Laminação Rolling
49º Seminário de Laminação - Processos e Produtos Laminados e Revestidos
49th Rolling Seminar - Processes, Rolled and Coated Products

ISSN 1983-4764

# DEVELOPMENT OF ROUGHING MILL WORK ROLLS AT ARCELORMITTAL TUBARÃO[1]

*Bruno Bastos da Silva Murad*[2]
*Denilson de Aquino Souza*[3]
*Roberto de Oliveira Costa*[4]
*Mônica Pedrada Soares Carneiro*[5]
*Michael Brandner*[6]
*Tommy Nylen*[7]
*Alexander Mayr*[8]

**Abstract**

Since the startup of the second Reheating Furnace in 2009, ArcelorMittal Tubarão has increased its hot rolled coil output towards the 4,0 Mtons/year-nominal capacity. One major issue in order to achieve this target is to increase the rolls campaigns and reduce the mill downtime dedicated to the roll changes. Among the continuous developments with strategic and reliable suppliers, the evolution of Roughing Mill work rolls outstands as a successful case, where static Cast Iron rolls used in the mill startup (2002) were sustainably replaced step by step to Chrome Steel and Enhanced Chrome Steel rolls till to the current spun Cast High Speed Steel grades. This migration involved many routine inspection and control adaptations at the Roll Shop (including new automatic Non Destructive Testing devices in the grinding machine), adjustments in the mathematical model of the Roughing Mill and personnel training. Also, it is mandatory to point out the development strategy, grounded on strict operational standardization and stability associated to the close partnership between ArcelorMittal Tubarão and ESW, with strong technical knowledge and capacity to understand the needs and to assertively design a customized product. As the main result of the development, target campaigns were risen from 13kt up to 75 kt, which represents 1,45% increase in the annual mill availability. The different targets and other achieved benefits will be presented in detail.

**Key words:** Work rolls development; Roughing mill; Spun cast high speed steel.

[1] *Technical contribution to the 49th Rolling Seminar – Processes, Rolled and Coated Products, October, 22nd-25th, 2012, Vila Velha, ES, Brazil.*

[2] *Materials Engineer, MSc. Reliability Engineer – Hot Strip Mill (ArcelorMittal Tubarão)*
[3] *Mechanical Engineer. Reliability Engineer – Hot Strip Mill (ArcelorMittal Tubarão)*
[4] *Materials Engineer, MSc, Sr. Operation Operating Technology Engineer (ArcelorMittal Indiana Harbor West)*
[5] *Metallurgical Technician. Non Destructive Testing Technician – Roll Shop Area (ArcelorMittal Tubarão)*
[6] *Materials Engineer. Quality Manager (Eisenwerk Sulzau-Werfen)*
[7] *Materials Engineer, MSc. Vice-President R&D (Eisenwerk Sulzau-Werfen)*
[8] *Metallurgical Engineer, Dr. Ing. R&D Engineer (Eisenwerk Sulzau-Werfen)*

ISSN 1983-4764

# 1 INTRODUTION

## 1.1 The Hot Strip Mill at ArcelorMittal Tubarão

ArcelorMittal Tubarão has been producing hot rolled coils since August 2002 and with the installation of its second reheating furnace in 2009, had increased the nominal capacity from 2,8 to 4,0 Mton/year. The basic layout of the equipment is presented in the Figure 1.

