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MmeMac09-002 - Influence of Thermomechanical Treatments on Hydrogen Permeation in Pearlitic 1075 Carbon Steel

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Introduction

The oil and gas industry demands high structural reliability in harsh environments (offshore), where the presence of hydrogen represents a critical factor for the integrity of components. To investigate the impact of thermomechanical processes on the properties of carbon steel 1075, advanced characterization techniques such as Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) were employed to identify and correlate the microstructural and crystallographic changes with the hydrogen transport behavior in the material.

Objectives

The purpose of this work is to investigate the hydrogen permeation in 1075 pearlitic carbon steel submitted to thermomechanical treatments. By means of SEM and XRD, the microstructural and crystallographic changes are correlated with the parameters of hydrogen transport and diffusivity in the material.

Methodology

Table 1. Chemical composition of the material studied (w.t. %).

C	Mn	Cr	Si	P	Mo	Fe
0.75	0.82	0.34	0.22	0.11	0.02	Bal

Table 2. Samples worked and thermomechanical routes subjected to them.

Sample	Rolling Reduction (%)	Full Annealing	
		Temperature (°C)	Time (min)
A.R.	---	---	---
25_900_100	25	900°C	100
50_900_1000	50		1000

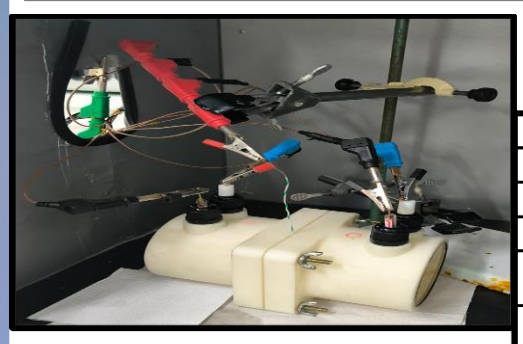


Figure 1. Devanathan-Stachurki cell in full operation in an H^+ permeation assay.

Table 3. Equations used to obtain the parameters.

Equations	Meaning of the parameters
$J_\infty = I_\infty/F.A$	I_∞: standing current;
$t_{lag} = t(0{,}63.J_\infty)$	J_∞: hydrogen mass flow rate during I_∞;
$D = L^2/2t_{lag}$	t_{lag}: lag time;
$S = (L.J_\infty)/D$	D: diffusibility coefficient;
$\varphi = D.S$	S: solubility coefficient;
	φ: permeability coefficient.

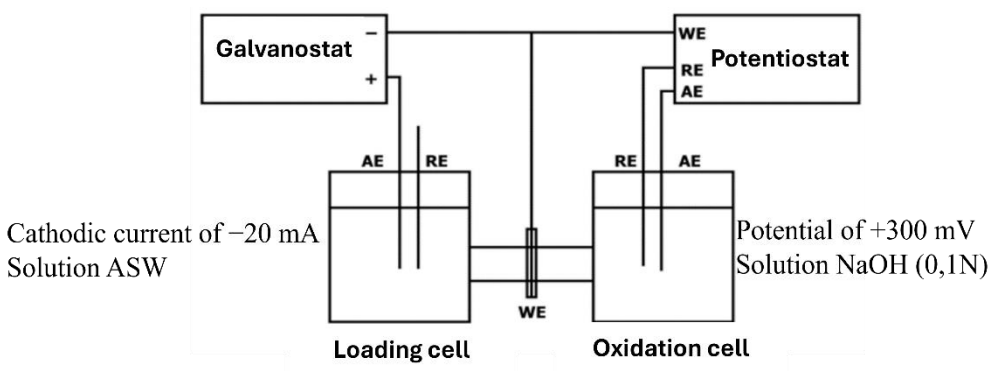


Figure 2. Schematization of the test with the main electrochemical parameters used.

Results and Discussion

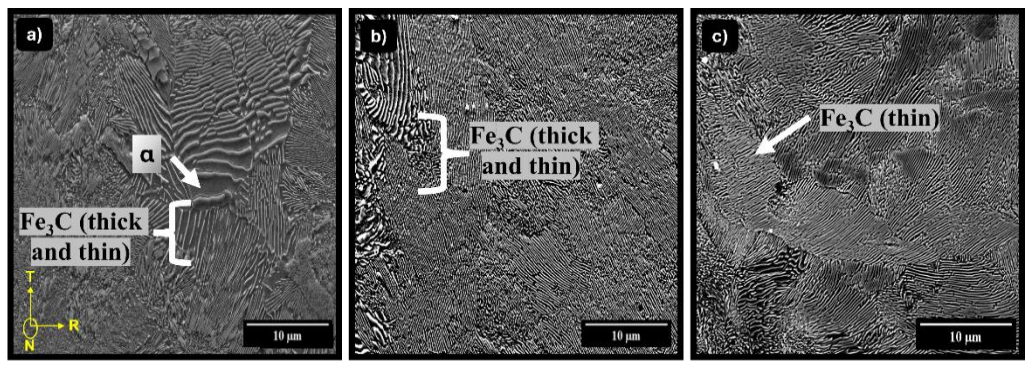


Figure 3. Micrographs obtained by SEM from the samples of a) A.R.; b) 25_900_100 and c) 50_900_1000.

