INNOVATIVE ANGLE ROLL PASS DESIGN*

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Abstract

The customer asked for a 5” angle roll pass design. For this angle, in a normal pass design, a 160mm billet is required. For the production of this billet would be necessary a new 160mm mold for the Continuous Casting Machine, which produces 150mm billets, increasing the complexity of the melt shop. The rolling mill is designed to produce angles up to 4", technical information recommended the replacement of a gearbox because this process would generate torque up to 15% above nominal. An innovative roll pass design was done using 150mm billet using the Aparecido-W Method that cause a higher spread in the first three passes, thus reaching the desired leg length. As this method is not used in any other known rolling mill, a FES (Finite Element Simulation) and FEM (Finite Element Modeling) was done by a Research & Development center which demonstrated that the design was viable. From July, 2018, three tests were done being produced around 700 t of good quality products without difficulty of set up. The rolling mill team carried out this project at a very low cost and in record time of five months. The average torque of the motors was 36%, without overload for the equipment.

Keywords: Angle; Ekelund, Pass design; Innovation

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1 INTRODUCTION

The author was consulted about the possibility of elaboration of a roll pass design for 5" angle using a 150mm billet. The rolling mill is designed for production up to 4" angles and technical information available presented the following restrictions:

- The billet should be 160mm or more;
- The melt shop would have to install the 160mm molds in the CCM that produced 150mm
- This process would generate a torque 15% above nominal capacity;
- For this reason a gearbox of the roughing train would have to be changed;
- Cardans would also have to be replaced;
- The rolls would have to be casting steel;
- Each roll would have a single center groove, instead of two.

These changes would require investments and an implementation time between one two years, which did not meet the needs of the customer.

Based on previous studies, three possibilities for high spread were analyzed [1]:

- Diagonal pass design [2] (Figure 1);
- Deep notch design (Figure 2).
- W design [3] (Figure 3)

