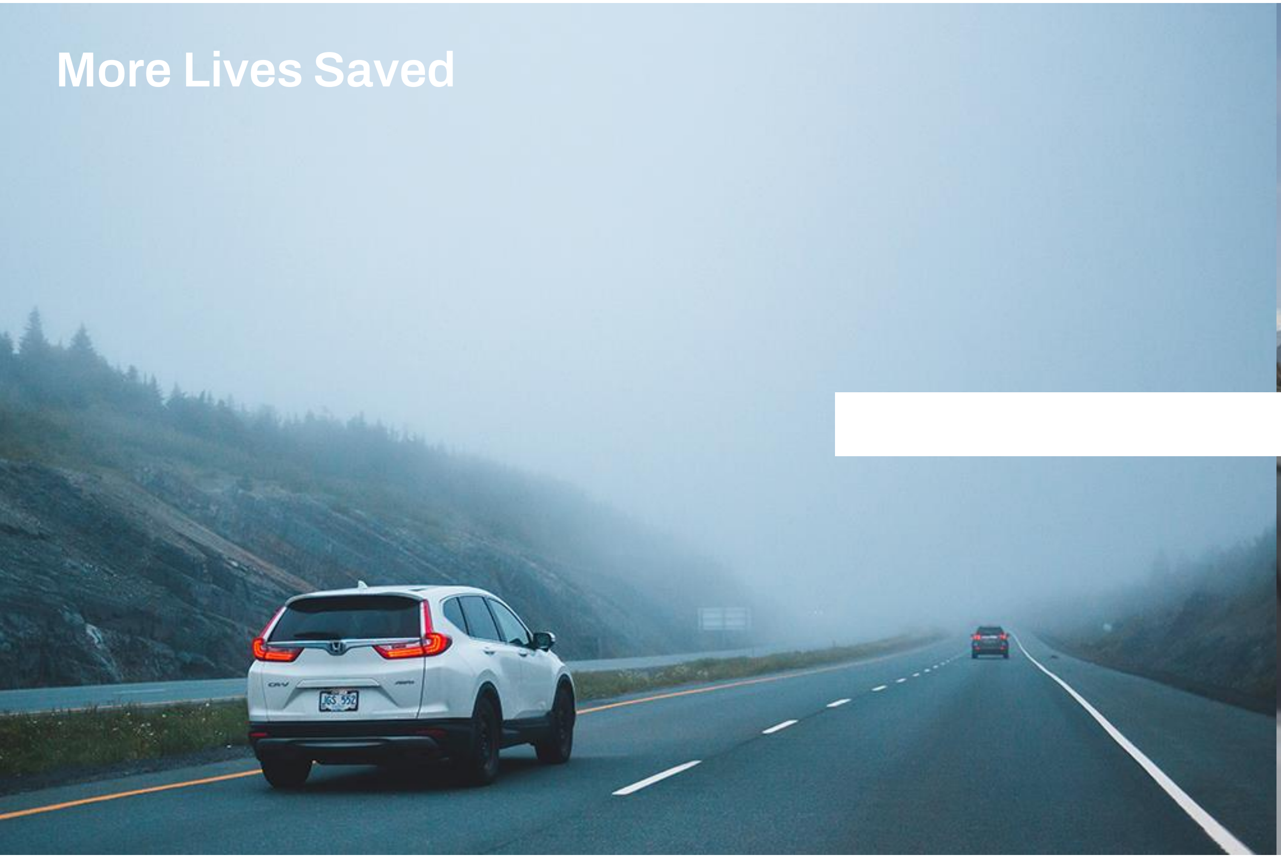

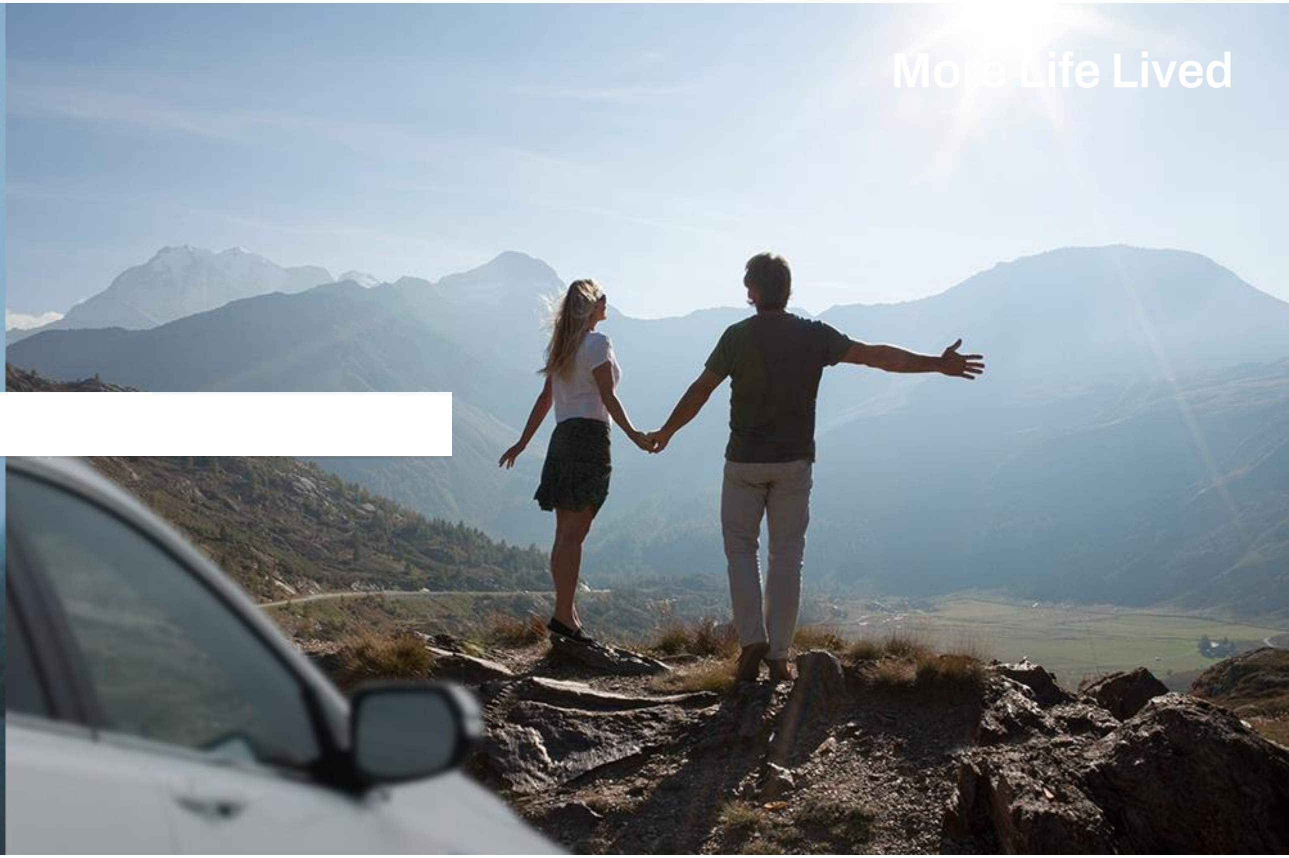

A novel method for characterizing seatbelt webbing bending response under tension force

Stefan Schilling; Dr. Anurag Soni; Dr. Tom-Michael Voigt; Felix Manneck; Stephan Gathmann

16. LS-DYNA Forum 2022, Bamberg, Germany

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Content

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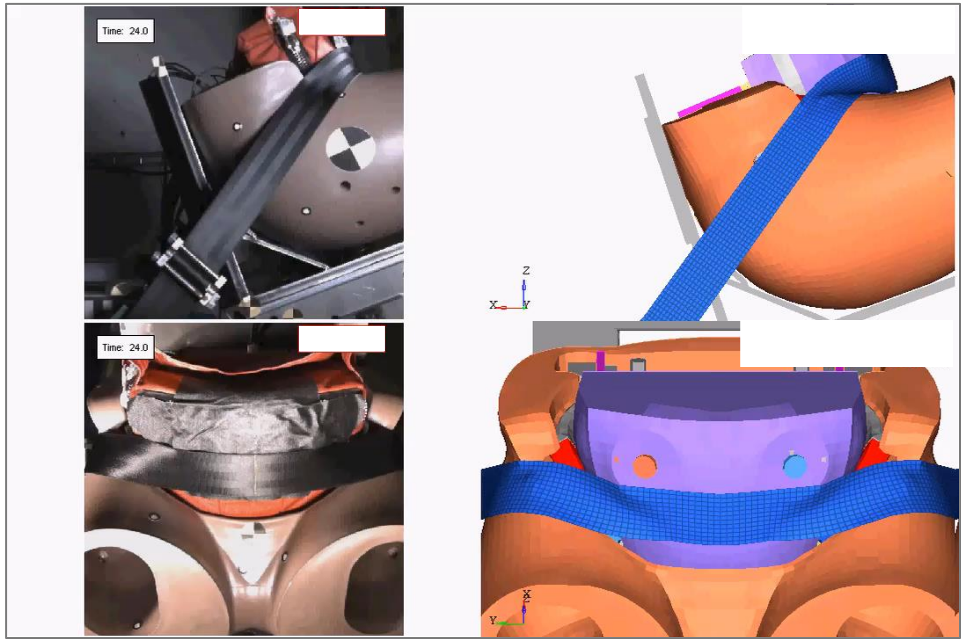
  Internal

Introduction

