Short Fiber Reinforced Plastics in Explicit Simulations

State of the Art Approaches for Efficient Modeling

11th German LS-DYNA Forum 2012, October 9-10, Ulm, GE

Jan SEYFARTH, e-Xstream engineering

Noriyo ICHINOSE, JSOL Corporation

Short Fiber Reinforced Plastics in Explicit Simulations

Overview

- ✓ **Company**
  - Some Recent Changes
  - Motivation
- ✓ **Technology**
  - Material Modeling
  - Solution Procedures
  - Mapping
- ✓ **Full Vehicle Simulation**
  - Lower Leg Impact
  - Front Crash

JSOL CORPORATION

NTT DATA

COMPANY

Some Recent Changes
Motivation

Some Recent Changes

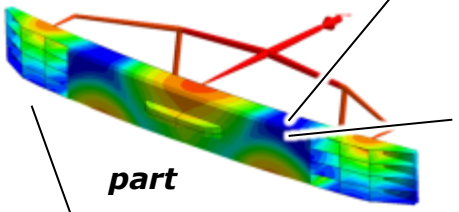
e-Xstream engineering

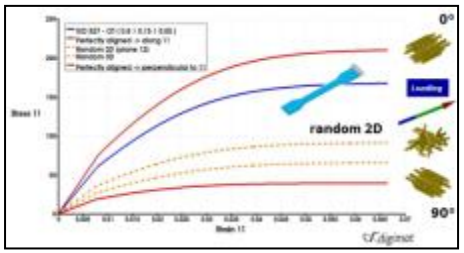
- ✓ **Now a « MSC Software company »**
  - Aquisition in October 2012
    - Team of 25 specialists has joined an organization of 1.100 worldwide…
    - e-Xstream will be kept & run as an independent company
- ✓ **What does this mean to the DIGIMAT users?**
  - Everything remains unchanged!
    - Full support of all FEA interfaces (Digimat-CAE/LS-DYNA, ...)
  - Same strategy for the future...
    - Focus on composite material modeling
      - » Stiffness, Failure, Creep, Fatigue, ...
    - Interface between processing & structural simulation
      - » Injection molding / Compression molding / ...
      - » Draping / Mucell / ...

Motivation

Industrial Application of Micromechanical Modeling

- ✓ **Automotive**
  - Reduce CO_2 emissons
    - Need to use lightweight material
  - Shorten developing time
    - 1.8 years to 9 months
- ✓ **Simulation of plastic parts**
  - Composite material modeling
  - Application to
    - Part design
    - Pedestrian safety
    - Full car crash





part

material

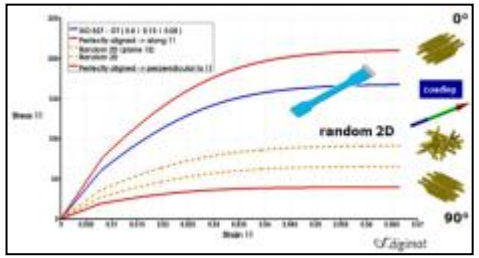
system

Motivation

Industrial Application of Micromechanical Modeling

✓ Requirements for Full Vehicle Crush Simulation

- **!!! Reasonable Calculation time !!!**
  - Within 1 night
  - Size of vehicle model is increasing
    - » Current: over 3M elem. (Expect over 10 M elem. in 3 years)
- Support of many types of load cases
  - Frontal(full frontal, Offset , small overlap), Side, Rear, Pedestrian, etc.
- Need 1 model that is suitable for all load cases



