

SLIVER DEFECTS ON LOW CARBON STEELS, COLD ROLLED STRIPS

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Abstract. *One definition of slivers could be: defects in the nature of irregularly shaped pieces of steel clinging loosely to finished steel. Slivers may result from defective composition (over-oxidized, high sulfur); defective teeming of molten steel; defective heating (burning); tearing of corners in early stages of rolling; etc. So, from the definition is obvious that the origin of slivers could be in different stages of steel flow route but, the main source of slivers is related to nonmetallic inclusions formed and entrapped on the subsurface of continuous cast slabs, as are FeO and Al₂O₃. These inclusions are generated by mould slag entrapment on solidifying shell, re-oxidation during continuous casting by air, refractory materials, ladle slag, etc. The present paper contains metallographic analysis of areas connected to slivers from 5 cold rolled coils of strips with thickness varying between 1.8mm to 4.1mm and the carbon content from 0.04% to 0.188% and in all analyzed areas have been observed only FeO inclusions related to slivers defects, inclusions formed during continuous slab casting process.*

Keywords: *sliver, low carbon steels, cold rolled strips*

1. INTRODUCTION

The quality of finished steel products is often impaired by the presence of ‘surface’ defects such as slivers, cracks, laps, etc. and/or ‘internal’ defects like cracks, porosity, segregation, etc. Defects in finished steel products may arise from poor steel quality (high non-metallic inclusion content) at steel making stages or may be caused during subsequent downstream operations such as casting, reheating, hot/cold rolling or drawing. Such defects may remain undetected in intermediate processing stages and ultimately show up in the finished product during final inspection.

Line defects appear on the surface of finished strip product, with several tens of micrometers to millimeter in width and 0.1 - 1.0 m in length slivers are irregular, flatly formed laminations of varying size and shape that occur in longitudinal direction of the strip and are distributed irregularly over the strip width (OKOF, 1996) This surface defect is believed to result from nonmetallic inclusions caught near the surface of the slab (<15 mm from the surface), coupled with elongated bubbles

The inclusions can be oxide particles, casting powder, alumina clusters, refractory, etc. When the sliver defects are examined, it is found that there are different causes for an identical macroscopic form. Electron probe microanalysis (EPMA), confirmed for some cases, these inclusions to be Al₂O₃ that formed during steel making and surfaced during hot rolling [1]

There are other slivers, which have Fe-oxide (scale) present along the lamination with an alloy enriched internal oxidation (IO) in the substrate. These solid-state re-oxidation products typically are about 1micron

in diameter and are formed as a result of oxygen diffusion ahead of a scale front where they precipitate from solid solution at elevated temperatures. In carbon steels, they often are accompanied by localized decarburization[2].

While IO has been observed to occur from damage as late as the first roughing stand, since the internal oxides form at elevated temperatures they are generally believed to be an evidence of the defect present in the slab before reheating.

Consequently, slivers with IO are commonly presumed to be the result open or coarse cracks on the cast slab, indicating a problem with the casting operation. A considerable share of sliver defects also has scale present along the lamination,

yet, because of the absence or only weak presence of internal oxidation in the sliver region, the hot rolling stage is attributed to be the cause. However, FeO-type sliver defects can occur with or without dispersed oxides often referred to as internal oxidation[3].

Some slivers were found from mold slag entrainment, Mold fluxes not melting homogenously tend to have several phases with areas of high melting and low viscosity oxides, which are available for entrapment, Mold fluxes during strand startup do not immediately supply the necessary liquid layer essential for lubrication, and consist of a combination of dry powder, semi-molten and molten [4]

Although several experiments have been conducted to establish how the defects form/evolve from slab to strip, many questions remain.

Table 1. Chemical composition of the coils

Coil.	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V
A	0,04	0,24	0,019	0,007	0,016	0,02	0,02	0,04	0,006	0,004
B	0,034	0,28	0,015	0,007	0,029	0,03	0,02	0,03	0,004	0,005
C	0,04	0,26	0,013	0,007	0,016	0,03	0,03	0,03	0,007	0,004
D	0,188	0,56	0,018	0,0096	0,015	0,01	0,02	0,02	0,007	0,003
E	0,106	0,35	0,01	0,0101	0,01	0,01	0,02	0,02	0,002	0,002

2. Defects on the surface of cold rolled coil

In the present paper have been analyzed the sliver defects observed on the surface of 5 cold rolled coils of strips with thickness varying between 1.8mm to 4.1mm and width being from 1092mm to 1219mm. In the Table 1 is shown the strips chemical composition. From Table 1 it can be observed the carbon content of analyzed strips varies between 0.04% and 0.188%, a quite large variation, and the

manganese content between 0.26% and 0.56%. In the case of another chemical elements from strips composition the variation range is quite small.

