Validation of Forging Simulations
Examples of industrial applications

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Validation of Forging Simulations - Examples of industrial applications

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

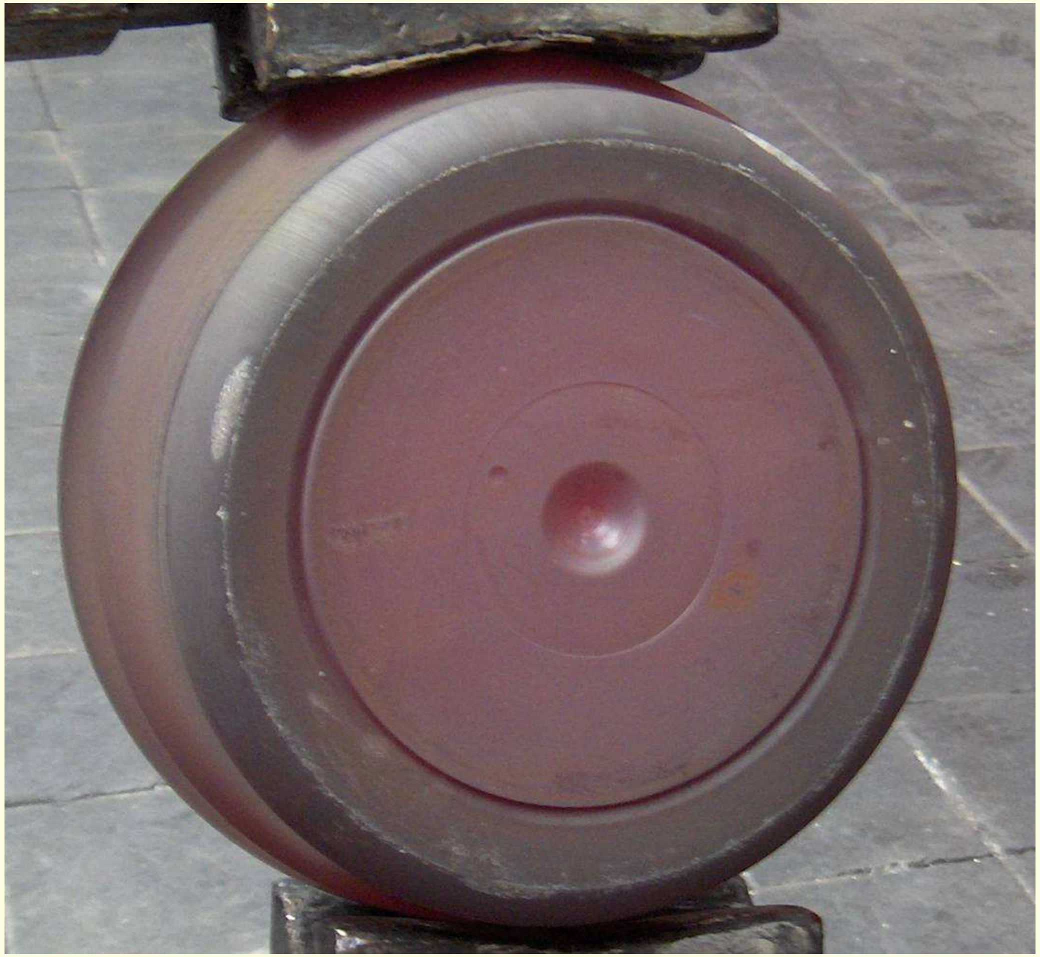
- Increase the acceptance of simulation as a reliable tool in process design
- Increase the understanding of the local and global results of a simulation
- In crease the technological understanding of the processes
- etc.

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

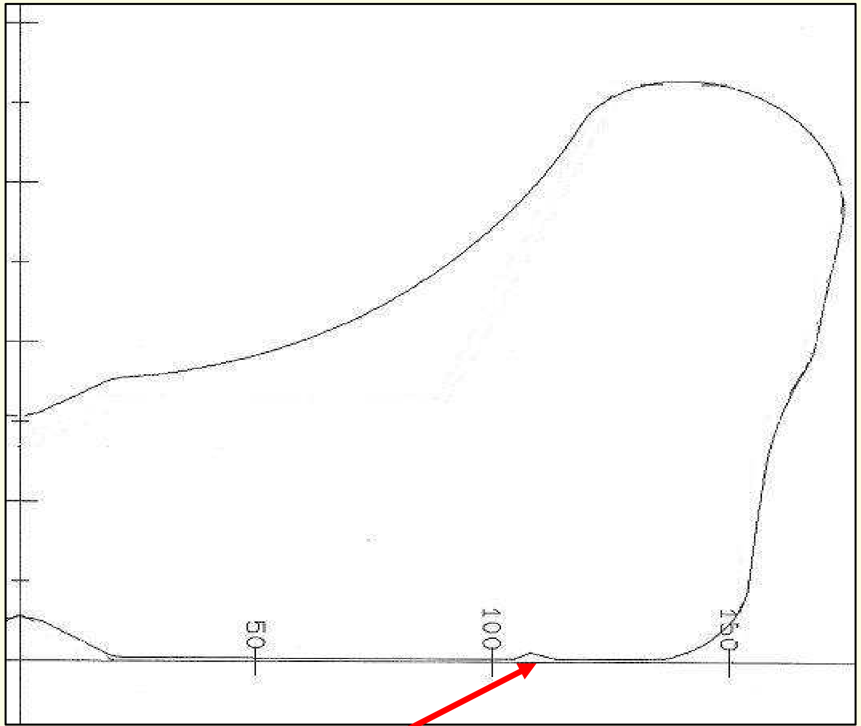
Example 1: Inconel 718 disc with a folding

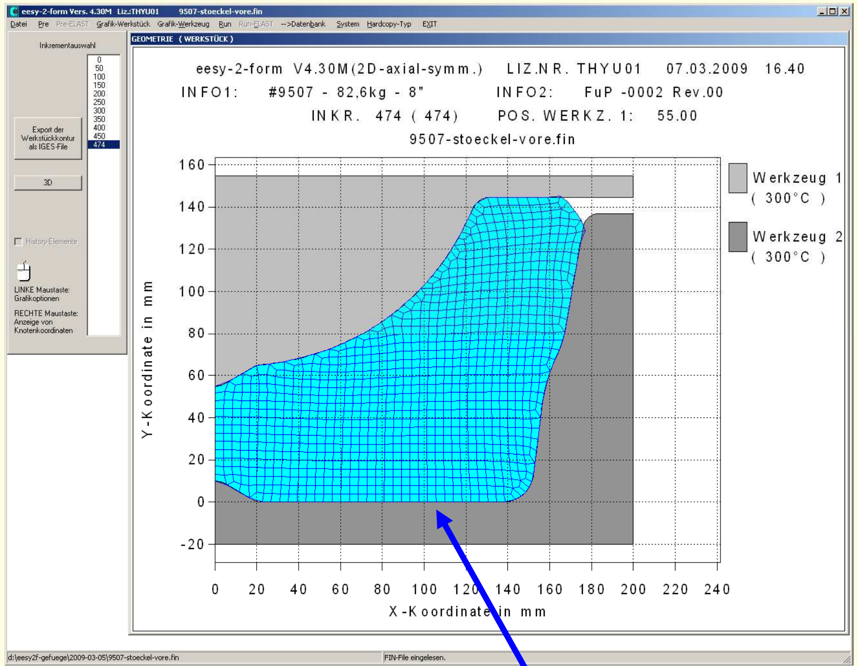


Problem:
folding on the bottom of the part
after the second operation.

Question:
Is the simulation able to show
the same folding so that
it can be used
for optimizing the process?

Example 1: Inconel 718 disc with a folding

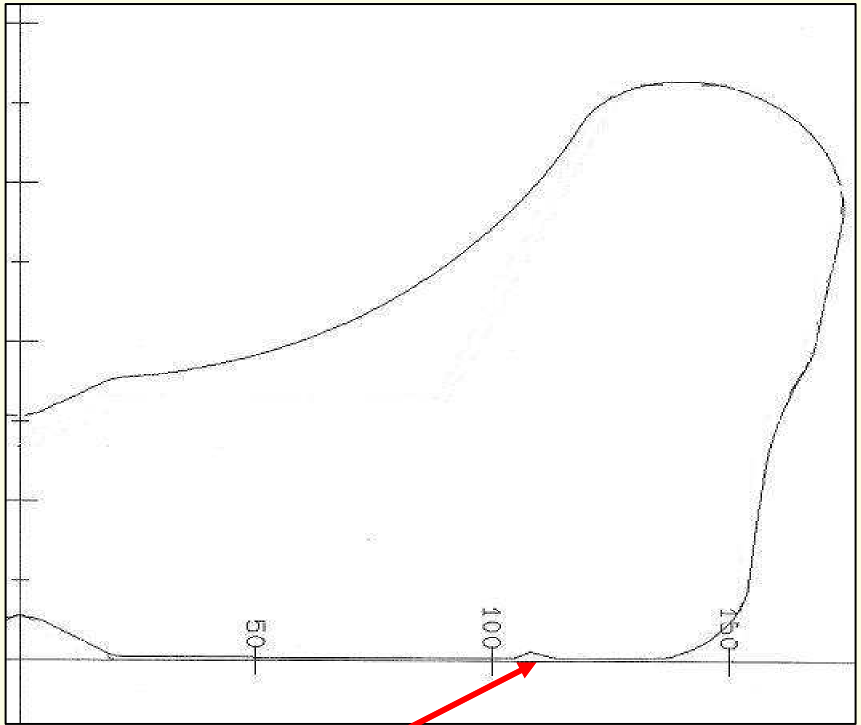


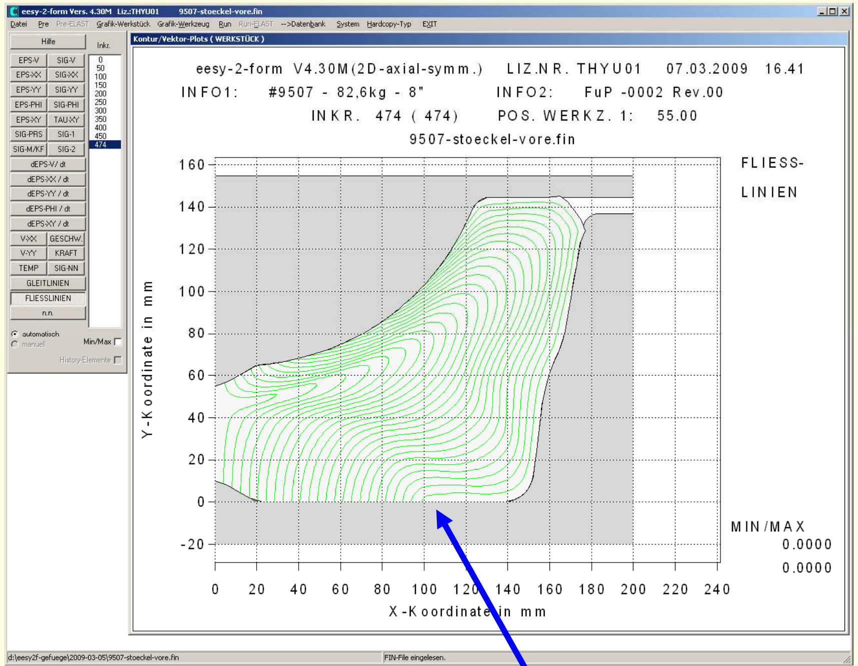


Measured profile with folding

Simulation result without folding

Example 1: Inconel 718 disc with a folding





Measured profile with folding

Simulation result without folding

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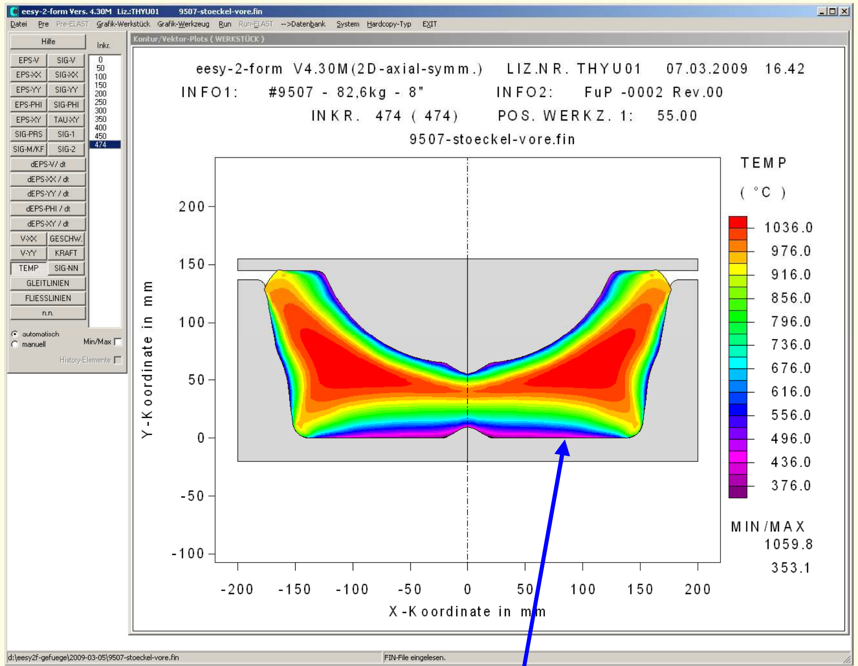
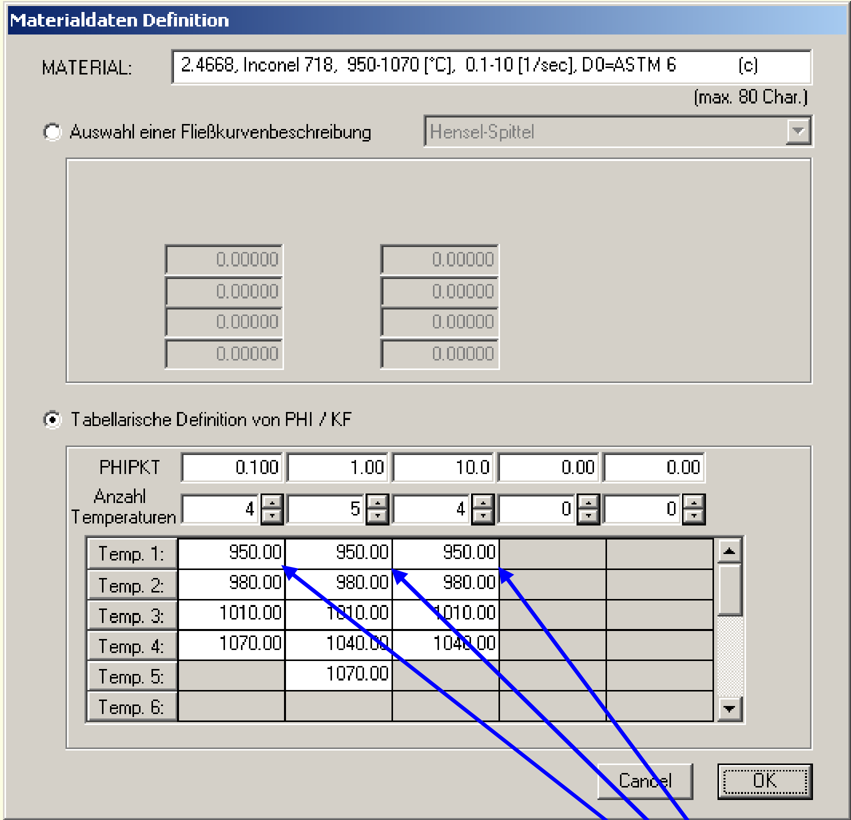