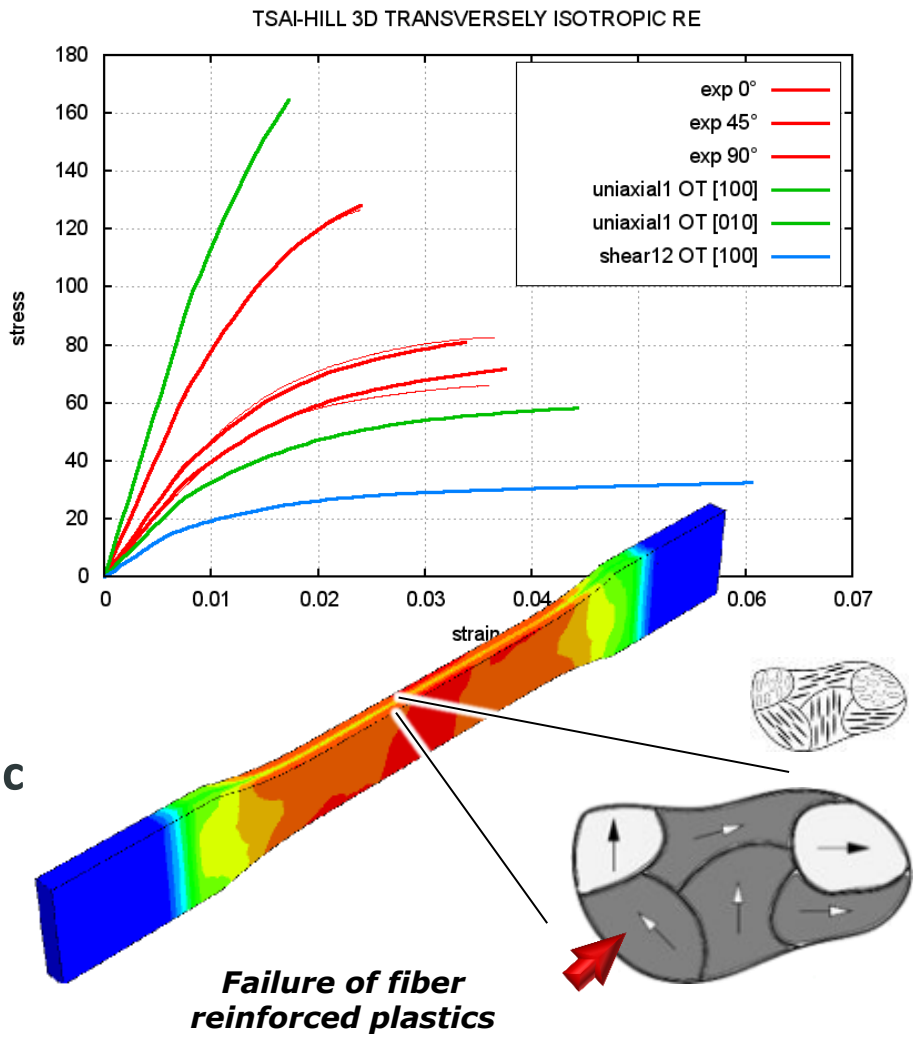
- Material definition for lightweight material
  - Strain rate dependency → Yield, failure
  - Composite → Anisotropy

TECHNOLOGY

Material Modeling
Solution Procedures

Material Modeling

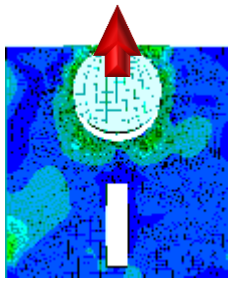
- Stiffness
  - ✓ **Composite properties**
    - Nonlinear
    - Strain rate dependent
  - ✓ **Mean field homogenization**
    - Properties of matrix / fibers
    - Microstructure
- Failure (SFRP)
  - ✓ **Tsai-Hill 3D transversely isotropic**
    - Only 3 parameters to define
  - ✓ **Applied on pseudo-grain level**



