THE WORK ROLL SURFACE DAMAGING STUDY: A KEY FACTOR IN USING HSS ALLOYS IN HOT ROLLING

Alberto Tremea (1a)
Massimo Grespi (2a)
Andres Esteban (1b)
Walter Martinez (2b)

ABSTRACT

In many hot strip mills the front stands of finishing group are working with rolls made in High Speed Steels. The success in using these rolls is strictly in connection with the mill technology but also with redressing methods applied in the turning shop. The HSS rolls show an impalpable wear and then the evaluation of roll surface damaging assumes a strategic role to determine their performance. Furthermore the study of roll surface damaging becomes very important especially when assessing a roll steel grade within the same class of steel. The contents of this paper is focused on the analysis of redressing procedures and their use to optimize the performance of HSS rolls.

Keywords: Hot Rolling, High Speed Steel Rolls, Roll Surface Damaging, Grinding Operations

(1a) R&D Dept. – INNSECILINDRI srl – Via Attilio Franchi 20, 25127 Brescia – Italy – alberto.tremea@innsecilindri.com
(1b) Sales Dept. – INNSECILINDRI srl – Via Attilio Franchi 20, 25127 Brescia – Italy – innse@innsecilindri.com
(2a) HSM Roll Work Shop Manager – TERNIUM SIDERAR – Centro Siderurgico General Savio – San Nicolas - Buenos Aires – Argentina – aesteban@terniumsiderar.com
(2b) HSM Roll Work Shop Coordinator – TERNIUM SIDERAR – Centro Siderurgico General Savio – San Nicolas - Buenos Aires – Argentina – wmartinez@terniumsiderar.com

INTRODUCTION

The manufacturing of rolls for hot rolling through the using of anti wear alloys has progressively focused the attention on the surface degradation of the roll as key factor for the definition of the duration of campaigns as well as the entity of dressings. The need of increasing wear resistance has lead to the introduction of High Speed Steel (HSS) rolls. This name of these alloys derive from the classic designation used for steels for cutting tools. The roll surface quality, in absence of wear, represents the most important factor to fix the real performance of the roll. This evaluation must be carried out in depth, mill by mill, stand by stand. Plant aspects connected with the mill running (descaling, roll lubrication, roll and strip cooling) influence the roll surface quality more than the microstructural differences among roll materials. In addition, the roll performance are very affected by the operative practices used in the roll shop for roll redressing.

HSM AT SIDERAR

The Hot Strip Mill (HSM) at Siderar is a continuous mill composed by 3 roughing stands (R2-R3-R4) and 6 stands like finishing group (F5 – F6 – F7 – F8 - F9 - F10). In this mill the stand R4 can be considered as the first stand of the finishing mill even if it does not work in "direct line" with the following 6 stands. Presently HSS rolls are used from R4 to F8 (Fig.1).
Typical yearly production is 2.7 Mton roughly divided in 60% Carbon steel, 15% HSLA and 25% among others families of steels. As far the production mix also in terms of thickness and width of rolled product see graphics in Fig.2.

