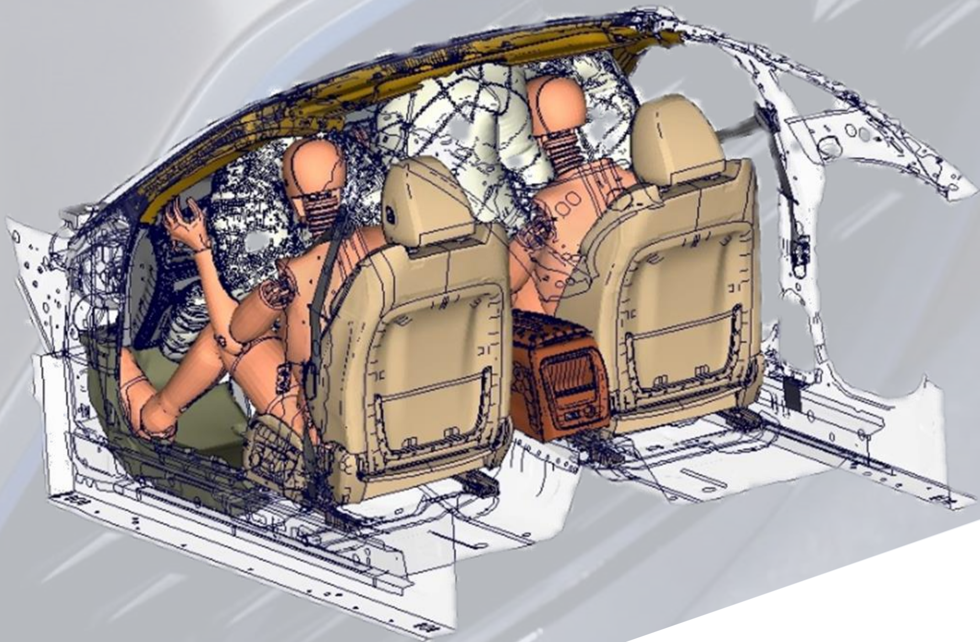
DEVELOPMENT OF COMPONENT TESTS TO REPRODUCE THE BENDING OF SEATBELT WEBBING UNDER A TRANSVERSE LOAD

In collaboration with:

- IAT Ingenieurgesellschaft für Automobiltechnik mbH



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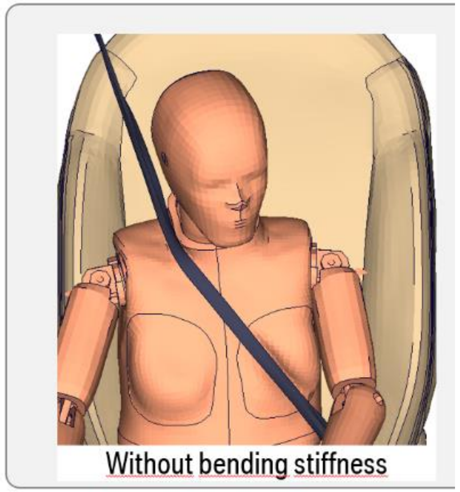
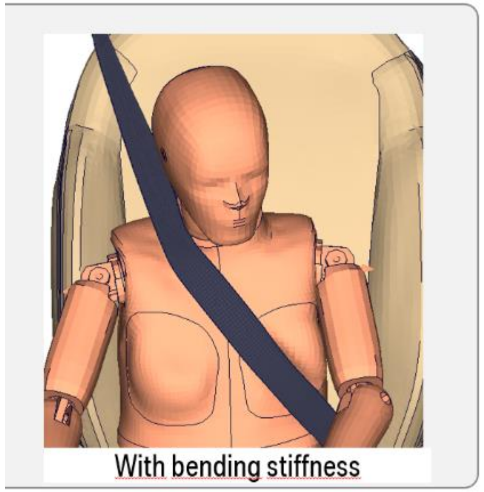
FACED WITH THIS SITUATION …

Look at the neck:



The webbing does not look realistic, does it?

It soon became clear that we needed to improve, so we introduced bending stiffness using a layer of beam elements.



But how to define the material parameters?

