A New Model for Simulation of Fabric Leakage in LS-DYNA

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Keywords:

Fabric, permeability, textiles

Uncoated fabrics will continue to have a major market share in airbag applications in the future. The reasons are smaller package size, easier recycling and reduced material cost.

In order to achieve proper prediction of performance and restraint function of an airbag module for occupant protection, a detailed and physical representation of all significant factors contributing to gas management within the airbag cushion is required. Inflator output and gas losses through vent holes as well as leakage through seams and the fabric itself must be clearly identified and described.

The FE-Code LS-Dyna has been used for many years to support the development of airbag systems and to optimize the restraint function in the specific vehicle environment. The code provides several options for the description of gas outflow including fabric leakage. But so far the available models for fabric permeability have shown limited predictivity in conjunction with standardized measured permeability data.

Therefore a new model for fabric leakage has been developed by Autoliv. It is capable of calculating the massflow through the fabric, depending on strain in the fabric. Each fabric is characterised by a set of constants. As for orifices the equation for the flow through nozzles and diffusors after St. Venant / Wantzel [1] has been used. This model is able to distinguish subsonic and critical flow. Autoliv's approach to the necessary but unknown effective area consists of a pressure dependent and a strain dependent part. It also takes the angle between warp and weft into account. This model has recently been implemented in LS-Dyna by Dynamore/LSTC.

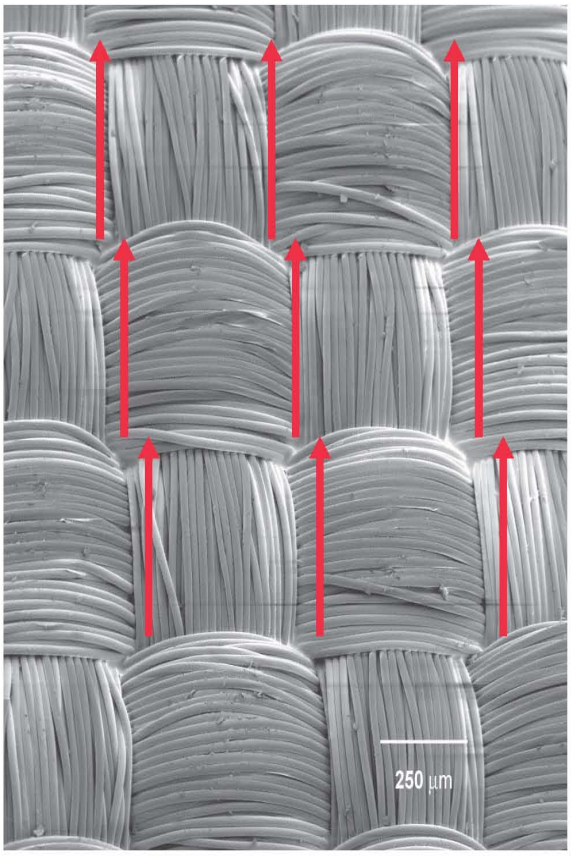
Data from Autoliv's leakage testing device (GES) for testing of fabric samples has been used to obtain the relevant input data for validation at fabric level. Reference tests as well as tests with fabrics having high, low and very low permeability have been performed. All tests have been carried out both with nominal strain (bulge) and with reduced strain (grid). It could be shown that even with reduced strain this in-house device delivers significantly different results for the fabrics with high and low permeability. After the simulation model of the test device had been validated according reference tests using a leakproof plate, sets of constants describing the fabrics' permeability could be determined. Very good correlation to the test results could be achieved.

In order to verify the model on module level whole passenger airbag modules have been tested on a linear impactor. Airbags with the above validated fabrics and two different ventsizes were used. Significant differences in the results for the different fabrics were obtained for the airbags with 2x8mm vents.

The simulation model of the airbag has been tuned according the test results with coated fabric in order to account for all other leakage besides fabric permeability. Simulation of the impactor tests with prevalidated fabric leakage data showed the validity of the new approach.

