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SIMULATION OF ROLL BENDING WITH THREE ROLLERS PYRAMID SYSTEM USING FEM

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ABSTRACT

In the present paper a FEM simulation of the roll bending with three rollers pyramid system is presented. The results of simulation are the variations of bending force and torsional moments at the roller centers. These results can be useful in the design of an industrial roll bending device for obtaining bent naval sheet. From numerical simulation the variation of radius of bent sheet can also result.

KEYWORDS: roll bending, cylindrical bending

1. INTRODUCTION

Roll bending is the process which induces a curve into metal sheets and it is used for bending metal sheets and plates. Naval bilge planking can be obtained using roll bending.

The main benefits of roll forming are as follows [1], [3]:

- handles any project size
- provides closest tolerance
- is proficient in complex and custom jobs.

Roll bending is similar to bending (three points bending), because the material is deformed by applying a force. In the roll bending process no material is cut or removed and for this reason the roll bending is among the cheapest sheet metal forming methods. Using roll bending there can be obtained large radius of a sheet.

The minimum bending radius is the value at which the material can be bent without any defects. In the case of steel the minimum bending radius depends on the sheet thickness multiplied by a factor of 1 to 3 [4] (Rime industries - Germany). This means that the thickness of a steel sheet or plate is 10 mm it can be bent with a minimum radius between 10 and 30 mm.

The arrangement of the three rolls relative to each other is important in order to bend the metal sheet uniformly.

In principle [2], [3], the system having three rolls (the pyramid system) has two rolls whose height is fixed and rotate in tandem (steel rollers in Fig. 1.1). Between these two rollers one roll (the bending roll) is attached vertically and the height of this roll can be changed depending on the two fixed rolls; this third roll can rotate (see Fig. 1).

There are two steps in deformations:

-the first step is the descending of the third roll which bends the sheet similar to three points bending test up to a determined position corresponding to inducing plastic deformations across the plate thickness at the prescribed radius

- the second step - at the final of the first step the two rollers whose height is fixed rotate and the sheet is forced to advance and deform.

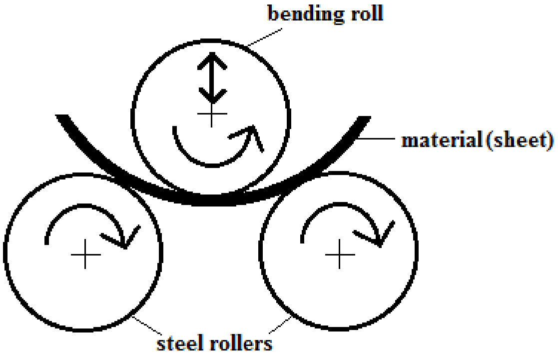

Fig. 1: The pyramid system for roll bending

2. FEM MODELING OF THE PROCESS OF ROLL BENDING USING A PYRAMID SYSTEM

The present paper proposed a numerical method to determine the force of bending at the top roller and the moment of torsion at the center of the two rollers which can rotate in tandem. Using this numerical analysis we can estimate the bent force and the radius of the rolling sheet.

These numerical values will be used in a project of an industrial roll bending device for obtaining bent naval sheet.

The diameter of the three rollers is of 189 mm and the distance between the centers of the two rollers with fixed height is of 320mm. The thickness of the steel sheet is considered of 10 mm, the width of sheet is 2000mm and the length of the rollers is of 2200mm. Two materials are tested in the process of roll bending: the steels **S235JR** and **S275JR**.

3. 2D MODEL DESCRIPTION AND THE HYPOTHESES OF FEM CALCULUS

The material of the three rollers was considered structural steel having elastic behaviour.

A two dimensional calculus (using plane strain assumption) is quite accurate. 2D model of roll bending is represented in Fig. 2.

The centers of rollers have the following prescribed displacements:

-translation and rotation for the top roller labeled by (C) in the Fig. 2.

-only rotation for the two rollers in the bottom labeled by (A) the left one and by (B) the right one (see Fig. 2).

The contact between sheet and rollers was considered to be frictional; the coefficient of Coulombian friction was considered 0.3.

