

QFORM3D
The most easy-to-use forging simulation software

QUANTOR
FORM

QForm3D

Advanced software for forging simulation

The goals of forging technology :

- **Make the parts of the required shape**
- **Provide required properties**
- **Do it in time and at the lowest cost**

Forging process is a very complicated phenomenon,

Thus even the forger with the years of experience ...

still require expensive forging trials

for each new part to develop

The help can be found

in use of advanced simulation tool like QForm3D

**QForm3D is created for forges
And to be used by the forgers**

QForm3D is

- **Precise,**
- **Affordable**
- **Very simple in use**

Case study: Large 6 Cylinder Crankshaft

Simulation Inputs:

ProEngineer 6 Cylinder Crankshaft Stepped Dies Models

Billet 133mm Square, 1040mm Long

Micro Alloy Steel at 1280°C

9000T Press

The task - to predict

Press Capability

Die Filling

Material Flow

Forging Defects

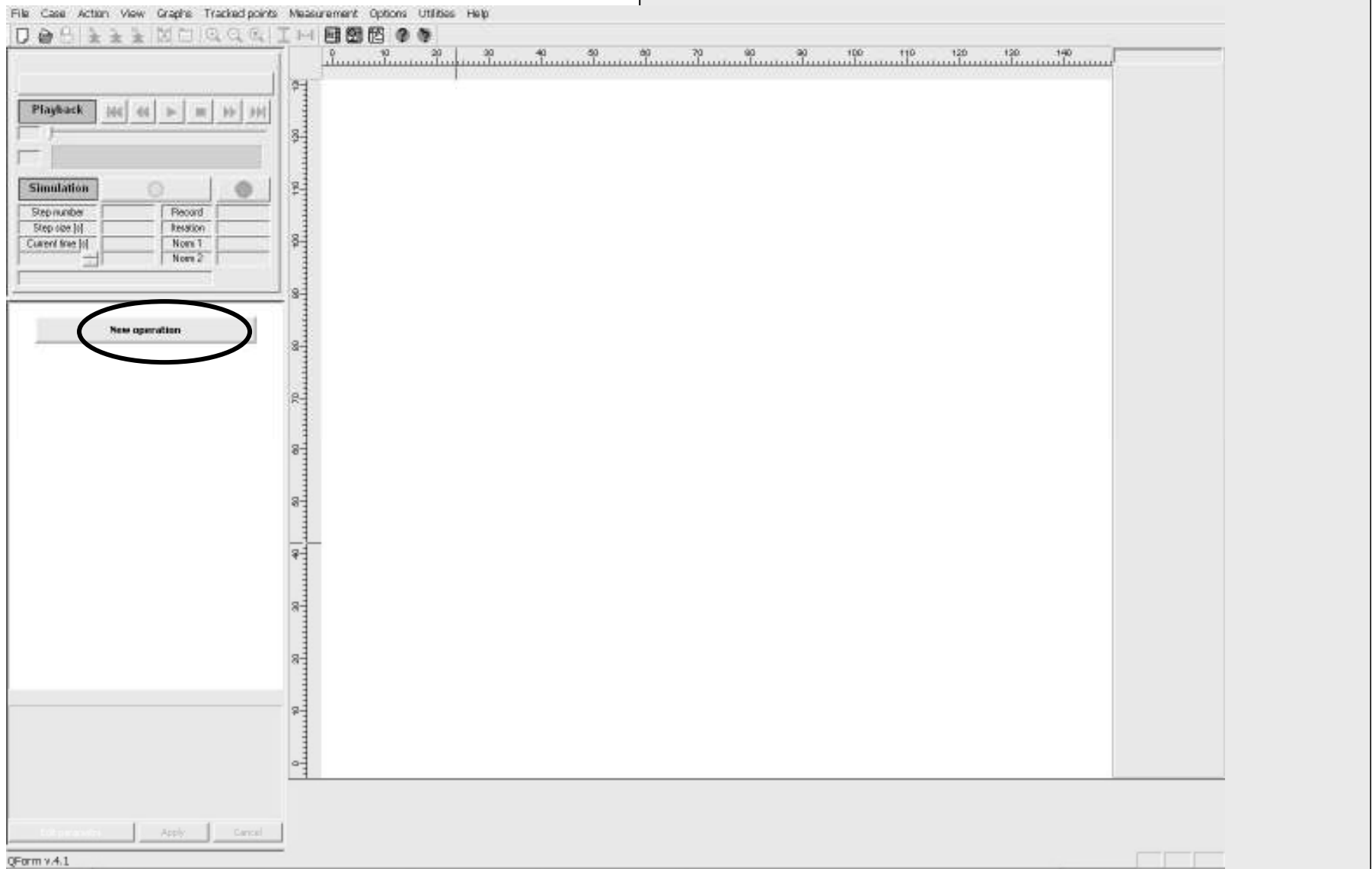
QFORM3D

The most easy-to-use forging simulation software

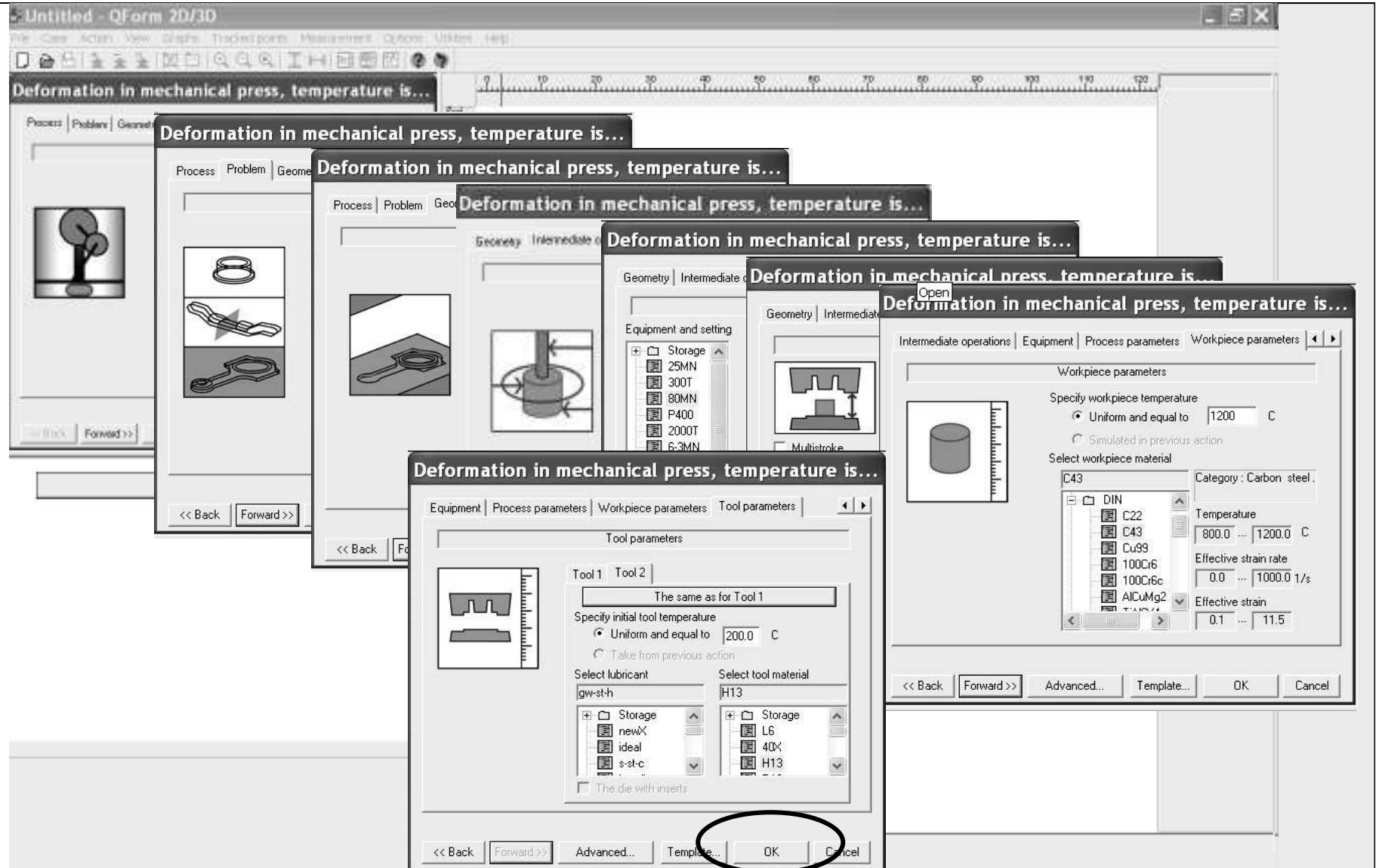
QUANTOR^{FORM}



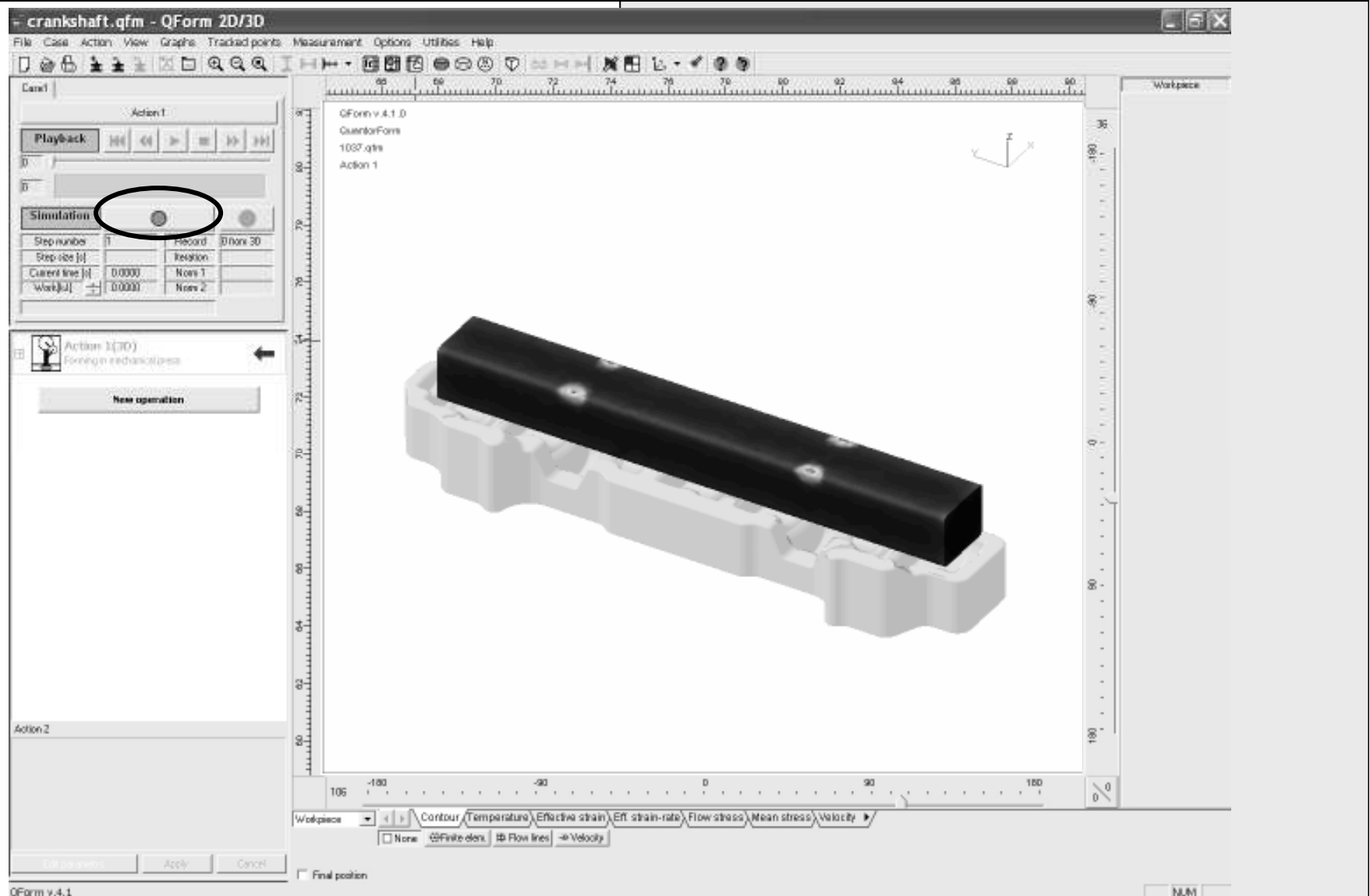