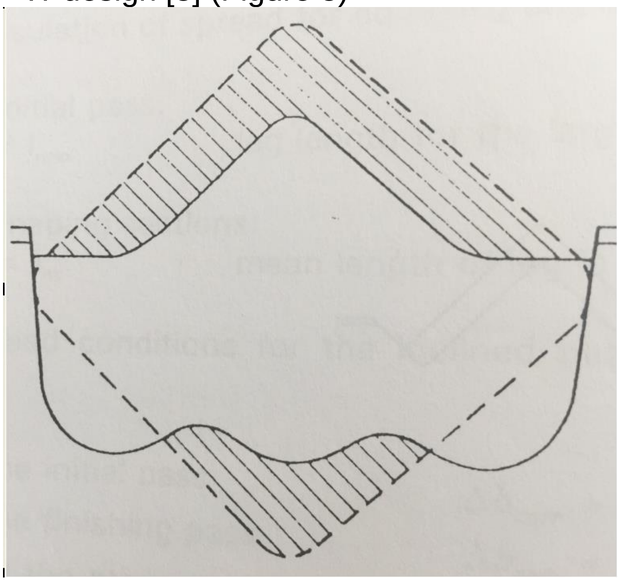

Figura 1. Diagonal roll pass design

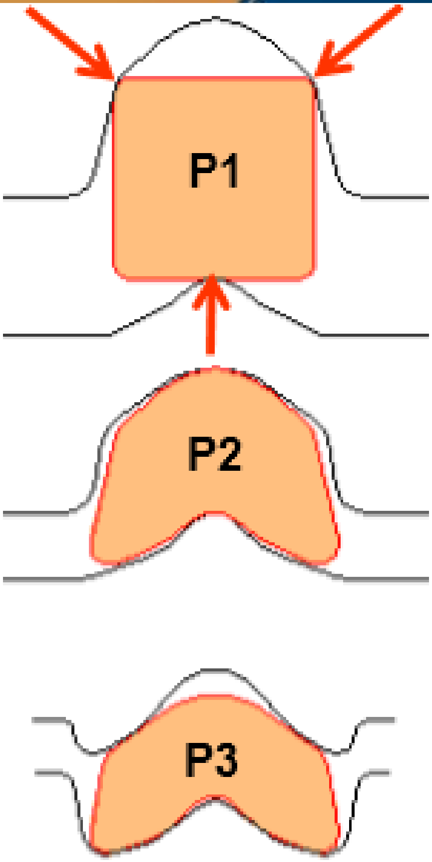

Figure 2. Deep notch roll design

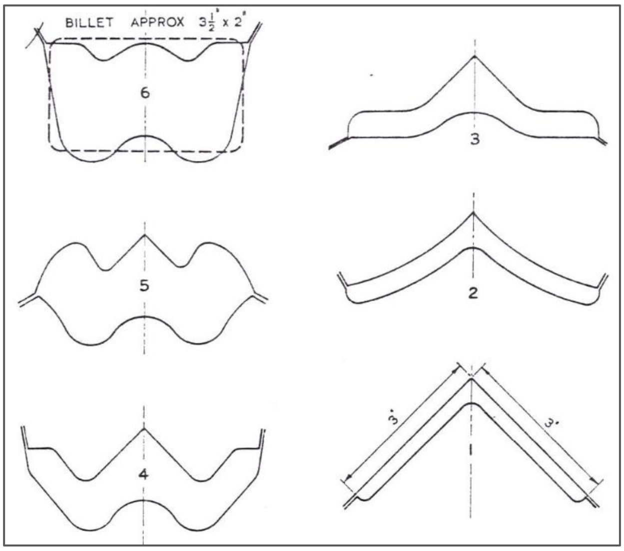

Figure 3. W roll pass design

2 MATERIAL AND METHODS

2.1 INITIAL SURVEYS

Diagonal roll design:
Diagonal roll design requires a torsion device for positioning the billet in the first pass. This would also imply on

modifications to the pinch-roll. For this reason this idea was initially discarded.

Deep notch roll design:
This method would apparently generate the expected results, it was analyzed and found two problems: Instability in the first pass and very deep grooves generating rolls with very large diameters. It has been temporarily discarded.

Roll pass design W-Method:
The Figure 3 shows a schematic 3" angle design with 6 passes. The literature [2] mentions that this design results in low loads for the mill, without mentioning an increase in the size of the legs due to a higher spread.
It was analyzed that based on previous studies of the author [1] this process could result in further spread in the first three passes.

2.2 PROJECT DEVELOPMENT
Considering a product with dimensions above the design capacity of the mill, which operated with 4"x1/4" angle, with an average section reduction of 24%, the following premises were adopted:
• 150mm billet;
• Average reduction: 19%;
• Number of passes: 11;
• 3 first passes with higher spread;
• Two grooves per roll;
• Cast iron rolls.

2.2 TYPES OF GROOVES

The following types of grooves have been defined:

- Pass 1: Notch;
- Pass 2: W;
- Pass 3: W;
- Pass 4: Horizontal butterfly;
- Other passes: Conventional Butterfly (Figure 4).