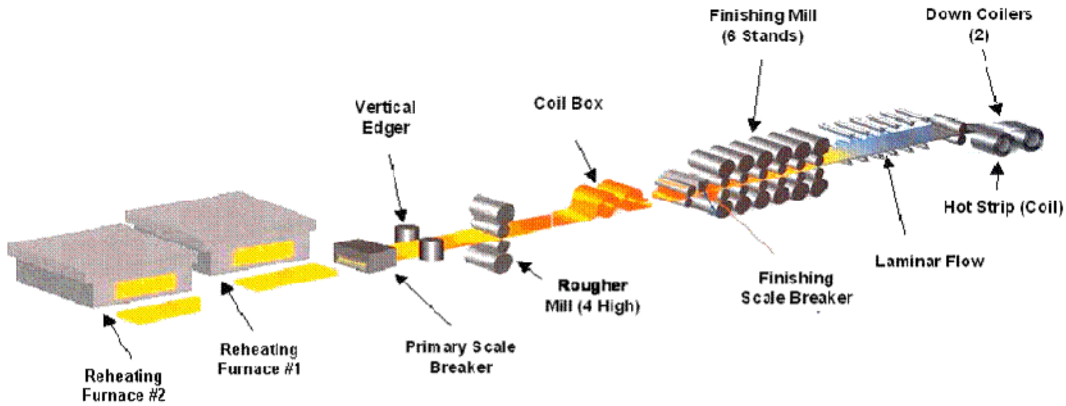


**Figure 1:** Schematic layout of the AMT's Hot Strip Mill.

The product mix comprises mild steel, low to high carbon grades, IF, HSLA, API steel in dimensions that may vary from 1,2 – 19,5 mm (thickness) and 700 – 1880 mm (width). Other products in the portfolio are checkered coils, thick coils and plates.
The hot rolled coil output has been continuously expanded (Figure 2) and one major issue in order to achieve this target is to increase the rolls campaigns and reduce the mill downtime dedicated to the roll changes.

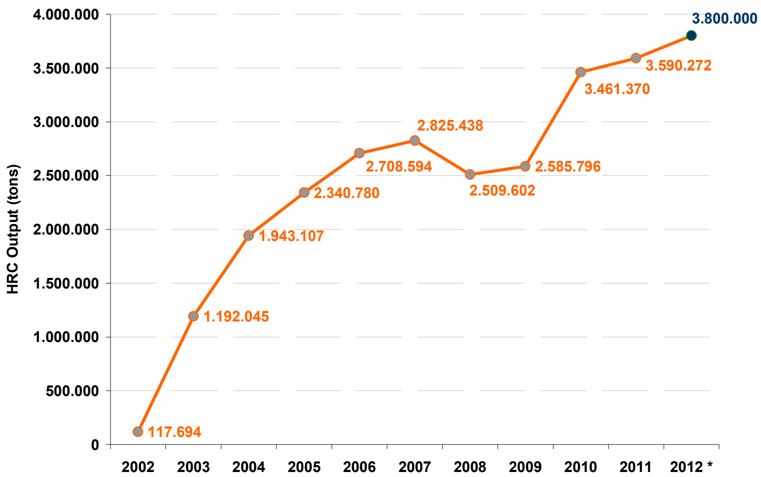


**Figure 2:** Evolution of the HRC Production at AM Tubarão (2002 – 2012).

The scope of this paper is restricted to the Roughing Mill Work rolls at ArcelorMittal Tubarão, whose main features are presented in Table 1.

ISSN 1983-4764

**Table 1:** Roughing Mill main features

| Feature | Description |
|---|---|
| Mill type | 1 x 4 High Reversible |
| Roll Features | WR:<br>Dimensions: 1.250 (New) x 2.050 x 6.240 mm (Life: 100 mm)<br>Weight: 32.589 kg (with accessories)<br>Hardness: 80 – 84 HSc<br>Material: Spun Cast HSS<br><br>BUR:<br>Dimensions: 1.500 (New) x 2.050 x 5.490 mm (Life: 150 mm)<br>Weight: 39.830 kg (with accessories)<br>Hardness: 70 – 75 HSc<br>Material: Forged 5% Cr Steel |
| Slabs | Thickness: 200, 225 mm and 250 mm<br>Width: 700 – 1.955 mm<br>Length: 4.500 – 11.500 mm<br>Transfer Bar: 20 – 40 mm |
| Motors | Power: AC 2 x 7.500 kW<br>Revolutions: 0 - 50 / 100 rpm<br>Roll Speed: 0 – 3,2 / 6,3 m/s |
| Separating Force | up to 41.500 kN |
| Bearing Type (BUR) | Morgoil bearing 54" – 75 KLS H |
| Technologies | Automatic Gauge Control (AGC) |

The work rolls materials evolution is based on the operational stability (Figure 3) and on the improvement of Non Destructive Inspection and roll control methods, allowing the utilization of grades whose main feature is higher wear resistance and the campaign extension without quality and stability losses. Since the startup in 2002, new grades have been developed and implemented in partnership with strategic and reliable suppliers.[1]