Literatur

[1] Bohl, W.: "Technische Strömungslehre", Vogel-Buchverlag, 2002



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13.10.2010

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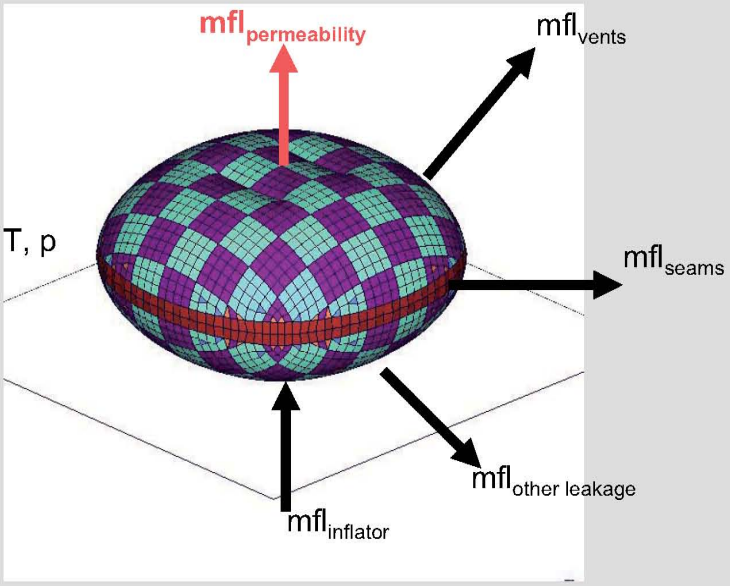
Fabric Leakage Model

Project Objectives

- Find procedure to model and measure fabric permeability
- Predict influence of a change of the fabric leakage in restraint systems dimensioning



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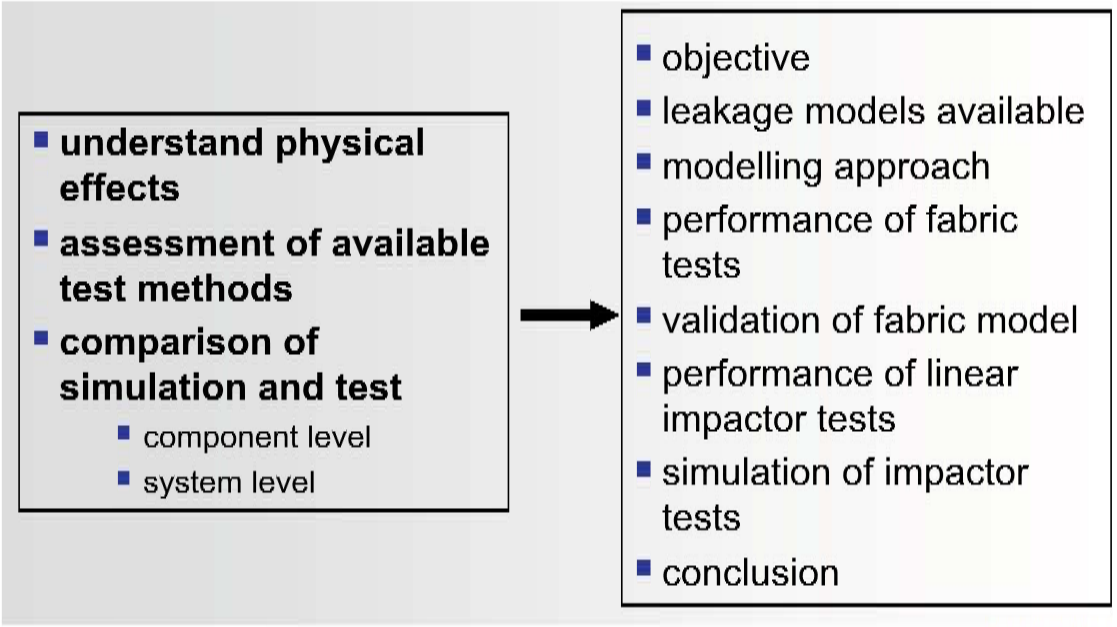
Fabric Leakage Model
Problem Solution



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Fabric Leakage Model

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Fabric Leakage Model

Leakage Models available in LS-DYNA

Software	Leak. Area	mass flow rate	volumetric flow rate	fabric leakage	exhaust orifice
		$\dot{m} = \dot{\overline{m}} A$	$\dot{m} = \rho \dot{\overline{V}} A$	$\lvert\dot{m}\rvert = CA\sqrt{2\rho\lvert\Delta p\rvert}$	$\lvert\dot{m}\rvert = CA\frac{p}{\sqrt{RT}}\sqrt{\frac{2\kappa}{\kappa-1}\left[\left(\frac{p_{orif}}{p}\right)^{\frac{2}{\kappa}} - \left(\frac{p_{orif}}{p}\right)^{\frac{\kappa+1}{\kappa}}\right]}$
LS-DYNA	FABRIC Aleak(p || pext/p)		v(p) C = f(t || A/Ao)	C = f(t || A/Ao) || C*A(A/Ao, pext/p)	C = f(t || A/Ao) || C*A(A/Ao, pext/p)
	AIRBAG A(p)				C(t)

Material/Element level

- Flow rate as input
  - TEXTEST FX3350
  - EMI (V=f(p))

