M2i Project: S16039

Predictive Modeling of Pinching in Cold Rolling of Advanced High Strength Steels

A. Cometa, H.J.M. Geijselaers, J. Havinga, A.H. van den Boogaard

materials innovation institute

TATA STEEL

Wuppermann

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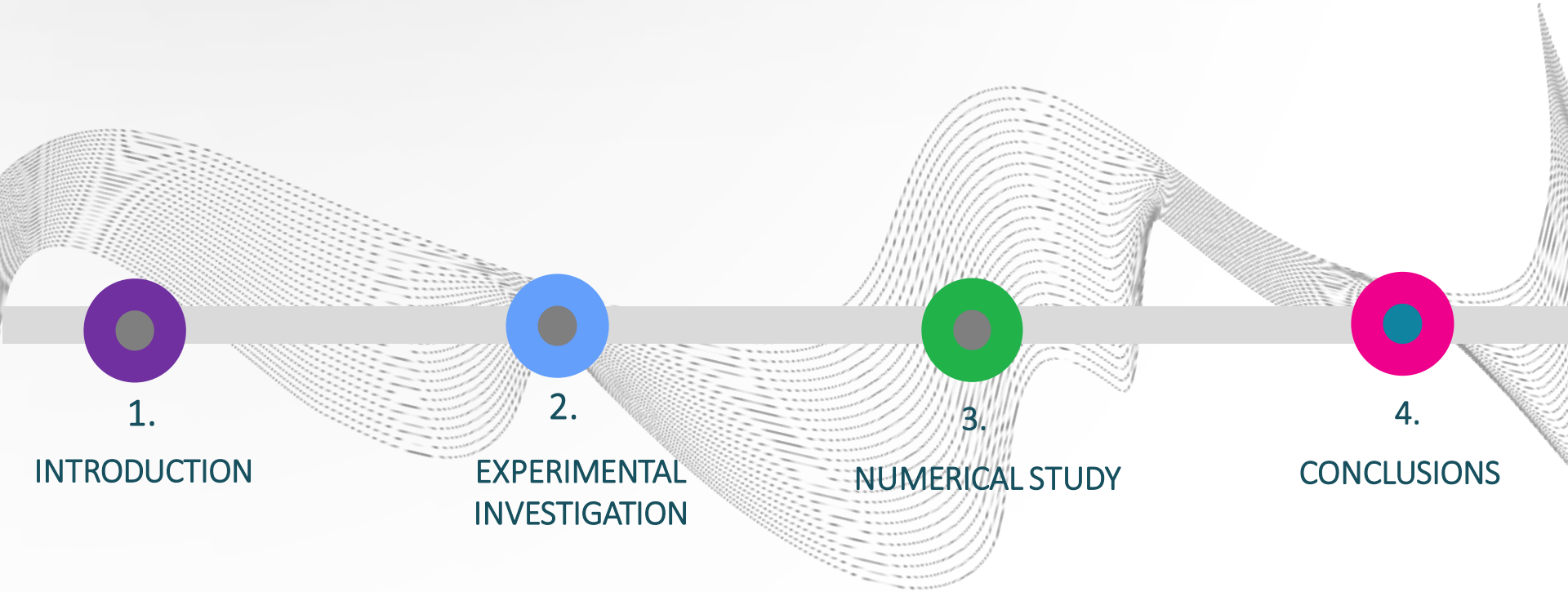
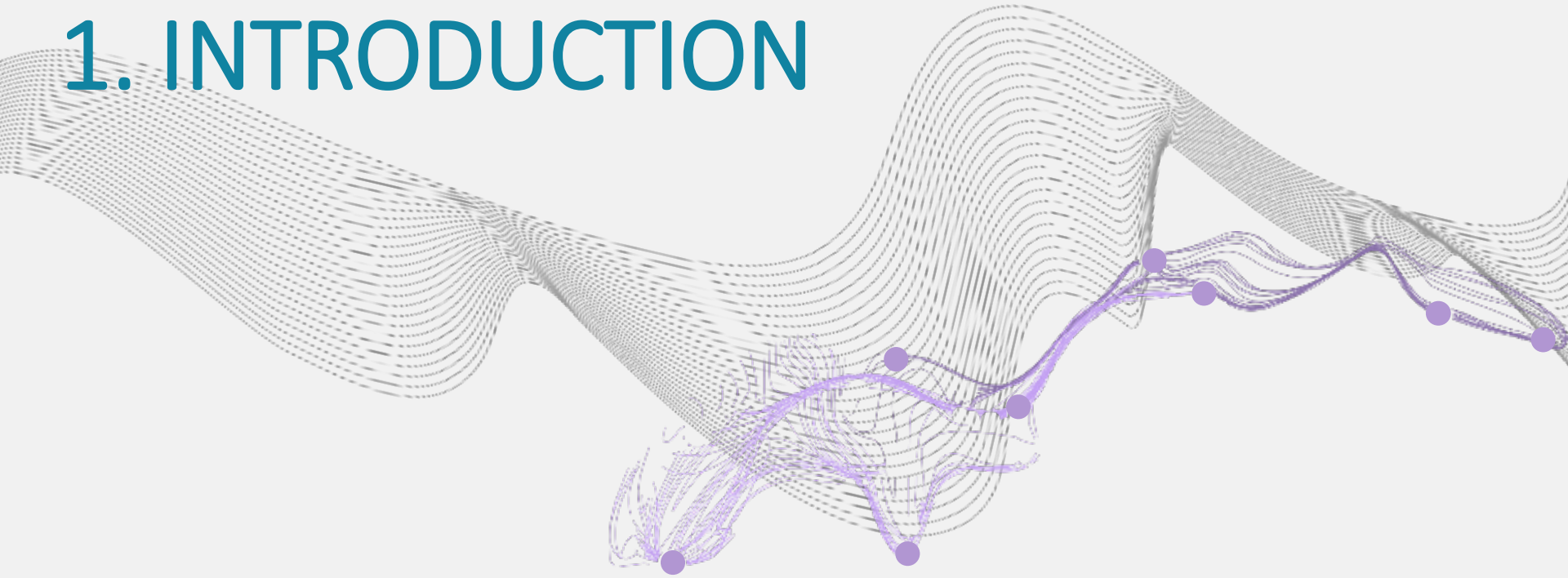
IN THIS PRESENTATION



1. INTRODUCTION
2. EXPERIMENTAL INVESTIGATION
3. NUMERICAL STUDY
4. CONCLUSIONS

1. INTRODUCTION



INDUSTRAIL BACKGROUND

Cold rolling of AHSS

Advanced High Strength Steels allow to:

- reduce the thickness of components;
- maintain high mechanical performances;
- reduce CO_2 emissions through weight reduction.

Rolling of thin strips often suffers from **instabilities**:

- shape defects;
- flatness defects.

Automotive steel

RESEARCH MOTIVATIONS

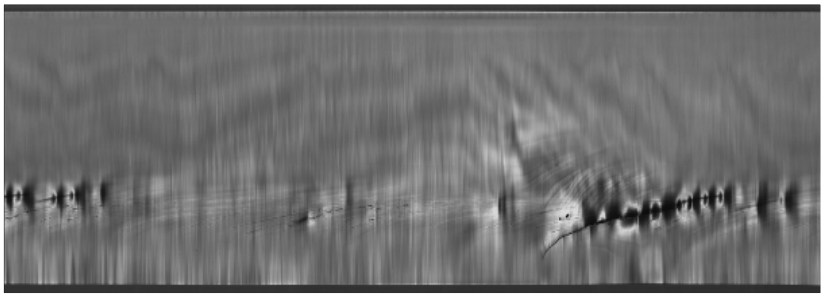
Pinching defects:

- local waviness;
- repetitive ripples;
- local ruptures;
- strip breaks.

