REDUCING THE WARPING EFFECT OF HOT ROLLED SAE15B29 FLAT BARS*

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Abstract

Boron steel is used in the industry due to its great wear and impact resistance. During the hot rolling production of 15B29 steel flat bars it is a recurrent problem that the bars will present warping while on the cooling bed. Control this phenomenon is an opportunity to have better productivity, preventing metallic losses. Through the observation of the macro and microstructure samples produced with different reheating temperatures and cooling rates, it was found the presence of residual stresses and cracks on warped bars macrostructure. The residual stresses appearance suggest that the material cooling is too fast. Billets temperature on the reheating furnace of 1230°C reduced to 1100°C and the production pace slowed down. Bars temperature when arriving the cooling bed was reduced from higher than 670°C to 625°C. The results obtained made it possible to produce the material with better quality, reducing the warping effect at the cooling bed. The major influence on the materials warping was identified as the cooling rate at the cooling bed and the reheating furnace temperature was adjusted to provide a homogeneous temperature along the bars.

Keywords: SAE 15B29; Warping; Flat bars; Cooling Rate; Residual Stresses; Hot Rolling.

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1 INTRODUCTION

In the hot rolling process, a hot metal stock is passed through a series of pairs of rolls that conform the material to a different shape.

The hot rolling mill in Gerdau Riograndense need to reheat the billets before continuing the rolling process, the rolling mill can use up to 14 stands and the first roughing stand is trio. The reheating furnace is a walking beam furnace and has two zones, the heating and the soaking zone, where the main goal is to heat the material in a homogeneous way. After rolled the material goes to a moving rake cooling bed where the material arrives with a temperature between around 600ºC and 800ºC and needs to be cooled down to the finishing end working temperature that is around 100ºC.

After the rolling process the material can present a series of defects induced by the process. One of these defects is the warping that affect bars during the cooling process in the cooling bed. When the bars present warp in the cooling bed they start to get stuck in the cooling bed components and it starts to slow the production pace, since it needs interference.

The main goal of this paper is to find the production parameters that can be related to the warping effect in SAE15B29 flat bars.

Usually the warp in steel bars can be related to the microstructural changes, steel's chemical composition, change of temperature along the section or residual stresses.

2 MATERIAL AND METHODS

According to Souza [1] one of the main causes of the warping effect in the cooling bed is the presence of airflow directed in the hot material. One of the ways to overcome the warp is to install a cover in the cooling bed forcing the material to cool down slower, also gray cast iron parts can be used in the first section of the cooling bed.

The main tool used in the monitoring of the rolling process parameters was the IBA software, that acquires data from every sensor installed in the rolling mill. As one of the major influences of the warping defect could be the uneven soaking of the billets in the reheating furnace, the heating zones temperature was acquired and its results were checked to see if there were sudden changes in the temperature. Also, the material rolling temperature in the third trio pass was acquired.

An infrared pyrometer (Fluke 62MAX) was used in the cooling bed monitoring to check the bars temperature when arriving in the rakes.

As the main cause of the warp defect is possibly related to the material temperature and cooling rate, it was decided to reduce the reheating temperature. To decrease the cooling rate in the cooling bed a curtain, as seen in the Figure 1, was installed in the cooling bed side to minimize the wind crossflow over the material.

Figure 1 Curtains installed in the cooling bed.

To realize the material microstructural analysis samples were taken from SAE 15B29 flat steel bars (60 mm x 8 mm section). The samples for the microstructure evaluation were taken from the same bar, taking pieces from the warped and straight parts of the bars after passing through the cooling bed as seen in the Figure 2.

Figure 2 – Sample piece of a flat bar.

After realizing the microstructural analysis and the process parameters changes in the processes the results obtained were compared.

3 RESULTS AND DISCUSSION

3.1 Parameter test results

The first production test was made using the usual reheating furnace temperature parameters, used in the rolling mill to produce steel flat bars, that can be seen in the Table 1.

Table 1. Reheating Furnace Temperature

Parameter	Zone 1	Zone 2	Trio
Temperature	1230ºC	1200ºC	1180ºC

After reaching the cooling process with a temperature around 670ºC the material started to warp and the bars tip started to get stuck in the moving rakes, delaying the production process, as it can be seen in the Figure 3 and Figure 4.

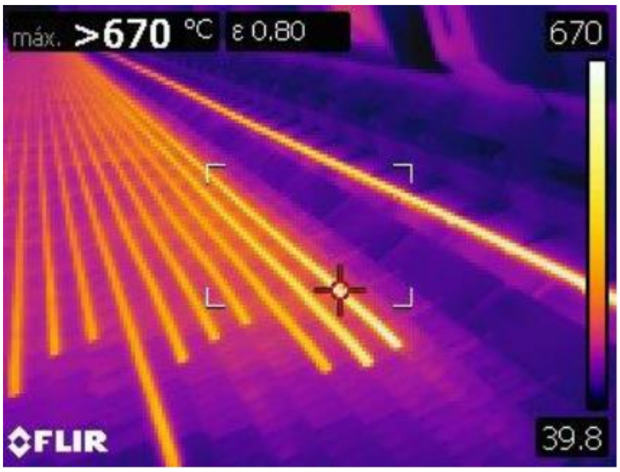

Figure 3. Temperature of the bars arriving the cooling bed.

