Composites forming simulations in LS-Dyna using the material law 249

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0. Agenda

Presentation content

Faurecia: Leader in automotive equipment

- **34** Countries
- **€20.7** Billion of total sales
- **103,000** Employees
- **330** Sites

- **489** Patents filed in 2015
- **6,000** Engineers and technicians
- **30** R&D centers
- **610** Programs in development

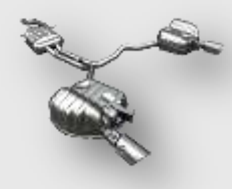
#3 Worldwide

#1 Worldwide

faurecia Automotive Seating

#1 Worldwide

faurecia Interior Systems



#1 Worldwide

faurecia Emissions Control Technologies

I. Introduction

Faurecia Composite Technologies

350
Employees

2
Composite plants

3
R&D + D&D centers

3
Countries

Structural parts

- Body in white, beam reinforcements
- Crash resistance, stiffness
- Luxury & Premium, mass market, trucks, EV

Semi-structural parts

- Large 3D parts, closures and panels
- Function integration, acoustics / NVH
- Luxury & Premium, mass market, trucks

A Class

- Visible parts, closures
- Painted or exposed carbon
- Luxury & Premium, trucks

Faurecia competence center

- Seat structures
- Cross Car Beams
- Heat shields

I. Introduction

Composites forming of continuous fiber plies

Continuous sheets

Complex geometry

- **Major step of two promising processes for a mass market composite parts production**

Thermoforming	RTM
Forming of organosheets	Dry fabric preforming

- **Advantages**
  - Short cycle times
  - High repeatability allowing automation

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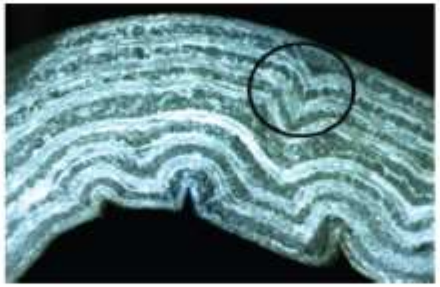
Composites forming of continuous fiber plies – Drawbacks

- **Defect intensive**

Fiber wrinkling



Inter-ply fiber wrinkling
Gazo-Hanna, E. et al. (2009) in JNC 16, AMAC

Fiber thinning

- **Waste intensive**
  - Increased process and material cost
  - Complex recycling
- **Important influence on mechanical part properties**

Process simulation fundamental

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II. Material models for composites part forming

Composites forming simulation: FCT- vision

- **Expertise domain (physics, mathematics, IT, product, process, materials …)**
  - Garbage in – garbage out

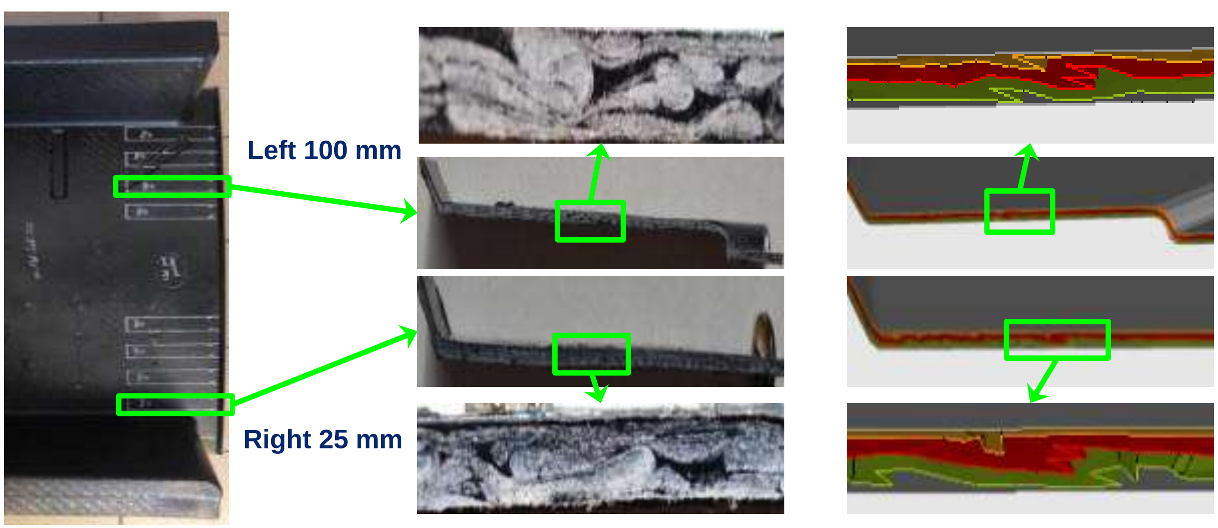
- **Important number of software codes and material models on the market**
  - Different levels of maturity and usability
- **Main material model selection criteria**

