Multi-scale Approach for CFRP Composite Simulation by JSTAMP/NV and DIGIMAT

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Engineering Technology Division

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Global IT Innovator

JSOL CORPORATION

OUTLINE

- **Company Introduction**
- **CFRP in Japanese Automotive**
- **JSTAMP Interface for DIGIMAT**
  - What is “JSTAMP/NV”
  - Procedure & Limitation
- **CASESTUDY**
  - Press forming Simulation
  - Crush Simulation
- **Summary**

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JSOL: Company Introduction

Company name: JSOL Corporation
Capital: 5 billion yen
Employees: 1,300(As of Jan 2009)
Headquarters: Tokyo
Branches: Osaka, Nagoya

日本総研 The Japan Research Institute, Limited

A solutions provider that aims to "create new value for customers"through knowledge engineering

株式会社JSOL

A "total service provider" responding to customers' trust and helping them to succeed

変える力を、ともに生み出す。 NTT DATAグループ

A partner that comes up with the vision and realizes the transformation of"working with customers to create the capacity for change"

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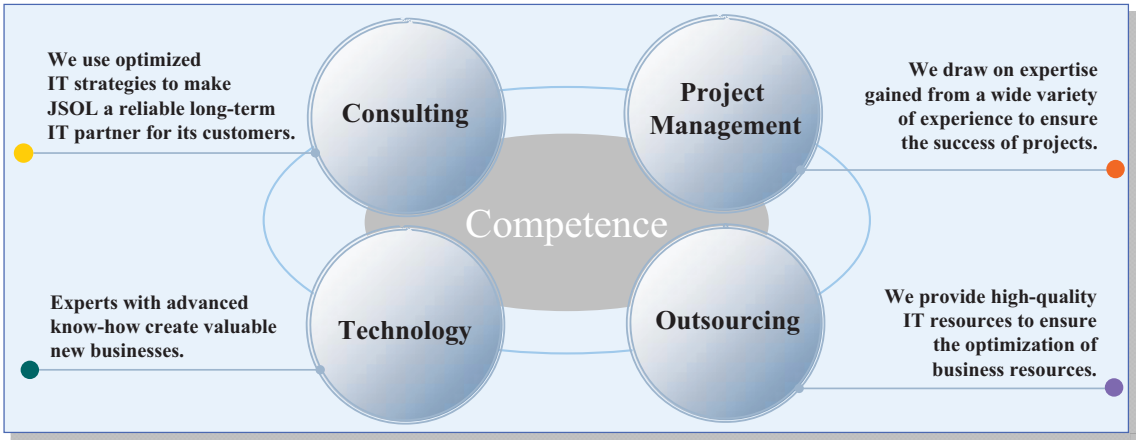
JSOL: Business Fields & Strengths

Business Fields:

IT system consulting & integration (Manufacturing, Public service, Banking etc)
CAE Service (Automotive, Electronics, Materials, Nuclear etc)

Strengths:

JSOL is a reliable professional organization helping customers to solve essential problems and build value for the future.



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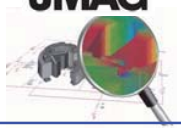
JSOL: Engineering Field

Cutting-edge simulations to support "the art of making things"

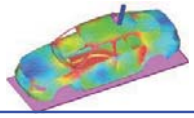
Through products harnessing the latest developments in computer science and engineering consulting services, JSOL delivers solutions to a wide range of problems, from design and development to manufacturing.

