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FE Simulation of Interfacial Delamination between SiO_2 Thin Film and Polymeric Substrate

C. Ho [1-2], A.Tongne [1], O. Dalverny [1], J. Alexis [1], A. Dehoux [2], S. Châtel [2], B. Faure [2]

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[2] Essilor International R&D – *Créteil, France*

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EUROMAT 2017
EUROPEAN CONGRESS AND EXHIBITION ON ADVANCED MATERIALS AND PROCESSES

General outline

1. Context
2. Experimental study
3. Numerical modeling of the test
4. Numerical simulation results
5. Conclusions and perspectives

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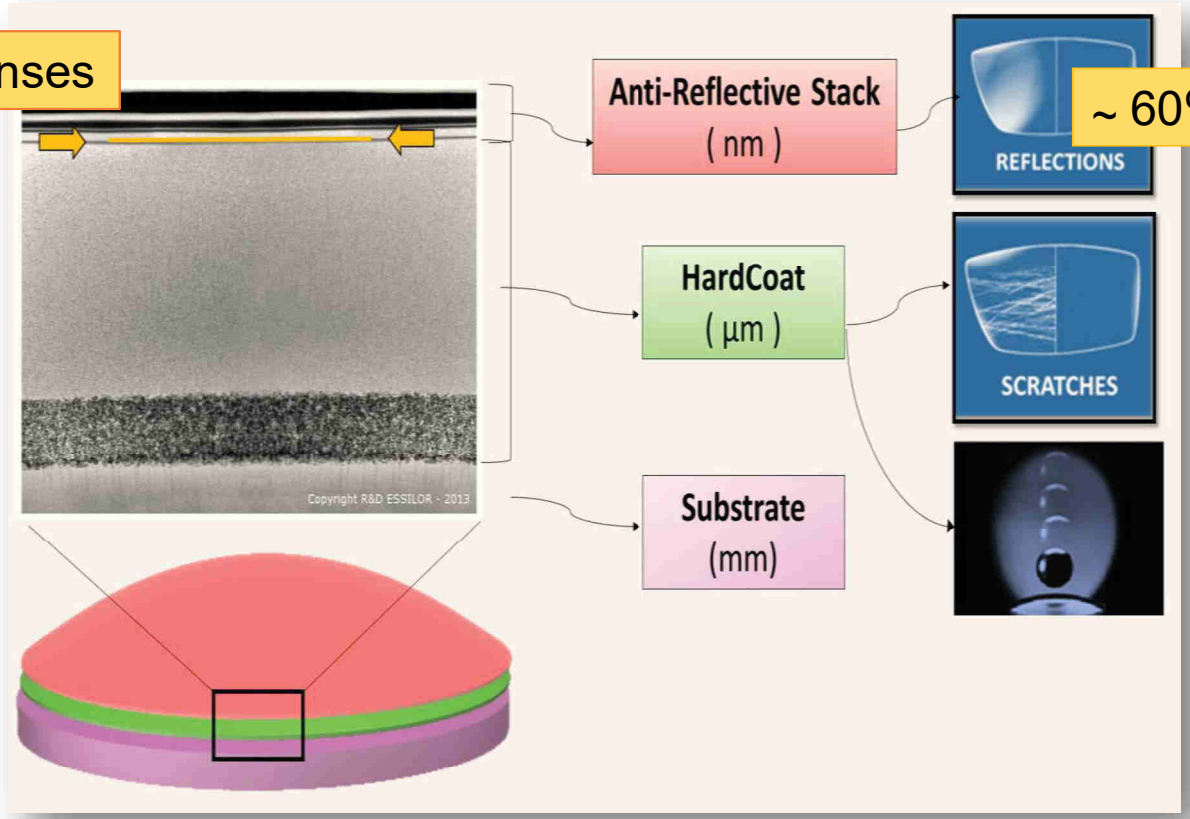
Context

70% of French population uses vision correction products

« Les Français et l'optique », Institut Ipsos (2012)

~ 10% contact lenses

~ 60% eyeglasses



→ Ophtalmic lens is a complex system (structure and materials)