Temperature gradient at the bottom (< 500℃)



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

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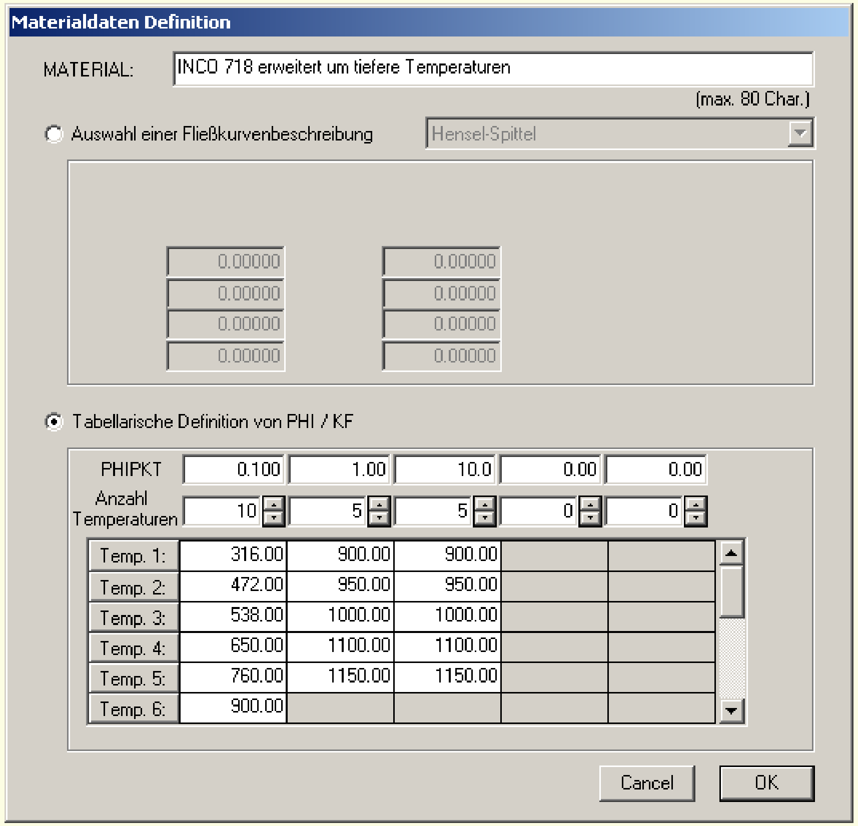
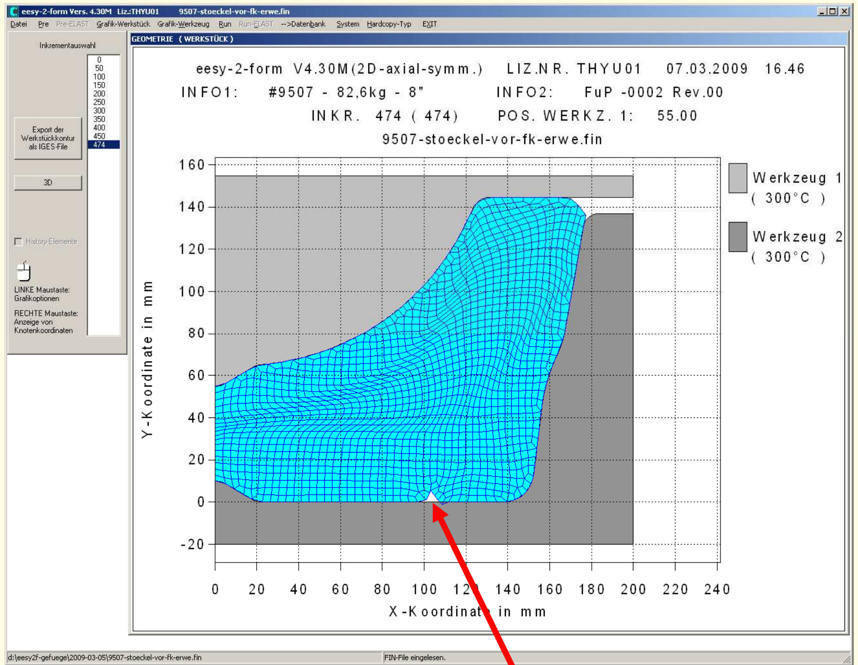
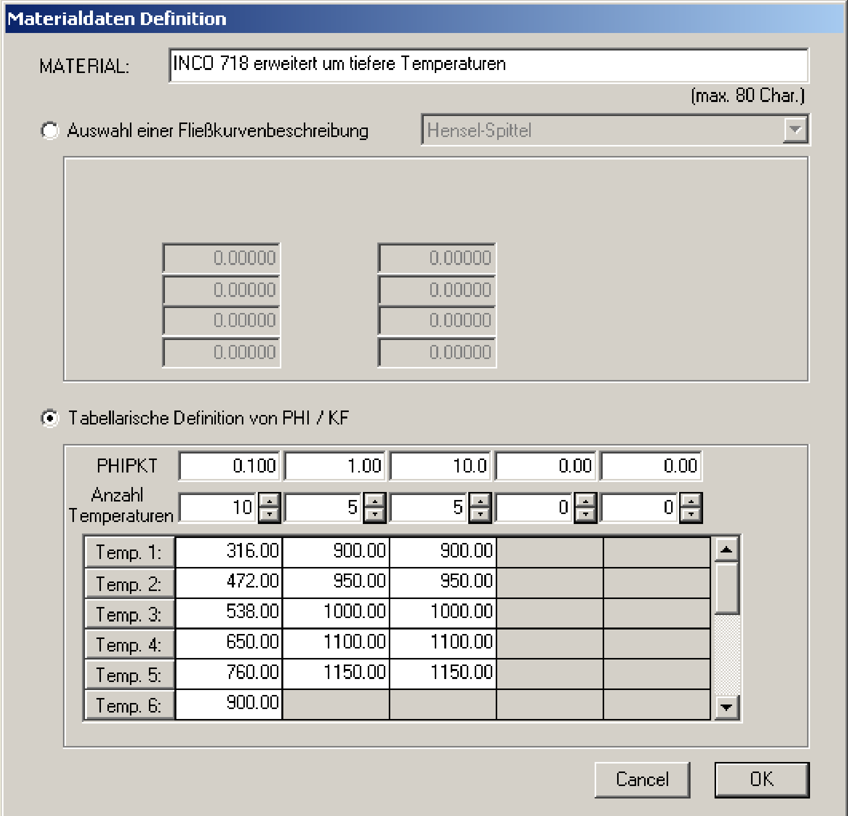


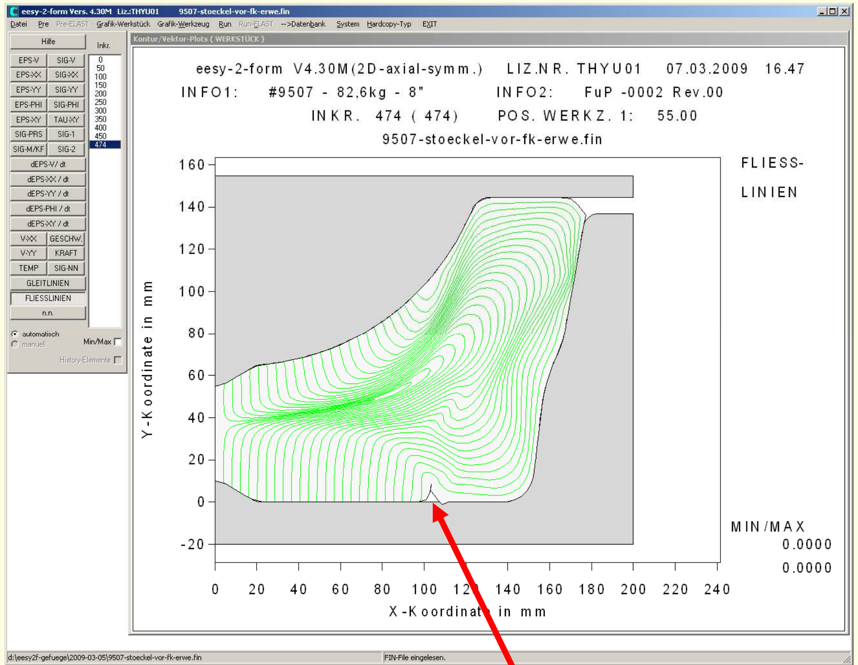


YS – Strain curves added at lower temperatures

With the added data the simulation shows the folding

Example 1: Inconel 718 disc with a folding





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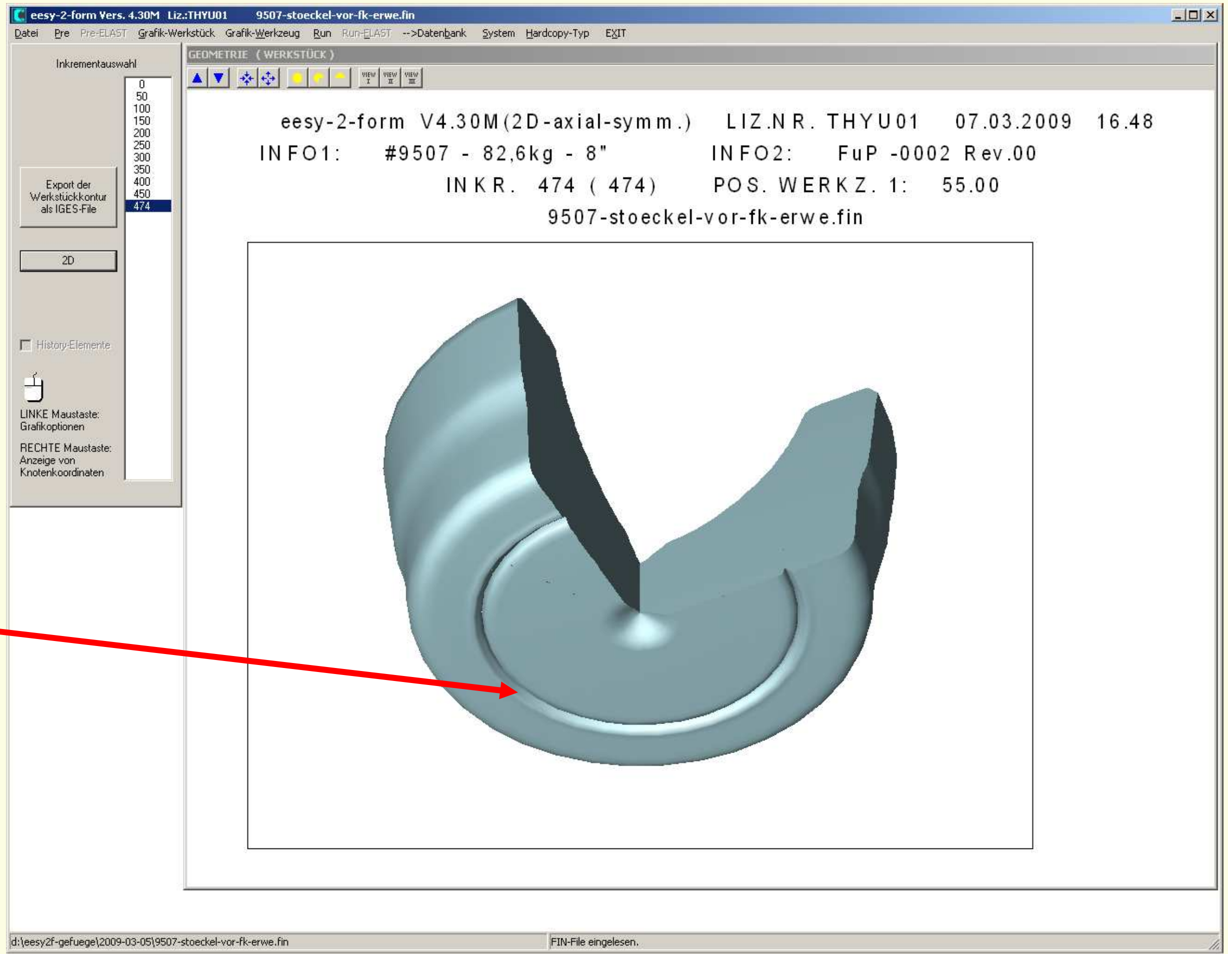
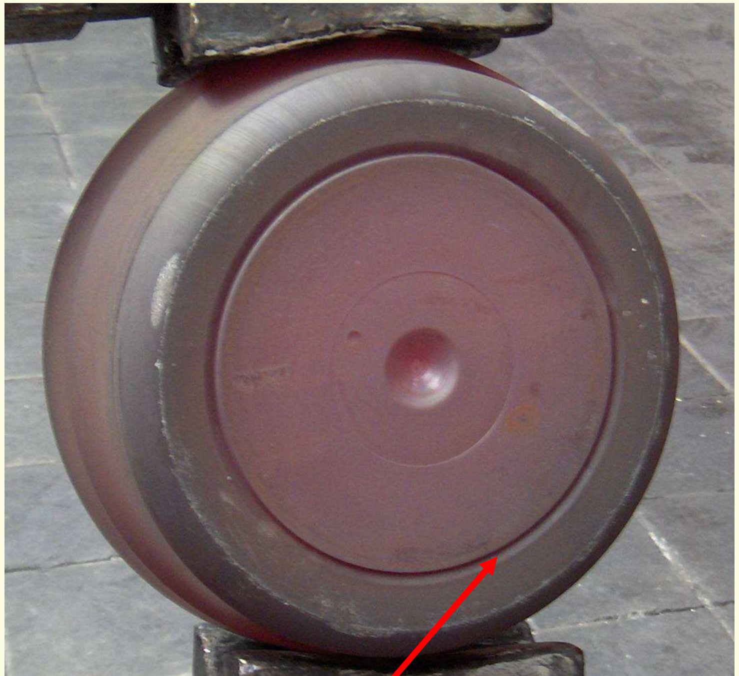
Example 1: Inconel 718 disc with a folding

