

Nucleation texture prediction on cold rolled IF-steel based on Advanced-Lamel Crystal Plasticity Model.

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Introduction

✓ Plastic deformation induces heterogeneities in dislocation density and preferred crystallographic orientations. During the early stages of the recrystallization process, rearrangement of dislocations generates migration of HAGB, which gives rise to strain-free crystallite volumes, and recrystallization nuclei.

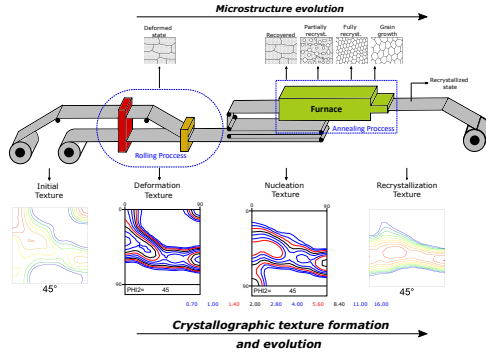


Figure 1. Evolution of microstructure and formation of crystallographic texture during rolling and annealing in an IF-steel sheet.

- ✓ An accurate description of the deformed state (rolling process) is required to predict the possible nucleation texture during annealing, see figure 1. The present work addresses the prediction of nucleation textures in cold rolled
- ✓ IF-steel samples based on crystal plasticity (CP) simulations performed with the Advanced-Lamel (ALAMEL) model [1].

Model Description

Simultaneous implementation of two nucleation laws. The first law is based on the absolute value of the plastically stored energy $M(g_i)$. The second emulates the Strain Induced Boundary Mechanism (SIBM) by considering the gradient of the Taylor factor between crystal orientations forming a pair in the ALAMEL crystal plasticity model.

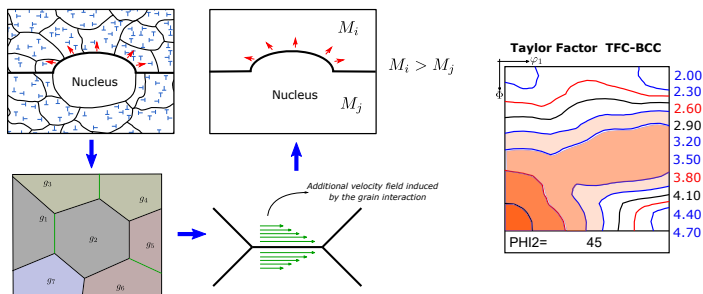


Figure 2. Left: Representation of SIBM nucleation mechanism from ALAMEL model information. Right: Taylor factor distribution in Euler space, calculated with Full Constraint Taylor (FCT) model.

- ✓ Oriented nucleation. Strain free nucleus take place in particularly oriented grains.
- ✓ Taylor factor is taken as an indirect measure of stored energy [2].
- ✓ SIBM based in the hypothesis that some grains already reached the critical size which allows them to growth towards their neighbor [3].
- ✓ In SIBM nucleation probability is a function of the Taylor factor gradient for a pair of grains.

$$P_N(g_{ij}) = \frac{a - b}{1 + \exp(-d(|\Delta M_{ij}| - c/2))}$$

References

- [1] P. van Houtte, S. Li, M. Seefeldt, & L. Delannay (2005) IJP.
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- [3] P. Bate & B. Hutchinson (1997) SM.
- [4] B. Beausir & J.-J. Fundenberger, ATEX-software, U.Lorraine - Metz, (2017)
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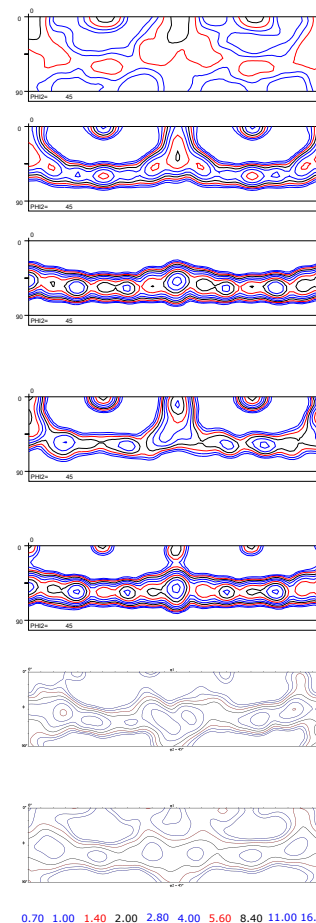
✓ In SIBM the orientation with higher stored energy is consumed by the one with lower store energy.

$$f_N(g_i) = \begin{cases} P_N(g) \cdot (f_D(g_i) + f_D(g_j)) & \text{if } M(g_i) < M(g_j) \\ 0 & \text{if other case} \end{cases}$$

$$f_N(g_j) = \begin{cases} P_N(g) \cdot (f_D(g_i) + f_D(g_j)) & \text{if } M(g_j) < M(g_i) \\ 0 & \text{if other case} \end{cases}$$

✓ Final Nucleation Texture: $f_N(g) = f_N(g_i) + f_N(g_j)$

Results



Initial texture

Experimentally measured IF-steel hot bad. Set of 5000 orientations.

Deformation texture

Alamel simulation 80pct rolling reduction. Slip systems: $12 \{110\} \langle 111 \rangle + 12 \{112\} \langle 111 \rangle$. Typical α -fibre and γ -fibre.

Nucleation law 1

Only orientations that meet: $M_{acm}(g_i) \geq 0.75$. Strong γ -fibre which corresponds to orientations with higher values of stored energy. Components outside said fibre are not captured.

Nucleation law 2

SIBM emulated from Alamel information. Strong rotated cube component and weaker γ -fibre. Mainly, orientations with lower values of stored energy are captured.

$$a = 0.7, b = 0.0, c = 0.9, d = 20.0, M_{acm}(g)$$

Nucleation combination

Law 1 and Law 2. Applied simultaneously according to weighting factors. Strong γ -fibre and some components on the θ -fibre are captured.

Nucleation experimental.

IF-Steel CR + Annealing 30min@630°C. EBSD measured texture, recrystallized fraction calculated based on GOS and GSZ calculations. RX-Fraction: 15%

Nuclei distribution.

ODF by number, [5]. IF-Steel CR + Annealing 30min@630°C. EBSD measured texture, recrystallized fraction calculated based on GOS and GSZ calculations.

Final remarks

✓ Predicting nucleation texture for rolled IF-Steel by the simultaneous application of the two nucleation laws described results in the appearance of a strong γ -fibre and some weak components on the θ -fibre.

✓ The current implementation of SIBM from Alamel model information favours the nucleation of orientations that typically present low stored energy values ($\{001\}$ grains and α -fibre). This as well suggests that orientations close to cube and rotated-cube components might display higher dispersion on the stored energy than orientations closer to the γ -fibre since these components are the ones that remain in the final nucleation texture.

✓ Effect of modelling parameters in nucleation laws as well as their weight factors need to be assessed in detail.

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