

ULTRAFINE FERRITE OBTAINMENT IN A LOW CARBON STEEL AT SUB-CRITICAL TEMPERATURE THROUGH HOT TORSION DEFORMATION AND TEMPERING. Otavio Villar da Silva Neto¹ and Oscar Balancin². ^{1,2}Department of Materials Engineering, Federal University of São Carlos (DEMa/UFSCar), Via Washington Luiz, Km 235, 13.565-905, São Carlos, SP, Brazil. ¹Email: pvillar@iris.ufscar.br

The ferritic grain ultrarefinement attributes considerable won in the mechanical properties of the common structural steels. The increases in the mechanical resistance and in the tenacity are the main advantages originating from grain refinement, checked to the mechanical behavior of these materials [1]. For treating of a processing technique, sparing the use of steels with microalloying elements and, in some cases subsequent thermal treatments, the grains refinement area is growing in several researches in the last years [1,2,3,4]. The preferential nucleation sites of ferrite are increasing with defects produced during deformation. So much the heavy deformation as high deformation rates promotes increases in amount of defects and deformation bands, which contributes for occurrence of dynamic recrystallization and the formation of the ultrafine ferrite [3]. This way, the obtaining of ultrafine ferritic grains can be associated to the dynamic softening process of ferrite: continuous dynamic recrystallization [4]. In this work, was investigated the ultrafine grains obtainment and took place the study of the microstructural evolution during the ferrite grain ultrarefinement, starting from the thermomechanical processing in the subcritical field. A common steel 0,16C1,34Mn with dispersion of globular cementite was submitted to the heavy deformation in the ferrite domain. Carbide dispersion was introduced through quenching followed subcritical tempering and strain. The samples were reheated to 900 °C, for 10 minutes kept at this temperature, and then water quenched. These samples were tempered at 685 °C during 1 hour. Heavy deformation ($\varepsilon \approx 5$) was applied by hot torsion test at 685 °C and at equivalent strain rates of 1.0, 0.5 and 0.1 s⁻¹. Also, in other tests, after each pre-certain deformation amount - 0, 1, 2, 3, 4 and 5 - the samples were water cooled, allowing the study of the microstructural evolution in the deformed condition the 0.1 s⁻¹. Regardless the routes to carbides spheroidization, the flow stress curves display a peculiar shape: the flow stress rises rapidly to a hump at the commencement of the straining, following by extensive softening in the flow region and, with the steady state final large straining levels were attained. The observation of the microstructure was accomplished with aid of optic and electronic microscopy of scanning. The electron backscattered diffraction (EBSD), accomplished in a microscope Philips of high resolution, XL30 FEG (30KV) model, it made possible the analysis of the disorientation among the contours generated during the deformation, determining the percentage of high and low angle boundaries formed after thermomechanical process. The final microstructure of the studied steel consisted of a matrix with medium size of smaller grain than 2 μm with dispersion of spheroidal cementite. The results showed that low times of tempering caused the presence of fine and dispersed carbides for all matrix. Also, it can be verified that the size of the particles exercised little influence on grain ferritic refinement. However, the cementite particles can interfere in the process of rotation of the subgrains and to inhibit the growth of the formed grains. The observation of the microstructural evolution during the deformation showed the formation of a group of uniform grains inside of the old ferrite, suggesting the occurrence of a continuous process of dynamic recrystallization. The occurrence of the dynamic recrystallization of the ferrite is due to the discharges rates and amounts of deformation imposed during the torsion in the subcritical field.

References

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- [3] Y. D. Huang et al., Journal of Materials Processing Technology (2003) 134, 19-25.
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Table 1 - Chemical composition of the investigated steel (wt%).

C	Mn	Si	Al	S	P	V	Cr	B	Ni	Cu
0,162	1,343	0,459	0,038	0,009	0,019	0,030	0,011	0,0002	0,230	0,012

