OPTIMIZATION OF ROLLING PARAMETERS FOR THE PRODUCTION OF REBAR *

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Abstract
In mid-2015 the steel industry faced a strong crisis due to the weak performance of the Brazilian economy and the persistent entry of Chinese steel into Brazilian territory. This situation demanded that Brazilian steelmakers seek to develop products to meet new export markets. within the volume of exports possible are the rebars, where its applications are in the construction industry. One of the largest importers is Peru which has a large percentage of this export volume. This market demands as a priority requirement the surface quality of blue condition (low oxidation index) and mechanical properties normative.in order to meet the items required by the customer at a competitive cost, a vanadium microalloyed steel was applied to the hot rolling process without heat treatment after the last rolling pass. Where the great challenge was to achieve a high level of stretching without compromising the minimum limits of tensile strength. Assuming that the steel used is the correct one interventions were made on rolling parameters such as set-point temperature, residence time of pieces in the furnace, linear mass and rolling speed. All the changes made were based on statistical tools and practical tests. Finally, with the execution of actions generated from the statistical analyzes and tests it was possible to reduce process losses by 96%.
Keywords: Rebars;Vanadium Microalloyed Steel;Rolling.

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1 INTRODUCTION

In order to develop new products that meet the market demand, it studied the optimization of rolling parameters for the manufacture of microalloyed rebar to vanadium, in order to solve some problems in achieving the required mechanical properties in standards [1]. These difficulties prevented the high performance during the production of these products. In this work, it was studied parameters that correlate help in the understanding of the behavior of this material during the hot rolling process.
The parameters studied were set-point temperature, residence time of pieces in the furnace, linear mass and rolling speed.
Through this study it was possible to reduce process losses in relation to the non-classification of the material in the requirements that the standard requests, thus guaranteeing a greater profitability and reliability of the process.

2 MATERIAL AND METHODS

For this study, two production periods, each of 3 days, were generated, generating sufficient data for the use of statistical tools to evaluate the behavior of the rolled product.
The study material in question is a rebar 3/8” NTP 341031 produced by hot rolling process and chemical composition (% weight) described in Table 1, according to the composition of a carbon steel SAE 1536 microalloyed to vanadium.

Table 1. Chemical composition of 3/8 "rebar SAE 1536.*[2]*

C	Mn	P	S
0.30 - 0.37%	1.20 - 1.50%	0.04% Max	0.5% Max

In order to evaluate the chemical composition variation, scatterplots were compared with the Tensile Strength with% C and% Mn.

For the parameters of the reheating furnace, interval plot were used analyzing materials that presented low mechanical properties with their discharging temperatures and their residence time inside the reheating furnace.
In addition, it was used the analysis of variables through contour plot to allow a better understanding of the influences of the parameters. The first was the analysis Residence Time x % C x Tensile Strength, the second was Linear Mass x Residence Time x Tensile Strength.
Finally, after some changes made in the parameters, an analysis of the Tensile Strength was performed through the capability process.

3 RESULTS AND DISCUSSION

The influence of the chemical elements such as carbon and manganese on the differences of identified mechanical properties was not statistically relevant to the process, because when performing the linear regression analysis, the obtained R-sq is less than 1% [3] and [4].

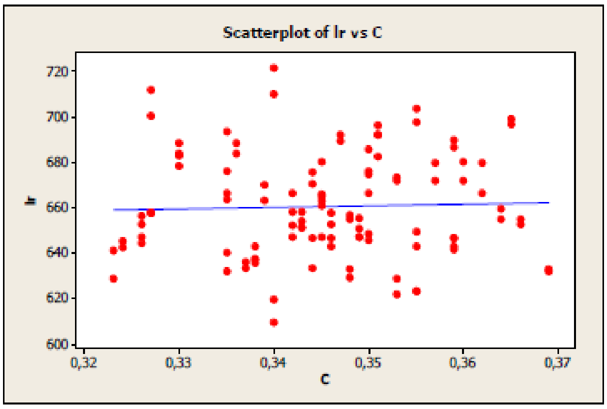

Figure 1. Tensile Strength x % Carbon

In relation to the mean discharging temperature, there is a more evident relationship with the results of Tensile Strength below the specified, but it is not possible to explain the phenomenon only with this parameter, since the average temperature range present in the scrapped productions is quite broad.