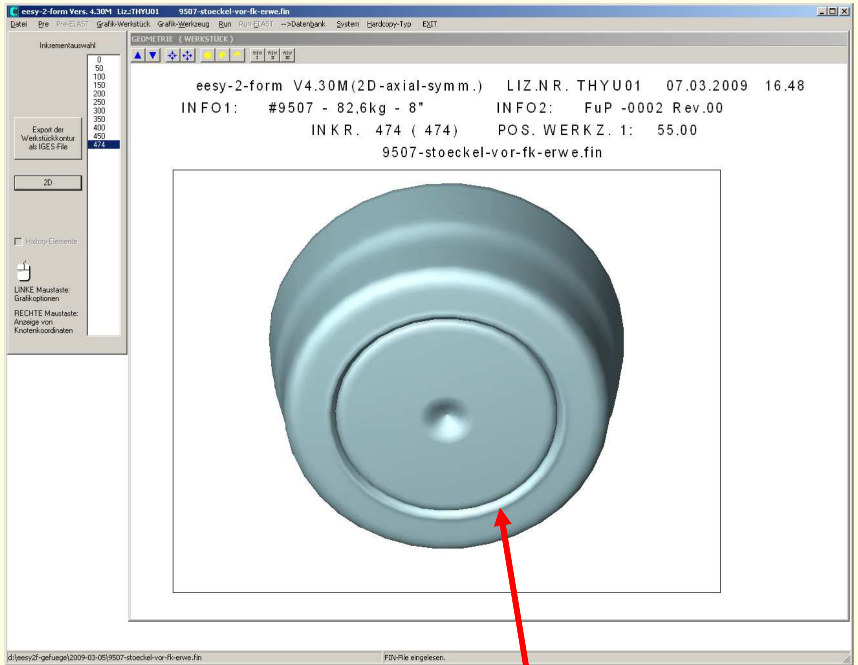
Geometry with folding



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

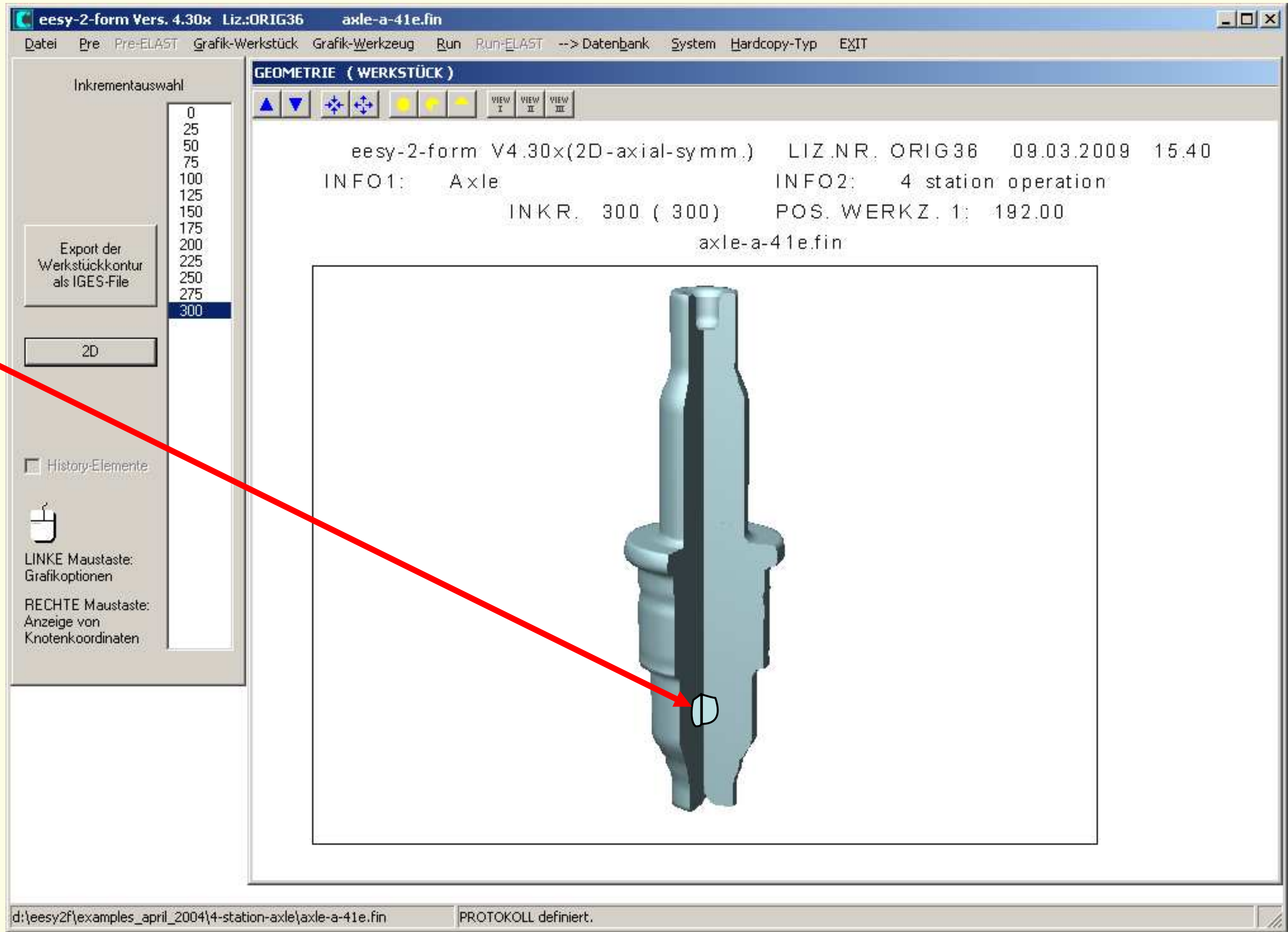
Fazit:

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?

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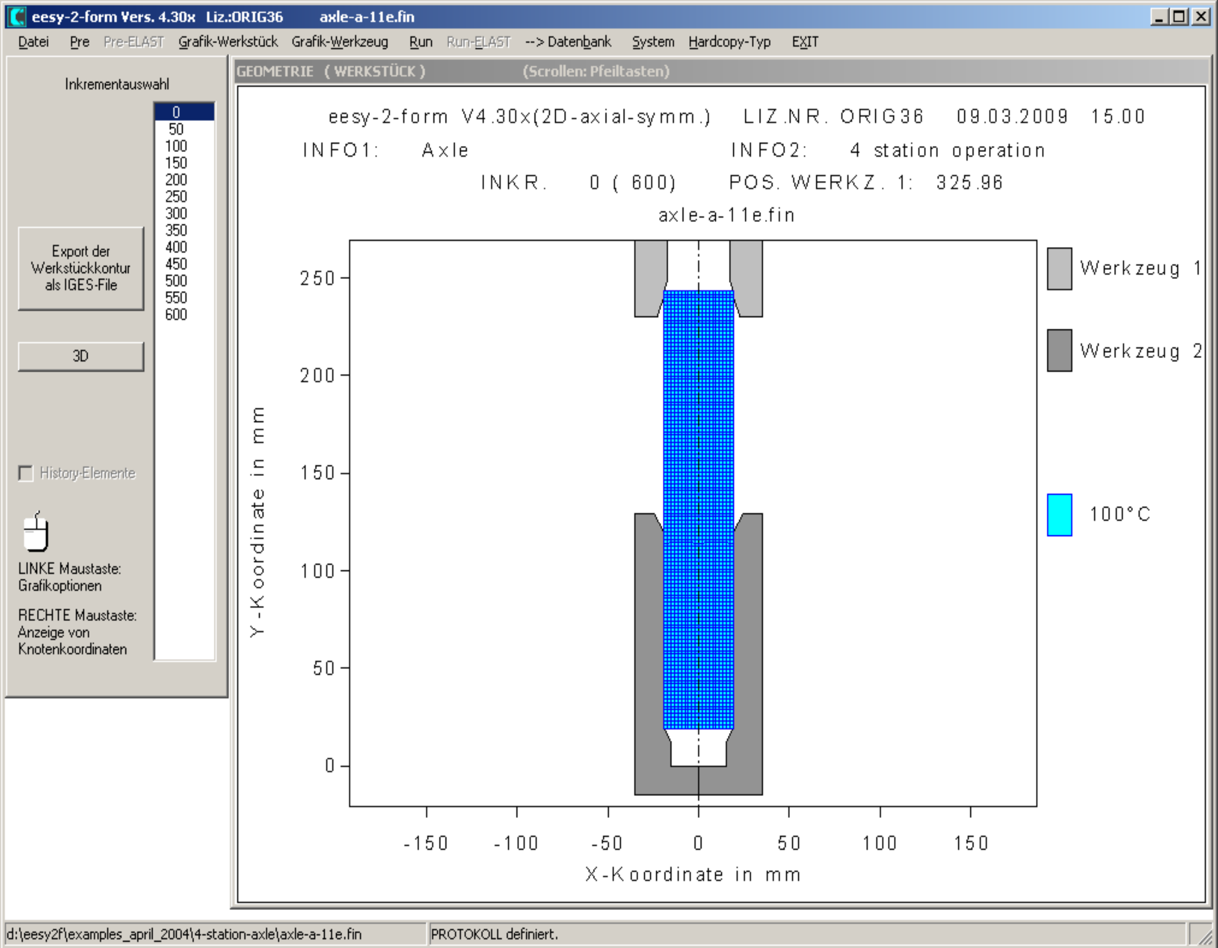
Example 2: Shaft with non sufficient hardness



Cutt off
1. operation

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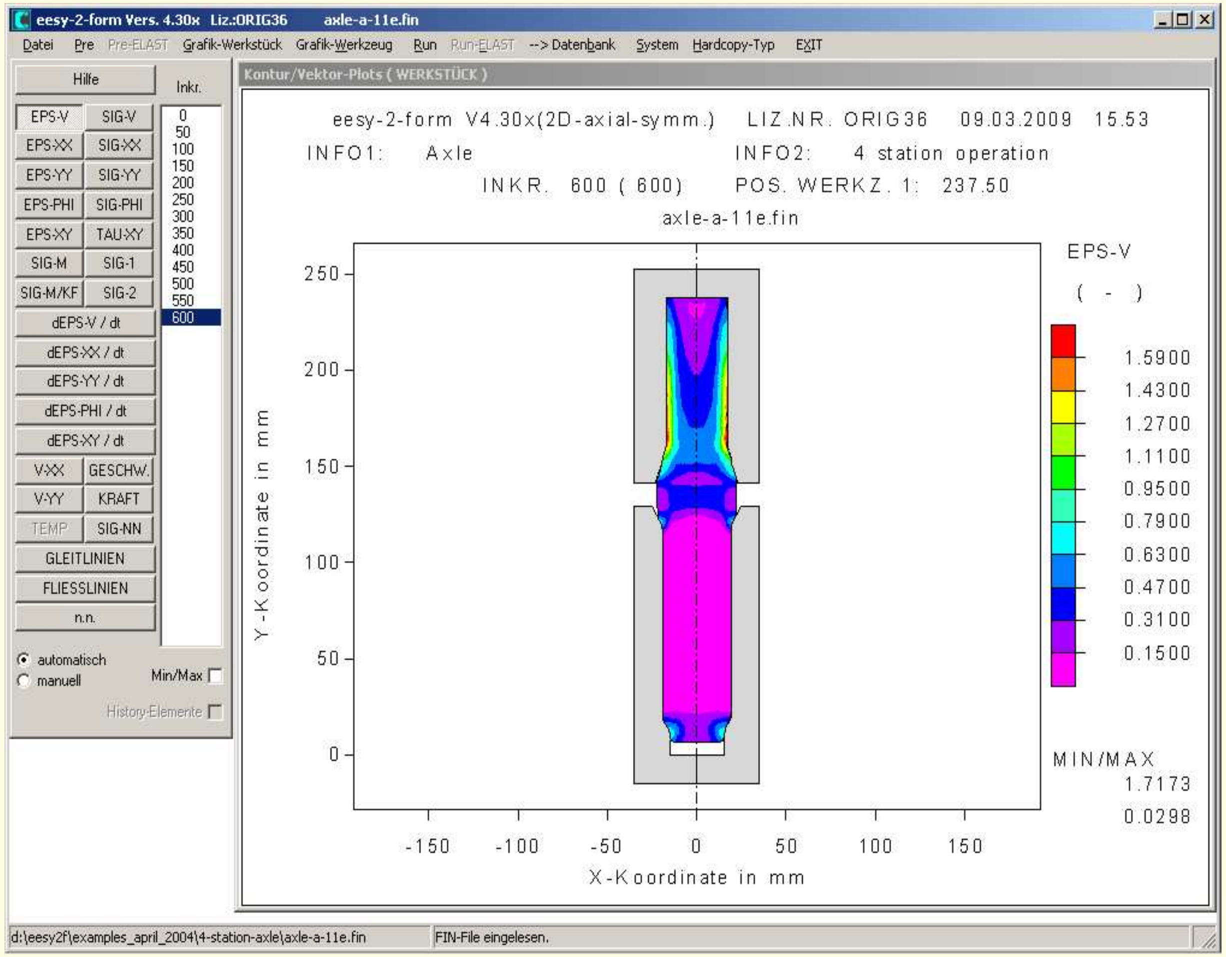
Example 2: Shaft with non sufficient hardness