By taking real seat belt webbing in our hands, we realized that we did not have the slightest clue:

- at which load level seat belt webbing starts to fold,
- what its bending characteristic looks like,
- of the influence of the axial preload on the above described aspects.

… it was about time to do something.

REQUIREMENTS OF TEST SETUP…

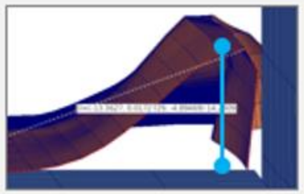
Workarounds exist to introduce bending stiffness:

- Adding beam elements in the transverse direction.
- Adding a shell layer accounting for the bending stiffness.
- Using the coating function of `*MAT_FABRIC`.

The need to **callibrate** these workarounds led …

…to the **development of component tests** that:

- reproduce the bending and folding characteristics of seatbelt webbing.
- account for the influence of belt preload due to different loadlimiter settings.
- reproduce a webbing kinematic comparable to that observed in sled and car tests.



Furthermore, to **ease the integration** in the product development cycle, the tests should have:

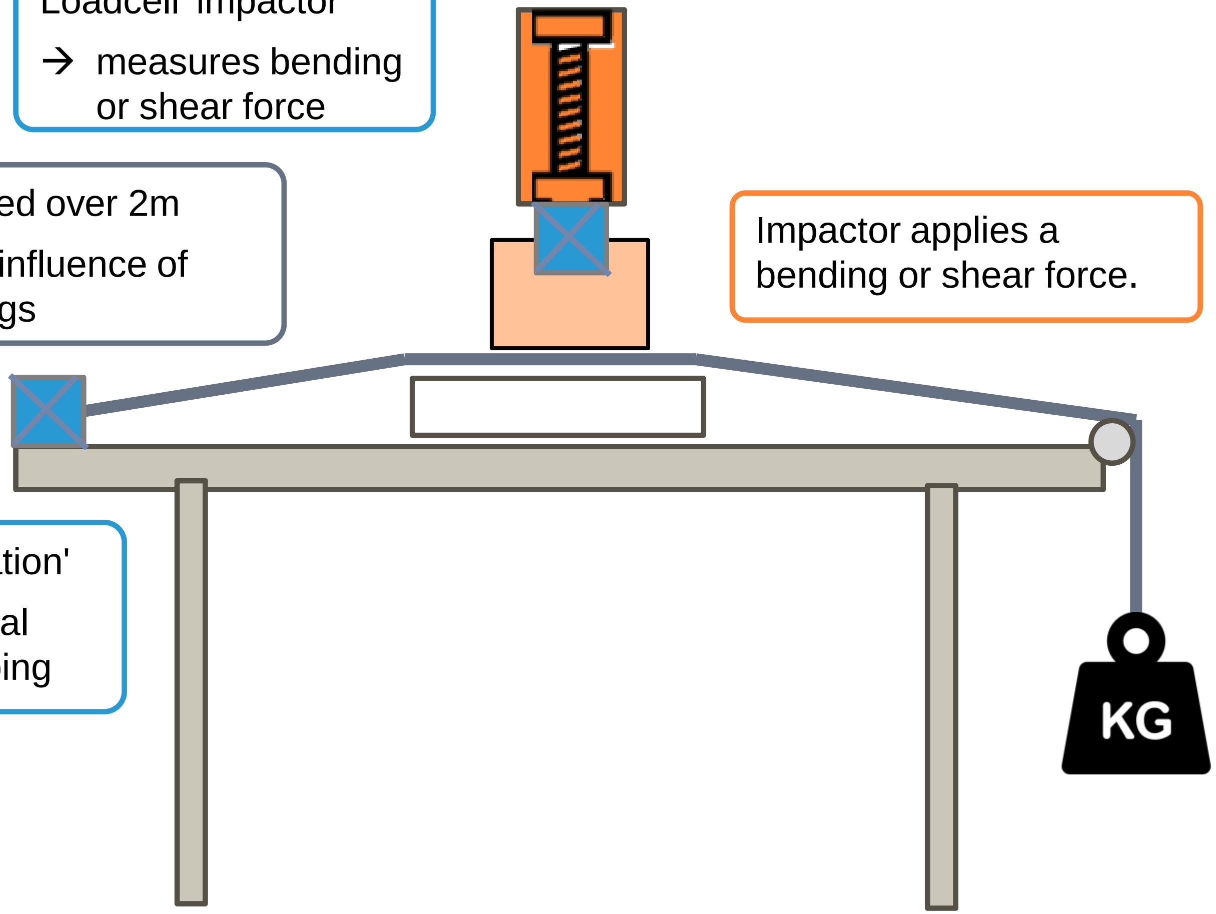
- a high degree of reproducibility.
- a low degree of complexity.