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Challenge

- Insufficient adhesion between layers can lead to delamination

Delamination after Process Modification

→ Important margin of safety prior to product launch

Need of a better understanding of mechanisms of adhesion

<u>Simplification of the system</u>: Study of Adhesion of SiO_2 thin film on Hardcoat

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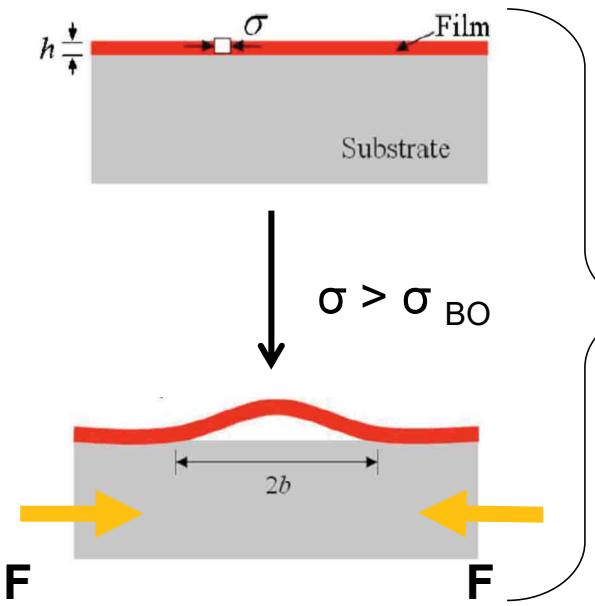
Experimental study

