MINIMIZATION OF SURFACE DEFECTS ON BARS AND WIRE ROD ORIGINATED IN BILLET CASTING(1)

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ABSTRACT

In order to minimise surface defects in long products, their origin needs to be assessed. To this purpose, a methodology was developed, that includes metallographic studies on bar and wire rod using several reagents. A description is made of the different steps involved in this method, including the use of etchants to determine the former position of the defect in the billet, oxygen penetration, etc. It is also discussed the interpretation given to internal oxidation, scale inside the defect, decarburisation, partial welding and other metallographic features.

A discussion of pin holes and transverse cracks on billets is made, taking into account its aspect and metallographic features on the billet, the evolution during reheating and rolling and the final aspect and metallographic features on the bar/wire rod.

Root causes for formation of these defects and solutions recommended are analysed for each case.

The paper is based on experience made by IAS Technical Centre while troubleshooting defect problems in carbon steel long products at South American steel plants.

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1. INTRODUCTION

Casting of carbon steel billets for commercial products usually implies silicon and manganese deoxidation, and is mostly carried out with metering nozzle and oil lubrication. Under these conditions, surface defects are often detected in the rolled products.

So, finding the origin of defects in the as-rolled products is helpful in keeping control of casting conditions. A methodology to reach this aim was developed at IAS along the time, as troubleshooting work for several plants was carried out.

2. METHODOLOGY TO DETERMINE THE ORIGIN OF DEFECTS

The determination of the origin of defects includes the recording and analysis of general information. It is important to know the frequency of the defect, position in the same corner or face of the billet, position in the bar or wire rod (in one or some longitudinal lines), dependence on steel grade, etc.

It is also relevant an exhaustive study of the general appearance of the defect by naked eye or with magnifying glass. After that, the observation of polished samples, generally transverse cuts, of the rolled product or the billet, and the microscopic study at higher magnification, etching with different reagents, give insight into defect features.
The information of the continuous casting and rolling processes is necessary and can give relevant data. Some times it could be important to design the follow-up of heats in the meltshop or/and rolling mill process. This general criteria is summarised in table I.

Tasks	Information
General information Microscopic study	frequency, position, in one of the strands or in one of the faces of the billet, position in the bar or wire rod (in one or some longitudinal lines), influence of some steel grades, etc. with naked eye or helped with magnifying glass; polished samples observation, in general transverse cuts from rolled products, and etching with different reagents.
Process information	routine data from the meltshop or rolling mill
Own background and public literature	search for similar defects in own reports and from other plants
Heats follow-up	in the meltshop and the rolling mill
Physical or mathematical simulation	generally it has only academic interest or for preventing the problem from repetition in the future

Table I. Methodology for determination of the origin of defects.

3. METALLOGRAPHICAL OBSERVATION

The metallographic observation of polished samples gives key information when the origin of a defect needs to be determined. Often, it is not possible to find out the origin of a defect with just the observation of a transverse cut in the light microscope, without an idea of the general aspect of the defect.

In table II different techniques for the study of defects, and information that can be taken from them, regarding to the origin of defects are mentioned. These techniques, and the information that can be extracted by using them, have been discussed in detail in a previous paper [1].

Observation type	Information obtained
With naked eye or with magnifying glass	Morphology, position, frequency
As polished	Position, penetration, direction, internal oxidation, partial welding, scale, inclusions, strange material
Nital etching	Decarburisation, banded structure, grain growth, segregation, transformation structures, material flow lines
Oberhoffer´s etching	Segregation, solidification structure, location of billet corner, midway cracks, deformation flow pattern
Alkaline sodic chromate etching	Oxygen penetration
Béchet – Beaujard´s etching	Hook formation, solidification structure
SEM observation and EDS analysis	Doubts about scale, macroinclusions origin, strange materials.

Table II. Techniques for the study of defects, and information they give regarding origin.

4. PINHOLES

Pinholing is observed often for semi-killed steels cast with oil. It can give place to defects in the final product if there is an important number in a small area or if they penetrate deep in the billet.

4.1 Appearance in the billet. Figure 1 shows pinholes on billet surface after sand blasting. In this particular case, pinholes are distributed as transverse clouds, forming a belt of pinholes, on all faces, repeating each 10 cm along the billet.