- Inadequate modelling of seatbelt webbing bending response often results in a rope-like folding deformation in the lap belt during passive safety crash simulations.



- To improve predictions of webbing folding, the webbing bending stiffness was quantified in a cantilever test setup with a tension-free webbing specimen [1], [2].

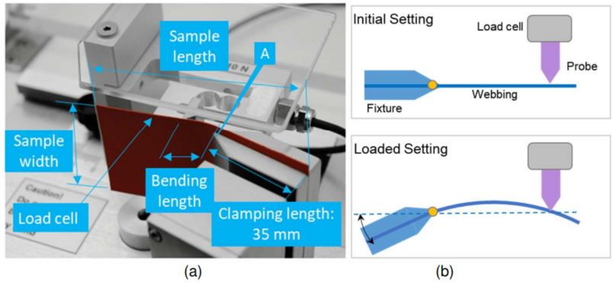


Fig.1: Bending test set-up (a) webbing specimen in the test device (b) schematic diagram illustrating bending in webbing when loaded during the test

[1]

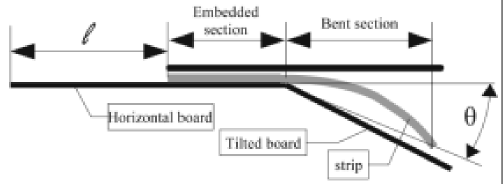


Fig. 1. Illustration of the Peirce test [6].

