Why is Intelligent Simulation Important?

- Metal forming simulation is inherently difficult
  - Creativeness of metal forming process design
  - Multi-stage and compound processes

- CAE application is diffusing widely to small or midsized companies
  - Many users are not proficient at the related theories or don’t have sufficient process design experience

- Chronic problems
  - Many engineers still think the usage is difficult
  - Many users still consider the predicted results as just one of references and don’t try to obtain more accurate solutions because of the lack of confidence in the solution accuracy.

- Ways to solve the problems
  - Intelligent metal forming simulation
Requirements for Intelligent MF Simulation

- **Solution accuracy**
  - Tensile test simulation
  - Minimum volume loss or change
  - Accurate solution for well defined defect formation problems

- **Intelligent remeshing**
  - Adaptive remeshing capability
  - Minimized difference in BVP between before and after remeshings
  - Maintenance of characteristic boundary or surface with sharp edges
  - Configuration-friendly mesh system
  - Minimized smoothing of state variables
  - Robustness of remeshing

- **Easy-to-use pre/post processor**
  - Many intelligent capabilities or fool proof functions
  - Automatic calculation of coefficients related to the theories
  - Easy to learn
  - Fully automatic simulation of multi-stage metal forming processes
  - 2D/3D or hot/cold combined simulation

- **Applicability to solve problems of industrial metal forming processes**
  - All kinds of bulk metal forming processes can be simulated by AFDEX
  - Applicability to new creative metal forming processes
Key Features

- Rigid or Elasto-Thermoviscoplastic FEM with Intelligent Remeshing
- Many Easy-to-Learn or Fool-Proof Functions
- Many User Friendly Capabilities and CAD I/F
- Fully Automatic Simulation of Multi-Stage Processes

Coupled Analysis in Forging

- Flow analysis of workpiece
- Heat transfer analysis of workpiece

Die Set Structural Analysis

- Die insert
  - Elastoplastic analysis
- Shrink ring
  - Elastic analysis

Other tools

- Elastic analysis

Contact load

- Heat generation
- Flow stress change
- Mechanical load
- Die geometry change
- Heat transfer
- Thermal load

2D: Quadrilateral

3D: Tetrahedral/Hexahedral
Accuracy – Tensile test

Engineering stress (MPa)
Engineering strain (mm/mm)

- Experiment (SCM435)
- Analysis (SCM435)
- Experiment (ESW95)
- Analysis (ESW95)
- Experiment (ESW105)
- Analysis (ESW105)
Applicability – Fracture prediction in tensile test
Accuracy – Compression test, Extrusion test

![Graph showing True Stress vs. True Strain for SCM435 and ESW105 materials.]

- **SCM435**
- **ESW105**

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**True strain (mm/mm)**

<table>
<thead>
<tr>
<th>True Stress (MPa)</th>
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<tbody>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>0.8</td>
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</tr>
<tr>
<td>3.2</td>
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<tr>
<td>3.6</td>
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**Contacted**

**Non-contacted**

**Metal Forming 2010**
Accuracy – Hot forging, bearing race

Accuracy – Cold forging, automobile part
Accuracy – Hammer forging, ship engine part

KSPT Spring 2009
Accuracy – Ring rolling, hot, cold, bearing races

Hot ring rolling

Cold profile ring rolling

Accuracy – Cold forging, rotor pole

Accuracy – Enclosed die forging, bevel gear

Enclosed die forging

Sizing
Solution Delicateness – Finite elements

Desired mesh density

Generated mesh system

Solution Delicateness – Minimized smoothing

DEFORM 3D, 2005

Jie Wan et al., 2005
Engineering with Computers
Vol. 21

AFDEX3D, 2007
Solution Delicateness – Specially constructed mesh
Solution Delicateness – Precision simulation
Solution Delicateness – Characteristic boundary
User-Friendliness – Automatic multi-stage simulation
Five-stage automatic cold forging sequence

1\textsuperscript{st} stage

2\textsuperscript{nd} stage

3\textsuperscript{rd} stage

4\textsuperscript{th} stage

2D/3D combined simulation

User-Friendliness – 2D, detailed metal flow lines

Precision simulation of metal flows

New 0.82kg

Old 0.91kg

Metal flow lines for design

Int. J. Maxh. Tools Manuf. 1998
User-Friendliness – 3D, detailed metal flow lines
User-Friendliness – Powerful Pre/Post processor

- Pre-processor
- Post-processor
Applicability – Examples applied while being developed
Applicability – Structural analysis, die with shrink fit
Applicability – Applications of the year 2009
Conclusions

- **Requirements for intelligent metal forming simulation (IMFS)**
  - Optimized and adaptive mesh generation techniques play key role at IMFS.
  - Solution accuracy should be verified.
  - Easy-to-use pre/post processors.
  - Applicability for all kinds of metal forming processes.

- **AFDEX is an intelligent metal forming simulator**
  - Intelligent meshing and remeshing capabilities.
  - Generalized metal forming simulator.
  - The most easy-to-use pre/post processors.
  - The most accurate solution.
  - Proven applicability.