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EFFECT OF PROCESS PARAMETERS ON NATURAL AGING IN A 1004 STEEL

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The effects of natural aging on the tensile strength, R_m, in a rod of 1004 steel were studied. Natural aging was performed at 298 K over a period of 126 h and values were recorded at different intervals. Electron microscopy observations showed just dissolution of perlite phase for the base metal and heat affected zone. The largest R_m value was obtained after 123 h, due to maximum aging, nitrogen and boron contents were found to be the most important elements in this research. The results indicate that, low velocity and high nitrogen concentration reduce, R_m, as heat treatment time and nitrogen increase solubility of nitrogen increases.

Keywords: steel, natural aging, tensile strength, nitrogen diffusion

INTRODUCTION

The ductility requirements for reinforcing steels used in different applications are not significantly more demanding. Sufficient ductility after yielding to enable the steel to keep its mechanical properties for subsequent process is necessary [1]. Although this ductility requirement is generally adequately provided for by carbon-manganese reinforcing steels in the hot rolled state, reinforcing rod is also present in the plastically strained state in many applications [2]. In addition there is a risk of control process on the subsequent manufacture stages, hence, the addition of strong nitride forming elements to reinforcing steels should reduce their susceptibility to natural strain aging. Ti, B, Al / N stoichiometric ratios have been shown to control or eliminate natural strain aging due to the formation of these nitrides [3,4] .

The purpose of the present study was to determine the cause of a back spring problem presented in the bending process of a hot rolled and heat treated 1004 steel rod caused by a phenomena of natural aging. After the heat treatment process, R_m values are acceptable for the bending process, but as time goes by, R_m increases, increasing scrap in the process, the investigation analyzed microstructure with an optical and SEM microscopy, and R_m as a function of time, at different process conditions, finding that N, B and Al contents and heat treatment time were the most relevant parameter to control this problem.

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EXPERIMENTAL PROCEDURE

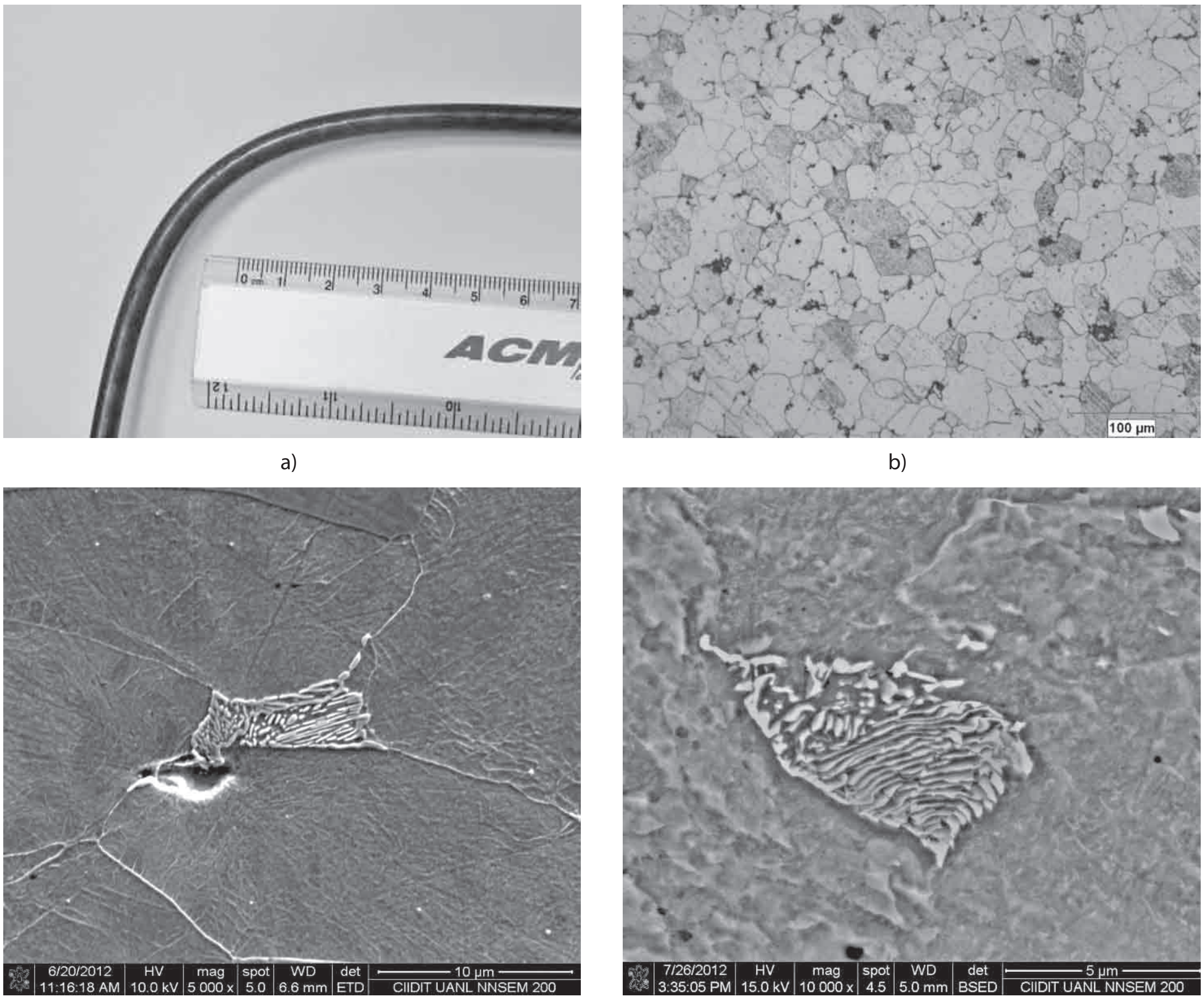
The material for the investigations is hot rolled rod 5,5 mm diameter of a 1004 steel which is used primary for security bars, Figure 1a. The chemical composition of the materials is shown in Table 1, being alloy A1 with 57 B, 37 Al and 90 N, and alloy A2, with 41 B, 38 Al and 65 N in parts per million. A preliminary microstructure comparison was made between a not heat treated and after heat treatment, Figure 1.