[2]

- These cantilever-like test setup lack the superimposed tension in longitudinal direction during occupant restraint [1]

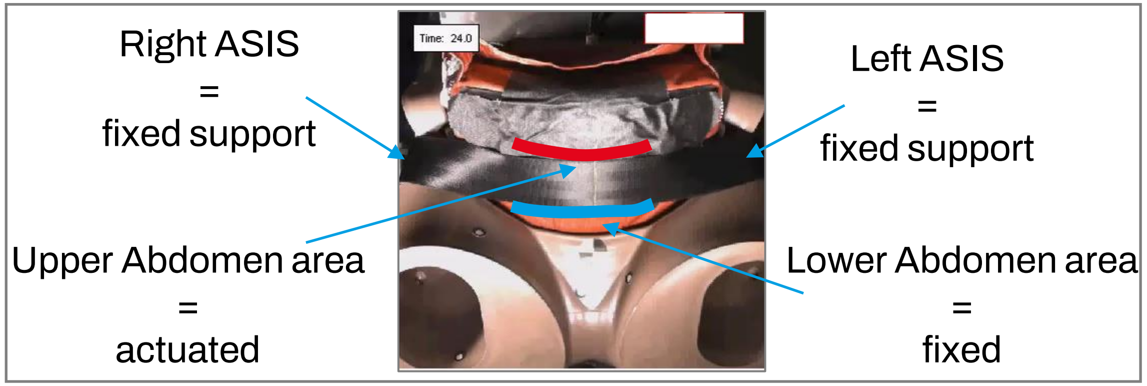
[1] Soni, A.: "Parameter Identification of Coating Parameters to Improve Webbing Bending Response", 13th European LS-DYNA Conference 2021, Ulm, Germany
[2] Peres, J., "Improving belt webbing material modelling for human body model simulations", IRCOBI 2022, Porto, Portugal

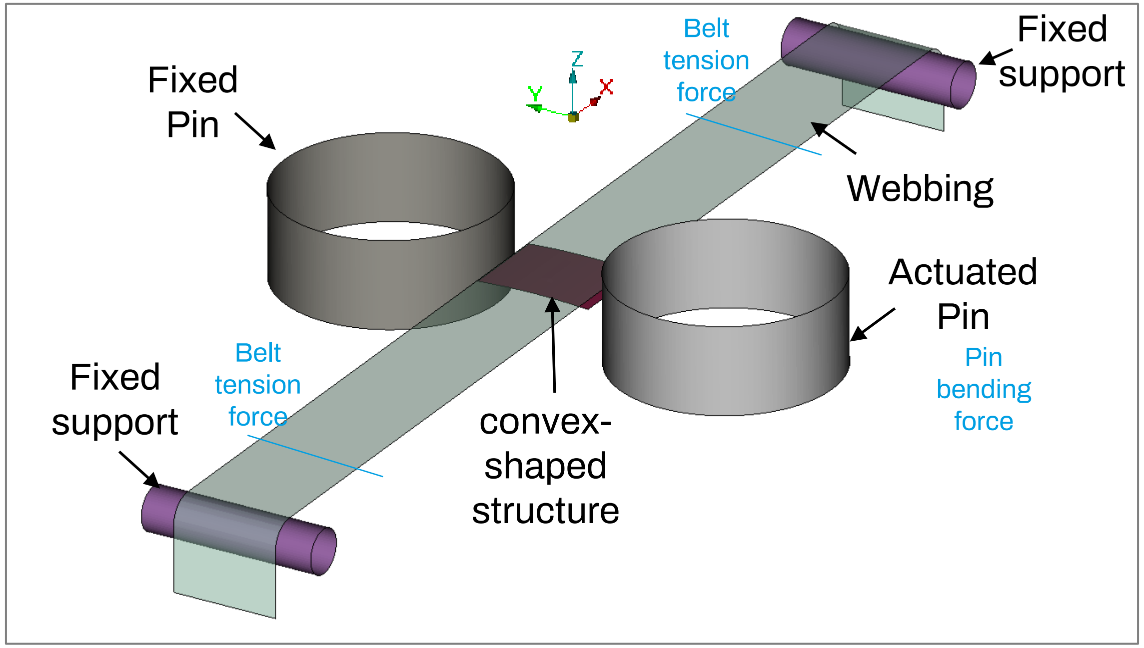
Objective

- This work presents a novel method for characterizing bending in seatbelt webbing under varying tension force.
- The method was conceptualized using simulations and thereafter a physical proof of concept was created.