Electromagnetics

JMAG

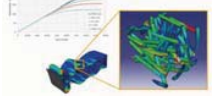


EMCoS

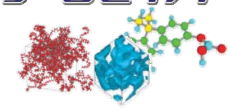


Materials

digimat



J-OCTA



Structural & Crush

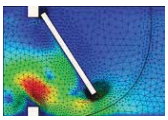
LS-DYNA

Jvision

JSTAMP

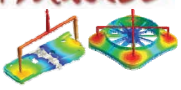
Fluid dynamics

AcuSolve™



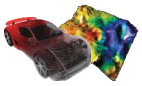
Injection molding

Moldex3D



Optimization

HEEDS



Meshing

simpleware

Measurement

DatapointLabs

expert material testing

CoreTechSystem

CFRP in Japanese Automotive

- Current Application
  - **2000 Nissan: Adopt CFRP hood for mass production**
  - **2003-7 Nissan and Toray: Start NEDO[1] project for lightweight car**
    - Developing high cycle RTM and special resin
    - Evaluating crush and recycling performance

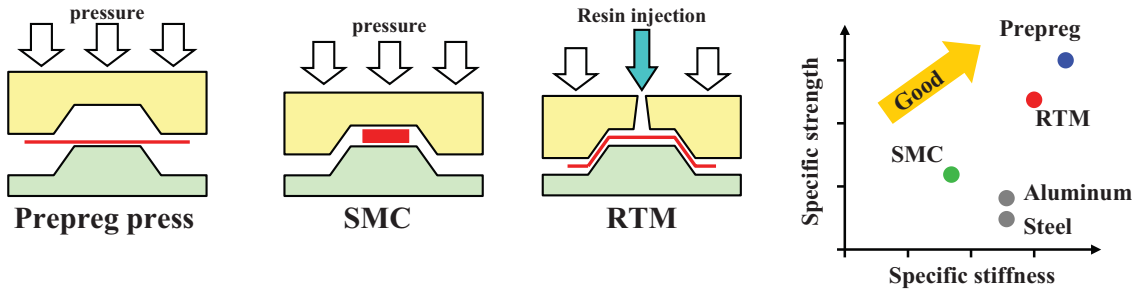
1) NEOD: Japan's public management organization promoting research and development as well as dissemination of industrial technologies

  - **2004 Honda: Legend (mass production) to market**
    - CFRP drive shaft is applied for weight saving and crash performance.
  - **2009 Toyota: Lexus LFA (limited production) to market**
    - CFRP molding processes comprises 65% of chassis structure .
    - Yielding a weight savings of 200kg over an equivalent aluminum design

- **CFRP is becoming the essential material in automotive**
- **To adopt mass production, high cycle forming method is needed**

CFRP in Japanese Automotive

- Forming Method



- **Prepreg sheet has good performance for strength & stiffness**
- **Press forming is suite for mass production**

⇨ **Need to develop the simulation technique for Press forming**

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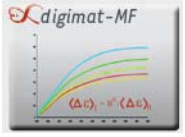
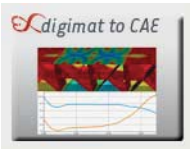
CFRP in Japanese Automotive

- Difficulties of CFRP Press forming simulation
  - Pre and Post processing
    - How to model the tools and set condition?
      - Meshing of tool, Positioning for each tool etc
    - How to evaluate the formability?
      - Wrinkles, Triming line etc

  - Materials definition
    - How to detect the nonlinear anisotropic property?



  - Forming process affects the crush performance
    - How to consider forming process effect on crush model?



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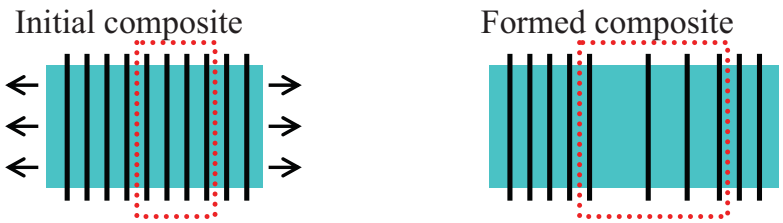
How to consider forming process effect