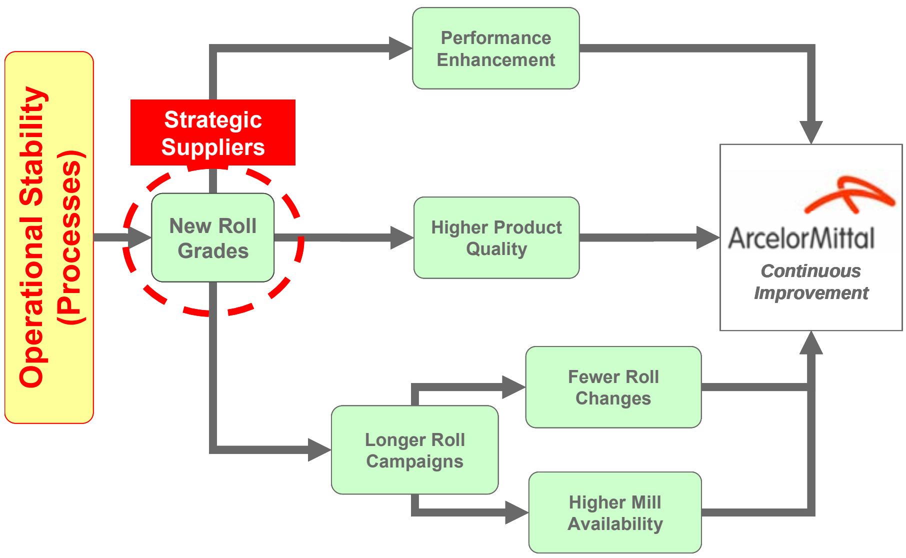


**Figure 3:** Roll development strategy at AM Tubarão.

ISSN 1983-4764

## 2 MATERIALS AND METHODS

### 2.1 The Contribution of a Roll Supplier to the Evolution of Roll Materials

The main goal for ESW was, to reach the target figures of the roughing mill application at ArcelorMittal Tubarão. As already presented, the start up phase had a campaign length of about 13.000 t. This was surely not enough for the demanding future in this mill. The start up was made with conventional cast iron rolls. The next step was to install Chrome Steel Rolls. At this point ESW started to deliver rolls for the ArcelorMittal Tubarão Roughing Mill. If we look at the various possibilities to modify rolls materials, Figure 4 shows the typical microstructure of a chrome steel roll.

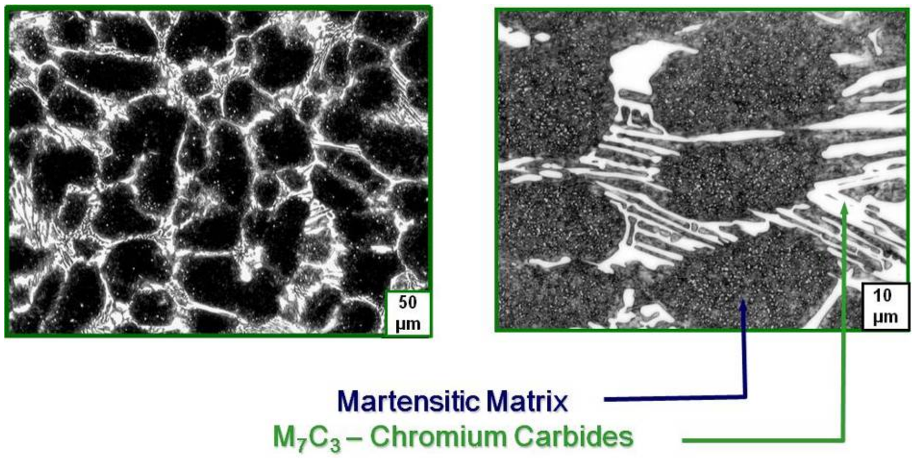


**Figure 4:** Microstructure of chrome steel roll material.

The next step in this direction is the carbide enhancement of chrome steel roll material. The possible alloying elements are all in the group of the special carbide forming elements, such as Tungsten, Vanadium, Molybdenum or Niobium. Figure 5 shows the different carbide types and possible hardness and a scan image of the microstructure of an enhanced chrome steel material.