Table 4. Microstructural parameters obtained by means of SEM.

Sample	Interlamellar Spacing (µm)	Lamella Thickness (µm)
A.R.	0.09	0.34
25_900_100	0.11	0.45
50_900_1000	0.22	0.23

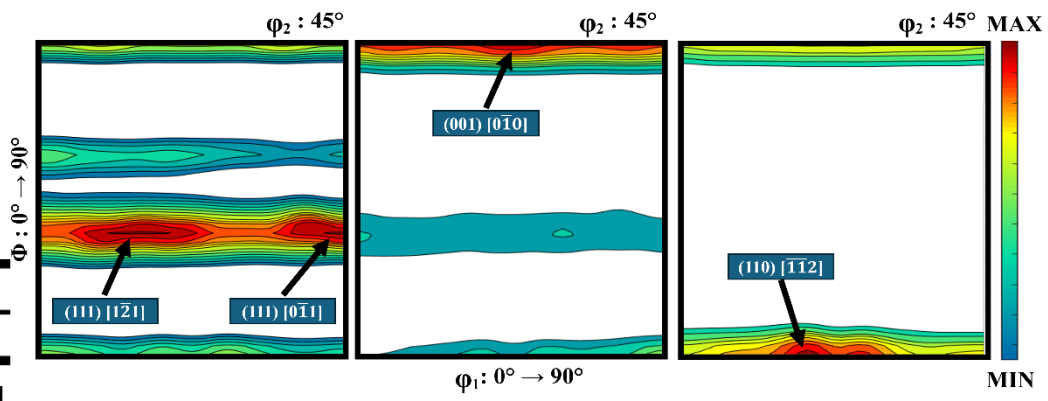


Figure 4. ODFs obtained by XRD of samples a) A.R.; b) 25_900_100 and c) 50_900_1000.

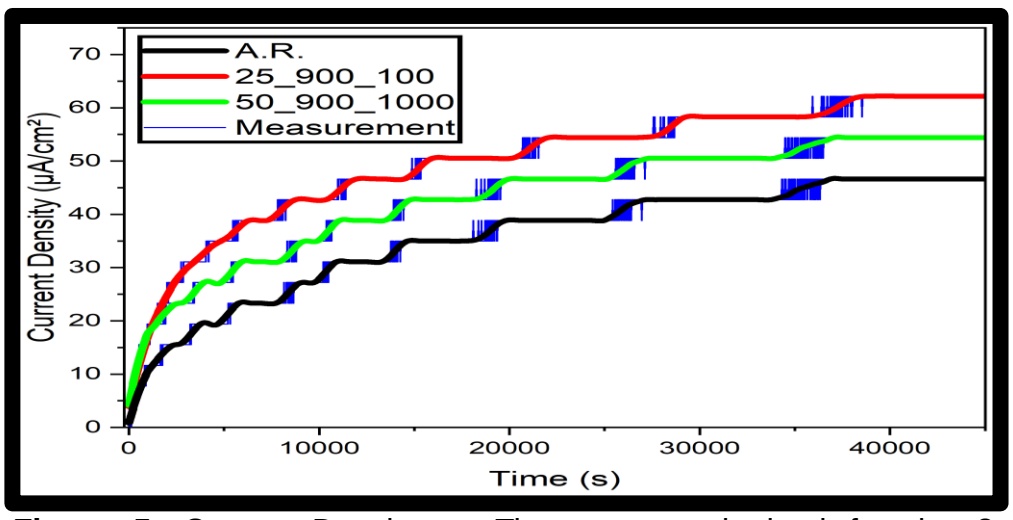


Figure 5. Current Density vs Time curves obtained for the 3 materials evaluated.

Table 5. Coefficients obtained and their numerical results.

Sample	Time-lag (s)	Coefficients		
		Diffusivity (m^2/s)	Solubility (mols H/m^3)	Permeability (H/m.s)
A.R.	5.4460E+03	3.7030E-11	1.5786E+02	5.8455E-09
25_900_100	7.8191E+03	4.1778E-11	2.3469E+02	9.8048E-09
50_900_1000	1.3907E+04	1.4501E-11	5.0238E+02	7.2849E-09

Conclusions

The results indicate that the crystallographic texture acts as a trap helping to define the retention of H+ in the material. Thus, the 50_900_1000 ({011}) sample is the most harmful because it severely retains hydrogen, followed by the intermediate A.R. ({111}) and the less critical 25_900_100 ({001}).

References and Acknowledgments

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