Figure 4 Warped bars in the cooling bed

Probably the causes of this warps can be related to the rolling temperature be too high, forcing the material to have a higher cooling rate that induces tensions in the material making it present the defects.

A test was performed reducing the reheating temperatures with the third trio stand pass being around 1100ºC. After reaching the cooling bed the bars presented a better aspect when compared to the first test that used higher temperatures in the furnace. The material can be seen in the Figure 5.

Figure 5 Bars in the cooling bed with the new parameters.

The parameters used were admitted as the new standard due to the material's great aspect when in the cooling bed. The new cooling rate was measured using the infrared pyrometer measuring the temperature every ten seconds during the first minute. Figure 6 shows the results of the temperature measures.

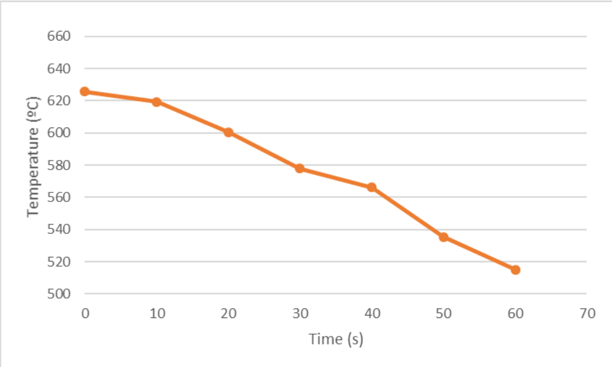

Figure 6 Bars temperature while cooling.

The bars temperature arriving the cooling bed decreased around 45ºC and the medium cooling rate measured was of 1,8 ºC/s. As it is not possible to detect warp in the bars when using this cooling rate the changes made to the processes were considered efficient.

Also, to ensure that the process parameters were effective the crew responsible for the reheating furnace control was trained to maintain the set temperature steady. It can be seen in the Figure 7 and in the Figure 8 the temperature data acquired before and after the crew qualification.

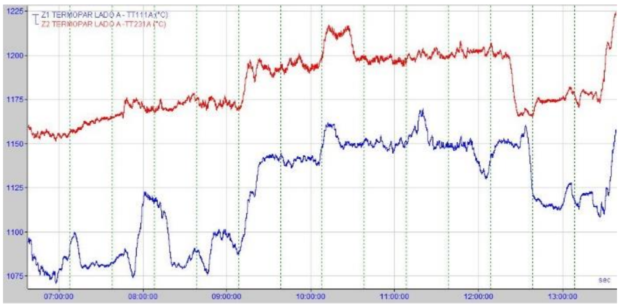

Figure 7 Reheating temperature before training.

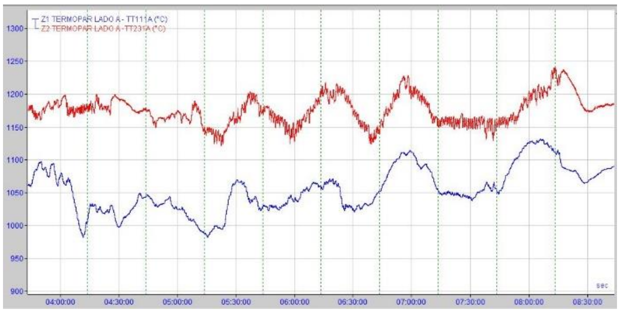

Figure 8 Reheating temperature after qualification.

3.2 Chemical analysis

As one of the possible causes of the warp is changes in the steel chemical composition three chemical composition analysis were made, using an optical emission spectrometer, on the extremities of the bar in warped and straight parts. The results can be observed in the Table 2 and Table 3.

Table 2. Chemical analysis of the straight sample.

Point	**C**	**Mn**	**Si**	**P**	**S**	**Al**
1	0,322	1,357	0,226	0,020	0,007	0,040
2	0,313	1,358	0,226	0,020	0,007	0,040
3	0,314	1,354	0,224	0,019	0,007	0,041
Mean	**0,32**	**1,36**	**0,22**	**0,020**	**0,007**	**0,040**
Point	**Cr**	**Ti**	**B(ppm)**	**Cu**	**Ni**	**Mo**
1	0,249	0,032	27,2	0,013	0,015	0,002
2	0,249	0,032	21,9	0,013	0,015	0,002
3	0,248	0,032	24	0,012	0,014	0,002
Mean	**0,25**	**0,032**	**24,4**	**0,013**	**0,015**	**0,002**

Table 3. Chemical analysis of the warped sample.

