Mechanistic Understanding of Stability of Residual Stresses in Aerospace Alloys with Crystallographic Texture

Muhammad Kashif Khan, Sunil Anandatheertha, Michael Fitzpatrick, Xiang Zhang [2]

[1]*Institute of Future Transport and Cities, Coventry University, Coventry, Coventry*

Laser Shock Peening (LSP) is a mechanical surface technique used for fatigue strength improvement the fatigue properties of new and damaged metallic components by introducing beneficial compressive stresses into the near-surface regions. A major prerequisite for effective LSP is development of an optimal residual stress field that can be reliably sustained during fatigue loading. The residual stresses that are developed in surface treatment can get changed in fatigue loading due to the thermal effects or local plasticity of favorably oriented crystals in materials with high intensity crystallographic texture. The initial residual stresses that are produced in surface treatment remain unaffected by the elastic loading in the service life of the components. However, the plastic deformation of the material can redistribute the residual stresses. The alloys with strong crystallographic texture, in many cases, show residual stress relaxation in fatigue cycling even for elastic loads. The grains with favourable crystallographic orientation deform excessively and their resolved shear stresses exceeds up to the order of the yield resulting in the redistribution or relaxation of the optimal residual stress fields. This relaxation behaviour directly depends on the initial crystallographic texture of the material before treatment, residual stresses that developed, and changes in the crystallographic orientation of the material due to LSP treatment.

In this paper we will present the mechanistic understanding of the role of crystallographic texture in extruded aluminium alloys on relaxation of residual stresses. The crystal plasticity based finite element modeling was used for determination of the dominant crystallographic slip planes in aluminium alloys. The cyclic loading of samples, extracted from alloys with similar crystallographic texture as identified in FE simulations, showed relaxation of residual stresses. The experimental measurements of the residual stresses before and after fatigue loading were carried out with neutron and synchrotron X-rays diffraction. The residual stress relaxations were well in agreement with FE simulations. The meso-scale empirical relationship of stability of residual stresses considering the initial crystallographic texture of the alloy is extremely useful in ensuring the safety of engineering components where the residual stress instability may produce premature failure of engineering components.