WORK ROLLS BEHAVIOUR IN THE ROUGHING STANDS AT SOUTH AMERICAN HOT STRIP MILLS[1]

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Abstract

The work roll in chromium steel is the typical type of roll for the roughing stands of a hot strip mill. This application, very hard from a thermal point of view, needs rolls made in high-strength alloys that can withstand heavy rolling loads and wear at high temperature. In this regards, already exist rolls with superior mechanical properties to those of rolls made in chromium steel. An example is represented by semi-hss rolls called in this way in analogy to the classification of tool steels. Laboratory tests on the semi-hss material has shown optimal results in terms of wear and thermal shock resistance, but in service it requires careful management if you want to exploit these features. For this reason, the operations in the roll shop hold a great importance both in routine grinding phases and when a roll is subjected to an accident. This work aims to underline that the synergy between the roll shop and the roll producer is the only way to optimize the roll performance. Working with this approach becomes possible a reasonable cost reduction for the roll shop as well a correct evaluation of real yield of the roll. The paper outlines the operating situations of roughing stands in some South American mills. This comparison can certainly help to better understand how to manage the many rolling variables when we want to evaluate the behaviour of a roughing work roll.

Key Words: Hot Rolling (Roughing Stands), High Alloyed Steel, Roll Performance

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INTRODUCTION

Roughing work roll for hot strip mill has a very important role because its behaviour strongly conditions the rolling rates of the mill. It is a roll that must allow a long rolling period (several days); therefore its safety is as important as its performance. Wear resistance has a primary importance in the definition of the trip duration; wear profile must be carefully monitored because too high consumptions create dangerous increments of stresses caused by the contact with the back up roll. Generally a consumption of 2 mm can be considered as “safe” while a consumption of 4mm can represent an insuperable limit. In these evaluations it is very important to know also the wear profile and the geometry of the back up roll, in order to fix the acceptable limit. Presently the materials used for work rolls manufacturing belong to the group of tool steels. Their classification can be made on the basis of the presence and the typology of the carbide former elements present in the material[1]:

- High Cr Steels (HCRS) – the large presence of chromium (>10%) and carbon (>1%) promotes the formation of M_7C_3 carbides that guarantee wear resistance at high temperatures.
- High Cr-Mo Steels (SHSS) - the strong and simultaneous presence of several hardening elements make possible the production of a steel with a martensitic matrix full of secondary carbides. The level of carbon is kept below 1%. Optimal characteristics in case of high stress and temperature.
- High Cr-Mo-V Steels (HSS) – the presence of very hard carbides guarantees an excellent wear resistance (carbon is around 1,5%).

These materials have common characteristics:

- network of eutectic carbides (quantity and typology depend on the balancing between carbon and main alloying elements);
- martensitic matrix (very hardenable and tempered at high temperature);
- hardness range (775-815 Ld depending on the heat treatment);
- high hot hardness (Fig.1).

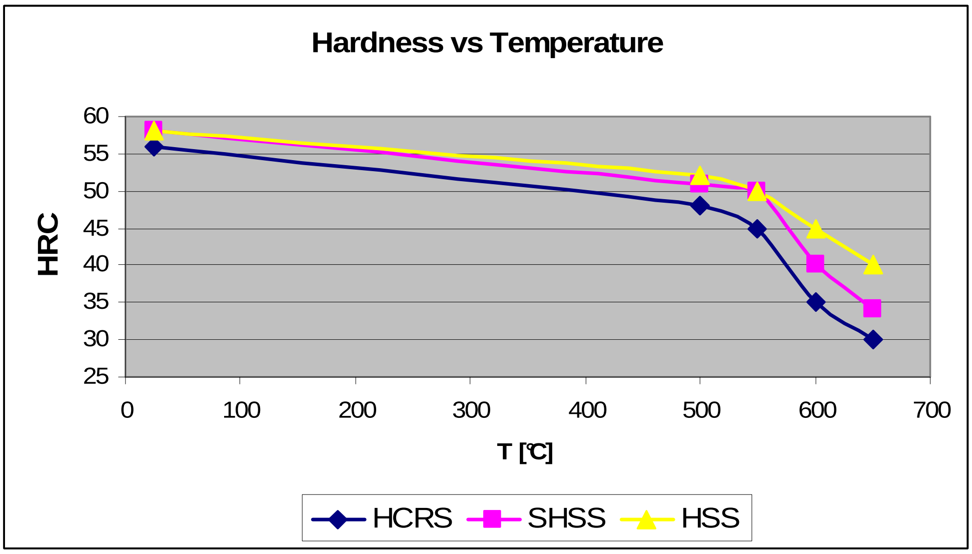

Fig. 1 Hardness & Temperature for roughers materials

Table 1 shows the chemical range of these materials, while Figure 2 shows their typical microstructure.

