

Main coil defects and mechanisms

Hot plant

Meeting CT Laminage, SF2M, Topic: « Coiling » - 8/11/2019

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$$\frac{\partial f_{i,j}(\vec{x}, \vec{c})}{\partial x_i} = \sum_{k \neq i} c_{k,j}$$

The right formula
for the steels of the future

R&D
STEEL





Hot strip coil defects

- Coil sagging (ovalization)
- Loose inner windings (LIW)
- Telescope + irregular coiling
- Coil springback



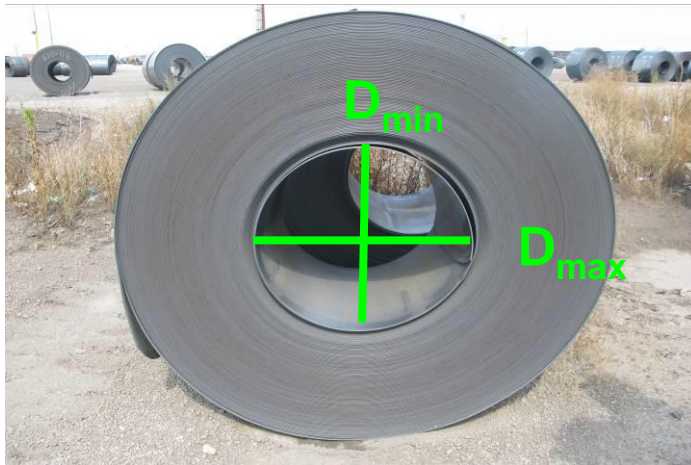
Coil sagging

Definition

Hot band coil collapse: loss of coil rigidity caused by its own weight

Aka: Sagging = Ovalization = Flattening = Squatting

French: Affaissement / Bobine affaissée



Timing:

Very variable

Immediately after
coil evacuation

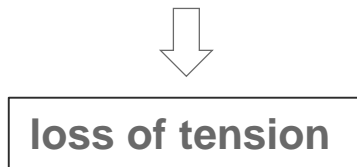
In the coil yard



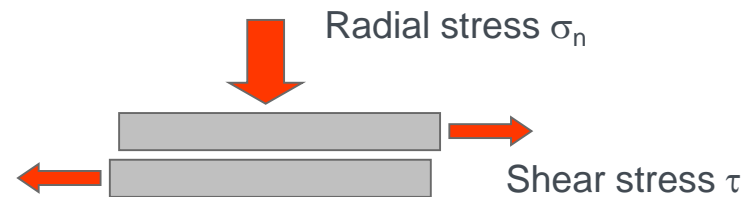
Coil sagging

Mechanism

- **Phase transformation** of austenite occurring during and after coiling
 - Transformation plasticity
 - Accompanying **volume changes** and associated stress changes
 - **Drop of yield strength** of material after coiling
 - Additional drop of yield strength after coiling induced by temperature rise due to release of **latent heat** of transformation into ferrite and especially into pearlite
- **Temperature gradients** (and related volume changes) in the coil
- **Creep** under coiling tension and gravity



- **Relative displacement of coil wraps:**



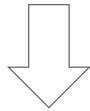
Relative displacement occurs if $\tau \geq \mu \sigma_n$



Coil sagging

Consequences

- Inability to load a collapsed coil onto pickling line mandrel
- Products not accepted by customer
- “Wobbling” of coil while uncoiling, resulting in strip steering issues – lower pickling line productivity and equipment damage



- Additional manufacturing cost (recoiling)
- Lower productivity (yield loss - scrapping)
- Problems downstream at CRM
- Safety issues (out of the standard operations of maintenance)



Loose inner windings

Definition



Loss of contact of the first windings (close to coil eye) from the rest of the coil

- Variable timing: right after coil evacuation, during coil transportation or later in coil yard

Loose inner windings

Mechanism

Phase transformation during coiling



- Transformation induced plasticity
- Phase density mismatch → volume changes

- Thermal gradient in the radial direction



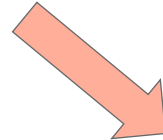
Tension loss



Loose inner windings

Consequences

- Problems for further coil manipulation
- Impact on productivity
- Impact on **safety**