TEST SETUP

Low impactor feed rate
→ quasistatic loading

Loadcell 'impactor'
→ measures bending or shear force

Belt stretched over 2m
→ reduces influence of mountings



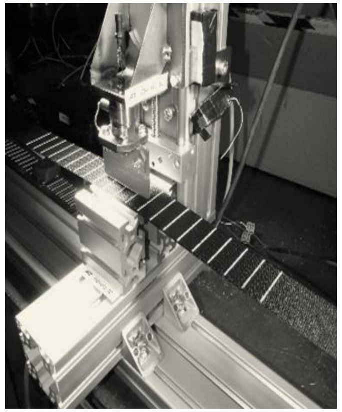
Impactor applies a bending or shear force.

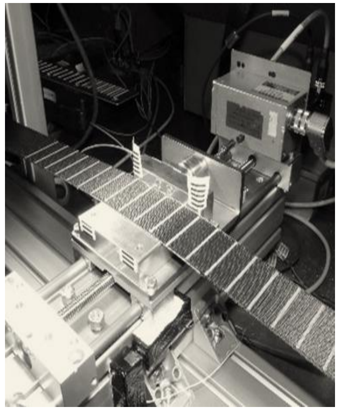
Loadcell 'belt fixation'
→ measures axial force of webbing

Applying weights lead to a constant force level of the axial preload
→ Seatbelt webbing has the tendency to creep

Preload of 2, 4, 6 and 8kN is applied
→ comparable to the load limiting level of retractors

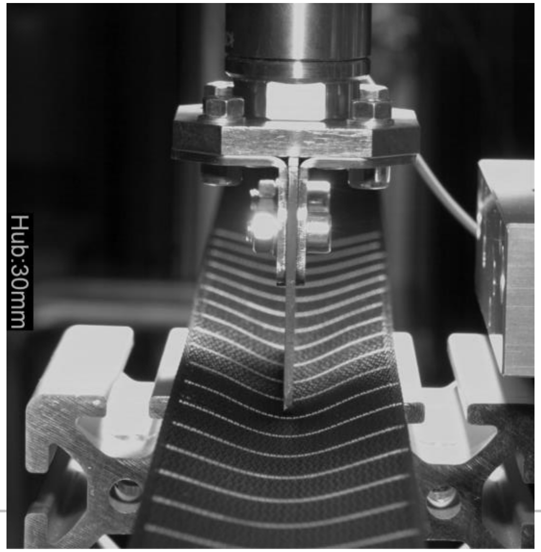
The two tests share the same basic setup.