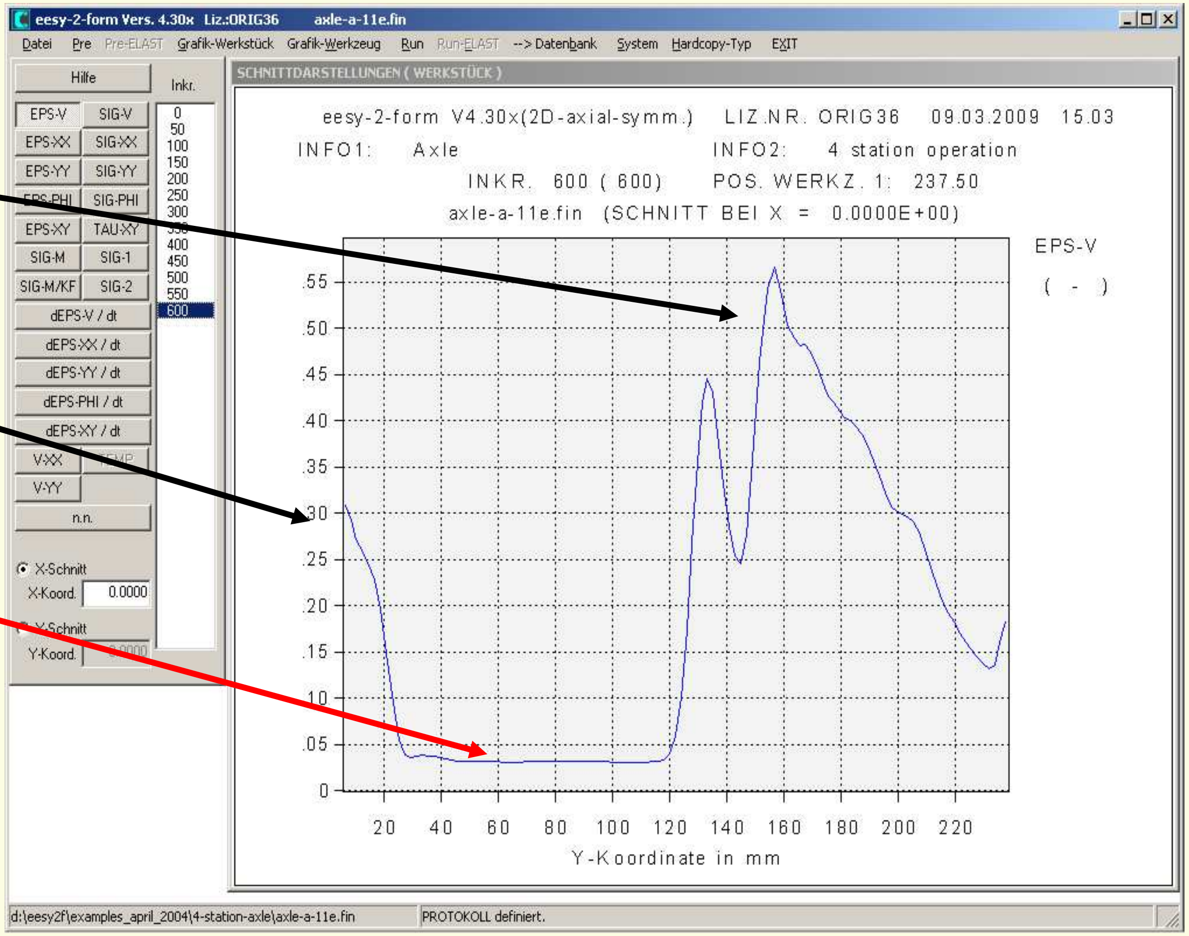


Strain distribution
after 1. operation

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

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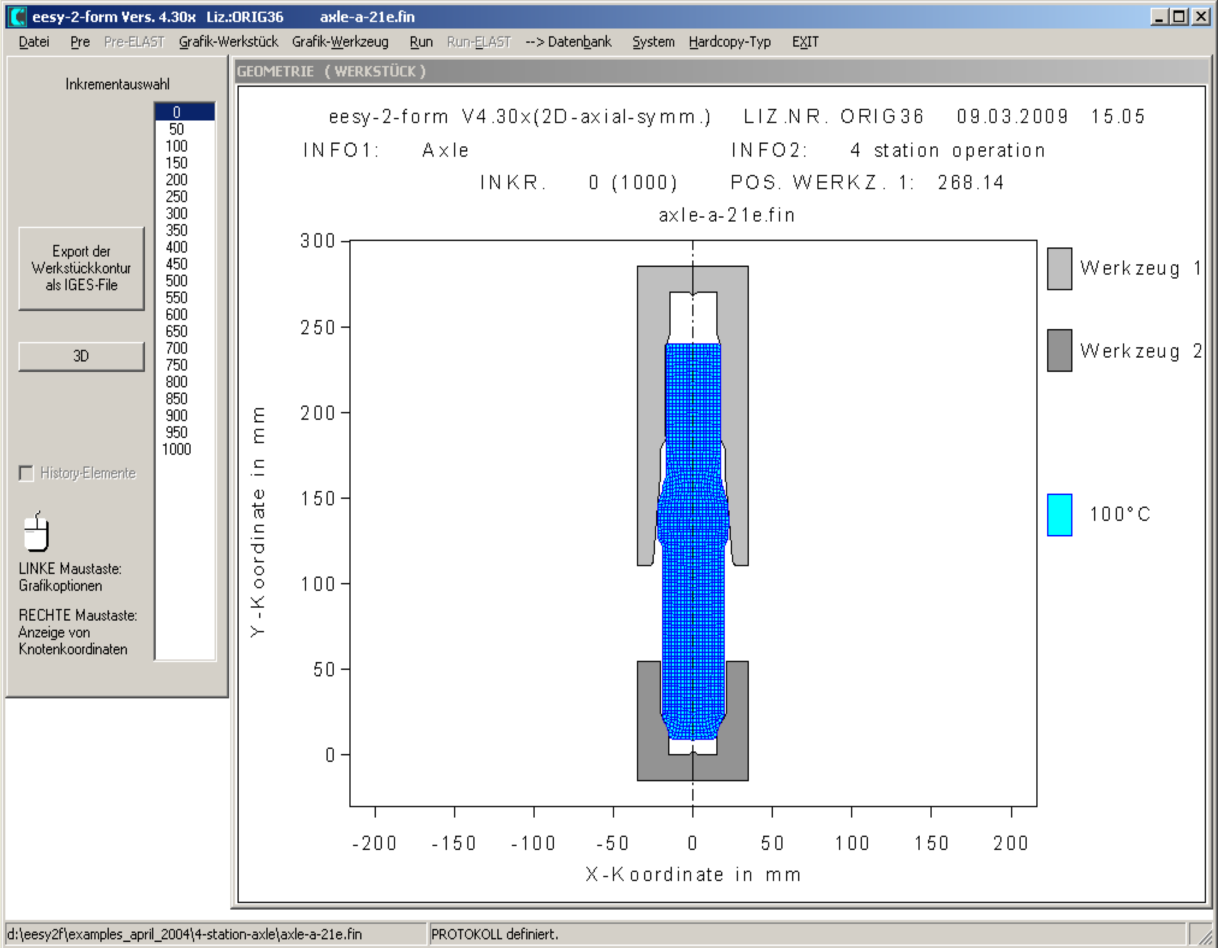
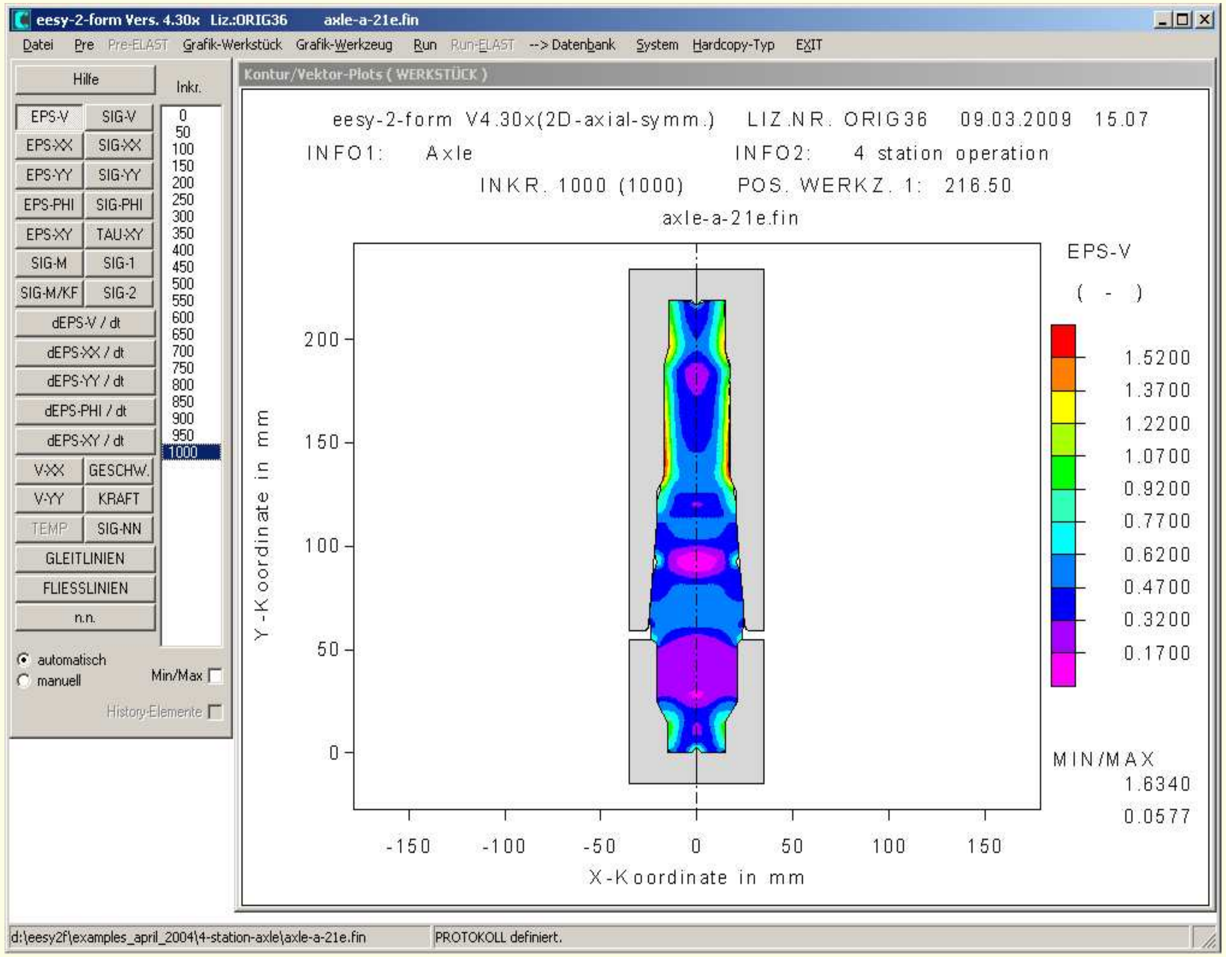
Example 2: Shaft with non sufficient hardness



Initial situation
2. operation

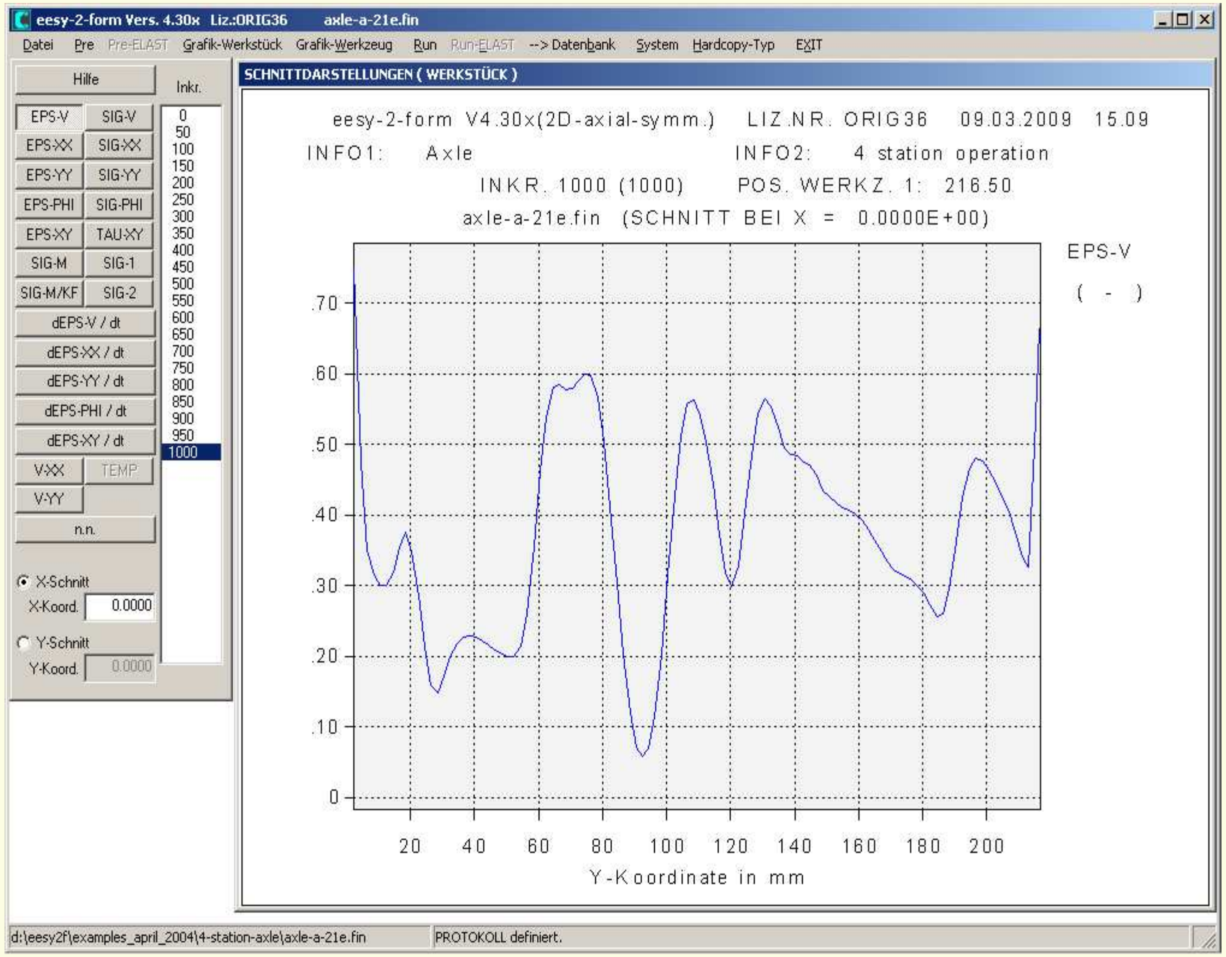
Example 2: Shaft with non sufficient hardness



Strain distribution
after 2. operation

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

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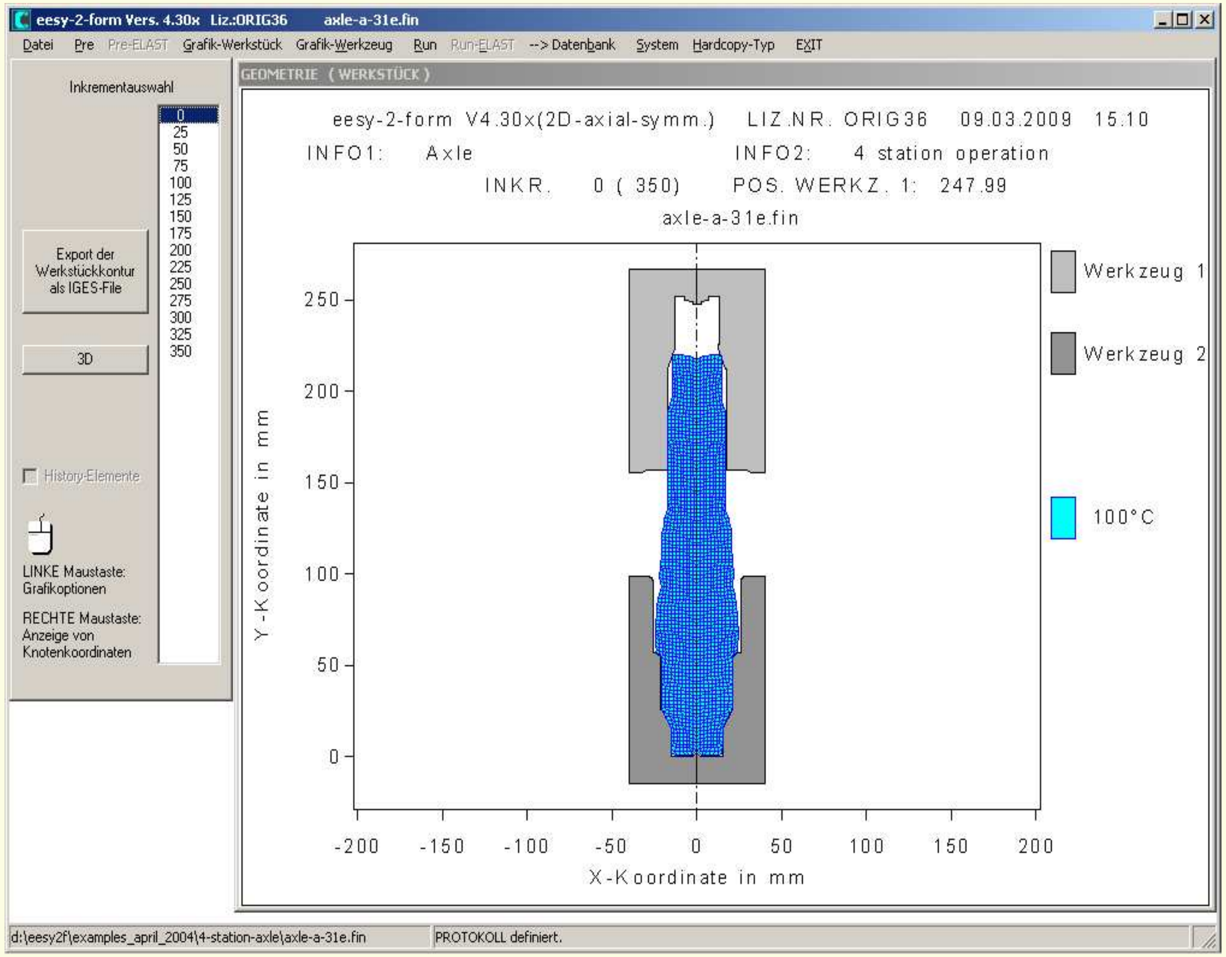
Example 2: Shaft with non sufficient hardness