Tab. 1 Classification of roll material for roughing stands

MATERIAL	%C	%Cr	%Mo (W)	%V (Nb)
High Cr Steel	>1,0	>10	<5	<1
Semi High Speed Steel	<1,0	5-10	<5	<1
High Speed Steel	>1,5	5-10	5-10	0-5

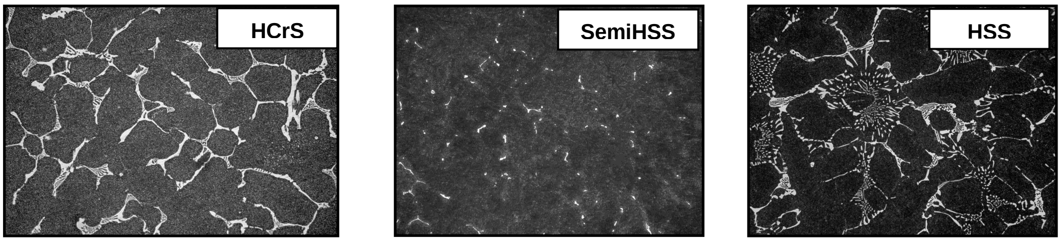

Fig. 2 Microstructure of work roll materials for roughing stands

This classification is quite general and leaves big possibilities of manufacturing modifications among the roll makers. For instance, not all roll makers produce the same HCRS. The ferroalloys content and heat treatment cycle can be different a lot both to equipment limits or costs; therefore sometime we compare materials that have the same name but not the characteristics.

An other important parameter of evaluation is the roll surface quality after its using. The roll undergoes a very heavy thermal cycle and firecracking is inevitable. The entity of the thickness of the material involved by firecracking is proportional to the severity of the thermal cycle ($T_{min/max}$, rolling rate)[2,3,4,5]. For this kind of damaging, theoretically the microstructure of the material could reduce its severity, but the kind of contact between roll and strip influence a lot the level of roll surface damaging (friction coefficient, oxidation status of the strip)[6].

An other factor that influence a lot the quality of the roll surface is the presence of retained austenite. The transformations of this unstable phase can produce an embrittlement of the roll surface with a consequent reduction of the firecracking resistance of the material. This situation can cause an heavy damaging with micro detachments of material and therefore a faster worsening of the surface quality. The control of the presence of this phase can be easily made using thickness gauges after a careful calibration on the basis of x-rays diffraction measurements (Fig.3).

Technological and mechanical characteristics of these materials are well known and studied in laboratory[7]: they are summarized in the following tables. In the same kind of material, differences of chemical content and/or heat treatment can modify the quantity of carbides; that is why carbides and other features are shown with a range.

Tab. 2 Carbides & Hardness

MATERIAL	CARBIDES	HRC$_{(RT)}$	HRC$_{(550°C)}$
High Cr Steel	8-12	56	45
Semi High Speed Steel	3-6	58	50
High Speed Steel	6-12	58	50

Tab. 3 Mechanical Properties

MATERIAL	TENSILE STRENGTH [MPa]	COMPRESSIVE STRENGTH [MPa]	THERMAL CONDUCTIVITY [W/mk]
High Cr Steel	800-850	2200-2600	18-22
Semi High Speed Steel	900-950	2400-2800	25-30
High Speed Steel	900-950	2400-2800	20-28

Tab. 4 Technological Properties

MATERIAL	WEAR	FIRECRACKING	FRICTION	OXIDIZABILITY
High Cr Steel	REF	REF	REF	REF
Semi High Speed Steel	-50%	-60/80%	+20/40%	±10%
High Speed Steel	-50%	-20/40%	±10%	+10/30%

As clearly appears looking at the values, the laboratory tests reject HCRS. The adding of alloying elements, different from Cr, gives to the material a better hot resistance and permit the formation of a carbide network less interconnected with harder carbides. Thus this situation has positive consequences both for wear and firecracking.