QForm window ready for new problem



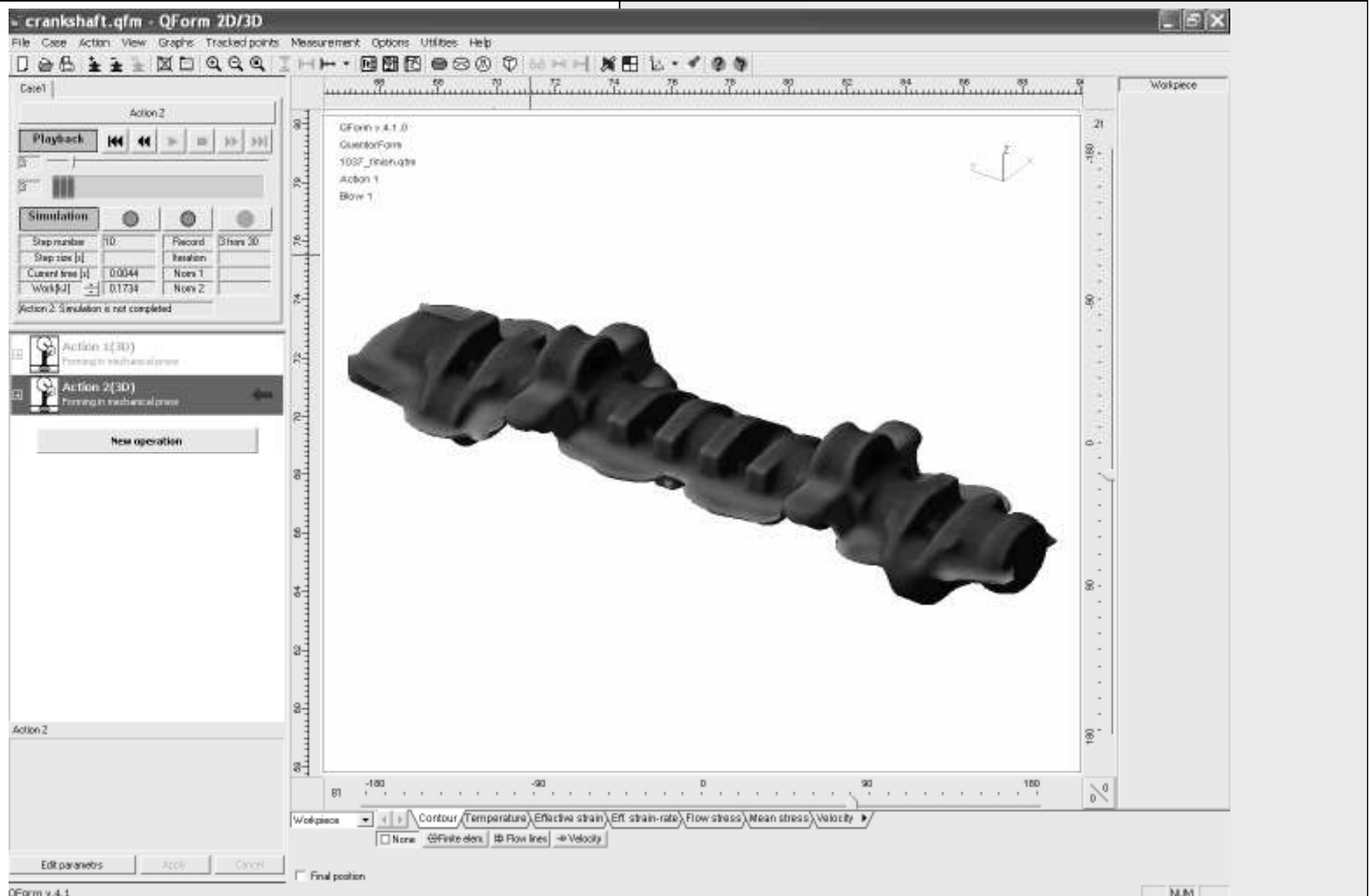
Data preparation Wizard



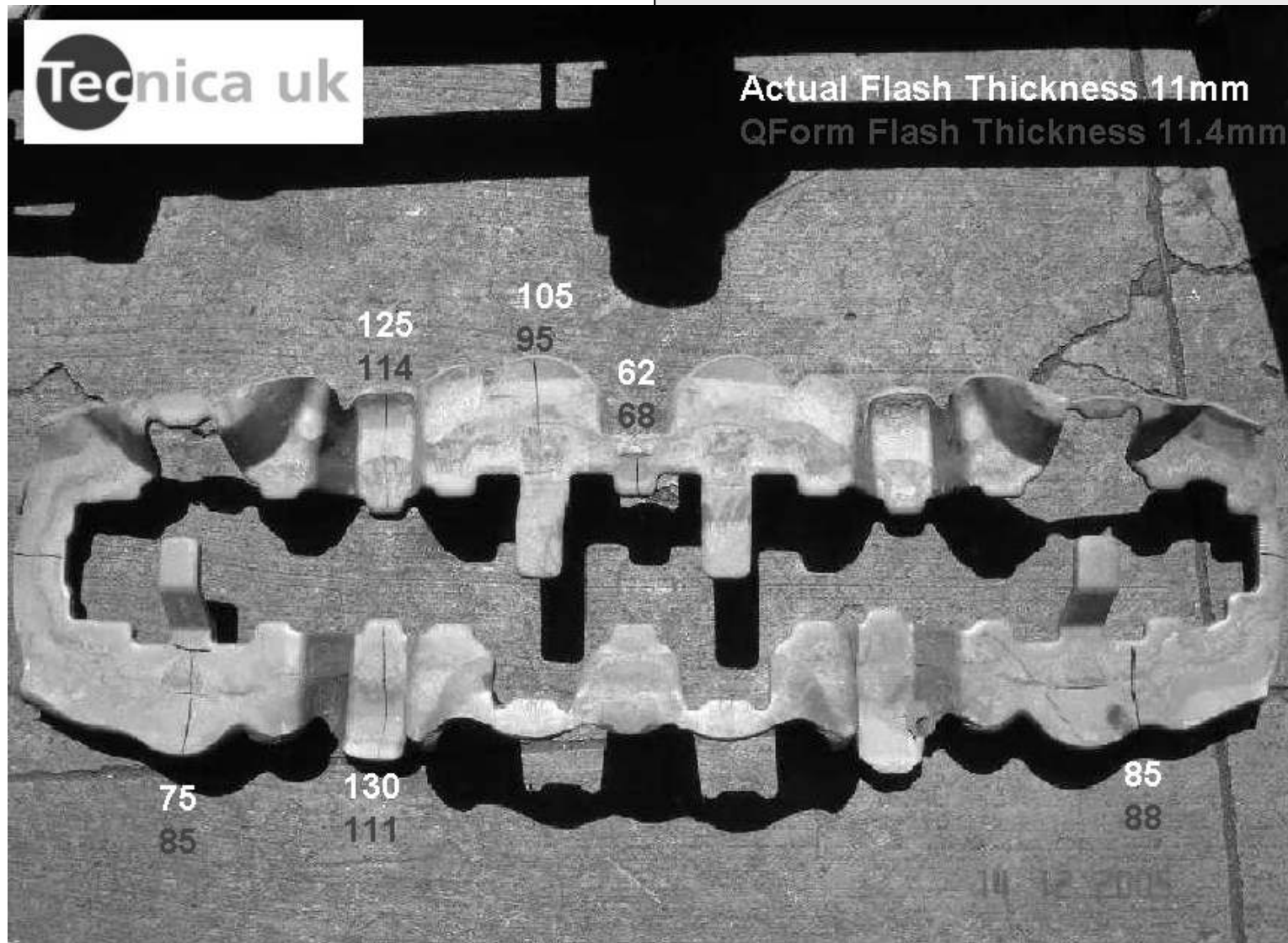
Simulation: Action 1 – Mould



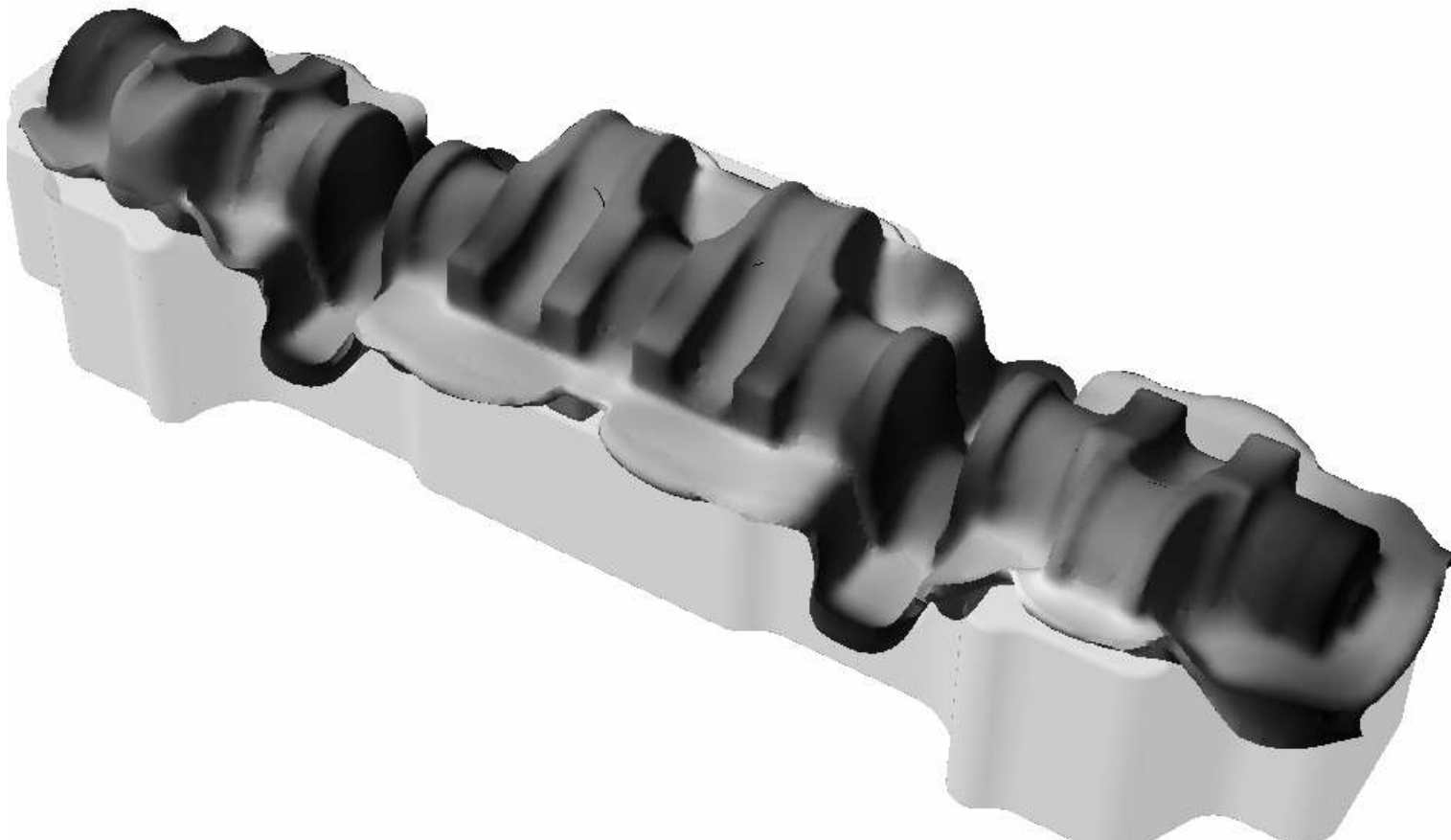
Simulation: Action 2 – Finish



Accurately Predicted Final Flash Thickness and Flash Widths



The temperature distribution

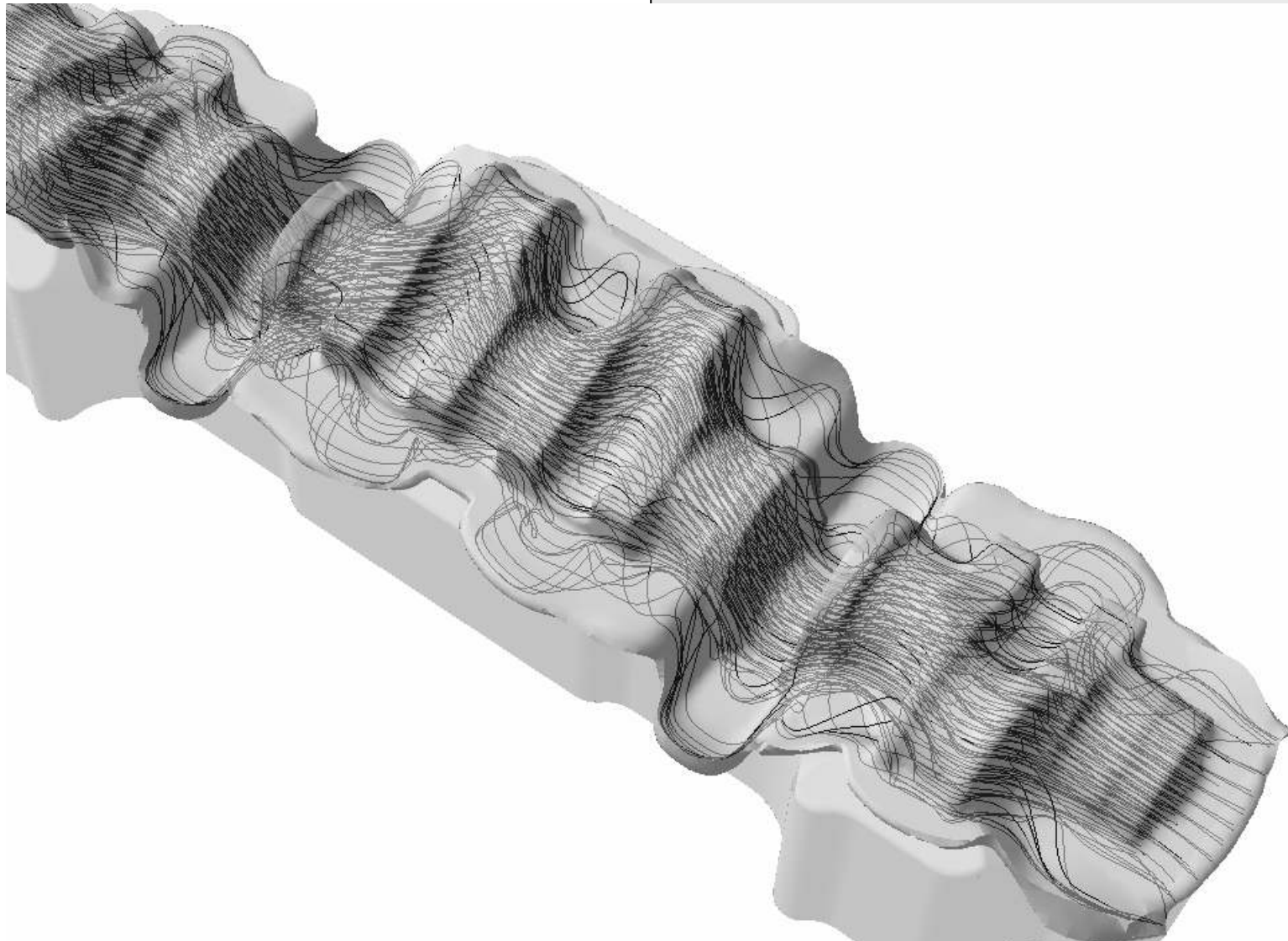


QFORM3D

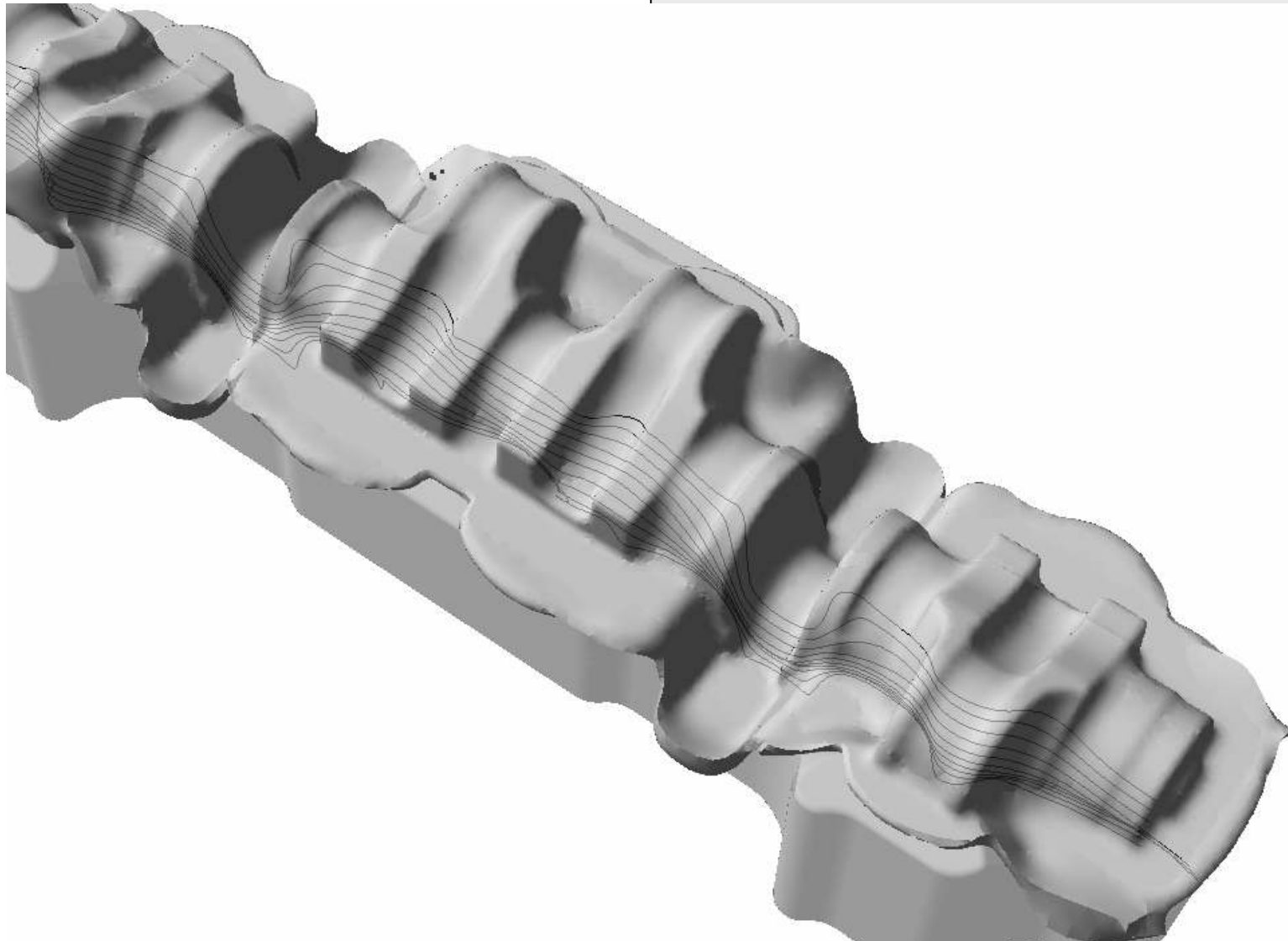
The most easy-to-use forging simulation software

QUANTOR^{FORM}

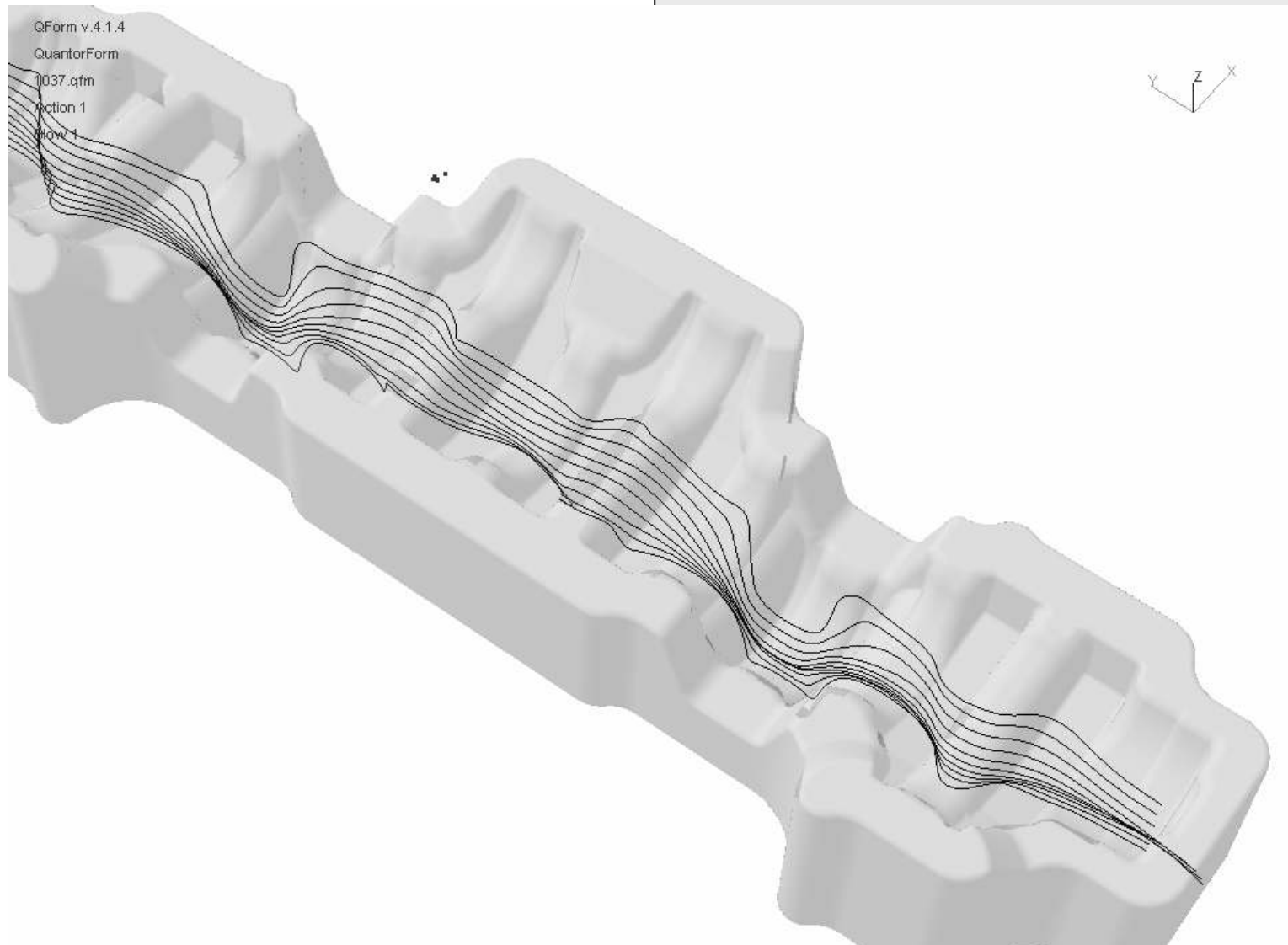
Look inside: the flow lines create the internal structure



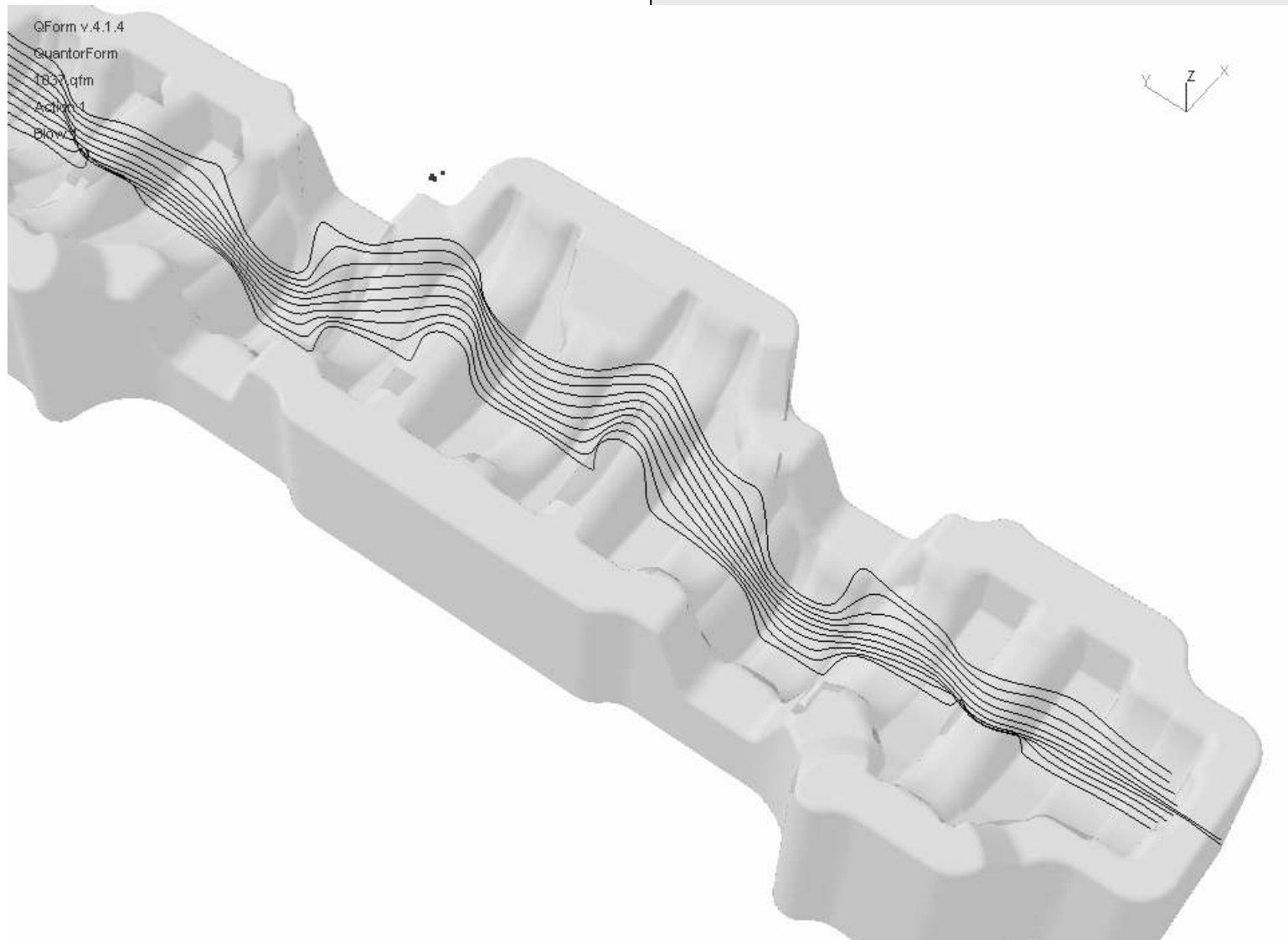
One layer of the flow lines



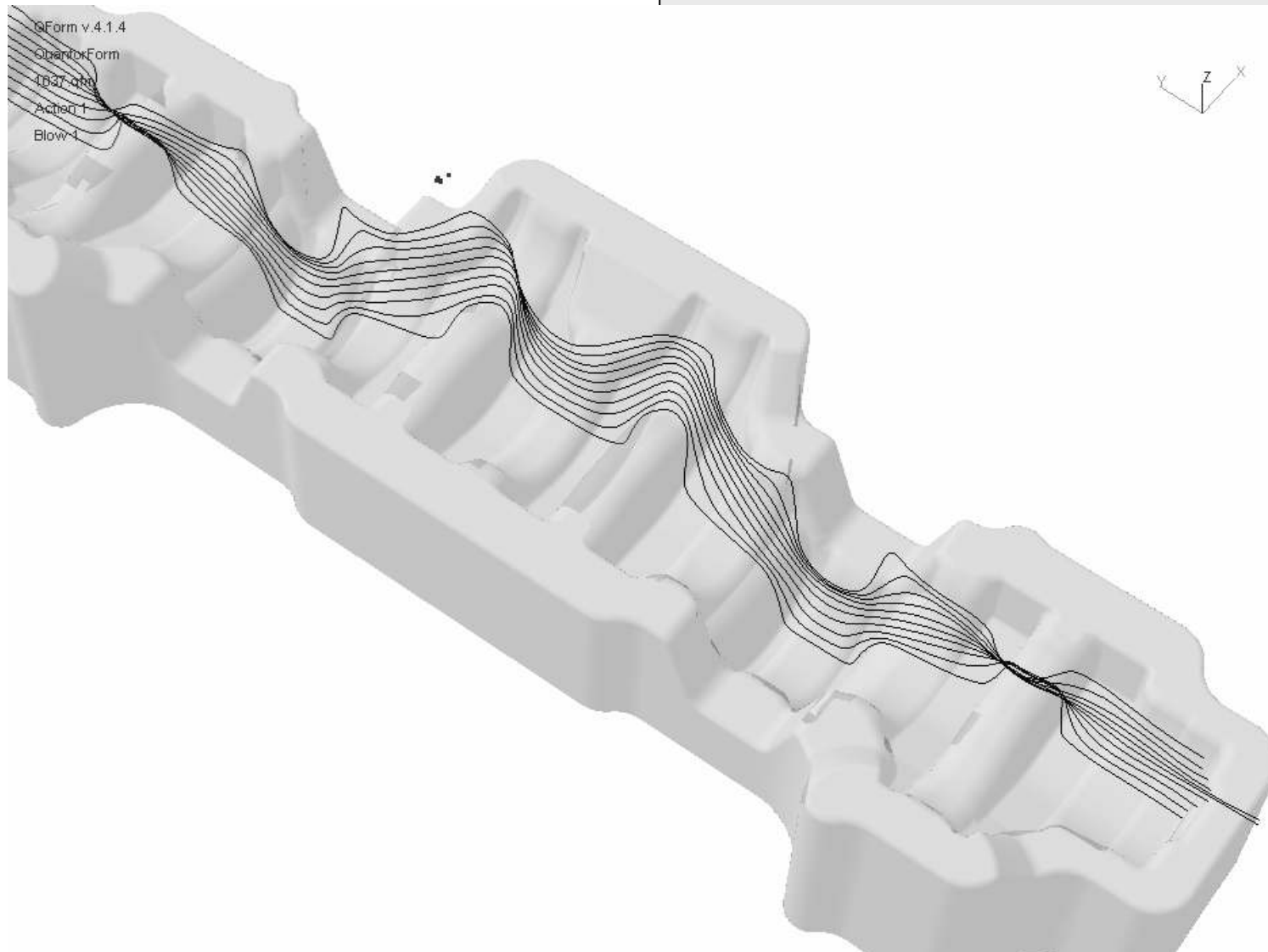
Analyze the grain flow layer by layer



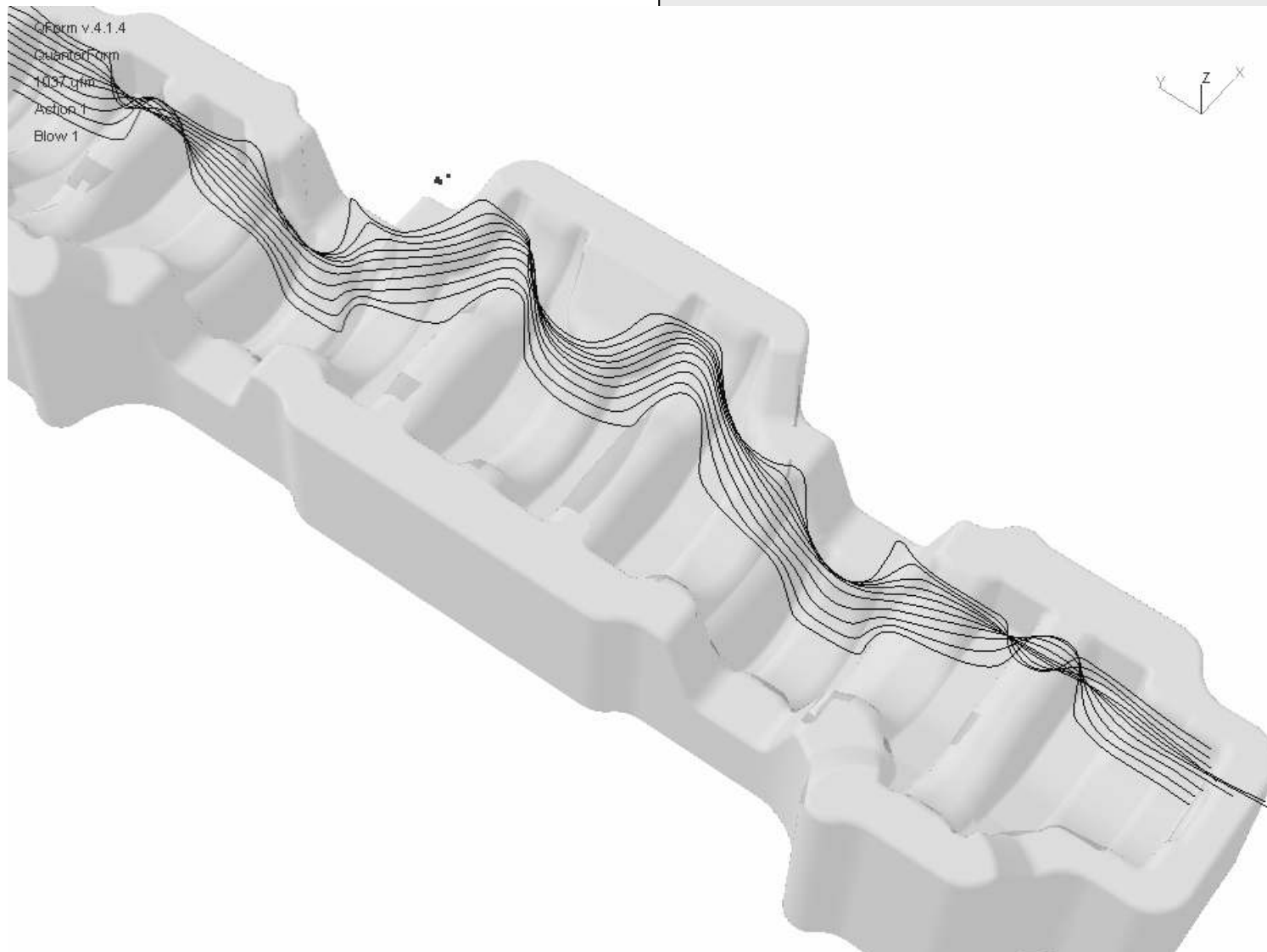
Analyze the grain flow layer by layer



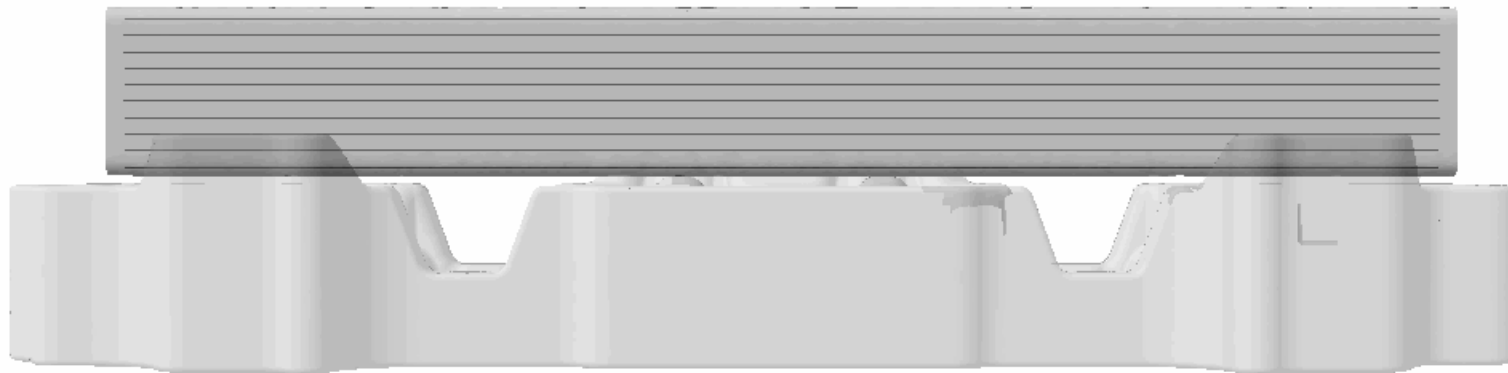
Analyze the grain flow layer by layer



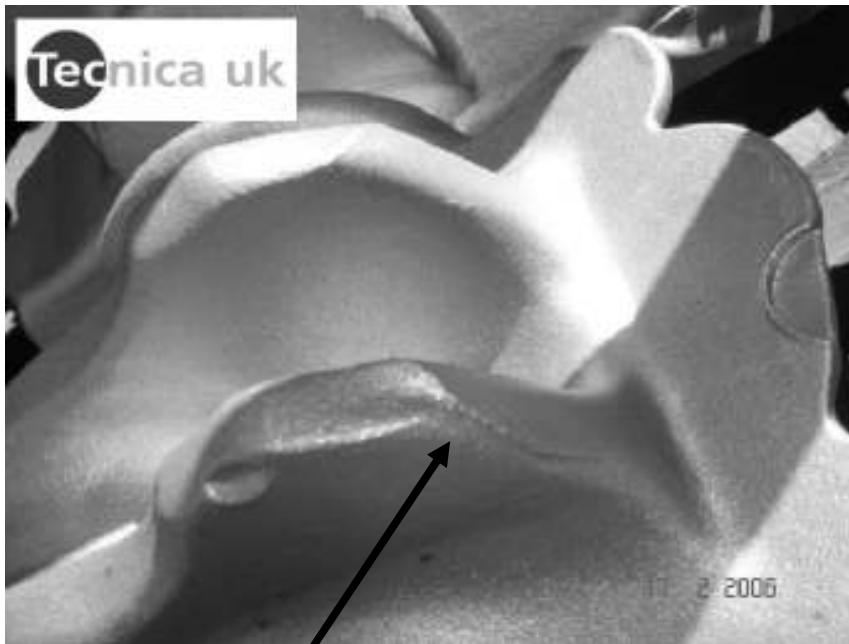
Analyze the grain flow layer by layer



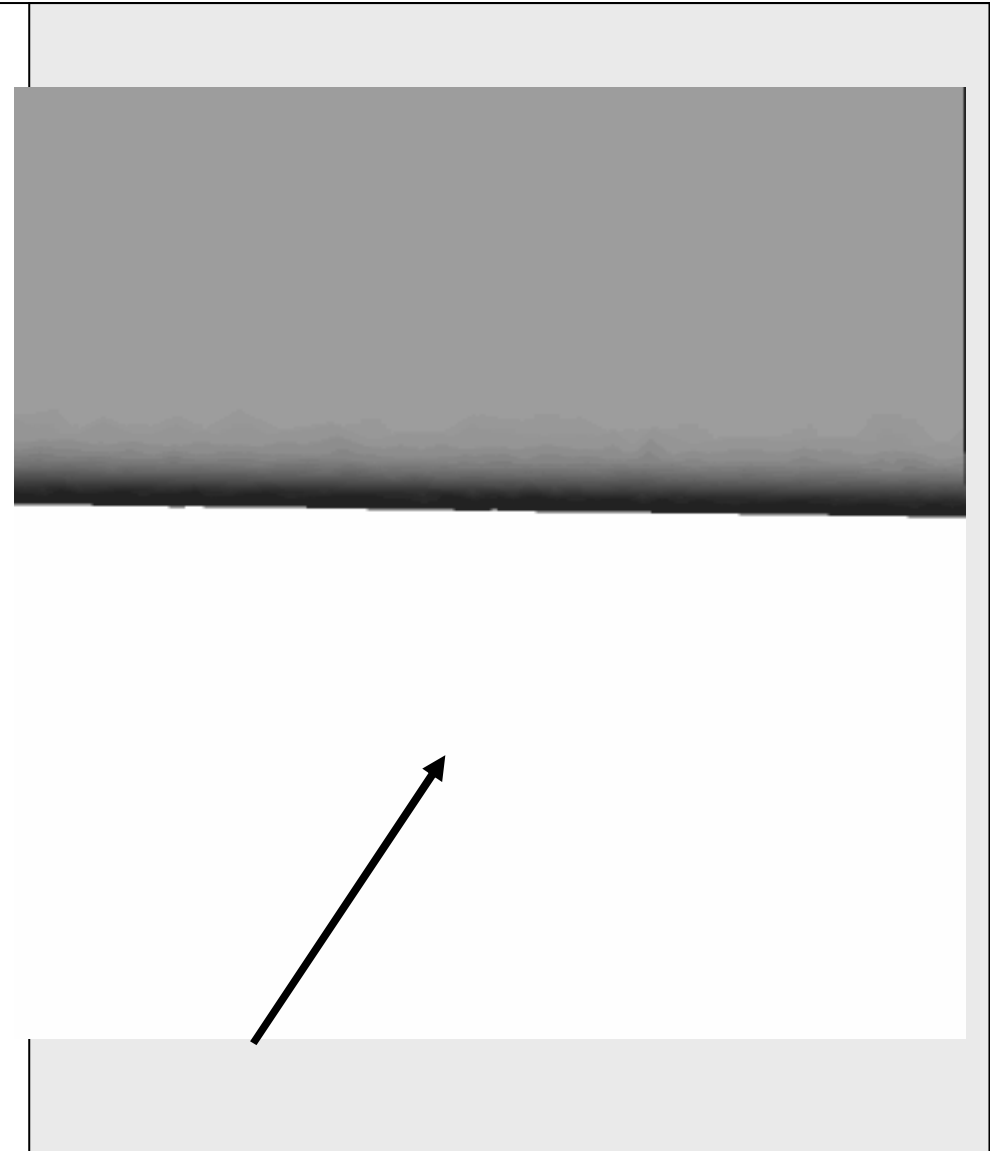
The evolution of the grain flow in certain location