The heat treatment process was made in tubular furnace being thermal characterized with a thermocouple type K of 1 mm diameter into the rod, having an electric resistance heating section and an nitrogen cooling section, the experimental parameters were established at the two alloys A1 and A2 at two velocities of 50 m/min and 30 m/min. Rod was pulled into the furnace and heated and cooled at the experimental conditions mentioned before, after heat treatment TS, was measured up to 126 hours for each condition.

RESULTS AND DISCUSSION

As shown in Figure 1b, the ferrite content of the material is about 95 % with small amounts of perlite is embembedded in the ferritic matrix, 5,5 ASTM grain size was found, Figure 1c and 1d correspond to the SEM microstructure before and after heat treatment conditions respectively, perlite change from a lamellar to rod-like morphology with heat treatment.

Figure 2 shows thermal profile for of rod wire vs distance where experimental temperature measurements got 515 °C as maximum temperature and decreasing in the cooling section, the maximum of heat treatment temperature corresponds to the highest nitrogen solubil-



a) b) c) d)

Figure 1 Micrographs of 1004 steel; a) rod as received b) optical c) after rolled and d) after heat treatment at 514 °C SEM

Table 1 **Chemical compositions with two levels of N and B, for Alloy A1 and A2 / wt %**

A1

C	Mn	Si	P	S	Cu	Cr	Ni	Sn	Mo	V	Ca	Ti	Zn	B ppm	Al ppm	N ppm
0,033	0,298	0,109	0,009	0,0073	0,09	0,024	0,041	0,007	0,008	0,002	0,0015	0,0008	0,0096	57	37	90

A2

C	Mn	Si	P	S	Cu	Cr	Ni	Sn	Mo	V	Ca	Ti	Zn	B ppm	Al ppm	N ppm
0,037	0,301	0,105	0,009	0,008	0,115	0,035	0,041	0,009	0,009	0,0026	0,0019	0,0009	0,0046	41	38	65

ity 0,08 wt % [5,6] and this temperature explains the dissolution or perlite as solubility of carbon increase with temperature [7,8] .

Change of R_m are presented in Figure 3a, for each condition A1 and A2 for 30 and 50 m/min, respectively, since nitrogen has the highest solubility at this temperature and A1 has the highest nitrogen and B and Al contents, so the lowest TS is observed in this alloy, this shows that there is a possibility to form BN or AlN and reduce natural aging, besides TS is decreased as velocity is decreased from 50 to 30 m/min, which means longer time of residence in the 3m heating zone, this process condition reduce the natural aging increasing ductility. On the other hand, A2 has lower N, B and Al contents and shows higher TS values this shows that there is no possibility to form BN or AlN and less nitrogen in solution, increasing natural aging and reducing ductility.

