Article **Journal of Mechanical Engineering**
June, 2023 Vol.7 No.19 1-5

Dimensional Analysis of thickness of strip for a four high cold mill

Análisis dimensional del espesor de la lámina para un castillo de laminación en frio cuatro alturas

DIAZ-SALINAS, Juan Andres†[1], SERVIN-CASTAÑEDA, Rumualdo*[2], ARREOLA-VILLA, Sixtos Antonio[2] and PEREZ-ALVARADO, Alejandro[2]

[1]*Doctorado en Ciencias – UAdeC, Centro Cultural 2º. Piso. Ciudad Universitaria, Carretera México Km 13, C.P 25350 Arteaga Coahuila, México*
[2]*Facultad de Ingeniería Mecánica y Eléctrica – UAdeC. Barranquilla S/N, Colonia Guadalupe, C.P 257500 Monclova Coahuila. México*

ID 1st Author *Juan Andres, Diaz-Salinas* / **ORC ID**: 0009-0009-0706-2355

ID 1st Co-author *Rumualdo, Servin-Castañeda* / **ORC ID**: 0000-0002-8655-2572

ID 2nd Co-author: *Sixtos Antonio, Arreola-Villa* / **ORC ID**: 0000-0002-6348-0860

ID 3rd Co-author: *Alejandro, Perez-Alvarado* / **ORC ID**: 0000-0003-0420-5153

DOI: 10.35429/JME.2023.19.7.1.5 Received: March 30, 2023; Accepted: May 30, 2023

Abstract

In the present study, a Finite Element Method (FEM)is used to model in 3D and simulation of a cold rolling mill Four High, to analyze flatness, geometry and thickness of rolling strip when constant variables of rolling force, materials properties, dimensions of rolls and strip; considering +0.03937mm of constant positive crown on Back Up Roll and combinations of +0.1016mm, +0.254mm y +0.508mm on Work Roll, The results shown that there is a instability zone of 76mm for all the analyzed cases in the end of the strip, this geometry is symmetrical in both ends of the strip. When the crown of work rolls is increase, the instability zone starts to move toward to the middle of the strip. With the increase of crown from +0.03937mm to +0.508mm the generated strain is only 0.020 mm, and we can see that strain is bigger in the middle of strip.

Strip, Flatness, Pressure

Resumen

El presente estudio se realiza utilizando un Método de Elementos Finitos para modelado en 3D y simulación de un molino de laminación en frio Four High, para analizar la planeza, forma y espesor de la lámina rolada cuando se utilizan variables fijas de fuerzas de rolado, propiedades de los materiales, dimensiones de los rodillos y la lámina rolada; considerando constante la corona positiva de +0.03937mm en los rodillos de apoyo y combinaciones de +0.1016mm, +0.254mm y +0.508mm en los rodillos de trabajo. Los resultados muestran que hay una zona de inestabilidad de 76mm para todos los casos en el extremo de la lámina, esta geometría es simétrica en los dos extremos de la lámina. Cuando la corona de los rodillos de trabajo se incrementa, la zona de inestabilidad comienza a moverse hacia el centro de la lámina. Con el incremento de corona de +0.03937mm a +0.508mm la deformación generada es de tan solo 0.020 mm, y se puede observar que la deformación es mayor en el centro de la lámina.

Lamina, Planeza, Presión

Citation: DIAZ-SALINAS, Juan Andres, SERVIN-CASTAÑEDA, Rumualdo, ARREOLA-VILLA, Sixtos Antonio and PEREZ-ALVARADO, Alejandro. Journal of Mechanical Engineering. 2023. 7-19: 1-5

† Researcher contributing as first author.

Introduction

Steel is one of the most important materials in the development of the current economy, it can be recycled without losing its mechanical properties, it is a sustainable material that makes it the most recycled material.

Consequently, steel is one of the most important materials in the world, due to its multiple uses it is considered the pillar of technological development in the economy.

Once the steel is produced, one of the most used mechanical forming processes is the rolling process, in which rolling mills are used to shape the products.

For this process there are many variables that must be considered, always keeping in mind considering the surface quality of the strip. Yan-Lin Li and Jian-Guo Cao (2015), developed a mathematical model where they consider the main variables of the rolling process with thermal crowns and wear of the rolls, Zhang Guo-min and Xiao Hong (2006) also developed a three-dimensional model, considering the same operating variables to study the pressure distribution between the rolls and the rolling strip.