Initial situation
3. operation

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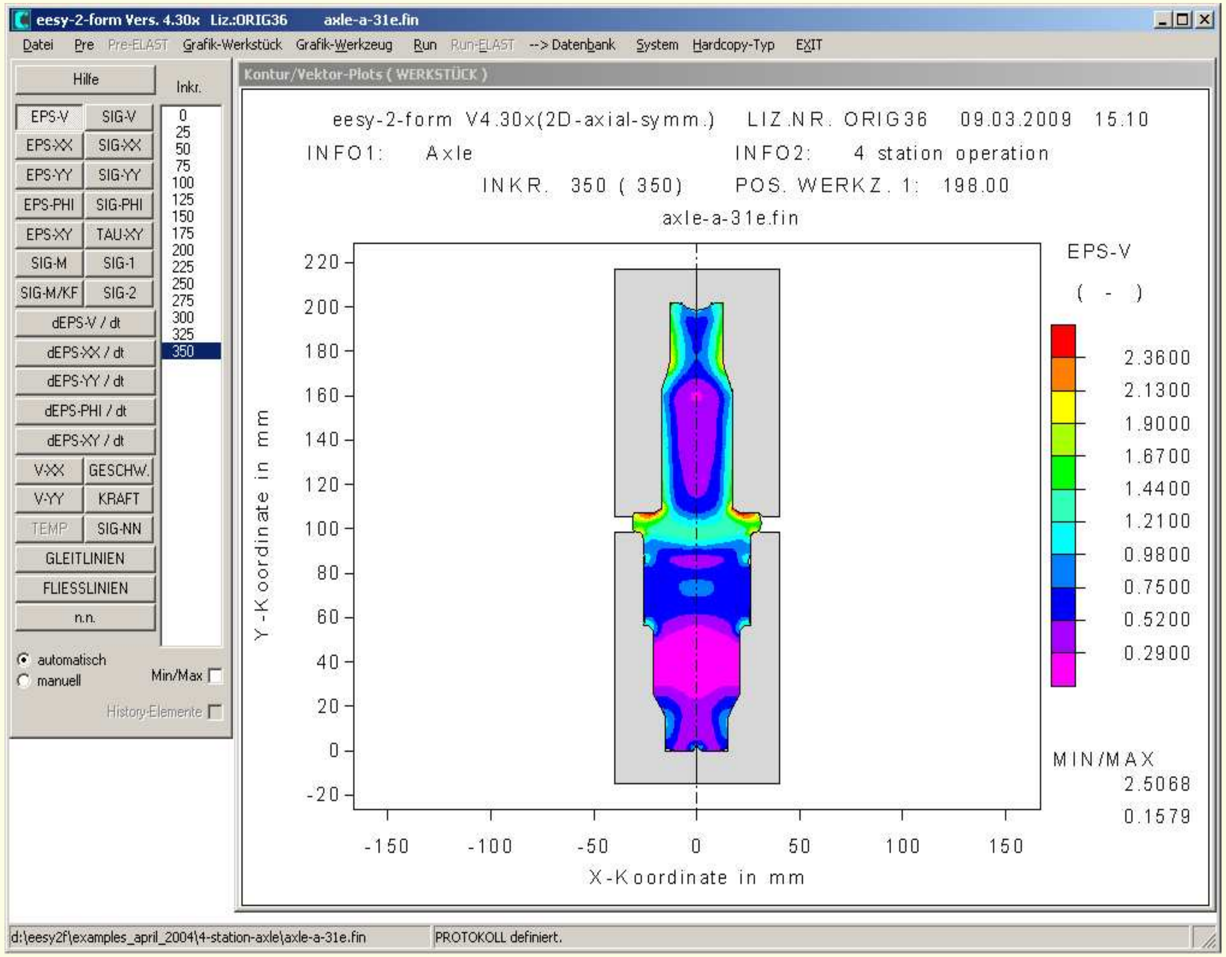
Example 2: Shaft with non sufficient hardness

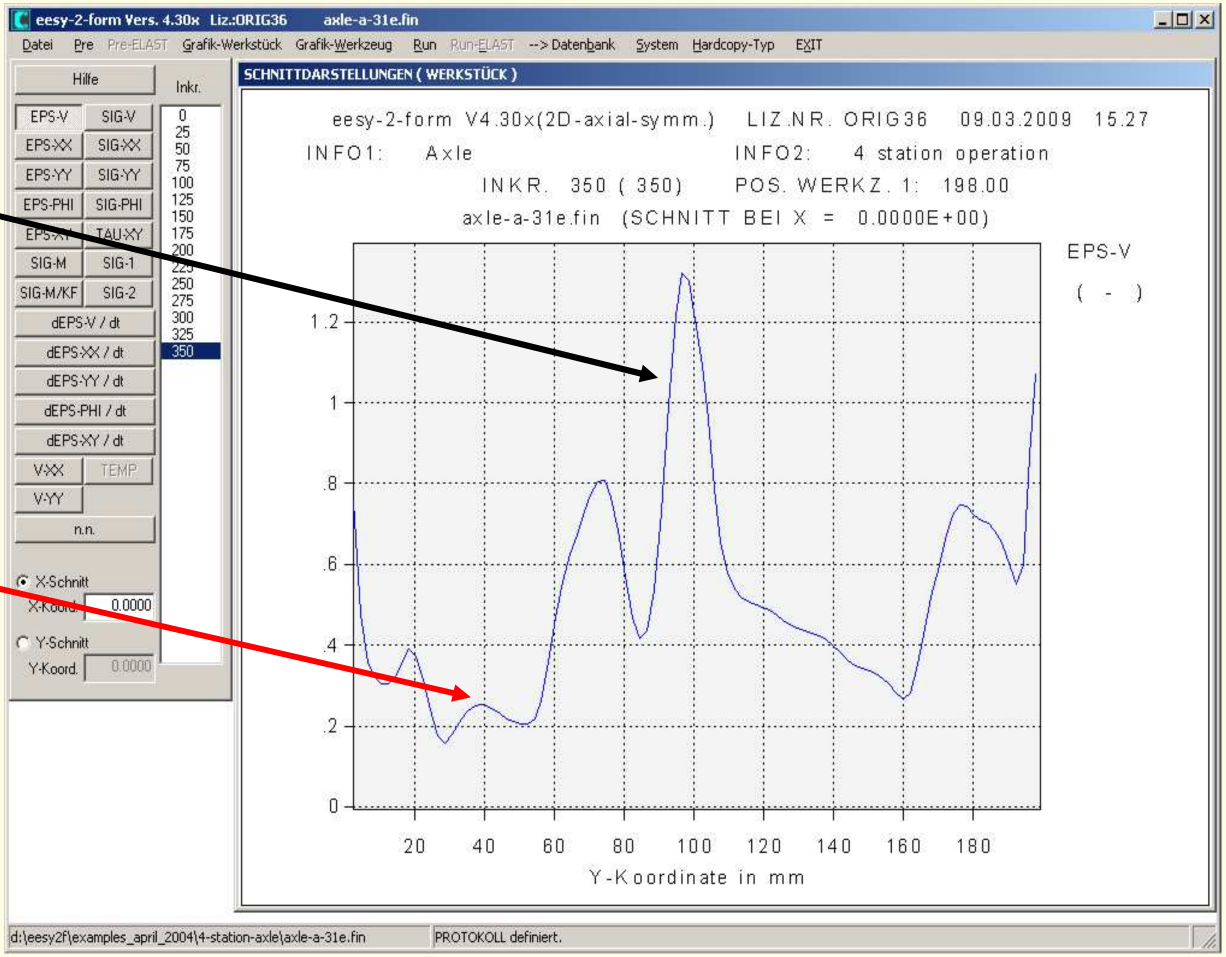


Strain distribution
after 3. operation

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

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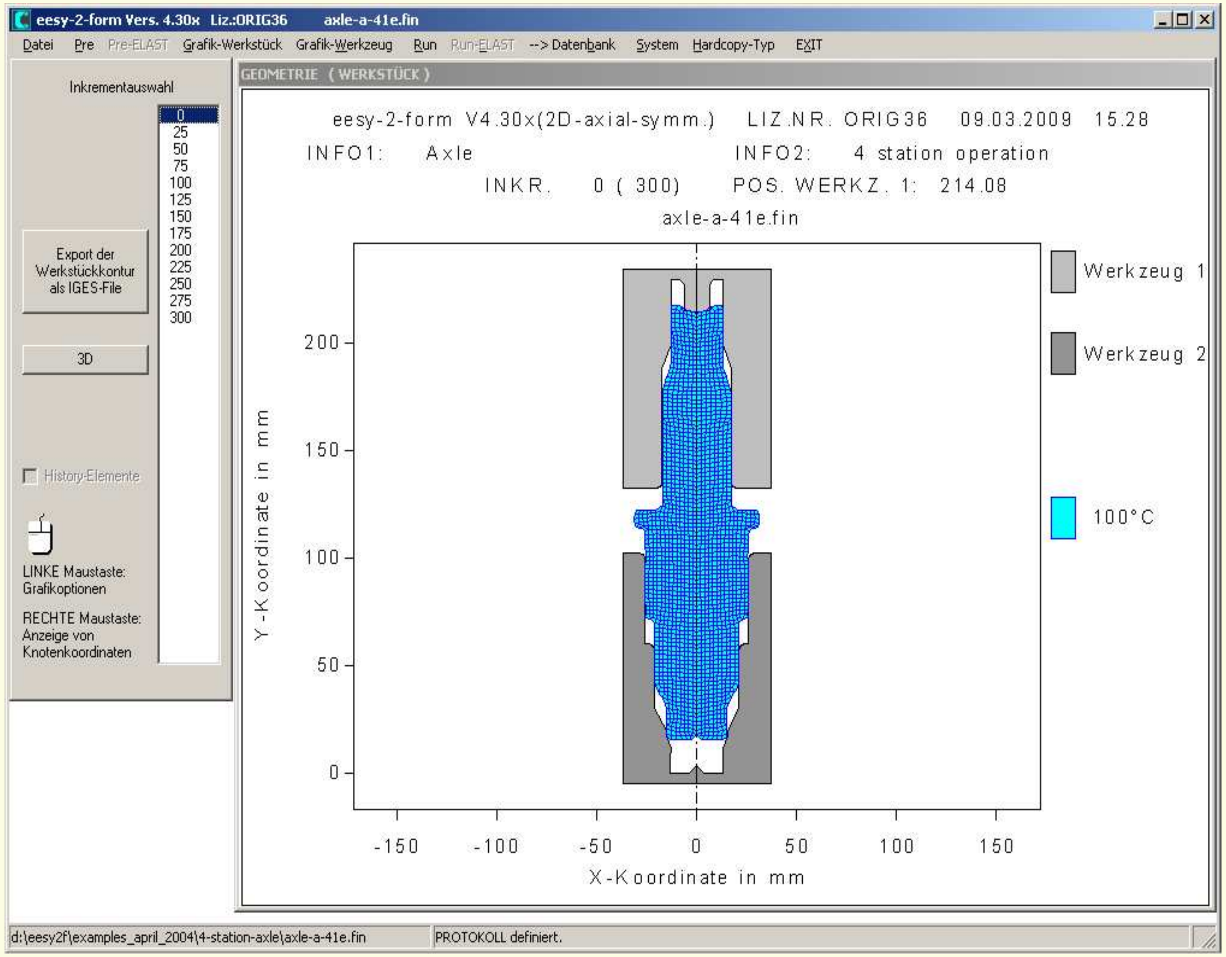
Example 2: Shaft with non sufficient hardness



Initial situation
4. operation

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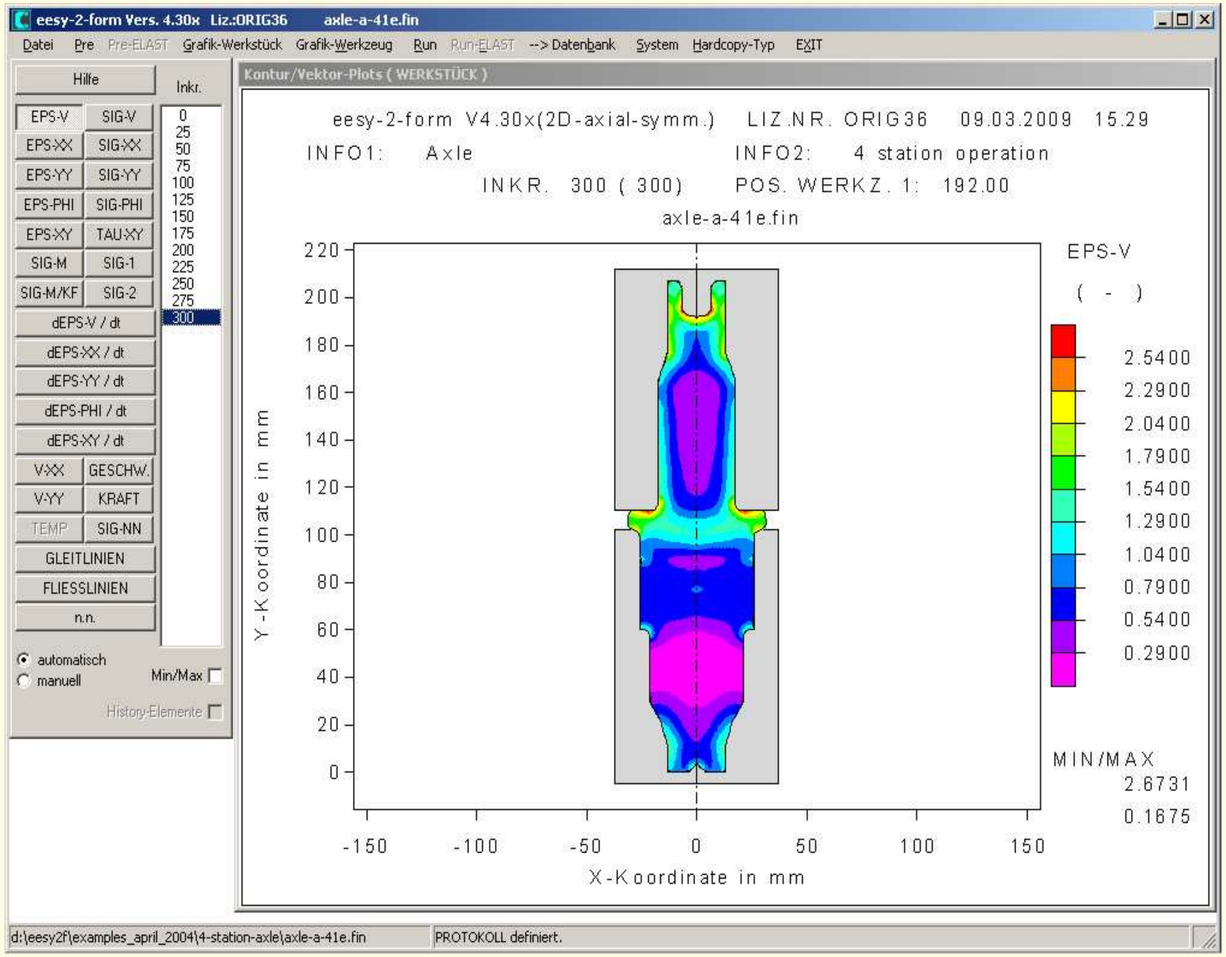
Example 2: Shaft with non sufficient hardness