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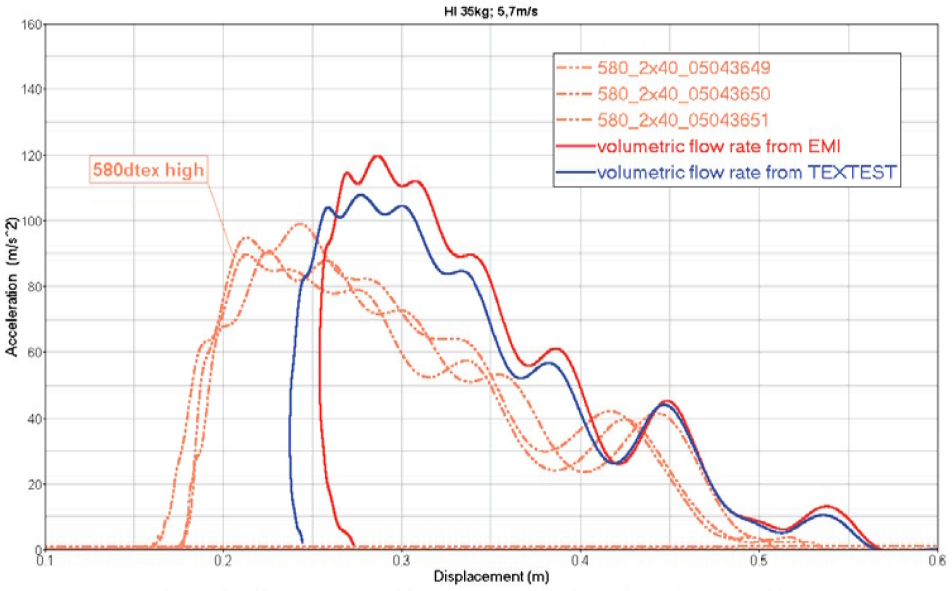
Fabric Leakage Model

Results of Linear Impactor Simulations



simulation results = model + test results

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Fabric Leakage Model

- objective
- leakage models available
- **modelling approach**
- performance of fabric tests
- validation of fabric model
- performance of linear impactor tests
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- conclusion

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Fabric Leakage Model

Literature Research

- **aim**:
  model that is capable of
  - calculating the massflow through the fabric
  - dependent on fabric strain
  - characterising fabric by set of constants
- **available models**
  - flow through particle beds based on Darcy's law
  - flow through nozzles and diffusors

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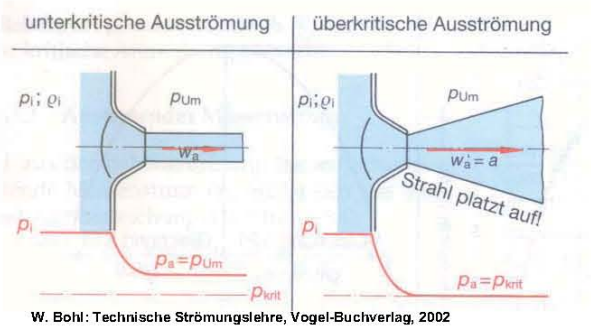
Fabric Leakage Model

Literature Research: Flow in Nozzles and Diffusors

St. Venant / Wantzel

(Shapiro, Eck, Bohl, Kecke / Kleinschmidt)
presumptions:
- kompressible fluid,
- adiabatic (isentropic) change
- intake velocity negligible



W. Bohl: Technische Strömungslehre, Vogel-Buchverlag, 2002

subsonic:

$$\dot{m} = \varphi \psi_k A_a \psi \sqrt{2 p_i \rho_i}$$

$$\psi = \sqrt{\frac{\kappa}{\kappa - 1}\left[\left(\frac{p_a}{p_i}\right)^{\frac{2}{\kappa}} - \left(\frac{p_a}{p_i}\right)^{\frac{\kappa+1}{\kappa}}\right]}$$

critical:

$$\dot{m} = \varphi \psi_k A_a \psi_{\max} \sqrt{2 p_i \rho_i}$$

$$\psi_{\max} = \sqrt{\frac{\kappa}{2}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{\kappa-1}}}$$

φ : *velocity coefficient (friction)*
ψ_k : *stream contraction coefficient*
ψ : *expansion coefficient*

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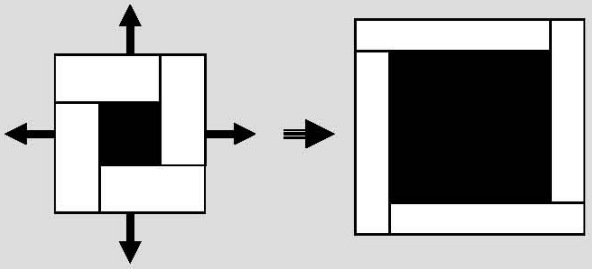
Fabric Leakage Model