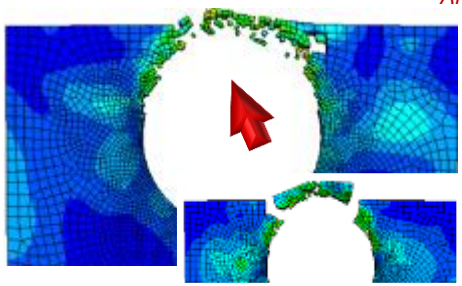
Failure of fiber reinforced plastics

Solution Procedures

- Coupled Solution

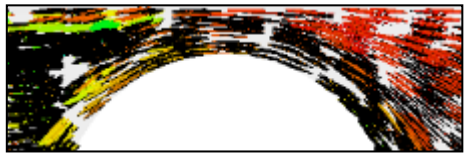


ANISO



ISO

failure



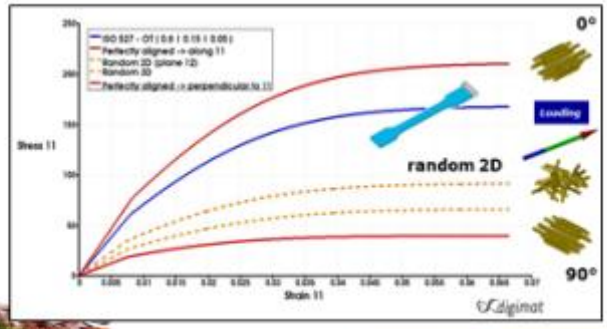
fibers

Measurements

σ/ε curves

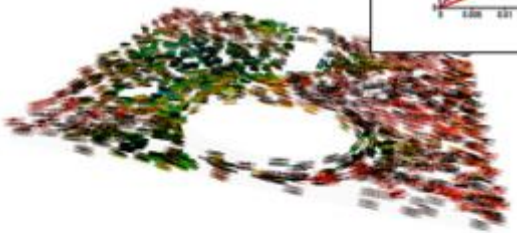
FEA

Structural analys



Material Model

Anisotropic (non)linear



Mapping

→ Structural mesh

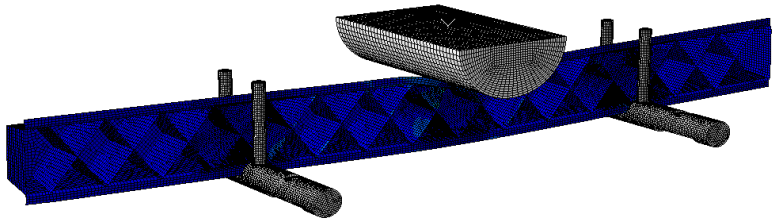
Process Simulation

Orientation data on processing mesh

Solution Procedures

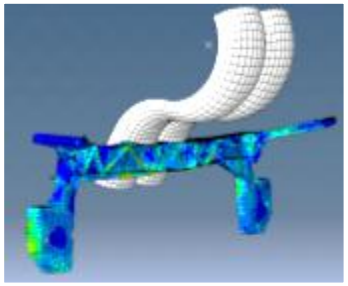
- HYBRID Solution → **explicit solvers**

  - ✓ **DIGIMAT 4.2.1** **January 2012**
    - 9 days / 3 CPUs → 1 day / 1 CPU
      - Good global response
      - Good local results
  - ✓ **DIGIMAT 4.3.1** **July 2012**
    - Up to 50% decrease in memory
  - ✓ **DIGIMAT 5.0.1** **January 2013**
    - About 30 – 50% gain in CPU
    - Up to 40% decrease in memory
    - Failure fully strain rate dependent



8 hours / 3 CPUs *{4.2.1}*

35 min. *{5.0.1}*



OT format	Version	1 Proc
.xml OT file	4.2.1	22 GB
	4.3.1	8 GB
.dof OT file	4.2.1	12 GB
	4.3.1	8 GB