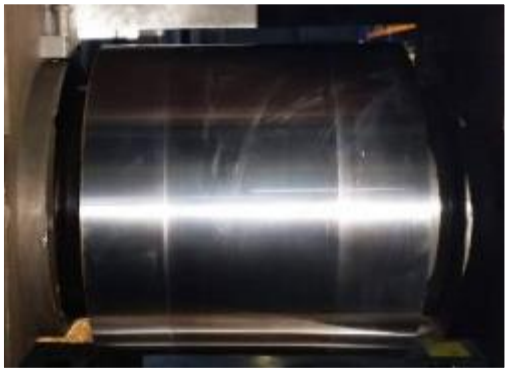
They result in:

- damages to the rolls;
- production delay;
- extra costs.

Rolling direction



Pinched strips from cold rolling production line (5242,88 x 1382,88 mm)



Damaged work roll

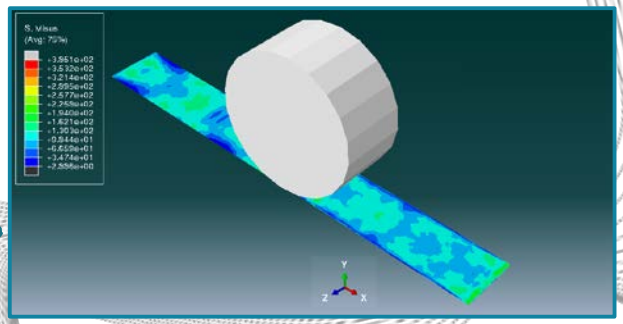
RESEARCH OBJECTIVES

The **industrial aim** of this project is to identify controllable process settings for preventing pinches.

Research objectives are:

- understanding the possible causes and mechanism leading to pinches;
- developing a predictive simulation tool (FEM model).

RESEARCH APPROACH

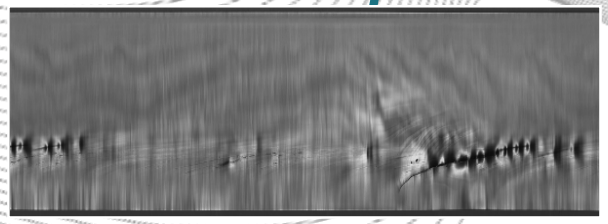


Development of a predictive simulation tool

Experimental investigation

Extensive characterization

Detection of possible mechanism



2. EXPERIMENTAL INVESTIGATION

ROLLING EXPERIMENTS

A set of rolling experiments was performed in a pilot mill (Tata Steel – IJmuiden) to create pinches by sudden perturbations in the rolling conditions.

Packaging steel

Strip width	Entry thickness	Reduction
180.00 mm	0.26 mm	30% - 60%

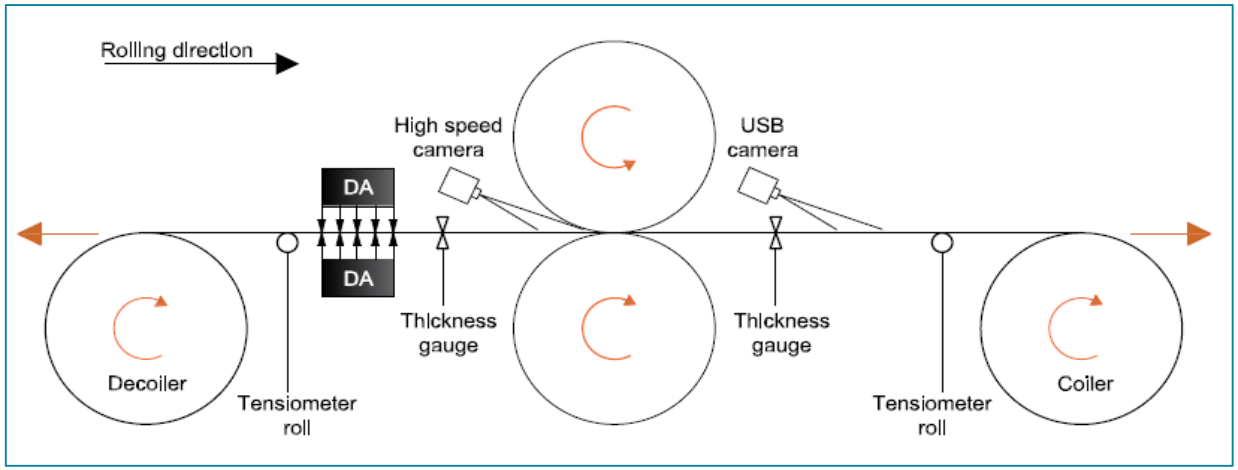
Purpose: answer the following questions.

- What is the nature of disruption that can trigger pinching?
- Which is the relation between shape defects and pinching?
- Which is the mechanism that leads to the formation of pinching defects?

ROLLING EXPERIMENTS

Single stand mill with:

- 2-high and 4-high configurations;
- cylindrical, concave, convex rolls.

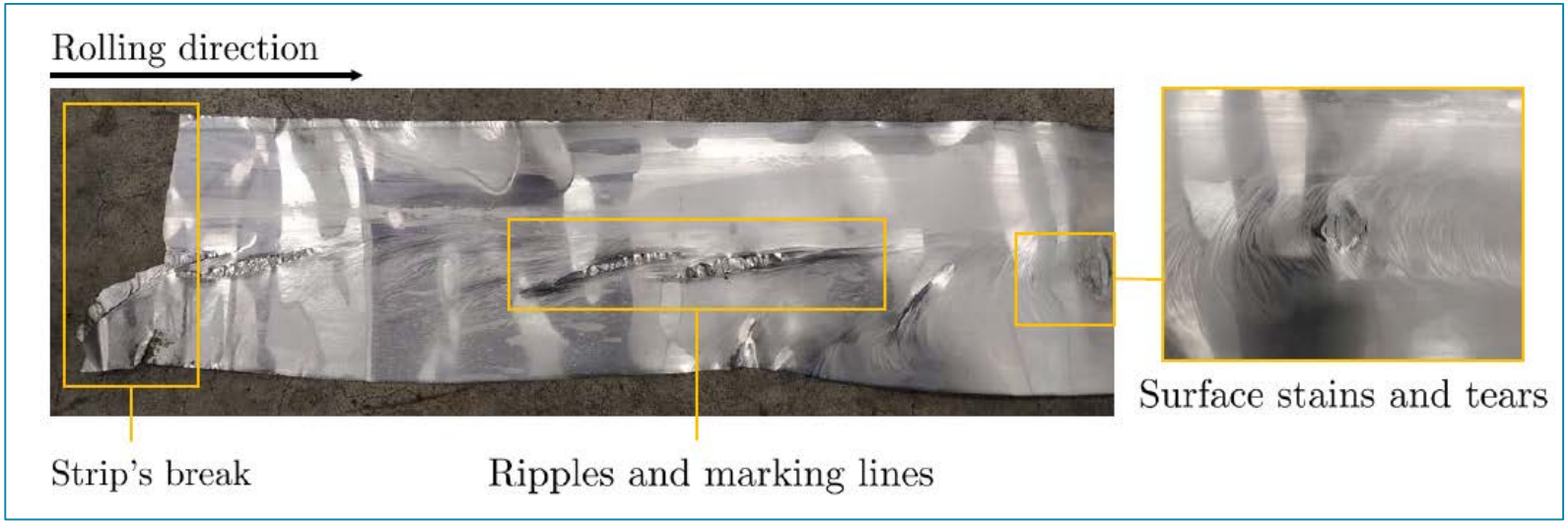


The observed phenomena were studied by:

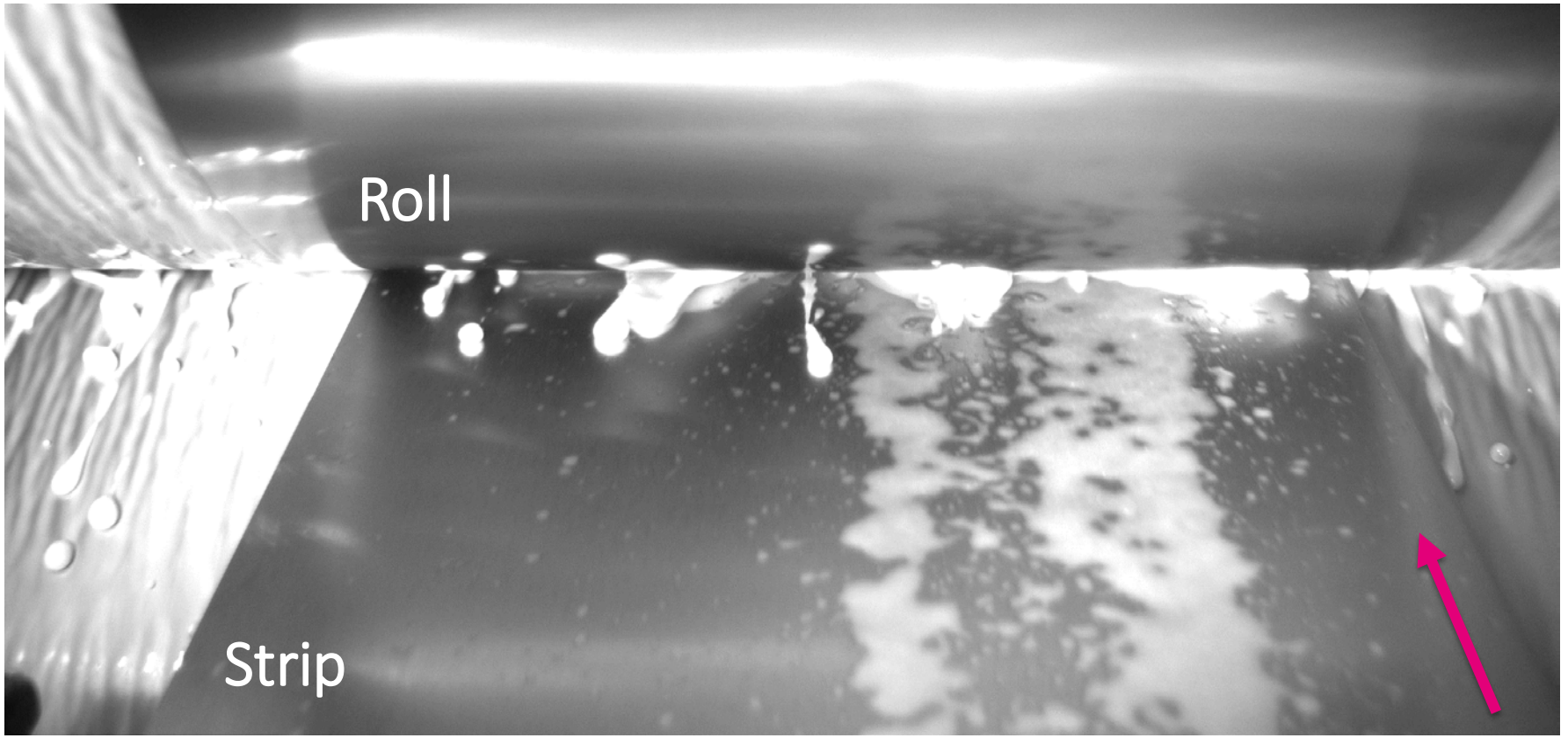
- monitoring the strip's behaviour (cameras);
- analyzing the signals (tension and velocity);
- analyzing the damaged sheets.

OUTCOME OF THE EXPERIMENTS

- Pinching can be created in a **single stand** rolling process;
- Created pinches are comparable with those reported in industrial mills;
- For the specific rolling settings chosen, disruptions in **lubrication** are a powerful mean to create shape defects that develop as pinches;
- The mechanism of formation of pinching from shape defects can be identified.

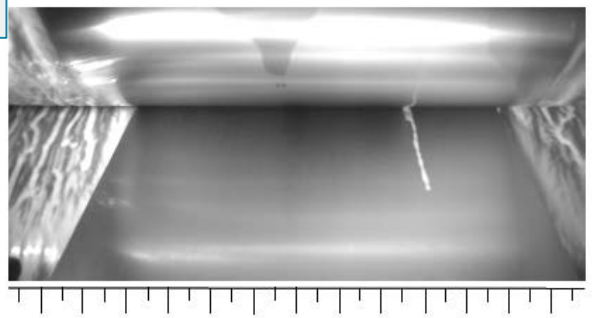


MECHANISM OF PINCHING



MECHANISM OF PINCHING

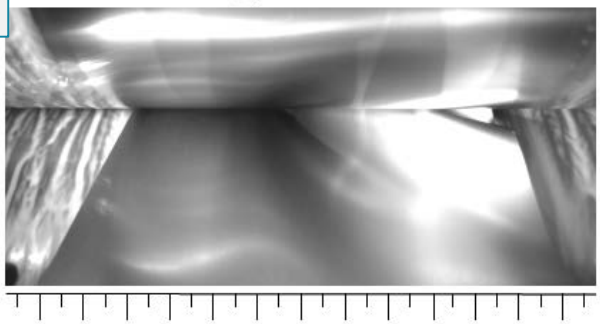
1



1) Disruption in the process: sudden changes in lubrication

- conditions at the roll bite change;
- difference of thickness reduction over the strip's width;
- uneven strip's velocity.