Autoliv's Approach to Effective Area

$$\dot{m} = \varphi \psi_k A_{eff} \psi \sqrt{2 p_i \rho}$$

pressure dependent *strain dependent*

$$A_{eff} = \frac{A_0}{L^2}\left[\left(C_1 \Delta p^{C_2}\right)\left(C_3\right)(L-2r)^2 + C_3\left(L\lambda_1 - \frac{2r}{\sqrt{\lambda_2}}\right)\left(L\lambda_2 - \frac{2r}{\sqrt{\lambda_1}}\right)\right]\sin\alpha_{12}$$



nonlinear increase of hole area because of constant volume of threads

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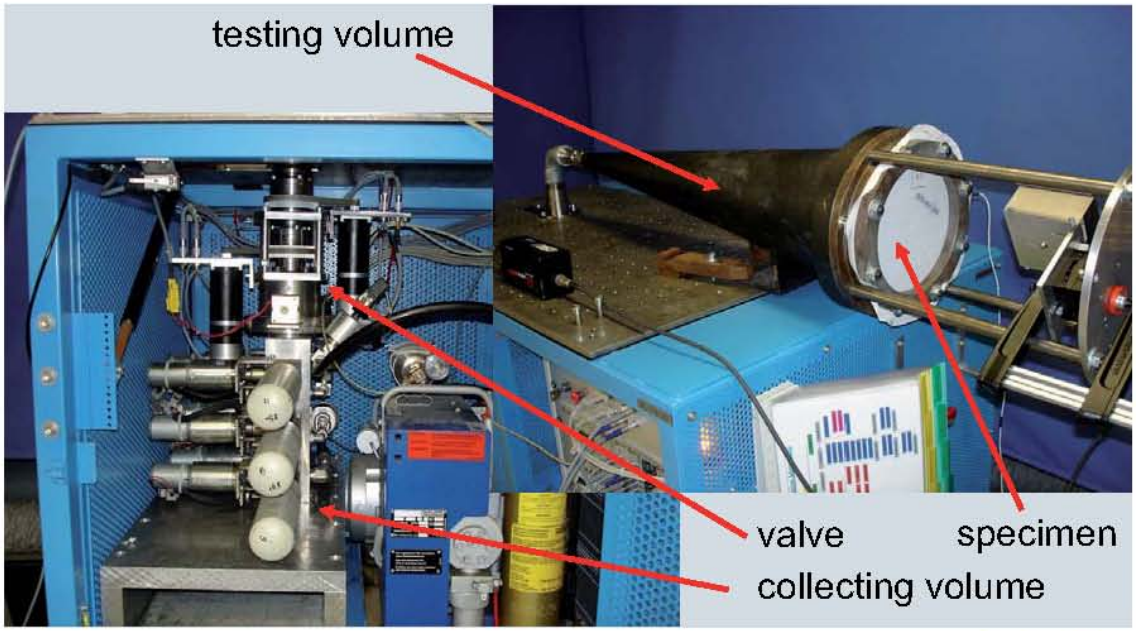
Fabric Leakage Model

Autoliv Leakage Testing Device (GES)



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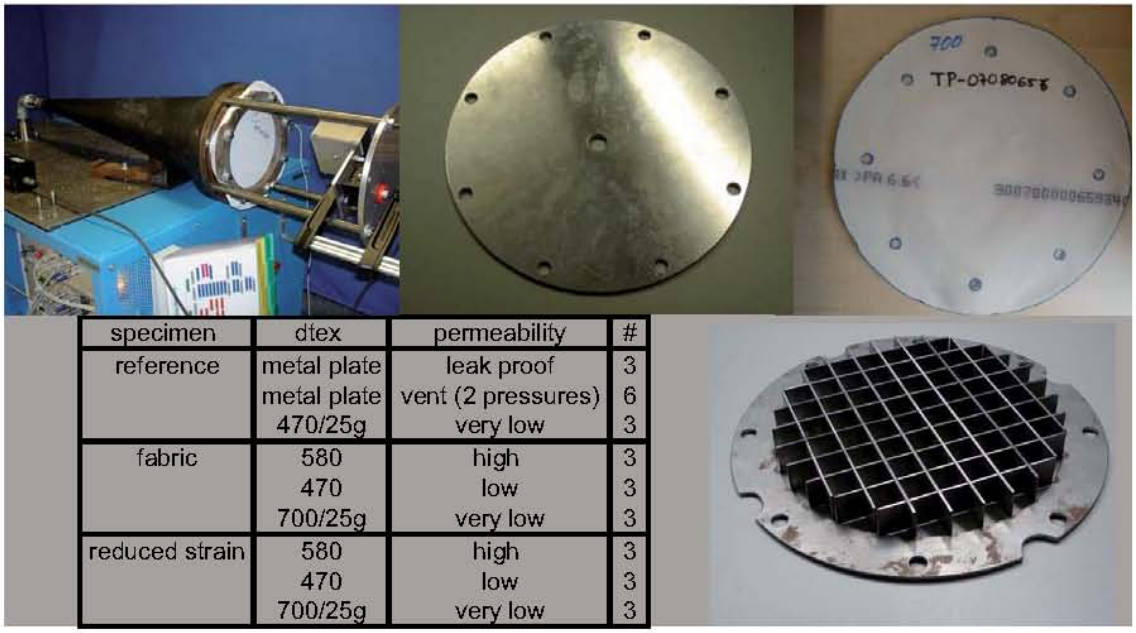
Fabric Leakage Model