Figura 1. Aspect of pinholes on the surface of a billet cast with oil, after sand blasting. Distribution in transverse "belts" along the billet.

Under light microscope, pinholes have a characteristic look, showing development of scale and a certain degree of decarburisation in the metal matrix around the defect (figure 2). This is an important difference with blowholes. Usually, the scale layer impedes welding of the defect during rolling.

4.2 Aspect during rolling. Most pinholes disappear during reheating due to scale formation. But the deeper pinholes are yet observed with naked eye on the billet, after reheating, when for any reason the billet is not rolled (figure 3) [2]. In this case they are completely filled with scale (figure 4).

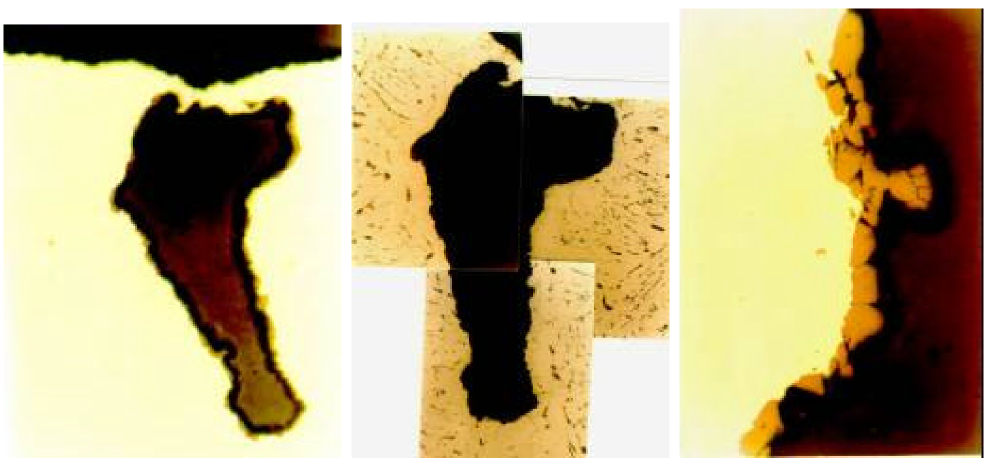

Figure 2. Aspect of a pinhole in a polished sample taken out of a low carbon billet, under the light microscope. Left: no etching. Centre: Nital 1%; some decarburisation is observed around the pinhole. Right: no etching; detail of the scale in the interior of the pinhole.

Figura 3. Aspect of pinholes remaining on the surface of a 150 x 150 mm medium carbon billet after reheating and cooling without rolling [2].

During rolling, remaining pinholes are elongated in the rolling direction (figure 5). Depending on reduction ratio and particular features, they look as a small longitudinal defect in the product or eventually disappear, at least under naked eye.

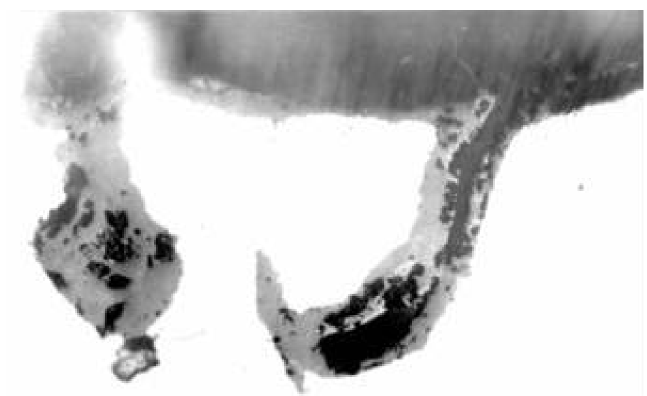

Figura 4. Aspect of pinholes after reheating of the billet. Scale fills almost completely the void (compare with figure 2, before reheating. Light microscope, no etching.