Other scientists such as Guang-ming Liu et al (2018), have studied the effect of roll geometry due to axial forces and more specifically *Guanghui Yang* et al (2008), Xianodong Wang et al (2012) and Ning Kong et al. al (2014) have studied the contour of the Back Up rolls seeking to optimize the pressure distribution between the Back Up Roll (BUR) and Work Rolls (WR), using Smart Crown or Continuous Variable Crown (CVC), looking for uniform pressure on the strip and develop a Finite Element Method (FEM) for systematic control for the shape and flatness of the strip as proposed by Li Hai-jun et al (2010) and Liu Xiang-hua et al (2008), and even validate data at industrial scale such as those shown in the technological development of Cao, J.et al (2008).

When there is no control in the rolling variables, it results in inadequate surface quality of the strip, obtaining products with dimensional differences due to the inadequate distribution of rolling forces; the use of FEM are indispensable tools for the technological development of rolling processes, the present study is a tool that allows predicting what the results would be if the crowns of the work rolls are varied.

Research Methodology

The present study consists of the analysis of pressure distribution and stresses that generate the deformation of the strip, applied to the cold rolling process for a Four High rolling mill, for which a FEM developed by Rumualdo Servin et al (2019), considering constant the main variables and conditions of the rolling process shown in Figure 1, and the parameters are specified in Table 1.

For the cases of analysis, the crown of the BUR is considered constant, which is 0.03937mm, and variable crowns of the work rolls, for which the following combinations are analyzed:

a) BUR0.03937mm-WR0.1016mm
b) BUR0.03937mm-WR0.254mm
c) BUR0.03937mm-WR0.508mm

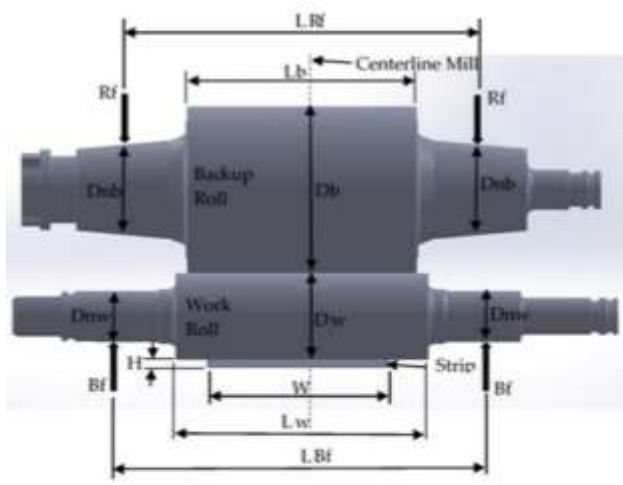

Figure 1 Representation of the main rolling variables

ISSN-2531-2189

Model Parameter	Value
Work roll diameter Dw	356.870 mm
Work roll barrel length Lw	838.200 mm
Work roll neck diameter Dnw	206.197 mm
Work roll Bending force length LBf	1428.750 mm
Backup roll diameter Db	812.800 mm
Backup roll barrel length Lb	857.250 mm
Backup roll neck diameter Dnb	479.221 mm
Backup roll Rolling force length LRf	1676.400 mm
Strip width W	520.700mm
Strip thickness H	6.096mm
Rolling force Rf	4,893 kN
Piosson´s ratio work roll	0.29
Poisson´s ratio backup roll	0.29
Young´s modulus work roll	200 Gpa
Young´s modulus backup roll	200 Gpa
Work Roll Crown	0.1016mm, 0.254mm and 0.508mm
Backup Roll Crown	0.03937mm
Young´s modulus strip	205 MPa
Maximum Thermal crown WR	0.150 mm
Maximum Thermal crown BUR	0.100 mm
Maximum wear WR	0.150 mm
Maximum wear BUR	0.600 mm
Chamfer of BUR	76.200mm x 6.604 mm
Chamfer of WR	No Taper

Table 1 Values for the parameters considered

The results were validated at industrial scale, obtaining similar results with a margin of error of ±10%. Figure 2, shows the illustration of the simulated model, the rolling forces are uniformly distributed and applied in the bearing area, as shown in the figure in the areas in red; elastic deformation is considered for the rolls and the strip, using a model with a linear relationship between stress and deformation, the arrangement of the model allows vertical movement in the direction of the applied force.

