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DETERMINATION OF THE MICROSTRUCTURAL EVOLUTION DURING THE BATCH ANNEALING OF MICROALLOYED STEEL COILS

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- INTRODUCTION

The determination of the microstructural evolution of coiled cold-rolled sheet during the batch annealing can provide vital data to correct specification of the industrial process parameters, allowing thus the reduction of its cost and assuring good quality and consistent properties to the final product. Such study, however, must take place under laboratory scale, to certify the precision of the treatment parameters and to avoid the considerable disturbance that would occur if the experiences were developed at the plant.

The annealing of microalloyed steels has some particular aspects, as Nb alters the process of austenitic and ferritic recovery and recrystallization. This element retards steel recovery and recrystallization, increasing the incubation time necessary for the nucleation of the ferritic grains, as well its growing rate. Niobium retards recrystallization either in solid solution as in the precipitated form[1].

Another feature that affects restoration kinetics is the heating rate. An increase on this parameter rises the recrystallization temperature of the steel, irrespective of its Nb content of coiling temperature[2].

- EXPERIMENTAL PROCEDURE

The steel selected for this study had the following chemical composition: 0.07% C, 0.65% Mn, 0.044% Nb, 0.079% N and 0.058% Al_t. The samples were extracted from a hot rolled strip submitted to a finish temperature of $870 \pm 20^{o}C$ and a coiling temperature of $600 \pm 20^{o}C$.

The annealing treatment applied to this material was similar to the industrial process at COSIPA. It was performed on a furnace coupled to an IBM-XT microcomputer. The evolution of the temperatures of the samples in relation with time was controlled through a BASIC program. The samples were placed into the furnace at room temperature, protected against oxidation and submitted to the annealing treatment. Samples were periodically taken during the heating and water quenched. An additional sample was furnace cooled after the treatment. All the temperature data from the furnace and samples were collected during the test and stored in floppy disks for subsequent data analysis.

The treated samples were submitted to quantitative optical metallographic analysis. The grain size, recrystallized fraction and Vickers hardness of the samples were determined. Precipitates were extracted through acid dissolution and analysed using X-ray diffraction. Some samples were observed at the Transmission Electronic Microscope to check the beginning of recovery/recrystallization processes during the simulated cycle.

- RESULTS AND DISCUSSION

The precipitate present in the microstructure after annealing was identifyed as Nb C. The metallographic analysis indicated that there was a competition between carbonitride precipitation and recovery until the 17^{th} hour of treatment, that is, 610°C. Beyond this point the recrystallization was activated, causing a large decrease in hardness, as can be seen in figure 1.

Although the applied treatment was anisothermal, the recrystallization kinetics could be expressed as an Avrami-like equation, as suggested by the shape of the curve recrystallized fraction versys time, as can be seen in figure 2:

$$f_r = 1 - \exp(0.0057\ t^{2.96}) \qquad r^2 = 0.95 \qquad (1)$$

Grain growth took place after the 25^{th} hour of treatment, at 660°C, and followed an asymptotic relation with time, as can be seen from figure 3:

$$G.S.\ [\quad] = 4.197\ t^{0.087} \qquad r^2 = 0.95 \qquad (2)$$

$$G.S.\ [\quad] = 5.712 - 1.438 \times 0.916^t \qquad r^2 = 0.97 \qquad (3)$$

Finally, it was verifyed that the cooling time of the coils after the annealing treatment can be reduced from 54 to 8 hours without alteration on its hardness.

- CONCLUSIONS

- The proposed method for the physical simulation of box annealing of steel coils with a microcomputer controlled laboratory furnace gave good results: it was achieved through this method samples with similar microstructures and hardness in relation to the coils processed at the plant;

- It was observed a competition between carbonitride precipitation and the recovery processes up to the 17th hour of treatment, when the temperature was 610ºC. After that recrystallization took place till the 25th hour of treatment, when grain growth processes began;

- The evolution of the recrystalized fraction and grain size with time showed a good agreement with the statistical regressions proposed;

- The time of cooling of the coils after the industrial box annealing can be decreased from 54 to 8 hours without changes on its hardness.

- REFERENCES

1) GALVEN, J.A. et alii. Scandinavian Journal of Metallurgy, 1975, 250-254.

2) GLADMAN, T. et alii. Journal of the Iron and Steel Institute, May 1971, 380-390.