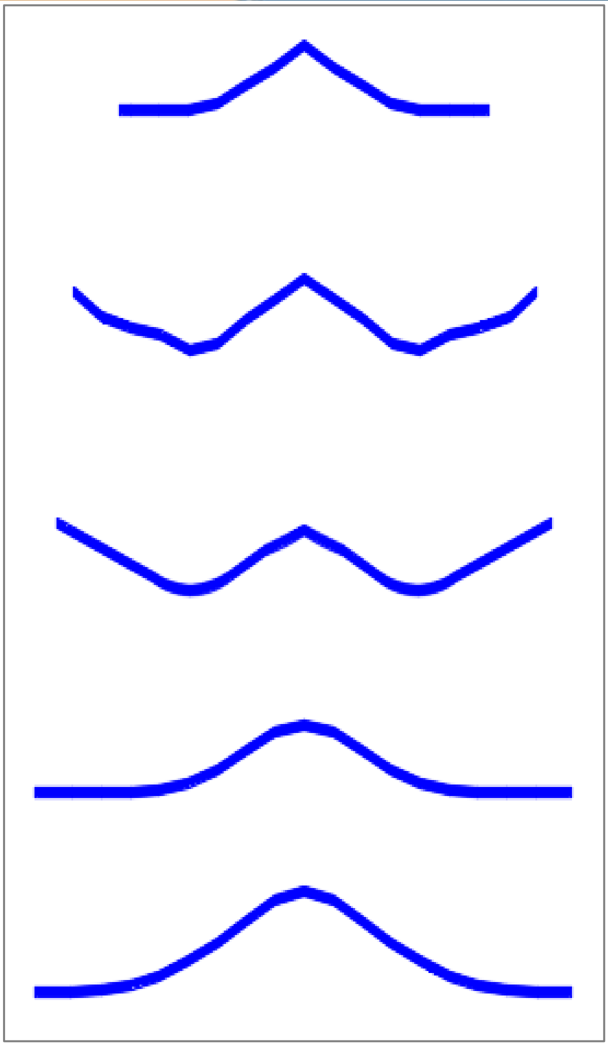

Figure 4. Initial passes sequence

2.3 INITIAL CALCULATIONS

The initial calculations were done using the methodology developed by Pereira [5], *New methodology for the calculation of the angle pass design*, according to the previously established premises.

As shown, the largest spreads occurred in the first three passes and it can be observed that the spreads in the last five passes are very low, this contributes to a good dimensional stability of the legs I (Figure 5).

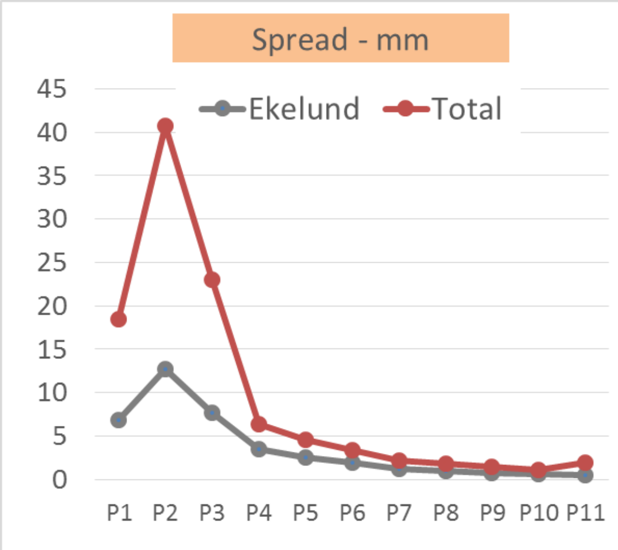

Figure 5. Ekelund spread and total

The passes # 2 - 3 - 4 have the highest section reductions and the average section reduction is 19% what is good to prevent groove wear (Figure 6).

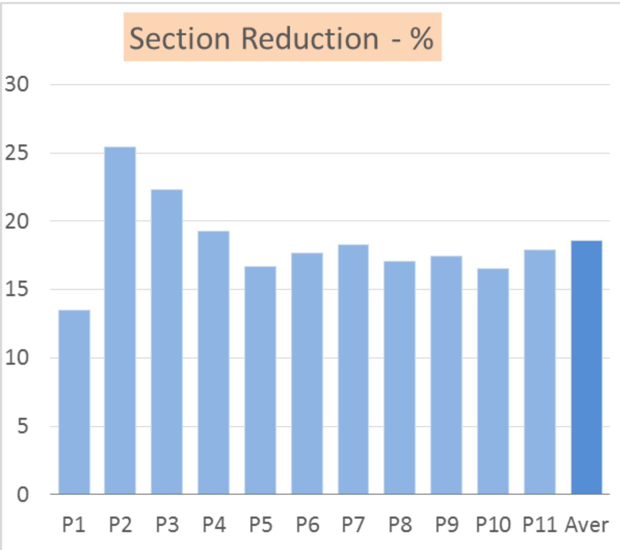

Figure 6. Section Reductions

The temperature starts at 1100 ºC, finishing at 934 °C. It can be observed:

- The gain by deformation increases along the passes due to the speed;
- The loss by conduction decreases along the passes due to less time in contact with rolls;
- The loss by radiation is high between stand with large distances, where are located crop shears (Figure 7).