Model size: 1.3 Mio elements

FULL VEHICLE SIMULATION

Lower Leg Impact
Front Crash

Lower Leg Impact

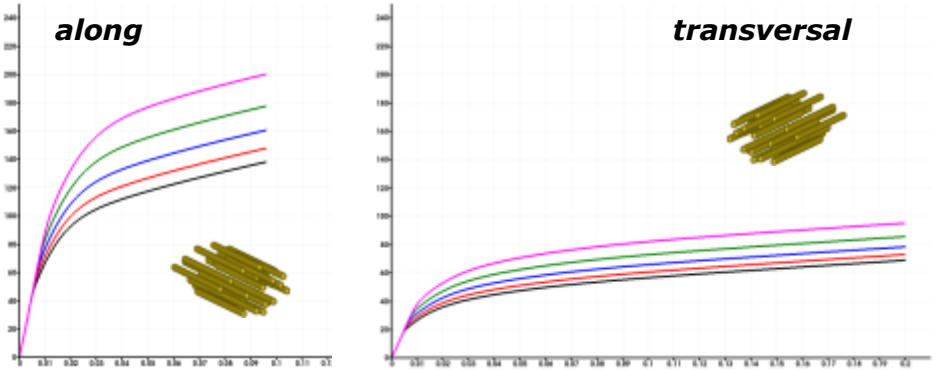
JSOL CORPORATION

NTT DATA

- Multi-Scale Approach

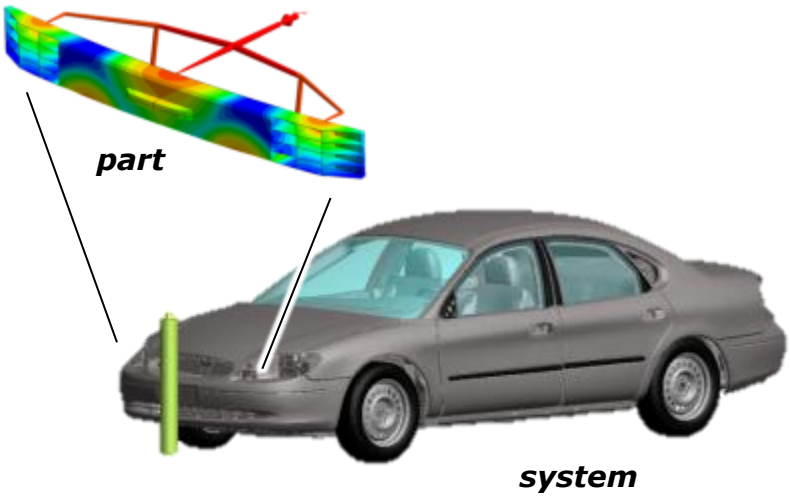
✓ **ANISOTROPIC Model**

- Elasto-Viscoplastic
  - Strain rate dependent
- Failure
- Large vehicle model
  - Over 3 Mio elements



