APPLICATION OF NEUTRON AND RADIATION BEAMS TO THE ASSESSMENT OF RESIDUAL STRESSES FIELDS INDUCED IN METALLIC MATERIALS BY LASER SHOCK COMPRESSION

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Laser shock processing (LSP) is progressing as an effective technology for the improvement of metallic materials mechanical properties in different types of components as a means of enhancement of their fatigue life behaviour. As reported in previous contributions by the authors [1-2], a main effect resulting from the application of the LSP technique consists on the generation of relatively deep compression residual stresses field into metallic alloy components allowing an improved mechanical behaviour, explicitly the life improvement of the treated specimens against wear, crack growth and stress corrosion cracking. Experimental results on the residual stress profiles and associated mechanical properties modification have been successfully reached in typical materials under different LSP irradiation conditions, the protective character of the residual stress profiles obtained under different irradiation strategies having been established. In particular, the specific behaviour of materials used in high reliability components (especially in nuclear and biomedical applications) as AISI 316L and Ti6Al4V has been analyzed, the effect of possible "in-service" thermal conditions on the relaxation of the LSP effects having been specifically studied [3].

The results relative to residual stresses measurements are most frequently determined on the basis of the application of the ASTM E837-13 Standard (strain gauge hole drilling method), able to provide RSs components perpendicular to the drilling direction and for which the proposers have developed a suitable uncertainty analysis procedure [4]. However, being the basis for the development of technological applications, the macroscopically averaged nature of the determinations made by the hole drilling method hinders a clear insight into the microscopic nature and origin of the material dislocations responsible for the observed RSs fields. In particular, the way in which the high deformation rate characteristically imposed by LSP processes is able to induce mechanical dislocations with a relative high degree of thermal irreversibility (as reported in references [3, 5-6]).

In an attempt to further elucidate these questions (fundamental in view of the desired process predictive assessment capability), the proposers have conducted previous studies [7,8] with the purpose of confirming the relative stability of such RSs fields upon aggressive thermal cycles with the aid of synchrotron X-ray radiation at the EDDI beam line of BESSY II (Berlin, Germany) and the SALSA instrument at the ILL facility (Grenoble, France).

In the present paper, a critical evaluation of the main results obtained by means of these alternative procedures in comparison with the traditional ASTM E837-13 method will be presented along with a reflection on the suitability and advantages of EM radiation- and neutron-based methods for the elucidation of material transformation signatures in LSP and other mechanical transformation processes.

REFERENCES

[1] OCAÑA, J.L. et al.: "Improvement of surface and mechanical properties of high strength metallic alloys by laser shock processing". Advances in Materials and Processing Technologies (2017), 3, 12–22.

[2] OCAÑA, J.L. et al. "Laser Shock Processing: an emerging technique for the enhancement of surface properties and fatigue life of high-strength metal alloys". Int. J. Microstructure and Material Properties (2013), 8, 38-52.

[3] OCAÑA, J.L. et al.: "Effect of Thermal Treatments on the Mechanical Properties Enhancement of High Reliability Metallic Materials by Laser Shock Processing". Materials Science Forum (2014), 783-786, 2376-2381.

[4] PERAL, D. et al.: "Uncertainty analysis for non-uniform residual stresses determined by the hole drilling strain gauge method". Measurement (2017), 97, 51–63.

[5] CHERIF, M.A. et al.: "Fatigue behaviour and residual stress relaxation of laser-shock peened and deep rolled Ti-6Al-4V". Ti-2007 Science and Technology. Proc. 11th World Titanium Conference (2007), Kyoto, p. 1711-1714.

[6] ALTENBERG, I. et al.: "On the fatigue behavior and associated effect of residual stresses in deep rolled and laser shock peened Ti-6Al-4V at ambient and elevated temperatures". Proc. 132nd Annual TMS Meeting, San Diego (2003), pp. 359-367.

[7] OCAÑA, J.L. et al.: "Compressive Residual Stresses and Associated Surface Modifications Induced in Ti6Al4V by Laser Shock Processing". Materials Science Forum (2017), 879, 1408-1413.

[8] OCAÑA, J.L. et al: "Use of Neutron Diffractometry for the Characterization of Microstructural Transformations Following High-Rate Deformation of Ti6Al4V by Laser Shock Processing". ILL Report 1-02-274 (2021).