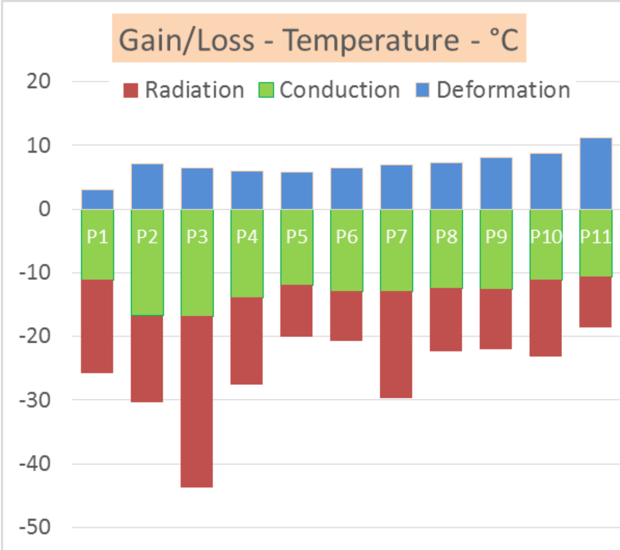

Figure 7. Gain/loss of temperature by type

The separating roll forces are higher in the passes # 2 – 3 – 4 that are stands with large roll diameters. In other ones the reductions are low what is good to prevent roll breakage (Figure 8).

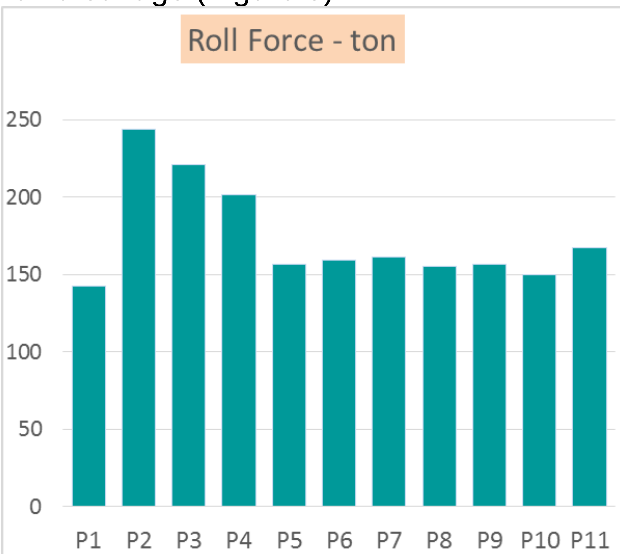

Figure 9. Separating roll force

The calculated torque is very low in all the stands excepted in the stand #2 that is 87% to the maximum. The average is 40%. These results show no problem with the gear boxes and cardans (Figure 10).

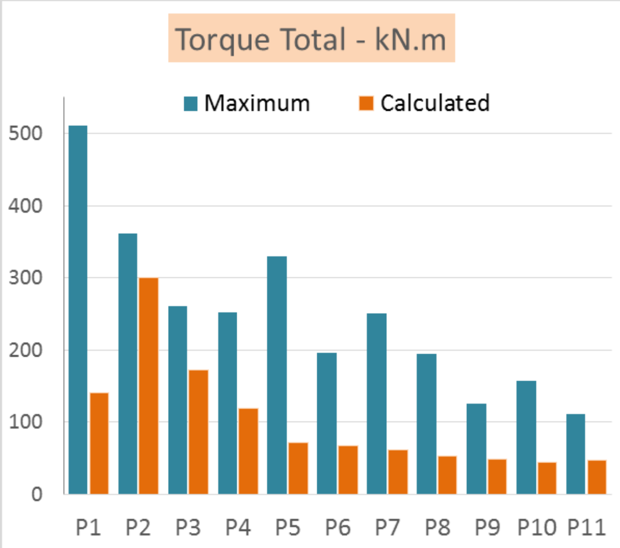

Figure 10. Maximum and calculated torque

The checking of the Power in relation to the Power Diagram shows that all the passes are below to the Power Curve (Figure 11).

