THE PATH TO HIGH FORMABILITY AND DAMAGE TOLERANCE IN 3RD GENERATION HIGH STRENGTH STEELS

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Abstract

The development of so-called 3rd Generation (3G) Steels with strengths well above 1GPa has opened up new opportunities for vehicle lightweighting, essential both to the fuel efficiency of gas-powered vehicles and the range of electric vehicles. For many applications high strength must be coupled with sufficient ductility to withstand impact during a crash or to enable complex-shaped parts to be formed. For stretch forming applications ductility can be adequately characterized by the tensile elongation. However, for forming operations involving bending or out of plane deformation or in the crushing of crash tubes it is the true ductility, i.e. the true strain at fracture, that represents the critical parameter. For some 3G steels true ductility can be remarkable, with fracture strains up to 0.8. This appears to be due to a combination of factors that provide damage tolerant microstructures in these materials. Two primary mechanisms involve grain refinement and TRIP effects, while the mechanical homogeneity of the phases also plays a significant role. With regard to the latter, Figure 1 illustrates the effect in a DP1300 steel to which V has been added. In the V-modified steel the strength of the martensite has been lowered while the ferrite is stronger. This reduction in micromechanical heterogeneity reduces the strain gradient across M-F interfaces making damage nucleation more difficult. The result is a factor of two increase in true ductility.

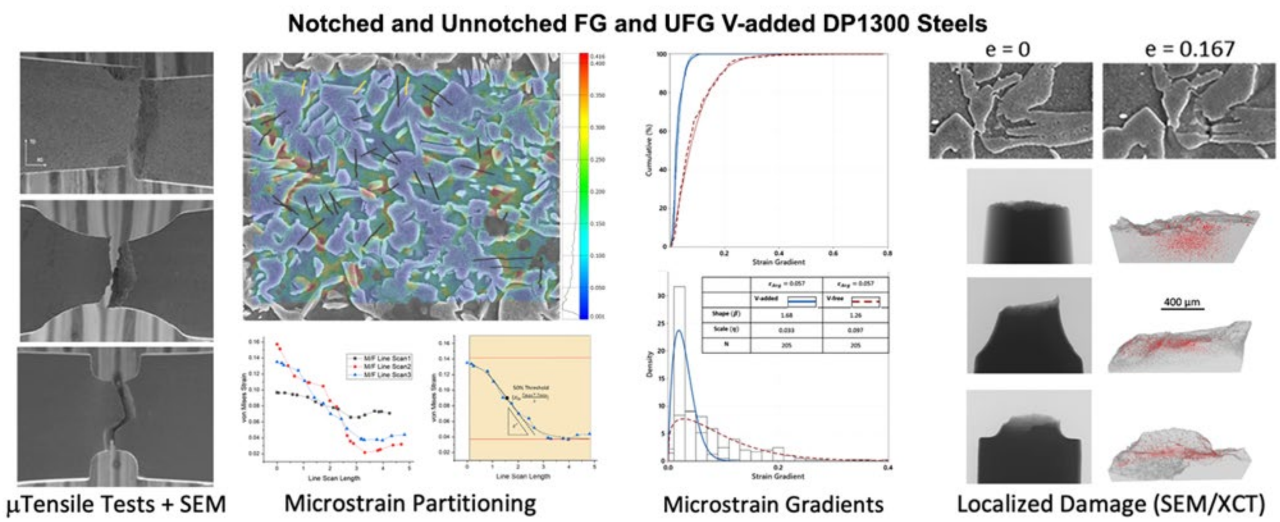

Figure 1: An illustration of the effect of microstrain partitioning on damage in a V-modified DP steel

The effect of grain refinement and TRIP are illustrated in Figure 2. The former effect is well known. The effect of TRIP is less clear but it appears that the volume expansion associated with TRIP lowers the stress locally, thereby making it more difficult for damage to nucleat.

This presentation will describe a series of studies in which in situ tests coupled with microscopic digital image correlation (μ-DIC) along with strain-resolved EBSD, XRD and x-ray tomography have been used to fully characterize and assess the role that each of these mechanisms plays in a range of 3G steels.