Performance of Permeability Tests



specimen	dtex	permeability	#
reference	metal plate	leak proof	3
	metal plate	vent (2 pressures)	6
	470/25g	very low	3
fabric	580	high	3
	470	low	3
	700/25g	very low	3
reduced strain	580	high	3
	470	low	3
	700/25g	very low	3

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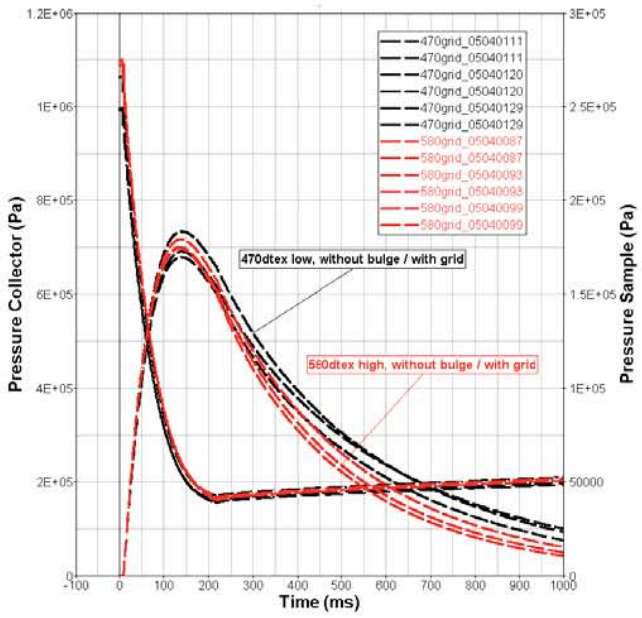
Fabric Leakage Model

Results of Permeability Tests



- different air permeabilities result in significantly different pressure gradients
- different maximum pressures are caused by differences in air permeability and in start pressure
- air permeability definitely increases with strain of fabric

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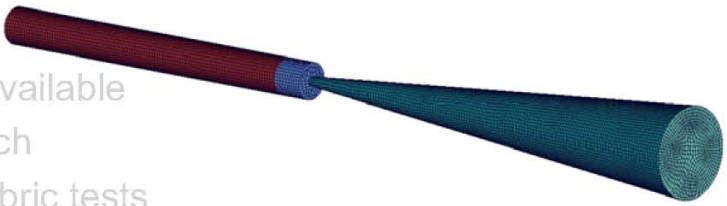

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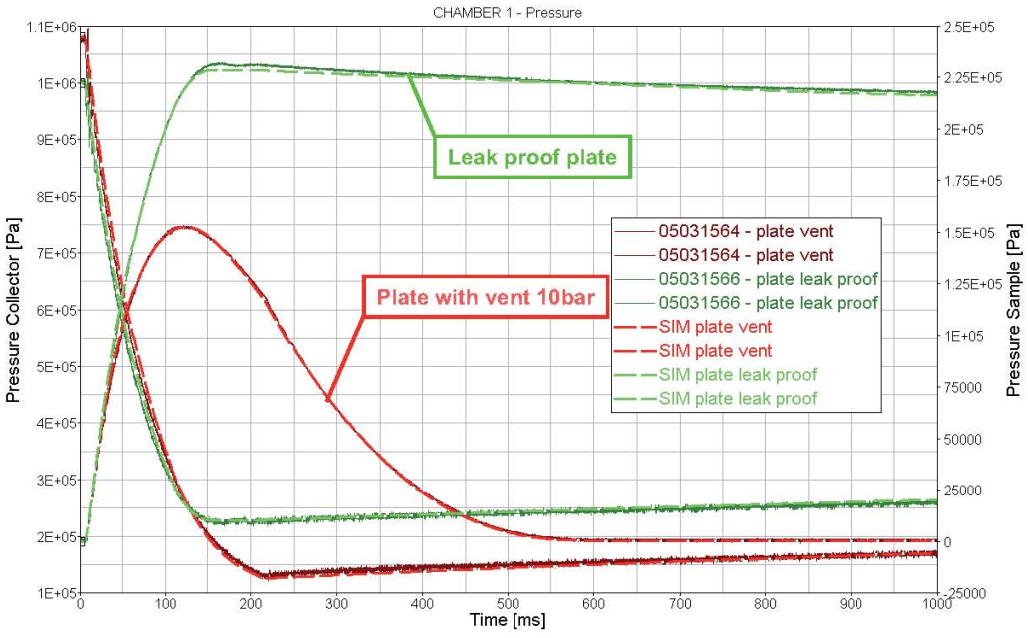
Fabric Leakage Model