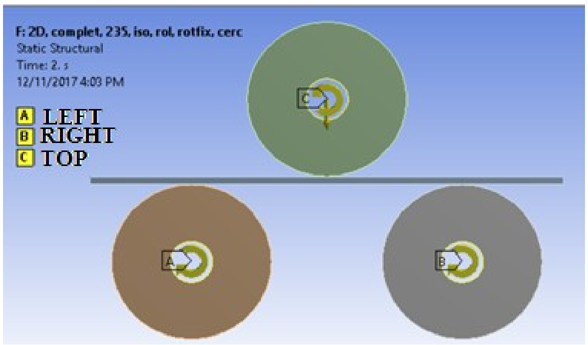

Fig. 2: The 2D model of the roll bending of pyramid type system (the plan of the model is XY)

The material of the sheet has an elasto-plastic behavior with isotropic hardening.

The stress-strain curves of the steel plate were generated according to the DNV rules for FEM modeling and there are represented in Fig. 3 and Fig. 4.

The calculus using the finite element method weas performed with the Static Structural module in Ansys Workbench [5].

The process of roll bending was considered with static application of loads so the “time” is not a veritable variable; the “time” can help only to establish the stages in the process so it is represented a loading step.

In the calculus in which the roll bending was simulated, the significant values of the "time step" corresponding to the process stages are:

0 - the undeformed initial state of sheet material;

1 - the top roll descents with 7.8 cm; the value of this limit displacement was obtained from a geometric compatibility of the elements of the system (the rollers do not intersect, and the sheet does not thin);

2 – the top and the bottom rollers (left-right) are rotated.

3 –the top roller is raised.

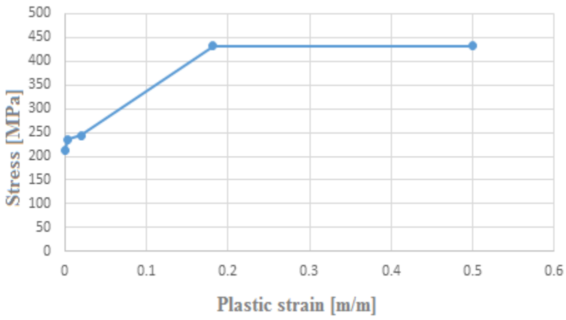

Fig. 3: The stress-strain curve for steel S235JR

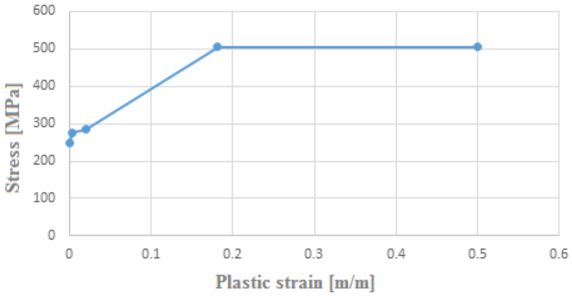

Fig. 4: The stress-strain curve for steel S275JR

4. FEM RESULTS

The variation of reaction forces and of torsional moments are evaluated in the roller axes.

In the Figure 5, 6 and 7 are represented the variation of bending force in the center of the roll from the top (see label C in the figure 2) and torsional moments in the axes of the lower rollers (left label A-right label B) which correspond to the steel S235JR.

In Figure 8, 9 and 10 are represented the variation of bending force in the center of the roll from the top (see label C in the Figure 2) and torsional moments in the axes of the lower rollers (left label A-right label B) which correspond to the steel S275JR.

From the above figures there is an asymptotic increase in bending forces and in the torsional moments close to the maximum displacements of 7.8cm.

This asymptotic increase in force and moments can technically correspond to blocking the system or to its incorrect functioning.

A maximum force in that area reaches 1000kN for steel S235JR (see Figure 5) and 1200kN respectively for steel S275JR (see Figure 8).