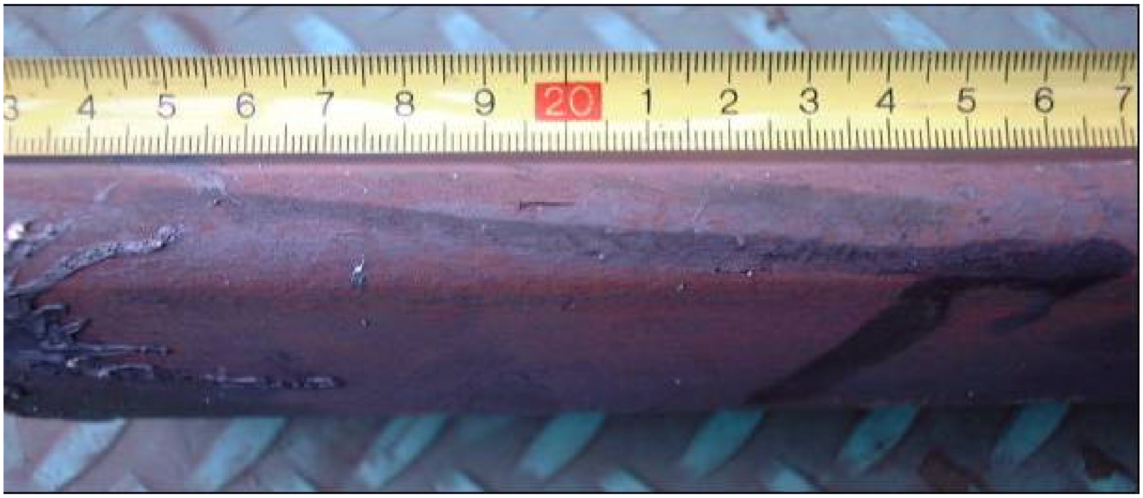

Figure 5. Evolution of a pinhole during rolling. Bar cut due to a cobble during rolling of rebar.

Finally, on transverse polished specimens of bar or wire rod, the pinholes are usually thicker in the inner part than near the surface (figure 6). The opposite situation is observed for defects originated in billet cracks. Other usual features are decarburisation and internal oxidation, also observed in figure 6.

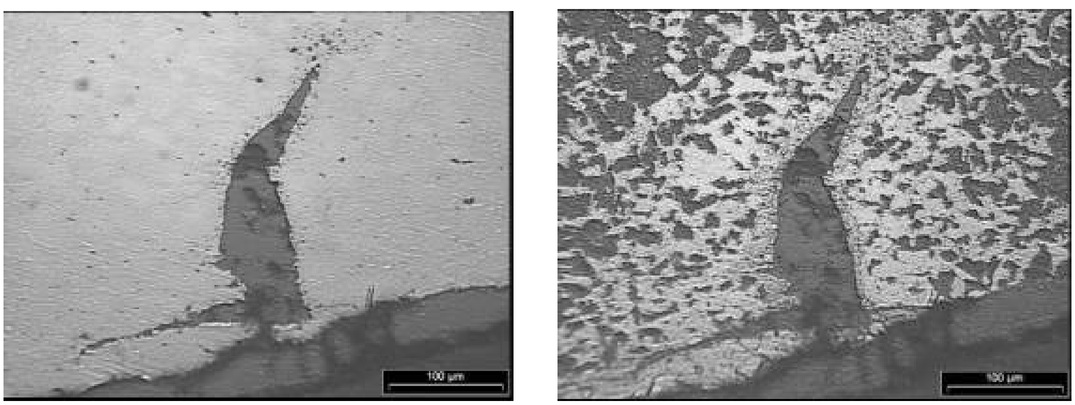

Figure 6. Aspect in light microscope of a pinhole related defect in rebar. Thickness larger in the inner part than in the surface. Left: no etching; internal oxidation is observed. Right: Nital 2%; strong decarburisation is present.

4.3 Causes and solutions. Formation of pinholes is mostly related to evolution of gases resulting from oil decomposition during casting and can be enhanced by high oxygen activity in the liquid steel.

Normal figures for lubrication rate are 20 to 30 ml/min, depending on oil properties, billet size and casting speed [3]. To minimise pinhole formation it is important not only to check if lubrication rate is within the usual range, but to verify if the oil distribution in the transverse section is homogeneous.