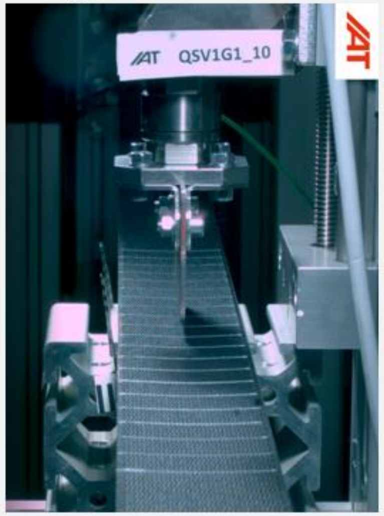


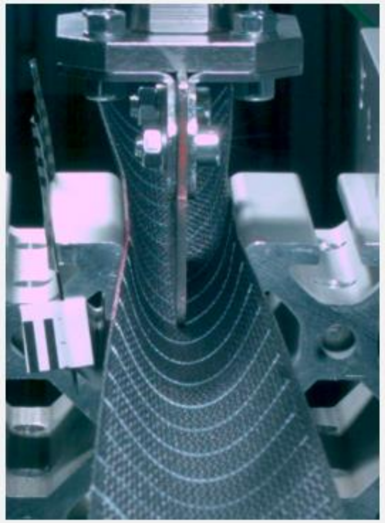
BENDING TEST

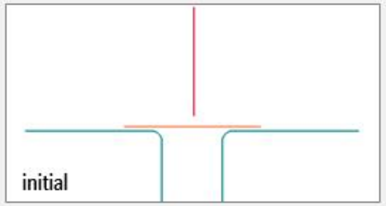
- An impactor 'pushes' the seatbelt into a gap between two blocks, provoking the seatbelt to bend; this can be evaluated visually.
- Furthermore, the resistance of the webbing against a orthogonal force can be evaluated in dependency of the preload.