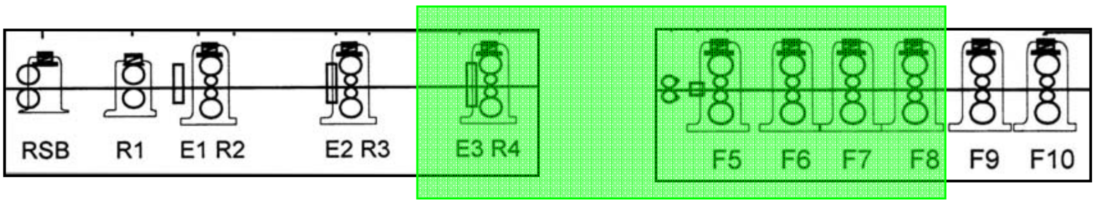


Figure 1 Sketch of Siderar HSM with stands mounting HSS rolls in evidence

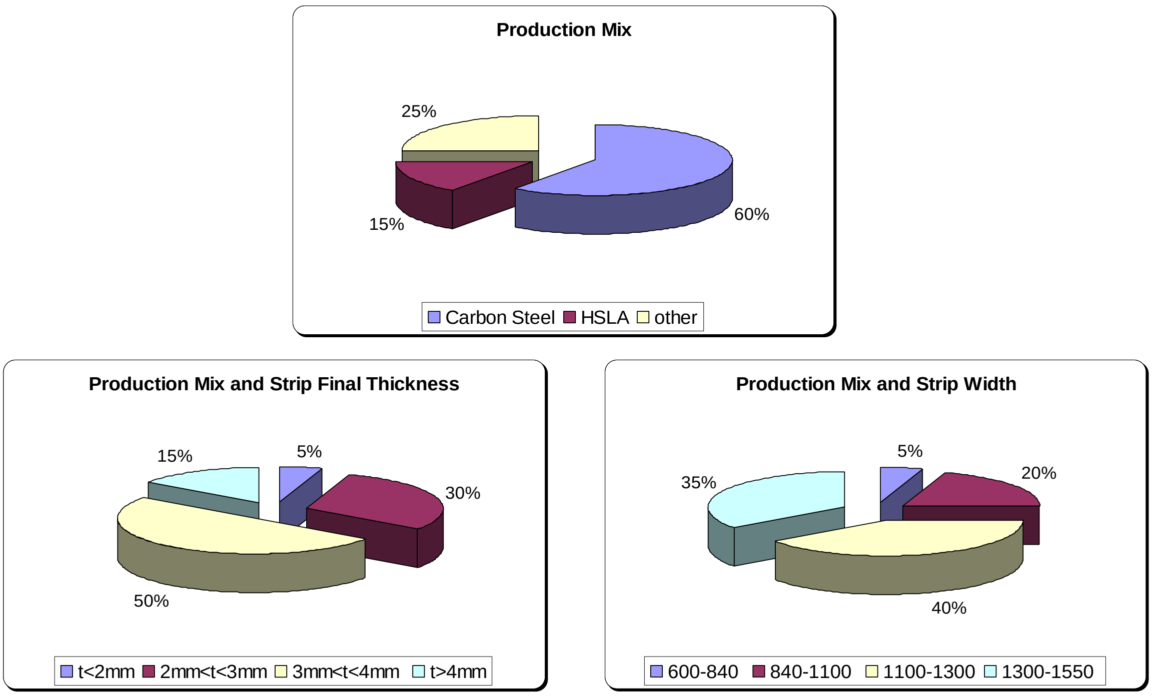


Figure 2 Mix of production of Siderar HSM

HIGH SPEED STEEL ROLLS

High speed steels used for the manufacturing of work rolls belong to the family of ledeburitic steels. The range of chemical composition is reported in Tab.1.

C	Cr	Weq*	V, Nb
1.5/2.0	5.0/10.0	5.0/15.0	2.0/6.0

***** Weq=W+2Mo

Table 1 HSS chemical analysis range [wt%]

Their main characteristic is the maintaining of the hardness at high temperature that permits to reduce wear during rolling. Their microstructure is characterized by the presence of different primary carbides dispersed in a tempered martensite matrix. In these steels, the presence of high percentages of carbides formers elements (Mo, V, Cr...) joined with the carbon content, permit the precipitation of a big amount of carbides different each other for shape and distribution in function of the relative balancing among the elements (Fig.3). The solidification of these steels is quite complex providing several eutectic reaction. In the last years the alloy design has been aided by the use of thermodynamic modelling, so that the composition can now be tailored to obtain microstructure meeting the needs of the specific application in the mill. (Fig.4). Over the carbides, a very important role is played by the martensitic matrix: this constituent, that fix the hot resistance of the material, must undergo the heavy rolling conditions without losing its own resistance characteristics. The iron matrix must contain precipitates (secondary carbides) that permit it to limit the degeneration of its properties; the presence of these precipitates depends by the chemical content but also by the heat treatment that has a main role for the behaviour in rolling of these special steels. The heat treatment has another important goal in these steels: the elimination of retained austenite. In general this phase impairs the properties of the roll, i.e., reduce local hardness and causing embrittlement due to its transformation during service. An example of HSS with retained austenite is in Fig.5 (microstructure and XRD spectrum).