Method

- The webbing was modelled using ***MAT_FABRIC** with an element edge length of 3 mm, coating feature is providing the bending stiffness [1] . All other structural parts were modelled using ***MAT_RIGID**
- Contact definitions with friction coefficient of μ = 0.3
- The webbing between the pins was pushed out-of-plane by a convex-shaped structure
- Step 1: Tension on the webbing / 0 – 250 ms
  - Force levels: 0 N, 125 N, 400 N and 1000 N by applying a ***BOUNDARY_PRESCRIBED_MOTION** 0 mm, 0.5 mm, 1 mm and 2 mm displacement
- Step 2: Bending of the webbing / 250 – 500 ms
  - 20 mm actuation of rigid cylindrical pin





- Result assessment
  - Belt tension force
  - Pin bending force
  - Bending pattern of the webbing

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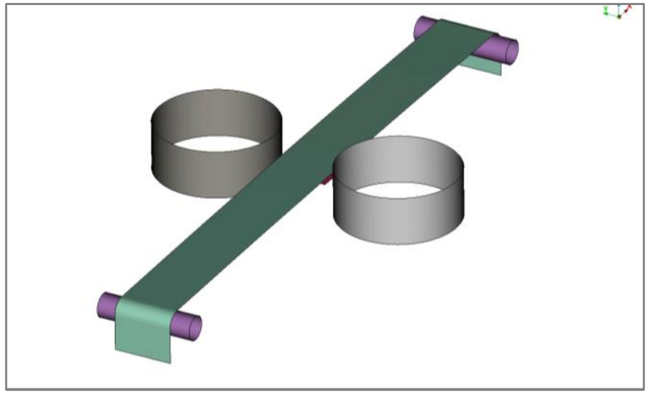
[1] Soni, A.: "Parameter Identification of Coating Parameters to Improve Webbing Bending Response", 13th European LS-DYNA Conference 2021, Ulm, Germany

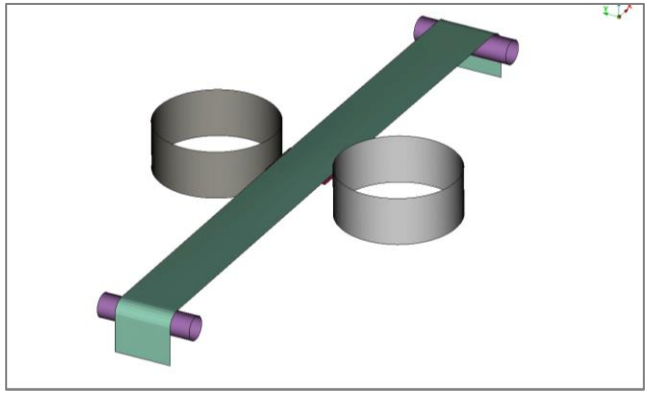
Results – CAE: Animation and bending pattern