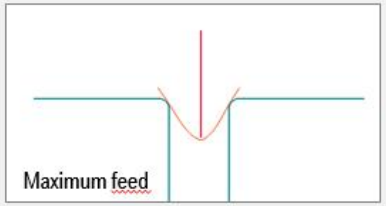


Test rig …

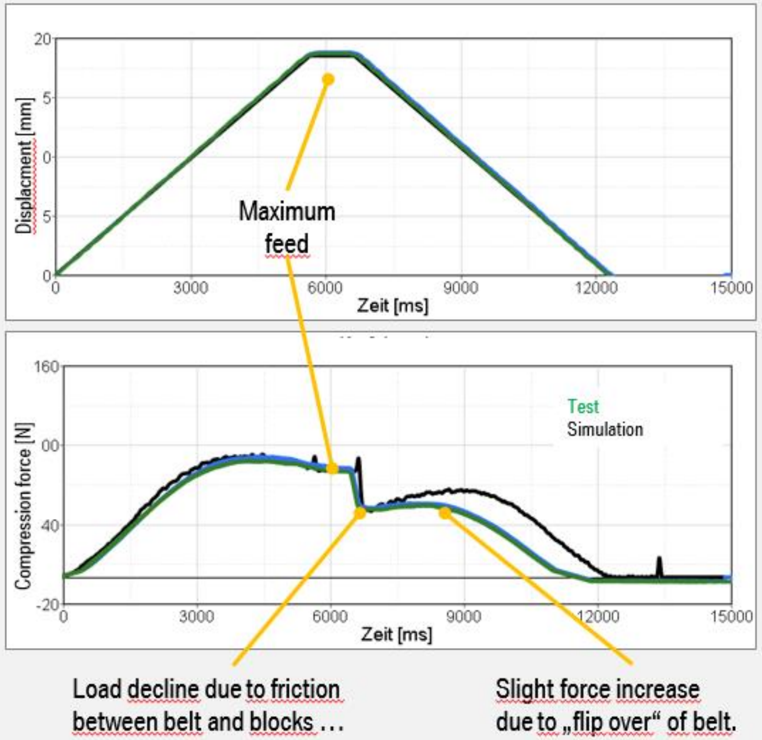






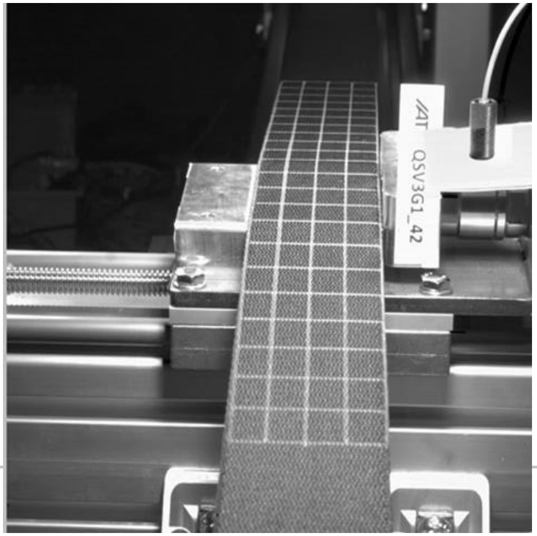


Realisation …

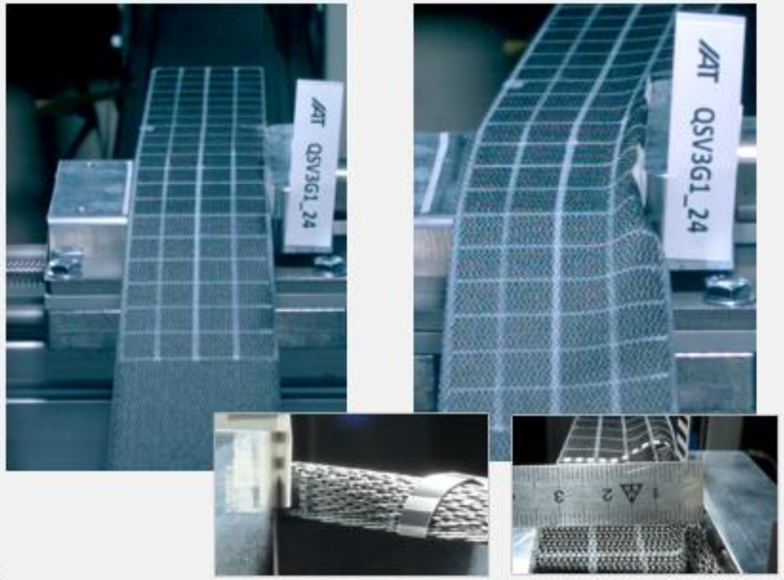


SHEAR TEST

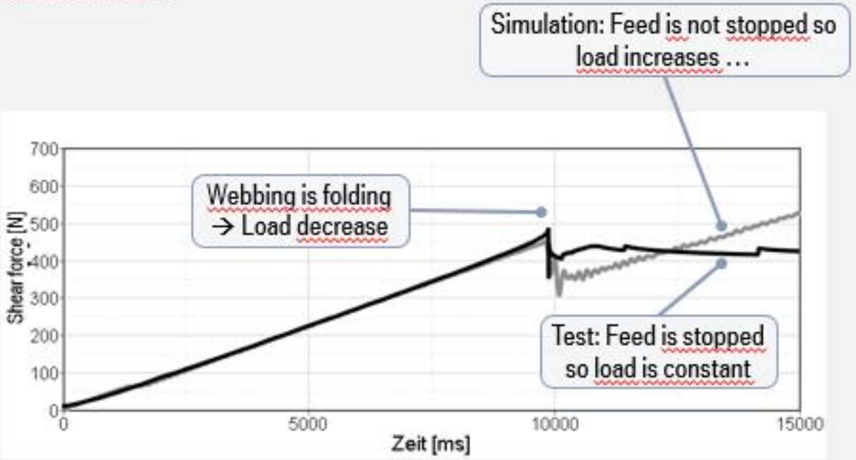
- In this test, an 'L-shaped' profile slowly pushes the belt sideways.
- This produces a shear force that gradually forces the belt to fold.
- Once the first fold is fully developed, the impactor is stopped.



Test rig ...



Realisation ...



The geometry of the belt-fold can be measured and used to calibrate different FE-modeling techniques.

	Test		Simulation (Beam)	
Beltforce [kN]	Height [mm]	Width [mm]	Height [mm]	Width [mm]
2	5	12	5	10
4	4,5	8	5	6,5
6	4	5	3	4
8	4	4	3	3

MODELING TECHNIQUE

Different modeling techniques were evaluated …

- The close bends in the shear test were best simulated using beam elements with an elasto-plastic material law.
- First tests to model this type of a 'plastic hinge' with a shell layer approach did not prove successful.
- This and the fact that the shell layer is incompatible with the use of 2D sliprings led to the decision to focus on the beam elements.

modeling technique	Slip Ring applicable?	Bending test		Shear test			Conclusion
		Loadcurve: characteristic & level	Visual: bending line belt	Loadcurve: characteristic & level	Loaddrop: time point	Visual: bending line belt	
Shell layer	N	Y	Y	(Y)	(Y)	N	Due to slipring incompability, not pursued
Plastic beams	Y	Y	Y	Y	Y	Y	All relevant demands fulfilled

