Validation of Forging Simulations
Examples of industrial applications

Dr. Michael Twickler, Dr. Gerhard H. Arfmann
CPM GmbH, Herzogenrath
### Validation: By whom? Why? How?

#### A) Software developer
- to check the correct implementation of the algorithms used
- to check the internal data management
- to check new approaches i.e. material modelling, friction, damage
- etc.

- by comparison with analytic solution (for simple applications)
- by examining the internal data transfer
- by using links to external data processing software to analyse local results
- etc.

#### B) Software user
- Increase the acceptance of simulation as a reliable tool in process design
- Increase the understanding of the local and global results of a simulation
- Increase the technological understanding of the processes
- etc.

**BY**
- comparison of global results with available measured process data
- checking the volume constancy during simulation
- **comparison of the simulated geometry with measurements of real parts**
- comparison with local defects like folding or other marks
- etc.
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding

Problem:
folding on the bottom of the part after the second operation.

Question:
Is the simulation able to show the same folding so that it can be used for optimizing the process?
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding

Measured profile with folding

Simulation result without folding

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFO - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding

Measured profile with folding

Simulation result without folding

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFORE - Porto Alegre, RS, Brazil
Example 1: Inconel 718 disc with a folding

Temperature gradient at the bottom (< 500°C)

Applied YS – strain curve without data at low temperatures
Lowest values are at 950°C

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAOR - Porto Alegre, RS, Brazil
Example 1: Inconel 718 disc with a folding

YS – Strain curves added at lower temperatures

With the added data the simulation shows the folding

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAOR - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding

YS – Strain curves added at lower temperatures

With the added data the simulation shows the folding

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAOR - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding
Validation of Forging Simulations - Examples of industrial applications

Example 1: Inconel 718 disc with a folding

Forged disc with folding

Simulation result showing the folding
Example 1: Inconel 718 disc with a folding

**Fazit:**

The simulation is sensitive enough to react to differences in the material data.

With correct material data the position and the size of the folding will be predicted correctly.
Example 2: Shaft with non sufficient hardness

Problem:
Measurement showed and area where the hardness was not sufficient.

Question:
Periodic failure in the wire or wrong process design leading to non sufficient plastic forming and therefore to lower hardness after heat treatment?
Example 2: Shaft with non sufficient hardness

Cutt off
1. operation
Example 2: Shaft with non sufficient hardness

Validation of Forging Simulations - Examples of industrial applications
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Deformation and therefore strain hardening by backward reduction in the punch and by forming the centring at the bottom of the shaft

No significant strain in the shaft.

Strain distribution along the axis after 1. operation
Example 2: Shaft with non sufficient hardness

Initial situation
2. operation
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Strain distribution after 2. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Slight increase of the strain level in general by further reduction in the punch and upsetting in the shaft

Strain distribution along the axis after 2. operation
Example 2: Shaft with non sufficient hardness

Initial situation
3. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Strain distribution after 3. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil
Example 2: Shaft with non sufficient hardness

Further reduction in the punch and upsetting in the middle of the part.

No further forming in the shaft.

Strain distribution along the axis after 3. operation
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Initial situation
4. operation
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

Strain distribution after 4. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

High strain by finishing the head

No further forming in the shaft

=> Non sufficient hardness after Heat treatment

Strain distribution along the axis after 4. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFORE - Porto Alegre, RS, Brazil
Validation of Forging Simulations - Examples of industrial applications

Example 2: Shaft with non sufficient hardness

The simulation explains the non sufficient hardness found in measurements.

The strain distribution along the axis can be used as criterion to optimize the process design.
Example 3: body of a spark plug (investigation in material flow)

4 forming operations with final additional piercing
Validation ofForging Simulations - Examples ofindustrial applications

Example 3: body of a spark plug (investigation in material flow)

1.

2.

3.

4.

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFOR - Porto Alegre, RS, Brazil
Example 3: body of a spark plug (investigation in material flow)
Example 3: body of a spark plug (investigation in material flow)

The cut surface of the cut off (no phosphate) forms into the shaft.

=> „Shining area“
Validation of Forging Simulations - Examples of industrial applications

Example 3: body of a spark plug (investigation in material flow)

Initial situation
1. operation with marking of the cut off area (point tracking)
Example 3: body of a spark plug (investigation in material flow)

Geometry after 1. operation showing part of the cut off area formed into the shaft
Validation of Forging Simulations - Examples of industrial applications

Example 3: body of a spark plug (investigation in material flow)

Flowline distribution
(the outmost line ends in the cylindrical shaft surface)
Example 3: body of a spark plug (investigation in material flow)

Flowline distribution (the outmost line ends in the cylindrical shaft surface)
Example 3: body of a spark plug (investigation in material flow)

Fazit:

The simulation is precise enough to show the local material flow leading to the forming of the cut surface into the cylindrical shaft surface.

Therefore for other effects resulting from the material flow similar precision can be expected.
Example 4: „Inner Race“ (with typical under filling)

Problem:
After operation 1 and after operation 2 as well the „Inner Race“ shows under filling in the lower area.

Question:
Can the simulation predict these under fillings?
Example 4: „Inner Race“ (with typical under filling)
Validation of Forging Simulations - Examples of industrial applications

Example 4: „Inner Race“ (with typical under filling)

Initial geometry

Geometry after 1. operation

Geometry after 2. operation

(c) CPM GmbH, Herzogenrath, Germany - 29th SENAFORE - Porto Alegre, RS, Brazil
Example 4: „Inner Race“ (with typical under filling)
Validation of Forging Simulations - Examples of industrial applications

Example 4: „Inner Race“ (with typical under filling)

Contact stresses on the tool surface showing the under filling (with mesh)
Validation of Forging Simulations - Examples of industrial applications

Example 4: „Inner Race“ (with typical under filling)

Contact stresses on the tool surface showing the under filling
Example 4: „Inner Race“ (with typical under filling)

**Fazit:**

The simulation is precise enough to show the under fillings.

The contact stresses on the tool surface can be used to analyse the contact situation and to optimize the filling.