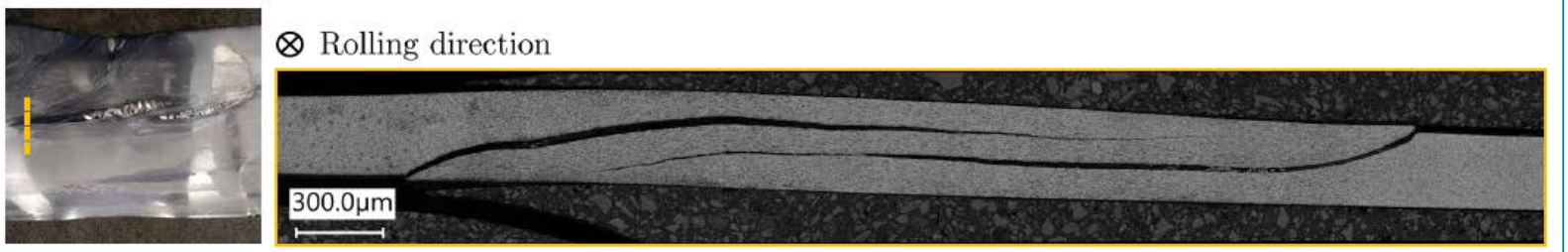
2



2) Shape problems: waviness upstream of roll bite

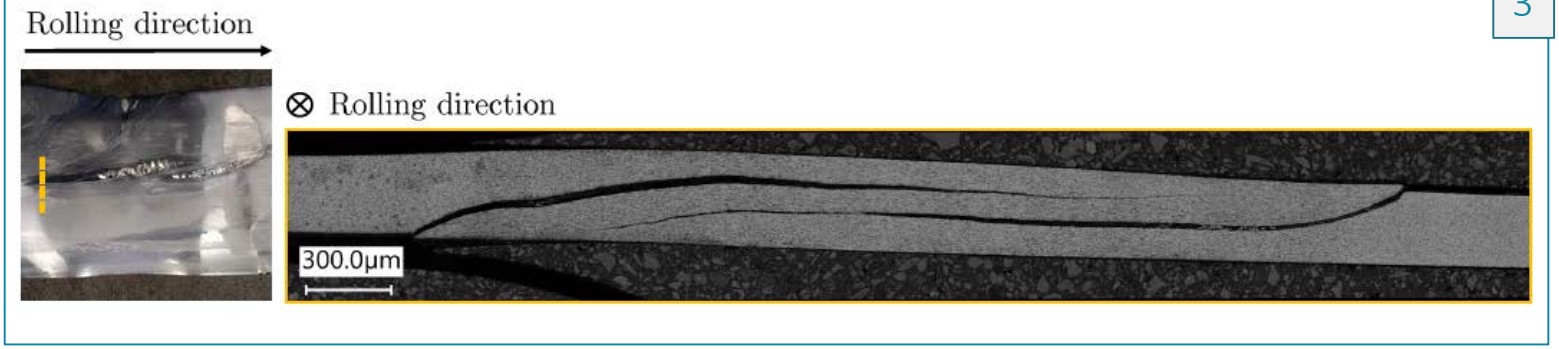
3) Buckles pass through the work rolls, topple on the side, creating folds

3

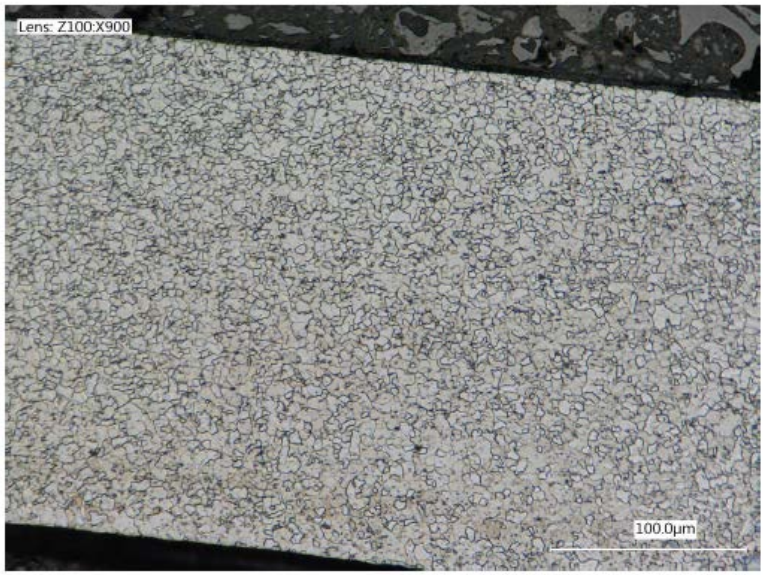


MECHANISM OF PINCHING

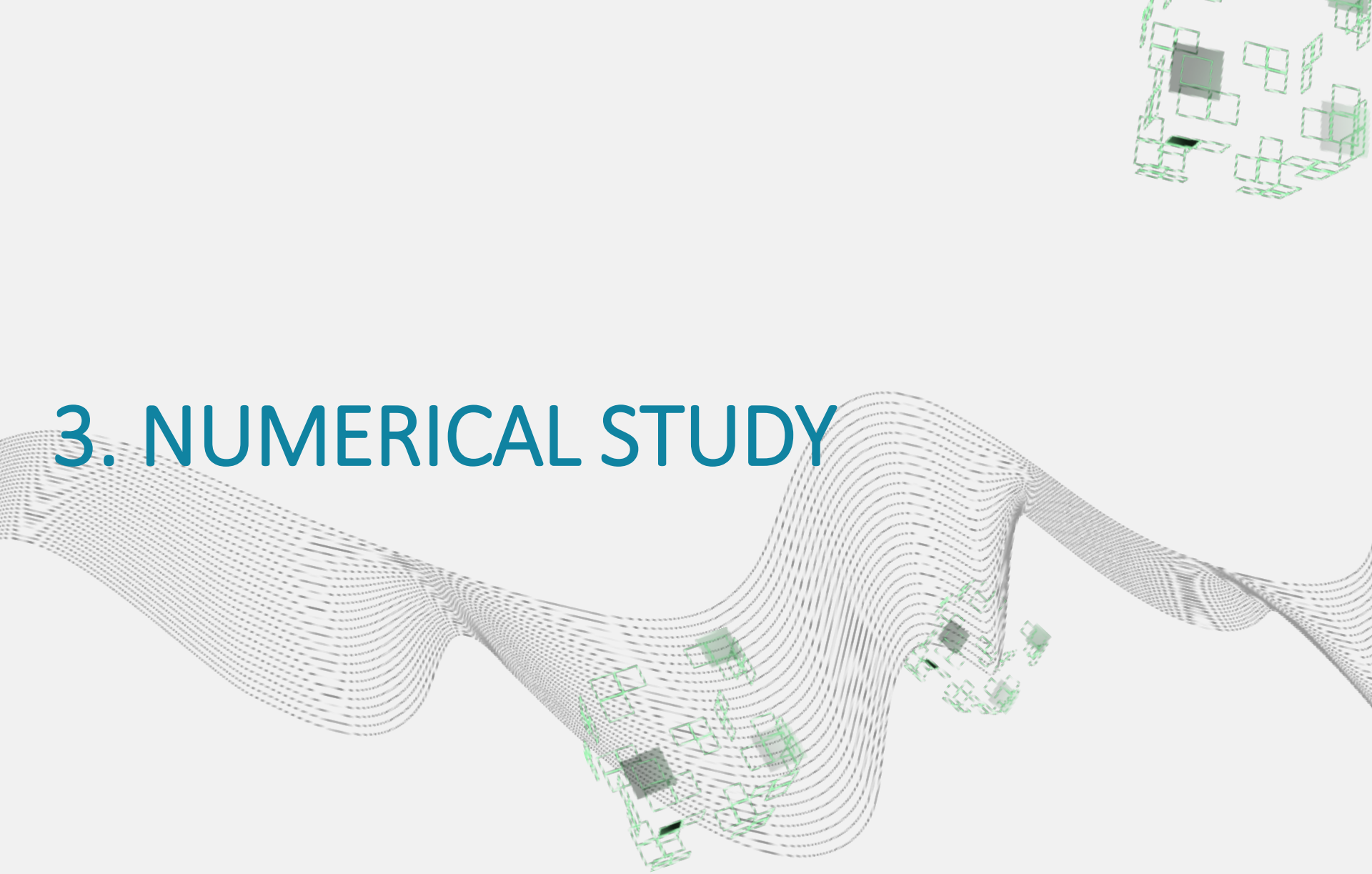
3



Microstructure in the defect zone.