Adhesion Characterization by compression test

➢ Buckling by compression test

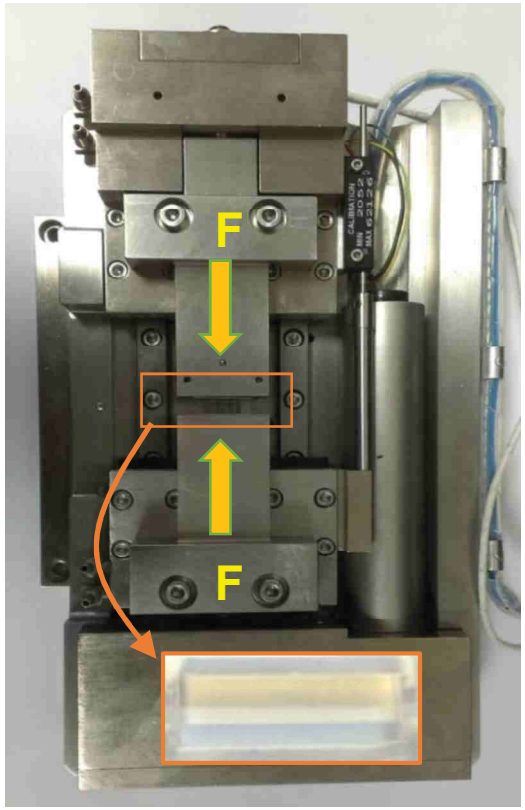


Hutchinson & Suo analytical model

↓

T(ψ), Energy Release Rate

➢ Experimental Set-up



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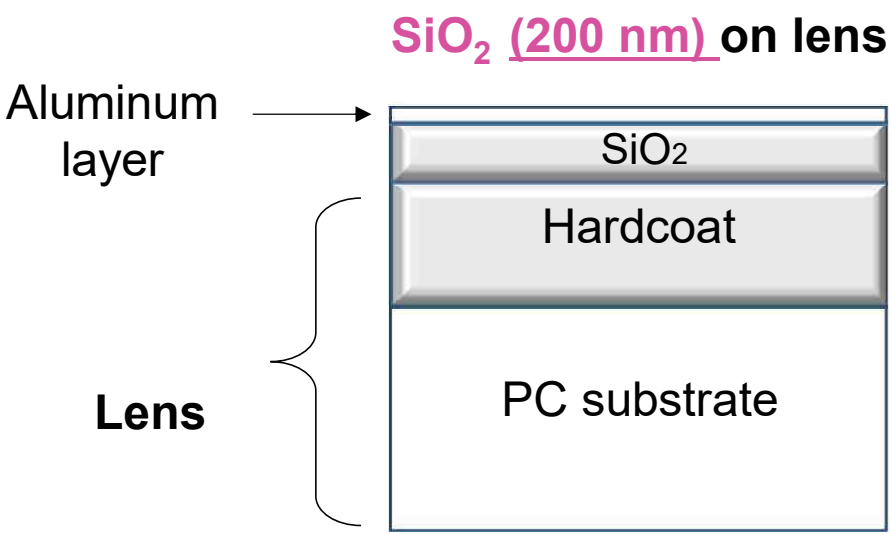
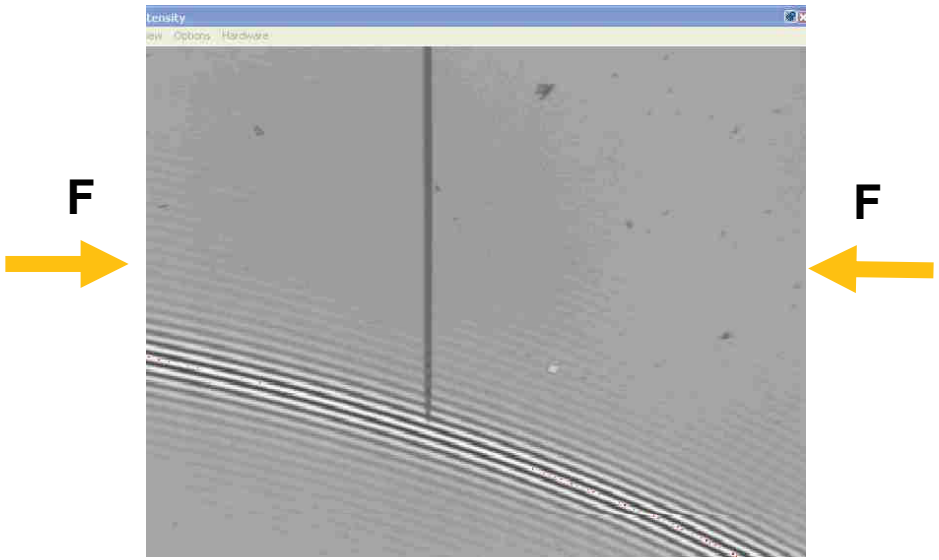
Experimental results