Modeling approach:
Webbing is modelled as a superposition of …

- Beam elements → bending stresses (1)
- Membran elemente → in plane stresses (2)

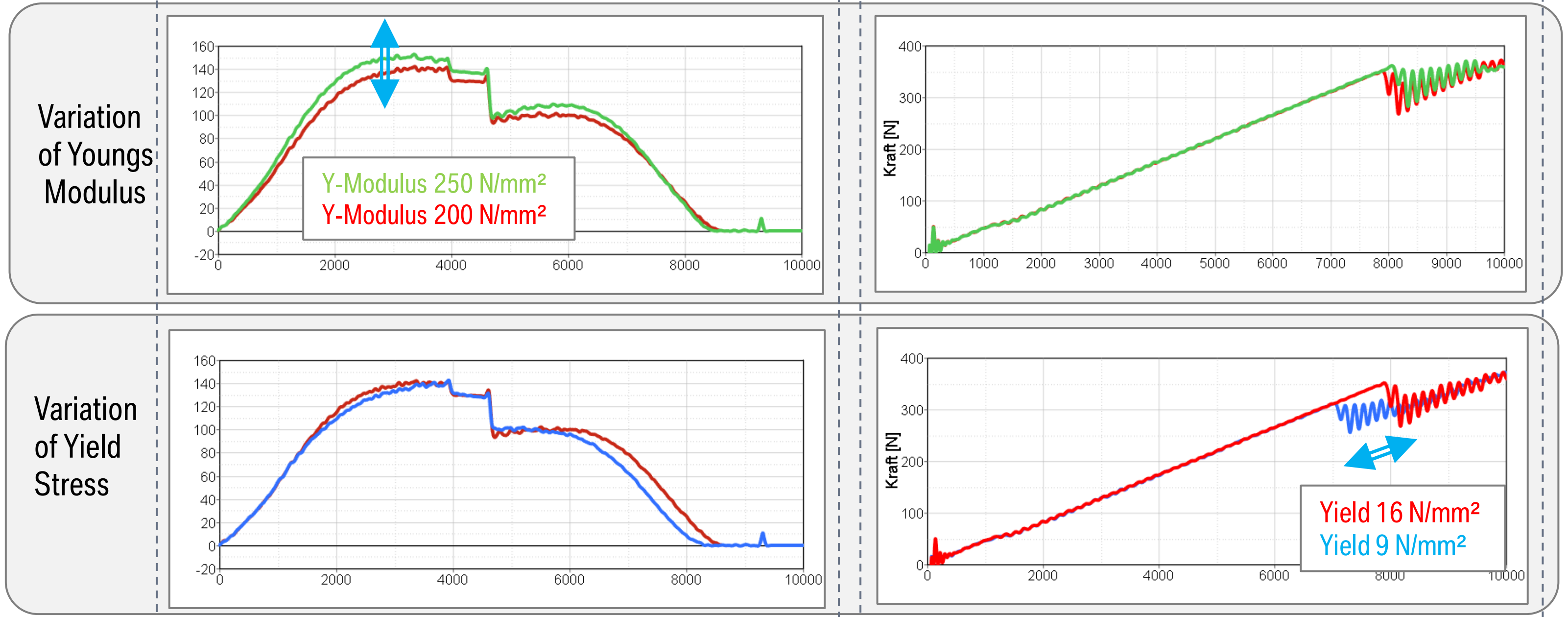
(1) Elasto-plastic beam elements form a plastic hinge.
Verification using the 'bending line' of the webbing & loadcurves of the component tests.

(2) Membran elements validated by the suppliers.
The elongation in axial direction is hardly influenced applying the transverse beam elements.