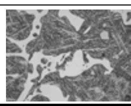
NAME	ELEMENTS	DENSITY [g/cm^3]	HV$_{0.1}$	ASPECT
MC	V, Nb, Mo (W)	6 – 8	2500-3000	 10-50μm
M_7C_3	Cr, Fe	7	1400-1800	 50-250μm
M_2C	Cr, Mo (W), V	9 – 18	1900-2100	 50-250μm
M_6C	Fe, V, Mo (W), Cr	7 - 14	1200-1500	 50-250μm
M_3C	Fe, Cr	7 – 8	1000-1100	 50-250μm

Figure 3 Carbides in HSS roll material

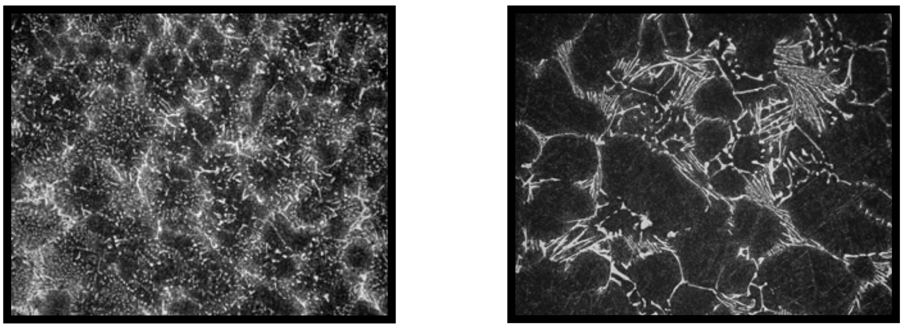


Figure 4 Examples of microstructures of HSS roll material

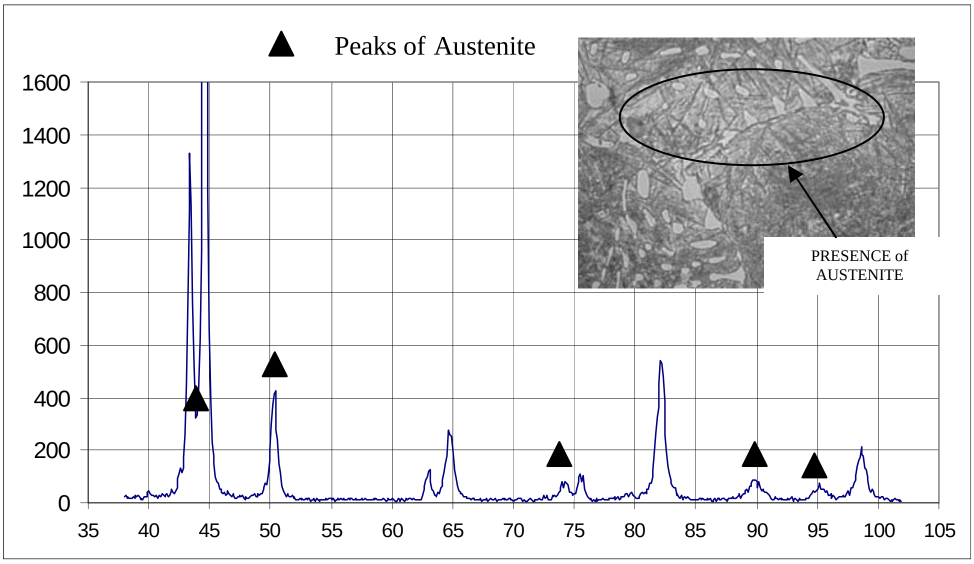


Figure 5 XRD spectrum and microstructure of HSS with a 15% of retained austenite

THE SURFACE DAMAGING OF WORK ROLLS

In a HSM HSS rolls are used in both roughing and finishing stands. In the rougher the roll wear practically characterizes the length of the campaign (not the roll surface quality). In the finishing stands the requirements are quite different and the degradation of roll surface becomes very important. HSS rolls aren't used in the last stands and therefore the following considerations are concerning the early stands of the finishing group.
In this work we focused the attention on the causes of roll surface degradation in normal rolling conditions. Following classification is built on the basis of the lost material of the roll ordered from big to low losses:

1. pure consumption – loss of roll material due to the wear
2. pitting – localized loss of roll material
3. banding – loss of scale that covers the roll
4. peeling – reduction of the oxide scale that covers the roll
5. thermal fatigue – fire cracking of a limited depth of the roll

The pure consumption

The consumption of material at the end of the campaign is a rough indication but represents a very important evaluation of the global behaviour of the roll. Today it is easy to get a profile form the grinding machine and therefore the evaluation of the wear resistance can be made without problems. Wear can be very low, reaching few hundredth of millimetre or less. Wear is proportional to the length of the campaign but the rolling force and the contact temperature strongly influence its level. This information is still not present in many data system that manage the roll life and so in these cases the wear evaluation become a complex and boring task.