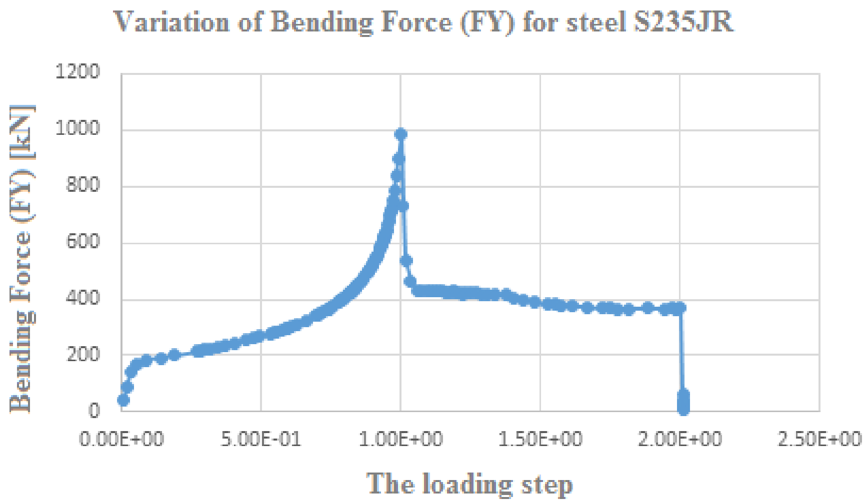

Fig. 5: The variation of Bending Force having Y axis direction (FY) for steel S235JR in top roll center

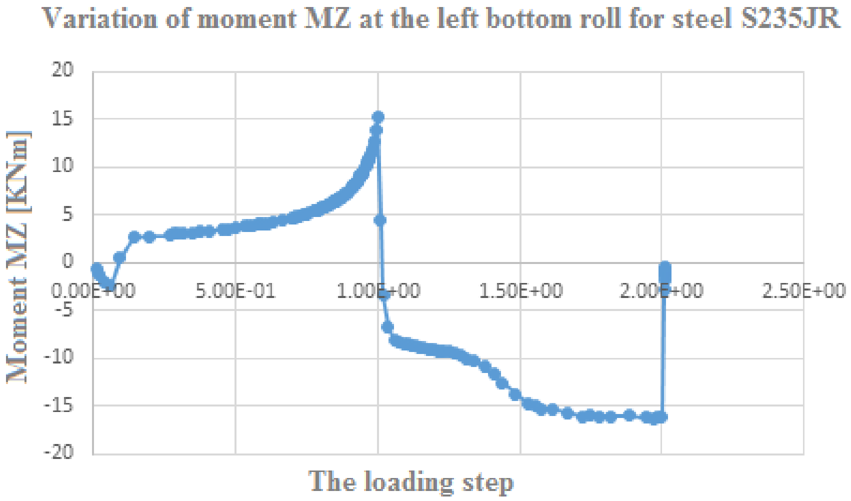

Fig. 6: The variation of torsional moment having Z axis direction (MZ) for steel S235JR in the left bottom roll center

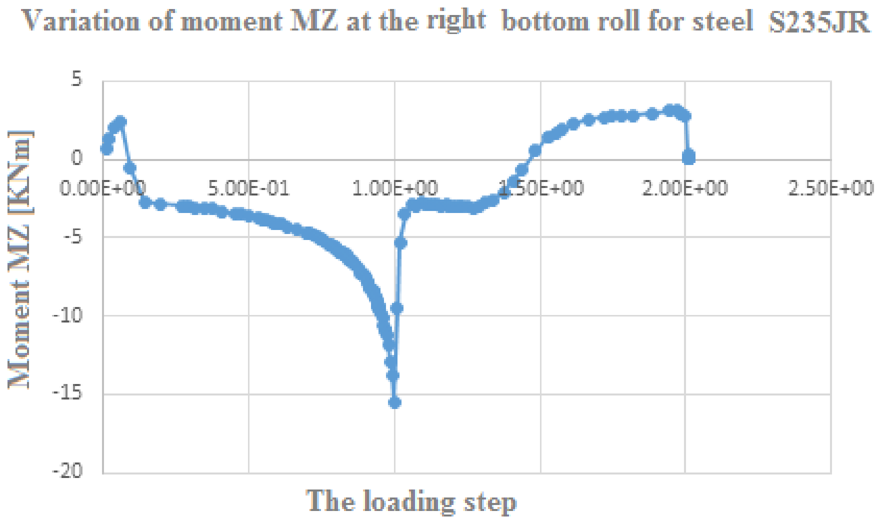

Fig. 7: The variation of torsional moment having Z axis direction (MZ) for steel S235JR in the right bottom roll center

