EXPERIMENTAL CHARACTERIZATION AND MODELING OF DAMAGE DEVELOPMENT IN 3RD GENERATION DUPLEX STEELS FOR AUTOMOTIVE APPLICATIONS

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CONTEXT and OBJECTIVES

European regulations [1]:

- Issues: cars = 13 % of the CO_2 emissions in UE + increased constraints for car manufacturers
- Solutions: - enhanced engines
  - lighter structures => Advanced High Strength Steels

[1] European regulation No 443/2009, http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/motor_vehicles/interactions_industry_policies/mi0046_fr.htm, 06/2015

	Emitted CO_2 ($g.km^{-1}$)	Consumption ($l.100km^{-1}$)
2011	136	-
2015 (aimed)	*130*	*5.2*
2020 (aimed)	*95*	*3.7*

Fine: 95 €/(g/km) for any vehicle

Advanced High Strength Steels (AHSS) [2]:

[2] Lee, Materials Science and Technology, 31(7), 2015

- 1st generation: ferrite-bainite matrix + carbides (DP, TRIP)
- 2nd generation: stable austenitic matrix (TWIP)
- 3d generation: ferrite(α)-austenite(γ) duplex structure
  → ANR_Matetpro-funded "MeMnAl Steels" project

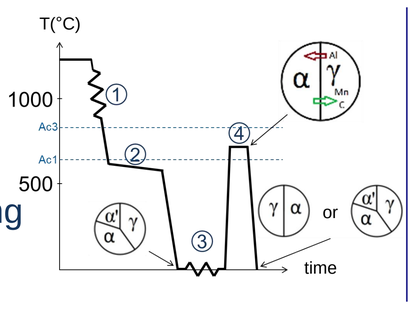
Objectives:

- Mechanical characterization of 2 families of steels (Medium Mn and Low Density)
- Detailed study of the most promising laboratory steel grades
- Development of a criterion connecting microstructure to damage and fracture properties

MATERIALS

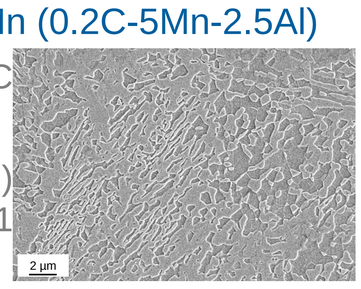
Processing

- ① Hot rolling
- ② Isothermal holding
- ③ Cold rolling
- ④ Intercritical annealing (IA)



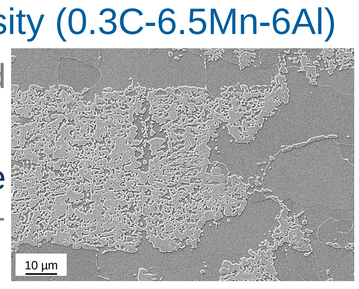
Family 1 : Medium Mn (0.2C-5Mn-2.5Al)

- 3 T_{IA}: 740ºC, 760ºC and 780ºC
- UFG (UltraFineGrained) microstructure (grain < 1 µm) α/γ ou α/α'
- Target: 1000 MPa-30%



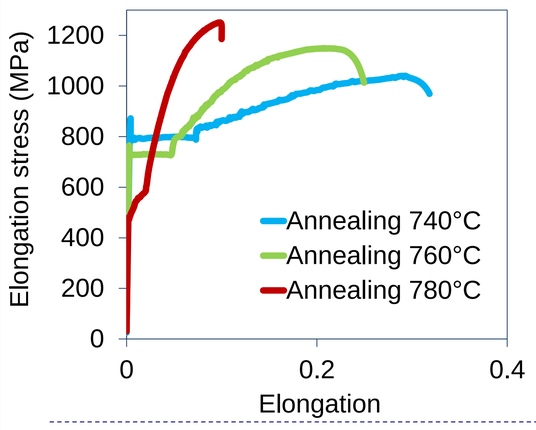
Family 2 : Low Density (0.3C-6.5Mn-6Al)

- 2 T_{IA}: 850ºC and 900ºC
- Bimodal microstructure (coarse grains α + UFG α/γ)
- Target: 800 MPa-30% with density reduction by 10%