✓ **Evaluation vs. ISOTROPIC**

- Elapsed time
- Robustness
- Global / local responses



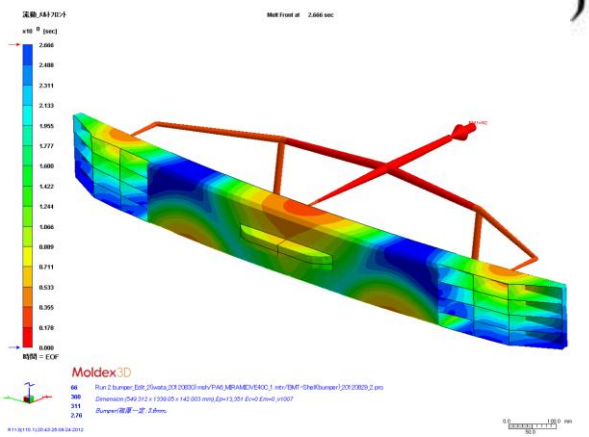
Lower Leg Impact

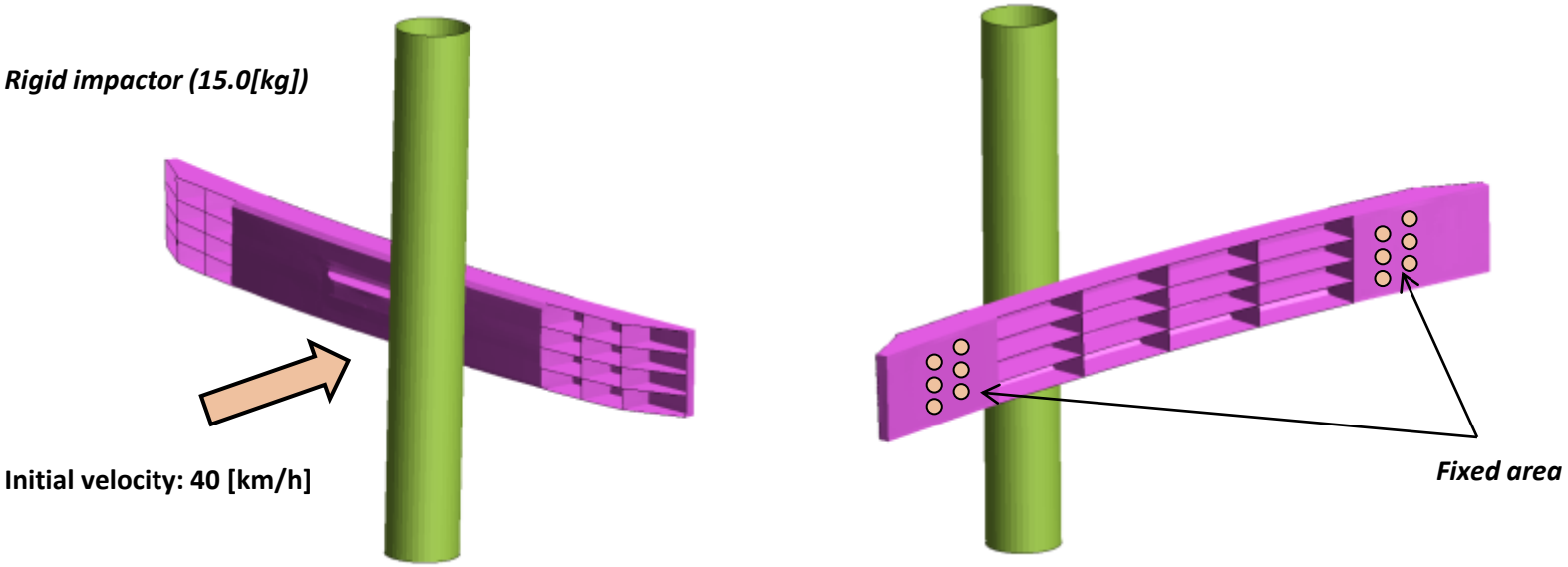
JSOL CORPORATION

NTT DATA

- Bumper Beam

  - ✓ **Rigid impactor**
    - Caluclation time: 10[ms]





Lower Leg Impact

JSOL CORPORATION

NTT DATA

Bumper Beam

✓ **Elapsed time [4.2.1] (16 cores)**

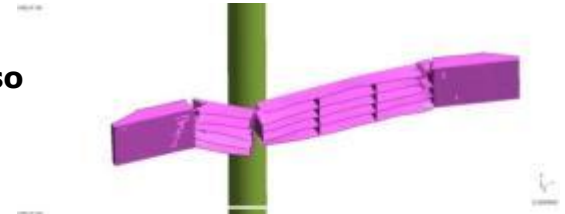
	Termination	Elapsed time	cycles	ratio
ISOTROPIC	Normal (10[msec])	**1 m 41 s**	**10674**	**1.0**
HYBRID	Normal (10[msec])	**1 h 27 m 45 s**	**31835**	**51.6**
MICRO	Error (1[msec])	**(39h 50m 16s)**	**(31835)**	**1420**

