19th International Conference on Strength of Materials (ICSMA 19th)
June 26 – July 1st, 2022, Metz, FR

The Development of Damage-Tolerant Advanced High Strength Steels

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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 in some cases. This appears to be due to a combination of factors that provide damage tolerance to these materials. Two primary mechanisms involve grain refinement and TRIP effects, while the mechanical homogeneity of the phases also plays a role. In this paper we 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.