickness, shell diameter and material property parameters are used to develop analytical models of equivalent thickness, equivalent width and maximum width based on power law to study the bend ability. These parameters are compared for four different materials grades of C-Mn steel in order to predict the bend ability.

A. H. Gandhi et al [6] discussed the formulation of spring back and machine setting parameters for continuous multi pass bending of cone frustum on three roller bending machine. Effect of change of flexural modulus during the deformation on spring back prediction is analyzed. Effect of plate initial radius, number of bending passes and step interval for two successive bend radii on the spring back is also presented. Analytical results are compared with experimental results.

Conical shells and sections are also widely used in various industrial applications like towers for wind mill, chimneys, air duct, etc., which are manufactured using three roller conical bending process. A lot of research work has been reported in the area of analytical modeling of conical bending process for single as well as multi – pass bending operation.

M. K. Chudasama and H. K. Raval[7-11] have developed analytical models for force prediction, top roller position for desired radius, spring back effect, etc. Experimentation has been carried out to validate the developed model, results of which are not exactly match with each other due to some unknown factor. Thus, a correction factor for each pass has been found and applied to the analytical model. Corrected analytical model can be effectively used to study the effect of various parameters of the bending force. Also, an attempt is made to develop the analytical model for the prediction of bending force during the stage of dynamic roll bending. The analytical model has been developed considering shear stresses. Model consists of various parameters like material parameters and geometrical parameters. Based on this model, effects of some of some of the material parameters on dynamic bending force have been studied. They concluded that force required for dynamic bending is very less as compared to that of static bending stage.

Shakil Kagzi et al[12] made an attempt to simulate the three roller bending process in ABAQUS (FEA) software and results of simulation are compared with reported analytical model for prediction of spring back. It is seen that, spring back results of the simulation and reported analytical model are in agreement with each other within reasonable range.

M. Hua et al [13-19] have extensively worked on four roller bending process considering various aspects like mechanism of the process, preliminary tests, spring back effect, internal and external moments, etc. M. Hua [14]reported the mathematical model for determining the plate internal bending resistance at the top roll contact for the multi pass four roll thin plate bending operations along with the principle mechanisms of bending process for single pass and multi pass bending. Hua and Lin [16] also investigated influence of material strain hardening on the mechanics of four roll bending process. Hua and Baines[15, 18] proposed an analytical model for continuous single pass four roll thin plate bending process considering the equilibrium of the internal and external bending moment. Hua and Lin [19] presented a mathematical model to simulate the mechanics in a steady continuous bending mode for four roll thin plate bending process. The differential equations governing the large deflection bending of elastic – plastic thin plate are derived.

Jong Gye shin and Jang Hyun Lee [21] described a finite element methodology to develop a logical procedure to determine the center roller displacement in the three roller bending process. The mechanics of the process is further analyzed by both analytical and finite element approaches. it is revealed that a simple analytical procedure, based on the beam theory, yields accurate relationship between center roller displacement and residual curvature.

Ahmed Ktari et al [22] presented a two dimensional finite element model of the three roller bending process using ABAQUS based on boundary conditions, material properties, meshing techniques and so on. Desired curvature radii are generated by varying the distance between bottom rollers and position of top roller and results are validated with experimental and numerical model.

Zhengkun Feng et al [23-25] presented a numerical model based on finite element method for a non - kinematical roll bending process with cylindrical rolls and model is then simulated to get desired cone with geometrical differences in cone angle, top and bottom radii. Feng [] also developed a numerical model to predict the position of lateral rolls in case of asymmetrical three roller bending process, numerical simulation is validated with experiments.

From the literature review, it is concluded that top roller position is a function of final radius of curvature. Final radius of curvature is a function of **[4]**:

A. Top roller radius.
B. Bottom rollers radii.
C. Top and Bottom rollers inclination (for conical bending only).
D. Center distance between bottom rollers.

E. Thickness and width of plate.
F. Material properties of plate (E, K, n, υ).
G. Number of passes
H. Coefficient of friction between rollers and plate material.