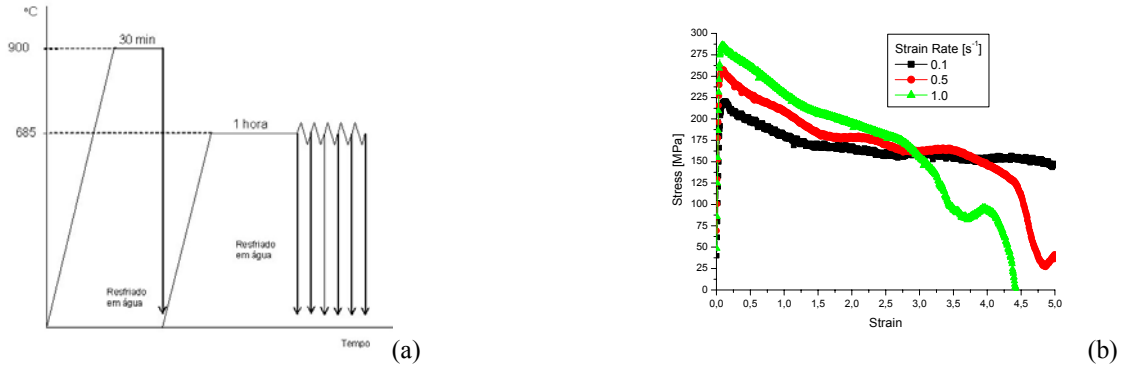


Figure 1 – a) Schematic representation of the rotes accomplished: until the fracture and interrupted isothermals tests; b) True stress-strain curve: tempering samples for 1 hour to 685 °C.

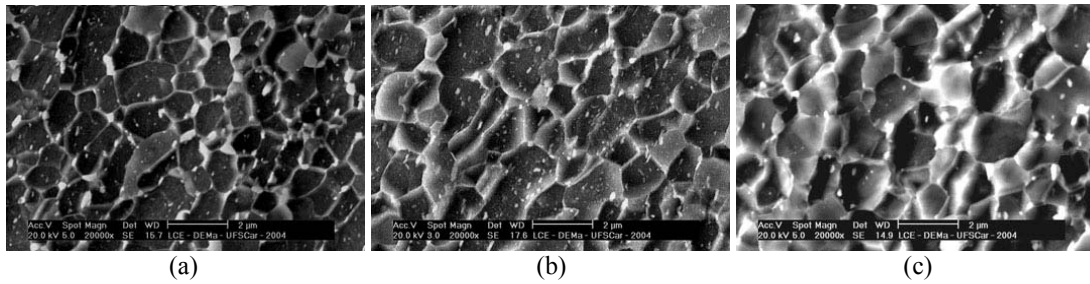


Figure 2 – Ultrafine ferrite grains in strained specimens: a) $\dot{\epsilon} = 1.0 s^{-1}$; b) $\dot{\epsilon} = 0.5 s^{-1}$; c) $\dot{\epsilon} = 0.1 s^{-1}$.

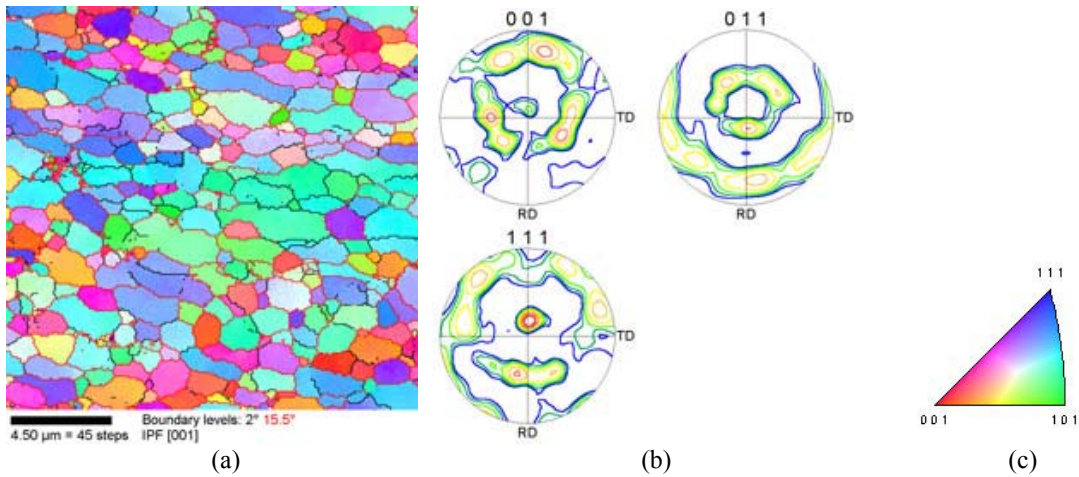


Figure 3 – EBSD maps: a) Inverse pole figure; b) texture; c) colors code - according to the preferential direction [001].