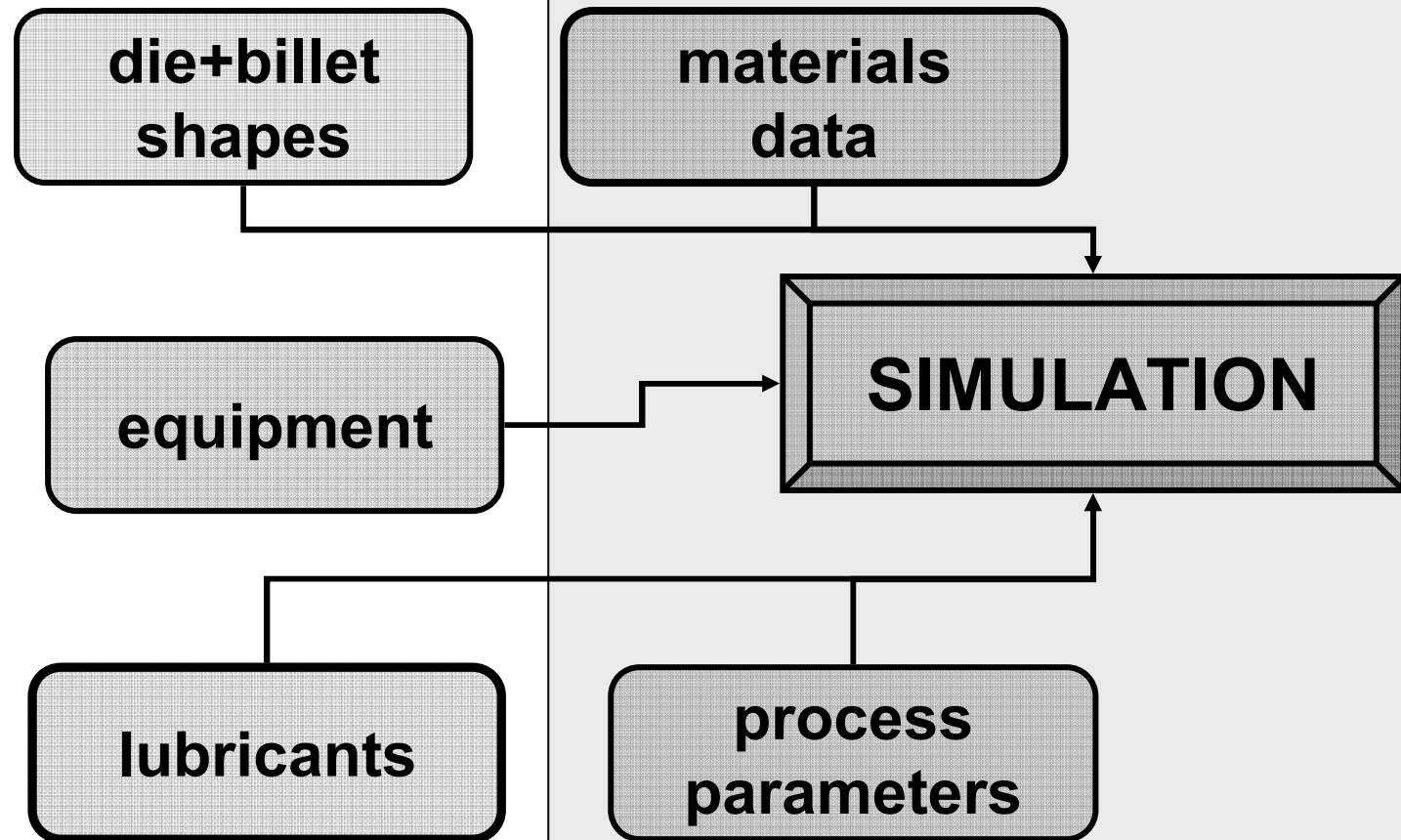
The lap formed on the web



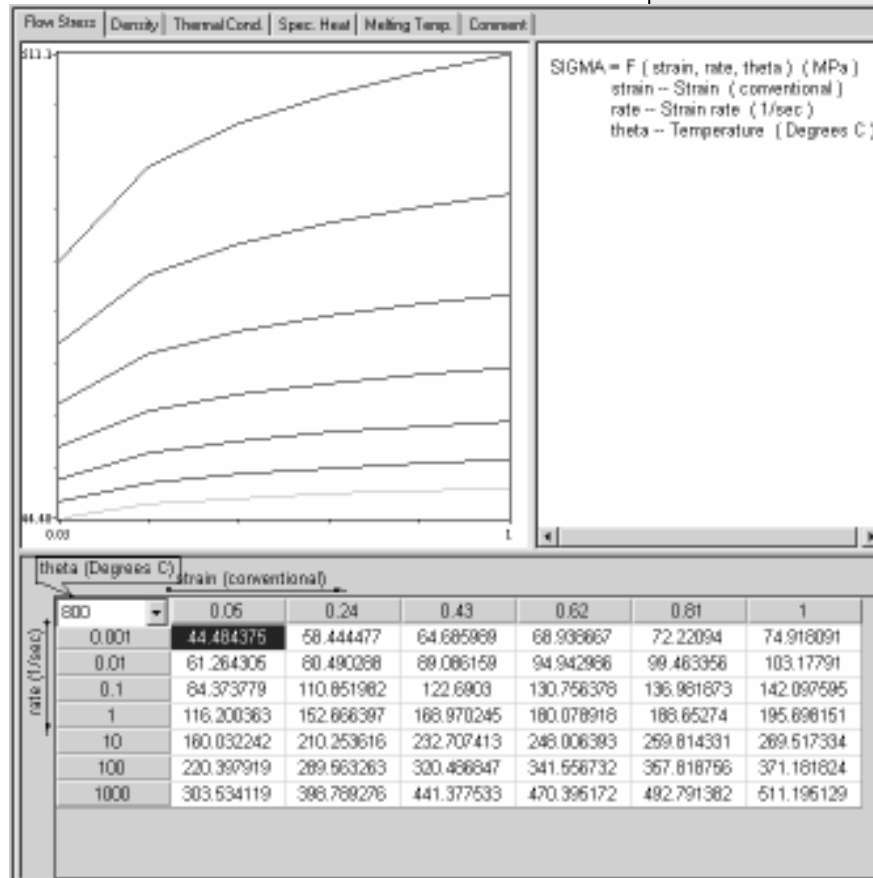
The lap



What is required for the simulation



Material & Lubricant: comprehensive Database



Example:

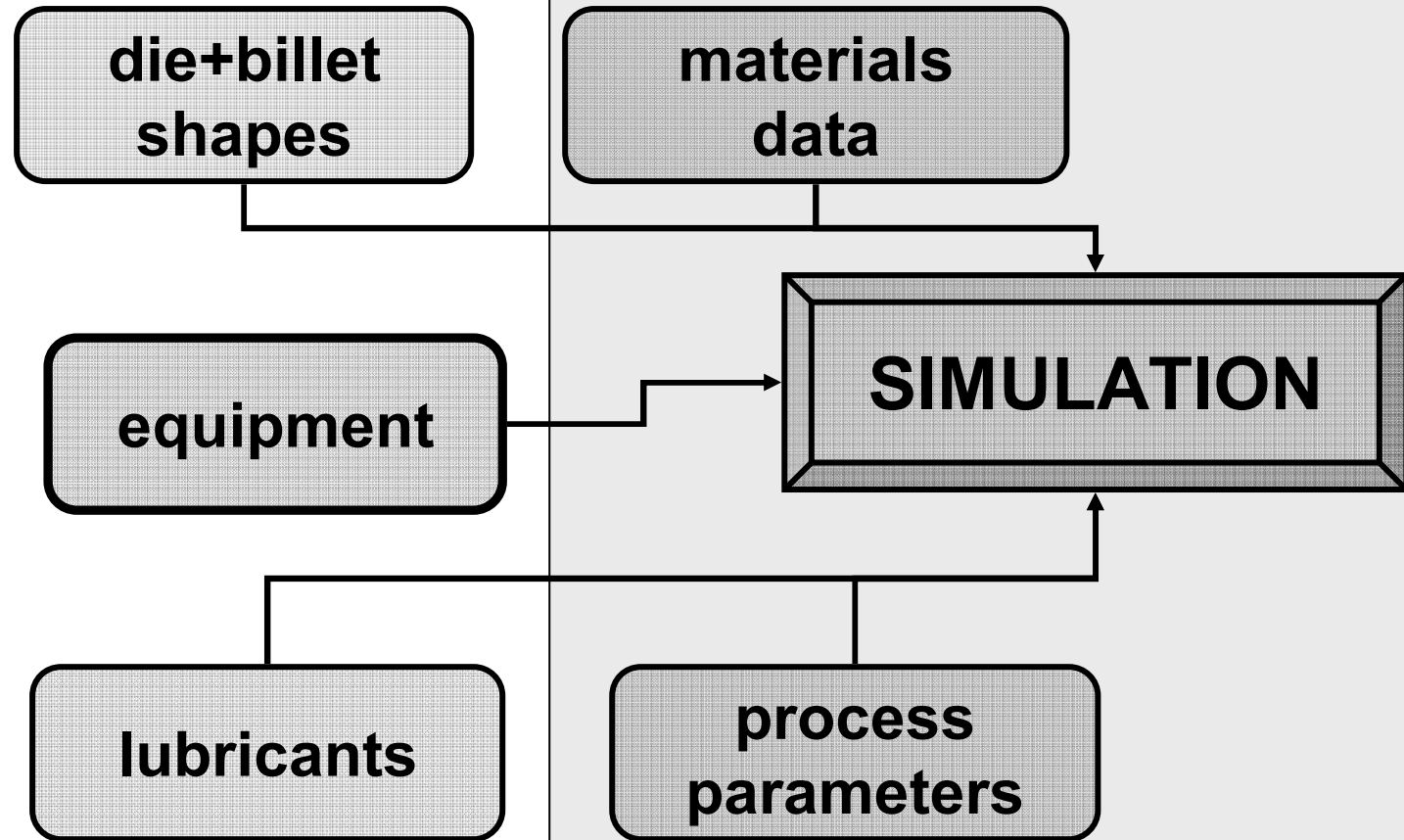
Flow stress depending on strain, strain-rate and temperature

QForm database contains flow stress for more than 430 steels, 30 copper alloys, 50 aluminum alloys, 20 titanium alloys, many nickel based alloys etc.

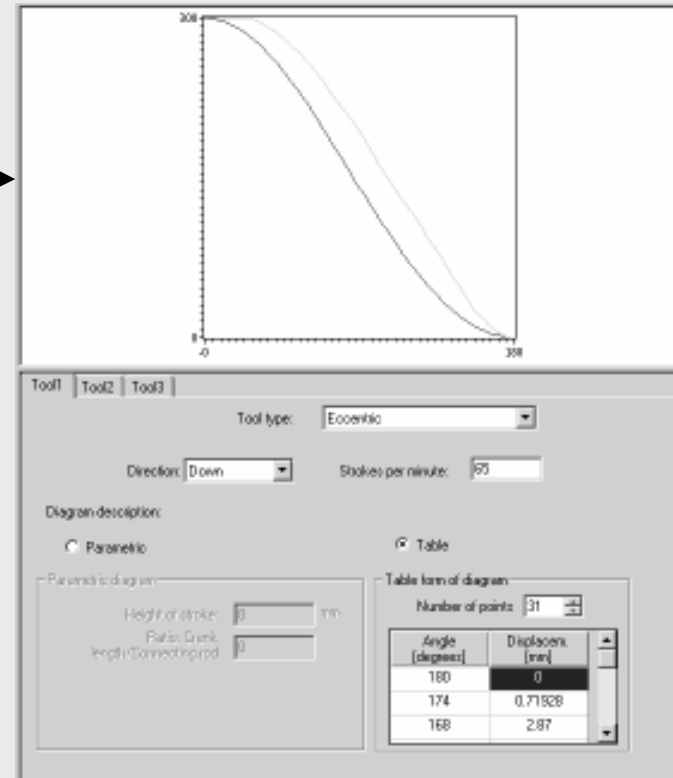
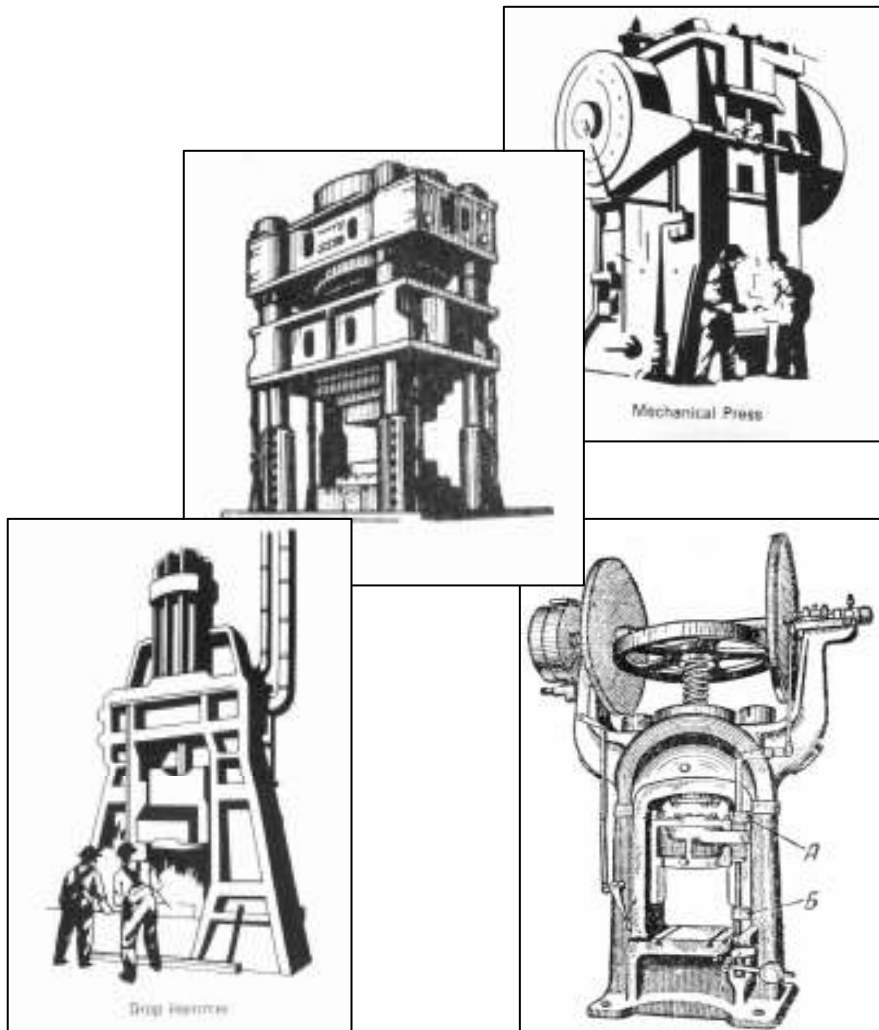
Next >>

**Every user receives the
customized material and lubricant database
according to his specification**

What is required for the simulation

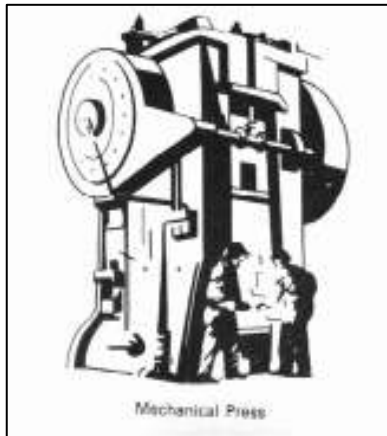


Simulation can be performed for any type of equipment

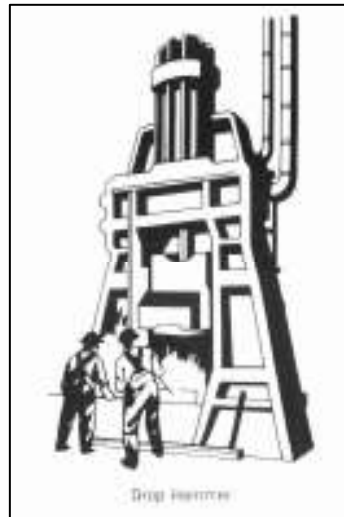


Example: Kinematics of the mechanical press with a holder

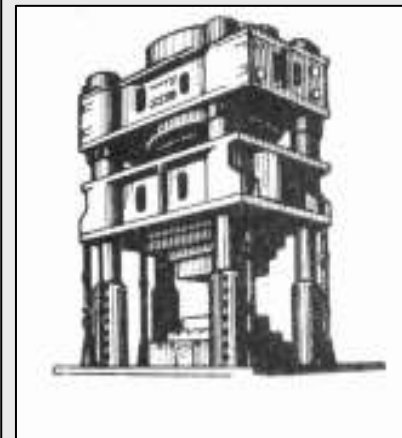
For every type of equipment the simulation gives you vital information:



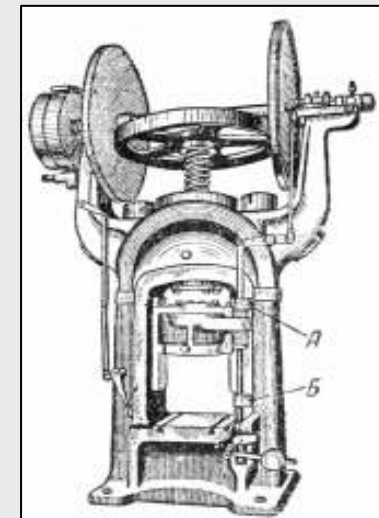
Critical load estimation



Required number of blows

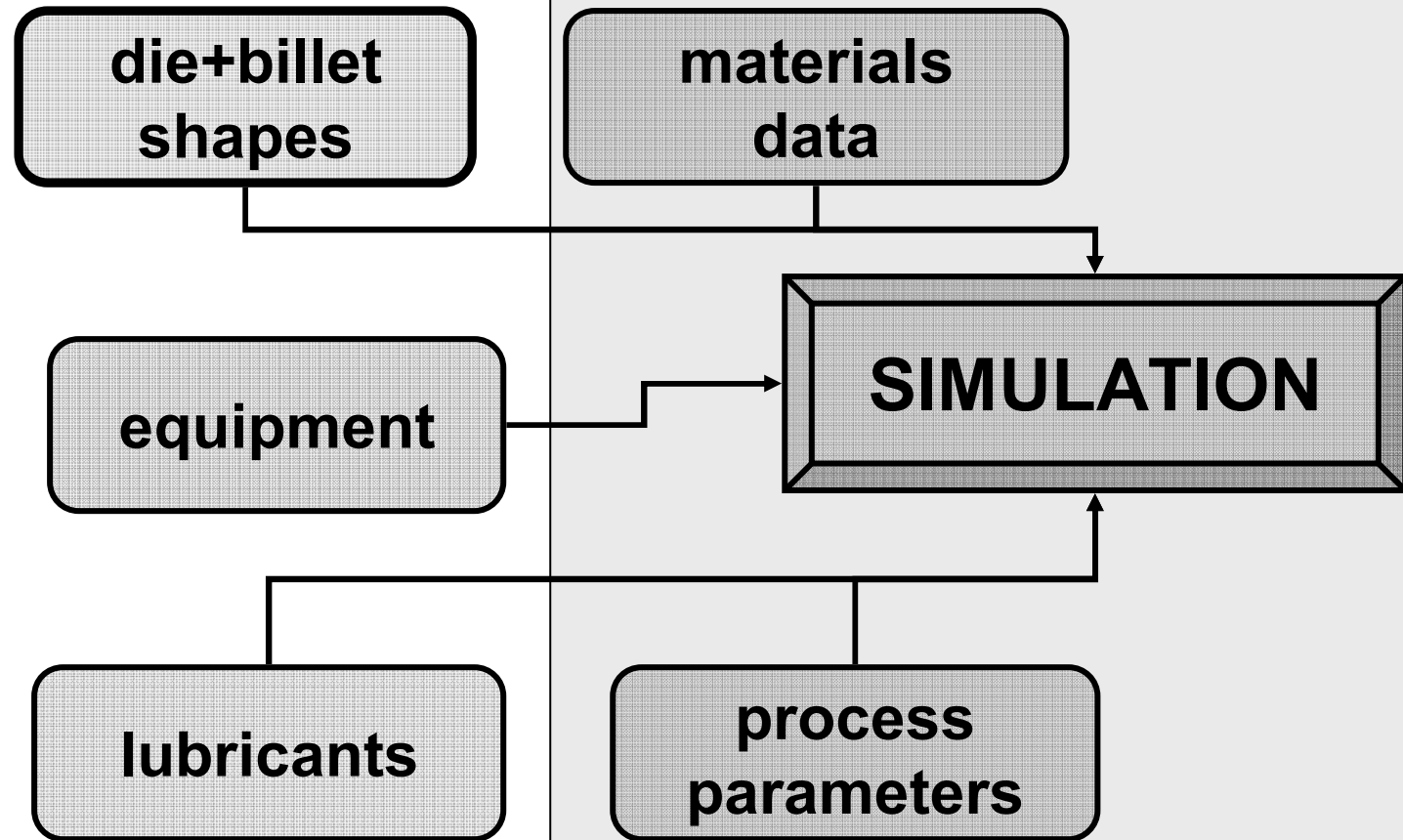


Energy and load requirements



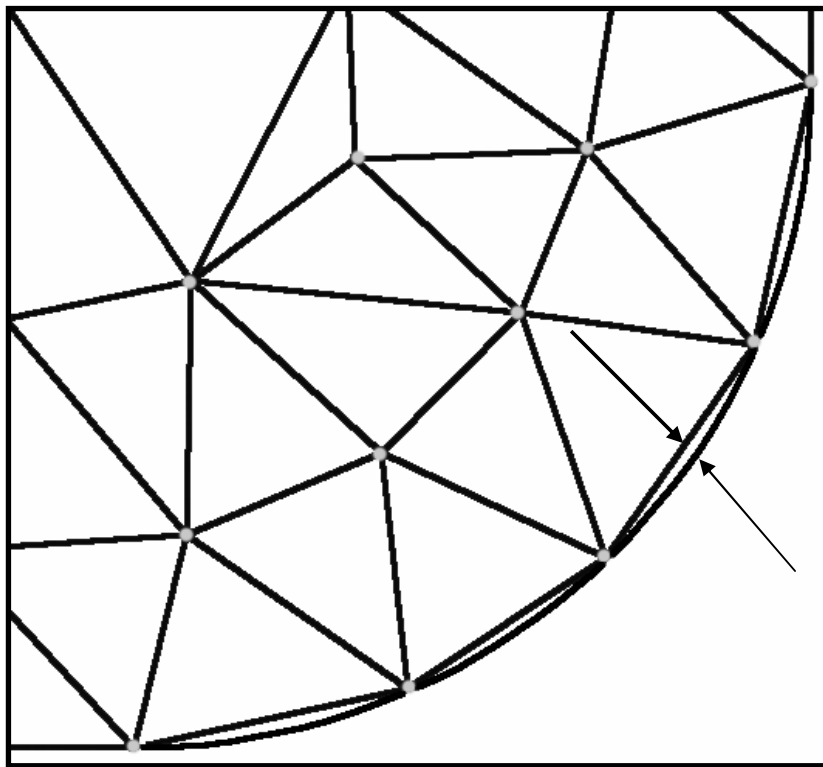
Optimal process parameter for safe use of press

What is required for the simulation

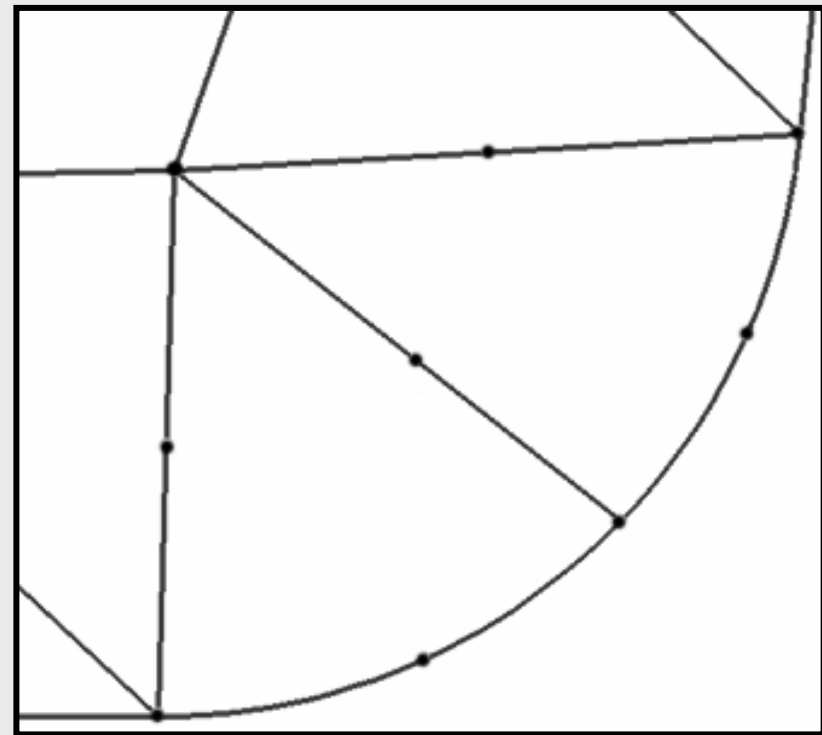


Quadratic approximation provides accurate solution for 2D

Linear (left) and quadratic (right) FE approximation of the surface with the same number of nodes