Criteria	Kinematic draping	Elastic / Viscoplastic material models
Accuracy	Only for simple kinematics (problematic especially for complex parts)	Most important defects can be detected
Availability	CATIA, Quick-Form, etc.	PAM-Form, LS-Dyna, RADIOSS, etc.
Computation time	Very fast evaluation	Computational time intensive
Considered physics	Largely simplified physics (e.g. no thermal considerations)	Comprehensive process simulation possible
Material characterization	Some non-physical parameters	Some non-physical parameters

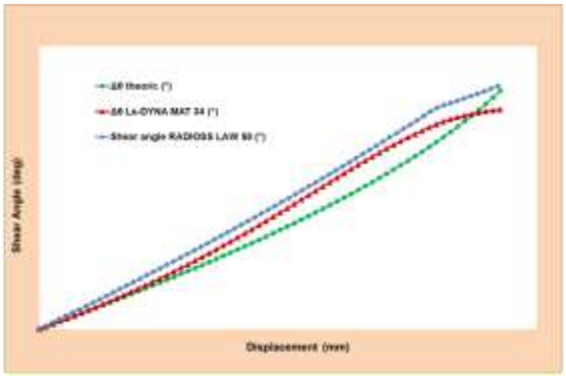
II. Material models for composites part forming

One-step forming

- **Comparison of 2 commercial software codes : LS-Dyna (MAT 34) and RADIOSS (Mat 58)**
  - Comparable results
  - However differences in the details and the usability
- **Inter-ply wrinkling prediction in multi-ply simulation**



School mold

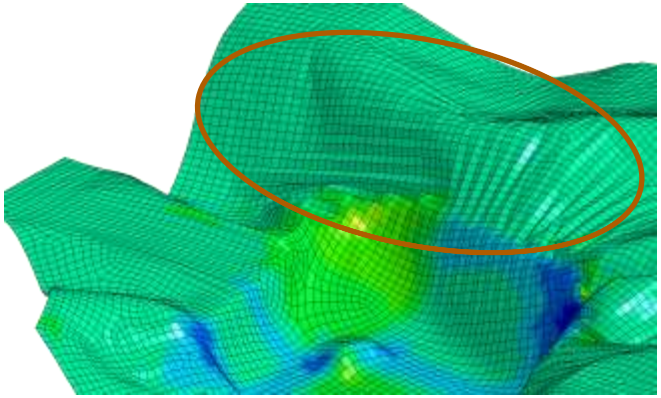


Shear displacement comparison for bias test

II. Material models for composites part forming

Multi-stamp-forming

- **Material model behavior in complex situations**
  - Numerical instabilities due to not considered physical phenomena
    - Convergence errors
    - Reduced prediction precision
  - Important computation times
  - Superposition with a second material layer necessary to consider matrix behavior



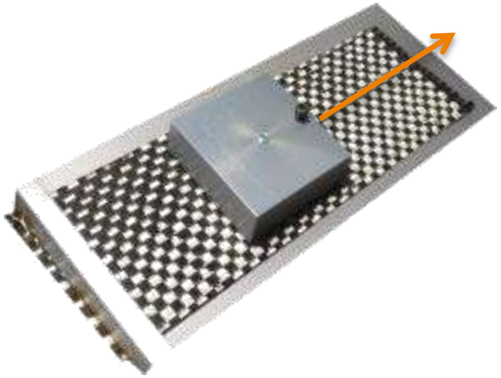
LS-Dyna MAT 34 forming with missing shear-distortion coupling

- **LS-Dyna Mat 249:**
  - Recently developed material law
  - Specifically developed for composite part forming
    - Independent fiber - matrix behavior in the same material law