- Concept



Low fiber density area = Low stiffness area

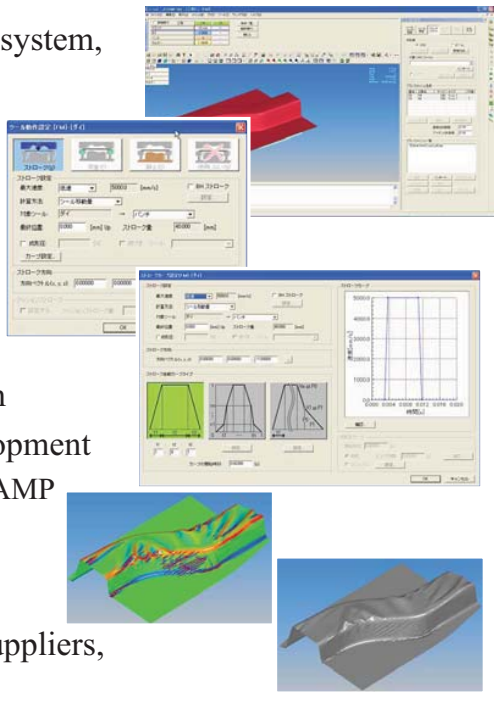
  - **Matrix deformation can be extracted from Digi2Dyna results**

Volume fraction of fiber in formed composite

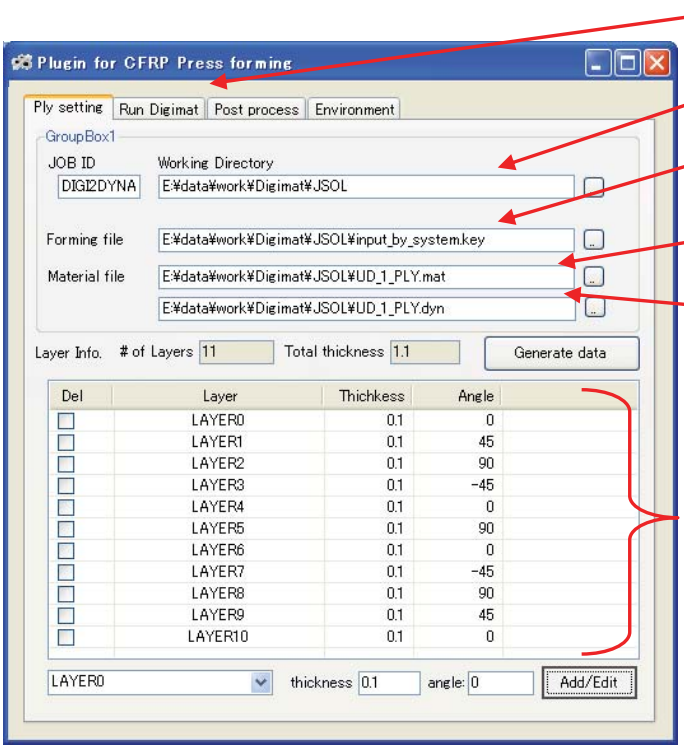
$$\alpha_{fiber}^{formed} = \frac{\alpha_{fiber}^{initial}}{\alpha_{matrix}^{initial}\left(1+\varepsilon_{v}^{matrix}\right)+\alpha_{fiber}^{initial}}$$

What is JSTAMP/NV

- **JSTAMP/NV is a**
  - general purpose sheet forming simulation system,
  - developed in JSOL based on LS-DYNA.
- **JSTAMP/NV is consisted of**
  - HYSTAMP/**LS-DYNA**/JOH-NIKE3D.
- **Feature's of the JSTANP/NV**
  - (1) Forming Evaluation
    - Crack & Wrinkle Prediction
  - (2) Springback Analysis & Compensation
  - (3) Initial Blank Line & Trim Line Development
    - Using One-Step Inverse Solver HYSTAMP
  - (4)Hot Forming Analysis
- **Widely used in over 100 companies,**
  - mainly automotive companies and their suppliers,
  - electronics, and steel companies.