Strain distribution
after 4. operation

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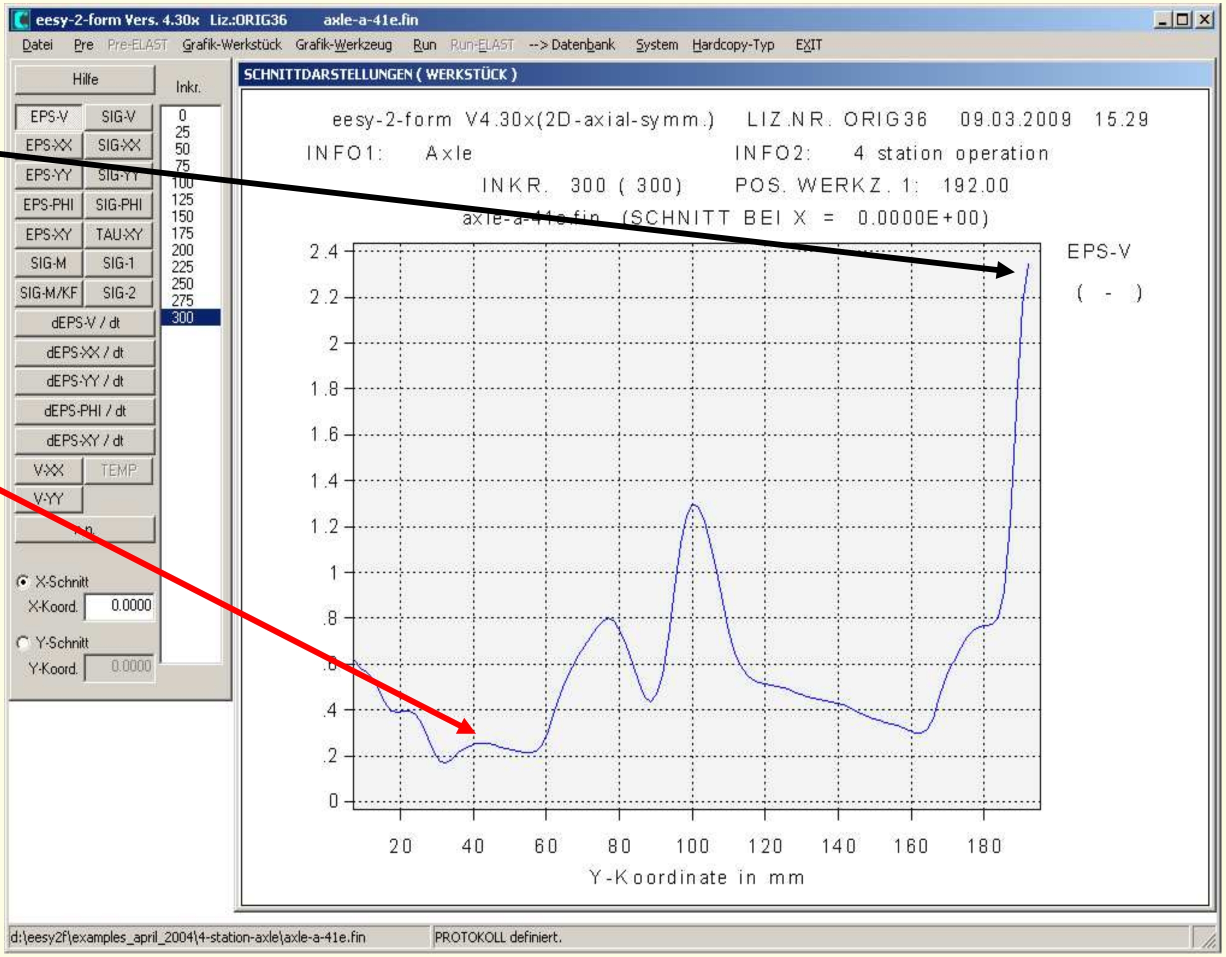
Example 2: Shaft with non sufficient hardness

High strain by finishing the head

No further forming in the shaft

=> Non sufficient hardness after Heat treatment



Strain distribition along the axis after 4. operation

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

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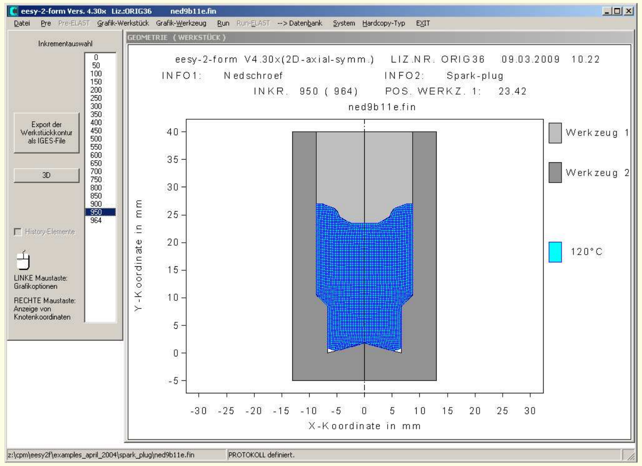
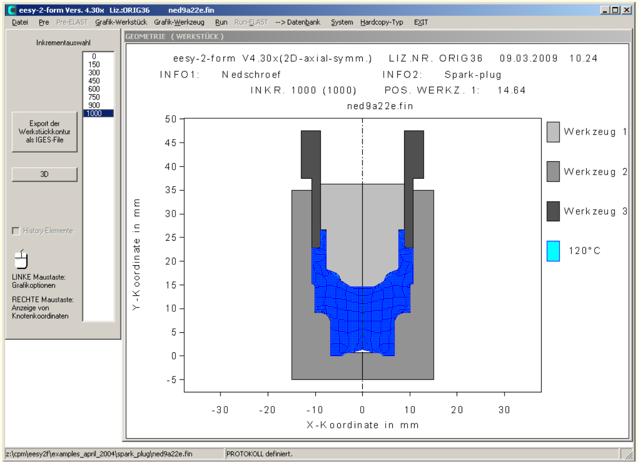
Example 3: body of a spark plug (investigation in material flow)

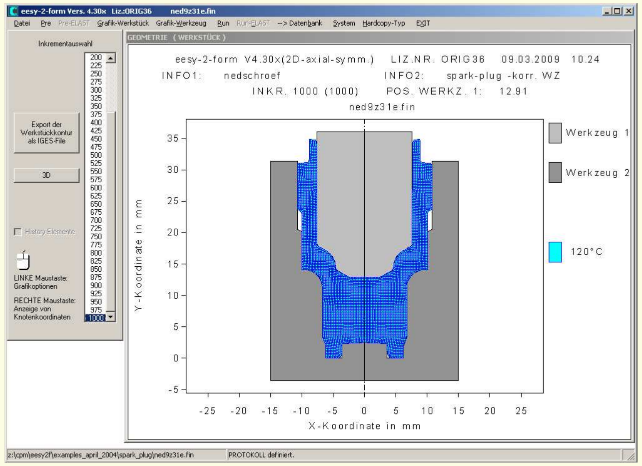
1.



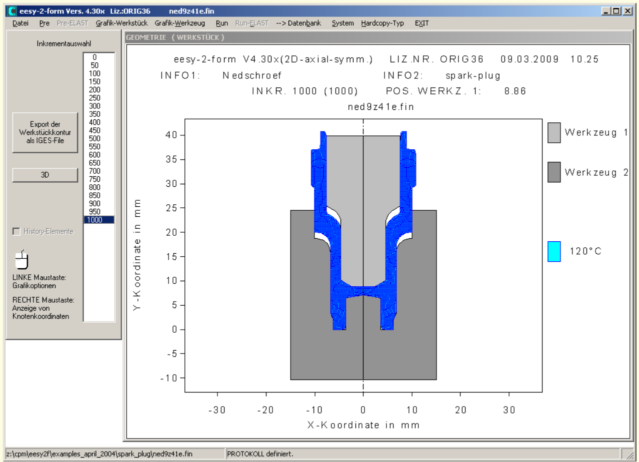
2.



3.



4.



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

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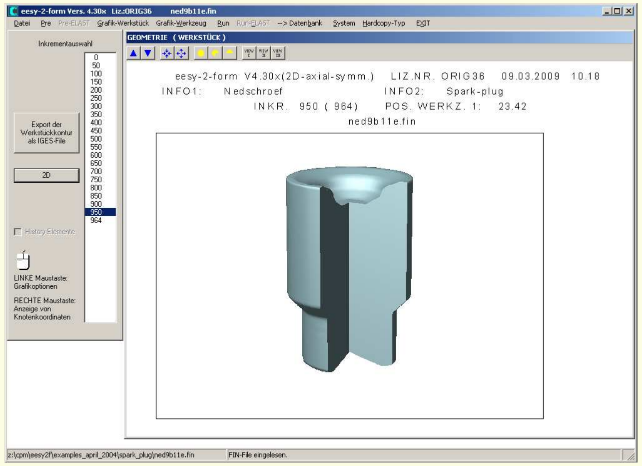
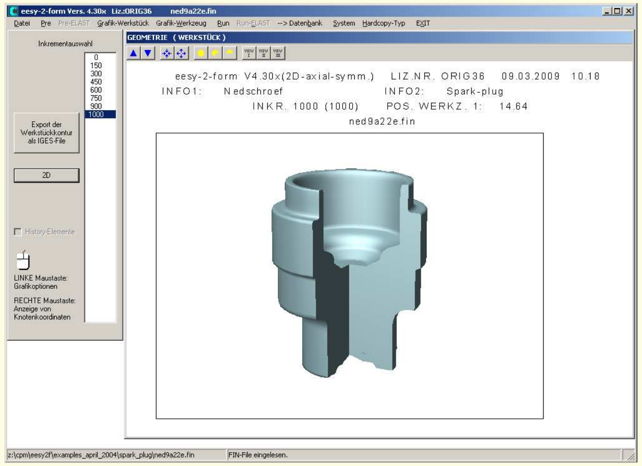
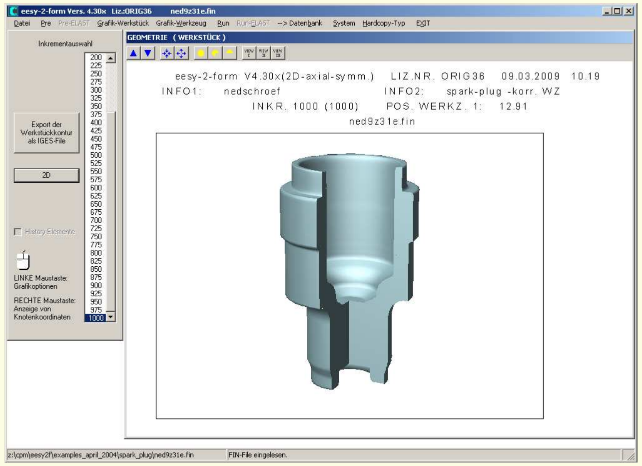


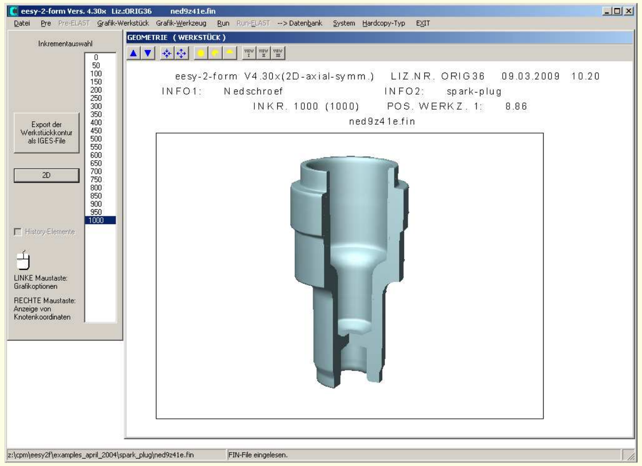
2.



3.



4.