✓ **Failure behavior (10ms)**

Iso

Hybrid

Iso



Hybrid

Lower Leg Impact

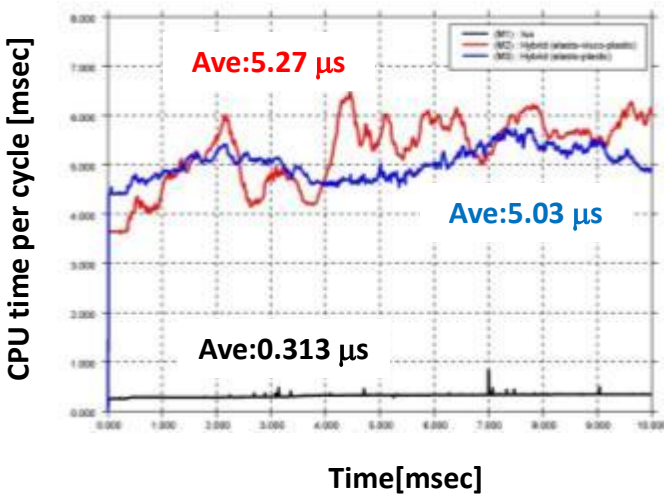
JSOL CORPORATION

NTT DATA

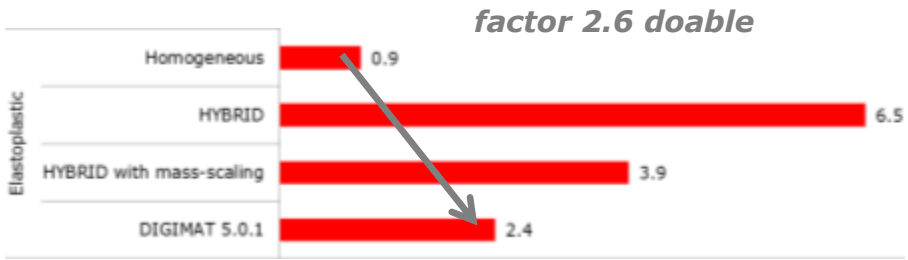
Bumper Beam

✓ **Why can HYBRID still take longer?**

- Timestep
  - Timestep size based on stiffness matrix
  - Minimum timestep
    - » DIGIMAT (HYBRID & MICRO) 0.315 µs
    - » ISOTROPIC 0.935 µs



- **Tune your model**
  - Adjust time step
  - Use mass scaling



- **Parallelize your computation**

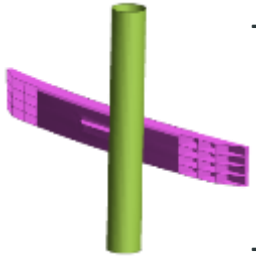
Lower Leg Impact

JSOL CORPORATION

NTT DATA

Bumper Beam

✓ **Why can HYBRID still take longer?**



- Digimat material subroutine
  - Average CPU time per Cycle
    - » ISOTROPIC 0.313 µs
    - » HYBRID 5.03 - 5.27 µs
    - » MICRO 179.8 µs
  - HYBRID material is
    - » 17 times SLOWER than ISOTROPIC
    - » 34 times FASTER than MICRO