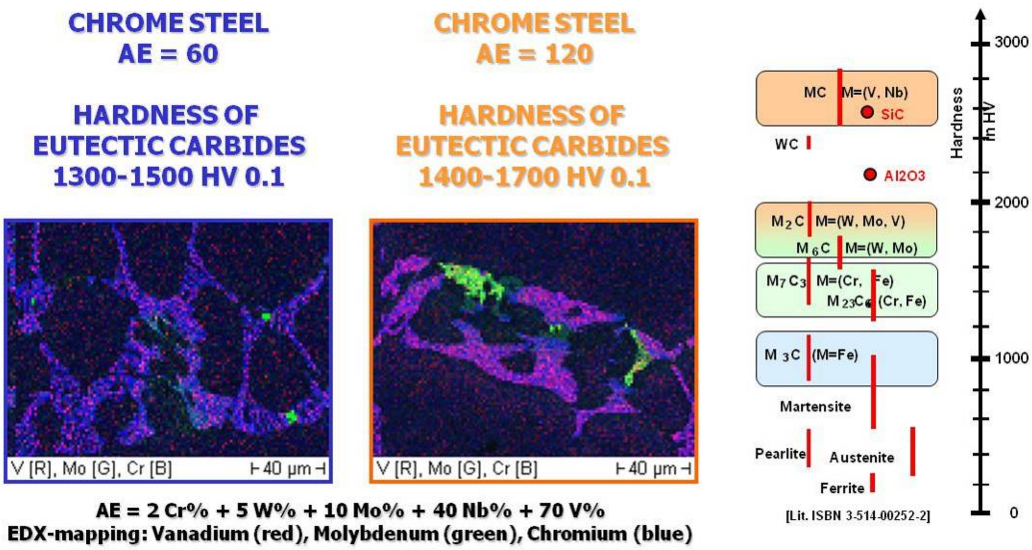


**Figure 5:** Carbide table and microstructure of enhanced chrome steel material.

ISSN 1983-4764

The enhanced chrome steel was working much better than the cast iron. But still the demand for the progress in the mill was to get even higher performance. The roll change was the limiting factor and the wish to reduce the downtime was still a high target. The next steps are all in the HSS Region.
Starting with the Cr-based HSS over the Cr-Mo based HSS and finally reaching the Mo-HSS roll. Figure gives the overview of the three different types of material; all of them were installed in the Rougher and made in each case a better campaign length.
Beside the campaign length, the operational safety and stability was the main concern at each step. So the material development was accompanied by all possible destructive and non destructive testing possibilities during the roll manufacturing.
Dilatometer samples to achieve the necessary transformation and annealing points were proven by the stress measurement. The hardness readings and transformation grade analysis on samples of the barrel ensured the right surface hardness at the end of the heat treatment.