In Fig.1A-D are presented the defects on the surfaces of coils and the position for metallographic specimens cutting. So, for example for A coil, the specimens 1 and 2 have been cut transversal and 3 longitudinal with respect to the rolling direction.

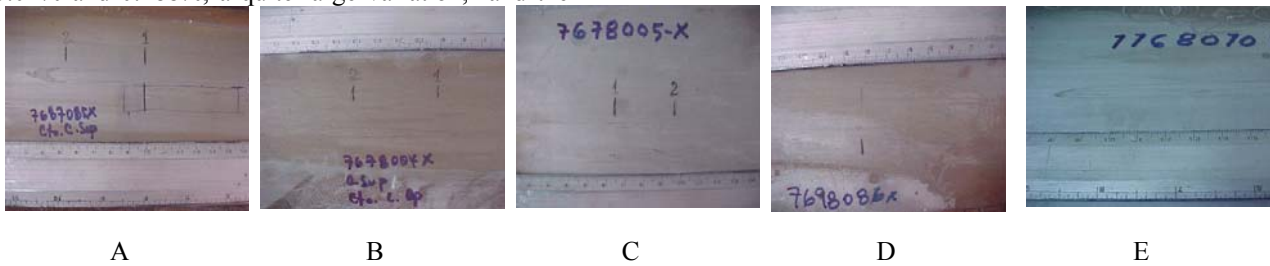


Figure 1. Metallographic specimens cut out from tested coils

The position of defects, with respect to the strip width, is different from one strip to another, consequently seems not to be related to rolls or another equipment damage, even the defects appearance is quite similar, width of 8-15mm and length from 70 to 100mm.

After un-etched metallographic examination of specimens cut longitudinally with respect to the rolling direction it can be observed for A coil (Fig. 2), the defect consists on sub-surface iron oxides which have variable thickness (max. 26 μ m) and are found along the surface at the depth varying in the interval: 16-23 μ m.



Figure 2. Metallographic examination of un-etched specimens (A coil)

The same defect has been observed for specimen no.2, the maximum depth being 26 μ m.

In Fig.3 the etched image of specimen no.1 shows that the defect belongs to a region without decarburization and the average grain size increases from the surface, where is 9, to 5-6 at 400 μ m depth.

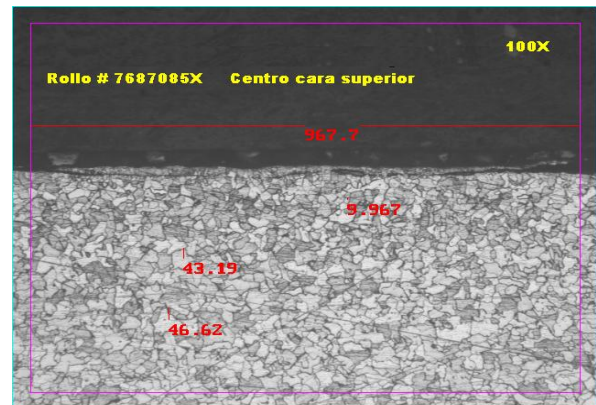


Figure 3. Metallographic examination of etched specimens (A coil; x100)

In Fig.4 is shown the defect zone at x500 magnification and can be seen the decarburization in the zone of defect.



Figure 4. Metallographic examination of etched specimens (A coil; x500)

In order to verify if the decarburization is related to the defect or not has been analyzed at the same magnification, another zone of the specimen, being observed the decarburized zone as in the Fig.4.

In Fig.1B is presented the defect on the surface of B coil and the position for metallographic specimens cutting. So, the specimens 1 and 2 have been cut transversal to the rolling direction. Even the defect aspect looks like to

the defect from Fig.1A on the metallographic analysis didn't been observed oxydized zones inside the strip but only surface irregularities. Consequently, we believe the defect has been removed by pickling.

In Fig.1C is presented the C coils surface defect and the position of metallographic specimens cutting.

The un-etched image of superficial defect shows iron oxides disposed under the strip surface at the depths which vary between 10µm and 20µm and defect thickness varies between 10 and 15µm.

The same results has been shown in Fig.5 for the specimen no.2, which is at 3cm distance from the specimen no.1.



Figure 5. Metallographic examination of un-etched specimens (C coil)

In Fig.6 is shown the specimen no.1 from C coil in etched condition. It can be observed that the defect is discontinuous and some regions of it are connected to the surface.