The pitting

Pitting is a localized form of degradation characterized by detachment of material usually distributed throughout the entire surface of the roll barrel in contact with the strip (pits on the barrel of the roll); the phenomena is higher at the centre of the barrel where thermal stresses are bigger. Micro detachments can extend over a surface area of $2mm^2$ and a maximum depth of 0.5mm. This problem is strictly connected with the thermal cycle undergone by the roll, but mechanical and microstructural characteristics of the roll can partially limit it. The Figure 6 shows a roll surface with pitting. The image in foreground is the roll surface before grinding while in the background there is the residual pitting after a redressing of 0.25mm.

Figure 6 Pitting on the roll surface (Stand F1 after 10000 ton)

Banding and Peeling

Both phenomena are related with the removal of the oxide scale that covers the roll in forms of strips extending circumferentially. In the case of peeling the oxide removal is only partial, while in the case of banding is more pronounced involving also the base material of the roll. The severity of this problem is mainly connected with the abrasion that the strip causes to the roll. The status of the skin strip (temperature and presence of scale) is very important for this problem. As far the plant, descaling and strip cooling equipments are strategic. This phenomena affects normally a thicknesses < 100μm but this loss of scale causes a drop in wear resistance of the roll and produces negative effects on the surface quality of the strip. The Figure 7 outlines an example of a roll surface with peeling.