JSTAMP Interface for DIGIMAT



Run DigimatCAE

Set output directory

Set input deck from JSTAMP/NV

Set *.mat from Digimat2CAE

Set *.dyn from Digimat2CAE

Set layer information (ply angle & thickness)

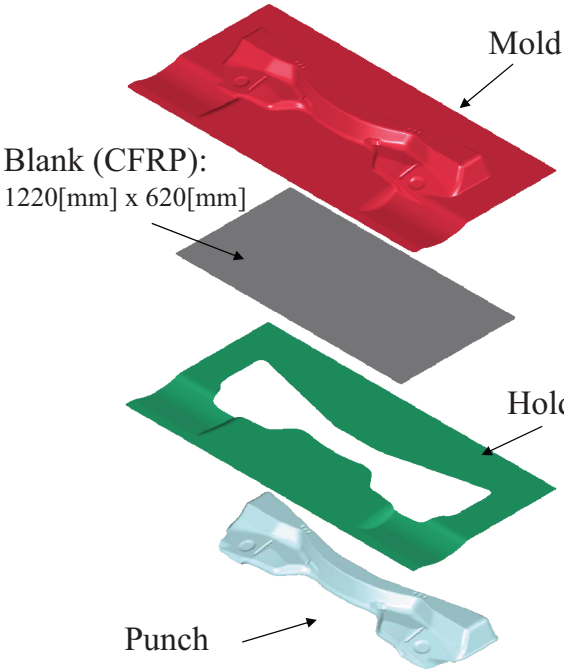
JSTAMP Interface for DIGIMAT

- Procedure for CFRP press forming
  - 1. Make input deck as metal panel by JSTAMP/NV
    - Automatic meshing & process setting
  - 2. Prepare *.mat & *.dyn for 1 ply by Digi2CAE
  - 3. Set Layer information (Ply angle and thickness)
  - 4. Convert metal to CFRP panel by Interface
  - 5. Run with Digimat to Dyna

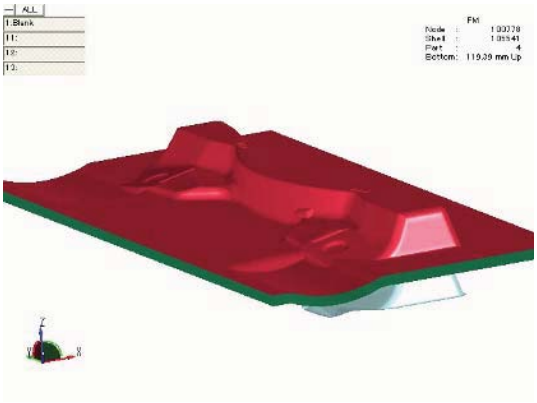
- Limitation
  - Fiber structure is assumed as uni-direction
  - Cannot consider thermal effect of polymer
  - Cannot consider delamination between each layer

CASE STUDY: CFRP Press Forming (UD 2ply)

- Press forming of Automotive cross member



Tool Motion



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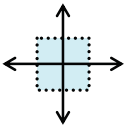
CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability of 2ply CFRP panel (top view)

CASE1:[0,90] 

CASE2:[45,-45] 

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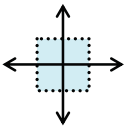
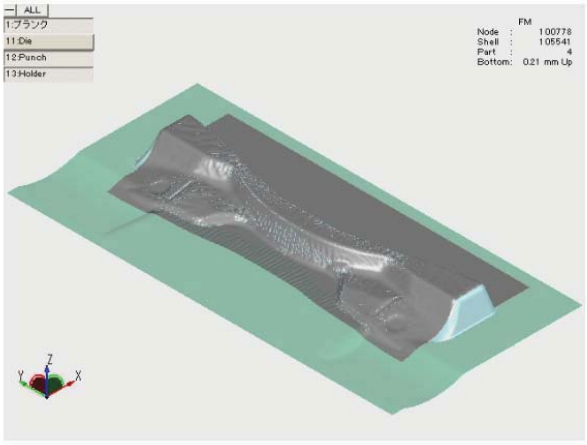
CASE STUDY: CFRP Press Forming (UD 2ply)