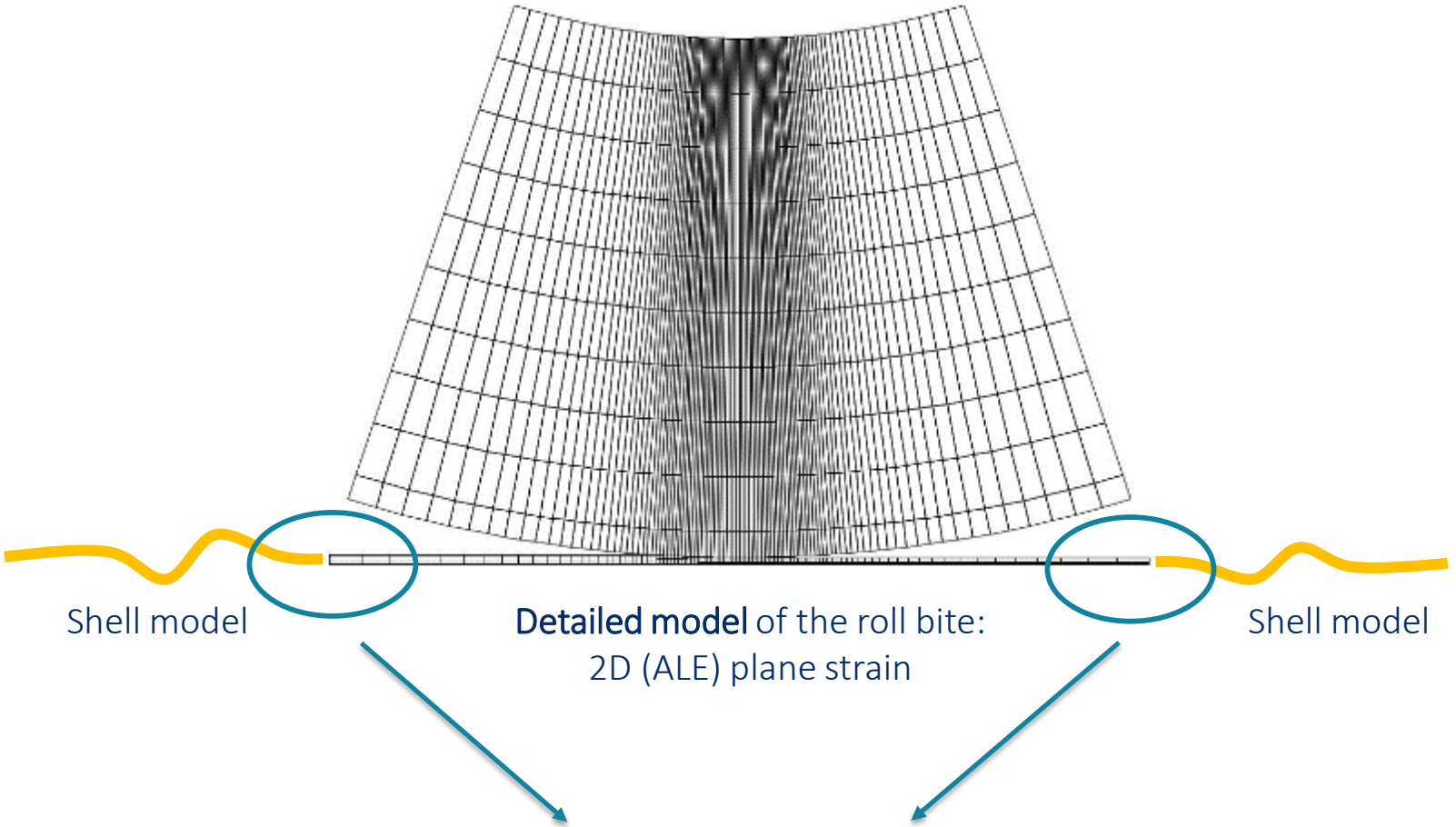


Microstructure out of the defect zone.



3. NUMERICAL STUDY

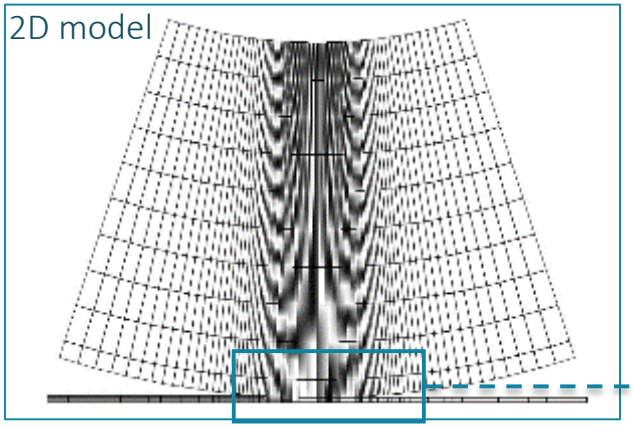
NUMERICAL MODEL FOR PINCHING

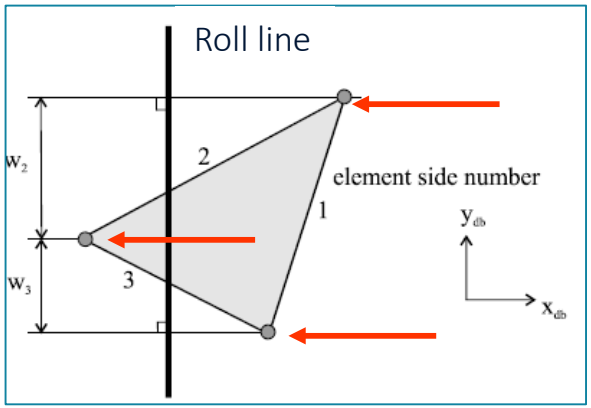


Coupling 2D-3D models via an **equivalent rolling model**

THE EQUIVALENT ROLLING MODEL

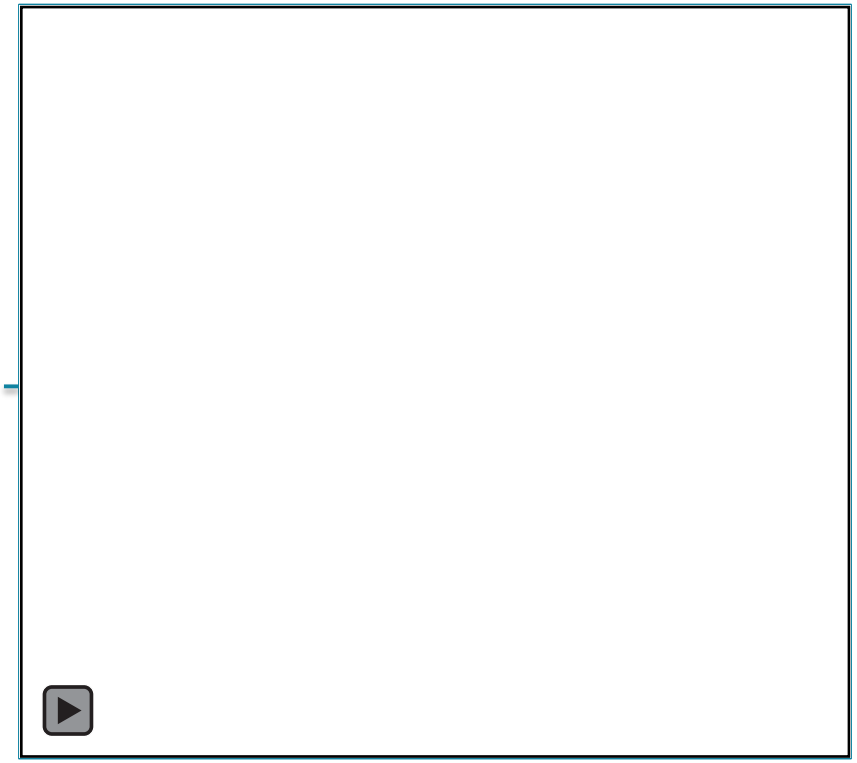
The roll-strip interaction is reduced to a line where a numerical algorithm acts.