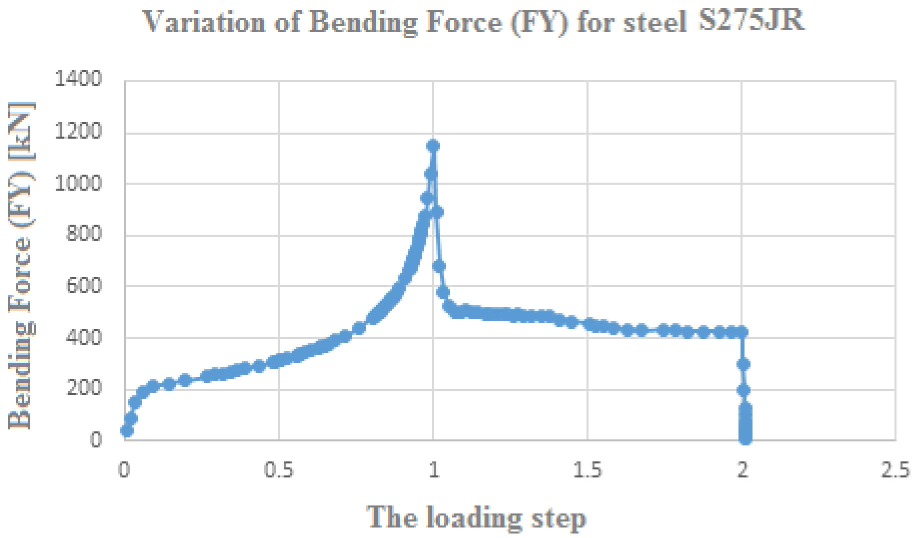

Fig. 8: The variation of Bending Force having Y axis direction (FY) for steel S275JR in the top roll center

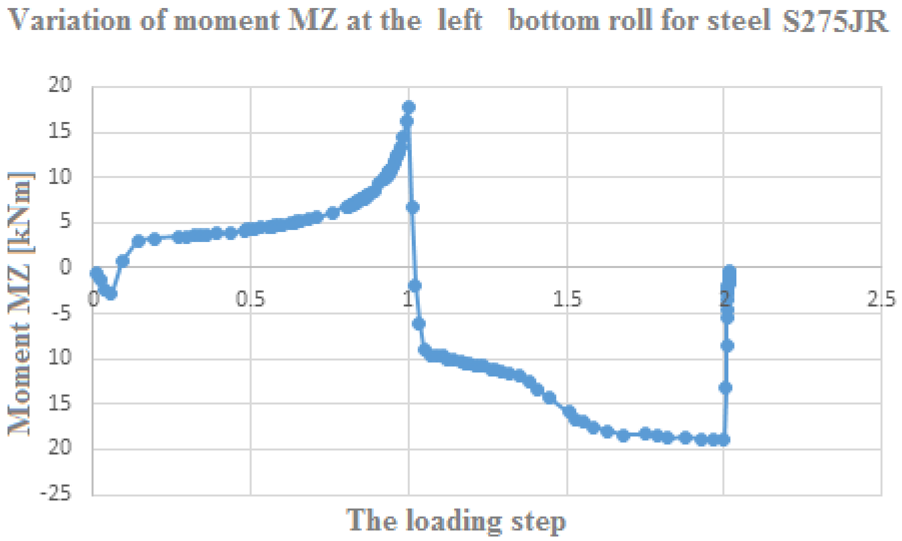

Fig. 9: The variation of torsional moment having Z axis direction (MZ) for steel S275JR in the left bottom roll center

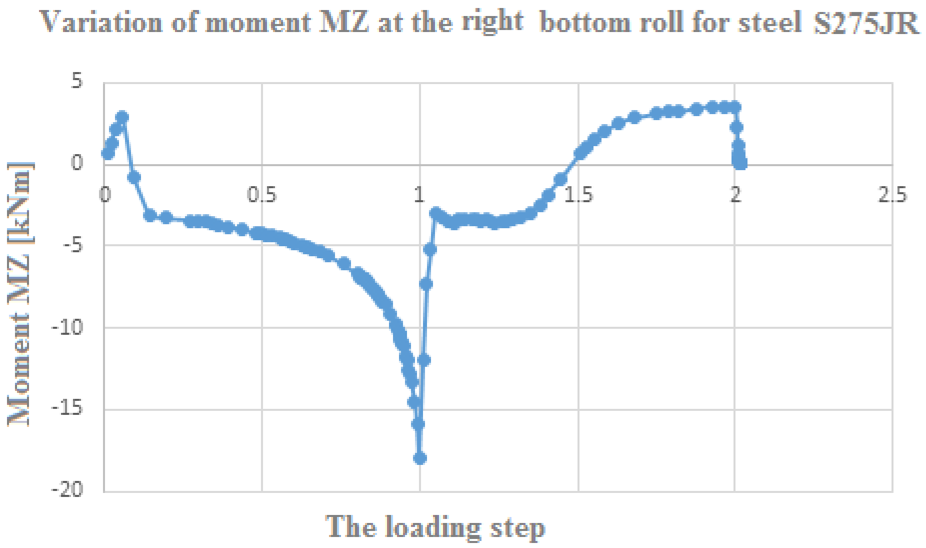

Fig. 10: The variation of torsional moment having Z axis direction (MZ) for steel S275JR in the right bottom roll center