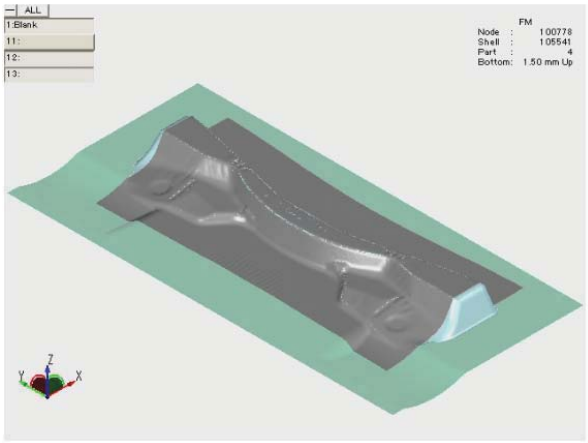
- Formability of 2ply CFRP panel (iso view)

CASE1:[0,90]



CASE2:[45,-45]

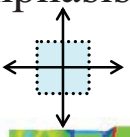




CASE STUDY: CFRP Press Forming (UD 2ply)

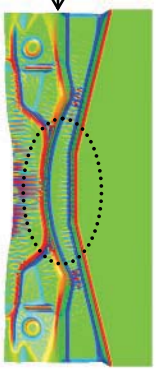
- Formability(enphasis view of Wrinkle)

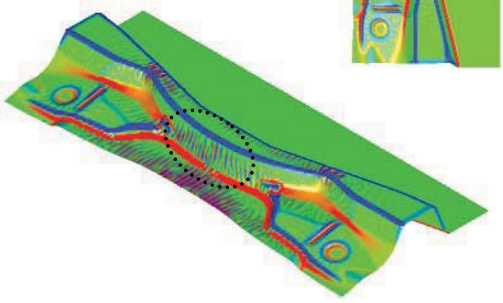
CASE1:[0,90]



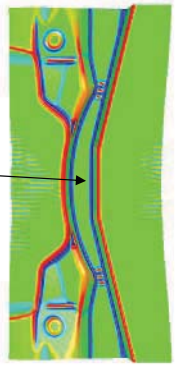
CASE2:[45,-45]

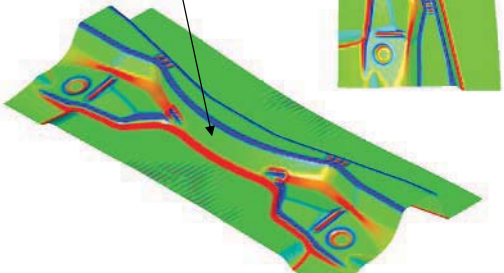
Problem is detected:
wrinkle on product face





No wrinkle

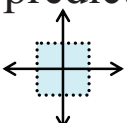




CASE STUDY: CFRP Press Forming (UD 2ply)

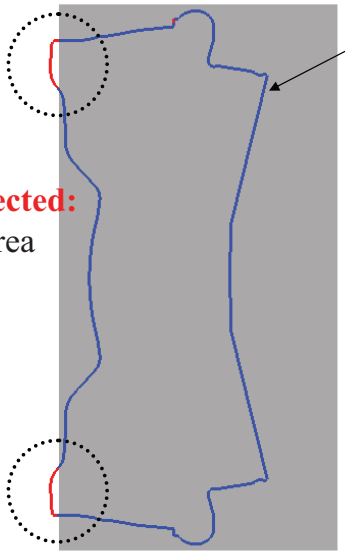
- Trimming line prediction from outline of CAD data

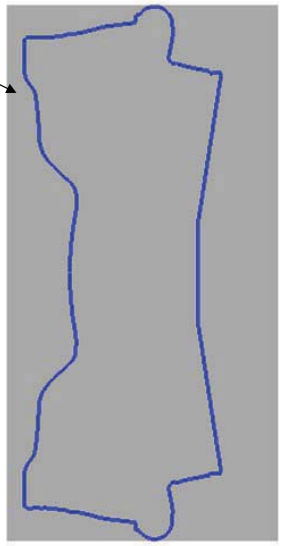
CASE1:[0,90]