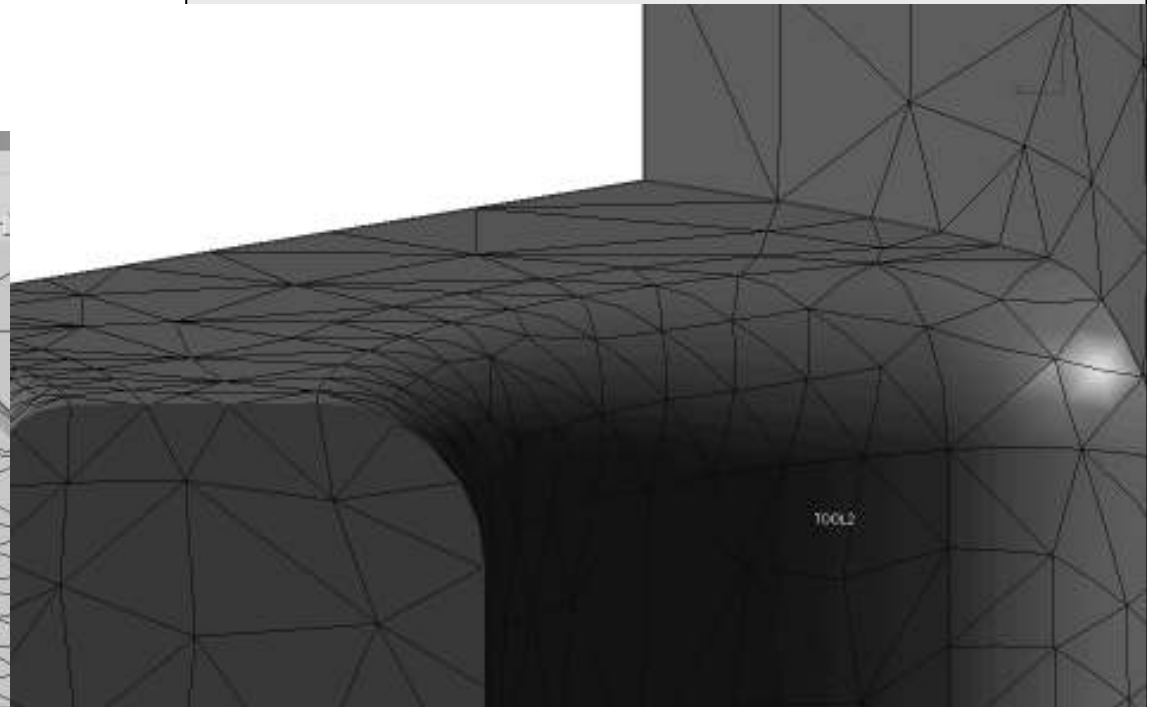
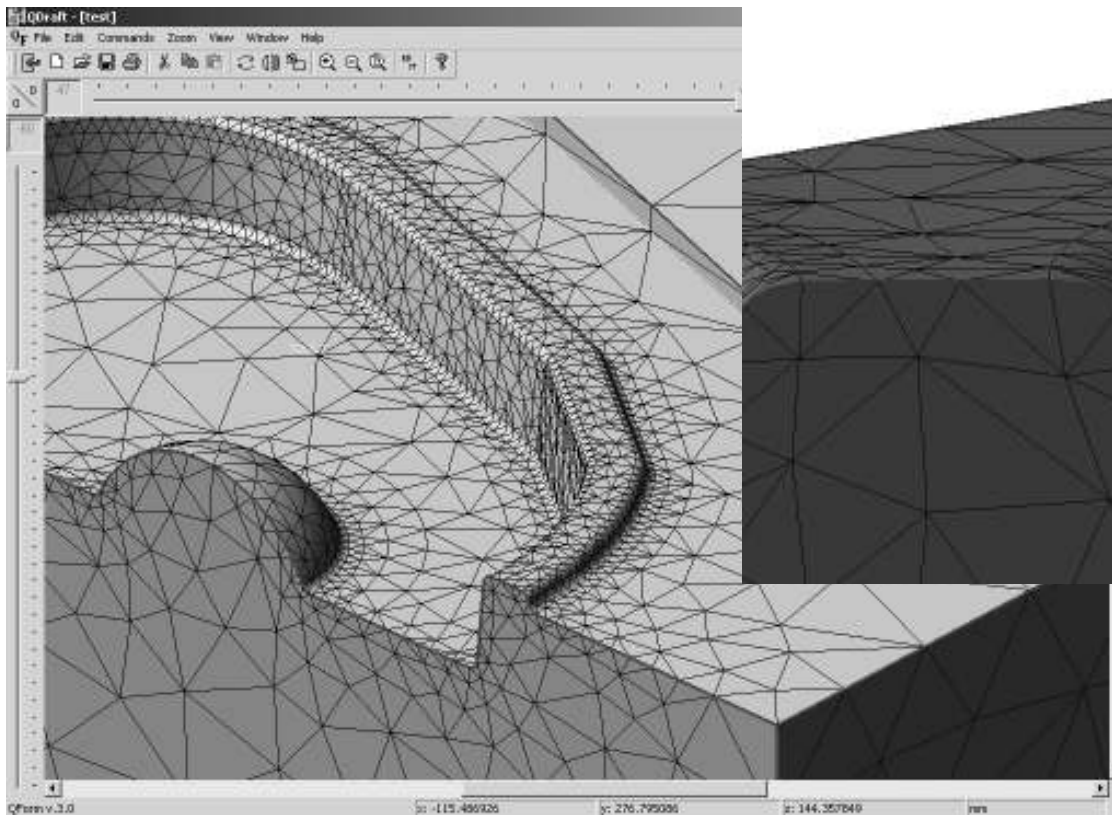


Error of the surface approximation



As in QForm 2D

Accurate representation of the 3D source geometry



As in QForm 3D

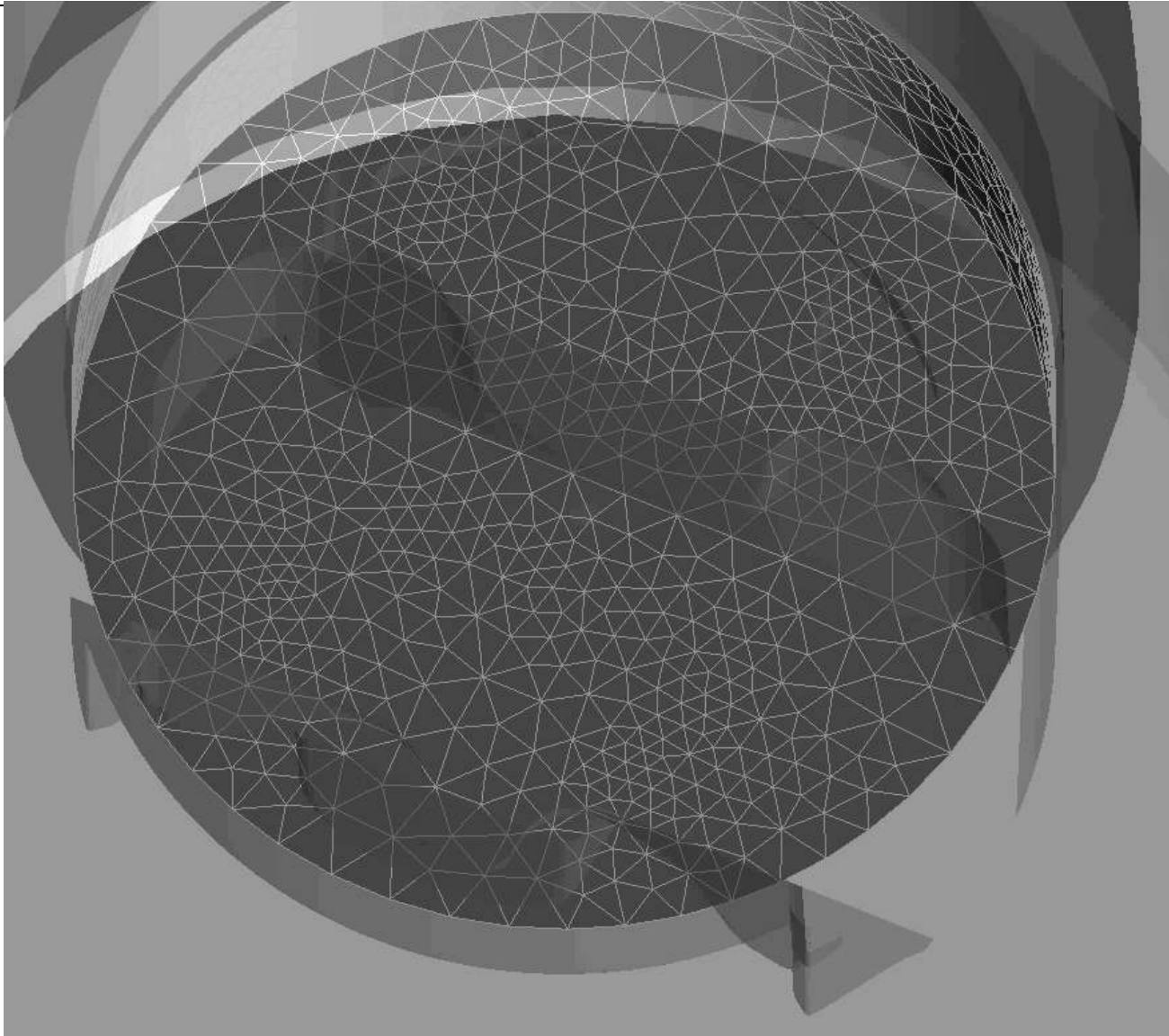
How simulation runs?

QFORM3D

The most easy-to-use forging simulation software

QUANTOR FORM

QForm makes optimal meshes in 2D and 3D without user's interference



Piston forging:

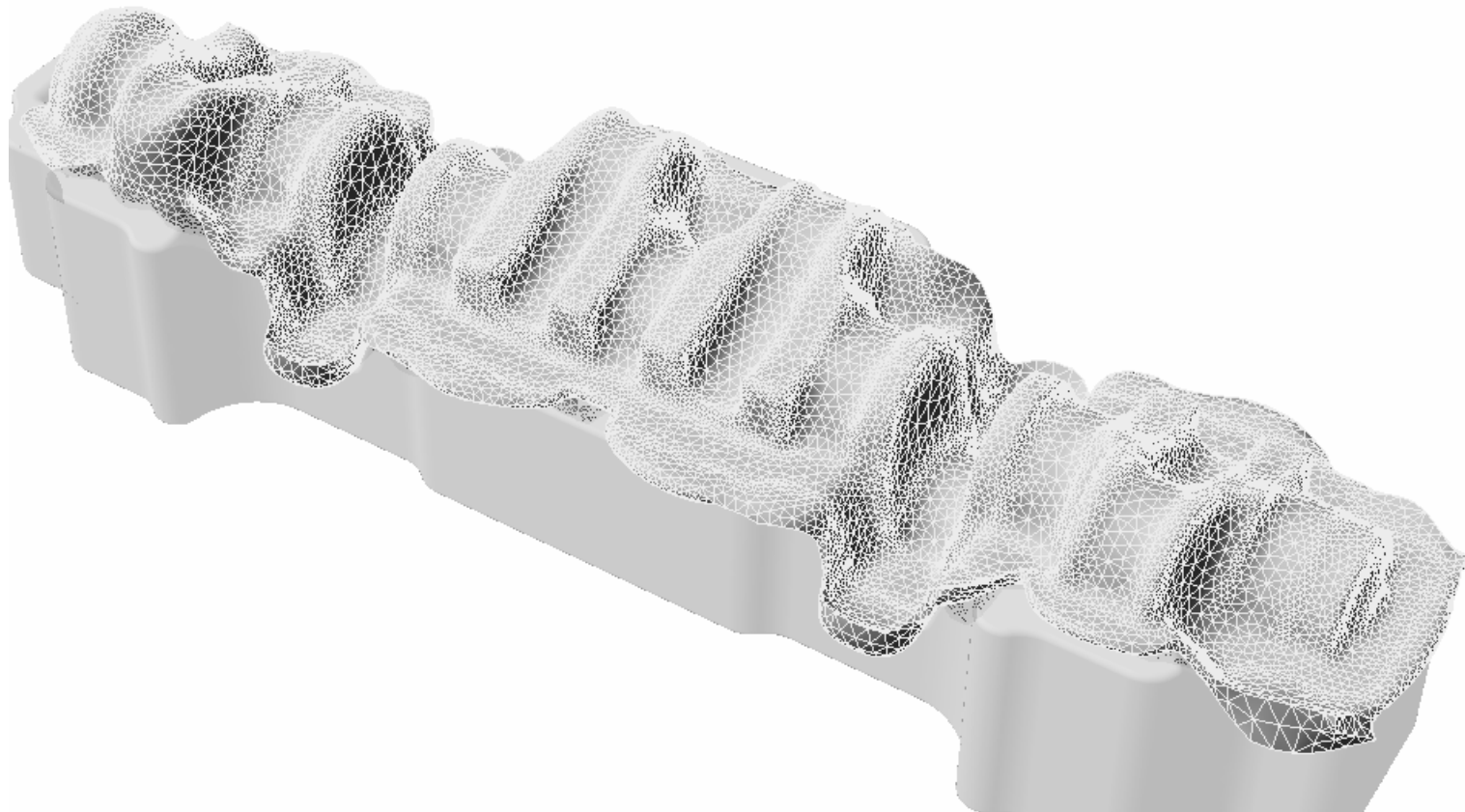
**Automatic
generation of
the mesh**

QFORM3D

The most easy-to-use forging simulation software

QUANTOR FORM

**The models with up to 100 000 nodes runs on a PC
with single, dual or two double core processors in parallel mode**



Practice of forging simulation

Hot closed die forging: the project, the cases, the actions

hejarsmide_d65_l220.qfm - QForm 2D/3D

File Case Action View Graphs Tracked points Measurement Options Utilities Help

D60mm D52mm Square 55mm

Action 3

Playback [Previous] [Play] [Next]

30 [Progress Bar] 30

Simulation

Step number	78	Record	30 from 30
Step size [s]		Iteration	
Current time [s]	0.0553	Norm 1	
Work[kJ]	15.7041	Norm 2	

Action 3: Simulation completed

- Action 1(3D) Forming in mechanical press
- Action 2(3D) Forming in mechanical press
- Action 3(3D) Forming in mechanical press**

Problem

Type of workpiece	Arbitrary (3D)
Thermal processes	Yes
Process in tool	Simulated

Geometry

File	D:\3d\Hejarsm
------	---------------

Intermediate operations

Before simulation

Cooling in air	Yes
Time of cooling in air	1
Cooling on tool	Yes
Time of cooling on tool	1
Piercing the hole	No
Trimming the flash	No

After simulation

Piercing the hole	No
-------------------	----

QForm v.4.1.3
QuantorForm
hejarsmide_jest.qfm
Action 1

Workpiece Effective strain 0

Max [4.574]
Min [0]

Hot closed die forging: the project, the cases, the actions

hejarsmide_d65_l220.qfm - QForm 2D/3D

File Case Action View Graphs Tracked points Measurement Options Utilities Help

D60mm D52mm Square 60mm

Action 3

Playback

30

30

Simulation

Step number	78	Record	30 from 30
Step size [s]		Iteration	
Current time [s]	0.0553	Norm 1	
Work[kJ]	15.7041	Norm 2	

Action 3: Simulation completed

- Action 1(3D) Forging in mechanical press
- Action 2(3D) Forging in mechanical press
- Action 3(3D) Forging in mechanical press

Problem

Type of workpiece:	Arbitrary (3D)
Thermal processes:	Yes
Process in tool:	Simulated

Geometry

File: D:\3d\Hejarsm

Intermediate operations

Before simulation

Cooling in air	Yes
Time of cooling in air	1
Cooling on tool	Yes
Time of cooling on tool	1
Piercing the hole	No
Trimming the flash	No

After simulation

Piercing the hole	No
-------------------	----

Workpiece Effective strain 0.315

Max: 1.772
Min: 0

Hot closed die forging: the project, the cases, the actions

hejarsmid_e_d65_l220.qfm - QForm 2D/3D

File Case Action View Graphs Tracked points Measurement Options Utilities Help

D60mm D52mm **Square 55mm**

Action 3

Playback [Buttons]

30 [Slider]

30 [Slider]

Simulation

Step number	78	Record	30 from 30
Step size [s]		Iteration	
Current time [s]	0.0553	Norm 1	
Work[kJ]	15.7041	Norm 2	

Action 3: Simulation completed

- Action 1(3D) Forming in mechanical press
- Action 2(3D) Forming in mechanical press
- Action 3(3D) Forming in mechanical press**

Problem

Type of workpiece:	Arbitrary (3D)
Thermal processes:	Yes
Process in tool:	Simulated

Geometry

File:	D:\3d\Hejarsm
-------	---------------

Intermediate operations

Before simulation

Cooling in air	Yes
Time of cooling in air	1
Cooling on tool	Yes
Time of cooling on tool	1
Piercing the hole	No
Trimming the flash	No

After simulation

Piercing the hole	No
-------------------	----

QForm v.4.1.3
QuantorForm
hejarsmid_je3.qfm
Action 1

Workpiece Effective strain 0.1862

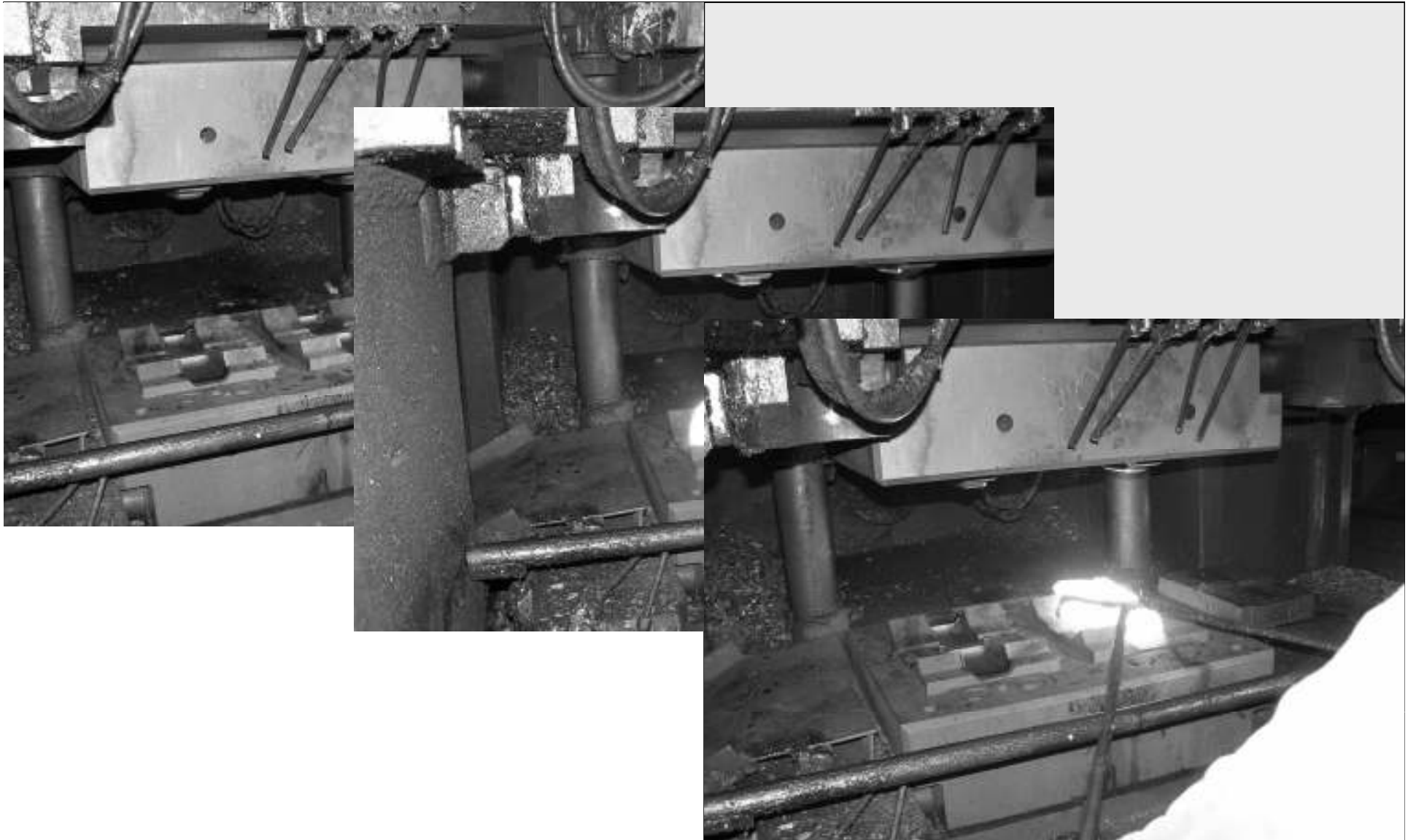
Max: [2.168]
Min: [0]

QFORM3D

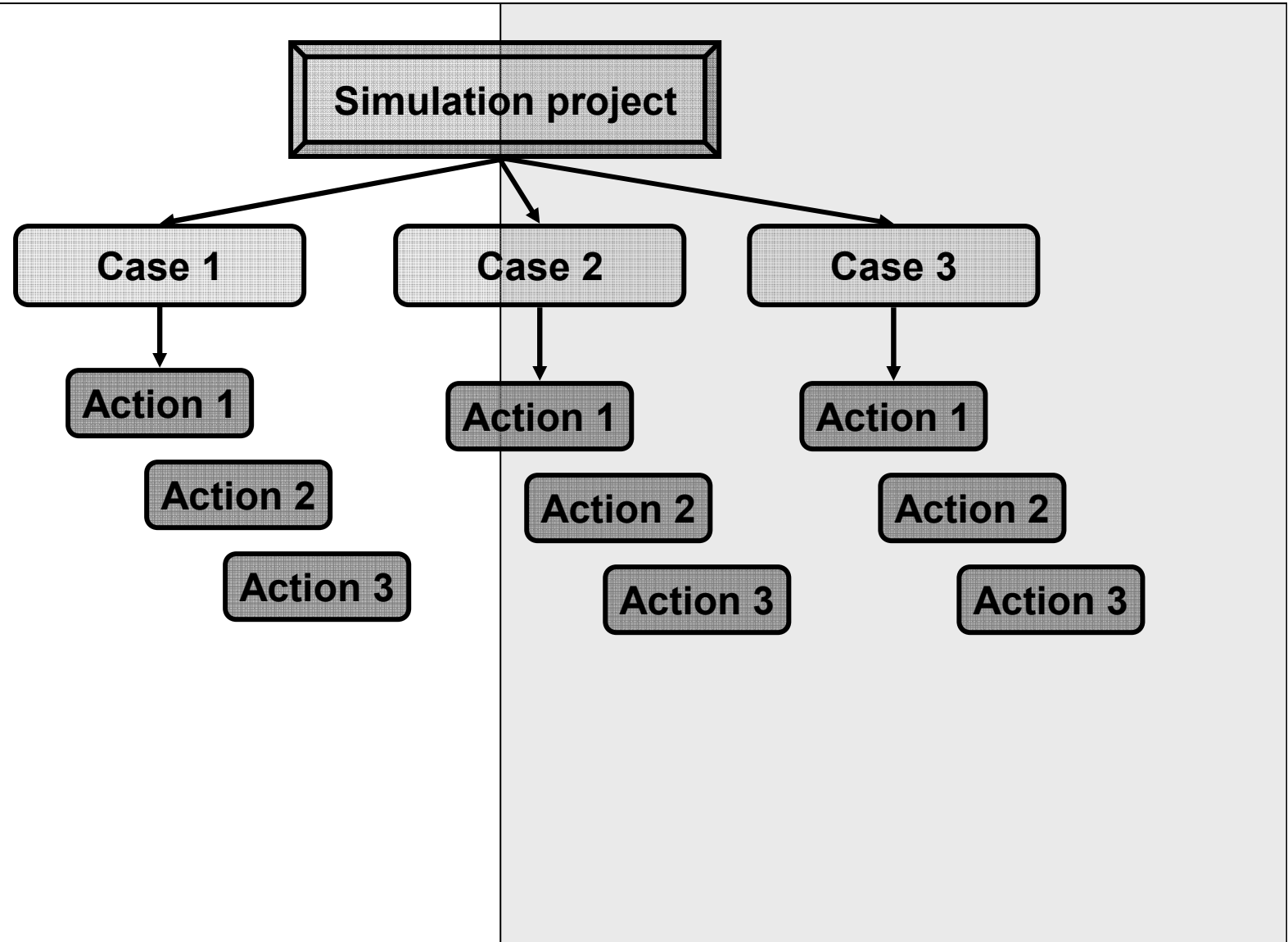
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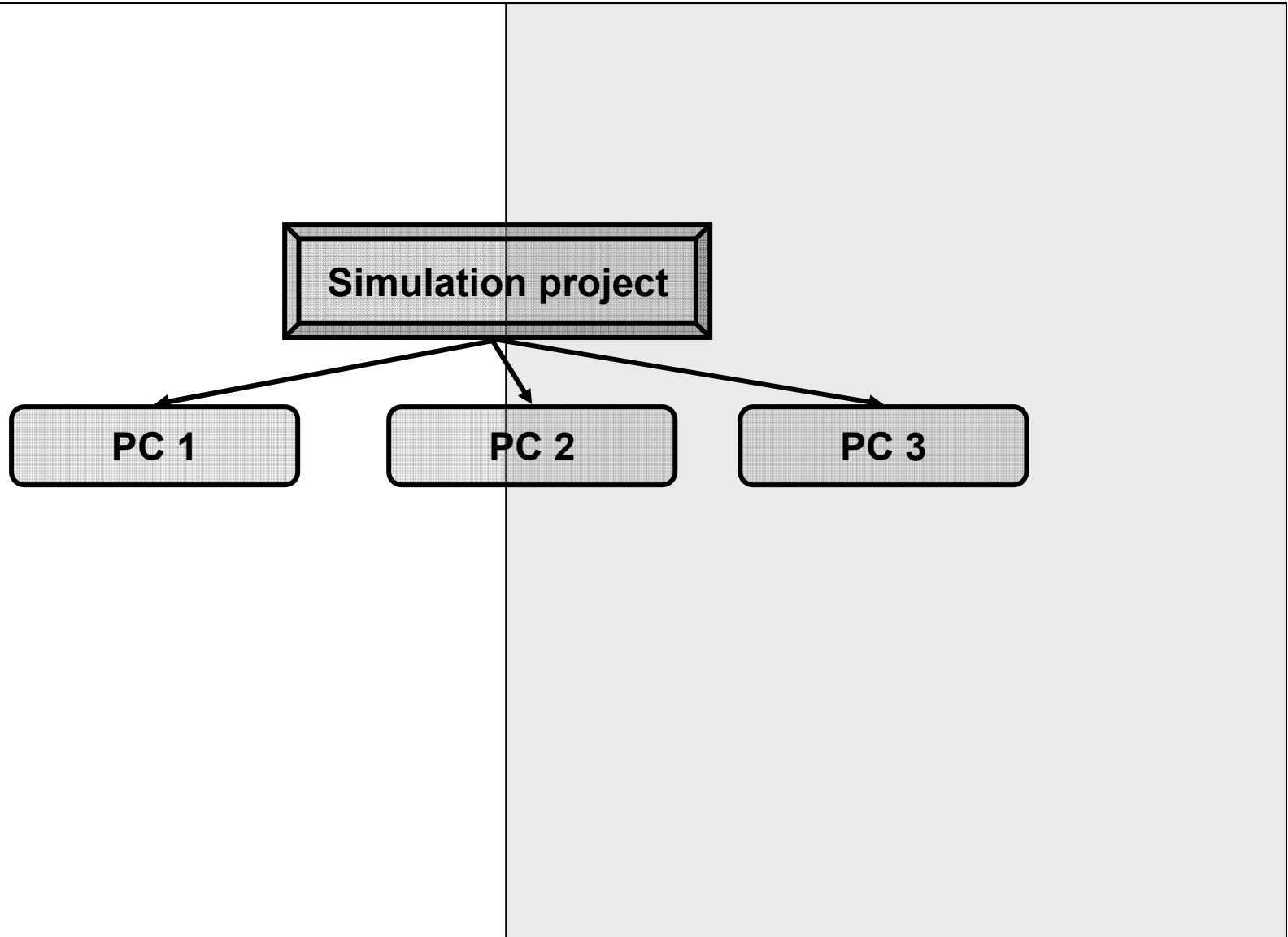
Hot closed die forging: quick feedback