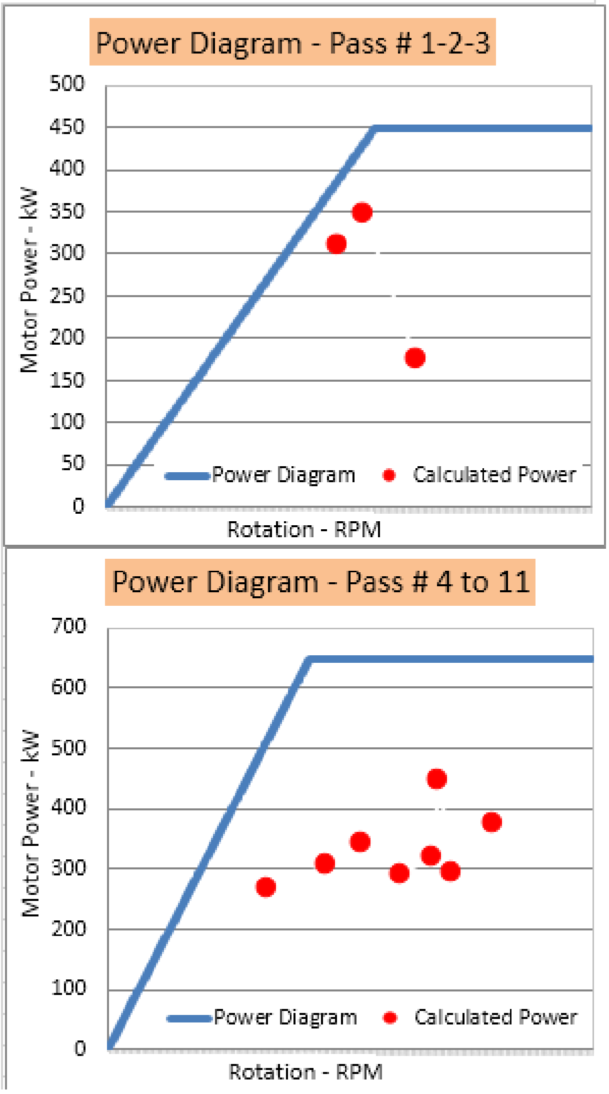

Figure 11. Power Diagram

2.4 FINITE ELEMENT SIMULATIONS – 2D

Applying the methodology developed by Pereira [5], the grooves were drawn in AutoCad and sent to the company R&D center to do FES–2D. This is the best way to check the correct filling of the grooves preventing stoppages in the rolling mill to correct the grooves dimensions.

The FES-2D showed the correct dimensioning of the grooves the Pass #2 is a little bit overfilled and the Pass #3 isn´t completely filled and it was corrected later. The other passes were correctly filled (Figure 12).

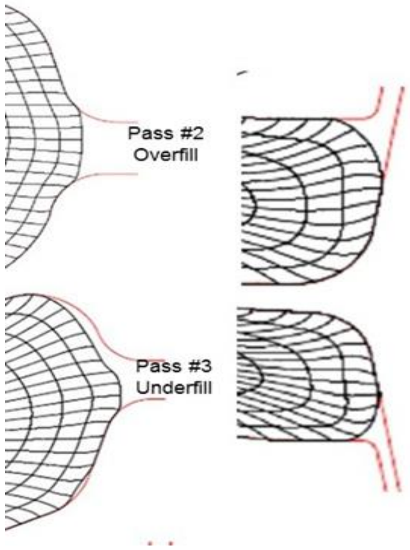

Figure 12. Finite Element Simulation - FES

The pre finishing Pass #10 is correctly filled and the length of finishing angle leg is close to the nominal dimension (Figure 13).

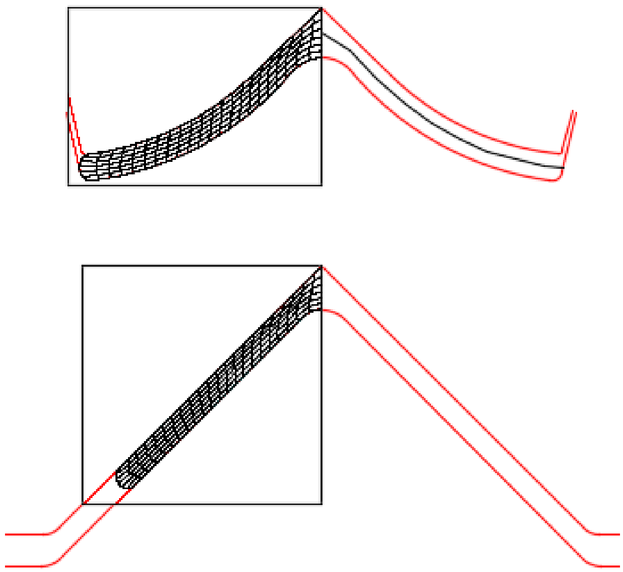

Figure 13. FES of the Passes #10 and #11

2.5 PREPARATIONS AND INDUSTRIAL TRIAL

The type of grooves of the passes 1 to 4 that are the deeper ones allowed to have with gaps at middle part of the groove. Due to this characteristic it was possible to machine the grooves at the end of life rolls. Exit guides were manufactured and at the end of June, 2018 it was possible to test the first six passes.