Point	**C**	**Mn**	**Si**	**P**	**S**	**Al**
1	0,319	1,378	0,255	0,006	0,002	0,054
2	0,256	1,329	0,220	0,020	0,008	0,041
3	0,306	1,317	0,219	0,019	0,008	0,041
Mean	**0,29**	**1,34**	**0,23**	**0,015**	**0,006**	**0,045**
Point	**Cr**	**Ti**	**B(ppm)**	**Cu**	**Ni**	**Mo**
1	0,249	0,035	18,9	0,015	0,012	0,001
2	0,244	0,031	13,6	0,011	0,013	0,001
3	0,243	0,030	20	0,011	0,013	0,001
Mean	**0,24**	**0,032**	**17,5**	**0,012**	**0,013**	**0,001**

Through the comparison of the data obtained in the analysis it its possible to see that there is a divergence of the Carbon percentual between the samples. However, it can be pointed that this difference observed in the chemical composition is not enough to change the material mechanical properties.

3.3 Macrostructural analysis

The samples taken from the steel bar were etched using nitric acid and were evaluated in a microscope to compare the warped and non-warped part Oliveira [2]. The Figure 9 and the Figure 10 shows the etched straight sample in two zoom rates.

Figure 9 Etched straight sample. 2,5x zoom.

Figure 10 Etched Straight sample. 6,3x zoom.

In the Figure 11 and Figure 12 we can observe the etched warped sample.

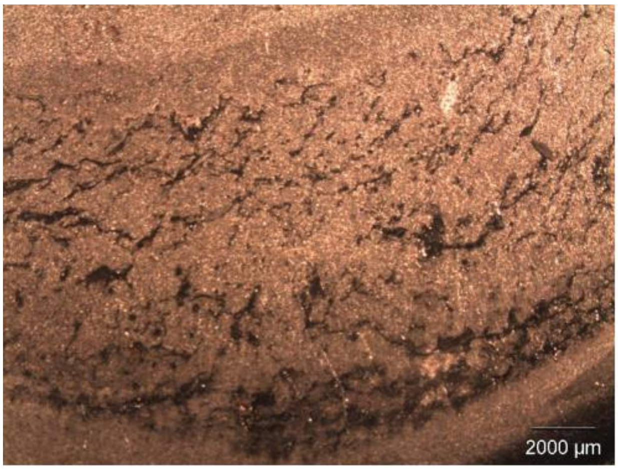

Figure 11 Etched warped sample. 0,7x zoom.

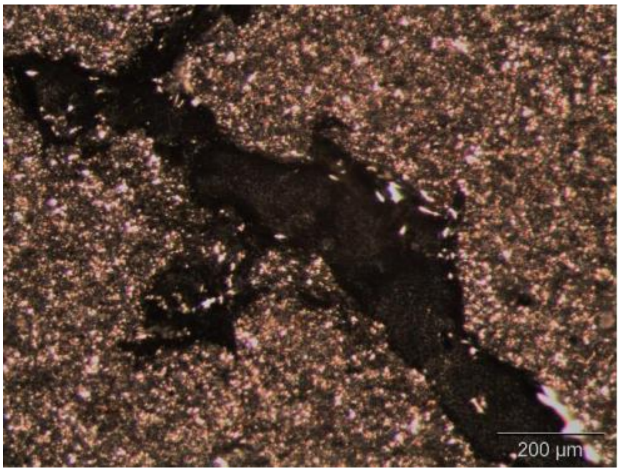

Figure 12 Etched warped sample. 11,5x zoom.

It is possible to see that the warped samples present cracks on the macrostructure. The cracks can be related to the existence of residual stresses in the warped samples and it could be generated as a relief of the stress that could not be eliminated only with the warp effect.

4 CONCLUSION

The analysis and the tests results obtained showed that it is possible to produce SAE15B29 steel flat bars with better productivity. The results show that the reheating furnace temperature must be kept around 1100ºC without being changed and the airflow through the cooling bed must be reduced using for example curtains on the cooling bed sides.

The thermal gradient of the bars in the cooling bed before and after the parameter adjustment made it possible to identify that the material warp is related to the cooling rate. When the cooling rate was reduced to 1,8ºC it was possible to see a significant reduction in the occurrence of warped bars.

Through the macrostructure analysis it was possible to perceive the presence of small cracks in the bars with the defect. This indicates a relief of residual stresses in the material.

Through the chemical composition analysis, it was not possible to show significative differences between the samples. Therefore, the chemical composition probably cannot be the source of the warps.

The new parameter obtaining when trying to improve the process was standardized. As future work there is the need of improving the soaking zone of the reheating furnace to make the temperature more homogeneous along the billets. Also, there is a need of installing definitive curtains in the cooling bed to reduce the airflow.

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