EVALUATION OF TRANSFORMATION INDUCED PLASTICITY IN MEDIUM Mn STEELS BY *IN-SITU* MAGNETIC MEASUREMENTS

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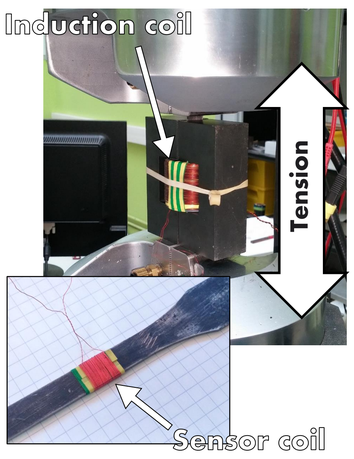
Objective & Material Studied

Sheets of Medium Mn TRIP steel (Fe-0.2C-5Mn-2.5Al) were ingot cast, hot-rolled, and cold-rolled to a thickness of 1.2mm (50% reduction).

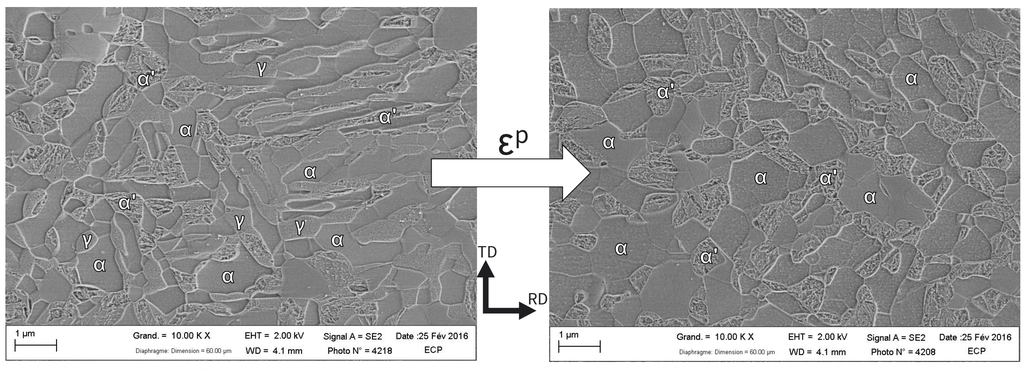
The sheets were annealed in the intercritical ferrite + austenite region at 740°C, 760°C, or 780°C to vary the retained austenite fraction and stability.

Objective:

Evaluate the TRIP kinetics by using in-situ magnetic measurements to determine the instantaneous volume fraction of ferrite + martensite.



Transformation-Induced Plasticity (TRIP)

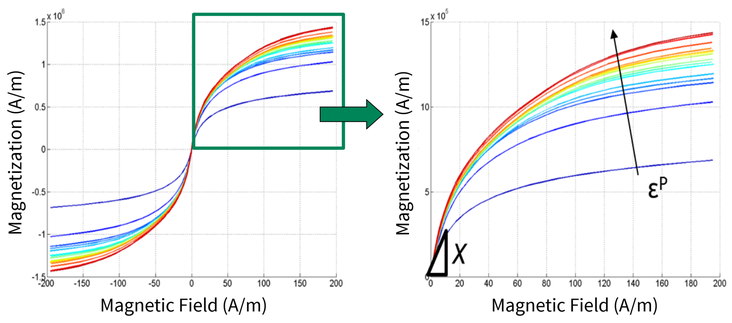


Sample annealed at T_{IA} = 780°C in the unstrained state (left) and strained to rupture (right). 1% Nital etch, 5s.

Strain-induced transformation of paramagnetic austenite to ferromagnetic martensite provides a significant contribution to the work hardening of the steel.

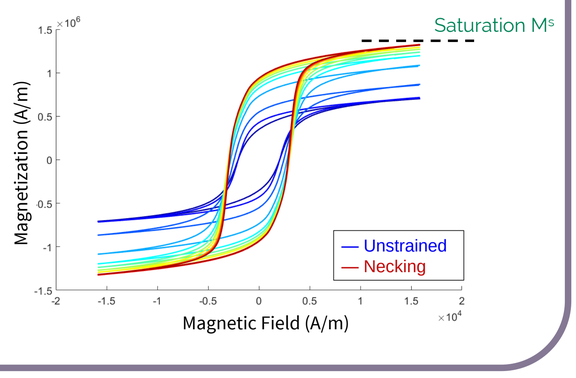
Anhysteretic Magnetic Measurements

+ Slope at the origin is equal to the magnetic susceptibility
+ More accurate
− Slow (~30 min per curve)