In the reality, HCRS is still on using in the roughing stands for economical reasons and for its reliability; besides, small analytical modifications have permitted to improve this alloy.

Summarizing the present using in the world, we can say:

1. Carbon steel rolling
    - 30% HCRS – 50% SHSS – 20% HSS
2. Stainless steel rolling
    - 25% HCRS – 75% HSS (no SHSS)

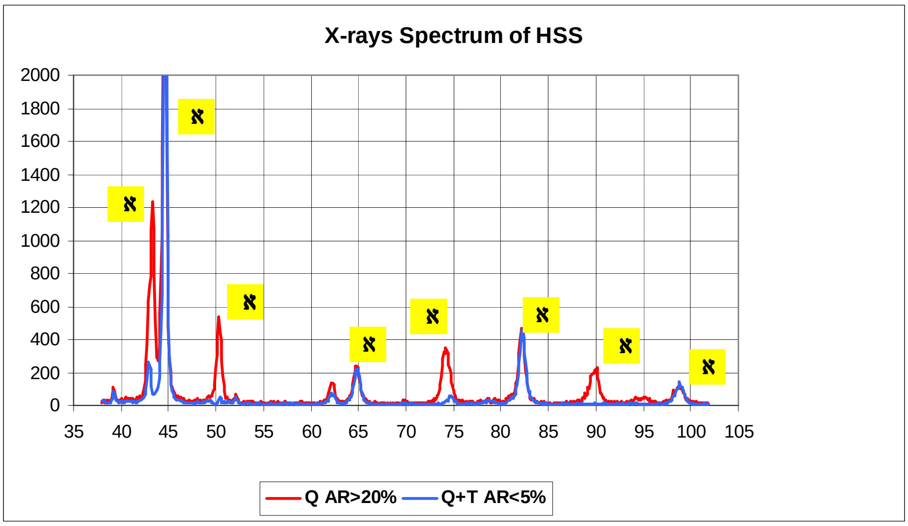

Fig. 3 XRD of HSS material (Q=Quenched – Q+T=Quenched & Tempered)

EVALUATION OF WORK ROLL BEHAVIOUR

The most common used index is the amount of rolled tons for each removed millimetre. If the stand is reversing, the tons are usually counted once. Today more customers take care also of the specific cost of the roll compared with the rolled tons; therefore the index is $/ton. This index involved commercial aspects, that sometime null the scientific aspects connected with the roll behaviour, but they are not for sure the subject of this job.

Total consumption of these rolls should be analyzed dividing it in three parts:

1. consumption during the campaign (index of wear resistance);
2. standard machining removal (index of the roll surface condition);
3. extra machining removal (index of a resistance to thermal shock).

It is necessary to have in hand at least this info to can make a serious comparison of results between different products.

RESULTS FROM SOME MILLS IN SOUTH AMERICA

CASE 1 – R2R3 of CONTINUOUS HSM

- This mill produces 2Mton/year approximately.
- Semi HSS and HSS rolls are in using.
- Rolling campaigns duration is two weeks, for 100000 ton/camp.
- Wear is 2-3mm.

Tab. 5 Results from HSM1

MATERIAL	ton/mm N	ton/mm T	mm/kton T	%inc
HSS	65000	19500	0.051	70
SHSS	60000	16000	0.060	74
SHSS (test)*	50000	37000	0.027	26

* data only from R3

These results highlight as the accidentalities reduce the performance of these rolls. If we exclude the SHSS that at the moment has rolled few campaigns, and in R3 stand only, the losses for thermal cracks are very high.
HSS and SHSS have a very similar behaviour; therefore it is thinkable that these 2 alloys can reach the same target of performance.
We do not have enough data for an analysis of the firecracking resistance.

CASE 2 – $R2_{rev}$R3R4 of SEMI CONTINUOUS HSM

- This mill produces 400000 ton/month approx.
- SHSS e HCRS rolls are in using.
- Campaigns depends on the single stand and on the roll material (50000 ÷ 150000).
- Wear is 1-1.5mm.