It was rolled four billets without problems and the sample of the Pass #6 was correctly filled as predicted in FES (Figure 14).

Figure 14. Sample of the Pass #6

The torque in stands situated between 27 to 54% of the nominal capacity.

3 RESULTS AND DISCUSSION

In August, 2018 it was done the complete test of the 5”x5/16” dimension.

- All the stands used rolls cast iron at the end of the life;
- The first rolled billet crossed the mill without problem, and in the same billet the traction was corrected resulting the first bar in accordance to the tolerance;
- It was rolled 10 ton (five billets) and the dimensional results are shown in the picture above.
- Random dimensions taken in the bundles shown all the bars were in accordance to the tolerance;
- Leg tolerances: Min: 124,0 – Nom: 127,0 – Max: 130,0 (Figure15).

Massa	Largur...	Largura B	Espess.
15,967	127,59	128,02	8,25
15,665	127,56	127,98	7,97
15,106	125,73	125,87	7,84
15,544	127,65	128,10	7,93
15,514	126,82	127,29	7,97

Figure 15. Samples dimensions.

* *Technical contribution to the 11th International Rolling Conference, part of the ABM Week 2019, October 1st-3rd, 2019, São Paulo, SP, Brazil.*

The average torque was 36% that is very close to the calculated value of 40% (Figure 16).

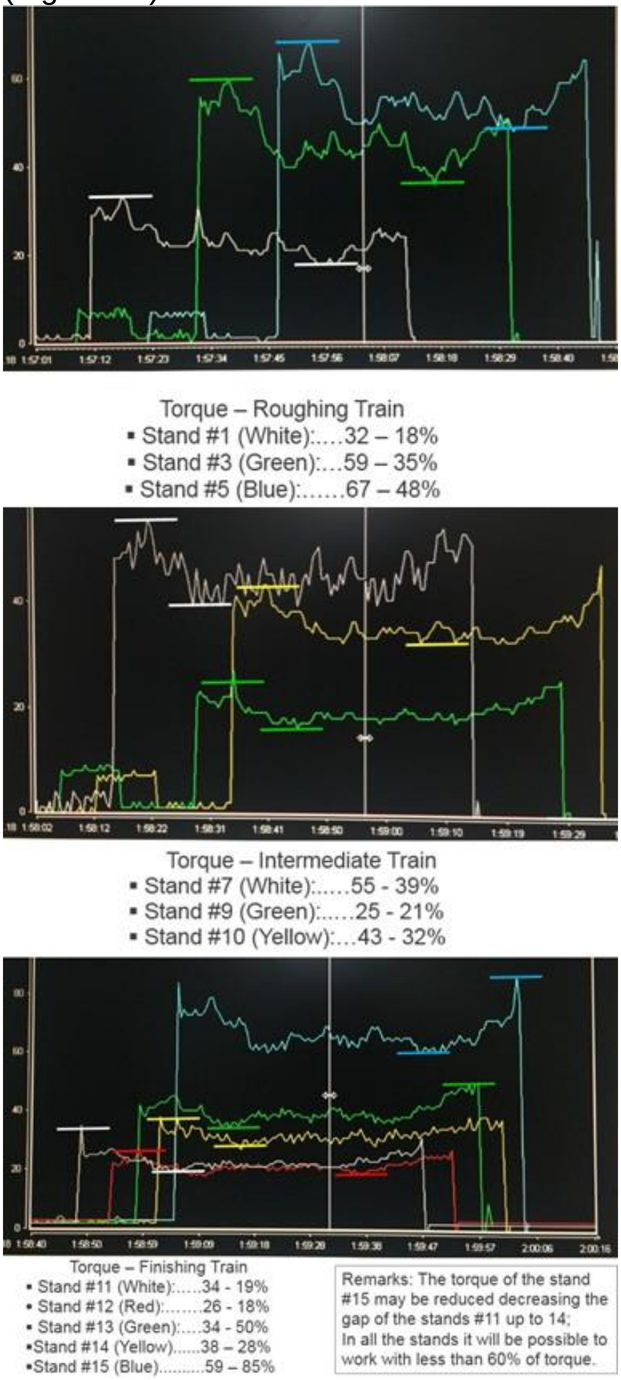

Figure 16. Measured torque

From July to December, 2018 three tests were made with the three thicknesses (5/16"- 3/8" - 1/2"), producing 700 ton of good quality products without difficulty of set-up.