Thinning (thickness strain)

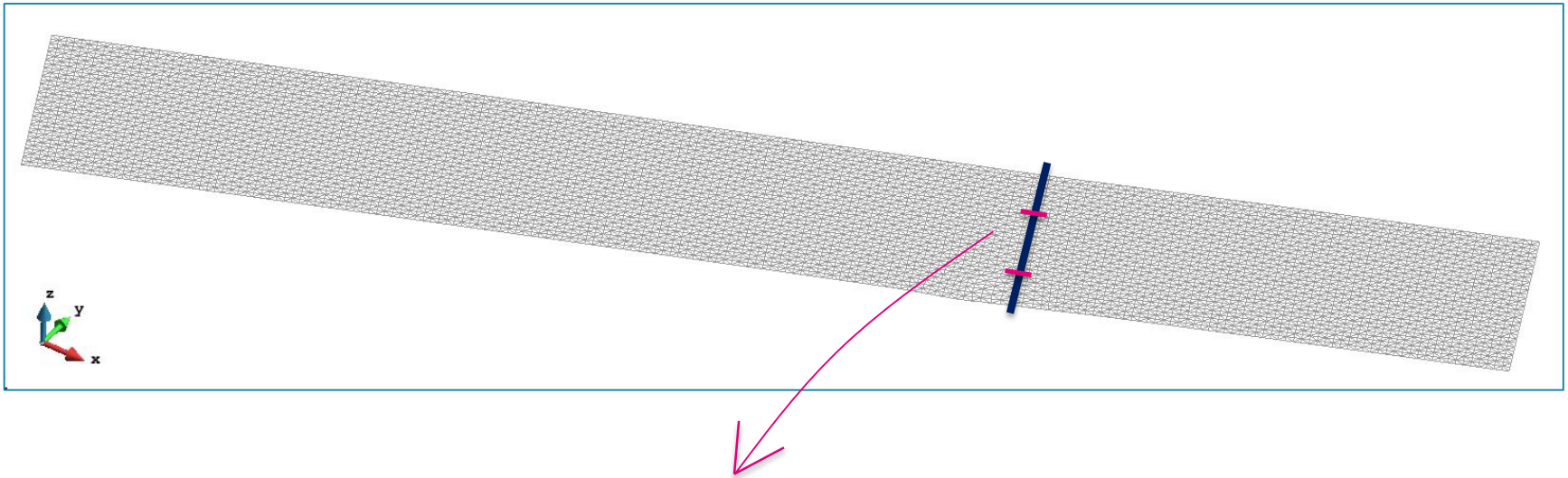
Forces opposing the flow



Reference: V. Meinders, B. Carleer, B. Carleer, H. Geijselaers, and H. Huetink, The implementation of an equivalent drawbead model in a finite-element code for sheet metal forming," Journal of materials processing technology, vol. 83, no. 1-3, pp. 234{244, 1998}.

THE EQUIVALENT ROLLING MODEL

How to predict pinching with the equivalent rolling model?

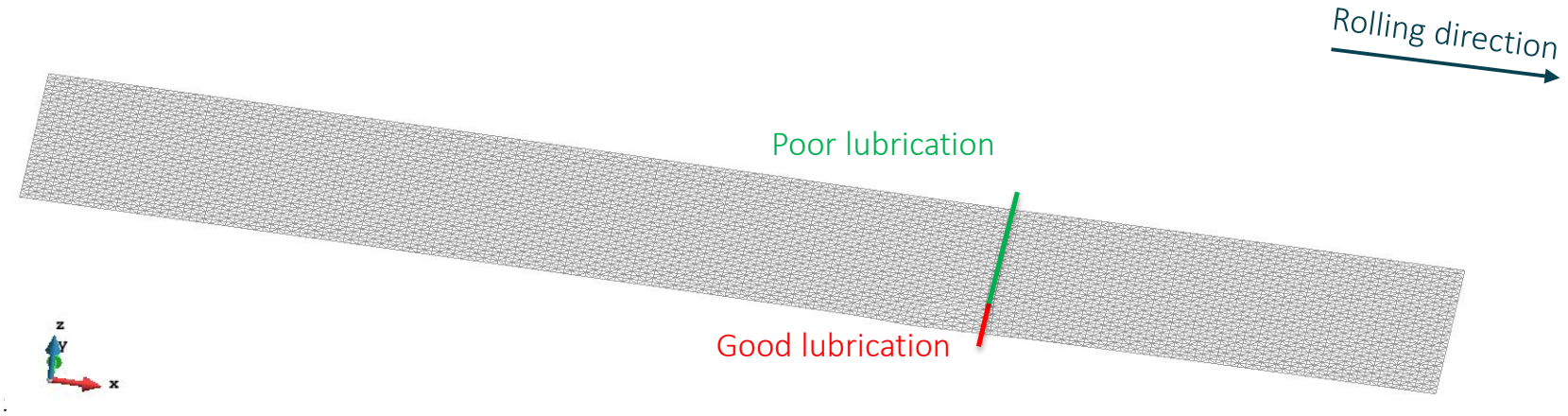


Apply non-uniform conditions over the strip's width at the roll bite (different strains and forces) to induce **shape defects**.

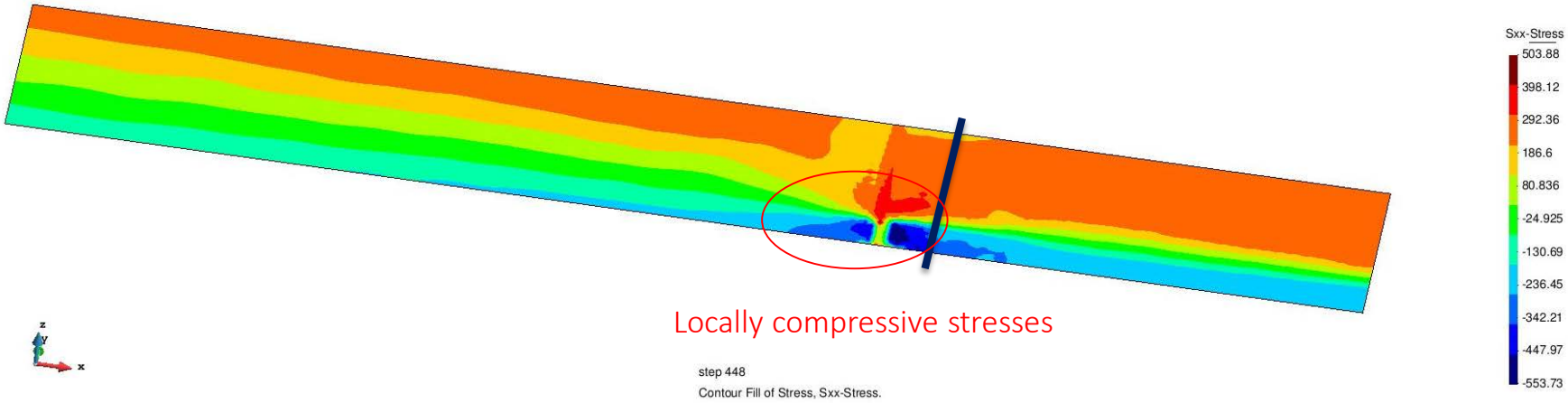
Input (different strains and forces) for the equivalent rolling model is obtained from the 2D plane strain model:

- different simulations;
- different rolling conditions.

