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EFFECT OF PROCESSING PARAMETERS ON THE SURFACE INTEGRITY OF THE 316 L STAINLESS STEEL TREATED BY SURFACE MECHANICAL ATTRITION TREATMENT (SMAT)

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ABSTRACT

The papers investigates the effects of the Surface Mechanical Attrition Treatment (SMAT) parameters on surface integrity - in terms of plastic deformation, residual stress and associated hardness - of the 316L stainless steel evaluated through XRD analysis and EBSD quantification of the geometrically necessary dislocations.

Keywords: surface integrity, SMAT, geometrically necessary dislocations, steels.

INTRODUCTION

Developed by J. Lu and K. Lu (2004), the Surface Mechanical Attrition Treatment (SMAT) is used to plastically deform and enhance the mechanical properties of metallic parts. In this technique, a large number of balls are placed in a chamber and resonated ultrasonically by a generator. The sample is fixed at the upper side of the chamber and impacted by the flying balls so that its surface becomes heavily plastically deformed. The repeated multidirectional impacts give rise to compressive stresses, hardening and ultimately to grain refinement down to the nanometer scale. Even if the basic mechanisms of microstructure changes and nanostructuration or plasticity of the surface have been addressed, the effect of the processing parameters needs to be precisely quantified. These parameters are for example the size, weight, speed and nature of the impacting balls as well as the duration, frequency and amplitude of the vibrating treatment. In the presented work, the 316L stainless steel samples were treated by SMAT with different conditions (vibrating amplitude, treatment duration, balls material, etc) and the effect of these processing parameters established in terms of residual compressive stress and microstructure evolution.

RESULTS AND CONCLUSIONS

The mechanisms of grain refinement under SMAT for the 316L steel have been detailed using Transmission Electron Microscopy (TEM) by Roland et al. (2006, 2007). SMAT produces gradients in grain size and structural defects below the surface. The magnitude of these gradients, which is directly related to the local strain sustained by the material, depends on the numerous processing parameters and still needs to be established. As TEM experiments are complex and time consuming, information obtained from Electron BackScattered Diffraction (EBSD) analyses are used here to gain rapidly more insights on the microstructure evolution and be able to determinate the effectiveness of the processing parameter.

The distinction between statistically stored dislocations and geometrically necessary dislocations (GND) is important because it is the GNDs, that ensure the compatibility of the deformation, which accommodate the strain gradients in the case of non-homogeneous deformation (Kubin, 2003). Thus, the amount of GND becomes more important at high strain and its local density is actually proportional to the local magnitude of the strain gradient. Therefore, a good indicator of the plastic deformation imparted by the SMAT treatment can be the distribution of the Geometrically Necessary Dislocations (GNDs) density as a function of depth. Figure 1 gives a map of the entry-wise norm of GNDs density tensor recorded by EBSD with a step size of 200 nm on the cross section of a SMAT treated sample. For the sake of visual clarity; only the band contrast was plotted for densities smaller than 10% of the GND density maximum. In Fig. 1b is given the corresponding in-depth evolutions of GNDs density.

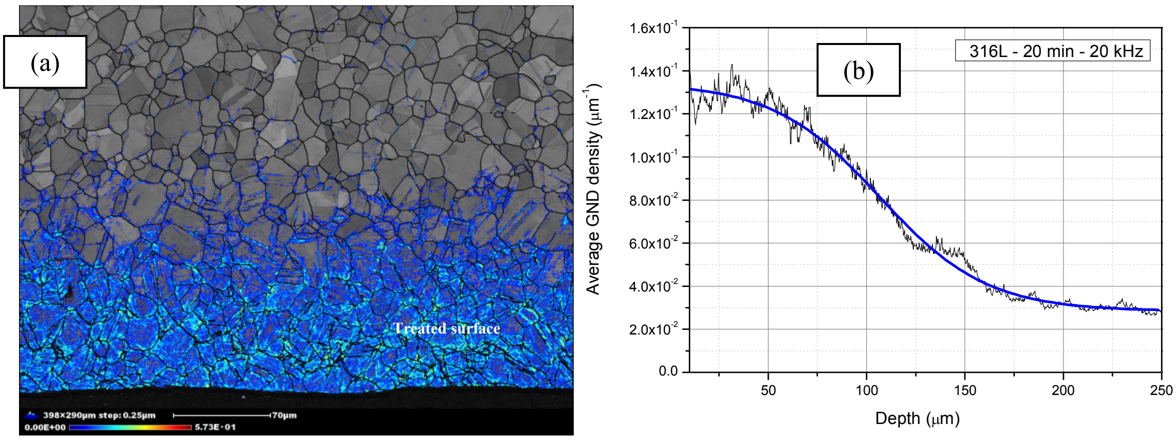

Fig. 1 - Distribution of GND density in the 316L stainless steel (a), corresponding average GND distribution as function of the depth below the surface (b)

Such a type of information obtained from EBSD is used to determinate, as a function of the processing parameters, the thickness of 3 different zones usually depicted in SMATed samples: (i) the ultrafine grains domain, with sub-micron sizes, that correspond to the ultimate stage of grain refinement under heavy deformation, (ii) the transition zone where the initial micrometric grains are fragmented under heavy deformation and (iii) the deformed zone where the initial grains are simply plastically deformed. The analysis is also done in terms of residual strain and rougness of the surface.

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