➢ Configurations of samples

➢ Video of buckling





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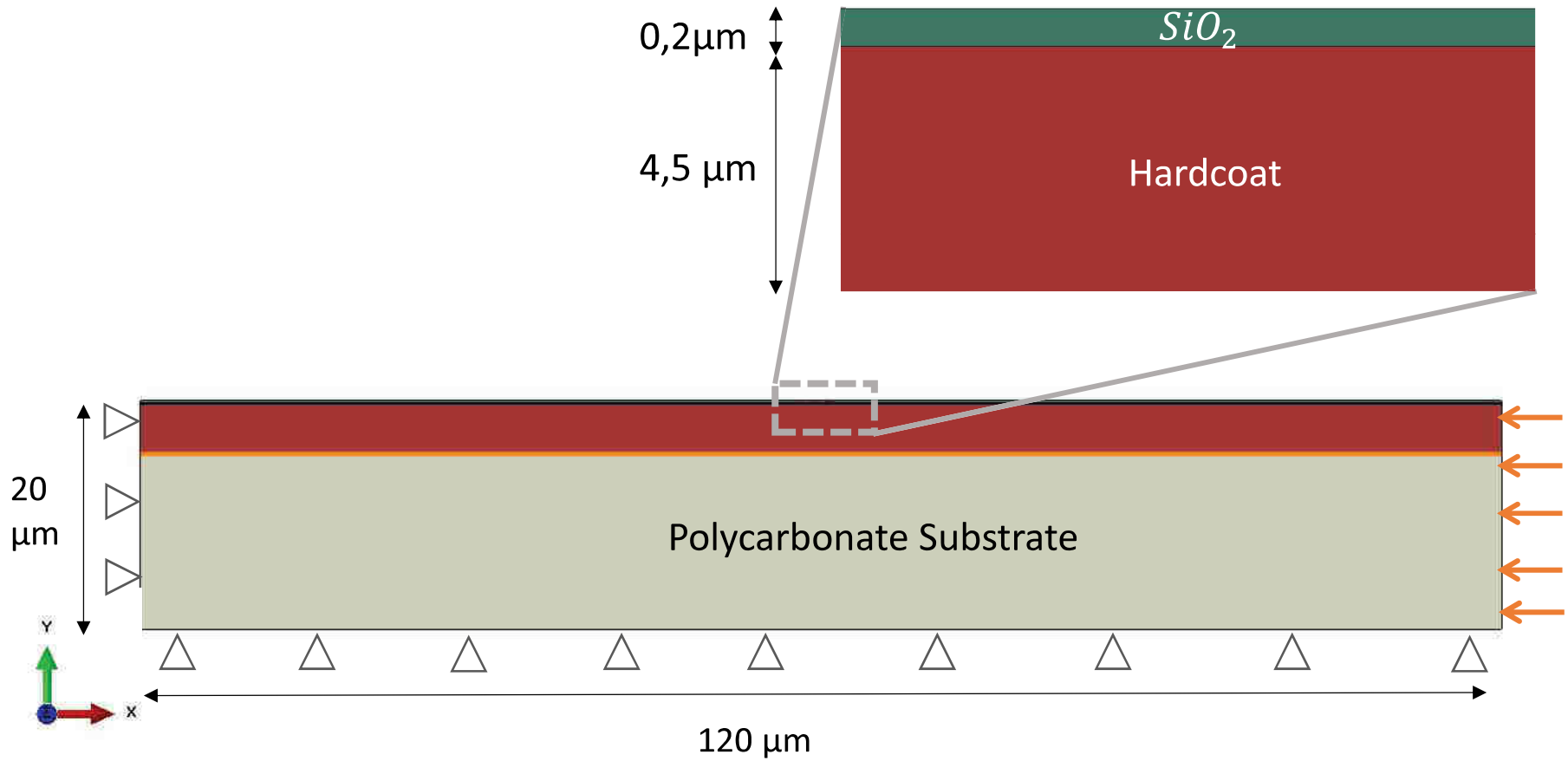
Numerical modeling of the test

Description of Numerical model

Geometry | Boundary conditions



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Numerical modeling of the test

Description of Numerical model

Physical model

- **Solving the momentum equation : Instability caused by buckling**
- **Interface degradation using damage model**

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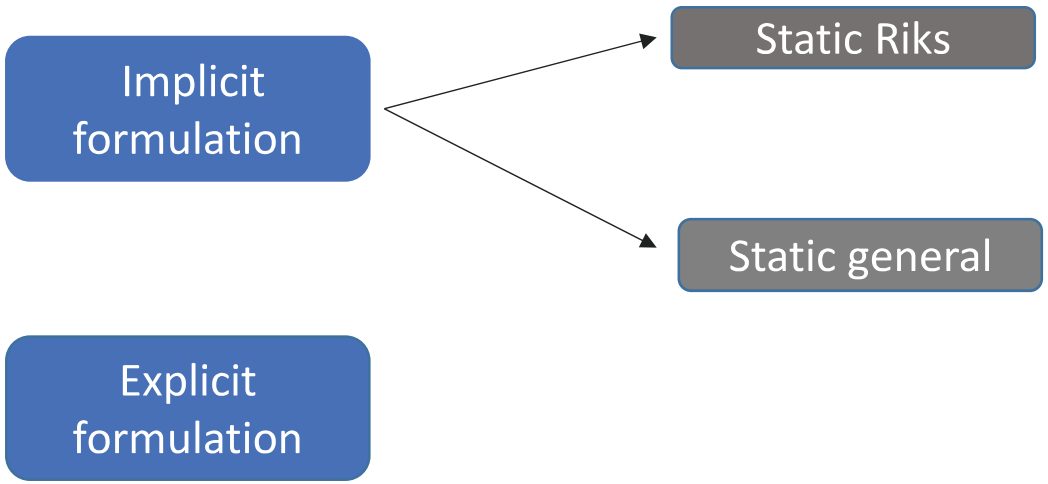
Description of Numerical model