CALIBRATION OF MATERIAL PARAMETERS

- A simple elasto-plastic material law is applied(**`*MAT_PLASTIC_KINEMATIC`**).
- Calibrating the relevant parameters from the test data is straightforward.
- Both tests are needed to calibrate the material parameter
  - bending test for youngs modulus,
  - shear test for yield stress.
- The material parameters were defined using one load level for the axial force and then verified with the other preload-levels.

bending test | shear test

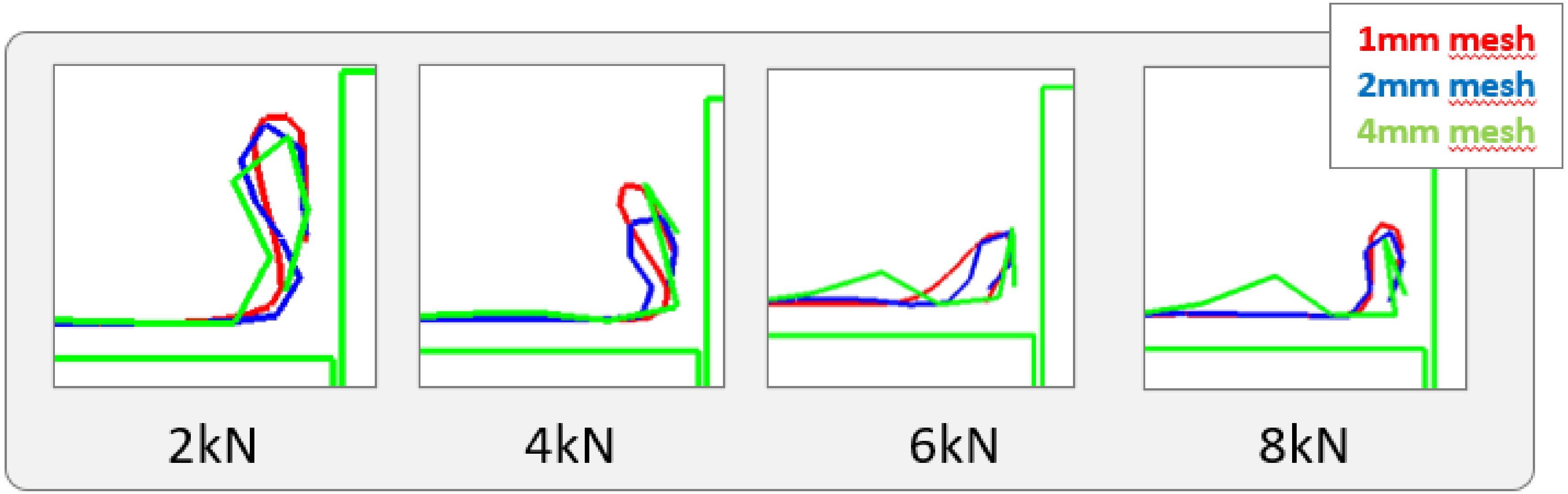


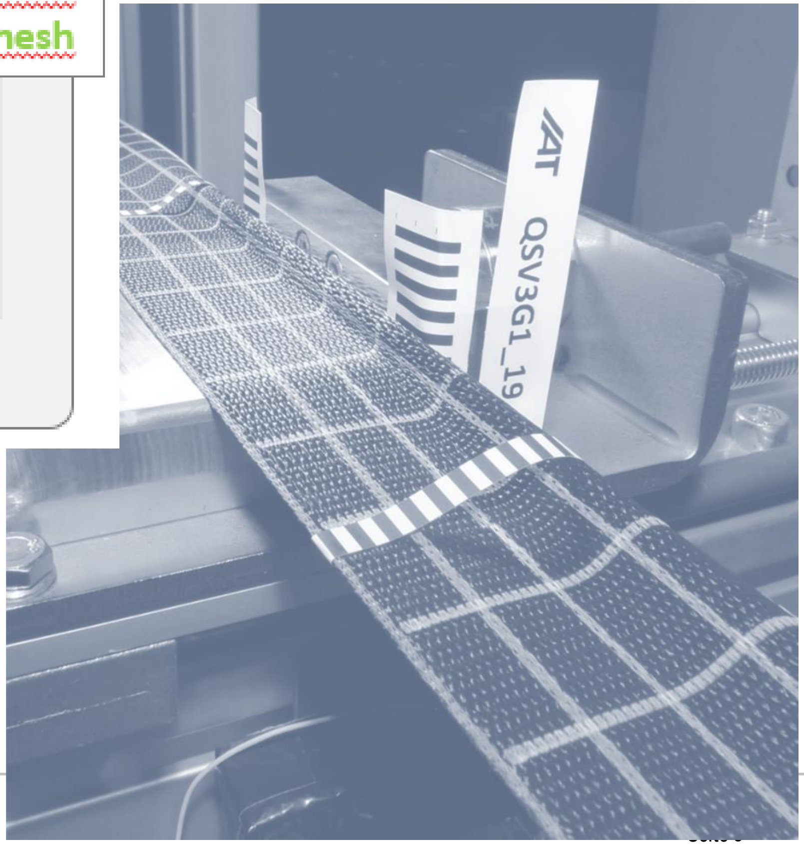
Bending test: by varying the young's modulus, the slope of the load curve and the maximum load are determined.