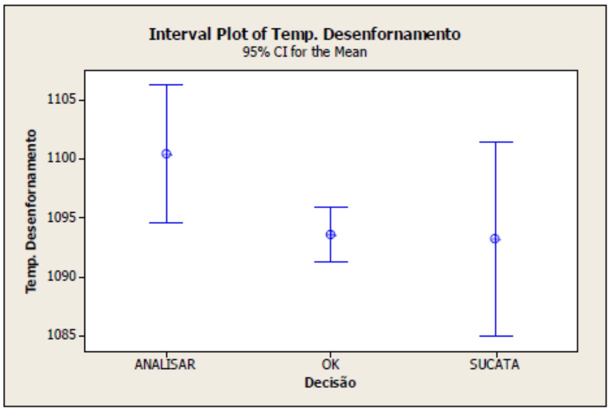

Figure 2. Production Groups x Average Discharging Temperature

In conjunction with the mean discharging temperature, the duration of the production within the Billet Reheating Furnace (BRF) was analyzed, which is related to the interruptions that may exist in the process and consequently increase the residence time of the billets within the BRF. Scrap production and those requiring clearance analysis had very high residence times when compared to production that were immediately released according to product specifications. This over time is the result of interruptions that occurred in the rolling process that were not foreseen and extended for a long time, causing the emission of a large thermal input in the billet that were in the BFR soaking zone, thus modifying the grain size of the microstructure of the steel.

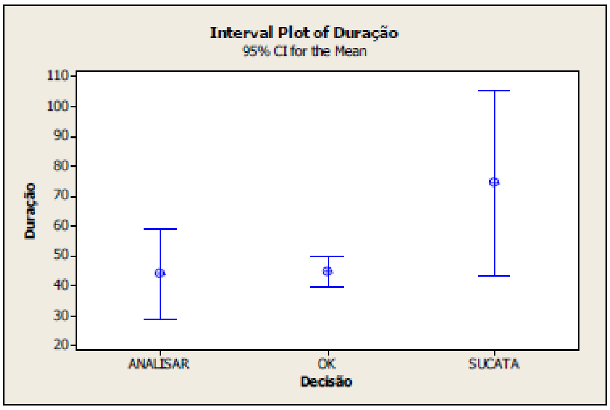

Figure 3. Production Groups x Residence Time

3.1 Multivariate Analysis

With contour plot analysis, it was found that carbon percentages below 0.345% along with rolling duration times greater than 80 minutes, there is a high probability of obtaining below-specified strength limit results.

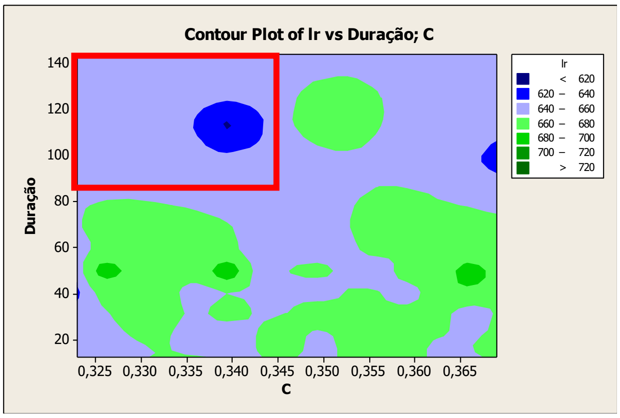

Figure 4. Contour Plot between TS x Rolling Duration x% Carbon

In another multivariate analysis, performed with the parameters of linear mass, Tensile Strength and residence time of the production.
The range with residence time bigger than 80 minutes and linear mass below 0.538 kg/m concentrated the productions with lower Tensile Strength obtained in the rolling process.

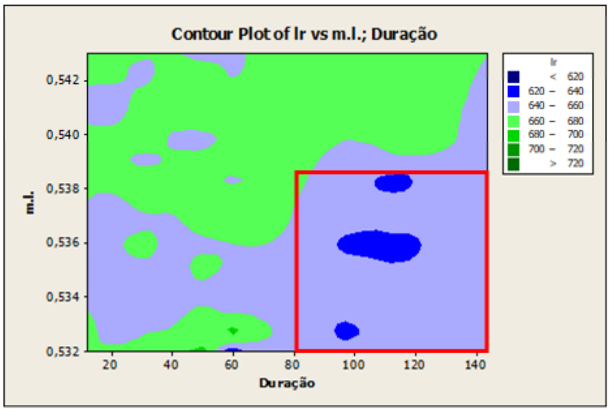

Figure 5. Contour Plot between TS x Rolling Duration x Linear Mass

3.2 Validation

With actions taken based on the results described above, the behaviors of the lots obtained better mechanical properties, where it was possible to observe an average displacement of 14 MPa for more, with practically the same standard

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deviation of the 1st campaign. With this, the results of mechanical properties improved by 60% in the observed process.