Simulation Model of Test Device (Reference Tests)



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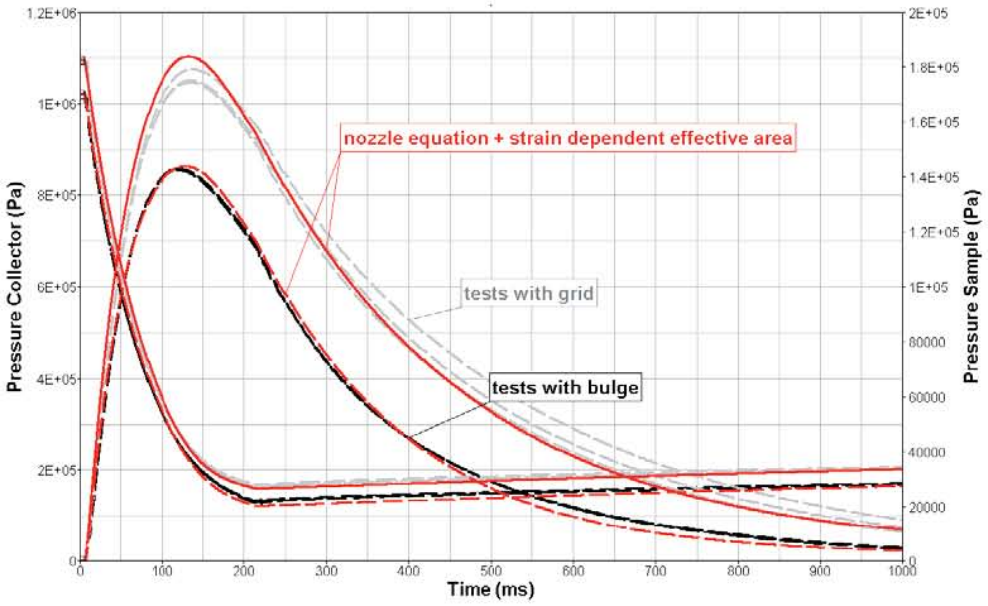
Validation of Constants for Autoliv's Permeability Model



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Fabric Leakage Model

Performance of Impactor Tests

Linear impactor tests with passenger modules to

- show importance of fabric permeability concerning module performance
- receive data in order to confirm simulation methodology
- Configuration: 35kg impactor with 5,7m/s max. velocity

dtex	permeability	#	vents
700 25g coated	very low	2	2x40mm round
700 25g coated	very low	3	2x8mm round
470	low	3	2x8mm round
580	high	3	2x8mm round
580	high	3	2x40mm round

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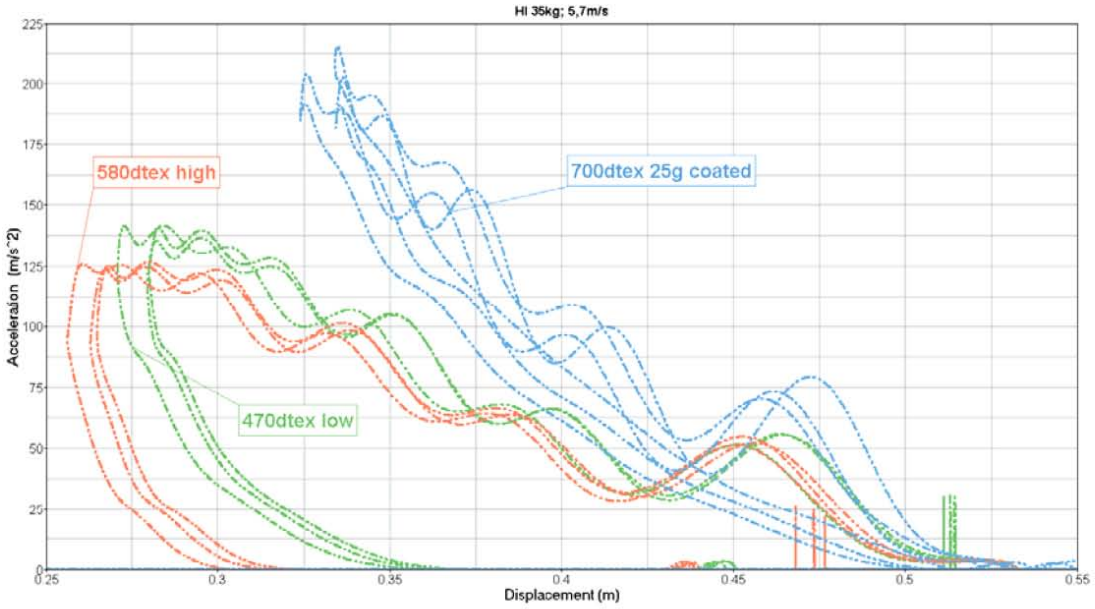
Fabric Leakage Model