CASE2:[45,-45]

Trimming line



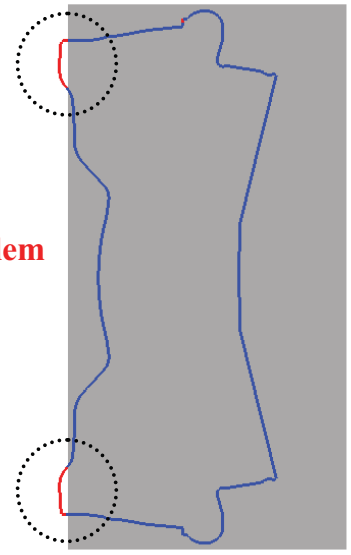


Problem is detected:
Lack of blank area

CASE STUDY: CFRP Press Forming (UD 2ply)

- Countermeasure: Lack of Bank area in CASE1

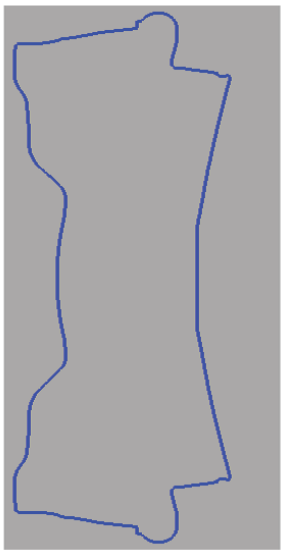
Initial blank position



Problem

Initial position is moved:
40mm

Modified position

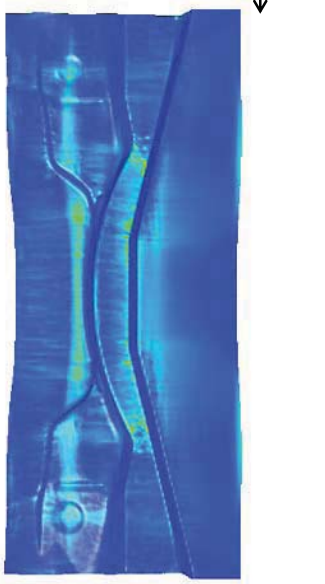


No Problem

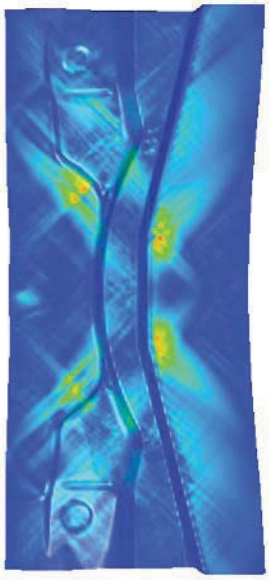
CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability (Max principal stress of Fiber)

CASE1:[0,90]



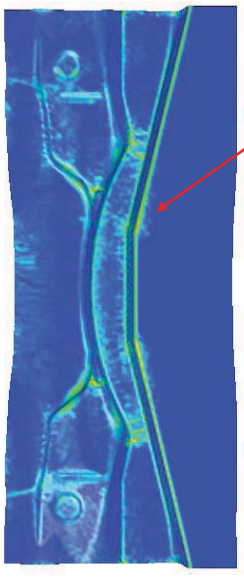
CASE2:[45,-45]



CASE STUDY: CFRP Press Forming (UD 2ply)

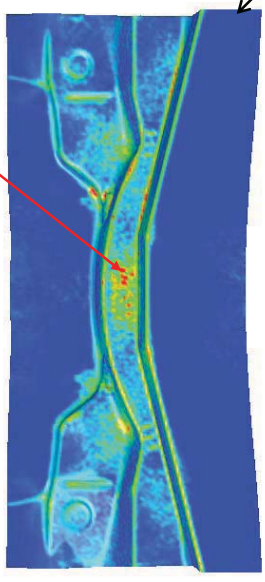
- Formability (Volumetric strain of Matrix)

CASE1:[0,90]



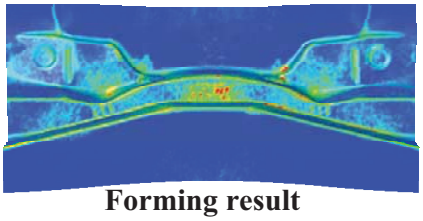
Warning:
Large deformation of matrix makes CFRP stiffness lower.