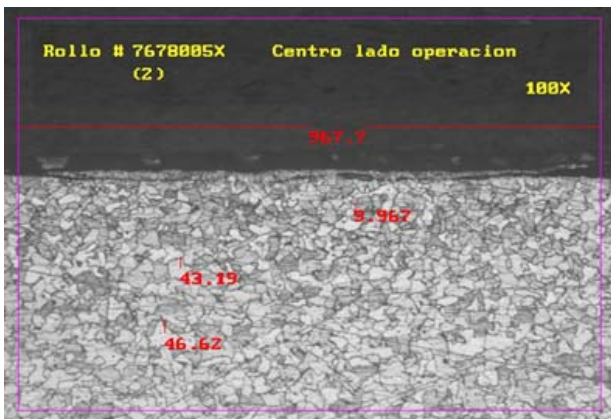


Figure 6. Metallographic examination of etched specimens (C coil; x100)

In Fig.7 the same defect area as in Fig.6 are presented at higher magnification.

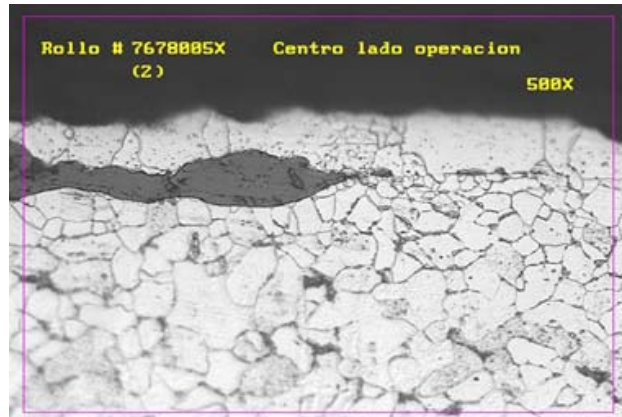


Figure 7. Metallographic examination of etched specimens (C coil; x500)

In these figure (Fig.7) can be observed a light decarburization, but only along of a one grain size depth. In Fig.1D is shown the defect on the surface of D coil and the position for cutting of metallographic specimen. From Fig.8 can be observed that the defect is similar to the previous presented and consisting of rows of iron oxides along the strip surface and at a depth of 30-40µm.

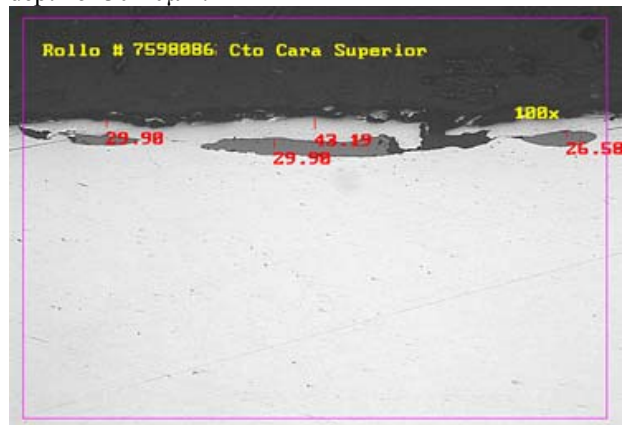


Figure 8. Metallographic examination of un-etched specimens (D coil)

The defect thickness varies between 20 and 36µm.

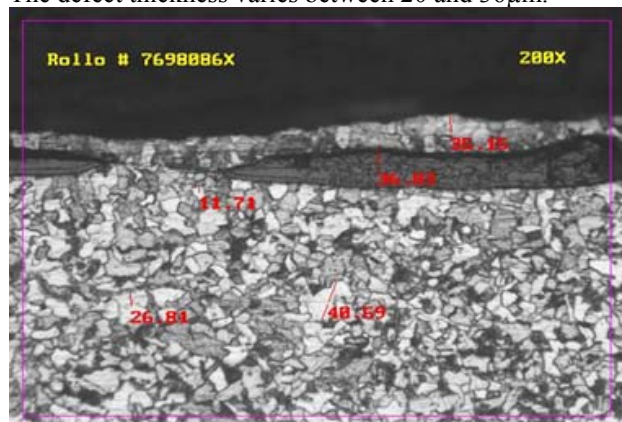


Figure 9. Metallographic examination of etched specimens (D coil; x100)

In Fig.9 is shown the etched image of the specimen and can be observed the grain size variation across

the thickness and the absence of decarburization along the iron oxides from the surface.

In Fig.10 is shown the defect zone at x500 magnification and can be observed the decarburized zone over the defect.

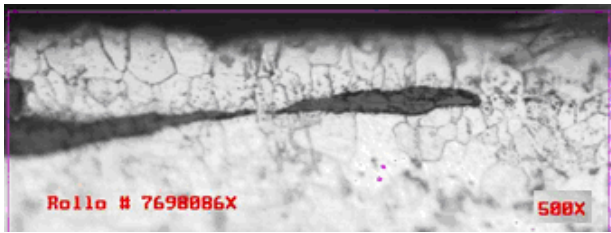


Figure 10. Metallographic examination of etched specimens (D coil; x500)

Metallographic examination at the same magnification performed over another zone of the specimen far away from the defect is shown a decarburized zone with the same depth as in Fig.10.