Results of Linear Impactor Tests 2x8mm Vents



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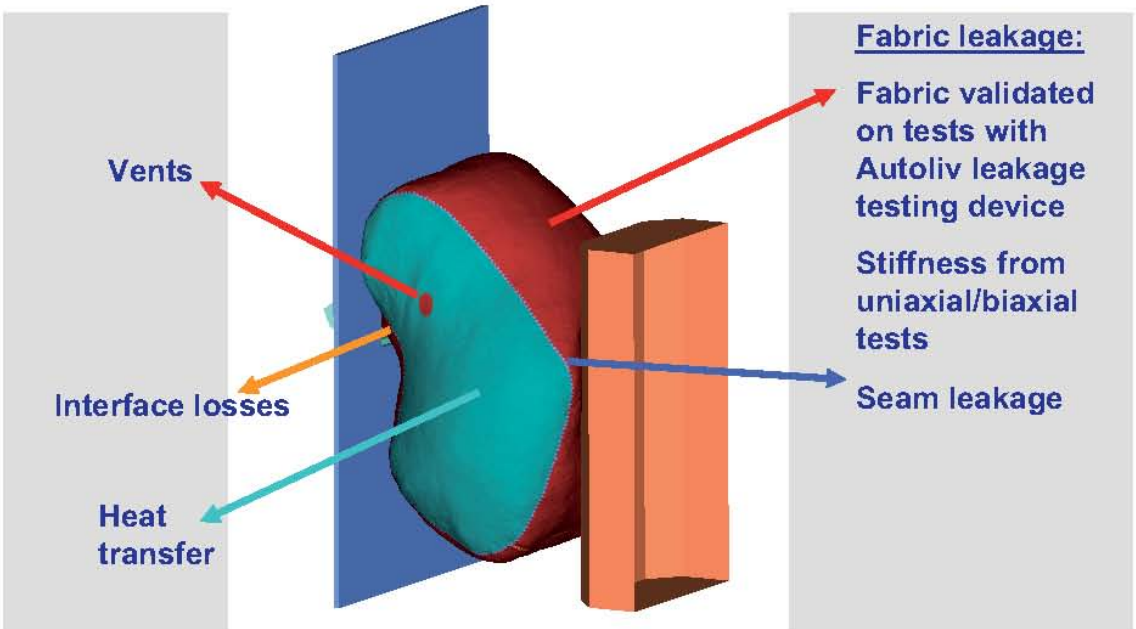
Simulation of Linear Impactor Tests



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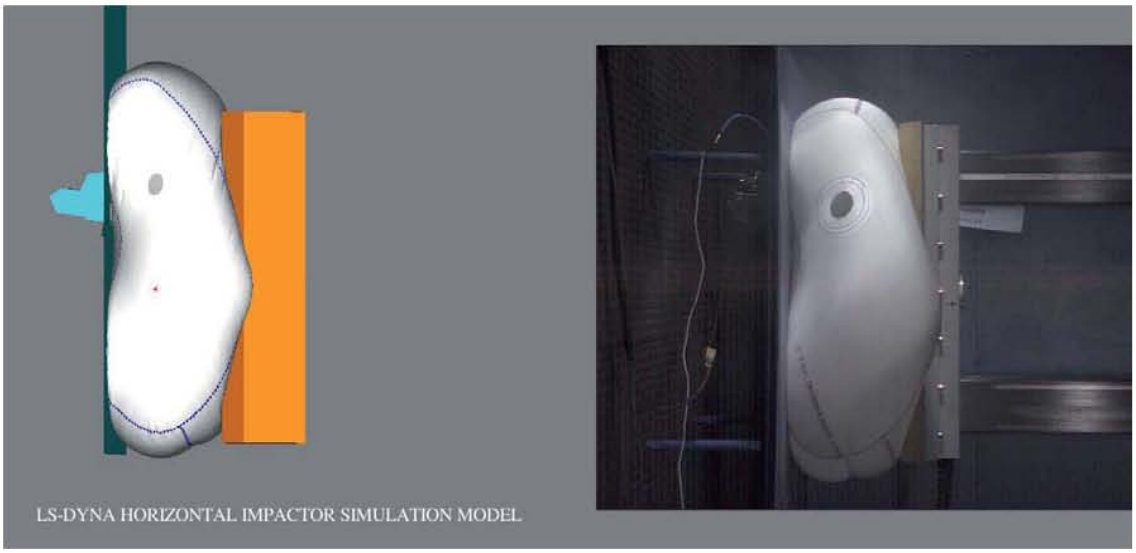
Fabric Leakage Model