Good oil distribution is favoured by thin slots, and by the use of a gasket to avoid excessive lubrication in the corners [4]. Sometimes the inhomogeneity is so large that pinholes are seen in some face or region, and at the same time double skin is observed, in another face or region, revealing lack of oil (figure 7).

If pinholes are present in the billet, long residence time and high temperature during reheating can worsen the problem in the final product.

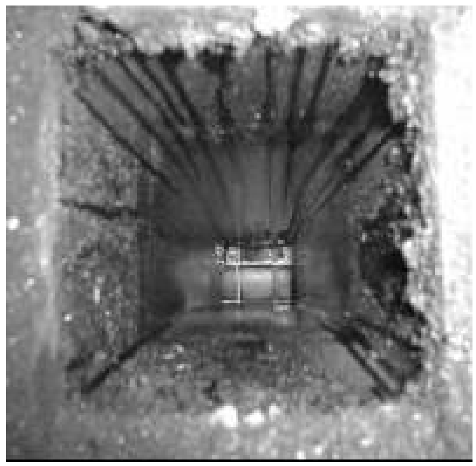

Figure 7. Cold test of oil distribution. The unbalanced distribution gives place to pinholing in overlubricated faces and double skin poorly lubricated faces at the same time [2].

5. TRANSVERSE CRACKS

Transverse cracks, although not always detected in the inspection of billets, give place to serious defects in the rolled product.

5.1 Aspect in the billet. Figure 8 shows the aspect of a transverse crack in a sand-blasted billet [2]. Figure 9 displays a detail of a transverse crack on a polished sample, in the light microscope. Close to the surface, the crack looks as if it has been formed at high temperature, probably in the mould. But the deeper part of the crack has intergranular appearance, so it was cold-formed, probably during strengthening, by propagation of the former hot crack.

Figura 8. Aspect of transverse crack on sand-blasted billet [2].

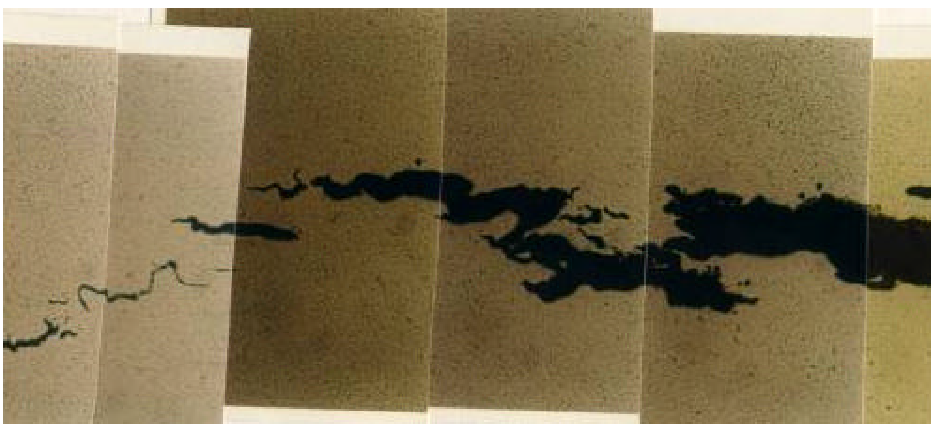

Figure 9. Detail of a transverse crack in the light microscope, after Oberhoffer etching.

5.2 Aspect during rolling. Transverse cracks during rolling gave place to V defects (figure 10, left). In a transverse cut, they display a change in direction (figure 10, right). For high reduction ratios, the defect continues to deform till look like a longitudinal defect (figure 11).