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“

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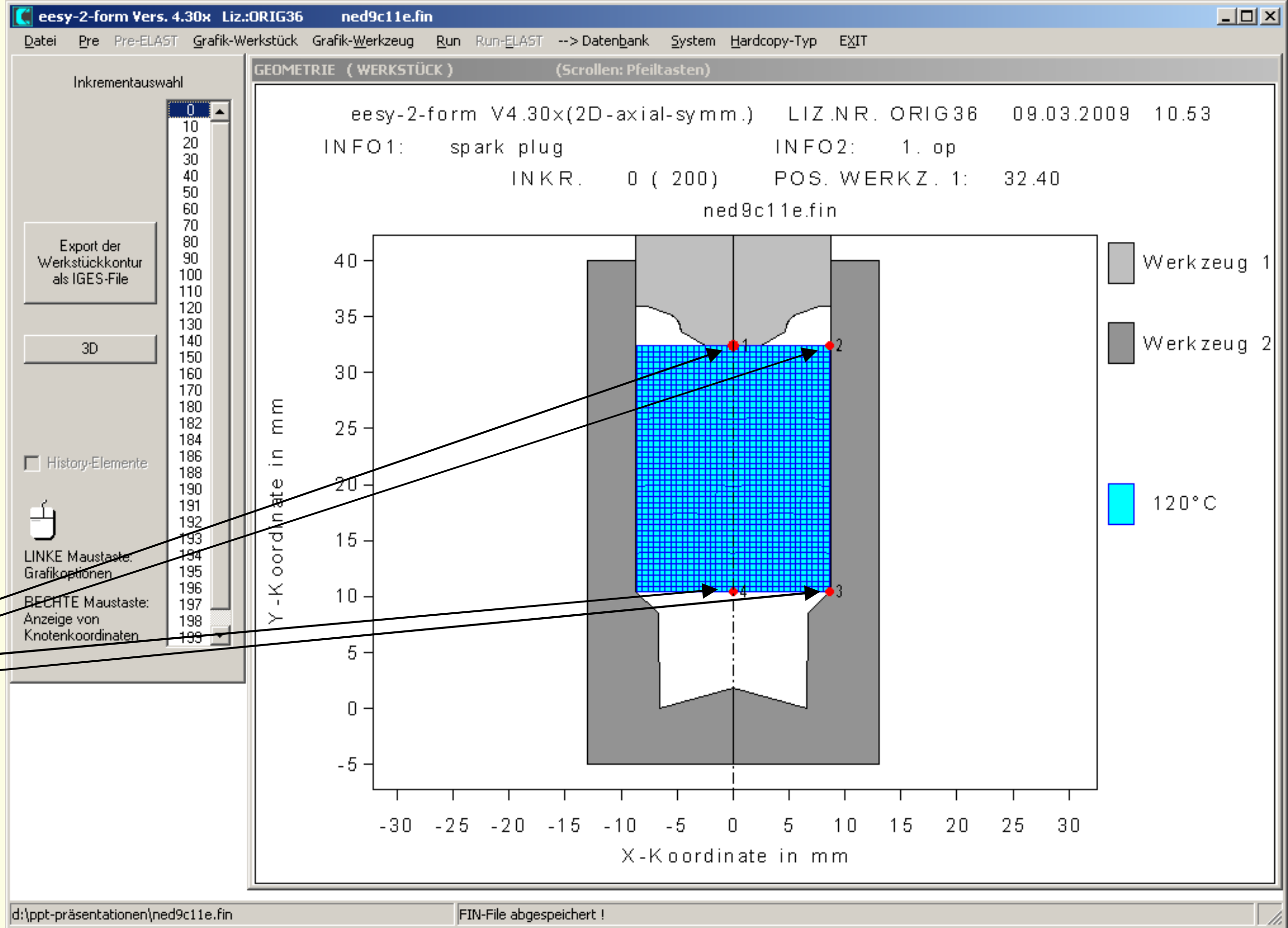
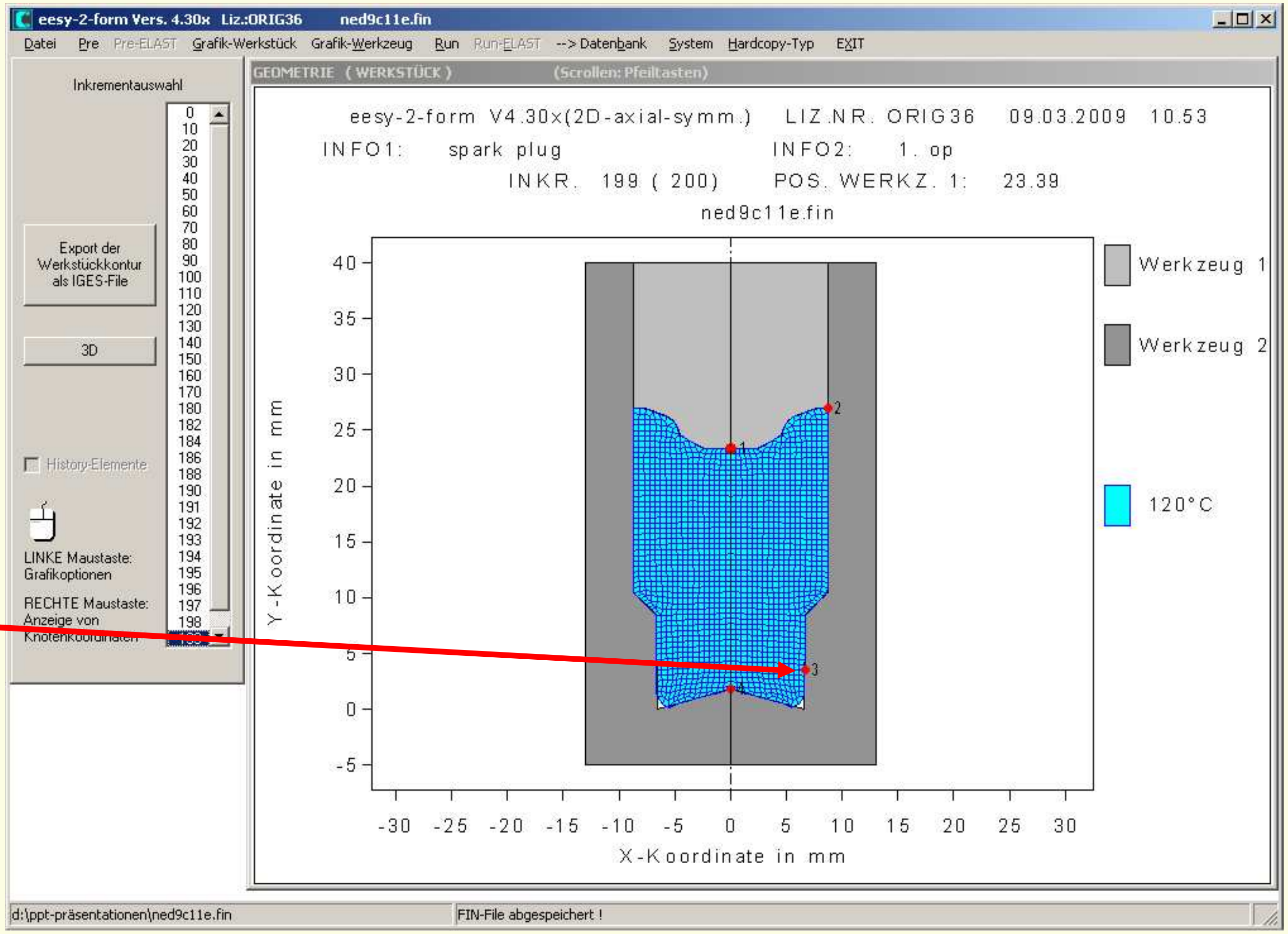
Example 3: body of a spark plug (investigation in material flow)

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

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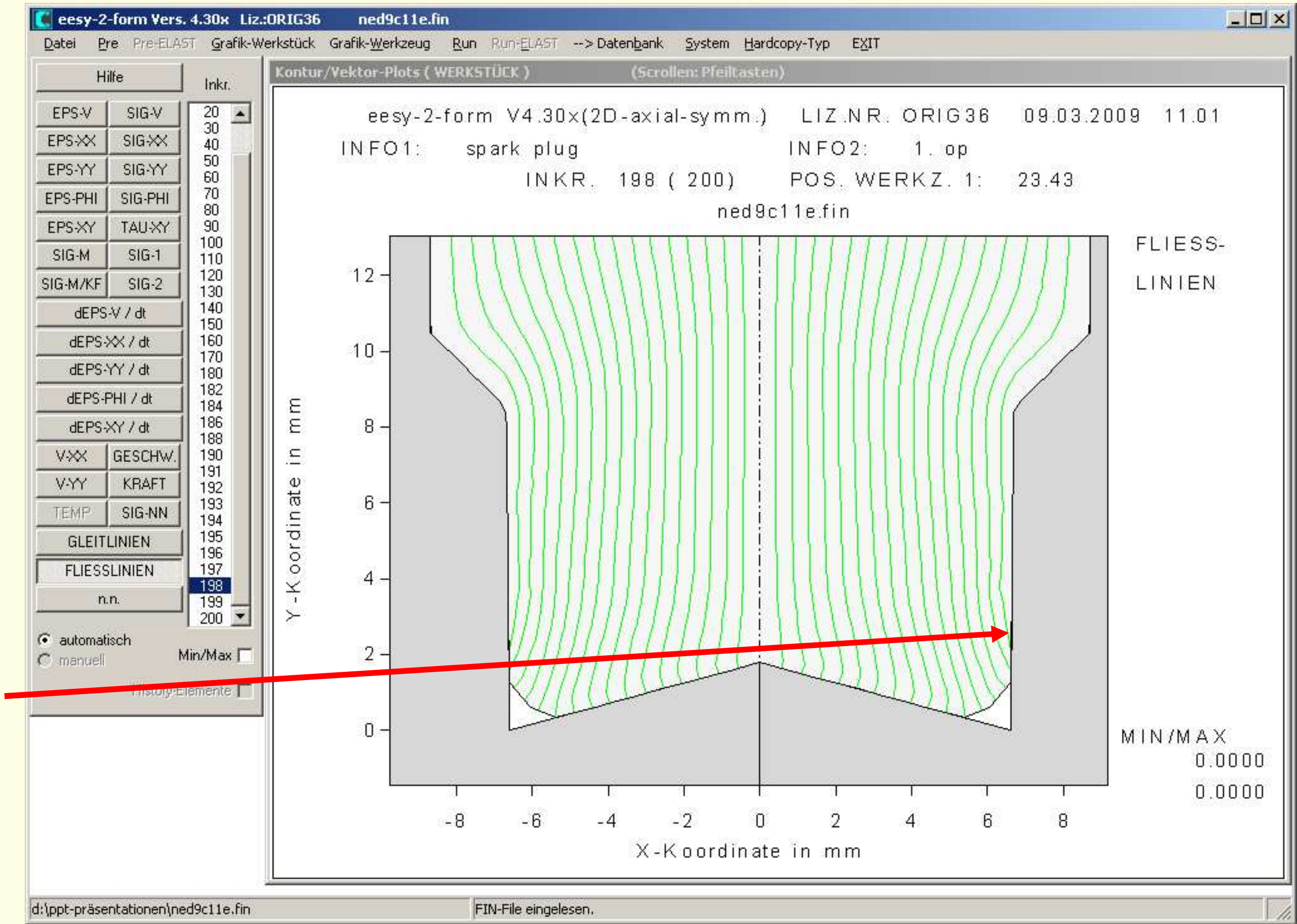
Example 3: body of a spark plug (investigation in material flow)

Flowline distribution
(the outmost line
ends in the
cylindrical shaft surface)



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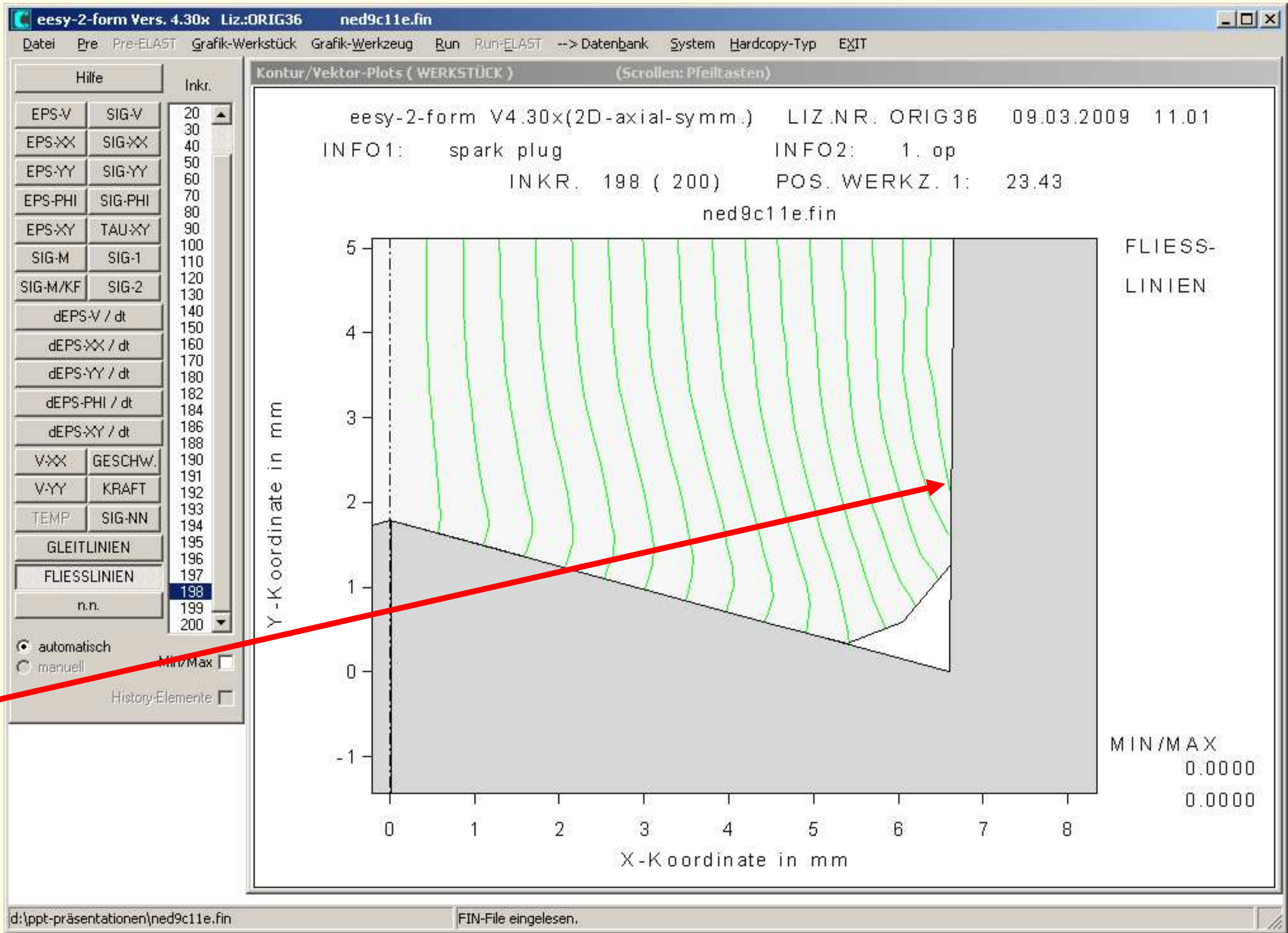

Flowline distribution
(the outmost line
ends in the
cylindrical shaft surface)

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 in to 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?

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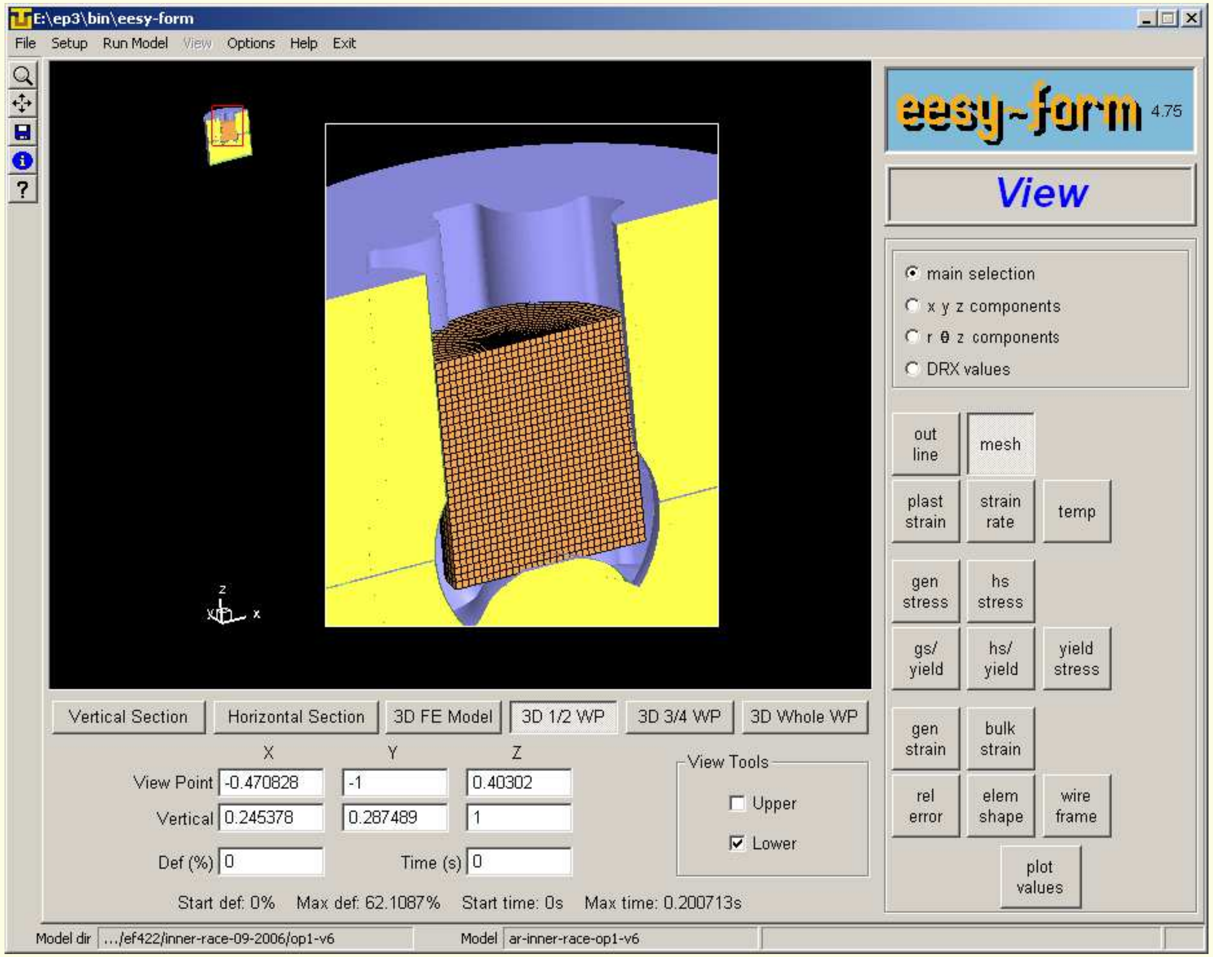
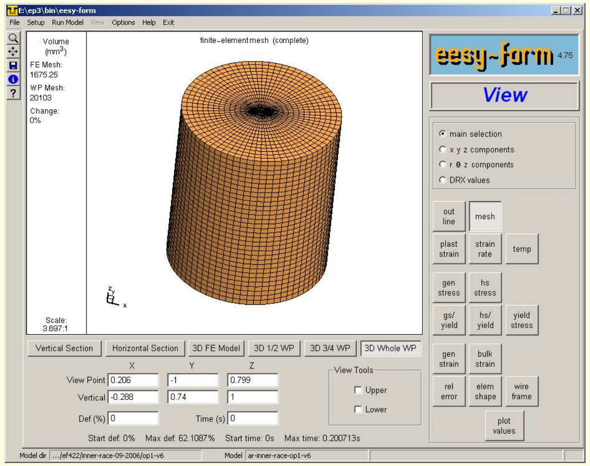
Example 4: „Inner Race“ (with typical under filling)