Tab. 6 Results from HSM2

$R2_{REV}$R4 HCRS	**ton/mm N**	**ton/mm T**	**mm/kton T**	**%inc**
HCRS**	53000	24600	0.041	54
$R2_{REV}$	**ton/mm N**	**ton/mm T**	**mm/kton T**	**%inc**
SHSS	148000	74000	0.013	50
HCRS	89800	46500	0.022	52
HCRS (test)***	135000	69500	0.014	52

** old results
*** longer campaign (no standard)

The consumption of SHSS roll is reduced by 50% compared with HCRS. It is possible to make longer campaigns, with an acceptable wear. Longer campaigns with HCRS rolls are on trial, but it is too early to make comments. If we compare the actual results of HCRS with the past it’s clear a big improvement; the progress made of this roll grade have allowed to increase the rolling campaign with a positive consequence on the performance.

CASE 3 – $R1_{REV}$ of SEMI CONTINUOUS HSM

- This mill produces 4.5Mton/year approx.
- SHSS and HCRS are in using.
- Rolling campaign duration is 70000 ÷ 80000 ton.
- Extra grindings are in practise only due to thermal cracks.

Following Table 7 shows the results in different periods of working.

Tab. 7 Results from $R1_{rev}$ stand of HSM3

Period 1	**ton/mm N**	**ton/mm T**	**mm/kton T**	**%inc**
SHSS	22300	8800	0.114	60
HCRS	21700	10360	0.096	53
Period 2	**ton/mm N**	**ton/mm T**	**mm/kton T**	**%inc**
SHSS	23400	11230	0.089	52
HCRS	21400	11750	0.086	45

In this stand the roll in SHSS seems to do not show improvements compared with the roll in HCRS, even for wear resistance. To go deeper in this aspect, it should be useful to analyze some wear profiles with the relative removals, but as of today there has not been this opportunity. It has to be noted as half consumption is generated by situations connected with firecracking caused by rolling accidents.

CASE 4 – RR_{REV} of STECKEL MILL

- The mill produces 800kton/year approx. Stainless steel is 50% of total production.
- HSS and HCRS rolls are in using.
- Rolling campaigns are different because the quantity and the typology of the stainless steel strongly influences the length of the campaigns. Presently with a mix of rolls divided on a fifty fifty basis between the 2 series, 3000 tons are rolled in average with a removal of 0.48 mm/campaign.
- Extra grindings are quite only due to thermal cracks and they are very considerable.

Tab. 8 Results from RR_{rev} stand of HSM4

MATERIAL	ton/mm N	ton/mm T	mm/kton T	%inc
HSS	10000	3500	0.140	65
HCRS	9000	1300	0.380	85

In this stand the using of HSS rolls permit longer trips compared with HCRS rolls, mainly when campaigns contain higher quantities of stainless steel. These results show also a high level of accidentability of these rolls in spite of their manufacturing material.

CONCLUSION

This job has shown some situations that describe the results of roughing work rolls in some south American mills. A lot of thinks are already well known, but they have been summarized in this report at the aim to:

- <u>promote a constructive dialogue between roll makers and roll users</u>

Once analyzed these situations, in order to make useful the efforts made by makers and users, it is necessary to fix (or to remember) some simple rules of “good behaviour”, if the wish is to measure the real performance of a roll:

1. to record the wear profile (if an automatic tester is not available, 3 measurements on one line along the barrel are enough);
2. to evaluate the damages (photos, measurement of roughness);
3. to choose a criteria for the removal of the cracks and keep it valid for all the duration of the test;
4. to identify the reasons of the removals (to create different codes for the different problems, for instance) so to highlight the criticality of the product.

If the above becomes operative, it is useful to discuss together on eventual qualitative improvements: this is the only way to give to the roll its right value.

A roughing work roll is big, heavy and expensive: it ought to have big attention in its using but also in its judgement.

Relating to a general judgement on collected results we can resume the situation as follow:

- more than 50% of useful layer of roughing rolls is loss due to firecracks and not in rolling the steel; among the three families of roll material it doesn't appear a better solution;
- in carbon steel rolling SHSS rolls show a superior wear resistance respect to HCRS rolls, but the real benefit of this isn't so tangible;
- when stainless steel is present HSS rolls make the difference.

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