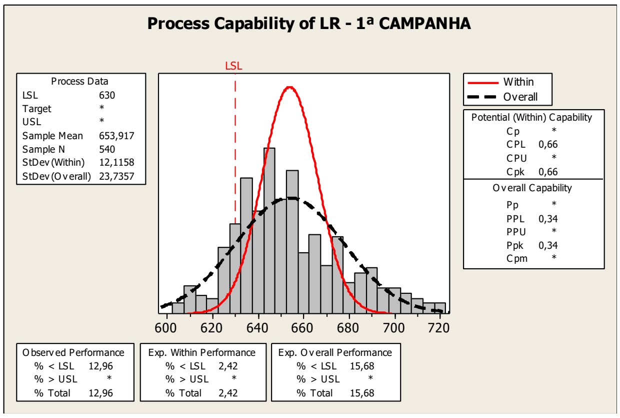

Figure 6. Process Capability TS (1st Campaign)

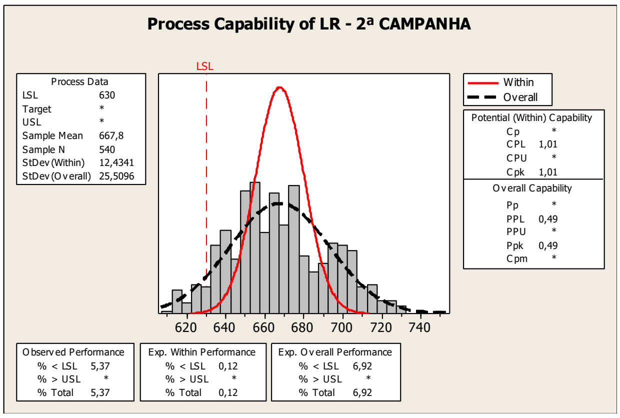

Figure 7. Process Capability TS (2nd Campaign)

4 CONCLUSION

In conclusion, in relation to the properties of yield limit and elongation, the process was able, with some opportunities referring to the Tensile Strength.

Productions with carbon below 0.34% along with rolling times above 80 minutes due to interruptions, tend to get low Tensile Strength. The fact that the production spent more time inside the Reheating Furnace causes an increase in grain size, especially in the billets that was in the furnace soaking zone (30 first billets).

Due to the use of theoretical rebar area for calculation of flow and Tensile Strength, lower linear masses have lower YS and TS (variable force divided by a fixed area).

Statistically, the minimum value to reach the TS of the Product Specification is 0.538 kg/m.

In addition, the internal pressure of the Reheating Furnace greater than 0.5 mmH2O influences the increase of grain size, since it conserves greater thermal energy inside the same and contributes to the kinetics of grain increase.

Finally, the high number of interruptions in a rolling mill causes negative consequences at various points in the process and the quality of the material is totally linked with this, since it depends on the control of parameters such as: Output temperature, rolling speed, BRF internal pressure, among others.

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REFERENCES

1 Karmakar, A., Mandal, A., Mukherjee, S., Kundu, S., Srivastava, D., Mitra, R., Chakrabarti, D. Effect of isothermal holding temperature on the precipitation hardening in Vanadium-microalloyed steels with varying carbon and nitrogen levels. Metall. Mater. Trans, 2008.

2 Associação Brasileira de Normas Técnicas. ABNT NBR NM 87:2000 - Aço carbono e ligados para construção mecânica - Designação e composição química. Especificação: Rio de Janeiro, 2000.

3 R.L. Manson, R.F. Gunst, J.L. Hess. Statistical Design and Analysis of Experiments: with applications do Engineering and Science, John Wiley & Sons, 1989.

4 Fundamentos do Controle Estatístico do Processo – Manual de Referência, IQA.