Inclusions and Ti+Nb microalloying element precipitation in Press Hardened Steels: towards improvement of in-use properties

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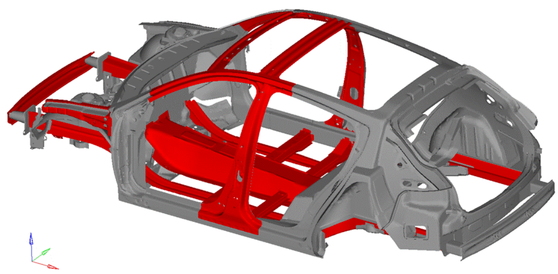

Typical applications of Press Hardened Steels in a Body-in-White structure

- Ultra-High Strength Steel
- Martensitic microstructure
- Effect of microalloying elements on mechanical properties
- Advanced damage and ductile fracture model

Abstract:

The automotive industry is facing two major challenges. On one side, vehicles must reduce their CO2-emission and, on the other side, standards for crash resistance are becoming more and more severe. The use of very high strength steels with improved ductility appears to be a suitable solution for structural lightweighting and improved crashworthiness behavior. One of the most commonly used steel families are the so-called PHS (Press Hardened Steels). These steels are delivered coated with low mechanical properties at hot stampers to be hardened by die-quenching before being used by carmakers. The hardening treatment is obtained by a first austenitizing treatment at 900°C followed by a rapid quench which transform the austenite into martensite. Formation of 0.1-0.3%C martensite microstructure results in the production of a high strength steel solution (between 1000 and 2000 MPa). These steels are now being intensively used in the body-in-white structures, in particular the Usibor® and Ductibor® families developed by ArcelorMittal. The development of these widely marketed materials is subject to a strong international concurrency.

One way currently investigated to improve their mechanical strength consists in introducing microalloying elements such as titanium which is able to protect boron against nitride formation and consequently, to retain its ability to refine austenitic grain size. Furthermore, the addition of microalloying elements is also used for grain size refinement either by solute drag or by grain boundary pinning by precipitation of fine (Ti,Nb)C. These additions come, however, together with a

coarser precipitation formed at the beginning of processing mostly during the solidification. This precipitation might affect their resistance to crack initiation, during tests such as bending tests which are used as a reference to evaluate their energy absorption through the calculation of fracture strain. The two interesting aspects in our study on crash ductility will be the energy absorption and the anti-intrusion resistance. The limited link established between the amount of these chemical elements, the surrounding martensitic microstructure, the form of microalloying elements (precipitates and solid solution) and ductile cracking resistance during bending is thus of prime importance. More generally, the project aims at improving the crashworthiness of these steels by providing process guidelines on the industrially used quantities of these elements.

The major industrial objective of this PhD project is to optimize the chemical composition of PHS with respect to their population of inclusions in order to improve their in-use properties, and then set up tools to enhance our comprehension of the mechanicals phenomena involved. The associated research work combines metallurgy, mechanics and modelling, aiming at a better understanding of:
1/ The effects of microalloying on inclusion formation and precipitation (amount, size and spatial distribution) as a function of carbon and possibly of nitrogen.
2/ The consequences of the addition of these microalloying elements on the other microstructural constituents.
3/ The link with in-use properties after the hot stamping step.
4/ The fracture mechanisms, in order to establish a fracture criterion taking chemistry-induced microstructural effects into account.