Shear test: varying the yield stress sets the time point when the 'plastic hinge' develops and thus the belt is folding.

INFLUENCE OF DISCRETIZATION

- To examine the influence of the discretization on the bending characteristic, different discretizations were evaluated by visually comparing the deformation pattern with the results from the shear test.
- The average distance between warp threads in the hardware tests was ~0.7mm.





1mm & 2mm discretization

- A similar folding patter for all preloads is developing.
- Pattern is comparable to the hardware tests.

4mm discretization

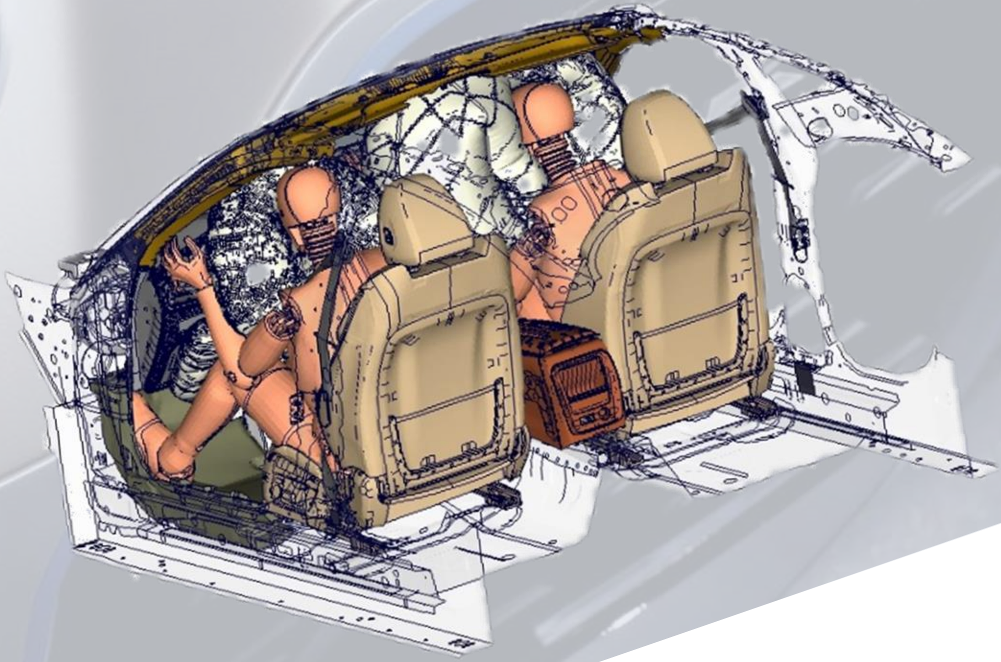
- Starting with a preload of 6kN, the pattern differs from the hardware tests.

CONCLUSION

- Two component tests that measure the resistance against a transverse load and the force initiating a fold in seatbelt webbing have been set up.
- Hardware tests with the above mentioned setups have been performed using different preload levels of the seatbelt webbing.
- Using the results of these tests, folding of the webbing comparable to that observed in full-scale hardware tests can be generated.
- The results of these tests can be used to calibrate the bending stiffness of existing modeling approaches.
- This calibration is needed to improve the prediction quality of occupant simulations.

Word of caution: Seat belt webbing made from interwoven warp- and weft-threads has a complicated inner structure, and using the approach that employs 2D seatbelt elements with added bending stiffness is still only an approximation of the effects of this structure on a macroscopic level.

THANK YOU FOR YOUR ATTENTION



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