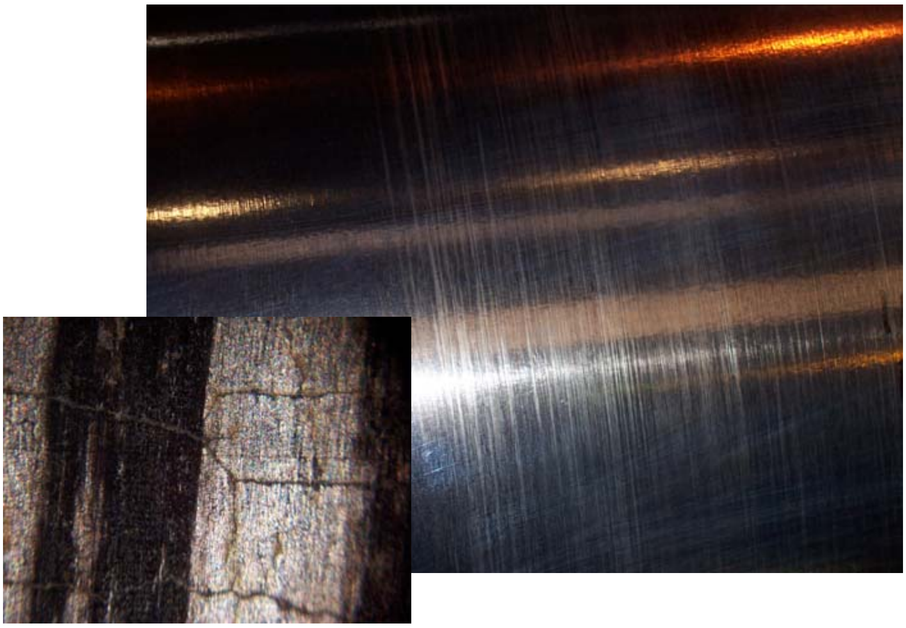


Figure 7 Peeling on the roll surface (Stand F1 after 2000 ton)

The thermal fatigue

The work roll undergoes a heavy thermal cycling that generates a thick cracks network that makes the roll material less resistant to the consumption. Locally some defects of the microstructure appear; they can degenerate in micro detachments favouring the pitting. Besides these cracks reduce the protective effects of the oxide scale that covers the roll because they make it less adherent. Normal rolling conditions for early finishing stands of HSM generate firecracks not deeper than 0.5mm. Figures 8 and 9 show an example of damaging due to thermal fatigue (HSM - stand F2).

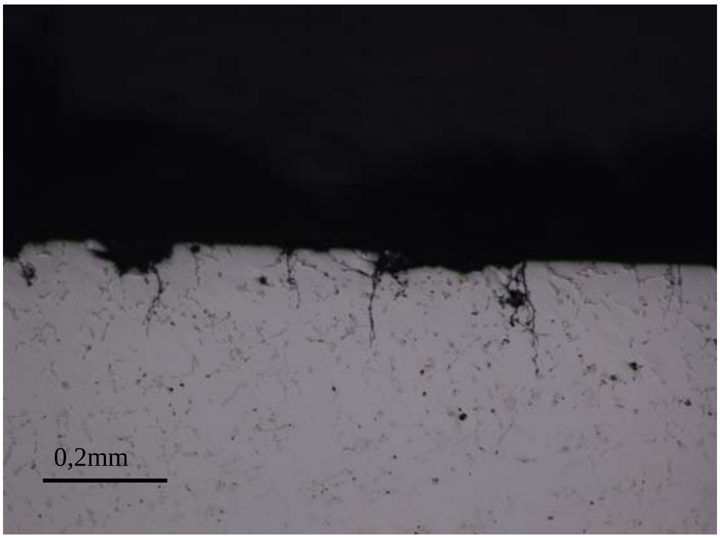


Figure 8 Firecracks due to thermal fatigue (section view)

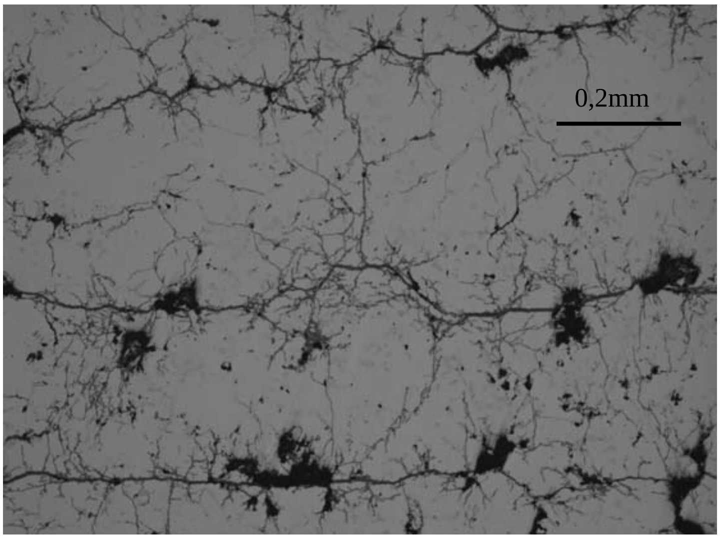


Figure 9 Firecracks network on the roll surface due to thermal fatigue

DAMAGING OF HSS ROLLS AT SIDERAR

In table 2 is summarized the typical damaging of HSS rolls in finishing stands of the HSM in Siderar.