CASE2:[45,-45]

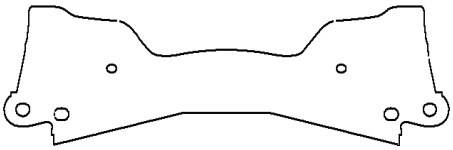


CASE STUDY: CFRP Press Forming (UD 2ply)

- Exporting procedure for crush model

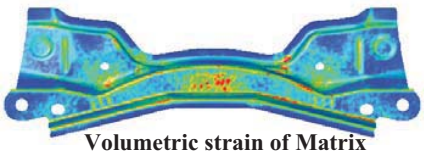


Forming result

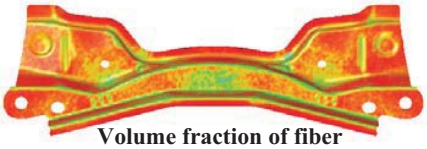


Product outline

Triming



Volumetric strain of Matrix



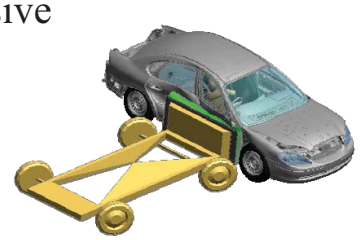
Volume fraction of fiber

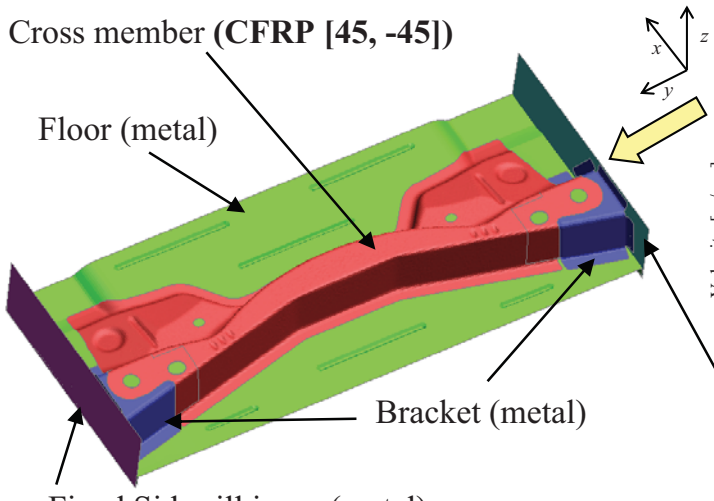
Decompose 4 PARTs

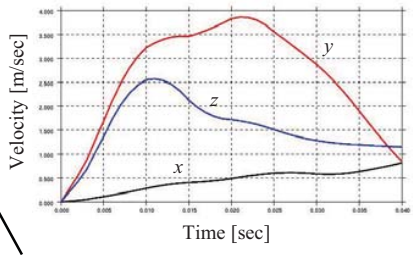
PID 1: 32.1%
PID 2: 34.8%
PID 3: 37.1%
PID 4: 39.0%

CASE STUDY: Crush performance (UD 2ply)

- Crush model
  - CFRP and metal parts connected by adhesive
  - Spot welding is used for metal connection