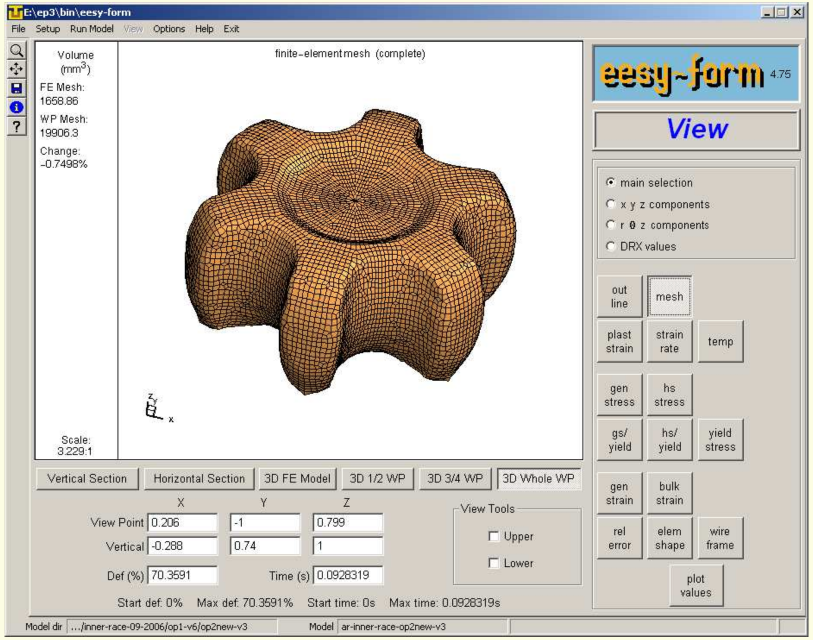
Part in the die
(initial situation)



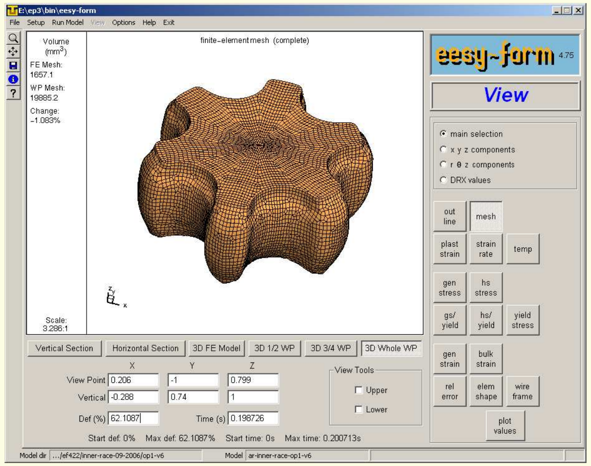
Example 4: „Inner Race“ (with typical under filling)



Initial geometry

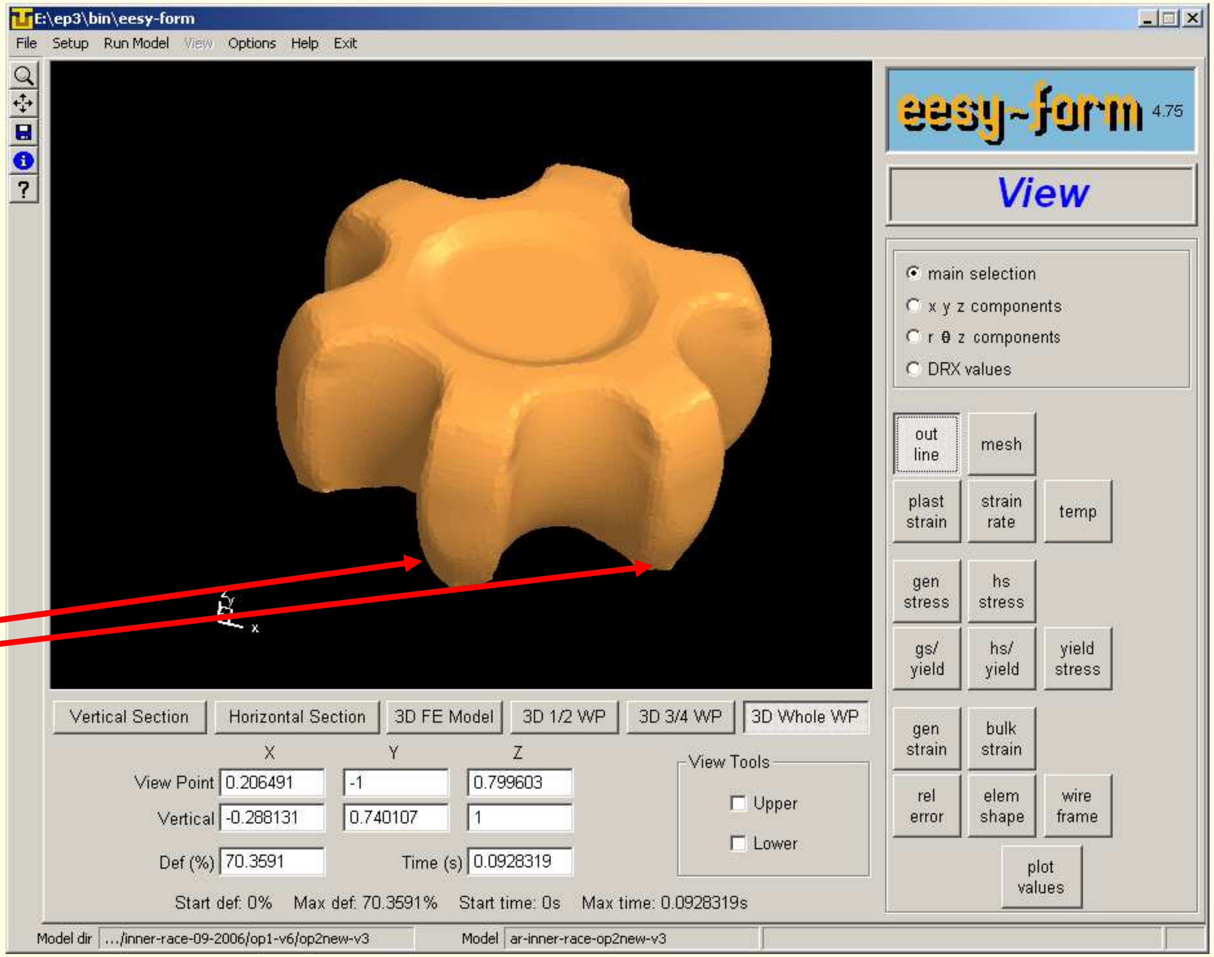


Geometry after 2. operation



Geometry after 1. operation

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



Geometry after
2. operation
with visible (?)
under filling in the lower
area

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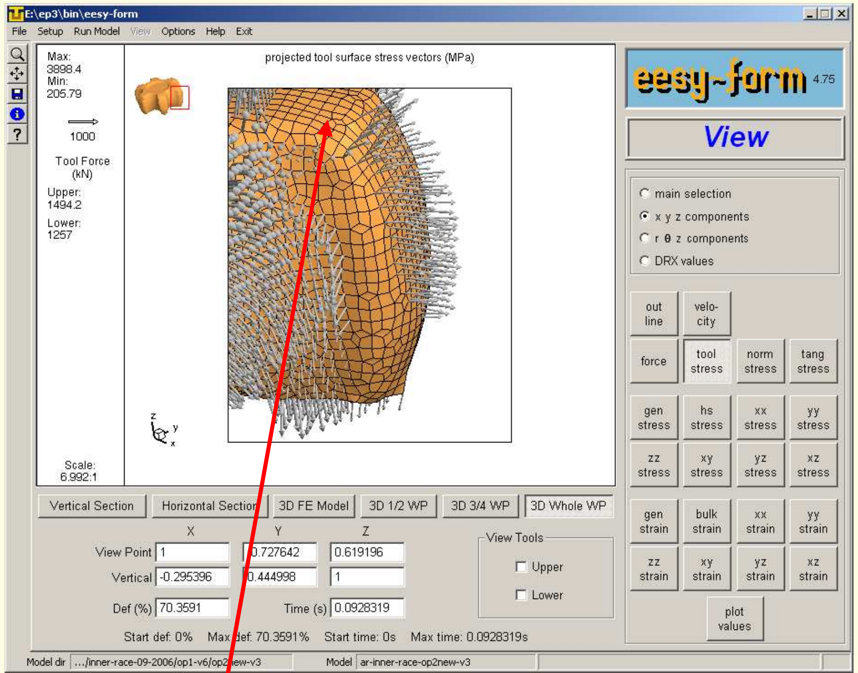
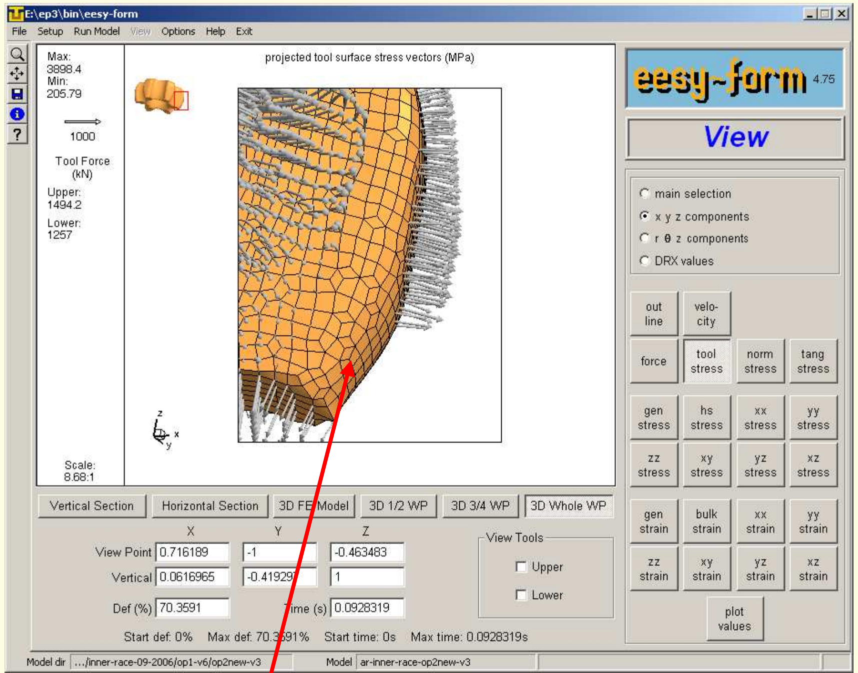
Example 4: „Inner Race“ (with typical under filling)



Contact stresses on the tool surface showing the under filling (with mesh)



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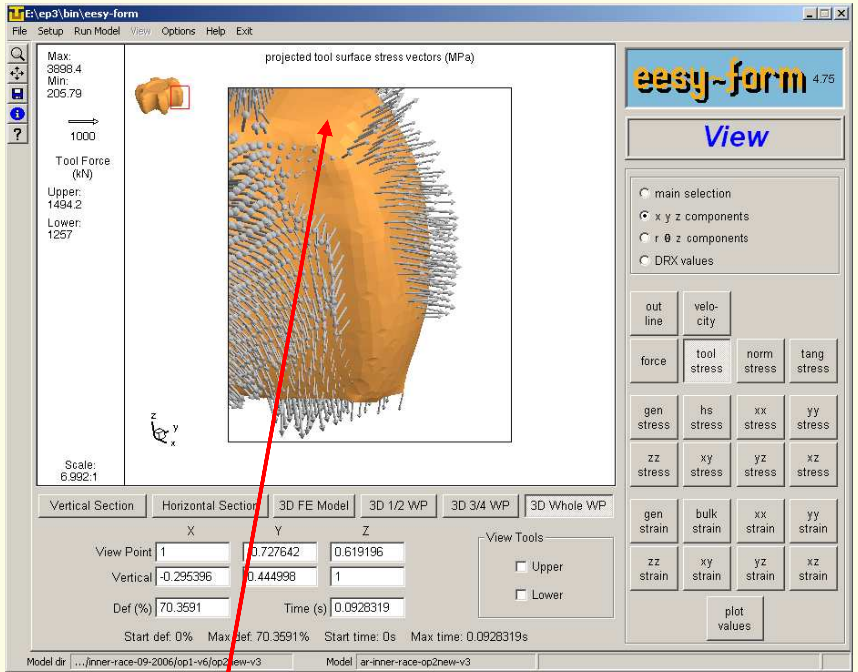

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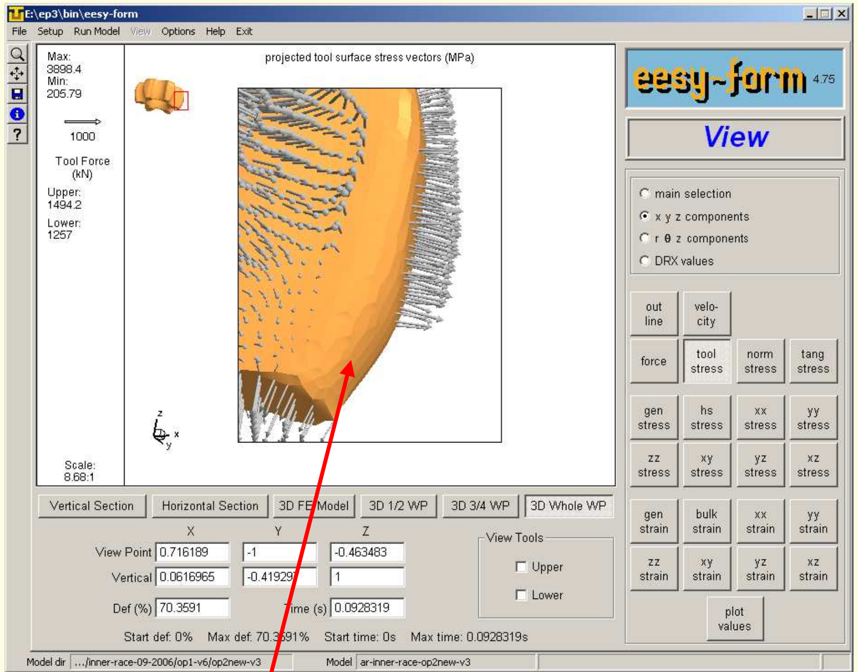

Contact stresses on the tool surface showing the under filling

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.