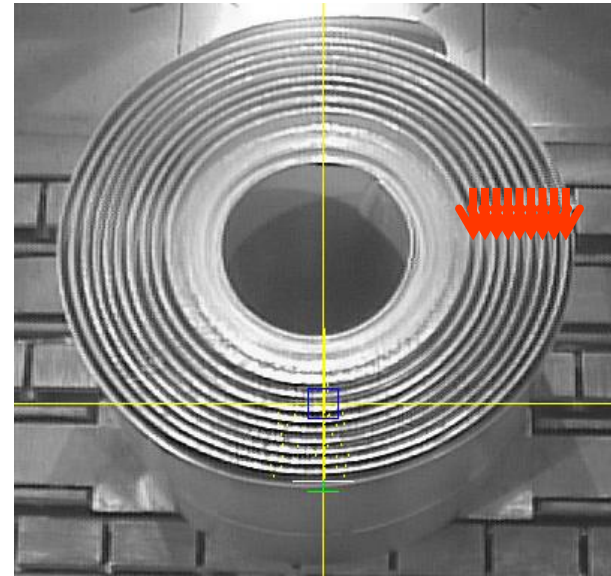




Telescope + irregular coiling

Definition

Windings are not perfectly aligned and protrude sideways (along axial direction)





Telescope + irregular coiling

Mechanism

1. The coiling tension is too low and the strip starts oscillating sideways ← possible causes: thick products, coiler not powerful enough, pinch roll cannot maintain tension level as the strip tail leaves the last finishing mill cage, ...
2. The guides are not correctly positioned → the strip enters the pinch rolls off center
3. Defective strip: head camber, flatness defects, ...
4. Coiler defects that cause lateral oscillations



Strip displacement along the transverse (= axial) direction



ArcelorMittal

Coil springback

Definition

Coil springs open





ArcelorMittal

Coil springback

Definition

Coil springs open





Coil springback

Mechanism

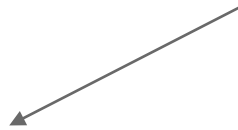
Thick strip, high strength material → difficult to keep the necessary coiling tension



The windings are not tight enough → friction or contact pressure are not high enough to keep windings together (phase transformation and thermal effects can play a role as well)



The elastic energy stored in the coil is released



BEFORE BANDING

The tail slips and the coil opens right after the end of coiling

AFTER BANDING

The springback energy is higher than the strapping bands limit and they break



Modeling

Main phenomena to model

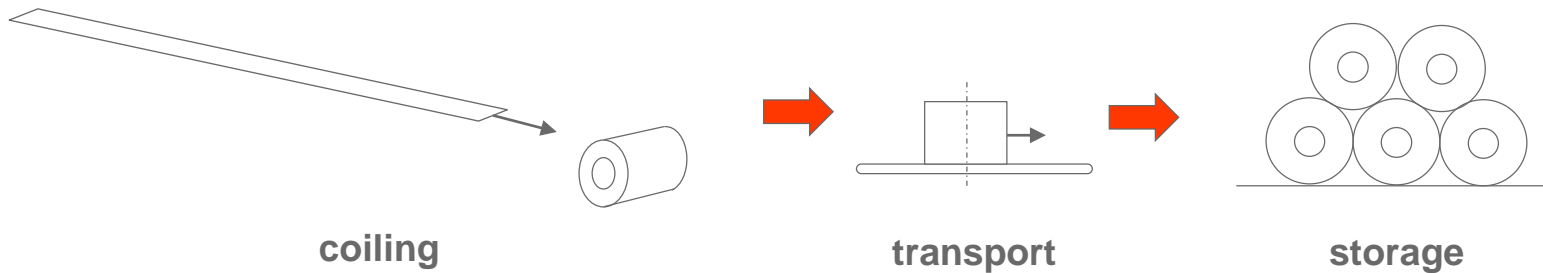
- Bending + traction stresses, although bending could be neglected for low thickness/high radius
- Asymmetric conditions (gravity, supports, temperature distribution, ...)
- Multiple contacts, wear
- Crown (« bombé ») effect
- Plasticity, Creep, time-dependent effects
- Temperature gradients → local thermal expansion/contraction
- **Phase transformation** → volume changes, transformation-induced plasticity, different material properties, heat release
- **Friction / slippage of the windings**, unwinding (slippage in one preferential direction only, I guess it's important for higher thicknesses)
- 2D vs 3D (depending on degree of accuracy and on type of defect considered)