Faction transformed as "α" function of time is given by a, and this could be expresses in terms of physical properties as $R_m(t)$ [9,10], experimentally obtained and expressed by [11]

$$\alpha = \frac{R_m(t) - R_m(o)}{R_m(\max) - R_m(o)} \qquad (1)$$

R_m (o) and R_m (max) correspond to the initial and final tensile strengths for each condition respectively, an isothermal analysis of R_m is considered for natural aging in this problem, although is well known that R_m de-

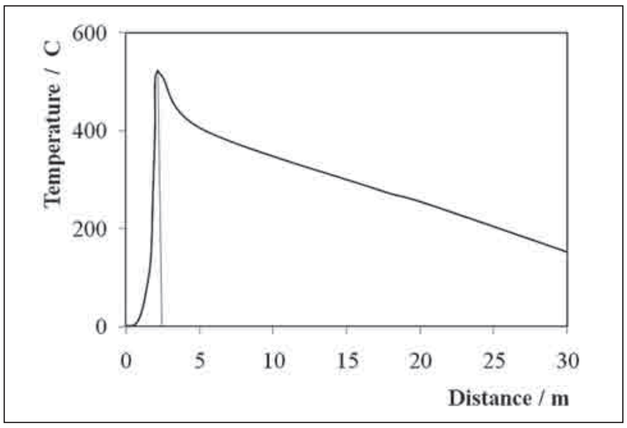


Figure 2 Temperature profile from: i) 3 m heating zone and ii) 27 m cooling zone

pends on temperature, and it is observed, Figure 3b, how tensile strength increases as time goes by up to 123 hrs reach a maximum value, A1 shows that α increases faster followed by A2 notwithstanding velocity, showing that equilibrium is reached faster for A1.

CONCLUSIONS

An analysis of a 1004 steel process parameters was made to reduce natural aging and increase ductility, in order control the bending process for manufacturing security bars.

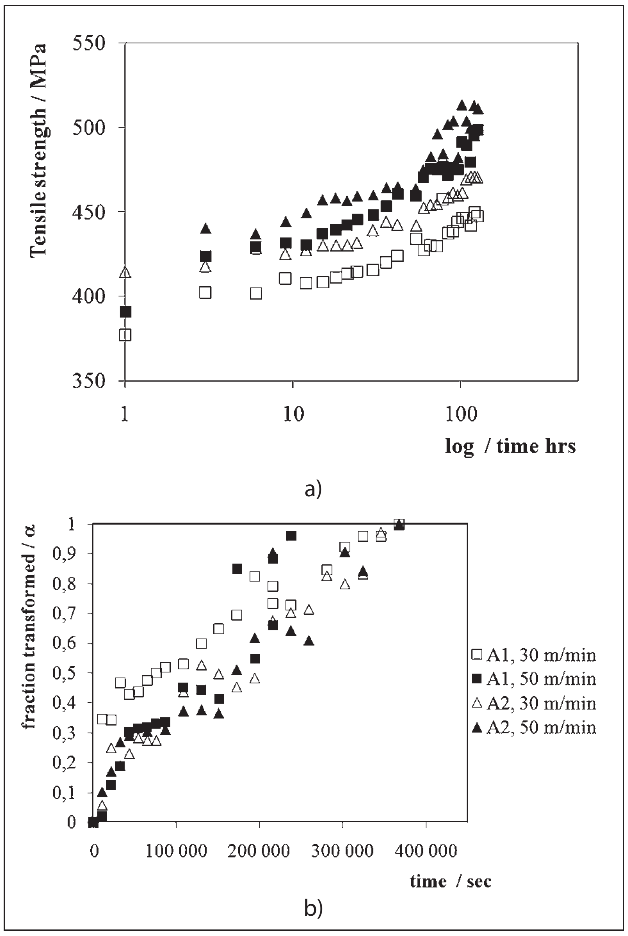


Figure 3 a) Tensile strength vs log time and b) fraction transformed, α vs time for A1 and A2 at 30 and 50 m /min

An analysis by optical and SEM on the 1004 steel shows a ferritic matrix with small amounts of perlite, which is partially dissolved after heat treatment, with 5,5 ASTM grain size.

Increase of tension strength corresponds to high velocity (short heat treatment time), with low N and B contents, which corresponds to A2 alloy at 50 m/min.

The lowest tension strength is observed in A1 alloy, with high N and B contents and a low velocity (long heat treatment time) this shows that there is a possibility to form BN or AlN and reduce natural aging, increasing ductility.

According to experimental observations it is proposed that high N and high B percentages with a low velocity of heat treatment increase ductility and reduce considerably the problem presented in the bending process of 1004 steel for manufacture security bars.

Acknowledgements

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Note: The responsible for english language is the lector from Faculty of Mechanical and Electrical Engineering, Nuevo Leon, Mexico