Physical model

- **Solving the momentum equation : Instability caused by buckling**



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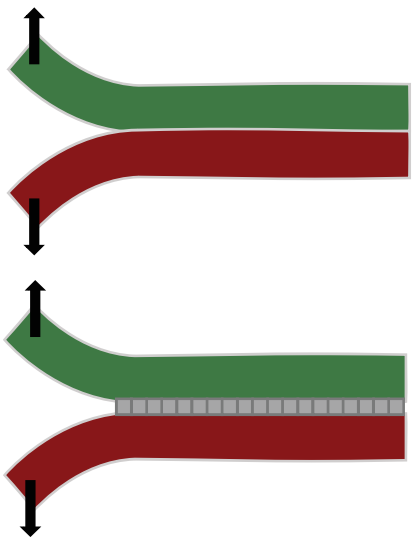
Numerical modeling of the test

Description of Numerical model

Physical model

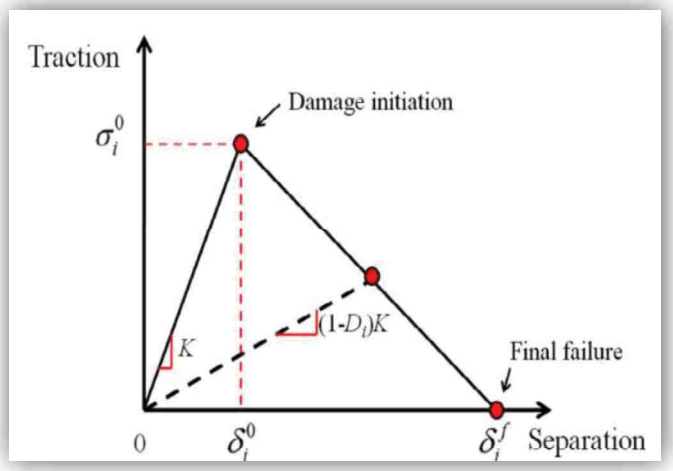
- Solving the momentum equation: Instability caused by buckling
- **Interface degradation using damage model**



Cohesive surface

Cohesive element

Traction – Separation Law



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Numerical modeling of the test

Description of Numerical model

Materials Properties

SiO_2 thin film	**E, ν**
Hardcoat	**E, ν**

Interfacial Properties

Cohesive Behavior	K_I $K_{II} = K_{III}$
Tangential Behavior	Frictionless
Damage Initiation	$\sigma_I = \sigma_{II} = \sigma_{III}$
Damage Evolution	Total Displacement
Damage Stabilization	Viscous Stabilization