The project, the cases, the actions



Splitting the project for parallel simulation on several PCs in a network



Simulation of preforming operations

Programmed simulation of cogging operation in a single action

Problem | Geometry | Intermediate operations | Equipment | Process parameters

Process parameters

Final distance between tools: 30.000 mm

in a point determined automatically
 in a point with coordinate

Multistroke

Problem | Geometry | Intermediate operations | Equipment | Process parameters

Process parameters

Final distance between tools: 30.000 mm

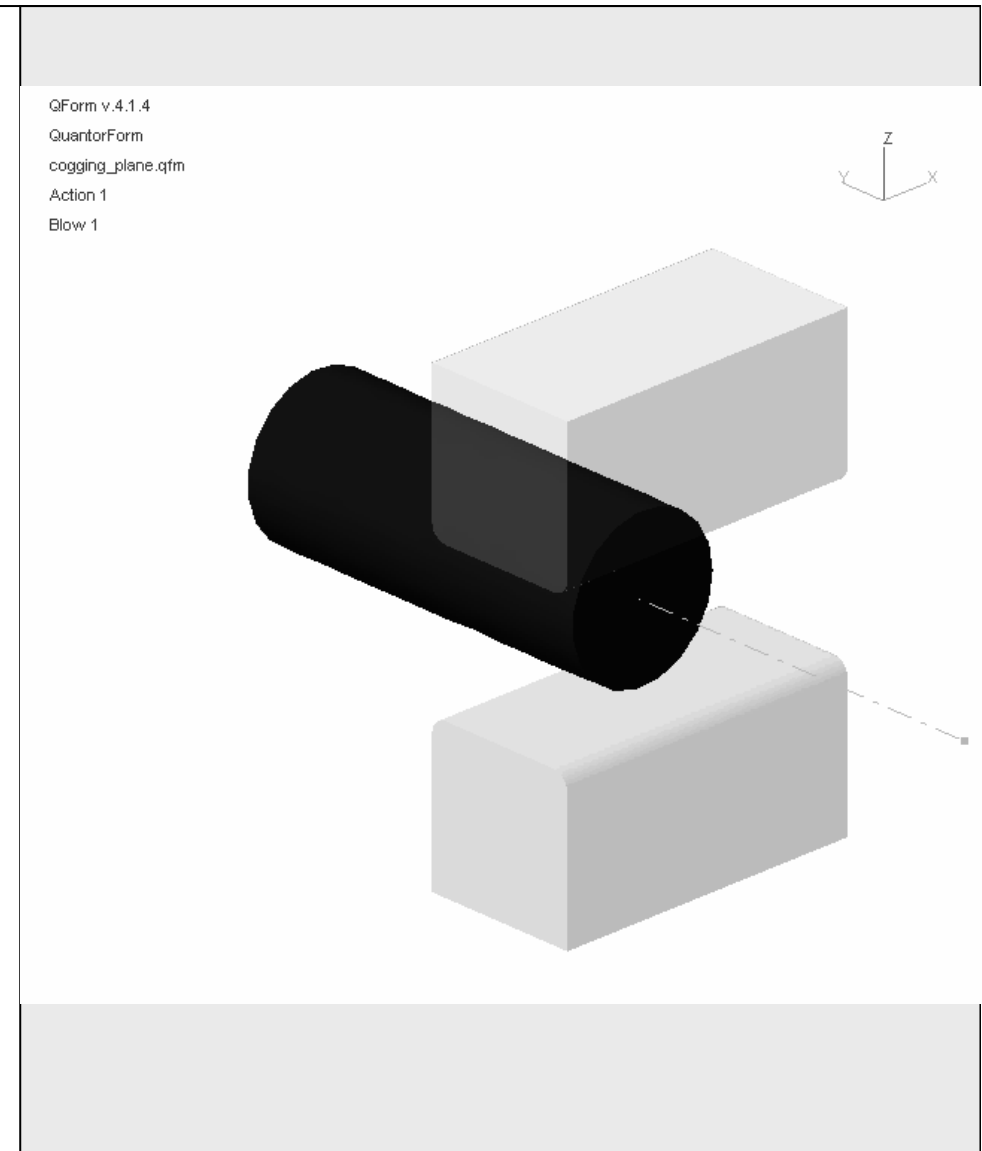
in a point determined automatically
 in a point with coordinate

Multistroke

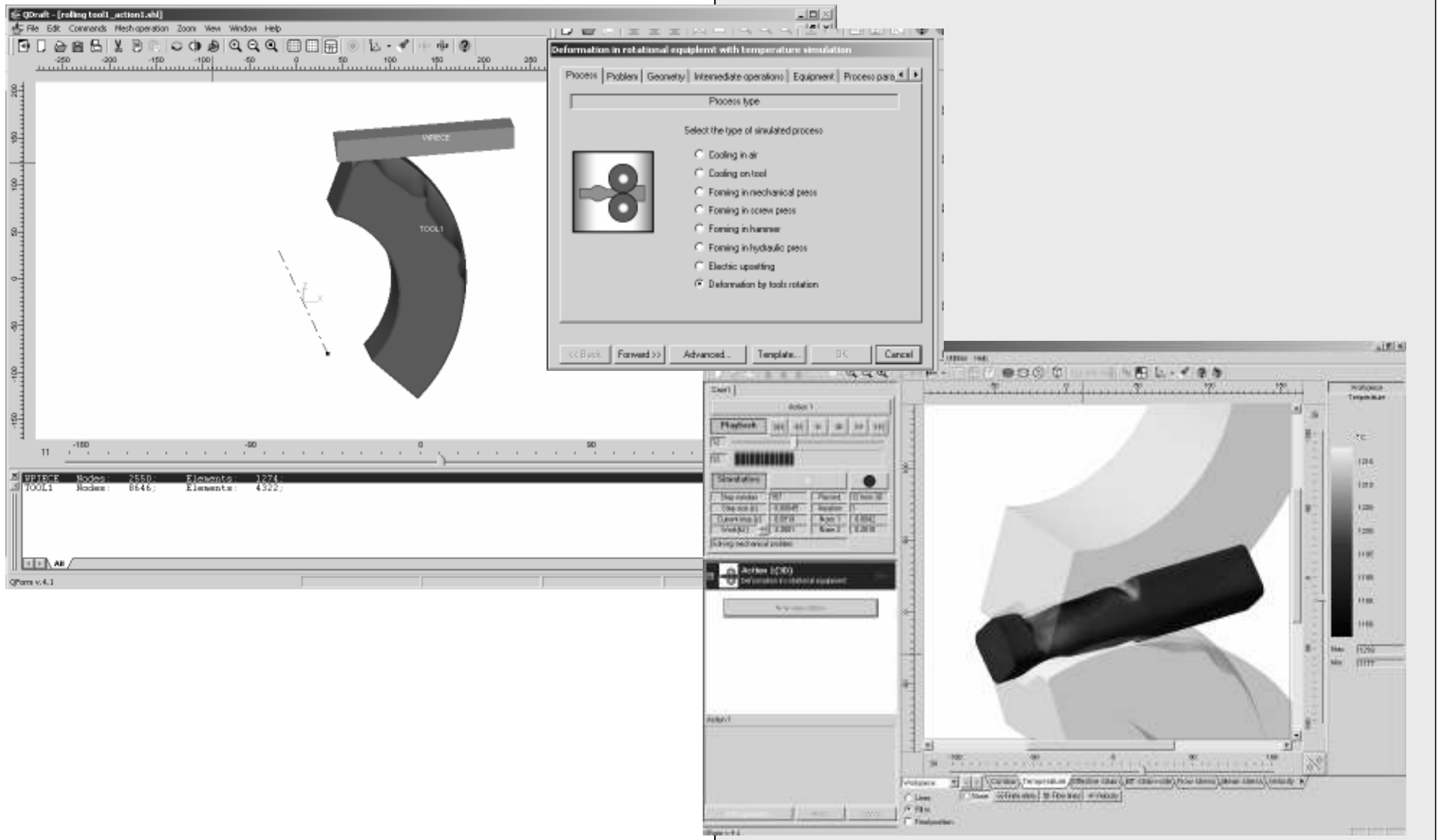
Maximum number of blows: 7

Blow	Cooling in air [s]	Cooling on tool [s]	Shift [mm]	Rotation angle [deg.]
1	3	2	0	0
2	2	1	0	90
3	2	1	-40	0
4	2	1	0	90
5	2	1	-40	0
6	0	0	0	90

<< Back | Forward >> | Advanced... | Template... | OK | Cancel



Simulation of reducer rolling



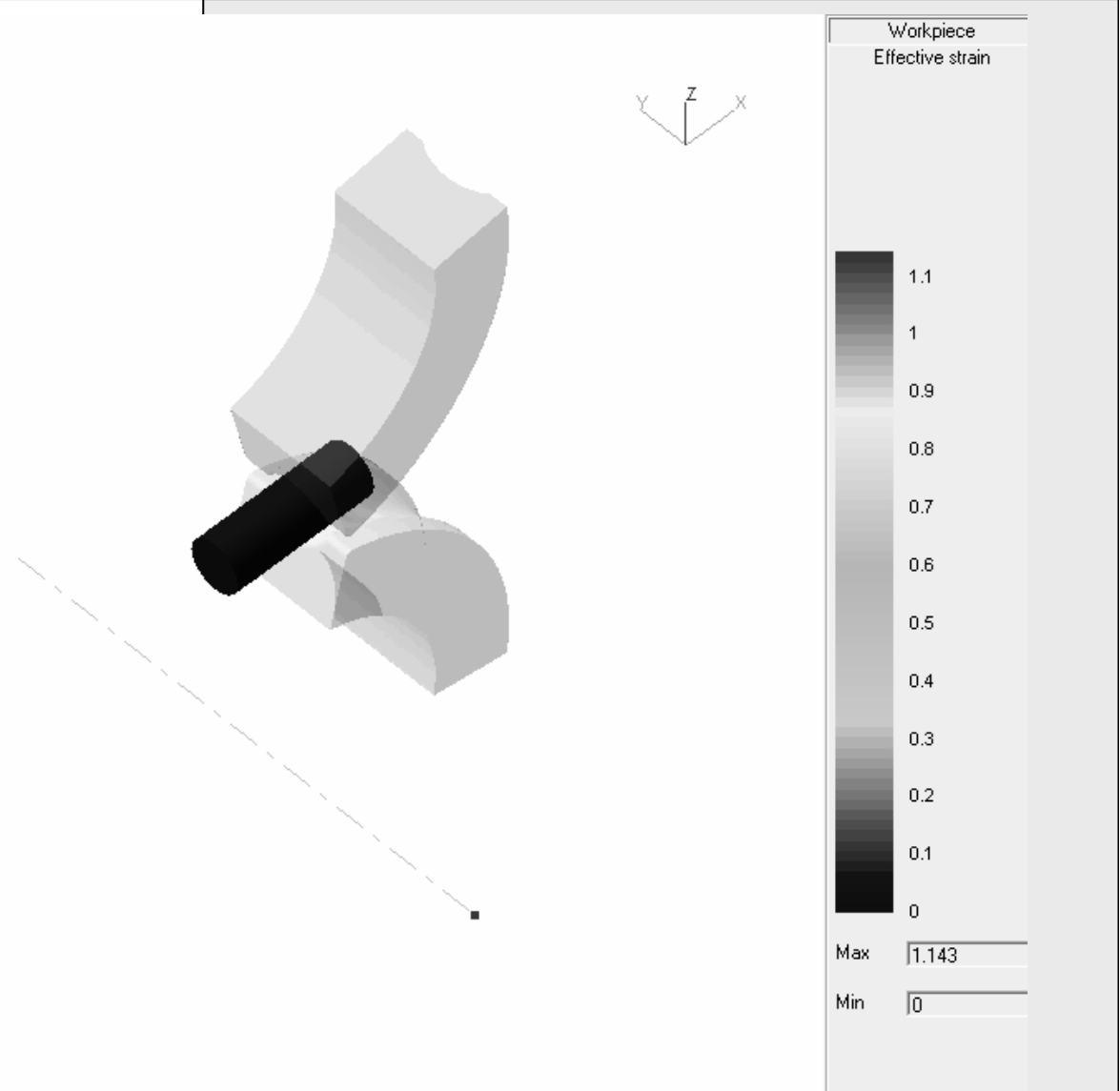
Simulation of reducer rolling

QForm v.4.1.3

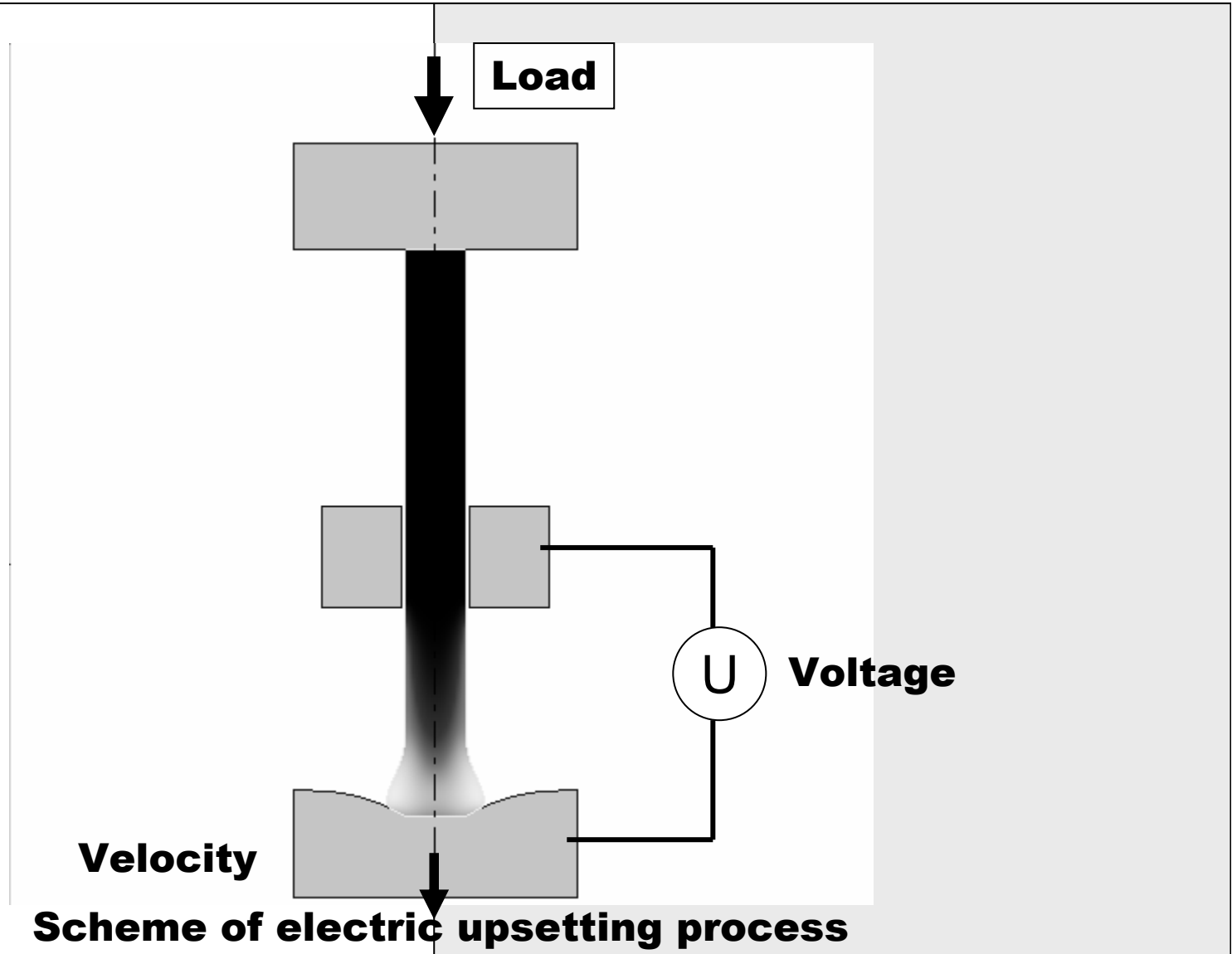
QuantorForm

ew10.qfm

Schritt 1



Simulation of electric upsetting



Specific data required for electric upsetting simulation

Electric upsetting

Process | Problem | Geometry | **Equipment** | Process parameters | Workpiece par

Forging equipment

Equipment and setting | Tool 1 | Tool 2 | Tool 3 | **Electric parameters** | Comment

Storage_EI L

Connection 1: Tool2
 Connection 2: Tool3
 Efficiency: 1
 Turns ration of transformer: 36.1

Number of points: 6

Time [s]	Current [A]
0	1150
20	1150

<< Back | Forward >> | Advanced... | Template... | OK | Cancel

Electric upsetting

Process | Problem | Geometry | **Equipment** | Process parameters | Workpiece par

Forging equipment

Equipment and setting | Tool 1 | Tool 2 | Tool 3 | **Electric parameters** | Comment

Storage_EI L

Tool type: Load
 Drive direction: Down
 Nominal velocity(m/s): 0.02

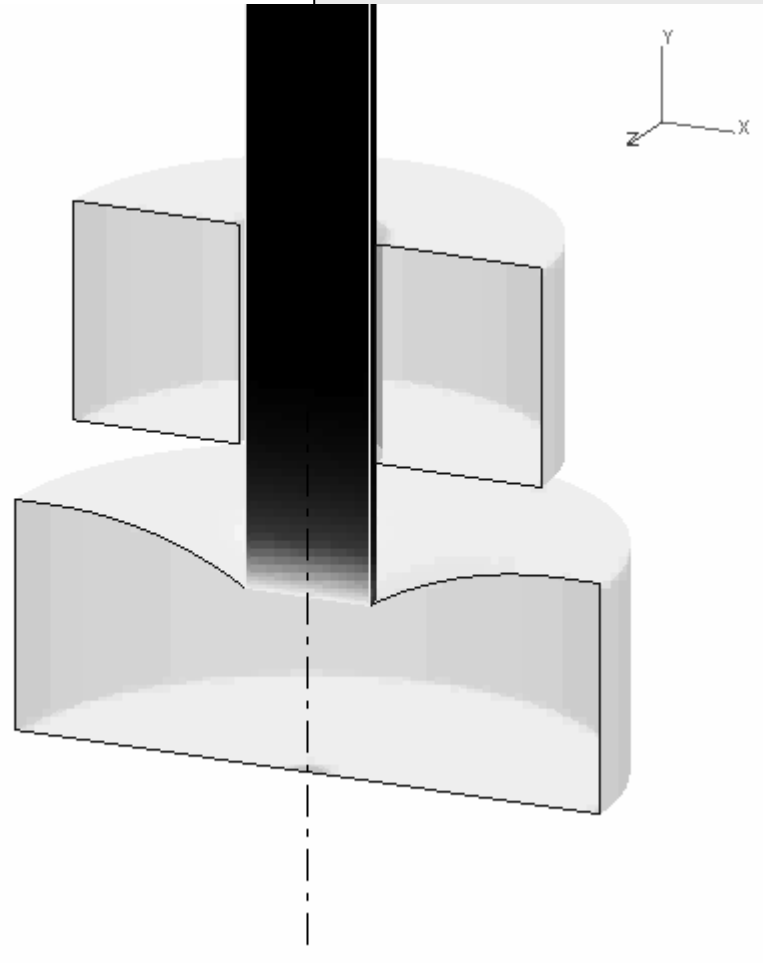
Number of points: 2

Time [s]	Load [MN]
0	0.26
70	0.26

<< Back | Forward >> | Advanced... | Template... | OK | Cancel

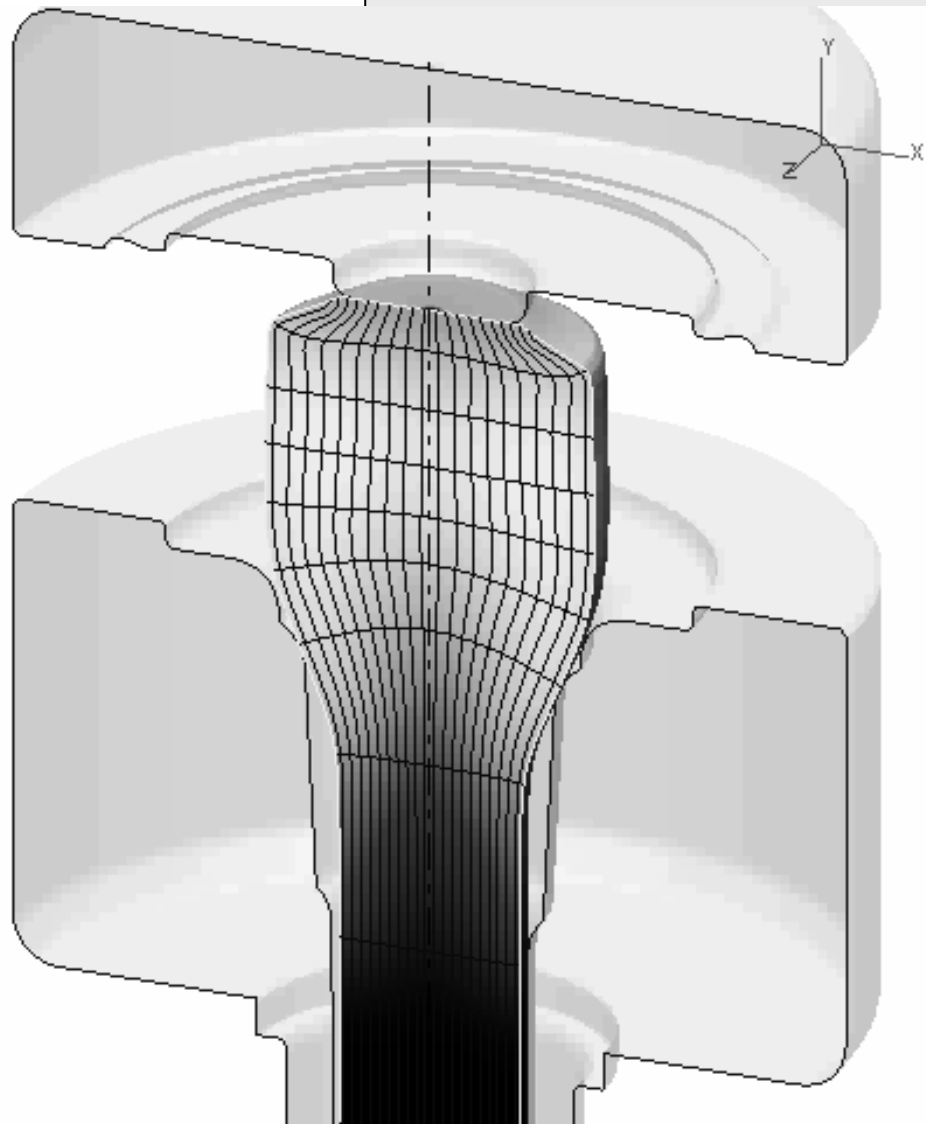
Electric upsetting simulation

**Electric
Upsetting**



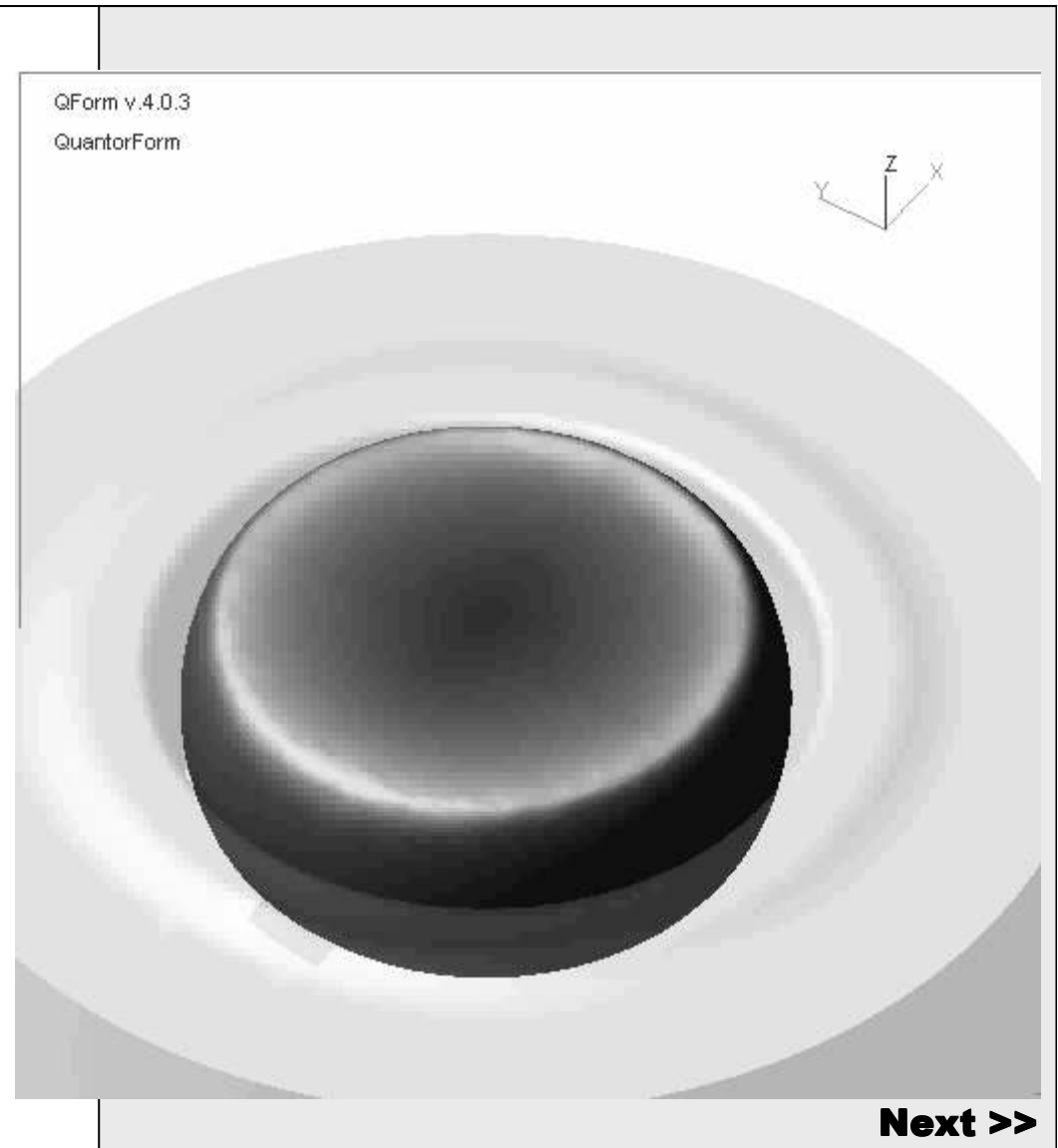
Forging of the shaft in a screw press

**Closed die
Forging**



Intermediate operations to be simulated:

