

Damage & Fracture Toughness of Fibrous Dual-Phase Steels for Automotive Applications

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Dual-Phase steels have long been used in the automotive industry due to their excellent mechanical properties in terms of strength and ductility, as well as their low processing cost. The good compromise between strength and ductility results from the very different properties of the constituent phases comprising ductile ferrite and hard martensite.

In contrast with their plastic flow properties, the fracture toughness of Dual-Phase steels (quantified by K_{Ic} or J_{Ic}) has been far less investigated. Common values of the fracture toughness are around $100[\text{kJ.m}^{-2}]$ or even lower; but seldom exceed the $200[\text{kJ.m}^{-2}]$. However, a minimum level of fracture toughness is required to prevent the propagation of small edge damage or cracked zones induced by cutting. Therefore, unravelling the relationship between fracture toughness, microstructure and damage mechanisms is essential to develop advanced steels with superior forming ability.

Dual-Phase steels are usually processed following an intercritical annealing which generally leads to equiaxed martensite inclusions. An alternative heat treatment, consisting of a double annealing first proposed N.J. Kim and G. Thomas [1] brings about fibrous martensite inclusions. A very recent study on such steels shows that this fibrous microstructure can potentially lead to a very high fracture toughness, while retaining good properties in terms of strength and ductility [2].

The general objective of this research is to investigate the fundamental damage mechanisms that govern the fracture toughness of Dual-Phase steels. Our approach is based on the processing of microstructures in which parameters are varied one by one. In particular, both equiaxed and fibrous microstructures were investigated in the form of thin sheets.

The Essential Work of Fracture (EWF) method [3] was used to quantify the work per unit area needed at the crack tip for material failure separating it from the total work expended for material failure. An extension of the EWF method

also allows us to separate the work of necking from the work of damage [4]. In addition, tomography experiments were conducted in order to study the nucleation and growth of cavities within the sheets. These preliminary measurements constituted the basis for the development of a micromechanics-based predictive model of the toughness of Dual-Phase steels.

References

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