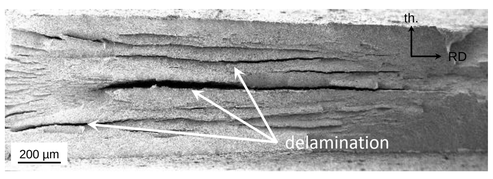


RESULTS

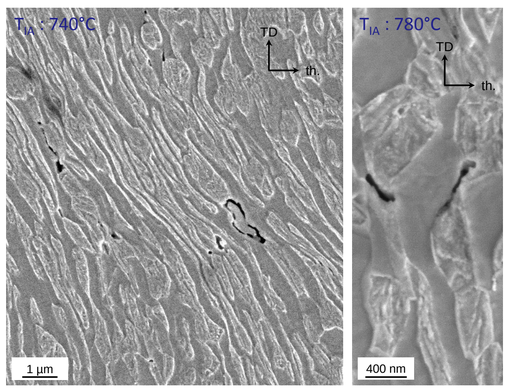
Medium Mn



- Strong sensitivity to T_{IA} ($\gamma_{retained}$ destabilized with ↑ T_{IA}) → variety in mechanical properties
- Lüders plateau specific to UFG MeMn
- TRIP effect for T_{IA} ≥ 760°C

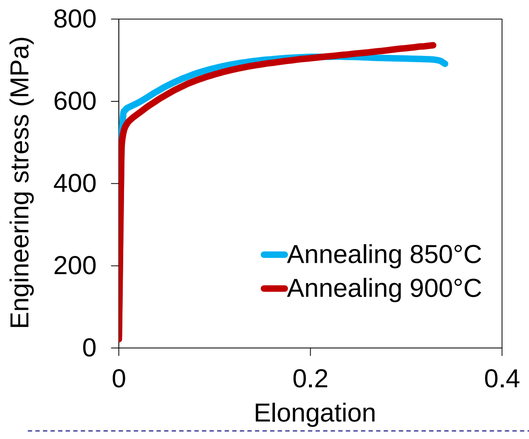


- Sensitivity to delamination
- Ductile fracture

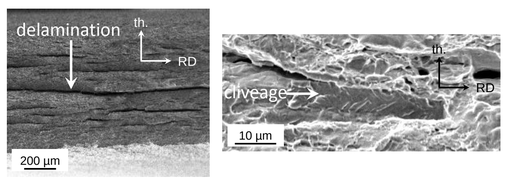


- Low T_{IA}: cavities located in shear bands at α/α' interfaces
- High T_{IA}: few cavities, located at α/α' interfaces and close to the fracture surface (20 µm)
- No damage in the bulk whatever T_{IA}

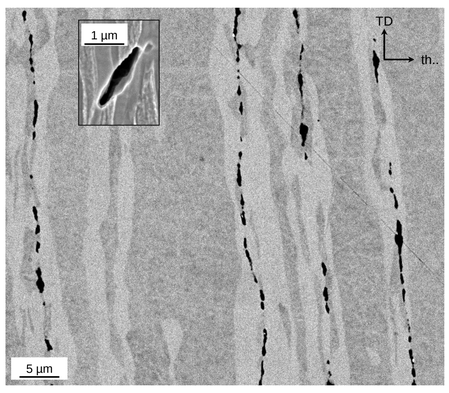
Low Density



- Low sensitivity to T_{IA} → good robustness regarding the manufacturing process
- No Lüders plateau (due to the bimodal microstructure)
- No obvious TRIP effect



- Sensitivity to delamination
- Ductile fracture with some cleavage facets (confirmed by tests at -50°C)



- Cavities located at α/α' interfaces
- Damage located in the first 200 micrometers below the fracture surface → no damage in the bulk
- Interfacial fracture at low temperature (-50°C)

CONCLUSIONS

- Medium Mn: - UFG microstructure
  - sensitive to T_{IA}, TRIP effect
  - ductile, almost no damage
- Low Density: - bimodal microstructure
  - no real TRIP effect
  - ductile, sensitive to cleavage, damage located at ferrite/martensite interfaces

PROSPECTS

- Medium Mn: - tensile tests at -50 °C → cleavage sensitivity
  - interrupted tests → TRIP effect characterization
- Low density: - EBSD analysis → cleavage cracking mechanisms
- Fracture modeling: development of a model connecting microstructure to damage and fracture properties
  → establishment of a criterion linked to the microstructure

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