The mesh is generated using smart meshing, defined by nodes and has three degrees of freedom per node, which are translation in X, Y and Z directions.

The mesh in the contact regions was refined, it is guaranteed that the zones are always in contact, there is no possibility of separation between the surfaces and the model was implemented without penetration.

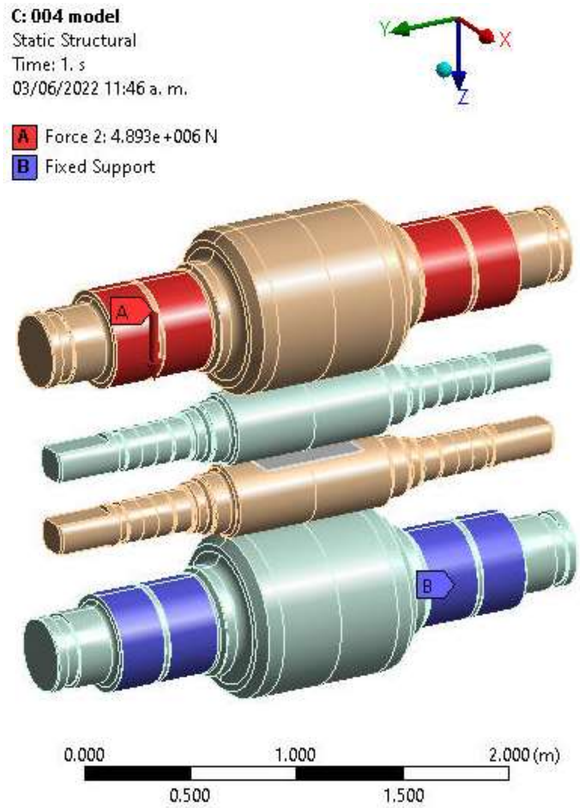

Figure 2 Graphic representation of the 3D model

Results

Figure 3 illustratively shows the stress values for crown combinations a), b) and c) respectively. Where it can be seen that the maximum stress values are 300 MPa and are located in two contact zones, the first contact zone is between the BUR and WR and the second is between the strip and the work roll; our case study is focused on analyzing only the contact area between the strip and the work roll, where we can see that for the three cases there are stress concentration points, however, for combination c), the stress tends to be concentrated in a punctual way in the center of the strip.

