MODIFICATION OF METALLIC SURFACES BY DUPLEX TREATMENTS INVOLVING SEVERE PLASTIC DEFORMATION

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ABSTRACT
The effect of different duplex treatments, involving a first step of severe plastic deformation followed by plasma nitriding, has been investigated on a AISI 316L stainless steel. The steel was treated under different processing conditions by Surface Mechanical Attrition Treatment (change in sonotrode magnitude, substrate temperature) or High Current Pulsed Electron Beam (change in electron beam energy and number of pulses) then subjected to Plasma Nitriding. The evolutions of the microstructure modifications, nitrided depths and hardness of the surfaces were then analyzed and discussed depending on the processing conditions.

Keywords: duplex treatments, HCPEB, SMAT, nitriding, microstructure, hardness.

INTRODUCTION
Long term surface peening, such as the Surface Mechanical Attrition Treatment (SMAT), was developed to upgrade directly the mechanical properties of the materials as well as a surface activator prior to chemical treatments such as Plasma Nitriding (Lu, 2004). The High Current Pulsed Electron Beam (HCPEB) technique is also a recent technique that has been proved to increase surface hardness as well as improve wear and corrosion properties (Grosdidier, 2008). These techniques create a heavily deformed graded microstructure at the surface and sub-surface for which the compressive residual stress, the grain size reduction and the introduction of structural defects (twins, dislocations, vacancies …) improve directly the properties. It was also suggested that they promote the diffusion of nitrogen and thereby, the reductions in the nitriding temperature and/or duration, leading to avoid the formation of nitrides which affect the corrosion behaviour of stainless steels. In the present work, the AISI 316L stainless steel was treated under different processing conditions by SMAT or HCPEB then subjected to Low Temperature Plasma Nitriding (LTPN) under 'soft' conditions (350 °C for 8 hours) in order to investigate the effect of the different processing parameters on the surface properties and microstructure modification at the light of quantitative analysis of the deformed state using a recently developed procedure (Samih, 2013).

RESULTS AND CONCLUSIONS
An interesting point about the SMAT + LTPN treatment is the high hardness value (700 HV) that could be reached compared to a conventional LTPN treatment carried out solely (370 HV). The drawback of this duplex treatment is that the nitried layer is not continuous. This is illustrated by the cross section SEM image given in Figure 1a which, consistently with the results found by Chemkhy (2013) and Samih (2014), revealed discontinuities in the nitrided
layer due to SMAT induced contamination inhibiting locally the nitriding process. Comparatively, figure 4b illustrates the very continuous nitride layer that was formed when the nitriding process was carried out after HCPEB. This technique, for which severe plastic deformation is done without mechanical contact, provide with the unique combination of a continuous nitrided layer and a hard sub-surface that should be beneficial for improving the combination in terms of corrosion and wear + fatigue resistances.

Fig. 1 - SEM cross-section images giving the general aspect of the nitided layer after the duplex treatments by a) SMAT + LTPN and b) HCPEB + LTPN.

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