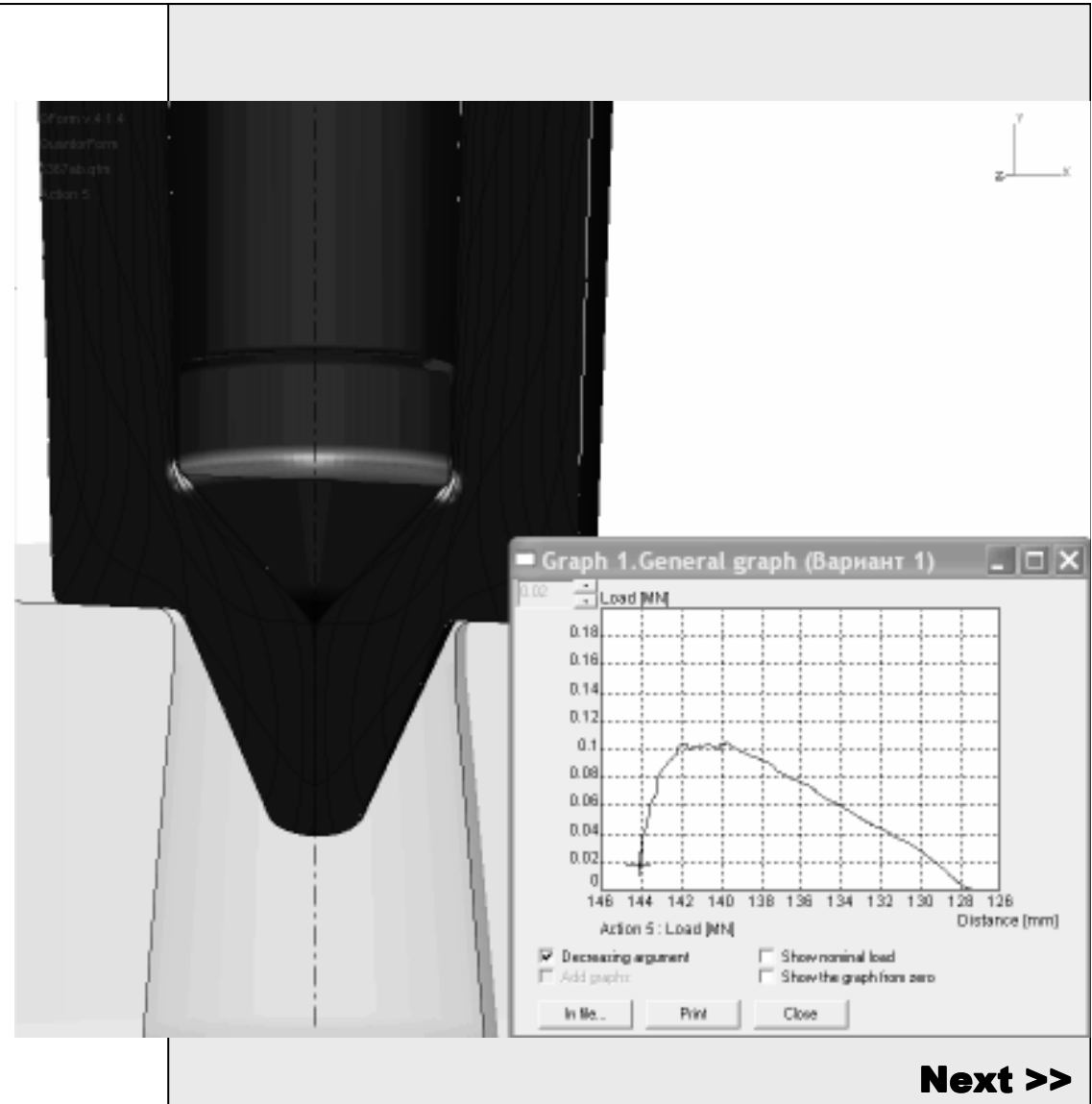
- **Piercing the holes and trimming the flash by clipping contour**



Intermediate operations to be simulated:

- **Piercing the hole by the punch**

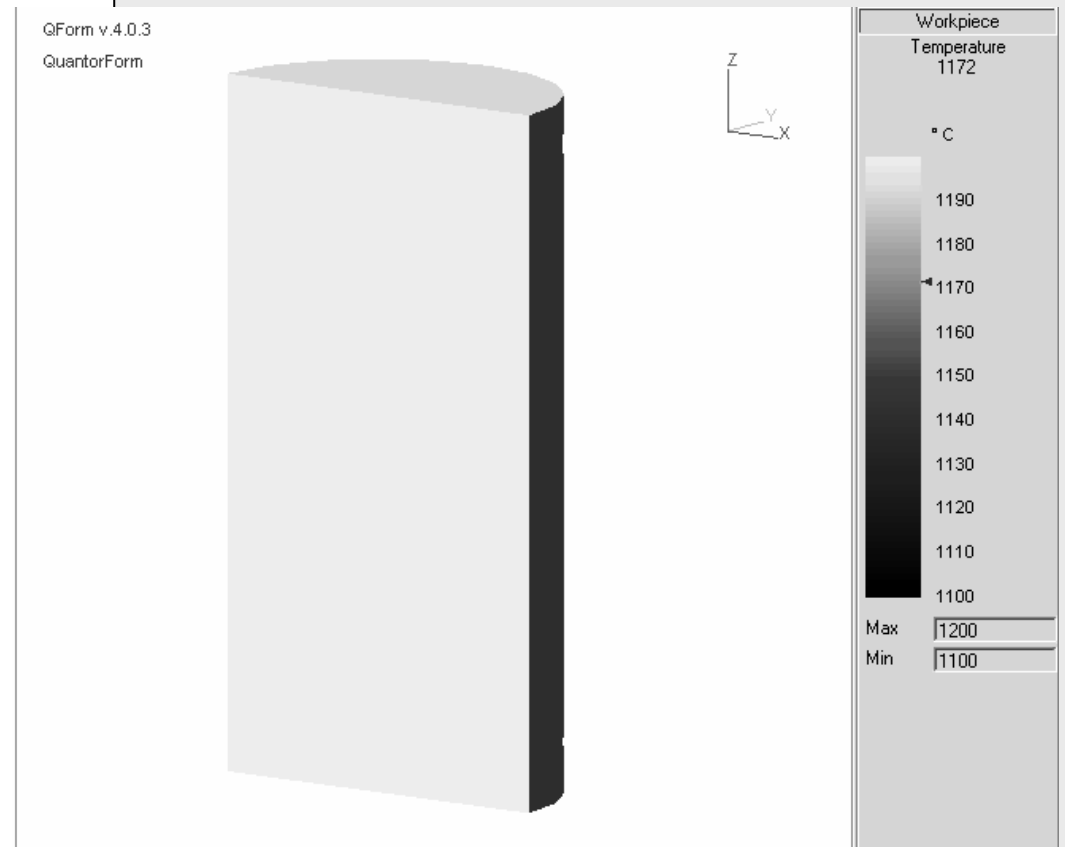
**Control of the dimensions
after piercing**



Next >>

Intermediate operations to be simulated:

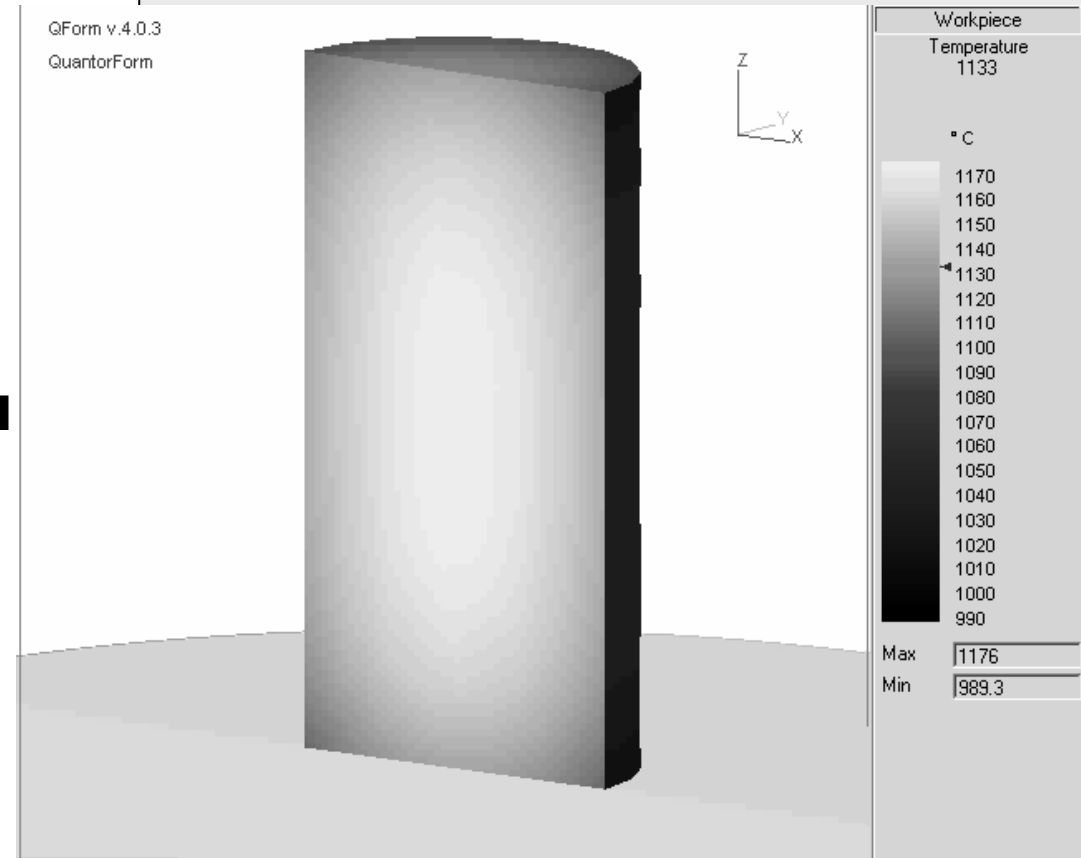
- **Piercing the holes and trimming the flash**
- **Cooling in air**
- **Cooling in tool**
- **Rotation and gravitational positioning**



Next >>

Intermediate operations to be simulated:

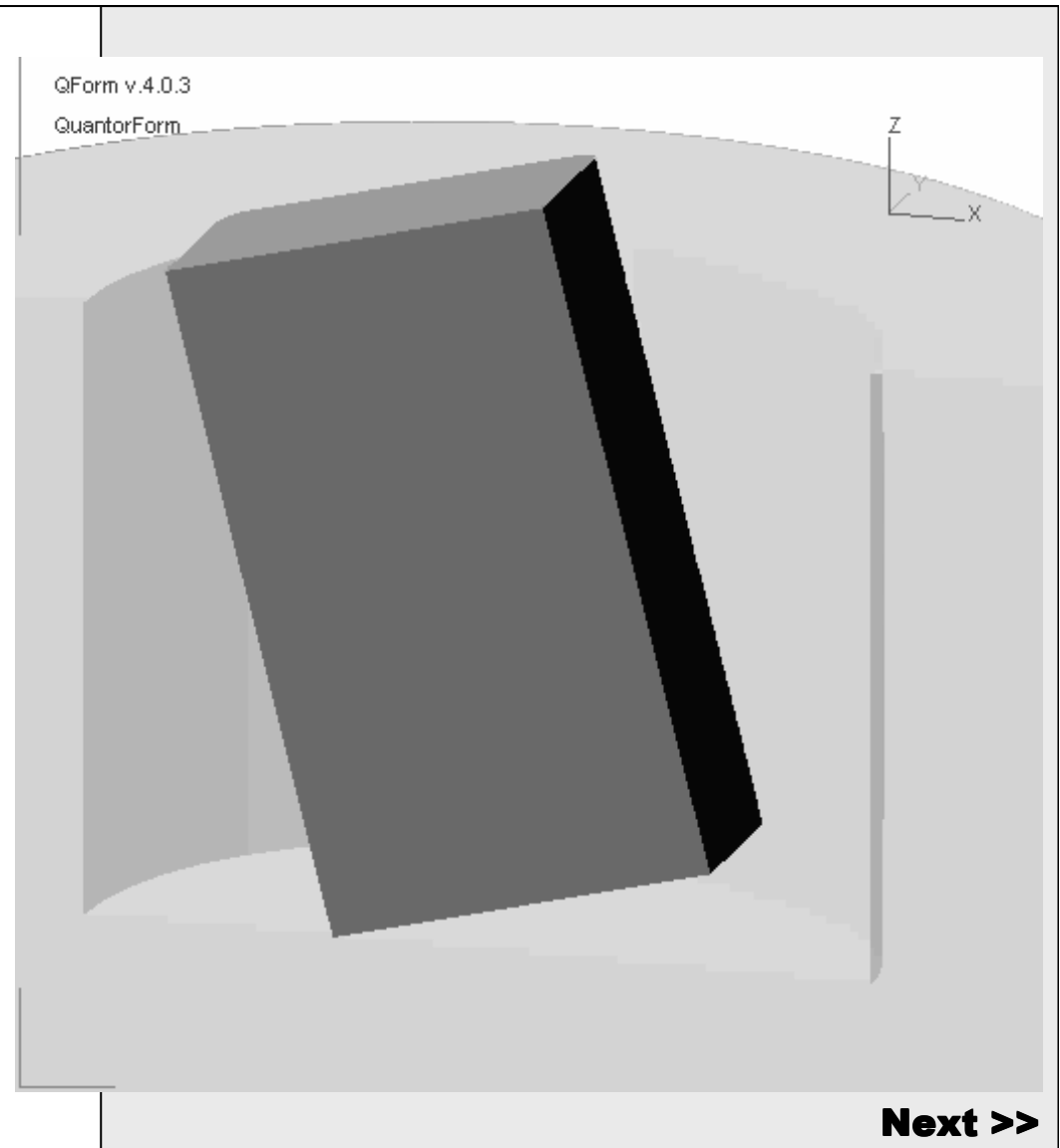
- **Piercing the holes and trimming the flash**
- **Cooling in air**
- **Cooling in tool**
- **Rotation and gravitational positioning**



Next >>

Intermediate operations to be simulated:

- **Piercing the holes and trimming the flash**
- **Cooling in air**
- **Cooling in tool**
- **Rotation and gravitational positioning**



**What benefits do
we get from
simulation?**

Solving technological problems

- 1. Die filling analysis**
- 2. Saving the material**
- 3. Prediction of material flow defects**
- 4. 3-tools-simulation**
- 5. Simulation of multi-stroke forging**
- 6. Positioning and gravity**

Next >>

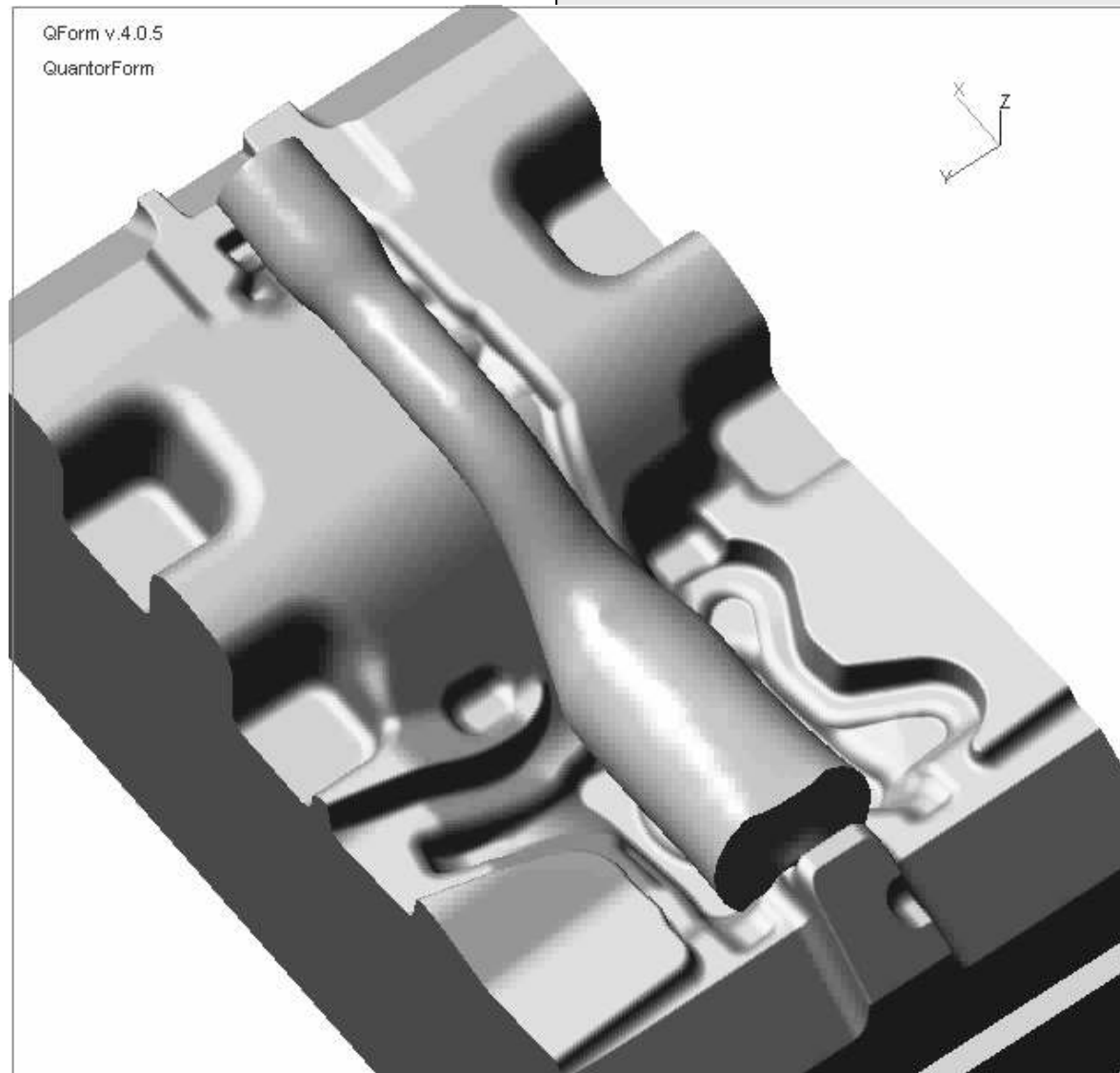
Forging simulation (the die filling is shown)

QForm v.4.0.1.0
QuantorForm



**Making 5 pieces of
equal high quality at a
time**

Forging simulation (the die filling is shown)

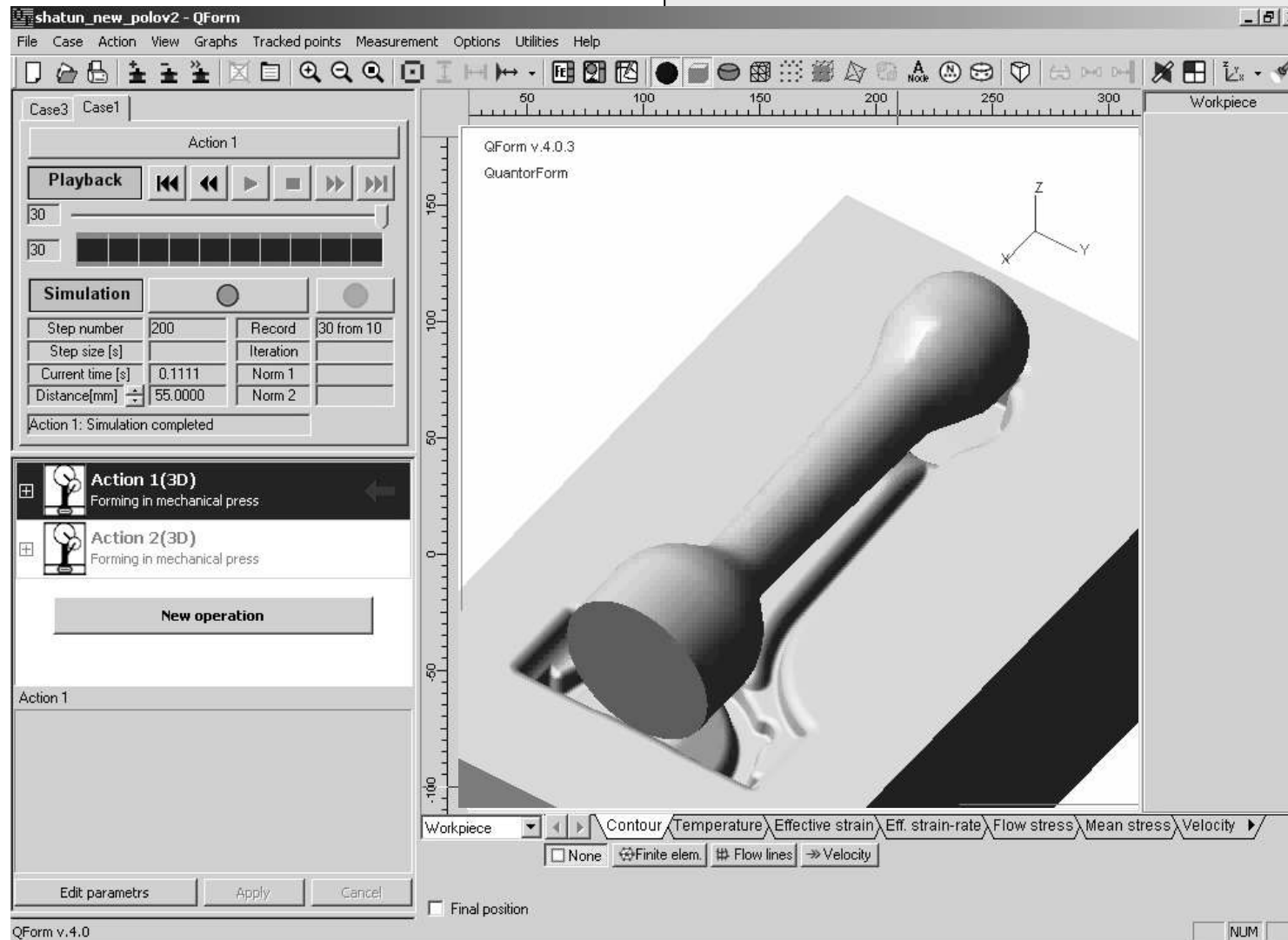


Saving the material

- 1. Filling the dies at lower load**
- 2. Saving the material**
- 3. Prediction of material flow defects**
- 4. 3-tools-simulation**
- 5. Simulation of multi-stroke forging**
- 6. Positioning and gravity**