The variation of bent sheet radius along the whole process of deformation can also be numerically obtained; for the displacement of top roller of 5cm the variation of bent sheet radius is represented in the Fig. 11.

The distribution of von Mises stress at the final position of the three key points used to determine the radius along the roll bending process is represented in Fig.12.

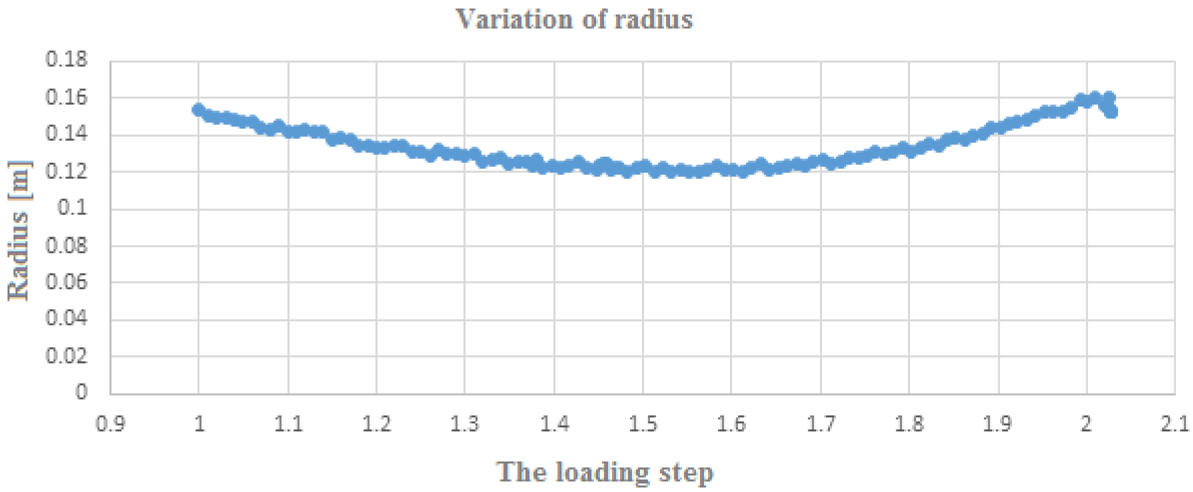

Fig. 11: The variation of bent sheet radius along the whole process of deformation corresponding to the 5 cm displacement of the top roller

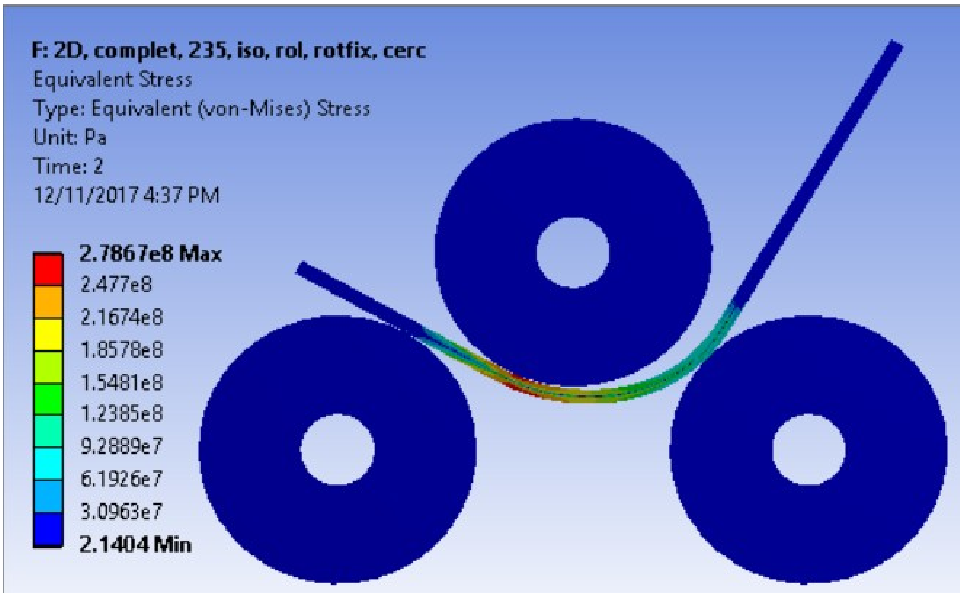

Fig. 12: The distribution of von Mises stress at the final position of radius evaluation