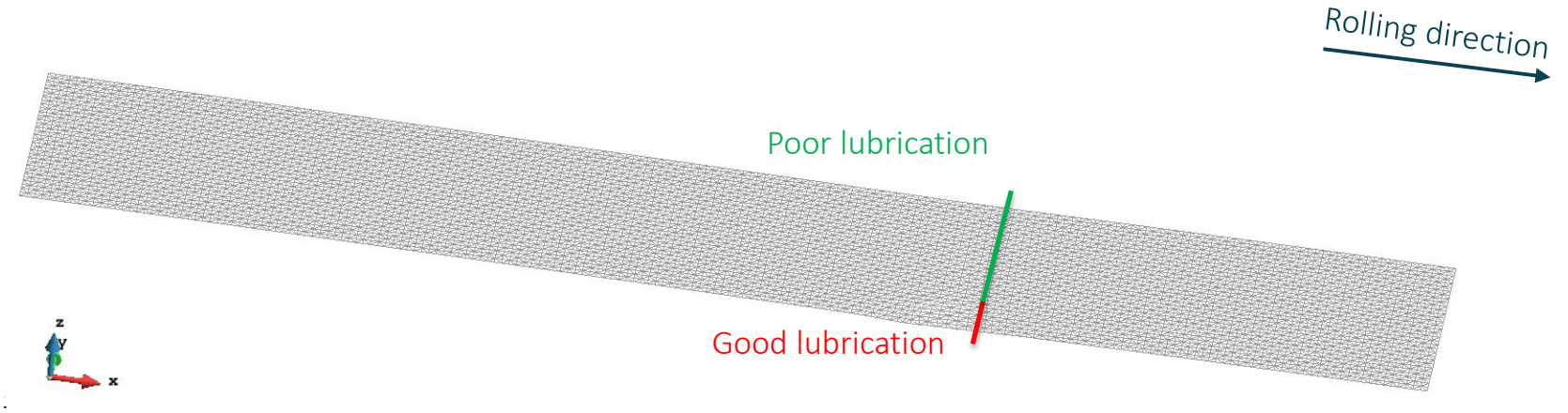
SIMULATION OF PINCHING



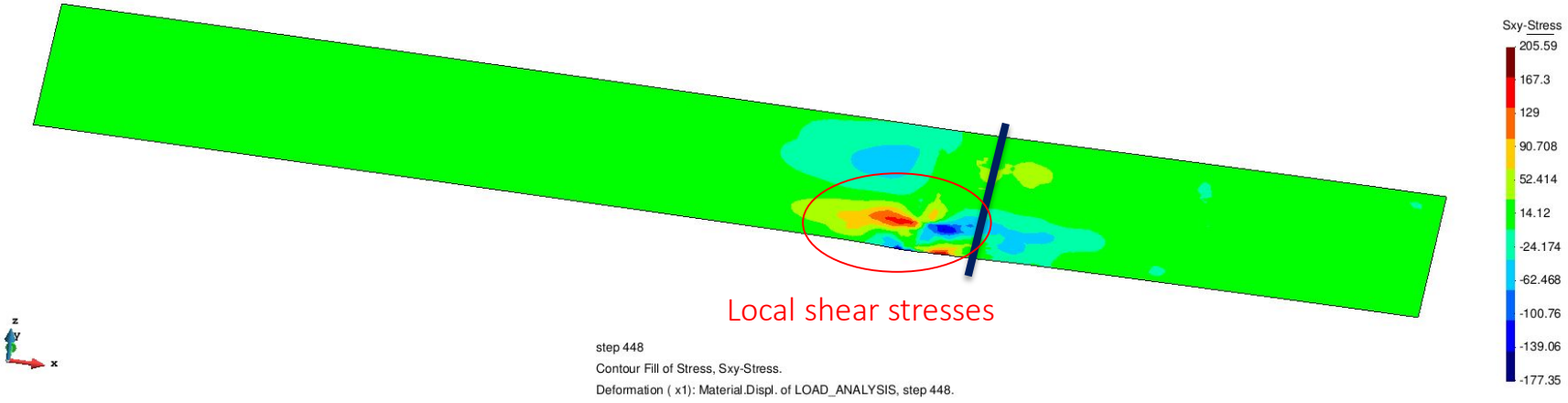
Stress in rolling direction (S_{xx}):



SIMULATION OF PINCHING

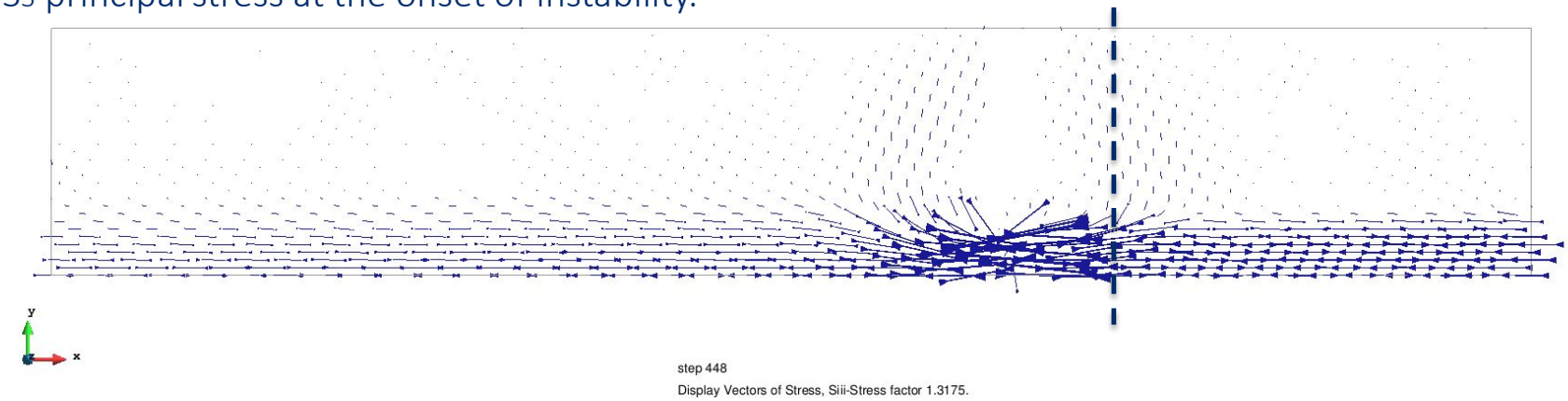


In-plane shear stress (S_{xy})