It was observed a strong trend of the bar head of the pass #5 to go up. The pass line and the roll diameter were checked and everything was OK. It was done a Finite Element Modeling – FEM-3D that detected a big difference in the section reduction (pressure) between the groove center and the extremities (Arrows orange and green) (Figure 17).

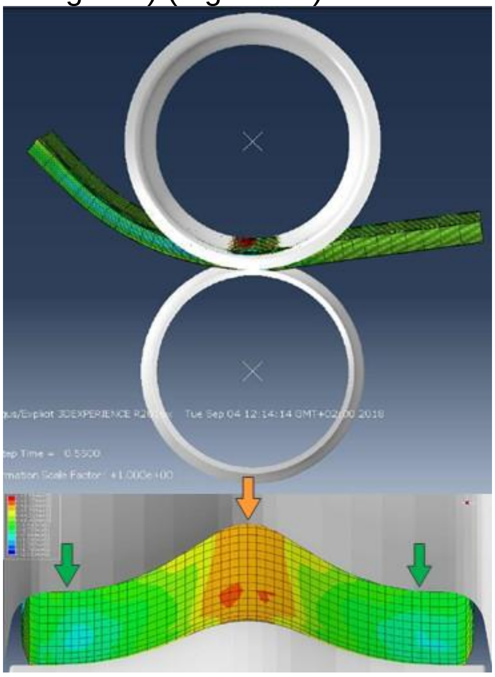

Figure 17. Different compression between center and extremities

The groove shapes of the passes # 4 and 5 were modified solving the problem as shown in the FEM (green arrows) and the practical results (Figure 18).

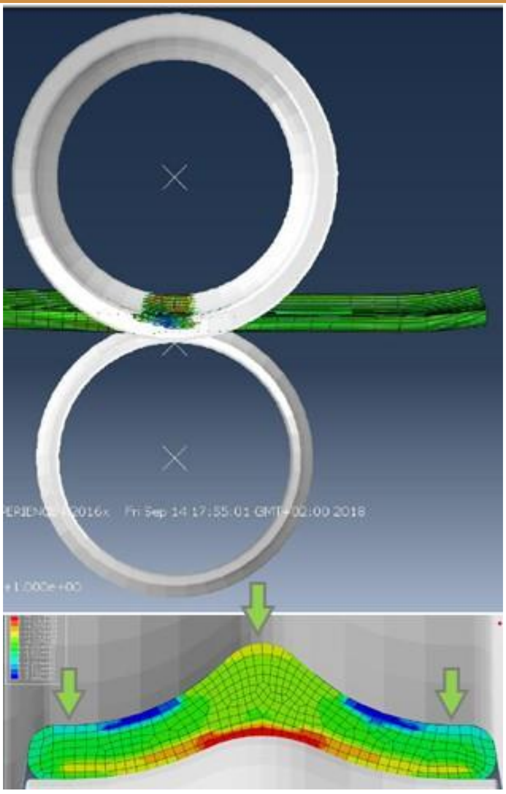

Figure 18. Equalized compressions

For the new rolls to be machined the pass design was revised, mainly for the 1/2" thickness, whose leg widths were close to the maximum of the tolerance, the grooves weren´t completely filled and with very low section reductions. For this size, were reduced two passes and created four specific grooves with smaller width in order to have a better control of the leg sizes.

4 CONCLUSION

This project proved to be fully feasible due to applied methodology.
Highlights of the project:

- ✓ Innovative roll pass design not tested in other known plants;
- ✓ Use of the Excel program for the full calculation of the involved values;
- ✓ Use of the Excel program for the determination of the groove drawing parameters;
- ✓ Use of the FES-2D for simulation of the groove fillings preventing stoppages of the mill for groove corrections;
- ✓ Use of the FEM-3D for simulation of the groove compression detecting the root cause of bar head up;
- ✓ Use of end of life rolls to reduce the test time and with the warranty of success when rolling with new rolls;
- ✓ The involving of the plant team in order to have results in short time at low costs.

5 KNOWLEDGES

The author thanks to the plant management for the confidence in the development of a new and innovative project and to the rolling mill team by the competence, agility, cooperation and friendly work environment.

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