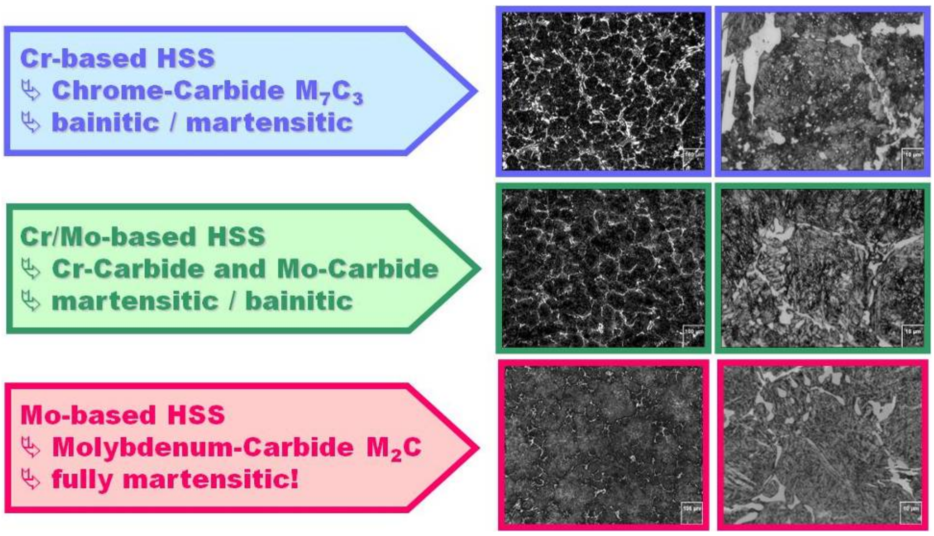

**Figure 6:** types of HSS with decreasing carbon content and alloying concept.

In the following pages, the roll evaluation in the mill is described. The different grades in Figure 7 are corresponding to the above mentioned development steps. The Cr-based HSS is named HSS-G1, the Cr/Mo based HSS is the HSS-G2 and finally the Mo-based HSS is corresponding to the HSS-G4. This type is still the standard material supplied to this mill.

### 2.2 The Evolution of Roll Materials applied to the Mill

The roughing mill work rolls materials have been evolved since 2002, as per Figure 7.
The idea was to introduce the rolls and evaluate its wear profile after the campaign in order to define the maximum campaign so the reference profile (0,75 – 1,00 mm in radius) was kept the same. With this information, mathematical modeling could be adjusted in order to consider each material's actual wear performance.

ISSN 1983-4764

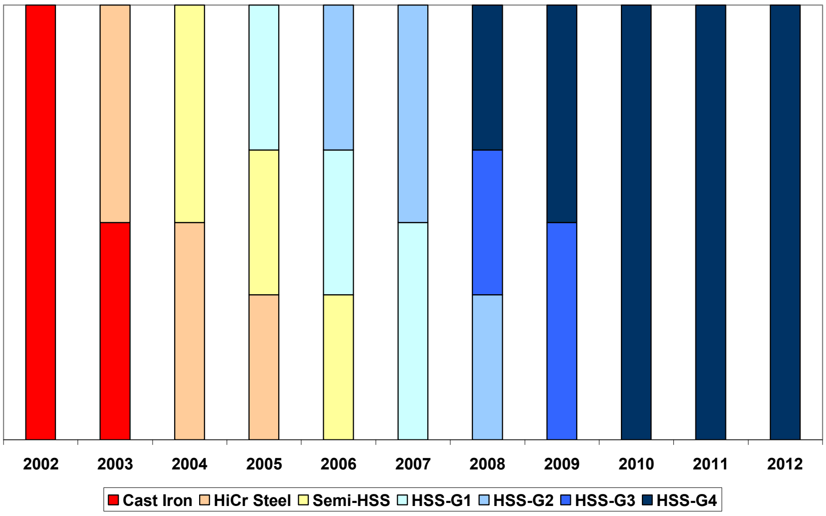


**Figure 7: Roll materials evolution at AM Tubarão.**

Considering the cooling system, no major changes were required to replace the roll material. A simple – but effective – interlock was inserted in order to prevent the rolling process in case of cooling failure (lack of water flow). By 2010, flow was increased not because the roll material, but to the production increase and faster pace (395 t/h → 600 t/h). On the other hand, since these grades are more sensitive to thermal cracking in case of bar stops, an automatic routine was developed so the cooling would shutdown, the gap would open and the rolls would keep rolling in a slow speed, preventing the concentration of heat transfer in a specific area.
In the Roll Shop, a new automatic Non Destructive Testing equipment, with both ultrasonic and eddy current probes was installed so 100% of the rolls would leave the machine free of remaining defects to assure the operational safety of workers and the HSM itself.
With the new production pace after the second furnace, the wear became a more concerning topic to be studied due to its implications on the transfer bar quality, flatness and crown, but the new system was already equipped with a modern measurement caliper, so profile would be checked both before and at the end of every grinding process. The Figure 8 presents an example of the wear profile measured after the roll campaign.
Another important point to be considered was the ever increasing hardness of the rolls, and new grinding wheels specifications and parameters had to be developed to keep the rolls cycle as short as possible. Also, standard operational procedures had to be revised in order to adequate the inversion of the spades in order to avoid extra clearances in the drive coupling.