Simulation of Linear Impactor Tests (580 2x40mm)



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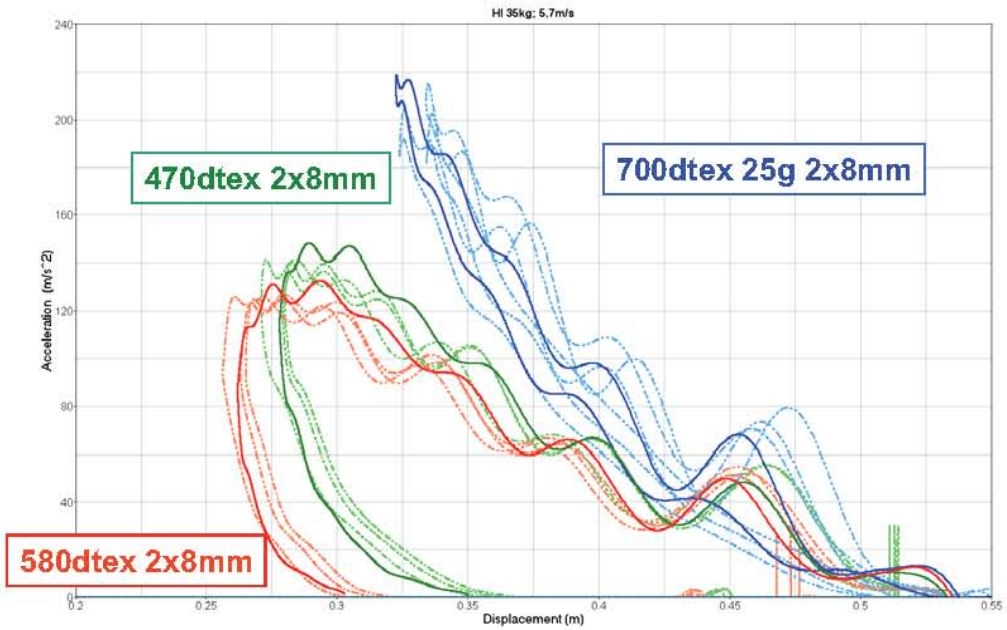
Fabric Leakage Model

Simulation of Linear Impactor Tests 2x8mm Vents



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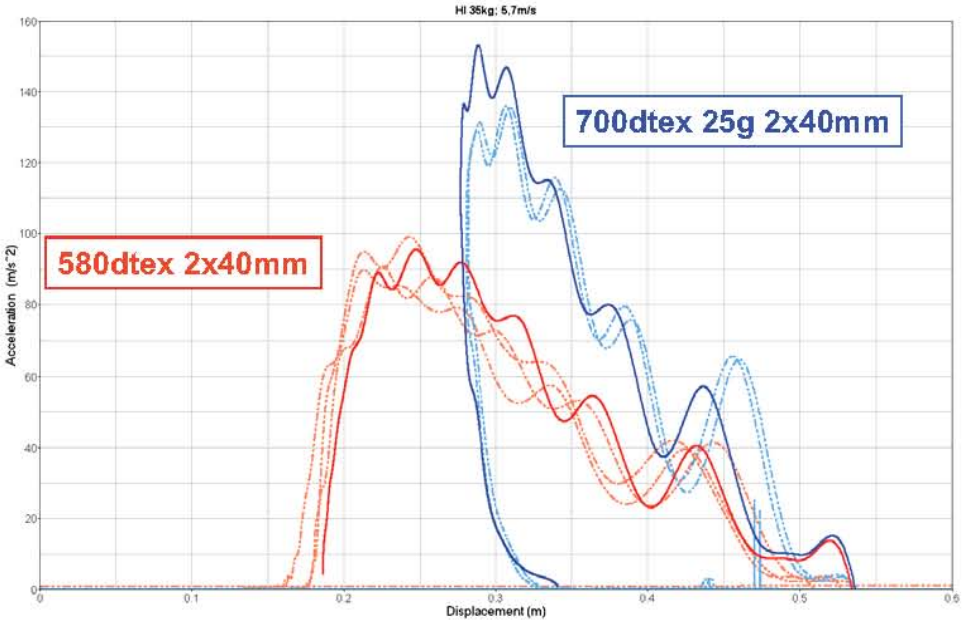
Simulation of Linear Impactor Tests 2x40mm Vents



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Fabric Leakage Model
Conclusion

- Autoliv leakage testing device (GES) delivers valuable test results for permeability investigation
- Tests with GES as well as with linear impactor showed significant differences for fabrics with different air permeability
- Best correlation for fabric permeability could be achieved with model according:
  - equation for nozzle (St. Venant-Wantzel) and
  - strain/pressure dependent effective area (Autoliv)
- Models delivered very good results in simulation of linear impactor tests
- The new permeability model is integrated in LS-DYNA v5

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