Base setup

- Animation: 0 N belt tension

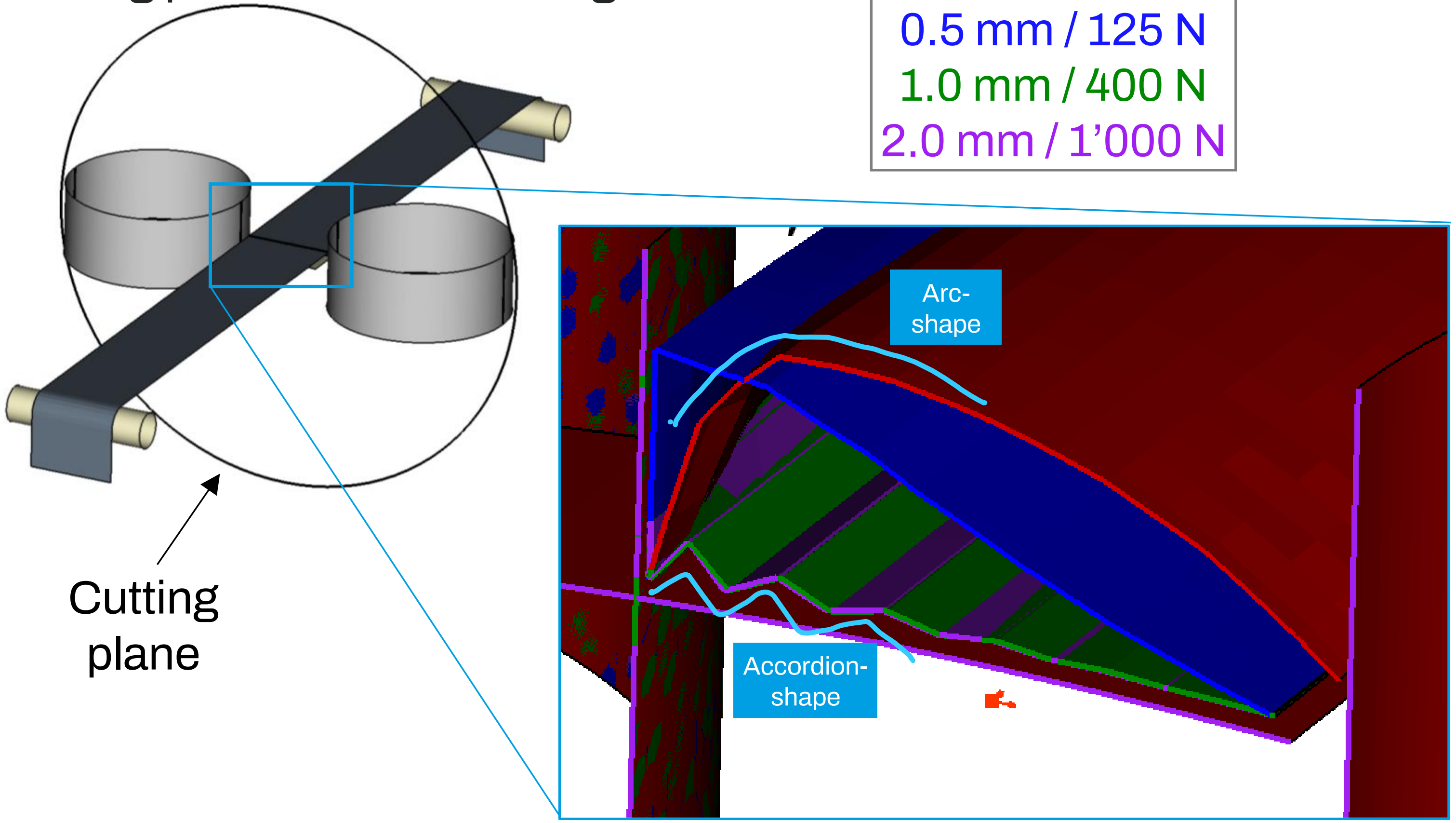


- Animation: 1000 N belt tension



- Bending pattern of the webbing

0.0 mm / 0 N
0.5 mm / 125 N
1.0 mm / 400 N
2.0 mm / 1'000 N



Dependent on webbing tension → Bending pattern variation:
Arc-shaped (low webbing tension), accordion-shape (higher webbing tension)

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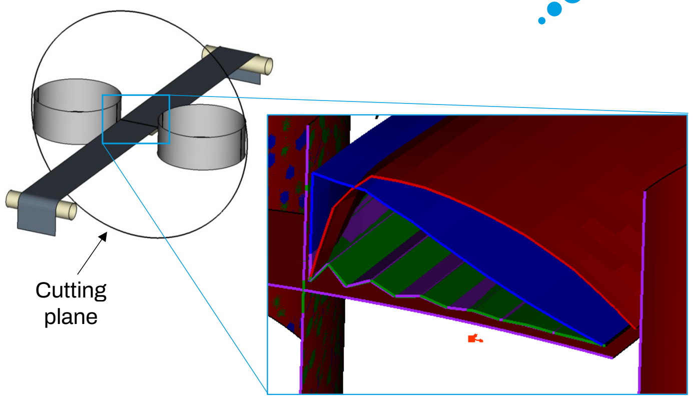
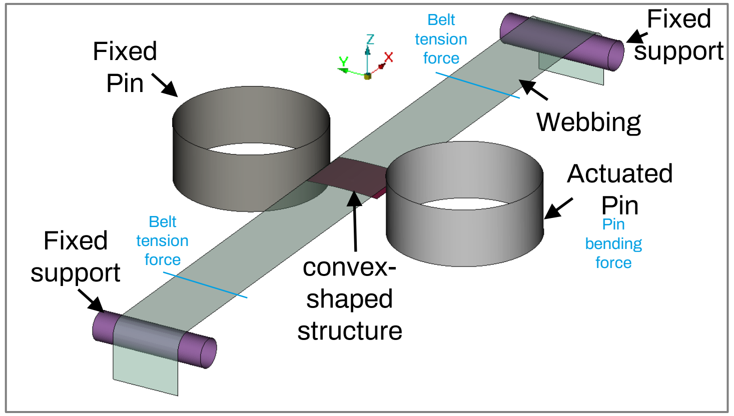
Results – CAE: Belt tension force and bending force