- FIGURES

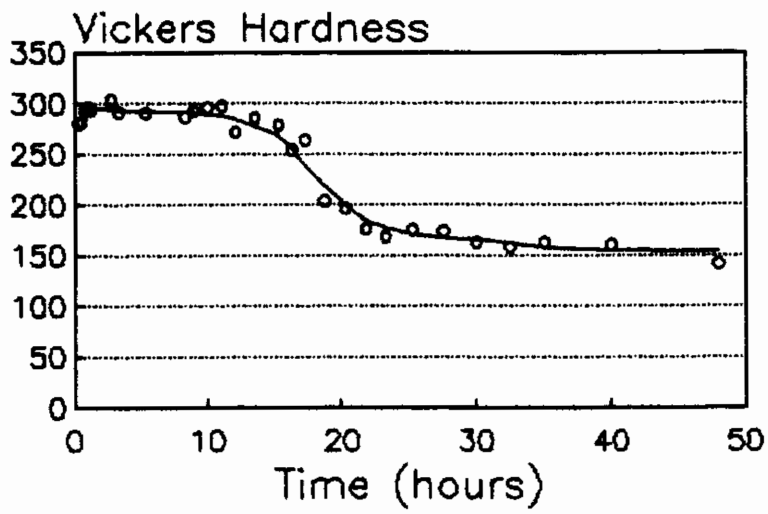

Fig. 1: Hardness variation during the annealing treatment.

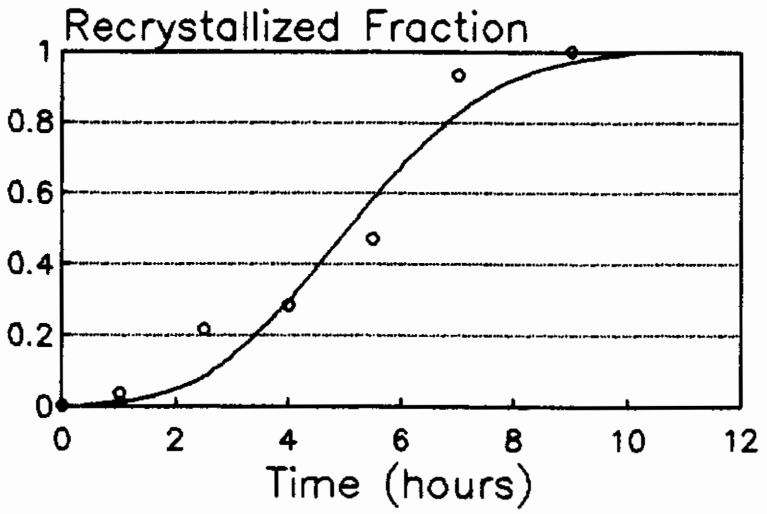

Fig. 2: Evolution of the recrystallized fraction in relation with time after the beginning of recrystallization.

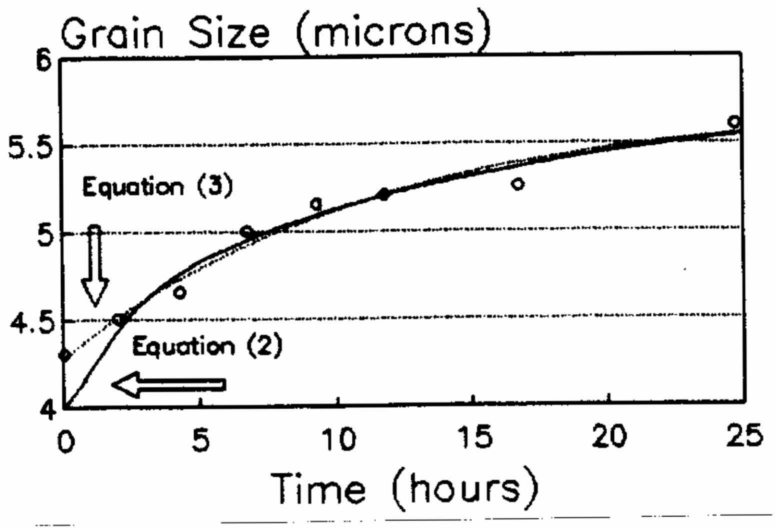

Fig. 3: Evolution of the ferritic grain size after complete recrystallization.