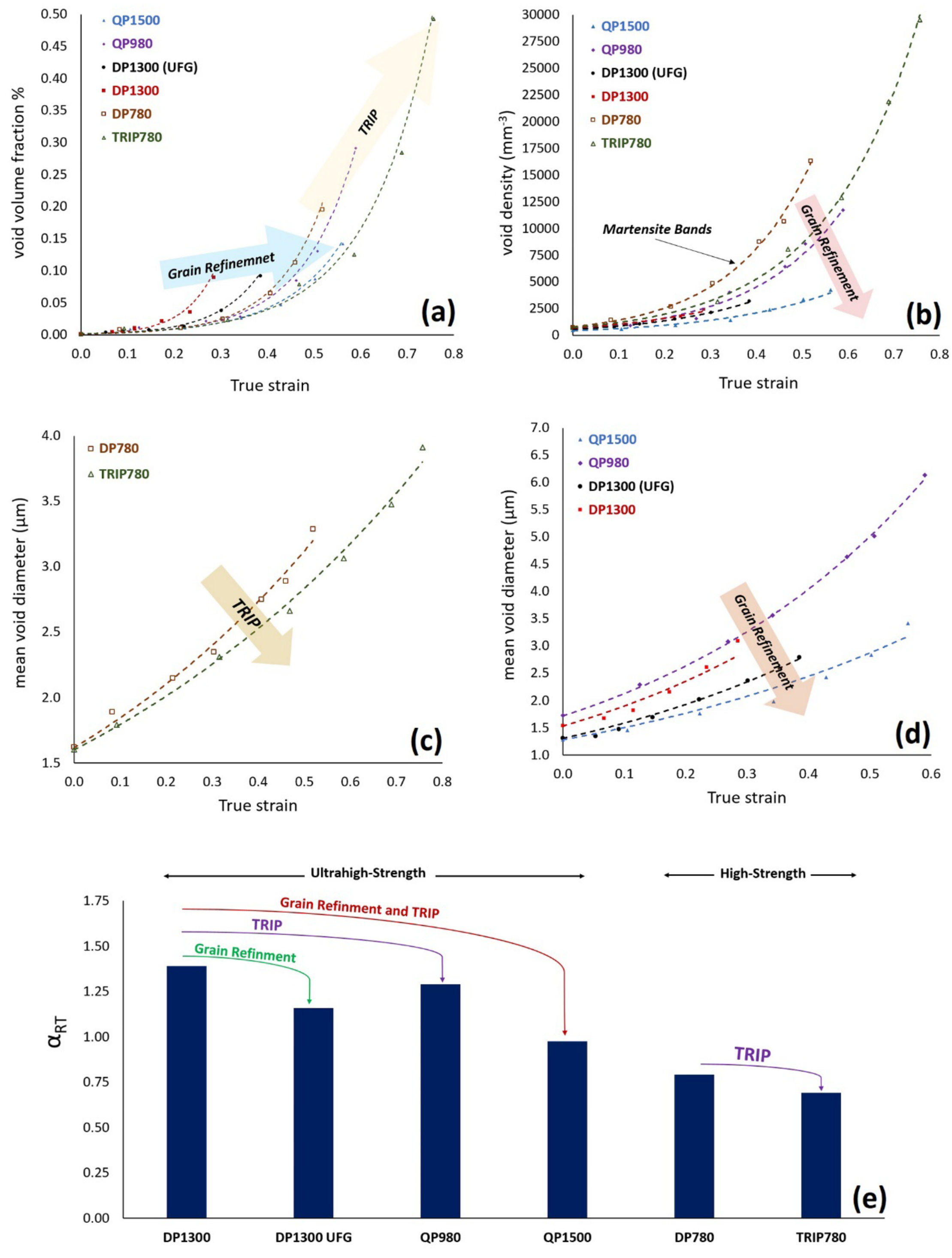

Figure 2: A summary of the rates of damage development in a range of high strength steels, indicating the role of both grain refinement and TRIP on the suppression of damage.

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