Material characterization

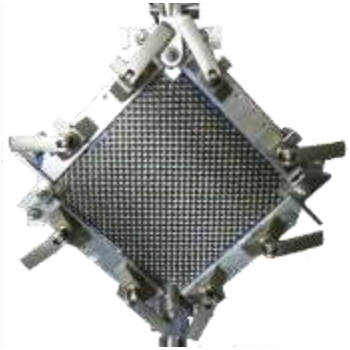
- **Specific characterizations of the matrix and the fiber material**

- **Friction coefficients**
  - Consideration in the *CONTACT Keyword
  - Traction of a mass over the composite ply
  - Differentiation between
    - Ply - ply contact
    - Ply - mold contact
  - Non-negligible influence on the material forming behavior



Friction trial at Fraunhofer ICT

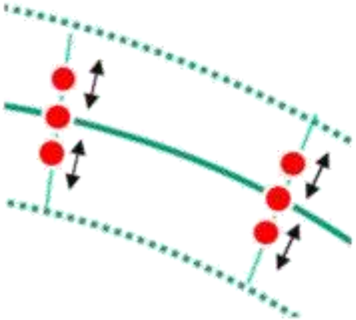
- **Fiber material parameters of Mat 249 – direct characterization**
  - Young modulus → E.g.: Tensile test, bias extension test
  - Shear behavior → E.g.: Bias extension test, picture frame test



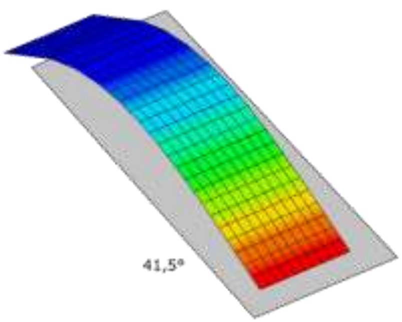
Picture frame test

Material characterization – Non-physical input values

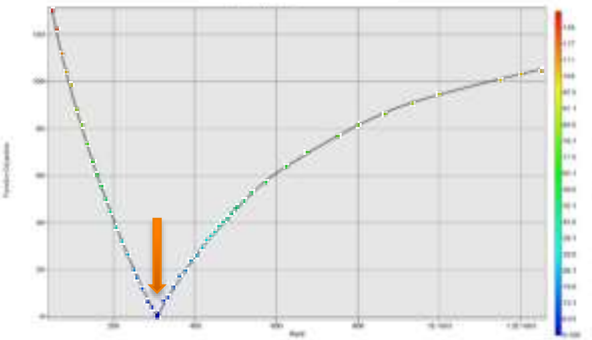
- **Direct input into material law not possible**
- **Mat 249: Bending stiffness**
  - Can be determined by the local integration point position
- **Characterization approach**
  - Numerical reconstruction of the DIN cantilever test
  - Optimization cycle in LS-Opt



Integration point position variation
Dr. T. Klöppel, 2016, New material model *MAT_249 for thermoplastic pre-pregs and dry fabrics



Cantilever test according to DIN - 53362



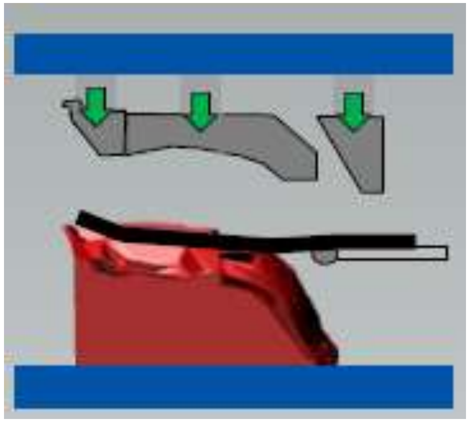
Identification of the material parameters through optimization

Specific characterization protocols for non-physical parameters

IV. Composites forming application

Dry fabric preforming with the Fraunhofer ICT

- **Preform stamping for the RTM process**
  - High influence on local permeabilities and thickness (dry zones, wrinkles…)
  - ➡ Mandatory to consider during RTM filling simulation
- **3 Materials**
  - Plain weave, Twill (2/2), NCF
  - Different forming behavior
- **Forming press at the Fraunhofer ICT**
  - 3 independent forming stamps
  - Multiple possible gripper positions
  - ➡ Optimization of the forming kinematics
  - ➡ Wrinkles elimination