TYPE OF ROLL DAMAGE	R4	F5	F6	F7	F8
wear	yes	yes	yes	yes	yes
pitting (visible)	yes	yes	no	no	no
banding	yes	yes	no	no	yes
peeling	yes	yes	yes	yes	no
thermal fatigue (visible)	yes	yes	no	no	no
length of campaign [ton]	4500	2200	4500	2200	2000

Table 2 Damaging of HSS rolls in the HSM of Siderar

Figure 10 Roll surface after 4500 ton in stand R4

Figure 11 Detail of the roll surface

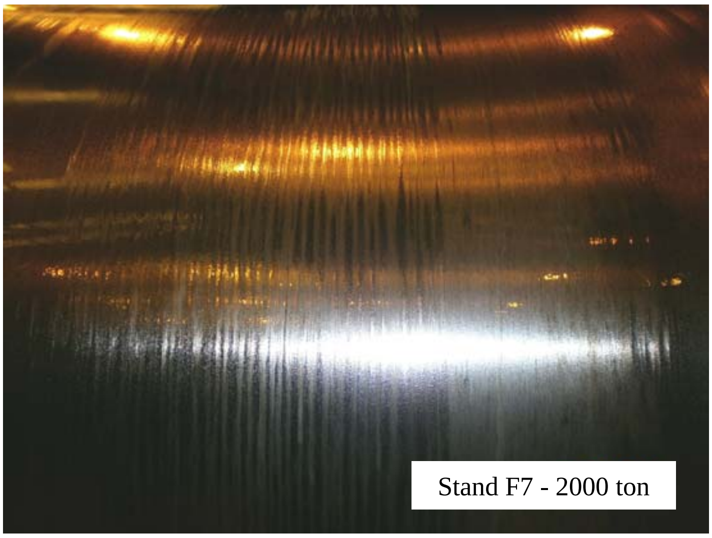


Figure 12 Peeling of the roll surface after 2000 ton in stand F7

The grinding procedures to restore the rolls are influenced by wear and the severity of surface damaging. This the approach in the roll workshop at Siderar:

- measurement of profile
- rough passes to eliminate wear
- evaluation of residual damaging of the roll surface (visual control)
- finishing passes to put the roll profile in tolerance

A continuous work is ongoing to optimize the grinding process on the base of the specific deterioration exhibited by the roll, in order to avoid uneconomic and time consuming extra-grinding passes. A systematic analysis is being carried out for each stand of the mill.

In Figure 13 there is an example of wear profile (stand F7).

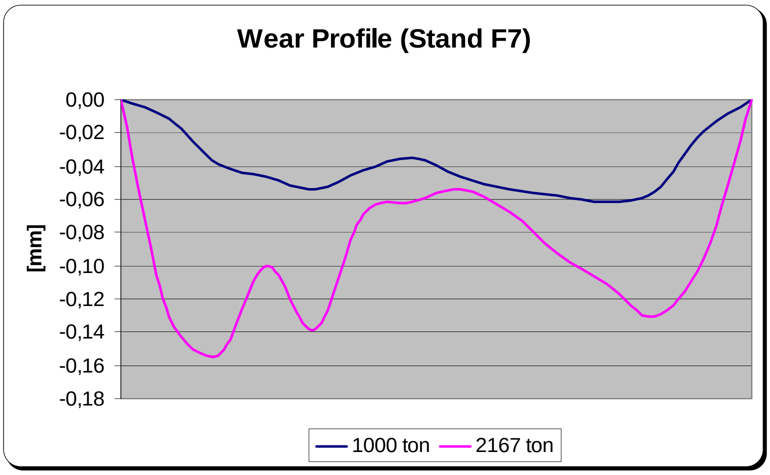


Figure 13 Examples of wear profiles in stand F7

HSS ROLLS BEHAVIOR AT SIDERAR

The analysis regards 2 types of Innse Cilindri HSS rolls in the mill since 2011. In this study only the campaigns where these rolls are used in pair were taken in account excluding the accidents (campaign with stock removal > 1mm).