ISSN 1983-4764

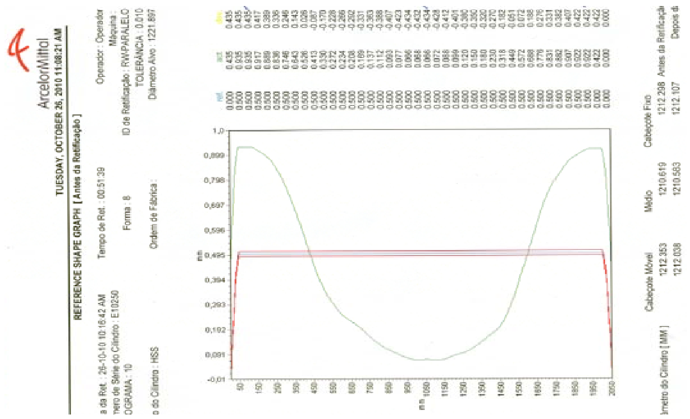

**Figure 8:** Example of an actual Roughing Mill HSS work roll wear profile after its campaign. Wear = 0,87 mm after 74.928 t/ 522 km.

### 2.3 Roll Evaluation

Instead of the price as a driving force or simply the consumption in terms of tons per millimeters, rolls are evaluated by a Total Cost of Ownership – TCO (Figure 9) approach that includes both direct and non direct costs.

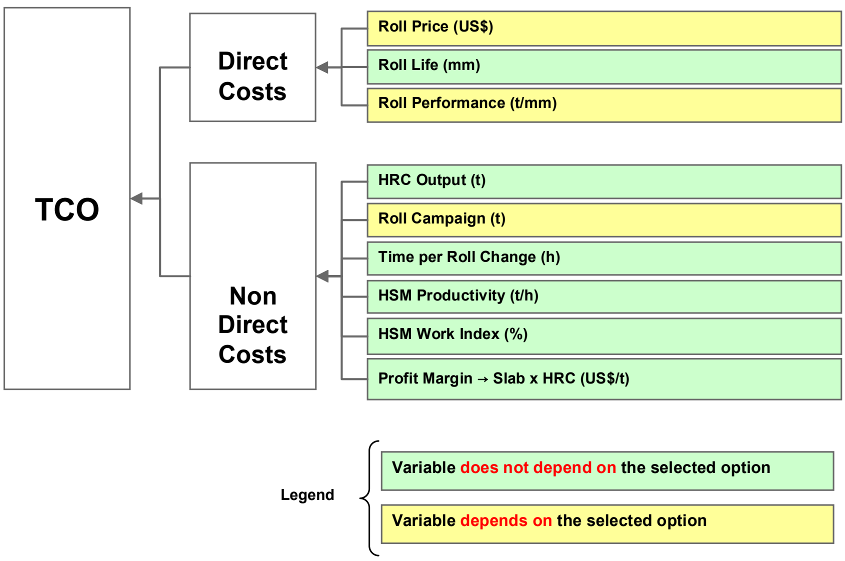


**Figure9:** Total Cost of Ownership main variables used to evaluate the rolls.

## 3 RESULTS

The wear resistance expressed in terms of millimeters per 100.000 tons and the campaign extensions are shown in Figure 10.