50% faster with DIGIMAT 5.0.1

~ 9 times slower than isotropic…
- no mass scaling / tuning

~ 3 times slower than isotropic…
- mass scaling / tuning

✓ **HYBRID is much FASTER than MICRO method!**

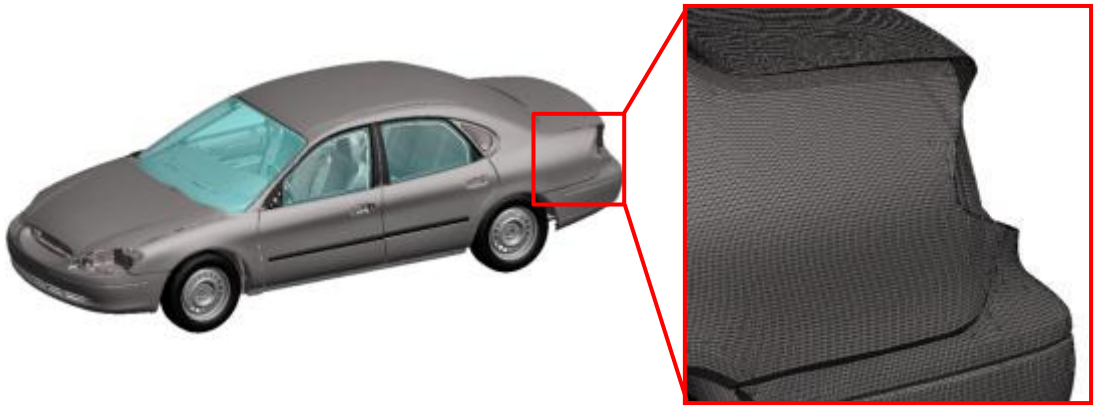
- If all elements are DIGIMAT material, still some CPU is consumed

Lower Leg Impact

JSOL CORPORATION

NTT DATA

- Full vehicle



Elements	3.1 Mio
Ave. elem size	5.0 [mm]
Min. time step	0.25 [μsec]
DIGIMAT	0.84% (26.000)

Pedestrain Protection (Lower leg)

Lower Leg Impact

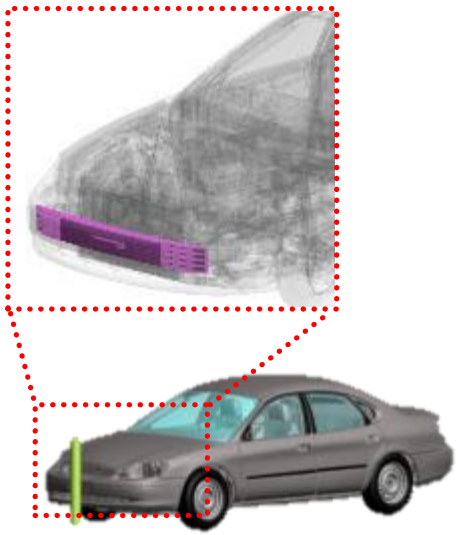
JSOL CORPORATION

NTT DATA

Full vehicle

✓ **Lower leg impact**

- Elapsed time is 4 times larger than ISOTROPIC



✓ **WHY?**

- Minimum time step?
  - No, time step of metal panel is smaller than DIGIMAT material…
- DIGIMAT calculation?
  - Maybe yes, but only 0.84% DIGIMAT in vehicle model
- Others?
  - Yes - **Elapsed time is highly depend on decomposition for parallelization!**

	Termination	Elapsed time	cycles	ratio
Iso	Normal	10h 31m	148149	1.0
Hybrid	Normal	**42h 13m**	148149	4.0

e-Xstream engineering

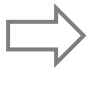
Lower Leg Impact

JSOL CORPORATION

NTT DATA

- Full vehicle

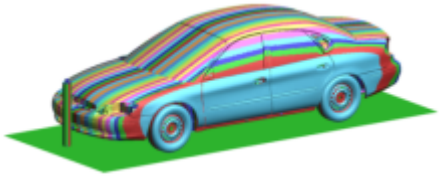
✓ **Default**

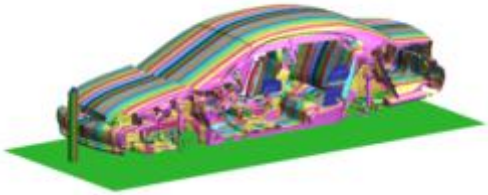


29 domains have no DIGIMAT elements

DIGIMAT elements in 3 domains

✓ **Improved**





10 domains have no DIGIMAT elements

DIGIMAT elements in 22 domains

✓ **Optimized**

- Almost same as improved but all domain have DIGIMAT elements

Lower Leg Impact

JSOL CORPORATION

NTT DATA

Full vehicle

- ✓ **Acceptable increase of calculation time**
  - 9 →14 hours on 32 cores
  - Only 8 hours on 64 cores
- ✓ **Loss in efficiency for ISOTROPIC**
  - On 64 cores
  - Overhead of communication
- ✓ **YES – WE CAN…!!!!!**