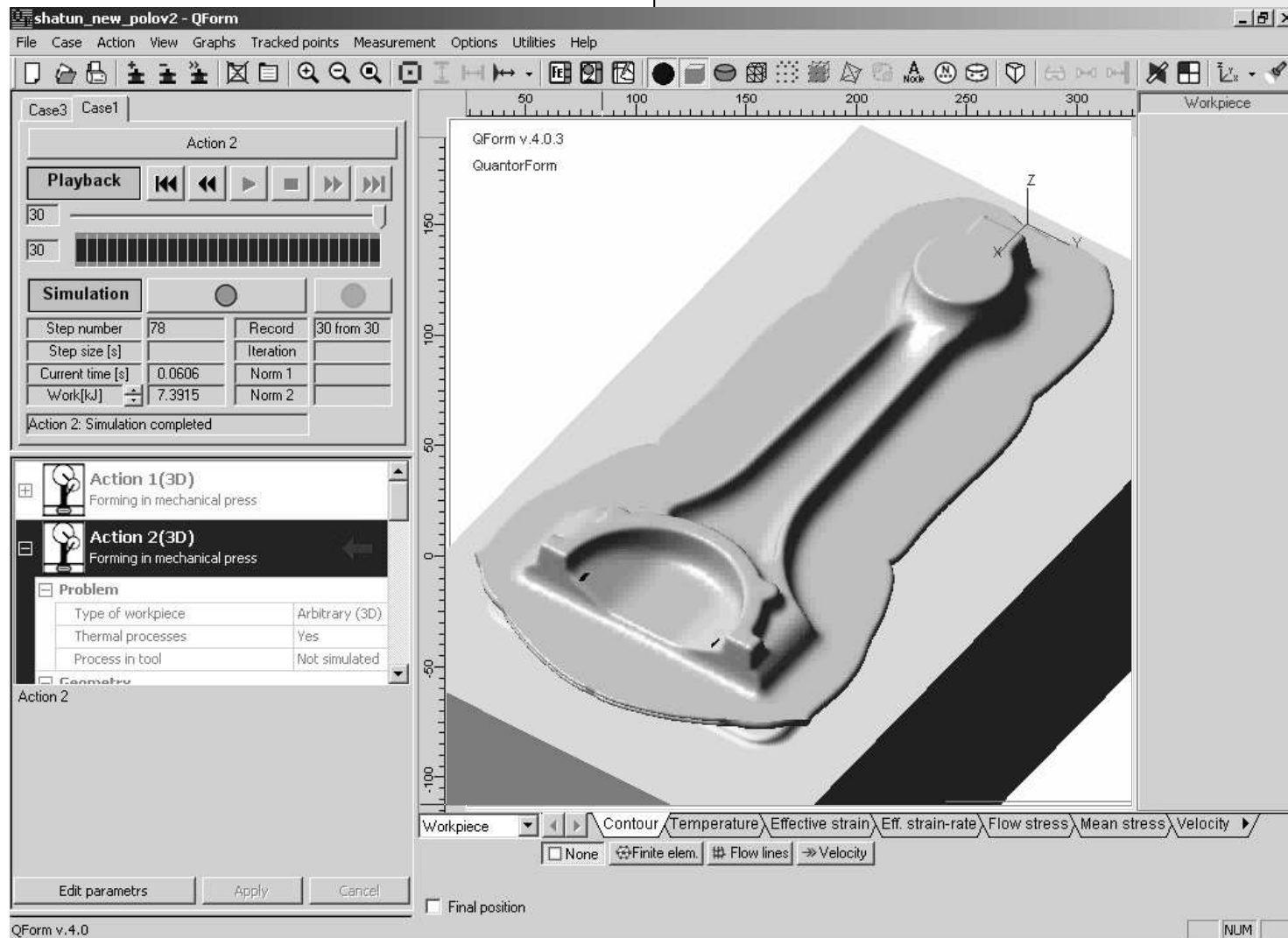
Next >>

Initial preform shape



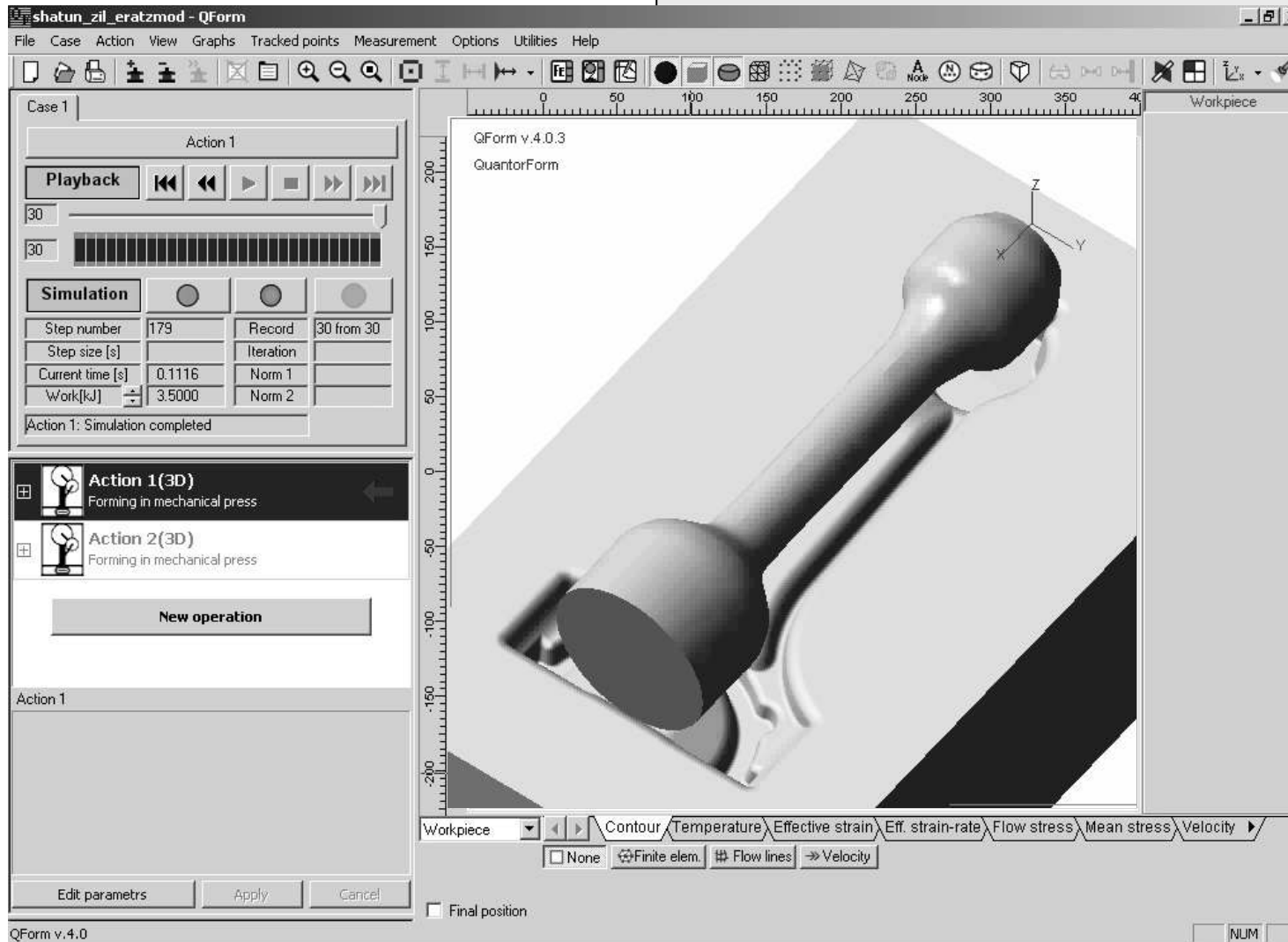
Next >>

Initial preform shape

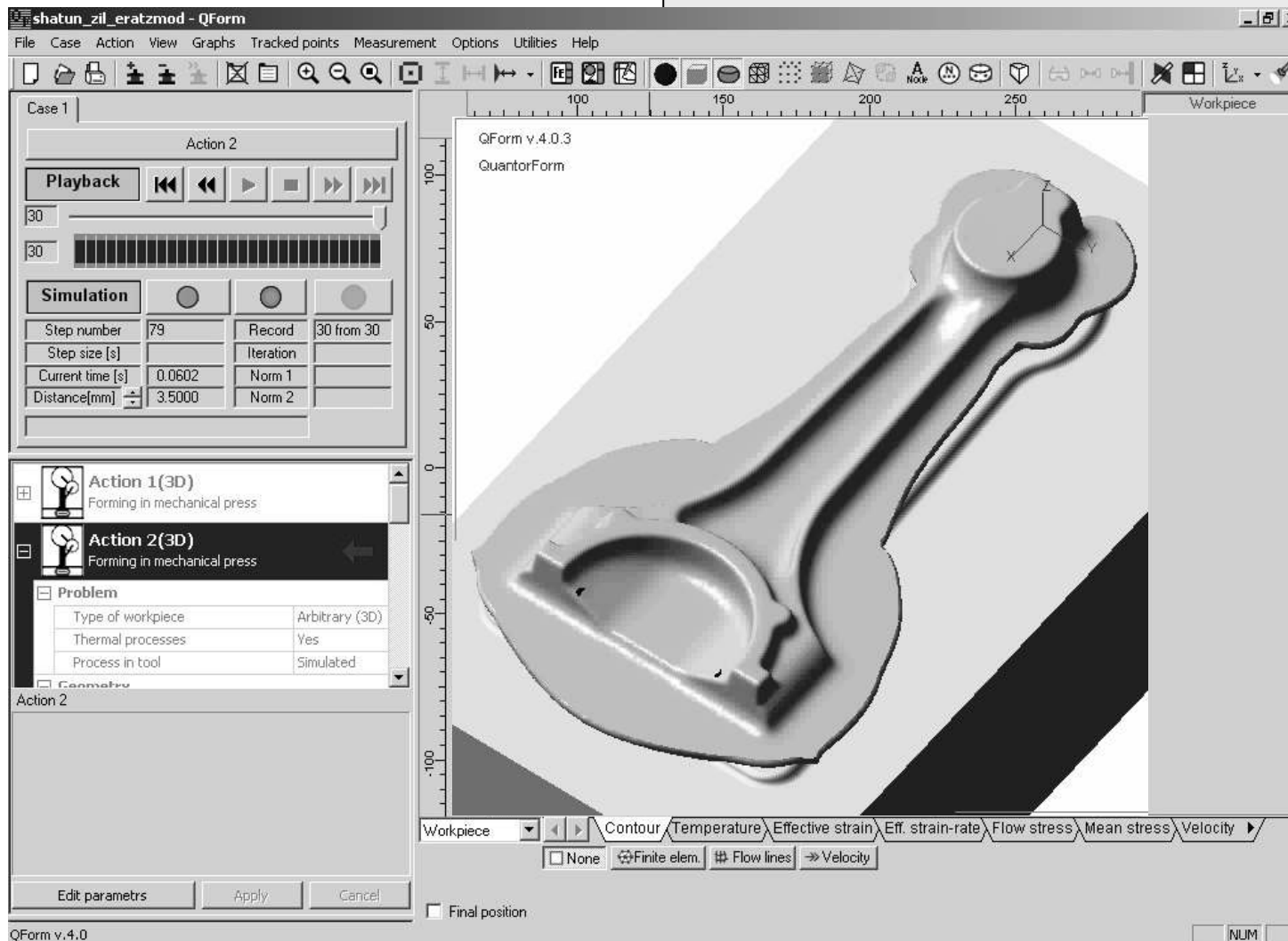


Next >>

Optimized preform shape



Optimized preform shape



Next >>

Material saving: billet weight reduced by 12%



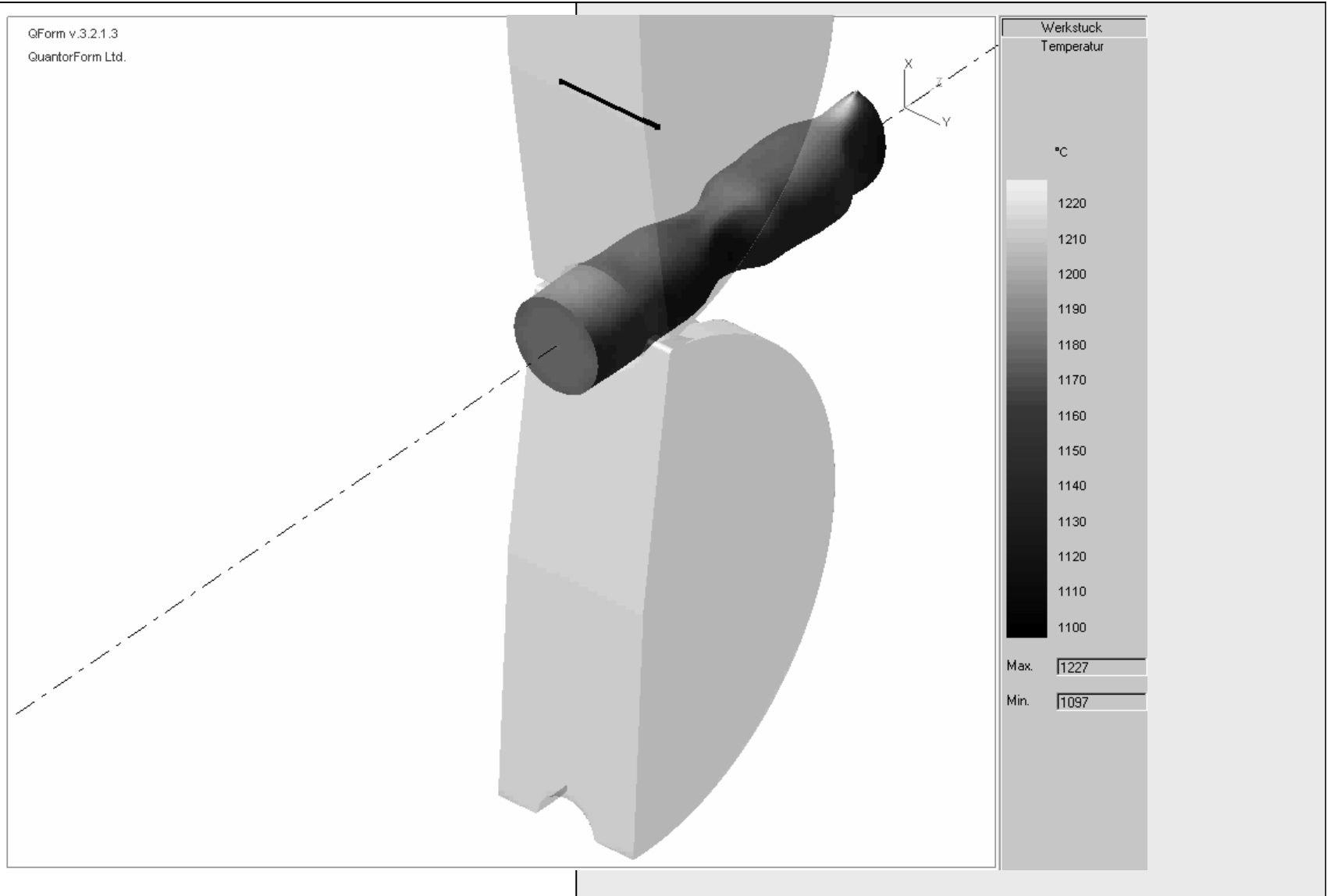
Initial preform shape



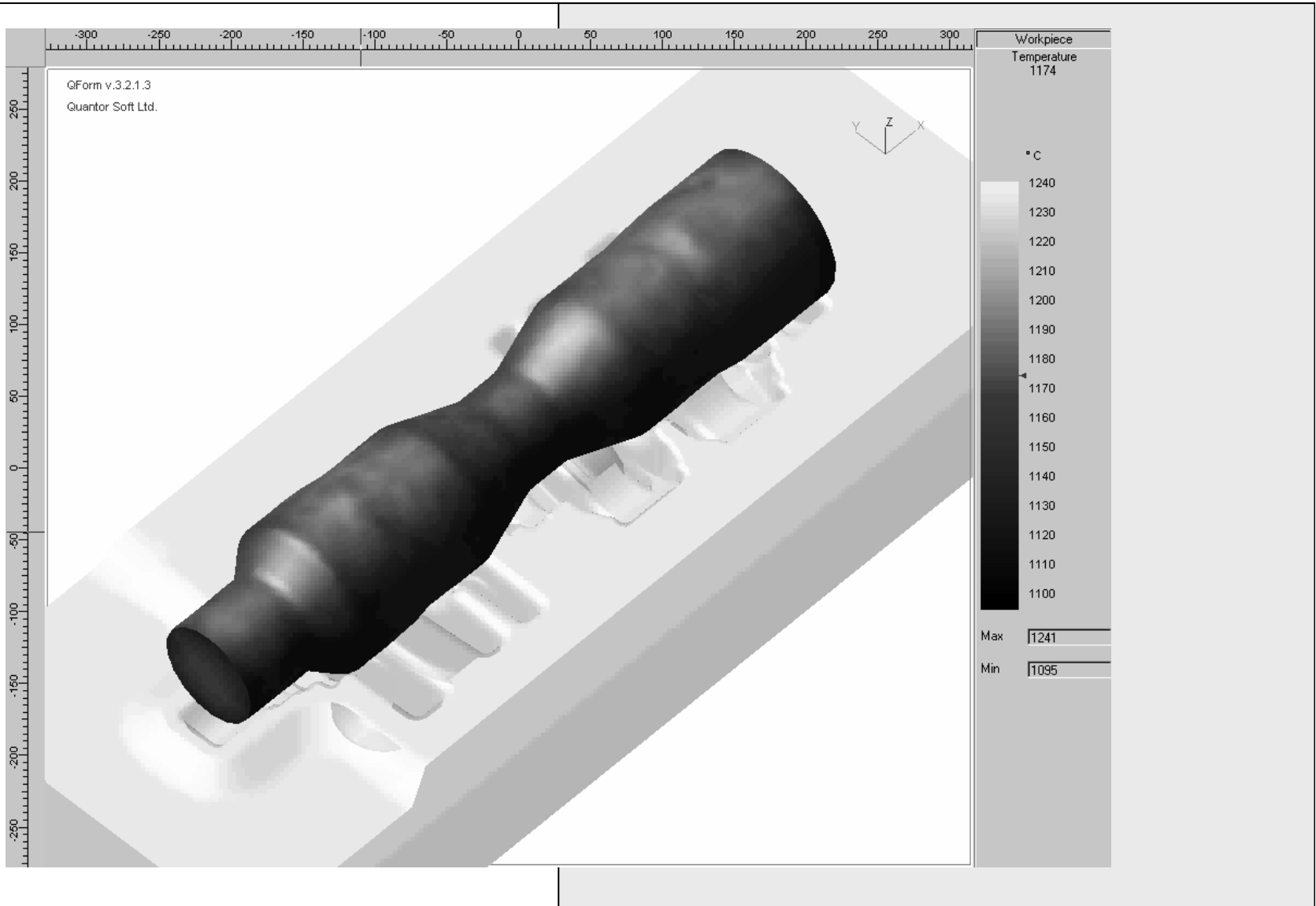
Optimized preform shape



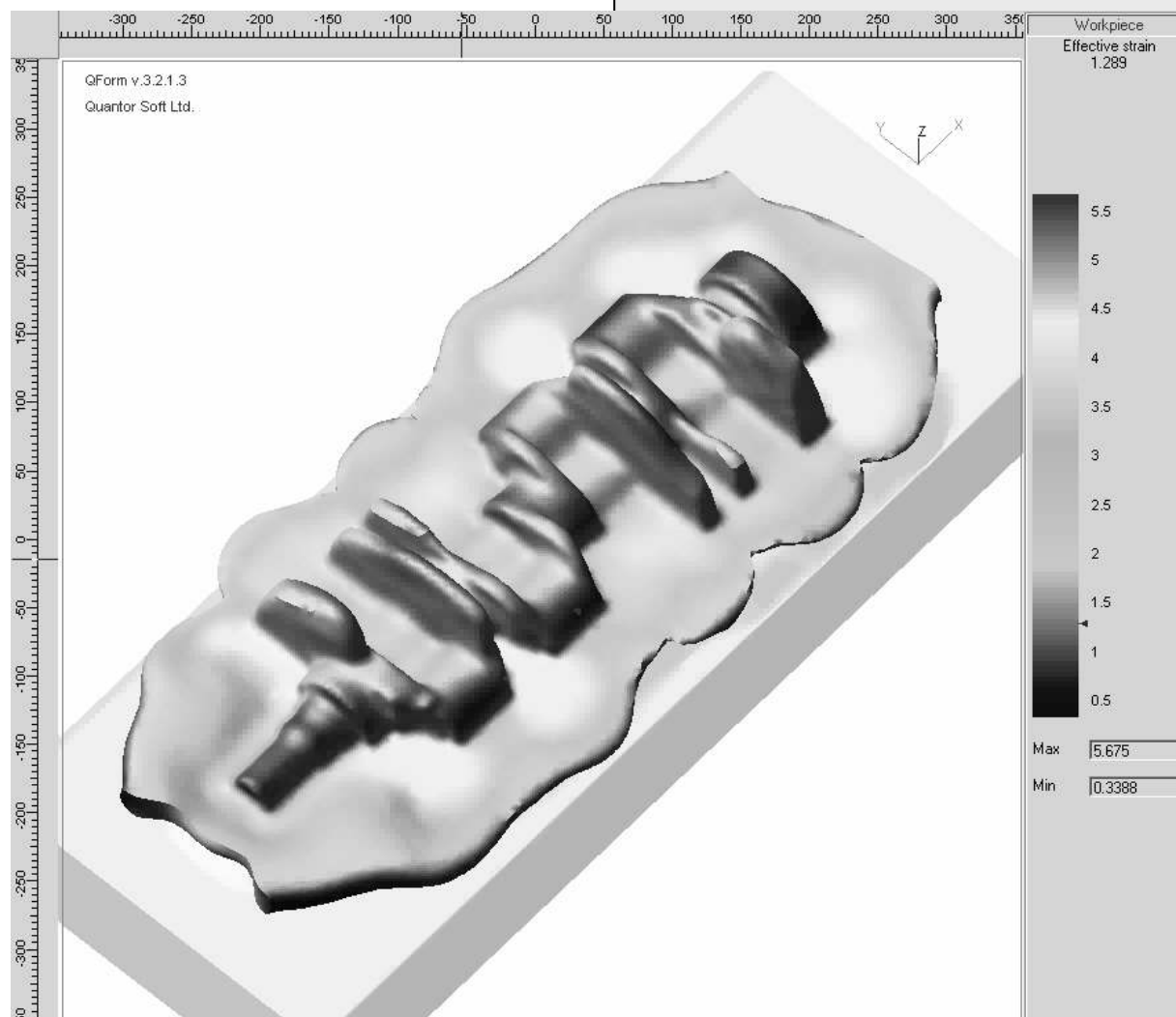
Distance 35 mm in front of center line in 3rd pass



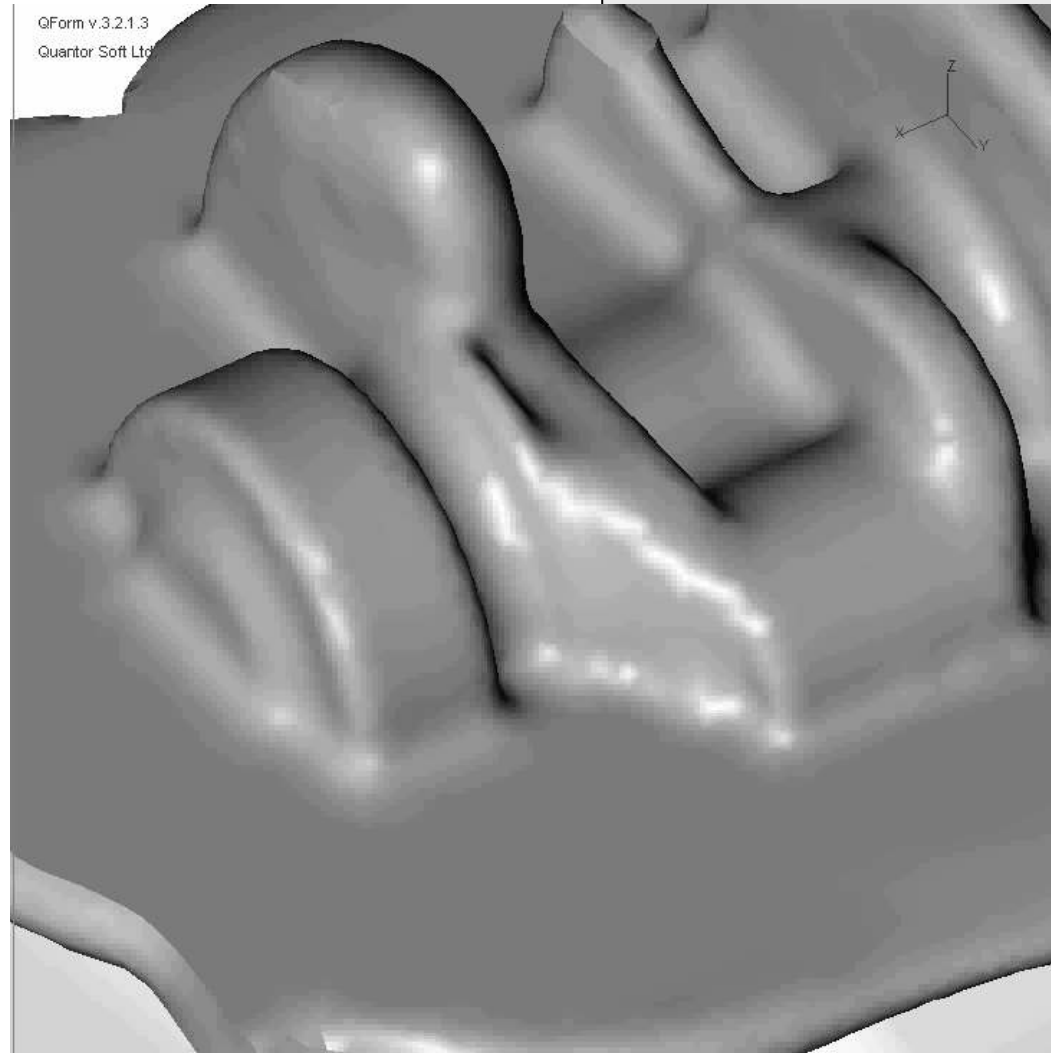
Crankshaft forging simulation (the first blow, temperature shown)




The second forging blow (strain distribution)



The lap formation in second forging blow

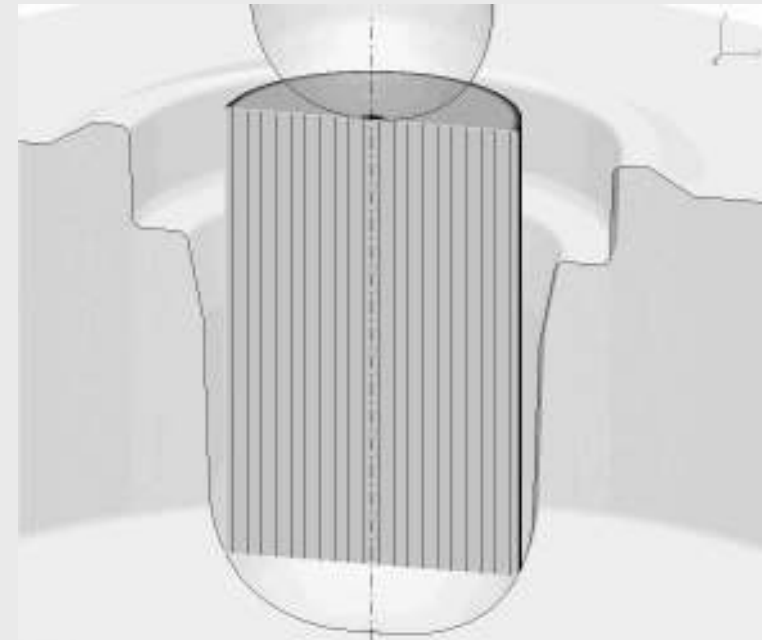
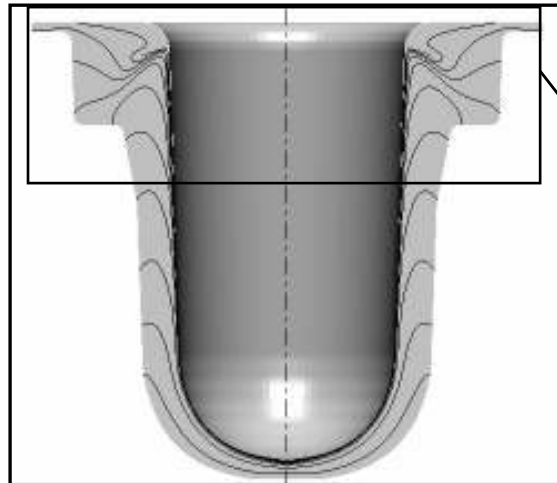


Part 2. Solving technological problems using QFORM3D

- 1. Filling the dies at lower load**
 - 2. Saving the material**
 - 3. Prediction of material flow defects**
 - 4. 3-tools-simulation**
 - 5. Simulation of multi-stroke forging**
 - 6. Positioning and gravity**
- 