ISSN-2531-2189

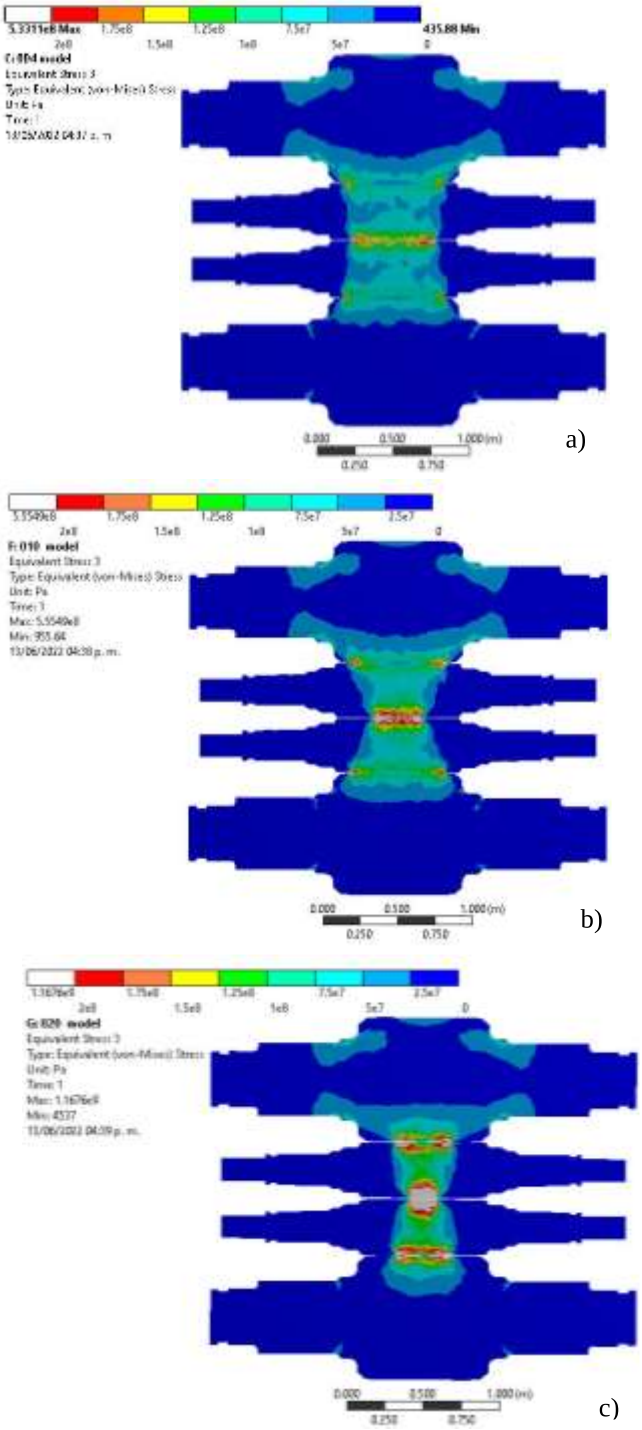

Figure 3 Illustrative representation of the stress for the crown combinations a) BUR0.03937mm-WR0.1016mm b) BUR0.03937mm-WR0.254mm and c) BUR0.03937mm-WR0.508mm

Figure 4 illustratively shows the deformation values, where it can be seen that for combination a), the greatest deformation is concentrated at the ends of the strip, approximately 76 mm wide; for combination b) the deformation tends to move towards the center of the strip and reaches values of 0.005mm and finally for combination c) the greatest deformation is found in the center of the strip, reaching values of 0.020 mm.

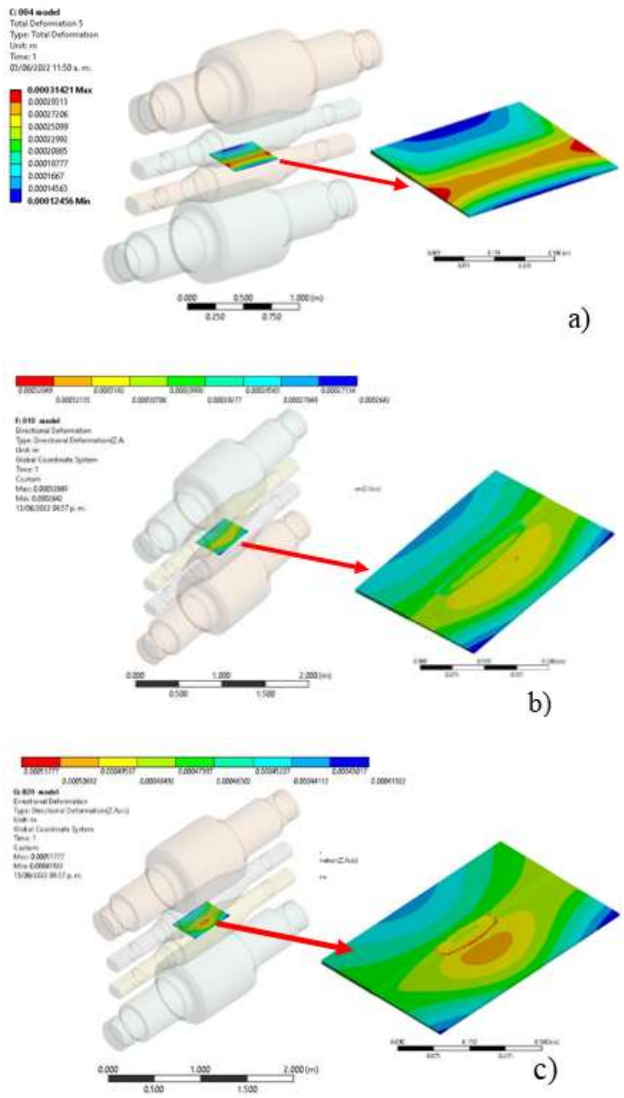

Figure 4 Illustrative representation of the deformation for the crown combinations a), b) and c)

For a better analysis of the deformations obtained, the graphs of Figure 5 were constructed, where it can be observed that the simulated deformation tends to concentrate in the center of the strip as the crown of the work rolls increases, for this case in particular for the 0.254mm crown it varies from 6.090mm to 6.095mm and for the 0.508mm crown it varies from 6.076mm to 6.096mm.