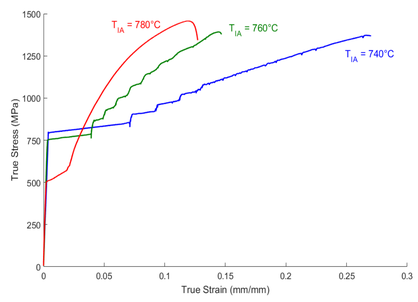


Hysteretic Magnetic Measurements

+ Very fast measurement (2Hz)
+ Can be performed in-situ
− No direct link to physical properties
− Assumes homogeneous microstructure → accuracy issues



Deformation Bands

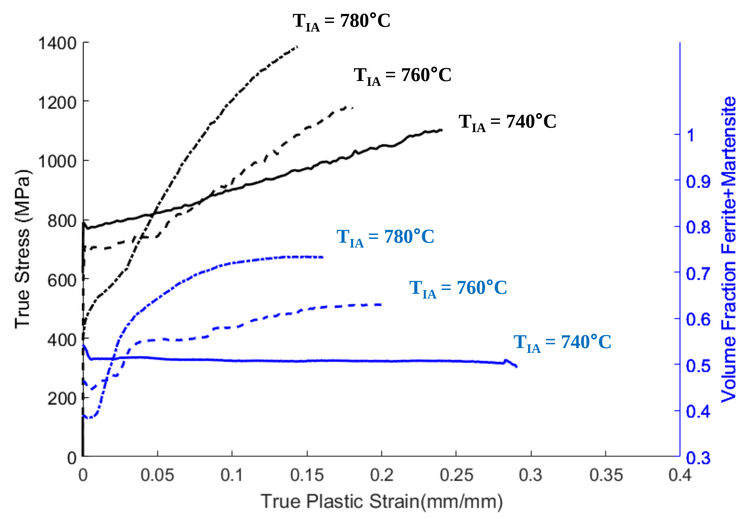


A stepwise behavior is observed in both the tensile data and magnetic volume fractions for samples annealed at 740°C and 760°C.

The steps correspond to the passage of deformation bands along the length of the sample, observable via DIC.

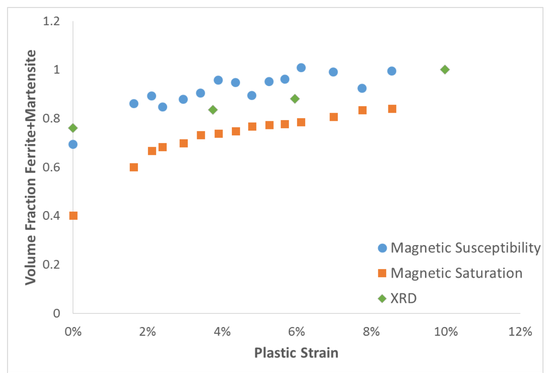
The passage of a deformation band coincides with the phase transformation!

In-Situ Results



In-situ experiments showed a significant difference in martensite transformation rate between the three annealing temperatures.

Verification by X-ray Diffraction



Anhysteretic (magnetic susceptbility):

$$f_\alpha = \frac{X_{\varepsilon^p}(3 + 2X_{\varepsilon^p} + X_\alpha)}{X_\alpha(3 + 3X_{\varepsilon^p})}$$

Susceptibility of 100% ferrite; Instantaneous susceptibility; ferrite + martensite

Hysteretic (saturation magnetization):

$$f_\alpha = \frac{M_\varepsilon^s}{M_\alpha^s}$$

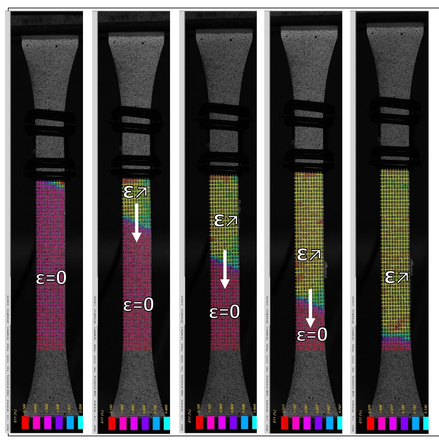
Instantaneous saturation magnetization; Saturation magnetization of 100% ferrite

Observation of Deformation Bands by Digital Image Correlation

The use of digital image correlation (DIC) permitted the observation of several deformation bands during unidirectional tensile tests on a sample annealed at 760°C.

The strain in the sample was very heterogeneous. The sample deformed by the passage of several consecutive strain bands that propagated from one side of the sample to the other.

It was also observed that the velocity of the band decreased with each passage.



There was originally a video here! You can watch it by scanning this QR code:

Conclusions

- The volume fraction of ferrite + martensite is able to be measured *in-situ* using the saturation magnetization of the sample measured via a coil on its surface.
- The magnetic method is in strong agreement with X-ray diffraction results.
- In the Medium-Mn TRIP steels annealed at 740°C and 760°C, deformation occured by the successive passage of strain bands that coincided with the martensite transformation.

References

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Acknowledgements

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