Effect of shot peening on microstructure of steels exhibiting a TRIP effect – Experimental and modeling approaches

ROMAIN GUIHEUX[1,2,3], SOPHIE BERVEILLER[2], DENIS BOUSCAUD[2], RÉGIS KUBLER[3], ETIENNE PATOOR[2], QUENTIN PUYDT[1]

[1]IRT M2P, Metz, France
[2]LEM3, Arts et Métiers ParisTech, Metz, France
[3]MSMP, Arts et Métiers ParisTech, Aix-en-Provence, France

Shot peening process is commonly used in mechanical industries to increase life duration of mechanical and structural parts, as automotive gears for instance. It is based on the development of residual compressive stresses at the surface of the component as the surface is hardened by the impact of steel shot. The stress magnitude and the affected depth depend on the process parameters, such as the shot velocity and diameter, their incidence angle with respect to the surface, the coverage… In the case of TRIP-effect steels, the metastable austenite can transform into martensite during shot peening. The final stress state is then more complex as it results from mechanical strain imposed by the process and the martensitic transformation that leads to stress redistribution between austenite and martensite. The aim of this work is to study the behaviour of TRIP-effect steels submitted to shot peening by taking into account martensitic transformation.

There are several existing models of shot peening giving the resulting stress field in the material as a function of parameters process; however, to our knowledge, none of these integrates the phase transformation. Therefore we have performed experimental characterizations and developed a specific model for shot peening using a AISI 301LN stainless austenitic steel.

Residual stresses are determined by X-ray diffraction in both phases, austenite (with Mn radiation) and martensite (with Cr radiation), using the classical $\sin^2\psi$ law. The martensite volume fraction is also measured by X-ray diffraction taking into account crystallographic textures.

The mechanical behavior was characterized by tensile tests at different strain rates. Shot peening was performed on 60*60*8 mm^3 samples using cut wire steel shots (700HV); the turbine rotational speed was varied between 500 and 2000 rpm. An augmentation of this speed increased the maximum residual stress in both phases. Moreover, the higher the turbine rate was, the higher the martensite volume fraction and the affected depth were.

In parallel, finite element simulations of shot peening are performed taking into account residual stresses, plastic strains and hardening parameters for each phase. It is based on the shot peening model with stress and microstructure gradients developed previously by Renaud (Renaud 2011); a semi-phenomenological transformation behaviour law for unstable austenite (Kubler 2011) has been implemented to consider microstructure phase evolution. Model parameters are calibrated from tensile tests and from single-shot impact experiments on AISI 301LN. Output data are the martensite volume fraction, the residual stress and strain fields in each phase, as a function of the depth from the surface. Numerical results are compared to experimental ones on shot peened surfaces.

References

Renaud P. (2011) : PhD Thesis - Arts et Métiers ParisTech ; Aix en Provence, France.

Kubler R., Berveiller M., Buessler P. (2011): Semi phenomenological modelling of the behavior of TRIP steels. International Journal of Plasticity, 27, 299-327.