In Fig.1E is shown the E coil surface defect. From the sample presented in this figure has been cut a metallographic specimen, cross to the defect, at 5cm from the defect tip.

In Fig. 11 is presented the un-etched image of the strip cross section in the defect zone and can be observed that under the strip surface there are rows of iron oxides which thickness varies between 10 to 17 μ m and they are at 16-27 μ m under the strip surface.

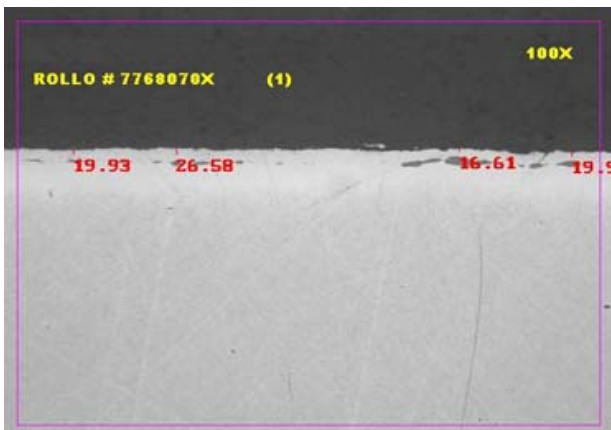


Figure 11. Metallographic examination of un-etched specimens (E coil)

In Fig.12 is shown the etched image of the cross section through the strip in the defect zone and can be observed the fine granulation of this strip, 10-11.



Figure 12. Metallographic examination of etched specimens (E coil; x100)

In Fig.13 the same zone as from the Fig.12 is observed at higher magnification (x500).

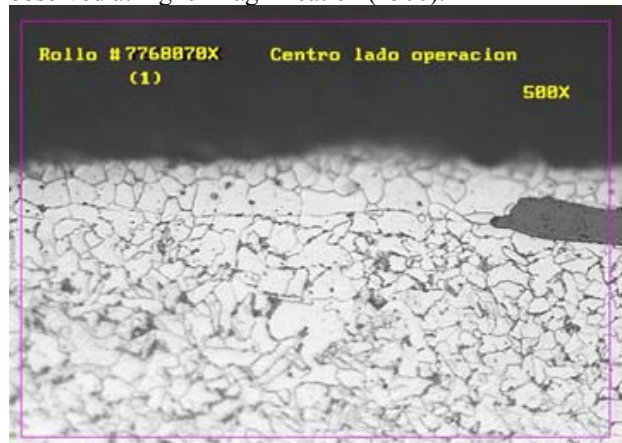


Figure 13. Metallographic examination of etched specimens (D coil; x500)

At this magnification can be observed that the iron oxides are connected to the surface by very fine cracks, which cross the grains, parallel to the specimen surface. Over this crack is observed a light decarburization.

3. CONCLUSIONS:

The metallographic analysis of 5 samples from 5 different coils showed clear defect evidences into 4 samples.

The sample from the coil B has no defect, no matter the surface aspect incriminated its presence. Surface roughness variation may explain the surface aspect. Probably, the defect has been removed by pickling.

In all 4 samples with defects, rows consisting of iron oxides, deformed in the rolling direction, (whose depth beneath the surface varies between 10 and 40 μ m) have been found. The average oxides depth, for each analyzed strip, was 20 μ m . The oxides thickness varies between 10 to 40 μ m.

The presence of iron oxide clearly indicates that no other inclusions of any kind are defect connected.

Even the macroscopic aspect of the defects on one coil to another is quite different, the source of iron oxide should be connected with slab preexisting defect subjected to furnace atmosphere during slab reheating and less probable to a defect induced into slab surface during rolling and oxidation occurring in the same process, because the defect position across the width is different for one coil to another.

The decarburization is not connected to the defect presence, being observed also in another surface zones, far from the defect and the presence of decarburized areas on the strip surface, even in the slivers zones, is a supplementary argument for the preexistence of defects during the rolling process.

4. REFERENCES:

- [1].P. Za'humensky', M. Merwin, "Evolution of artificial defects from slab to rolled products", Journal of materials processing technology 196 (2008) 266–278.
- [2].Weihua Sun, A.K. Tieu, Zhengyi Jiang, Cheng Lu, "High temperature oxide scale characteristics of low carbon steel in hot rolling", Journal of Materials Processing Technology 155–156 (2004) 1307–1312.
- [3]. Zhang Li-feng, "Inclusion and Bubble in Steel- A Review", Journal, of Iron and Steel Research, International, 3 (3) (2006), 01-08.
- [4].Hiroshi Utsunomiya, Shoichi Doi, Ken-ichiro Hara, Tetsuo Sakai, Shusuke Yanagi, " Deformation of oxide scale on steel surface during hot rolling", CIRP Annals - Manufacturing Technology 58 (2009) 271–274