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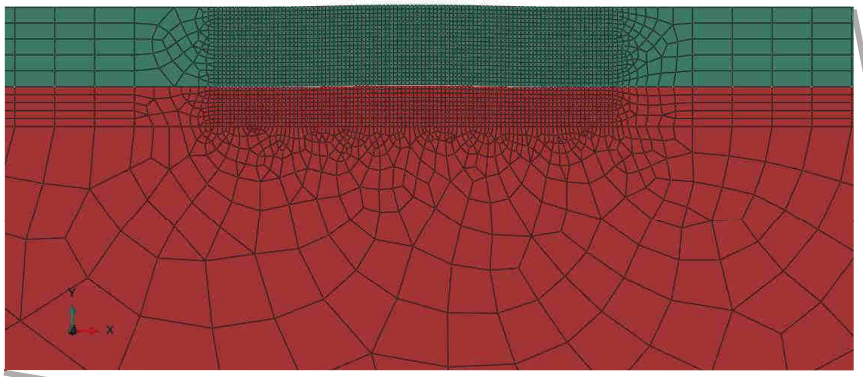
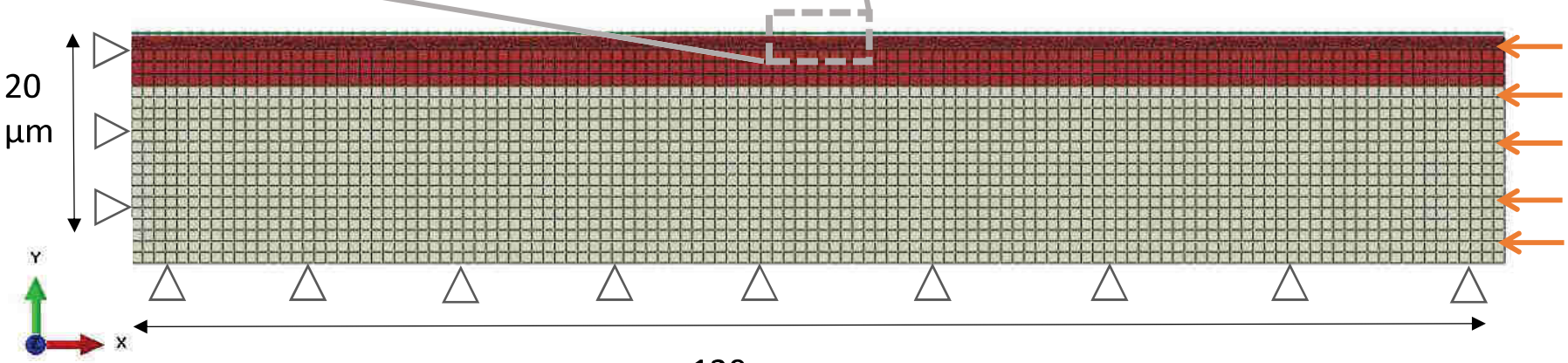
Numerical modeling of the test

Geometry | Boundary conditions | Mesh

- **Homogeneous meshing** near the interface
- **Element Type** : CPS4, CPS3
- **Element Size**
  - → Defect : x = 10 nm ; y = 0,1 nm
  - → SiO_2 layer : x = 100 nm ; y = 40 nm
  - → First 100 nm of Hardcoat
    x = 100 nm ; y = 20 nm



SiO_2 200 nm



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Numerical simulation results

- Video of simulated buckling

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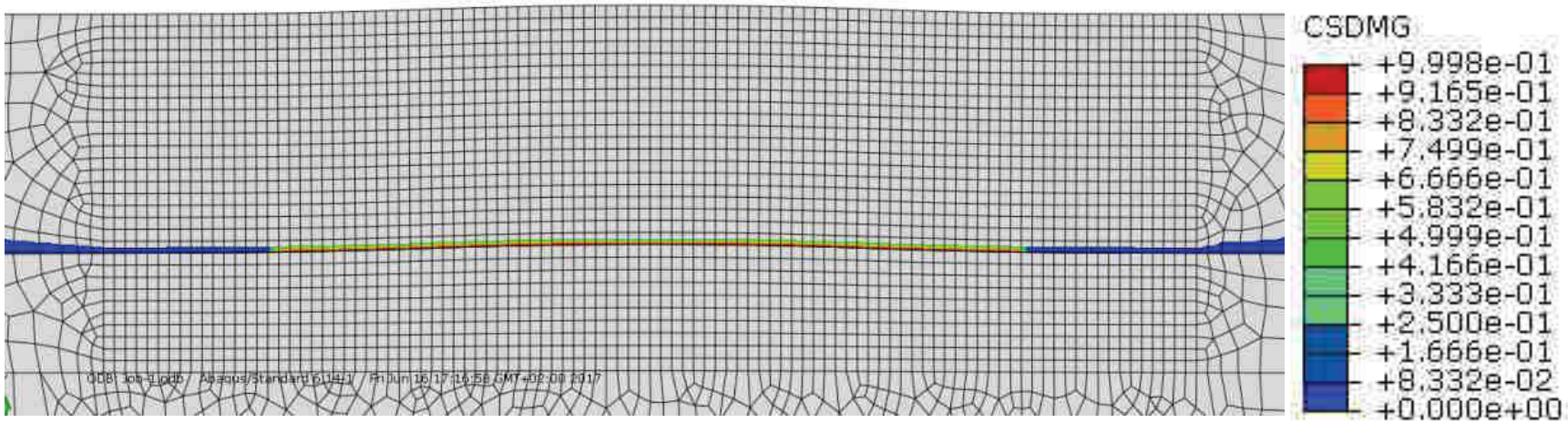
Numerical simulation results