ISSN 1983-4764

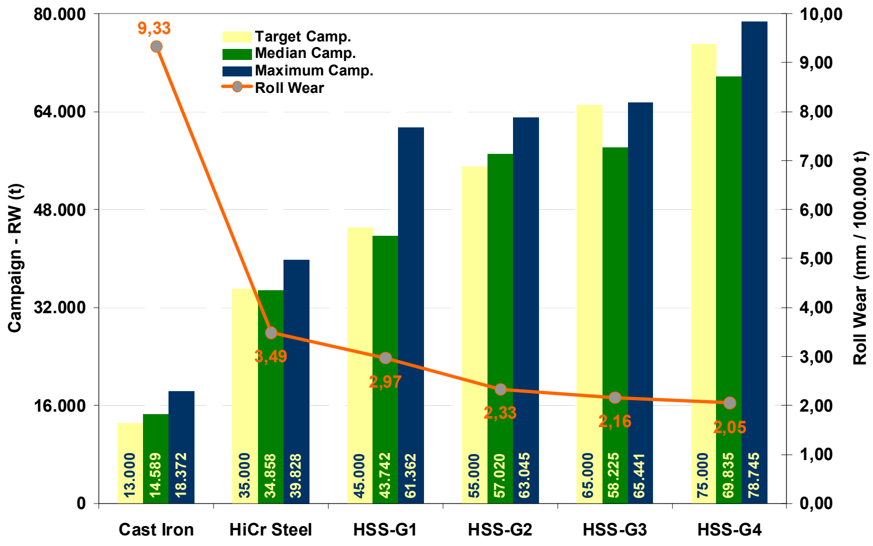


**Figure 10:** Wear resistance and campaign extension for each roll material.

The reflex of this evolution is very clear in the work index of the Hot Strip Mill, showing a considerable reduction in the mill downtime in order to change the roughing mill work rolls (Figure 11).

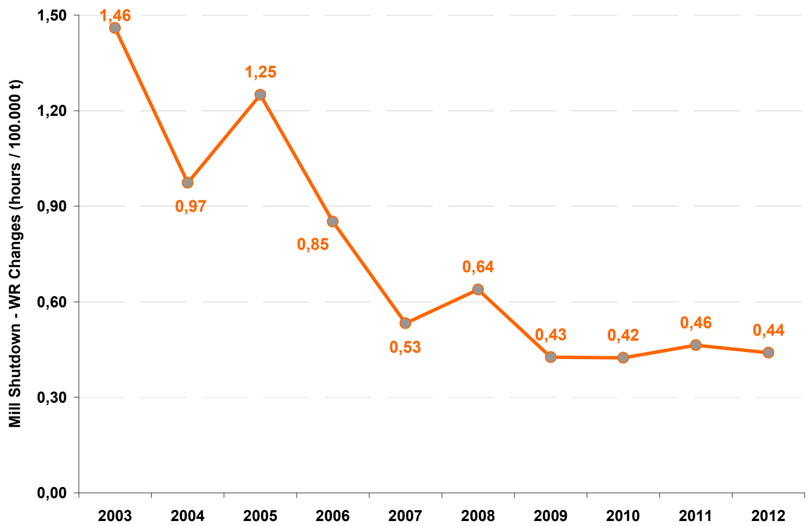


**Figure 11:** Reduction of Mill downtime related to Roughing Mill work roll changes.

The comparison between High Speed Steel and High Chrome Steel in terms of roll performance is shown in Figure 12.

ISSN 1983-4764

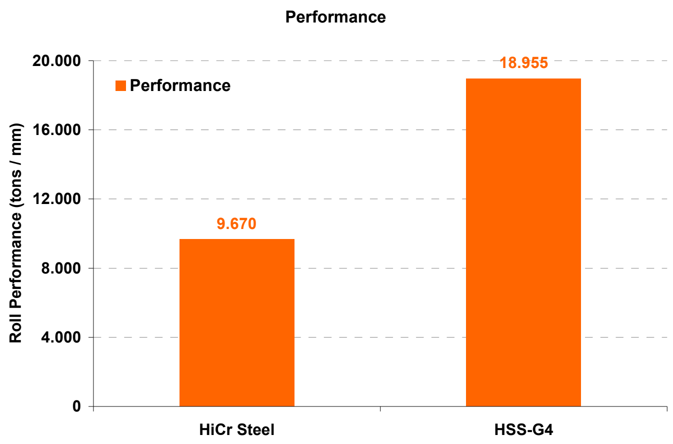


**Figure 12:** Roll performance comparison (HiCr x HSS rolls).

Finally, no quality issues regarding the roll surface aspects have been detected during the testing phases (Figure 13).


**Figure 13 :** Roll aspect after the campaigns.

## 4 DISCUSSIONS

The use of high performance roll grades demand lots of improvements and maturity of a well developed systemic control and inspection routine. The higher hardness values and higher internal stresses requires the performance of NDT (ultrasonic testing and eddy current) in 100% of the rolls so no remaining internal defect creates risk to operational safety and may lead to catastrophic failures while in service; this item has direct effect on the costs of the mill if not taken into account when moving towards these grades. Also, it is mandatory to care about bar stops and it is highly recommended to change the rolls or to develop specific automation routines in such cases.