	16 cores	32 cores	64 cores
ISOTROPIC improved	17 h 59 m	9 h 17 m	10 h 0 m
HYBRID default	-	42 h 31 m	-
HYBRID improved	26 h 37 m	14 h 16 m	8 h 15 m
HYBRID optimized	-	12 h 5m	-
MICRO improved	-	152 h 51 m (6.4 days)	-

e-Xstream engineering

Front Crash

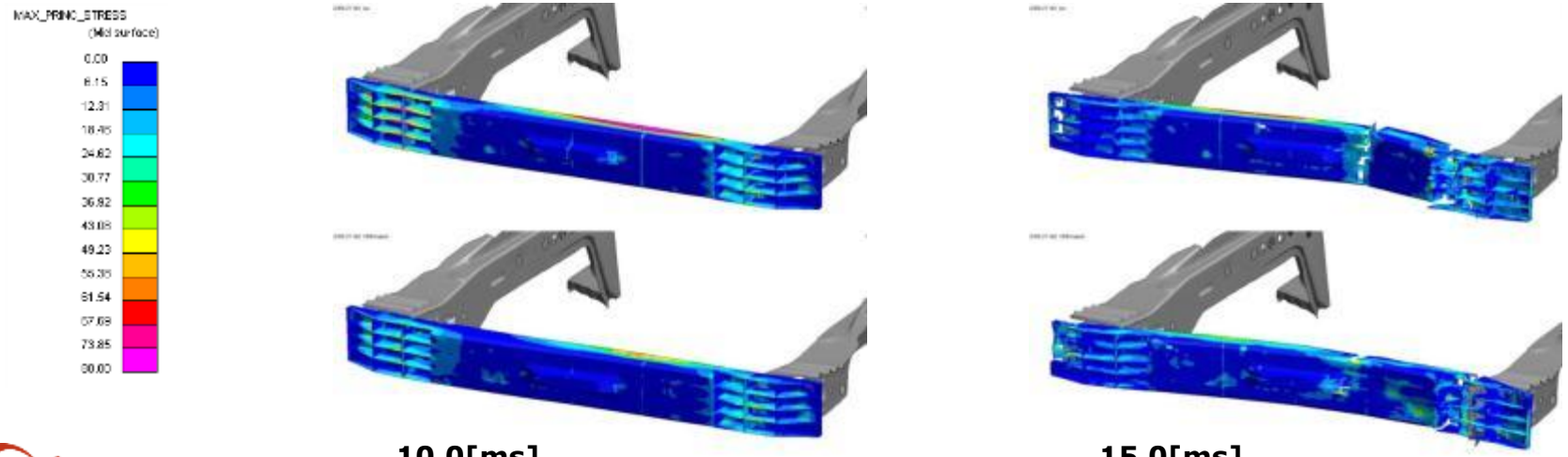
JSOL CORPORATION

NTT DATA Global IT Innovator

- Full vehicle

✓ **What is the impact on the results?**

- Stress distribution different
- Failure area different



10.0[ms] **15.0[ms]**

Short Fiber Reinforced Plastics in Explicit Simulations

SUMMARY

- ✓ **Injection molded plastic parts in full vehicle simulation…?**

- ✓ **YES – WE CAN…!**

e-Xstream engineering

Dr. Jan Seyfarth

Product Manager DIGIMAT

e-Xstream engineering (L)

Phone: +49 (0)89 / 306 007 94
Mobile: +49 (0)176 / 70 55 47 59
Skype: eX_JSH
Email: jan.seyfarth@e-Xstream.com

Z.I. Bommelscheuer
L-4940 Bascharage
LUXEMBOURG
www.e-Xstream.com