The distribution of von Mises stress for sheet made of S235JR is represented in Figures 13, 14 and 15 and correspond to:

- initial contact between top roller and the sheet – Fig. 13;
- maximum displacement of the top roller (5cm) – Fig. 14;
- rotated position of the three rollers with 30 degree – Fig. 15.

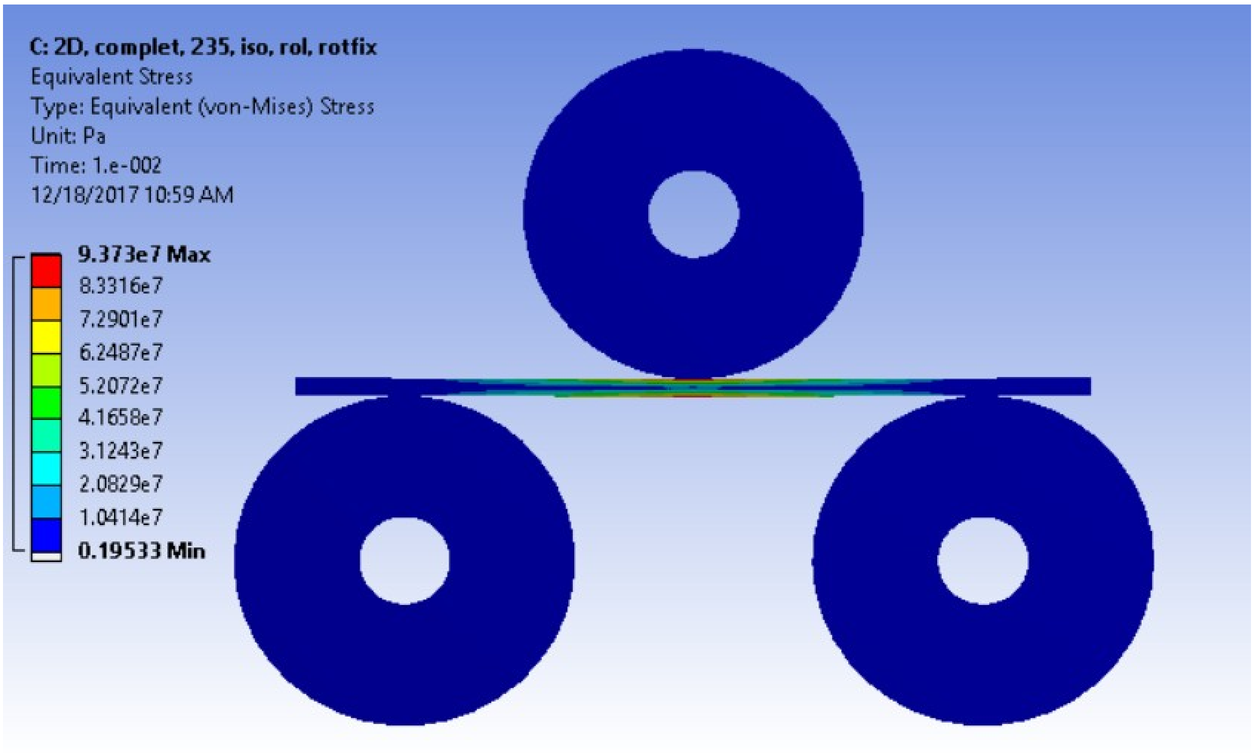

Fig. 13: The von Mises stress distribution correspond to the initial contact between top roller and the sheet