If we look at the classical parameter that describe the roll performance (ton/mm), HSS rolls show the better behaviour in stand R4 where the campaign is double. If we analyze the specific roll consumption with reference to the kilometre of rolled material the situation is completely different with better results in stand F8. The stock removal can be considered a constant value around 0.5mm (Tab.3).

STAND	R4	F5	F6	F7	F8
ton/mm	8900	4700	6300	4600	3400
mm/km	0.037	0.037	0.018	0.015	0.013
ton/campaign	4500	2200	2800	2200	2000
mm/campaign	0.500	0.465	0.460	0.490	0.575

Table 3 Behavior of HSS rolls of Innse Cilindri

STAND	R4		F5		F6		F7		F8	
ROLL GRADE	A	B	A	B	A	B	A	B	A	B
ton/mm	9765	8500	4575	5050	5805	6440	4570	4890	3420	3210
mm/km	0.033	0.038	0.037	0.037	0.020	0.017	0.015	0.017	0.013	0.014
mm/campaign	0.481	0.508	0.481	0.425	0.489	0.449	0.485	0.574	0.588	0.487

Table 4 HSS roll results splitting between different roll grade

The analysis splitting data between different grades of HSS doesn't outline any clear trend (Tab.4).
In laboratory, the grade B shows a superior wear resistance respect to grade A. The data examination only considering the wear confirms this aspect: the grade B shows a lower consumption of about 10% (Tab.5). The calculation of the wear is made in the middle of the roll barrel. This method to calculate the wear isn't the best but it allows a good estimation. Many times the wear profile is like in Fig. 13 so this approach can underestimate the wear.

STAND	R4		F5		F6		F7		F8	
ROLL GRADE	A	B	A	B	A	B	A	B	A	B
μm/km	12.4	12.6	14.7	12.0	7.8	7.2	6.5	4.8	2.6	4.3*

* few campaigns

Table 5 Amount of wear stand by stand

FINAL REMARKS

The roll workshop of Siderar HSM is conducting activities related to the study of roll surface damaging thinking to a continuous improvement in managing HSS work rolls. In this work attention was paid to the finishing stands of HSM. Following conclusions can be drawn:

1. The specific total consumption in stands R4 and F5, given by the contributions of wear and grinding (expresses as mm/km), is double than in other stands;
2. Wear (expressed as μm/km) decreases moving from R4 to F8;
3. The stock removal (expressed as mm/campaign) doesn't significantly change for different stands;
4. The tests performed in the mill with two different grades of HSS rolls confirm the laboratory results.

The selection of the grade and of the roll play a crucial role but the knowledge of its damage is an essential starting point towards roll management optimization. The results of this paper confirm the importance of a proper management of the mill and the roll workshop. Underestimating these factors can frustrate the efforts aimed at the possible improvement of the roll. Undoubtedly, the fruitful cooperation between rollmaker and people of the mill is the best assumption to successfully approach an improved yields of roll and mill. From this point of view, the collaboration started between Innse Cilindri and Siderar represents a good practice which will give results in a near future.

REFERENCES

- Innse Cilindri Technical Reports.
- Ternium Siderar Technical Reports.
- M. Pellizzari et al., “Laboratory testing aimed at the development of materials for hot rolls”, Proc. Steel Rolling 2006, 19-21 June, Paris, France.
- M. Pellizzari et al., “Wear and friction behaviour of high chromium iron and high speed steels for hot rolls”, Abrasion 2005, São Paulo, Brazil, 189-198.