Independent forming stamps
Prof. F. Henning et al., 1st International Composites Congress (ICC) - 2015 "Cost-efficient Preforming as leading process step to achieve a holistic and profitable RTM product development"

Gripper positions

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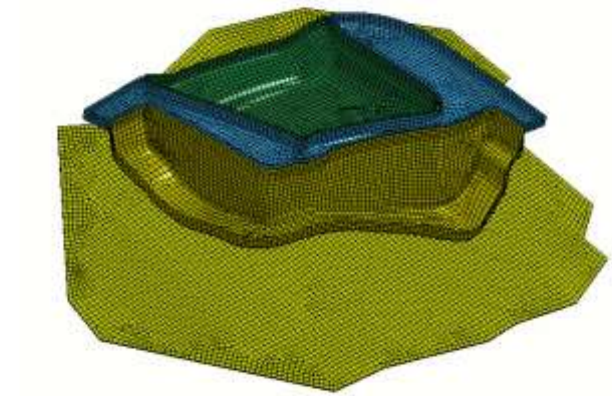
IV. Composites forming application

Dry fabrics forming simulation

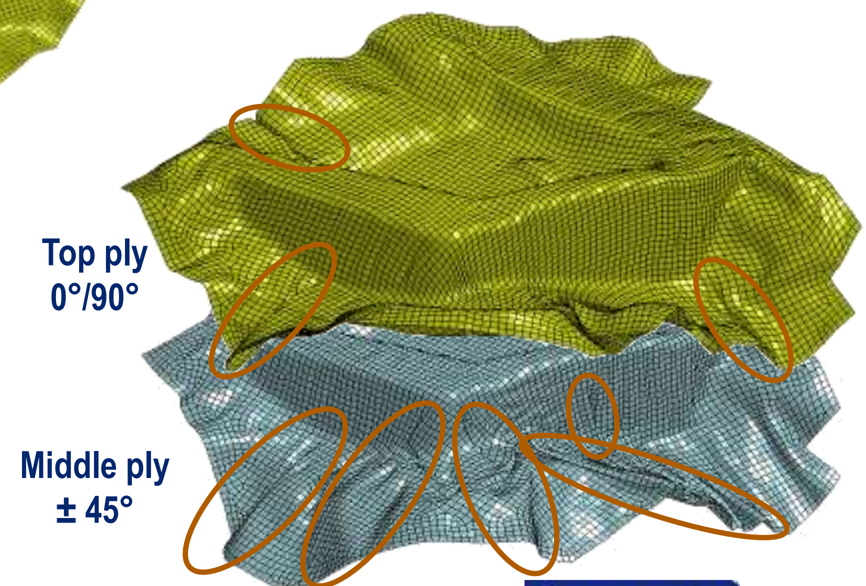
- **High grade of correlation for all three materials**



Forming with Mat 249

  - Independent of the forming sequence

- **Detection of wrinkles for the interior plies**
  - Detection very difficult for the real part



IV. Composites forming application

Dry fabrics forming sequence optimization

- **Simulation driven optimization**
  - Manual variation of the stamp displacement curves
  - Manual analysis of the wrinkle number and location for all plies
  - All wrinkles eliminated for two materials but not the NCF fiber material
- **Validation of the simulation results by physical trials**

Wrinkles elimination via simulation / optimization reduces part development cost and time

V. Conclusions

Outlook

- **Important influence of forming sequence on final mechanical part properties**

➡ **Mechanical part simulation using mapping of fiber orientations and wrinkles**

- **Application on other formed composite parts**
  - One-shot process for visible parts

V. Conclusions

Take-away

- **Simulation and optimization: a key to reduce Cost, Weight & Time**
- **Forming is an essential part of the complete composites product-process chain**
  - Application in main automotive processes
    - RTM – preforming of dry fabrics
    - Thermoforming of organosheets
  - Managing the forming kinematics
    - Guarantee and optimize the mechanical properties of the final part
    - Enable advanced process combinations
- **Main reasons for a successful industrial application of a material model**
  - Exhaustive representation of all main defects and physics
  - Reasonable computational effort
  - Easy material law characterization and availability of characterization protocols

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Technical perfection, automotive passion