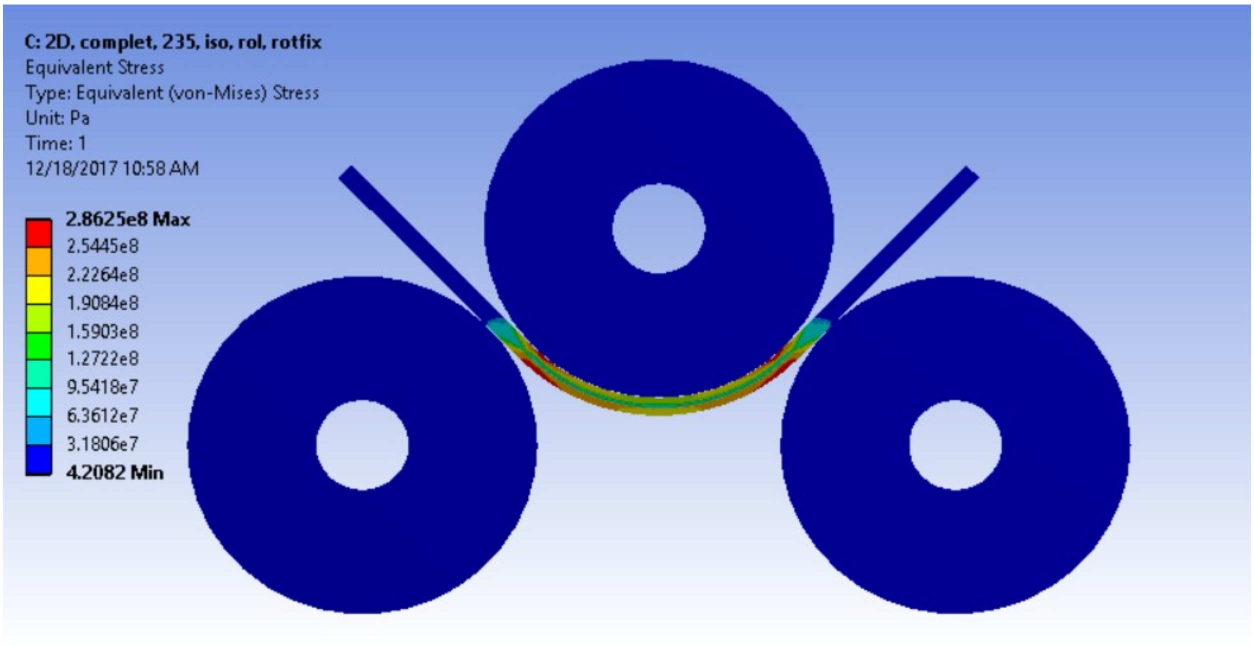

Fig. 14: The von Mises stress distribution corresponds to the maximum displacement of the top roller