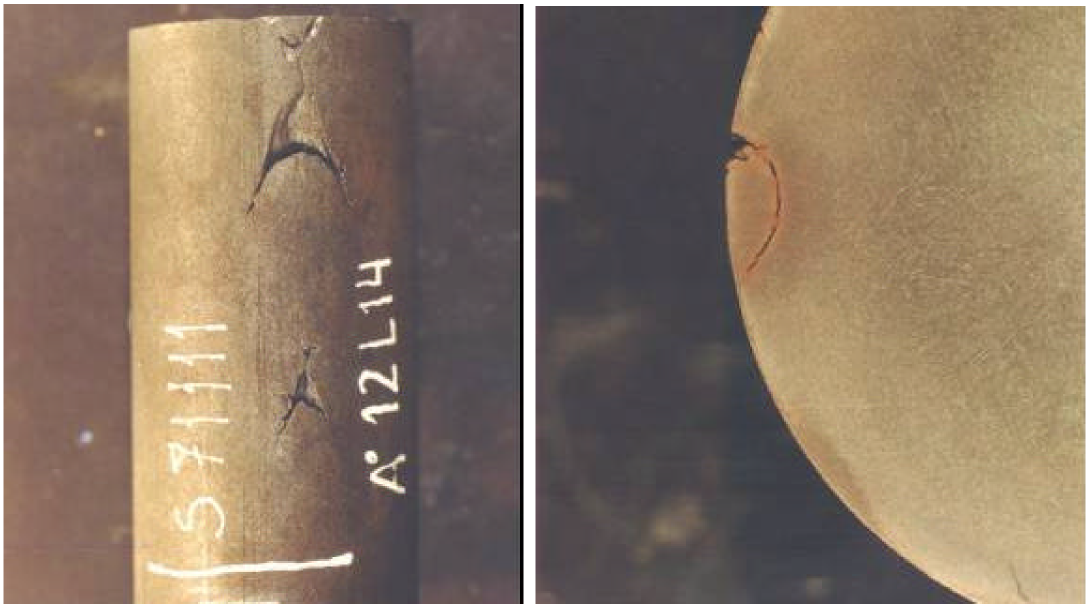

Figure 10. Evolution of a transverse crack during rolling, forming V defect. Left: aspect of a low C bar. Right: transverse crack of the same bar, after etching.

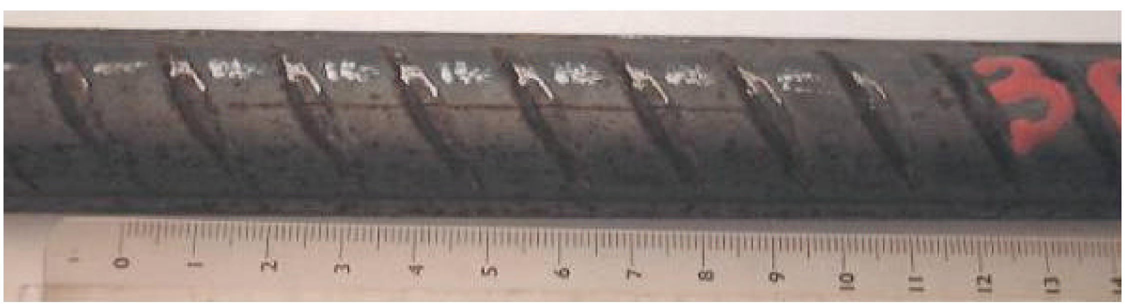

Figure 11. Transverse crack-related defect in rebar [2].

5.3 Causes and solutions. Transverse cracks can form in the mould or during strengthening. When they are located in any corner, they are likely to be formed due to tensile efforts related to sticking [5]. This can be worsened by deep oscillation marks.

When cracks are present only in the corner belonging to the inner radius, they could be formed by tensile efforts during strengthening. This is common when corner temperature is within the low ductility range [5].

A sound approach to solve the problem is to determine the ductility curve of the corresponding steel grade for the conditions prevailing in the caster. At IAS this is made with the help of a hot torsion test machine. Then, with temperature measurements or by using a validated solidification/heat transfer model, the

secondary cooling can be set to avoid the dangerous temperature range in the corners during strengthening.

6. CONCLUSIONS

A methodology to study defects in carbon steel long products was developed at the Instituto Argentino de Siderurgia, while trubleshooting defect problems for the iron and steel industry in Argentina and Latin America.

For the study of defects many lab techniques were developed, that allow to have different tools when the step where the defect was originated is to be determined. This way, it is much easier to take action in the plant in order to minimise a given defect.

This is exemplified with two defects commonly encountered when billets are cast with oil lubrication: transverse cracks and pinholes.

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