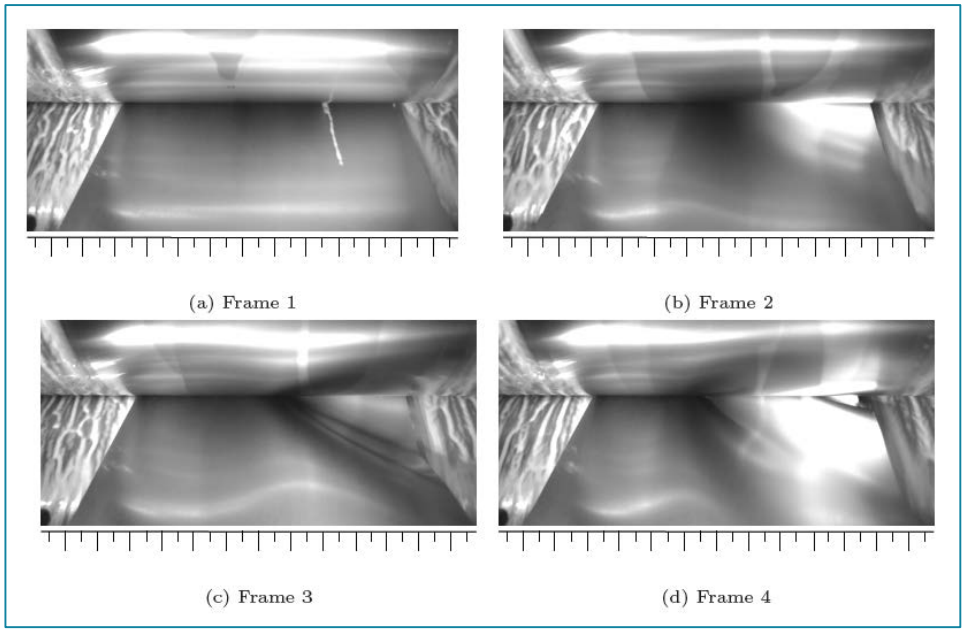


SIMULATION OF PINCHING

S_3 principal stress at the onset of instability.

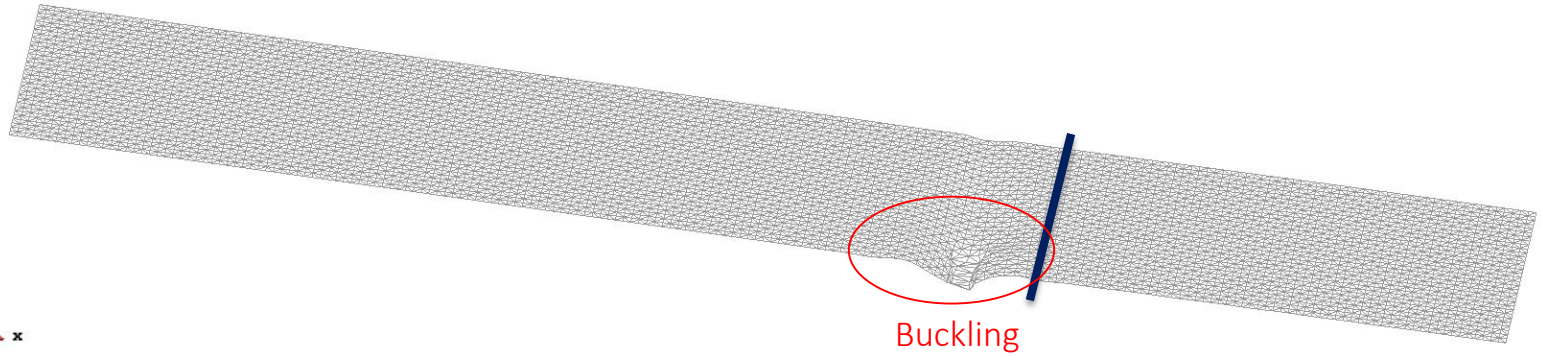


View form the entry side of roll bite.



PINCHING

Strip's deformed configuration.



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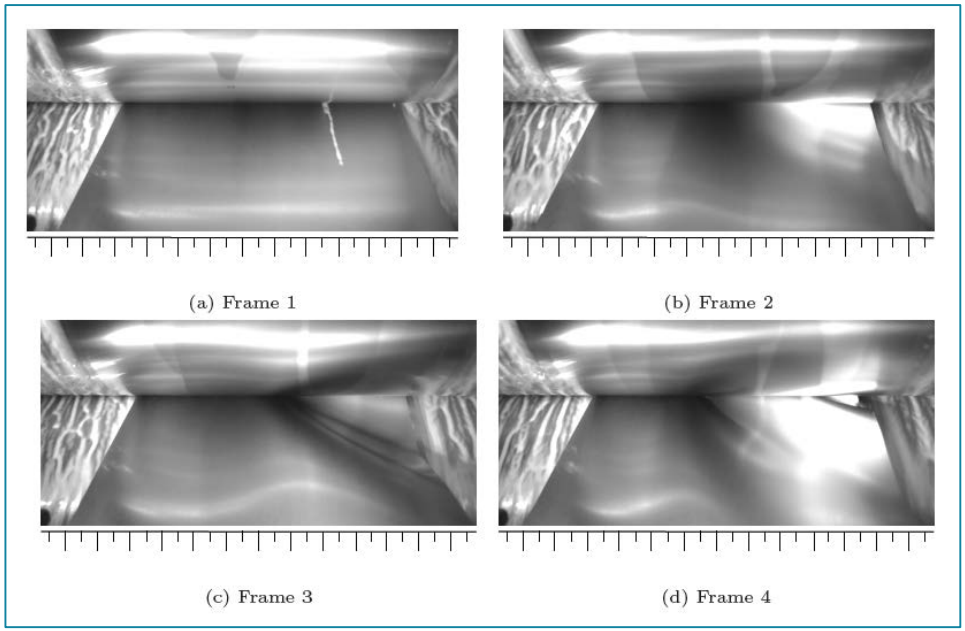

4. CONCLUSIONS

CONCLUSIONS

EXPERIMENTAL INVESTIGATION

- Pinches can be created in a **single stand** rolling process;
- During rolling, conditions in the roll bite may vary, due to **disruptions** in the process;
- These changes may lead to **uneven thickness reduction**, which results in **shape defects**;
- Locally compressive stresses are the source of **buckling** at the entry side of the roll bite;
- **Folds** develop when buckles pass through the rolls (ripples);
- Repetitive **ripples** are the prominent features on pinched strips.

Main contribution to the research field: relation between shape defects and pinching has been identified.

CONCLUSIONS

NUMERICAL INVESTIGATION

- A **detailed model** is needed to model the deformation process in the roll bite;
- An **equivalent rolling model** can be connected to the detailed model to simulate the 3D strip's behavior out of the roll bite;
- The equivalent rolling model can be used to represent the strip's behavior due to uneven conditions at the roll bite: **shape defects**.
- Similar strip's behaviour as in the pinching tests can be reproduced.

Industrial value: the pinching predictive model can be used to identify pinching sensitive regimes.

Final utilization goal: control strategies can be implemented to keep stable rolling conditions.

Thank you.

Contact: a.cometa@utwente.nl.

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