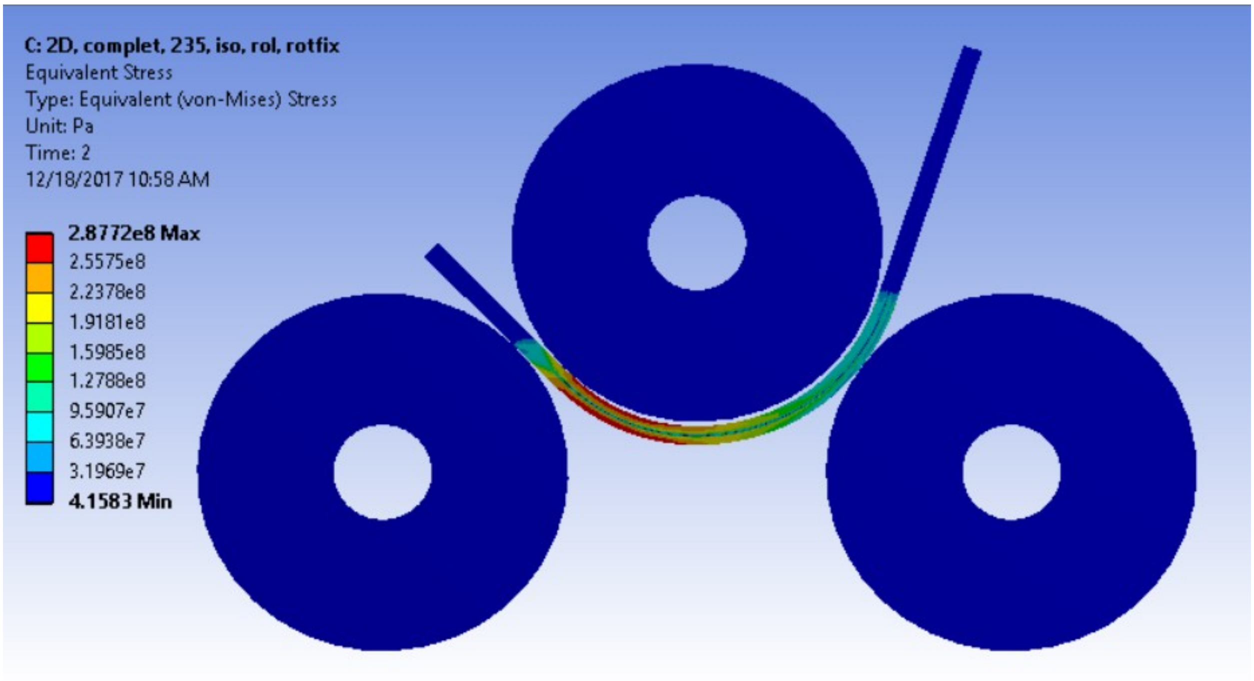

Fig. 15: The von Mises stress distribution corresponds to rotated position of the three rollers with 30 degree

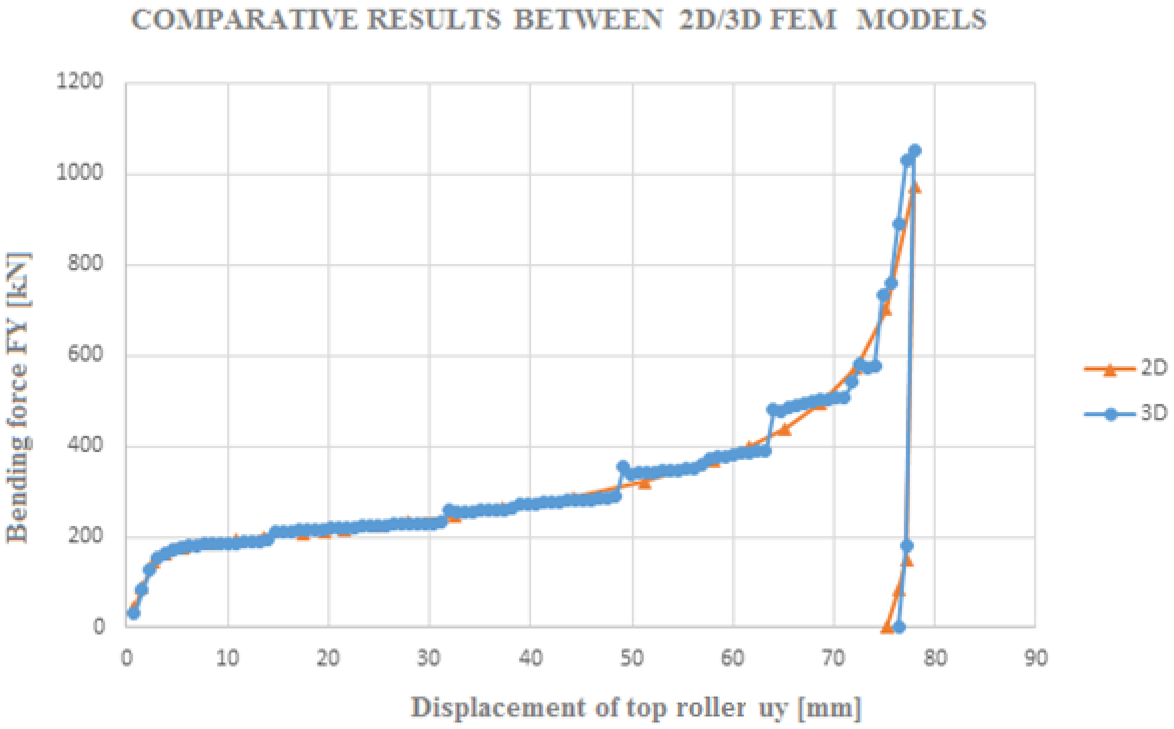

Fig. 16: Comparative results between 2D and 3D FEM models of roll bending

5. CONCLUSIONS

A two dimensional calculus (using plane strain assumption) is quite accurate because the 3D model similar results were obtained (see in the Fig. 16 the comparative results for Bending force vs displacement in 2D and 3D FEM models).

Using this 2D FEM model (with prescribed rollers diameters and material thickness) for a certain material, a certain sheet bent radius can be obtained with the following parameters useful in design of roll bending:

- pyramid system:
- the displacement of top roller and the reaction force at its center;
- the moments at the centers of rollers with fixed axes.

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