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

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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

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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.

- **Consulting**
  - We use optimized IT strategies to make JSOL a reliable long-term IT partner for its customers.

- **Project Management**
  - We draw on expertise gained from a wide variety of experience to ensure the success of projects.

- **Technology**
  - Experts with advanced know-how create valuable new businesses.

- **Outsourcing**
  - We provide high-quality IT resources to ensure the optimization of business resources.
Current Application

- **2000 Nissan**: Adopt CFRP hood for mass production
- **2003-7 Nissan and Toray**: Start NEDO¹) project for lightweight car
  - Developing high cycle RTM and special resin
  - Evaluating crush and recycling performance

¹) NEDO: 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

  ![Forming Method Diagram](image)

  - 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, Trimming 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?
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 JSTAMP/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

- **Wideley used in over 100 companies,**
  - mainly automotive companies and their suppliers,
  - electronics, and steel companies.

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How to consider forming process effect

- **Concept**

  ![Diagram showing initial and formed composite with high fiber density areas highlighted.]

  - Low fiber density area = Low stiffness area

  - Matrix deformation can be extracted from Digi2Dyna results

  \[ \alpha^\text{formed}_{\text{fiber}} = \frac{\alpha^\text{initial}_{\text{matrix}} (1 + \varepsilon^\text{matrix}_v) + \alpha^\text{initial}_{\text{fiber}}}{\alpha^\text{initial}_{\text{matrix}}} \]

  Volume fraction of fiber in formed composite

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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

Blank (CFRP): 1220[mm] x 620[mm]

Mold face
Holder
Punch

Tool Motion

CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability of 2ply CFRP panel (top view)

CASE1: [0,90]
CASE2: [45,-45]
CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability of 2ply CFRP panel (iso view)

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]

**Problem**

Initial position is moved: 40mm

**Modified position**

No Problem

**Problem is detected:**
Lack of blank area

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CASE STUDY: CFRP Press Forming (UD 2ply)

- Countermeasure: Lack of Bank area in CASE1

Initial blank position

Modified position

Initial position is moved: 40mm
CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability (Max principal stress of Fiber)
  - CASE1: [0,90]
  - CASE2: [45,-45]

Warning:
Large deformation of matrix makes CFRP stiffness lower.

CASE STUDY: CFRP Press Forming (UD 2ply)

- Formability (Volumetric strain of Matrix)
  - CASE1: [0,90]
  - CASE2: [45,-45]
CASE STUDY: CFRP Press Forming (UD 2ply)

- Exporting procedure for crush model

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

Cross section force (Y direction)

Cross section force (X direction)
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?