Base setup

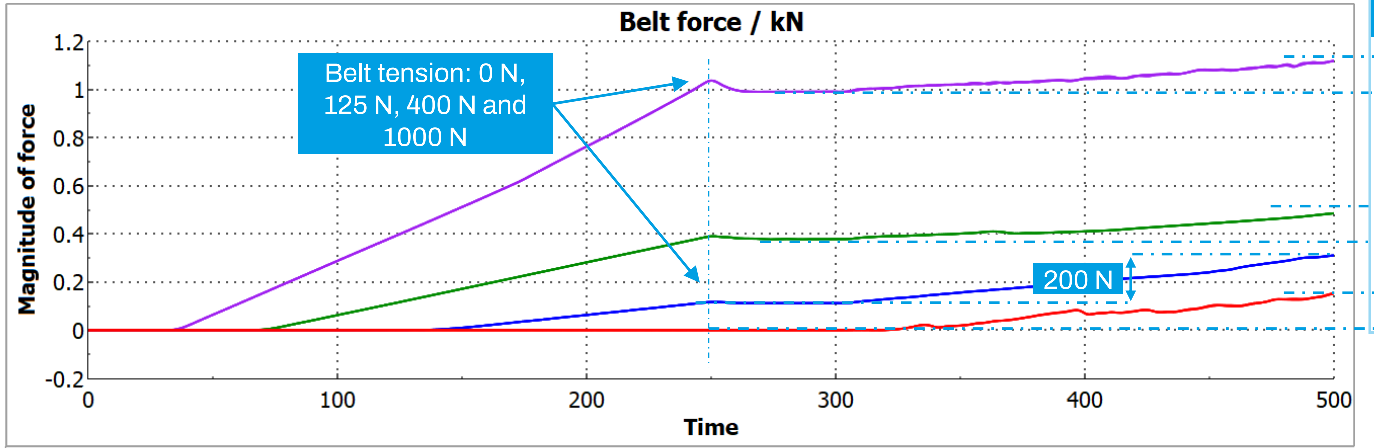
Reminder from last slides





Webbing tensioning

Webbing bending



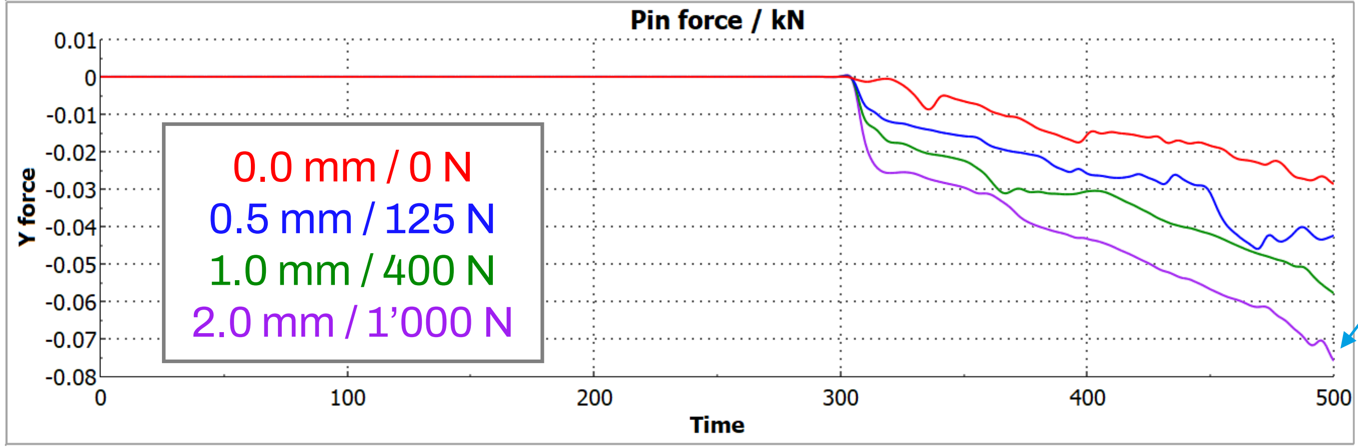
Geometry effect

Increase in the belt force:

140 N

100 N

150 N



bending force: 30 N, 50 N, 60 N and 80 N

Bending force increases with tension force.

Geometrical effect leads to material loading

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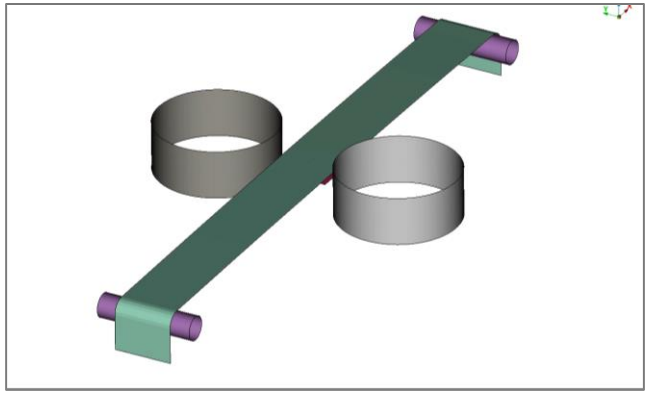
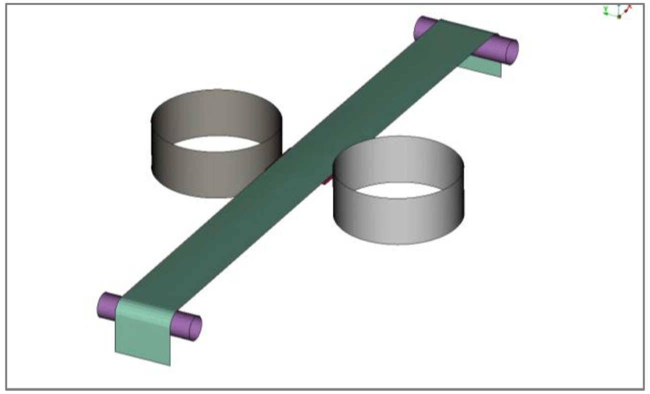
Results – CAE: Animation and bending pattern

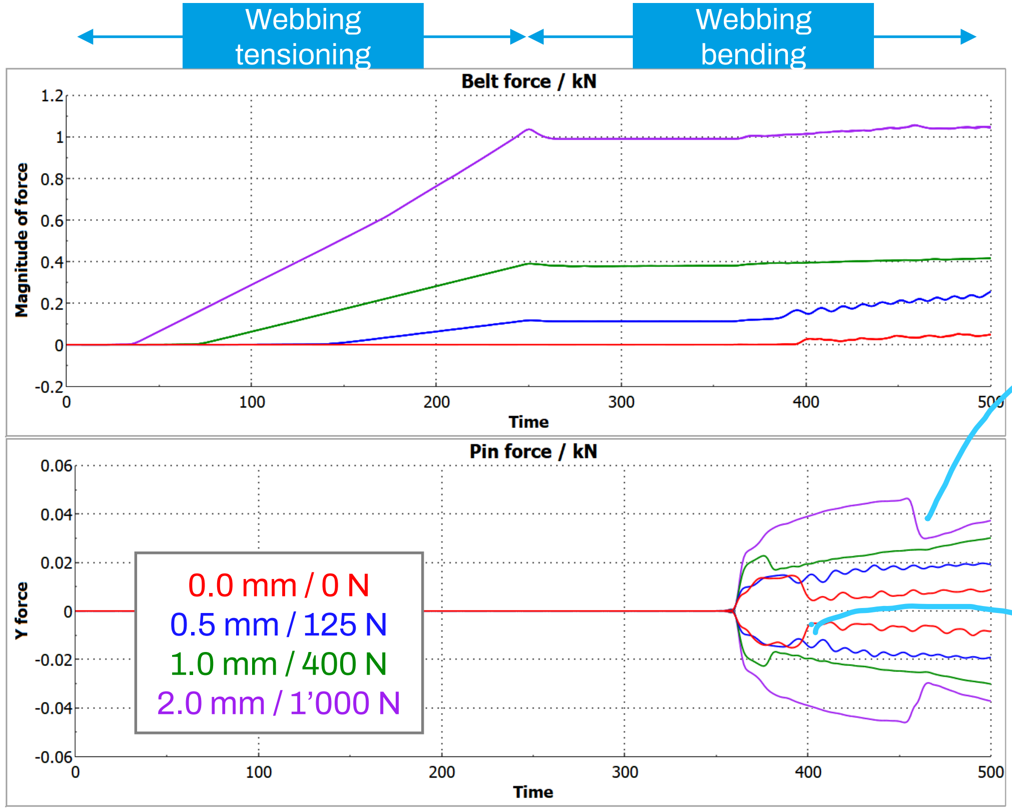
Synchronous symmetric actuation of the pins