- Interface damage variable CSDMG



➢ <u>Initiation Strain</u>

Experimental : 3,8 % strain
Numerical : 3,9 % strain

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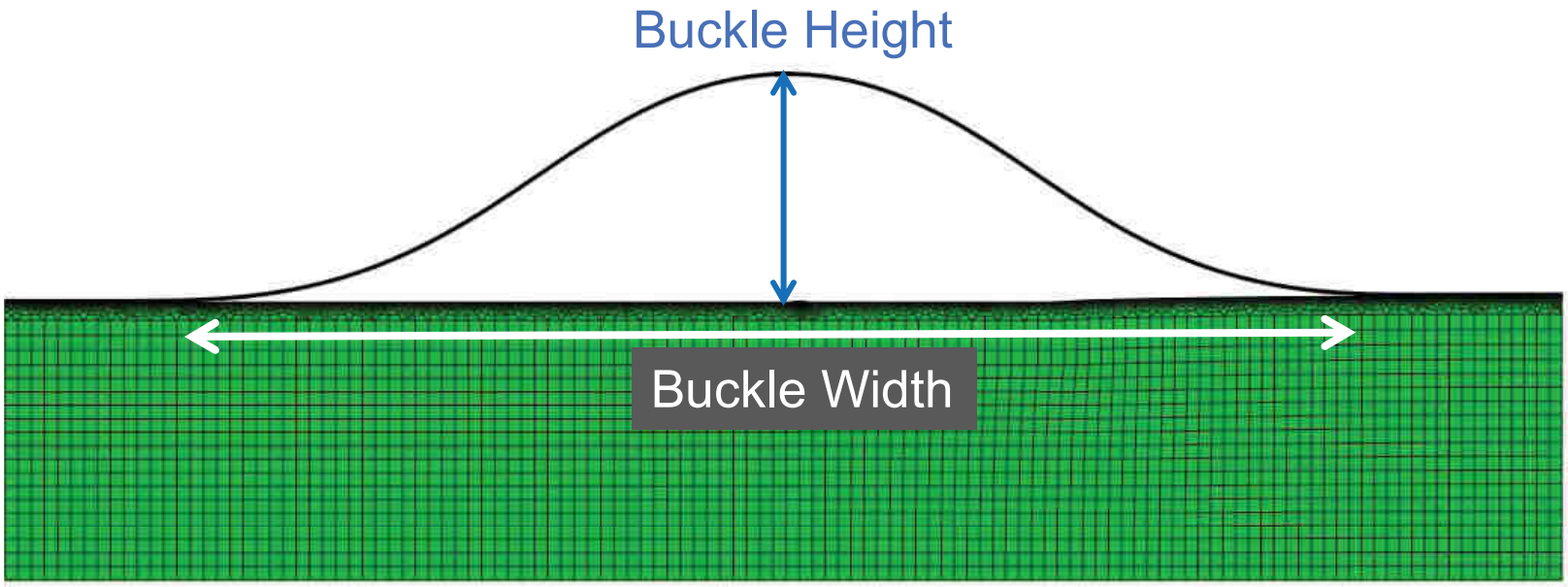
Numerical simulation results



➢ <u>Buckle Height</u> Experimental : 6 µm Numerical : 15 µm	➢ <u>Buckle Width</u> Experimental : 51 µm Numerical : 73 µm

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Conclusions and Perspectives

Conclusions

- Model using static calculation with cohesive surface
  → Buckling obtained with numerical model
- Good match of Initiation strain with experimental results
- Buckle dimensions to be improved upon

Perspectives

- Parametric study
- Analysis of energy dissipated

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Acknowlegments

Essilor International
Innovation and Technology Center

ANRT
Research and Technology National Association

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