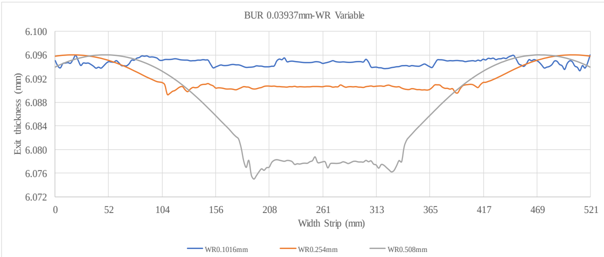

Figure 5 Graphs of simulated deformation, for the different types of crowns in WR and constant crown in BUR

Conclusions

For all three cases the same performance behavior is observed, the maximum stress concentration is located in two zones, BUR and WR contact zone and WR and strip contact zone; for the case of WR and strip contact zone the stress produces the deformation of the strip due to difference of mechanical properties of the strip, in others words, it is due to the WR is harder than the strip.

There is a stress concentration zone of 76mm wide approximately in the end of strip, it is symmetrical on both sides. When the Crown is increased in WR the stress concentration zone starts to move towards the middle of the strip. The width of 76mm is maintained moreover the direction of deformation changes. The phenomenon continues being symmetrical on both sides.

With the modification of positive Crown on WR from 0.1016mm to 0.508mm, the maximum deformation generated on the strip is only 0.020mm, moreover, it is considerable for the dimensional quality of the strip.

The stress concentration indicates instability of distribution of pressure and consequently alterations on the flatness and thickness of the strip, such as shown in the above images and graphics. There is a relationship between the Stress and deformation of the strip, and consequently it is due to the pression distribution along the width of the strip.

References

Cao, J.; Wei, G.; Zhang, J.; Chen, X.; Zhou, Y. VCR and ASR technology for profile and flatness control in hot strip mills. *J. Cent. South. Univ. Technol*. 2008, *15*, 264–270. http://dx.doi.org/10.1007/s11771-008-0049-0

Guanghui Yang, Jianguo Cao. Backup roll contour of a Smart Crown tandem cold rolling mill. *Journal of University of Science and Technology Beijing, Materials, 2008, 357-361* https://doi.org/10.1016/S1005-8850(08)60067-5

Guang-ming Liu, Yu-gui Li. Axial Force Analysis and Roll Contour Configuration of Four-High CVC Mill. Mathematical Problems in Engineering, 2018, 1-12. https://doi.org/10.1155/2018/7527402

Li Hai-jun, Xu Jian-zhong. Development of Strip Flatness and Crown Control Model for Hot Strip Mills. Journal of Iron and Steel Research International, 2010, 21-27. https://doi.org/10.1016/S1006-706X(10)60067-2

Liu Xiang-hua, SHI Xu. FEM Analysis of Rolling Pressure Along Strip Width in Cold Rolling Process. Journal of Iron and Steel Research International, 2007, 22-26. https://doi.org/10.1016/S1006-706X(07)60068-5

Ning Kong, Jianguo Cao. Development of Smart Contact Backup Rolls in Ultrawide Stainless Strip Rolling Process. Materials and Manufacturing Processes, 2014, 129-133. https://doi.org/10.1080/10426914.2013.822979

Rumualdo Servin, Sixtos A. Arreola, Ismael Calderón, Alejandro Perez and Sandra M. San Miguel. Effect of Crown Shape of Rolls on the Distribution of Stress and Elastic Deformation for Rolling Processes, **Metals** 2019, **9**(11), 1222. https://doi.org/10.3390/met9111222

Xiaodong Wang, Fei Li. Design and Application of an Optimum Backup Roll Contour Configured with CVC Work Roll in Hot Strip Mill. ISIJ International, 2012, 1637-1643. https://doi.org/10.2355/isijinternational.52.1637

Yan-Lin Li, Jian-Guo Cao. ASR Bending Force Mathematical Model for the Same Width Strip Rolling Campaigns in Hot Rolling. Steel Research International. 2014, 567-575. https://doi.org/10.1002/srin.201400133

Zhang Guo-min, Xiao Hong**.** Three-Dimensional Model for Strip Hot Rolling. Journal of Iron and Steel Research International, 2006, 23-26. https://doi.org/10.1016/S1006-706X(06)60020-4

ISSN-2531-2189