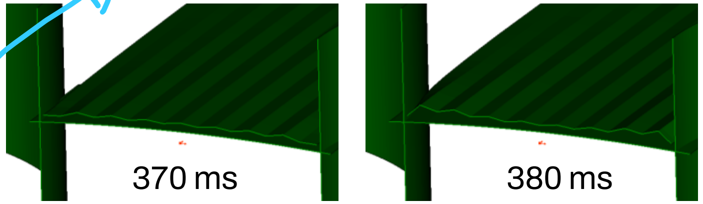
- Animation: 0 N belt tension



- Animation: 1000 N belt tension







Symmetric bending of the webbing shows change in bending modes

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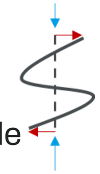
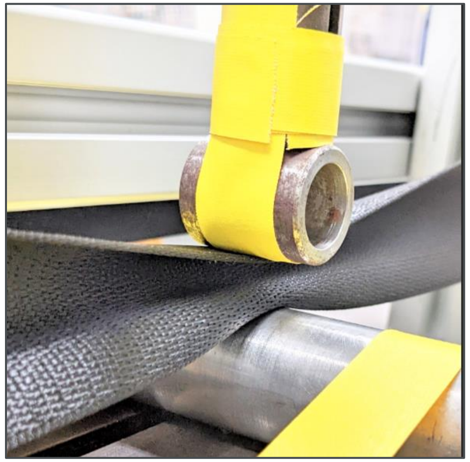
Results – Physical testing (Part 1)

- First set of test series were conducted:

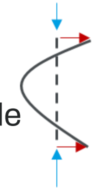
  - Limit/Margin for friction (e.g., Sandpaper vs. greased)
  - Understanding the mechanisms of webbing bending modes
  - Objective → Define controlled environment

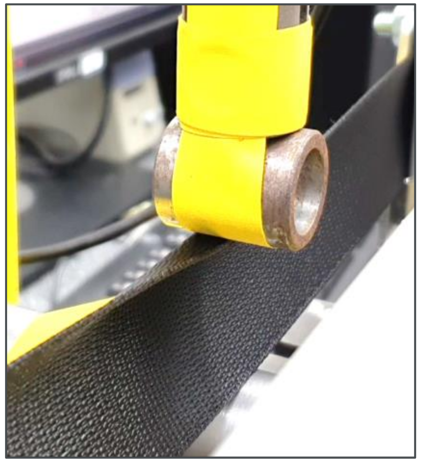
S-shape Bending mode





C-shape Bending mode





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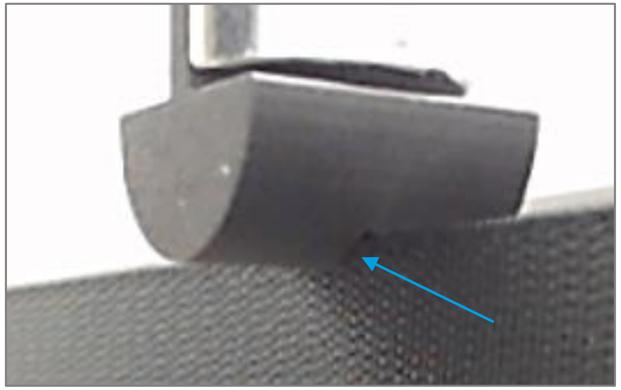
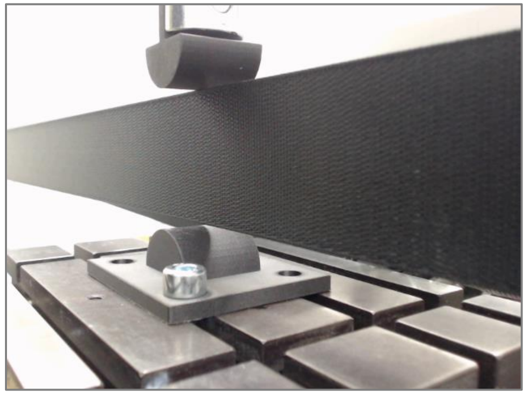
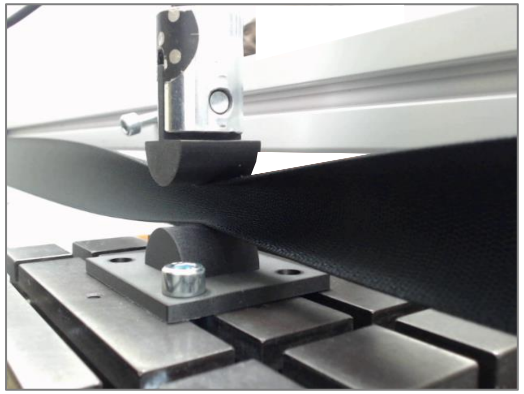
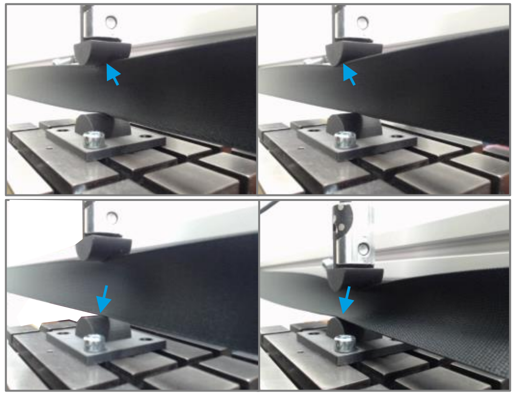
Results – Physical testing (Part 2)