High Speed Steel rolls are approximately 50% more expensive than the High Chrome Steel grades and the decision to implement it depends on the strategy adopted by each site. The main benefit of these grades is the campaign extension and the TCO approach (Figure 14) is the most recommended way to evaluate such investment and must consider even the idleness of the mill for it may not convert all the potential into gains if the site is not running near its full capacity.

ISSN 1983-4764

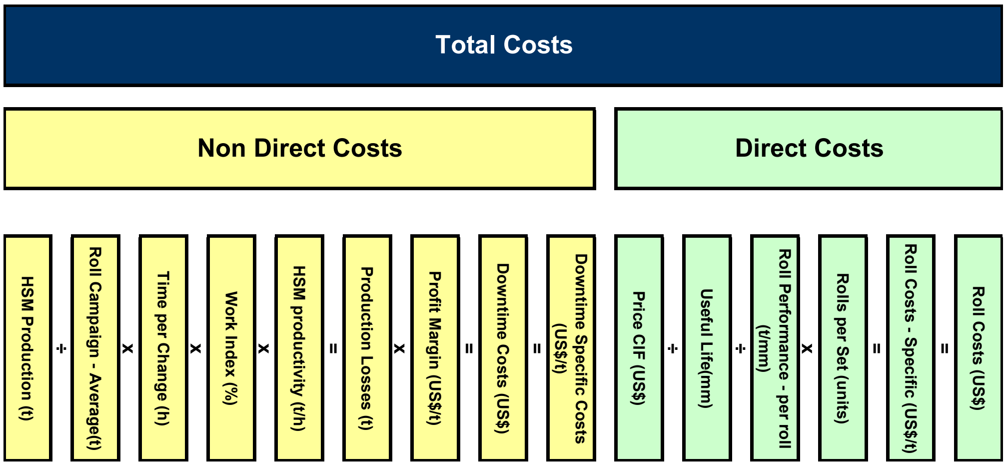

**Figure 14:** TCO example used to evaluate the new roll grades at AM Tubarão.

It is important to emphasize the stability of the results in terms of campaigns and work index since 2009 and how considerable is the effect on the production schedule. Considering a full capacity pace (4,0 Mt/y) or approximately 12.000 t/day, the use of the cast iron rolls would represent almost 1 roll change (30 minutes) per day.
Also, HSS roll presented a performance 96% higher when compared to Cast High Chrome Steel rolls, reducing costs by approximately 22%.
As the final results, target campaigns were safely and sustainably risen from 13.000 t (2002) up to 75.000 t, which represents 1,45% (127 hours) increase in the annual asset availability (Table 2).

**Table 2:** Work index increase due to the WR development

| Production (t) | WR Campaign - Target (t) | Scheduled WR Changes (#) | Δ Roll Changes (#) | Time per Roll Change (h) | Δ Total Time (h) | Calendar (h) | Work Index Savings (%) |
|---|---|---|---|---|---|---|---|
| 4.000.000 | 13.000 | 308 | 254 | 0,50 | 127 | 8.760 | 1,45% |
| | 75.000 | 53 | | | | | |

## 5 CONCLUSIONS

The development of new roughing mill work roll materials at ArcelorMittal Tubarão have been entirely based on the operational stability of the rolling mill and roll shop processes and made in close cooperation and open relationship with strategic suppliers. Since the rolls are more sensitive to cracks in case of incidents in the rolling mill, a stable rolling process is required in order to utilize the full potential of the new grades as they are designed for.
It is highly recommended that the evaluation of new roll materials should be not only carried out by computing the roll cost given by the relation of the price (US$/mm) and performance (t/mm), but also considering additional factors like the mill availability and the working index increase.
By replacing the static cast iron rolls by the spun cast HSS grades, target roll campaigns could be increased from 13.000 t up to 75.000 t, which represents a 1,45% work index and a 22% roll cost reduction.

ISSN 1983-4764

## REFERENCES

1 MURAD , B.; CARVALHO, J.G.; SOUZA, D; LEITE, A. Desenvolvimentos de Cilindros do LTQ na ArcelorMittal Tubarão: Novos Materiais e Extensão das Campanhas de Laminação. In: 45º SEMINÁRIO DE LAMINAÇÃO, 2008, Porto de Galinhas, PE, Brasil. **Anais**... São Paulo: ABM, 2008. 1 CD.