Modeling routes and roadblocks

Coiling model

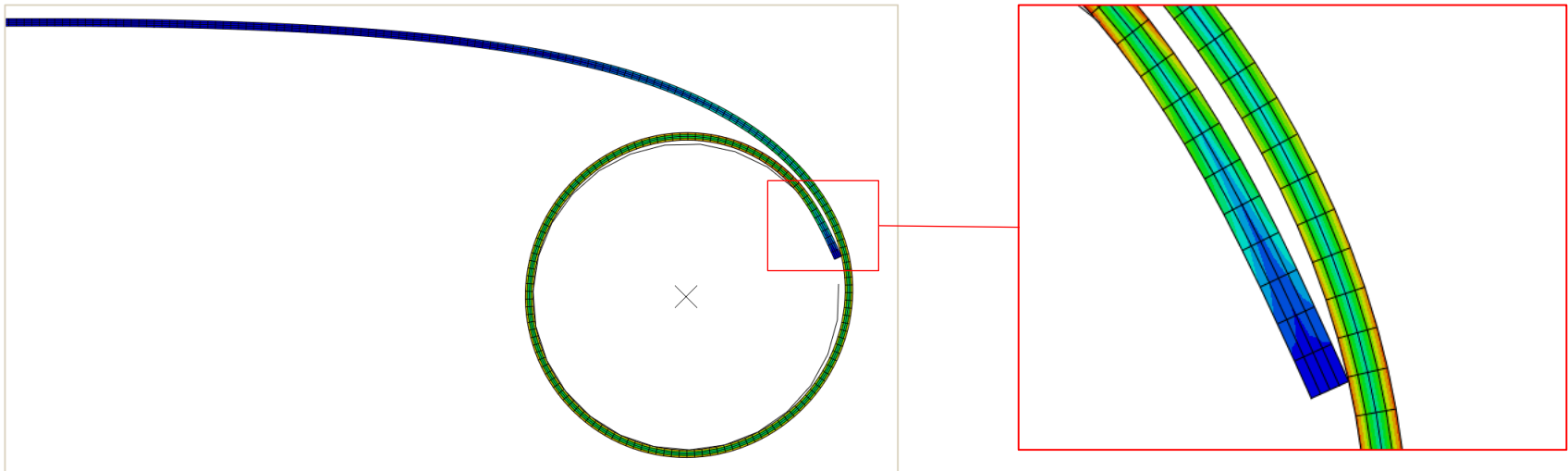
- Ideally:
 - ❑ full coiling operation from strip to complete coil (→ telescope, flatness defects)
 - ❑ followed by evacuation, transportation and storage (→ sagging, LIW, elastic springback)



Modeling routes and roadblocks

Coiling model

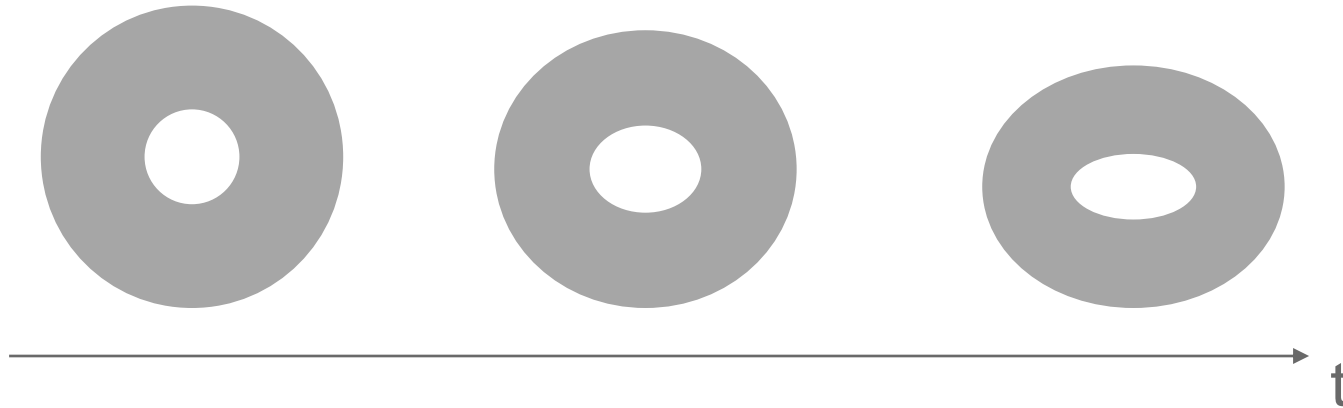
- Practically:
 - ❑ large number of degrees of freedom necessary → through-thickness precision, long strip
 - ❑ contacts between wraps, difficult to estimate friction and other contact conditions
 - ❑ highly nonlinear model: inelastic material behavior, temperature dependent, contacts
- Need to make assumptions and restrict the focus





Modeling routes and roadblocks

Focus example: coil collapse



- Full coil \rightarrow no need to simulate coiling operation \rightarrow bulk orthotropic body
- Dynamic problem: cooling \rightarrow phase transformation \rightarrow loss of tension \rightarrow inter-wrap sliding