- Second set of test series were conducted:
  - 3D printed parts
  - Controlling the friction with clean surface / notched pins / Sandpaper

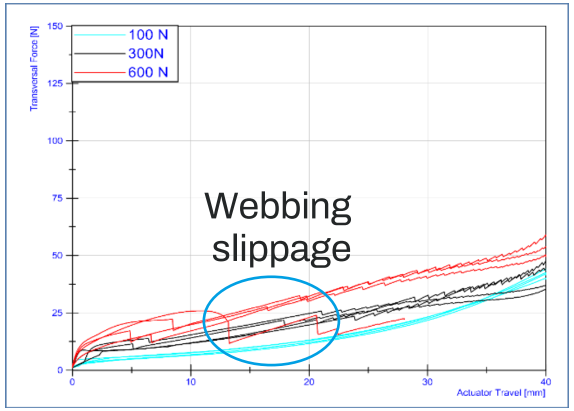


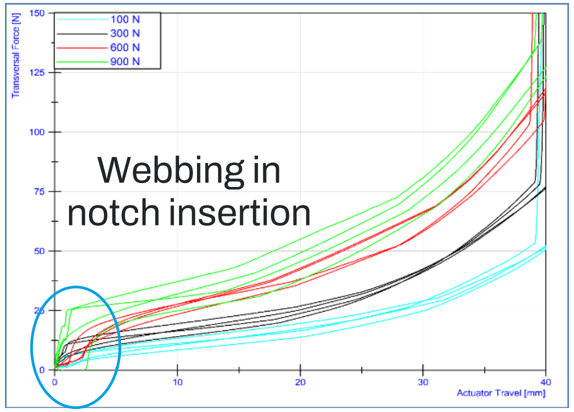






- Conclusion extract for friction study:
  - Rectangular notch: could be too narrow for manual webbing insertion.
  - Clean surface: webbing slippage leads to noisy signal
  - Sandpaper shows most predictable and repetitive results





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Discussion

- The conceptualized test setup in CAE showed an expected **arc-shape** bending mode for the two lower tension force load cases (0 N, 125 N).
  Further, an a**ccordion-shape** bending occurred in the two higher tension force load cases (400 N, 1000 N).

- It is yet not known, whether the accordion-shape from simulation is a numerical artifact, induced due to improper element size, shape, formulation or material model.

- Based on the simulation outcome, a physical proof-of-concept was built.
  Two sets of tests were conducted with varied
  - belt tension force from 100 N to 900 N.
  - Friction setups between pins and webbing

- The physical test results showed the following conclusion
  - The phenomena of the webbing edge sliding on the actuated and fixed pin was observed.
    It can be reduced by high-friction setups which is preferred over notched pins.
  - Geometrical stiffness influence needs to be reduced by e.g., longer free-length setup and possibly symmetrically actuated pins.
  - All the webbing bending pattern resulted in the arc-shape, this indicates remaining limitations in the webbing modelling, as the simulation model showed different bending patterns.

Discussion

- More improvements to the physical test method are required to achieve repetitive, robust, and reliable results.
- In the future, test results will be utilized to optimize the coating parameters available in **`*MAT_FABRIC`** and **`*MAT_SEATBELT_2D*`**.
- The controlled bending deformation of the webbing should ultimately help in improving the procedure for validating the webbing response in simulations.
- With such extended validation procedure, webbing folding in crash-simulation could be predicted more precisely.

* Coating in *MAT_SEATBELT_2D is available in >R12.1

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Conclusion

- A novel method of seatbelt webbing bending stiffness characterization under tension loading was presented.
- The conceptualized setup successfully captured the effects of belt tension on the webbing bending response. The webbing deformation pattern varied with tension force.
- A physical proof-of-concept was built, and the first sets of tests was conducted.
- The test method seems promising to address current shortcomings in the webbing modelling, incorporating for the tension-dependent bending stiffness characteristics.

Thank you

Q/A

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