III. CONCLUSION

Published research work on three as well as four roller bending process is reviewed. Based on the literature review, it is concluded that reported research on the forming of cylindrical shells mostly discusses the modeling and analysis of the process. Mechanics of the process is presented using analytical models based on assumptions. Results of analytical models are varied with experimental models due to some unknown factors. Also, a very few research work is reported defining number of passes required to produce precise final shape. Thus, there is a scope to develop simplified and generalized mathematical model for step intervals of top roller movement to obtain desired final shape of curvature in optimum number of passes, which can reduce required power consumption by rollers and thus to increase productivity.

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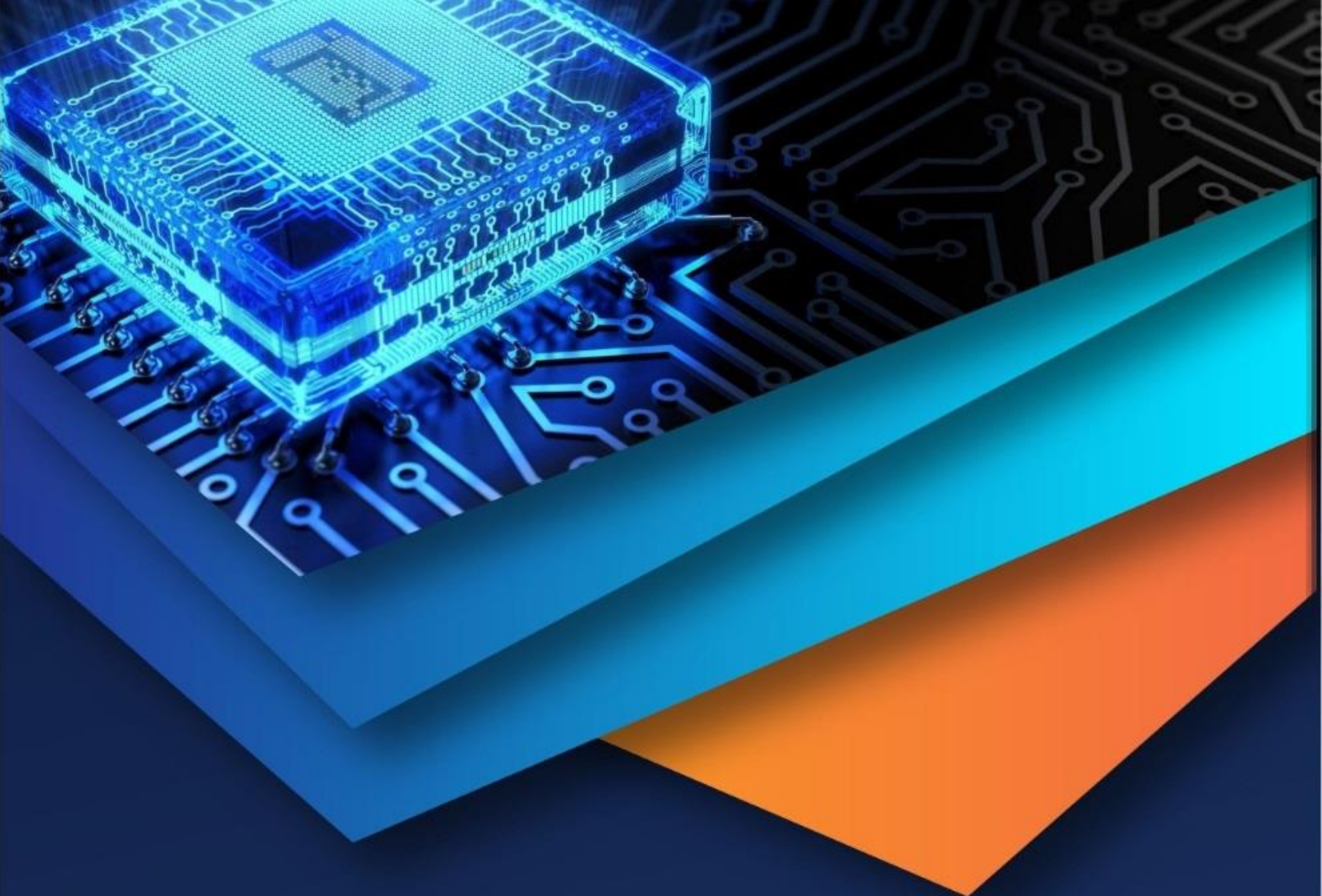

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