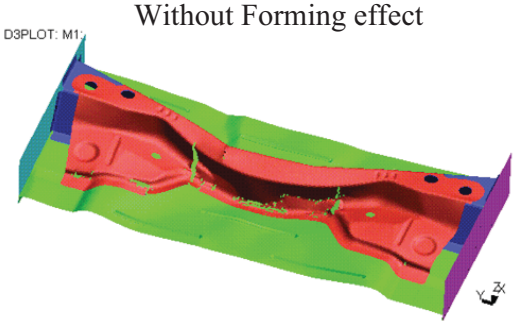




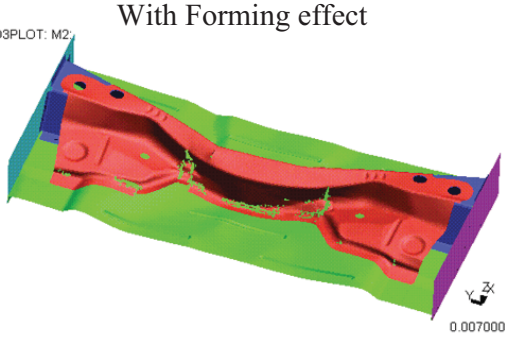
CASE STUDY: Crush performance (UD 2ply)

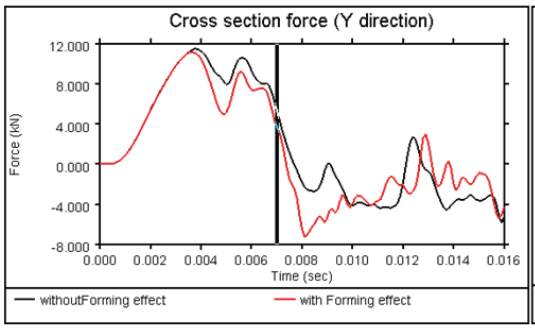
- Results

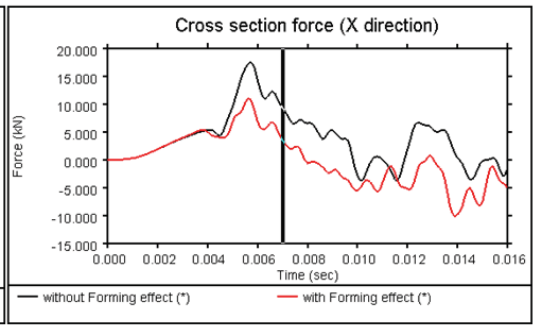
Without Forming effect



With Forming effect







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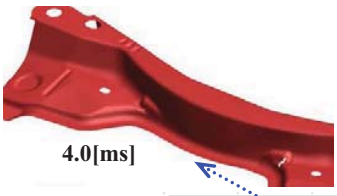
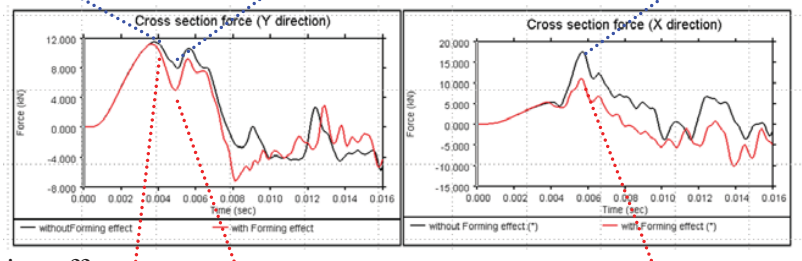
CASE STUDY: Crush performance (UD 2ply)

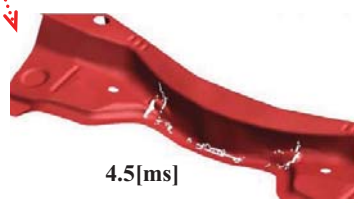
- Results

Without Forming effect





With Forming effect



JSOL CORPORATION

Summary

- Develop interface between DIGIMAT and JSTAMP/NV.
- Run Digimat to Dyna for CFRP forming simulation.
- Export crush model considering forming results.
- Show Different formability for each ply angle.
- Show Effect of forming process on crush performance.

- Future work
  - Correlation with experiment
  - Warpage prediction after de-molding and curing/cooling process
  - Modeling for delemination on crush

Thank you for your attention!!

Any questions?