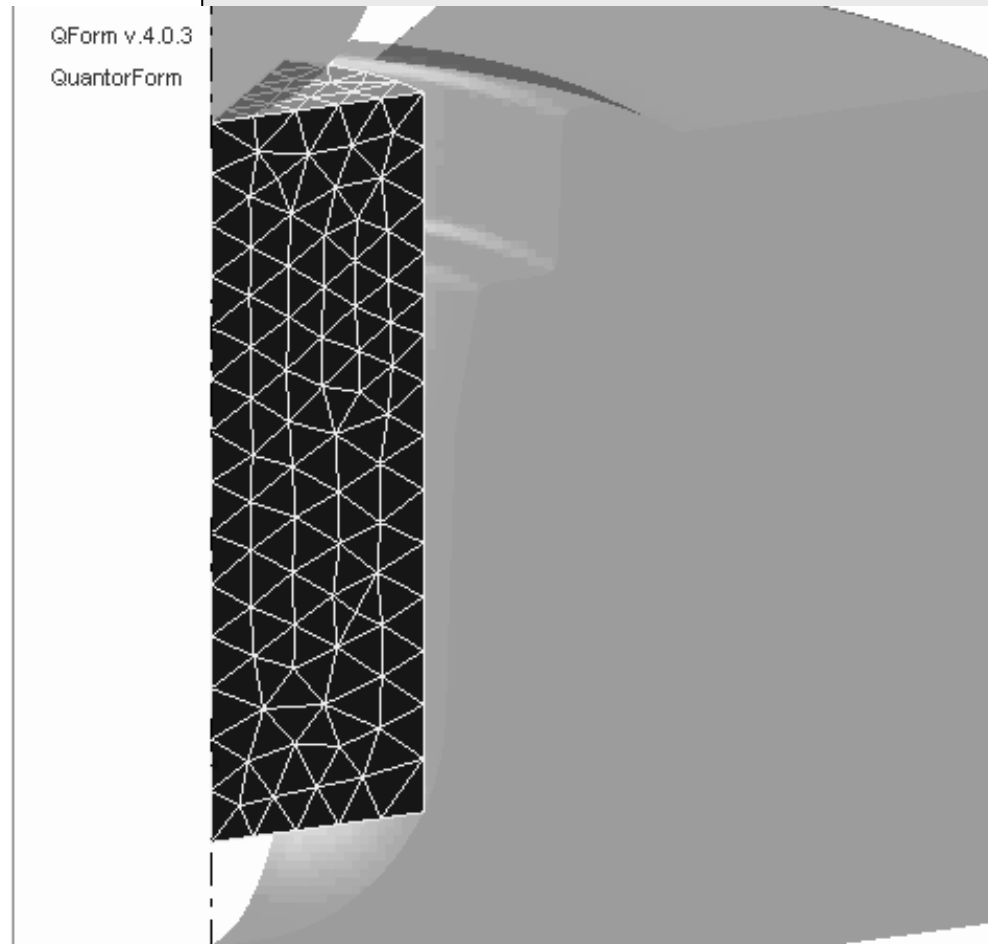
Prediction of material flow defects

Identification of the laps in simulation in QForm2D

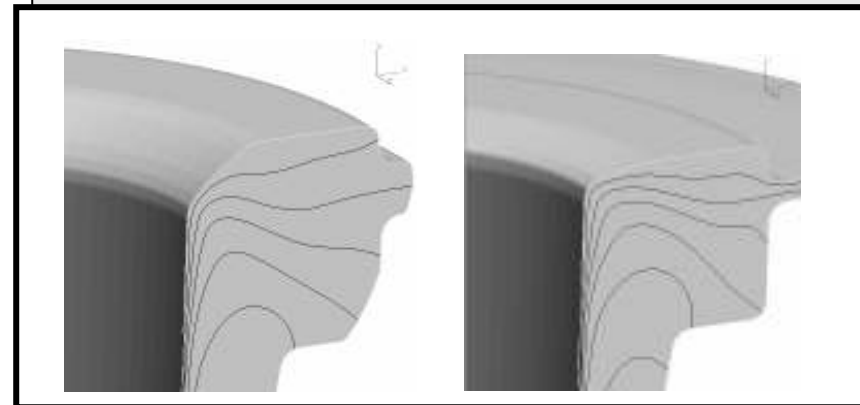
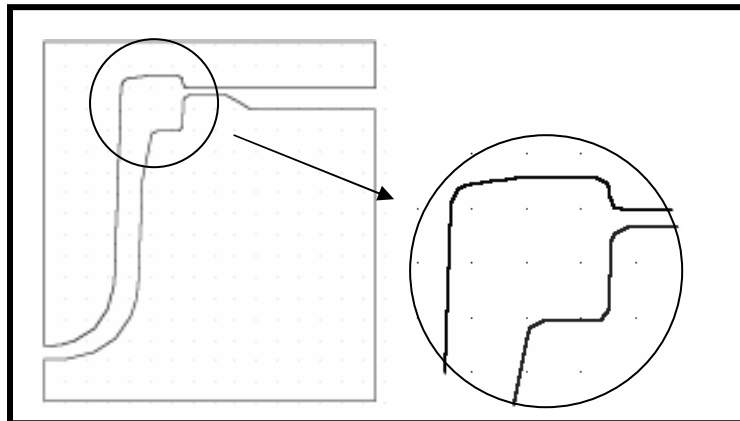
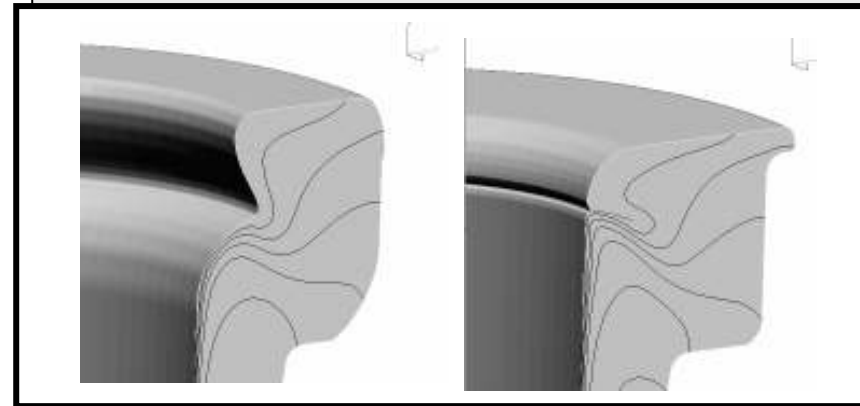
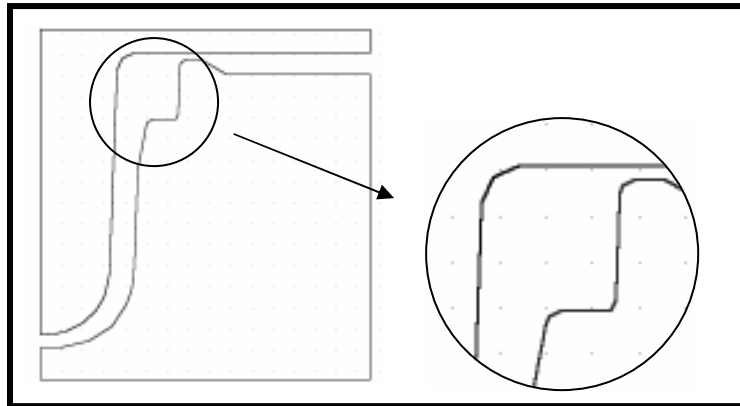


Identification of the laps in simulation in QForm3D

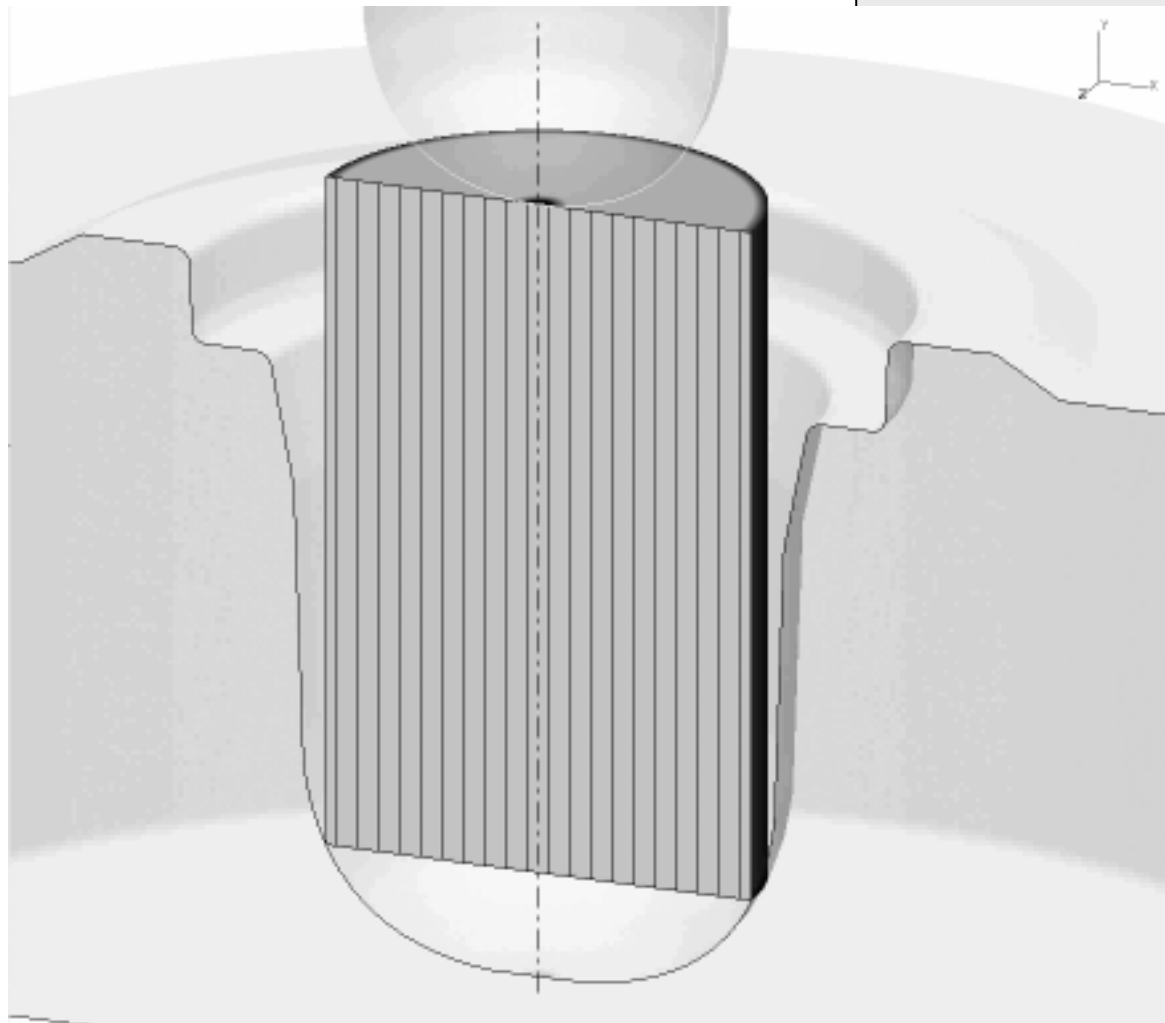
The lap



Finding the solution by means of simulation

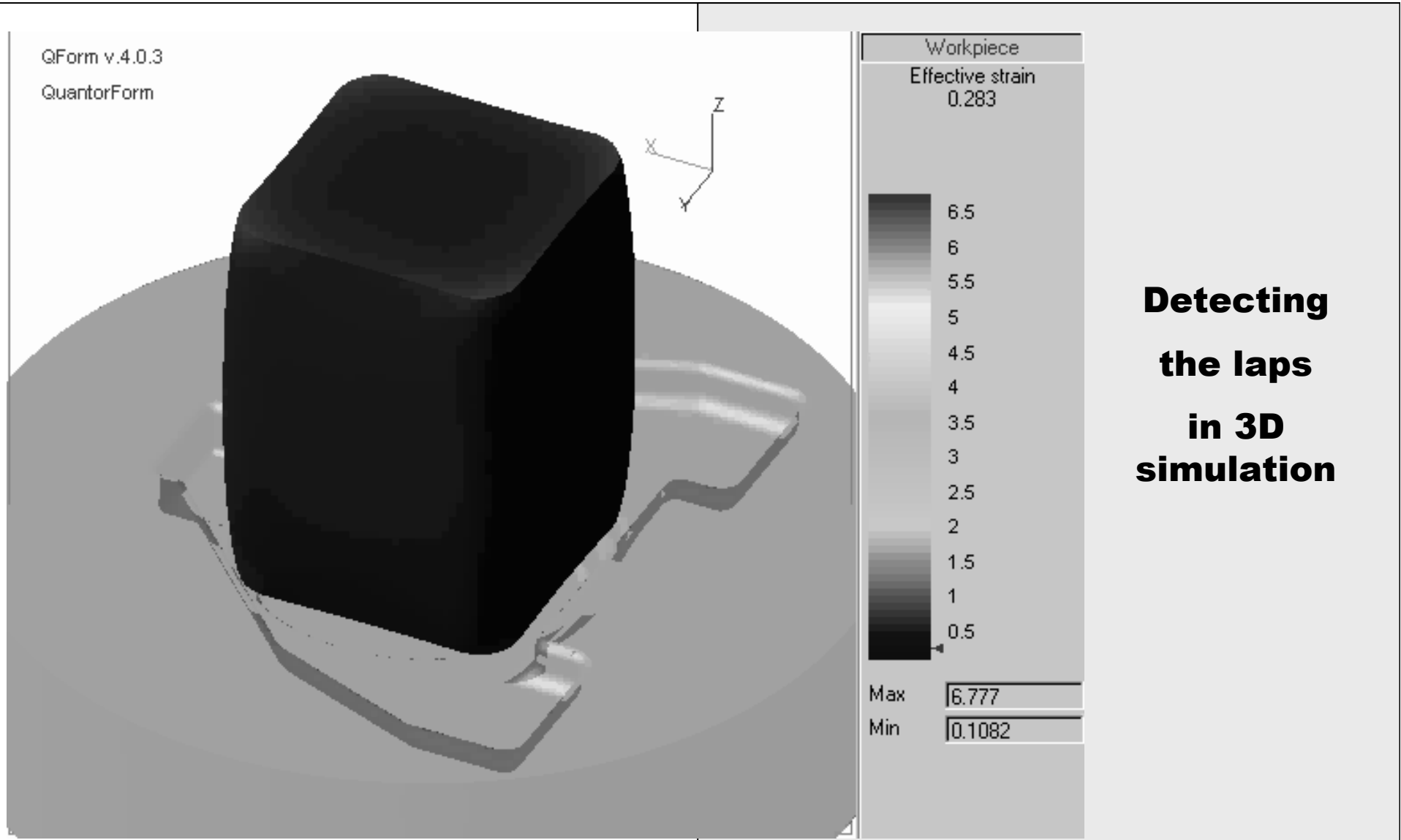


Finding the solution by means of simulation

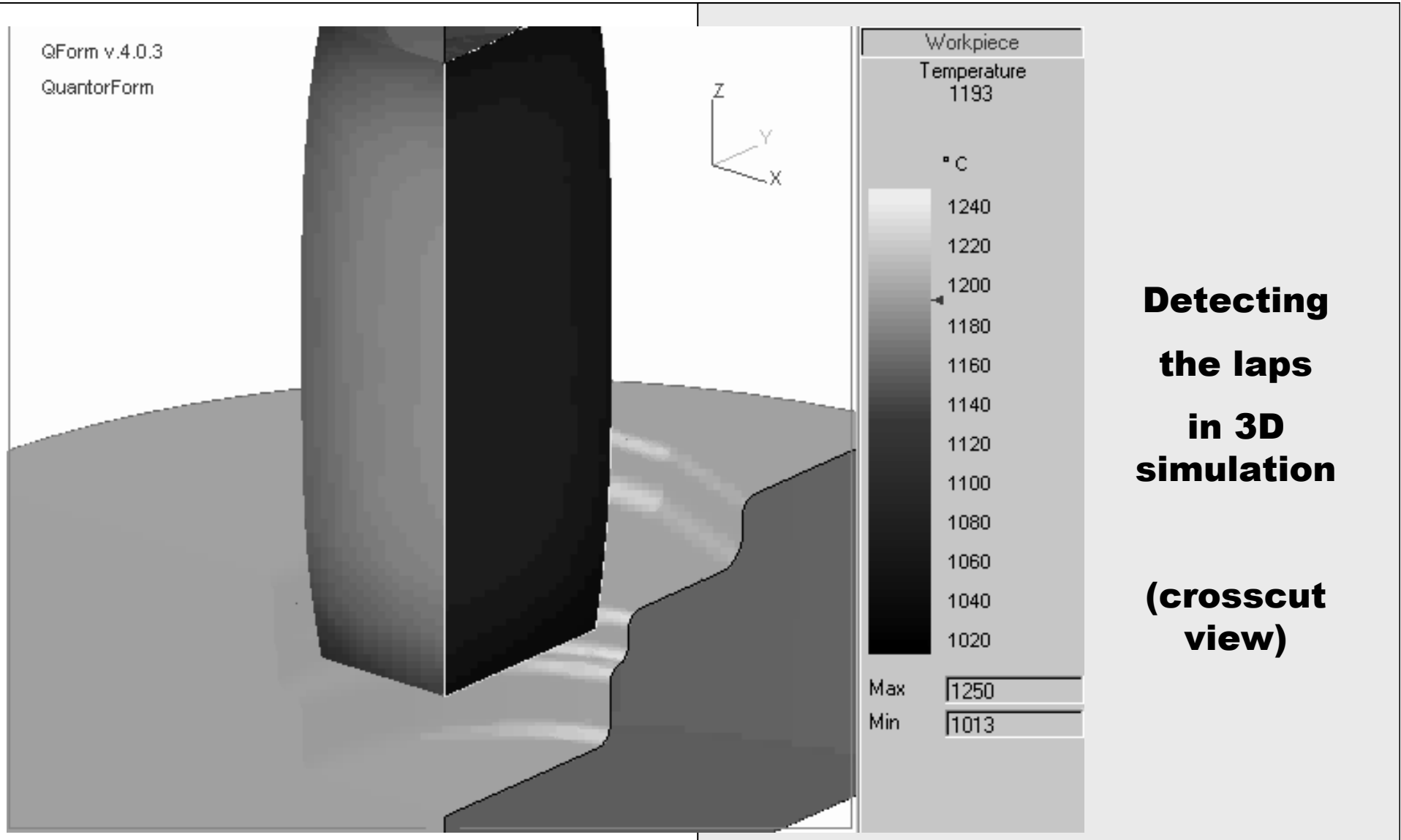


No lap after the die modification

Identification of the laps in simulation

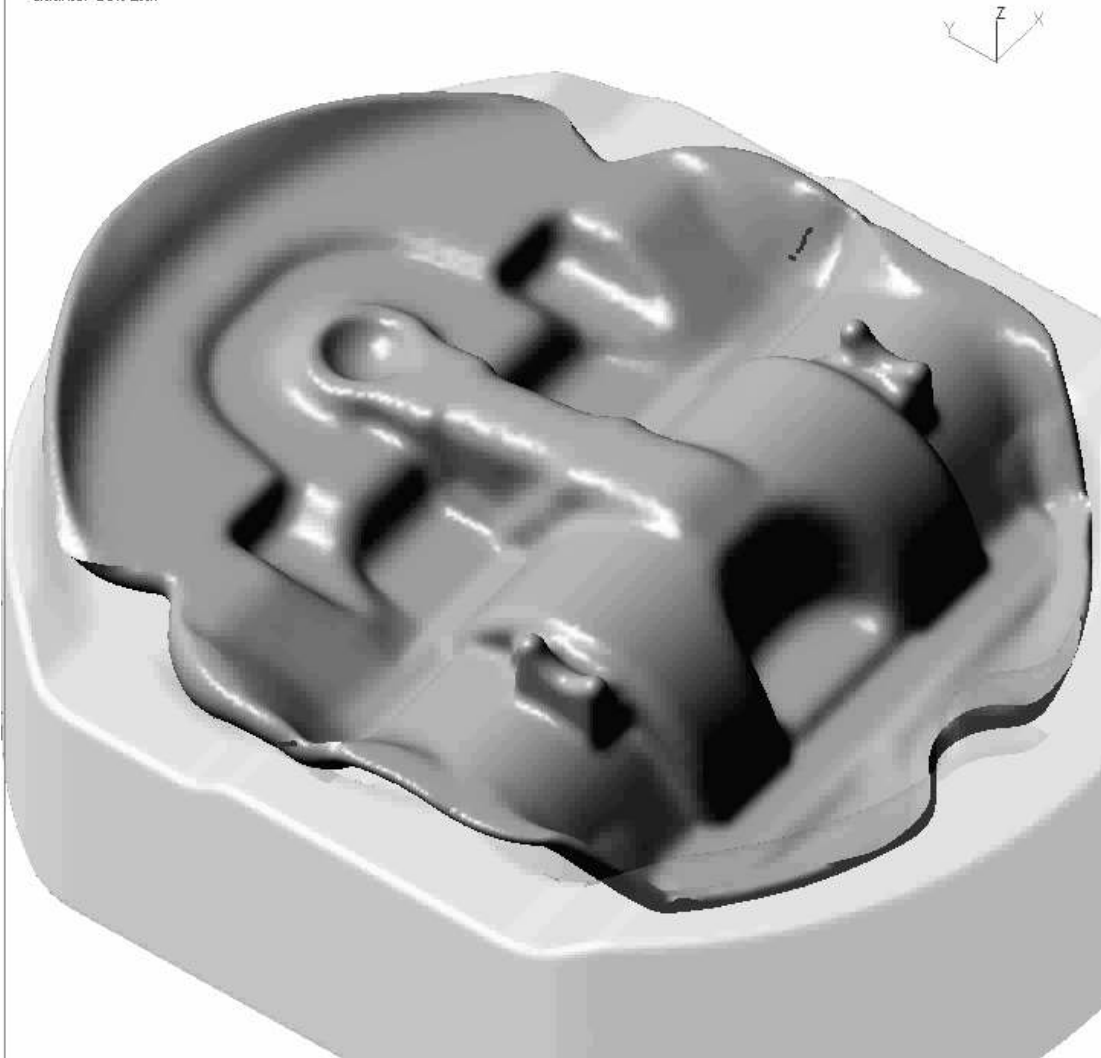


Identification of the laps in simulation



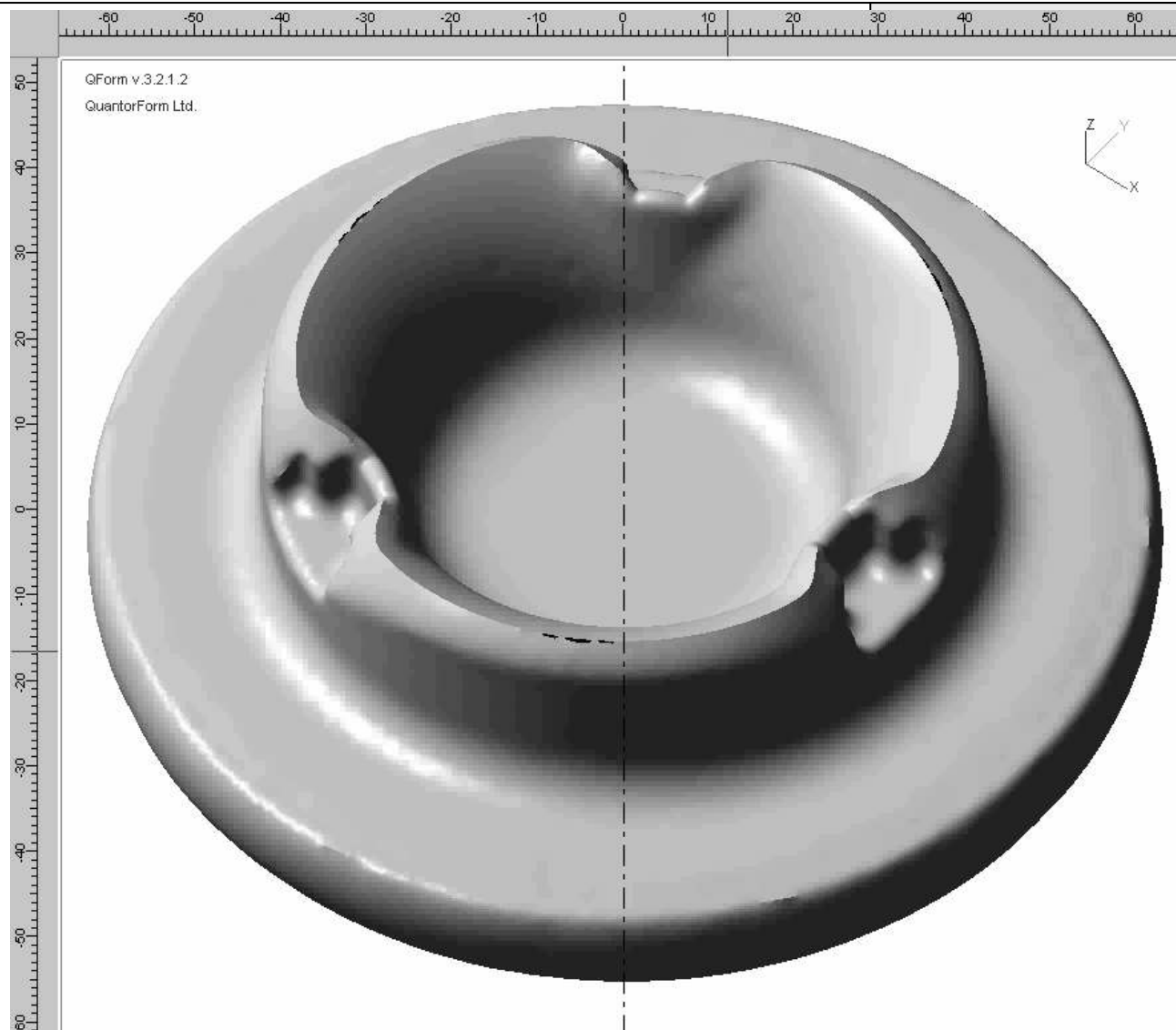
Identification of the laps in simulation

QForm v.3.2.1.3
Quantor Soft Ltd.



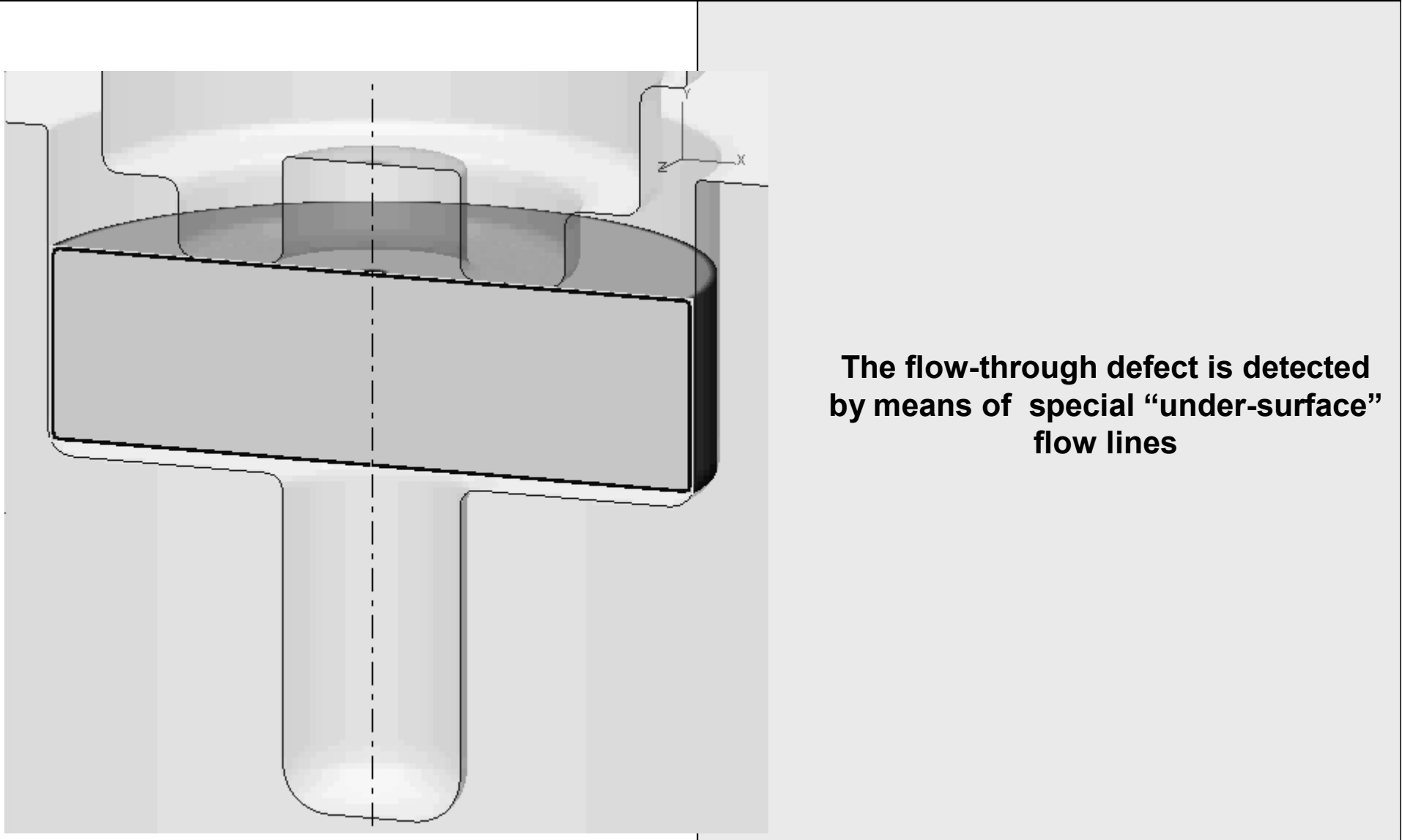
**Precise shape
prediction and location
of possible defects**

Identification of the laps in simulation

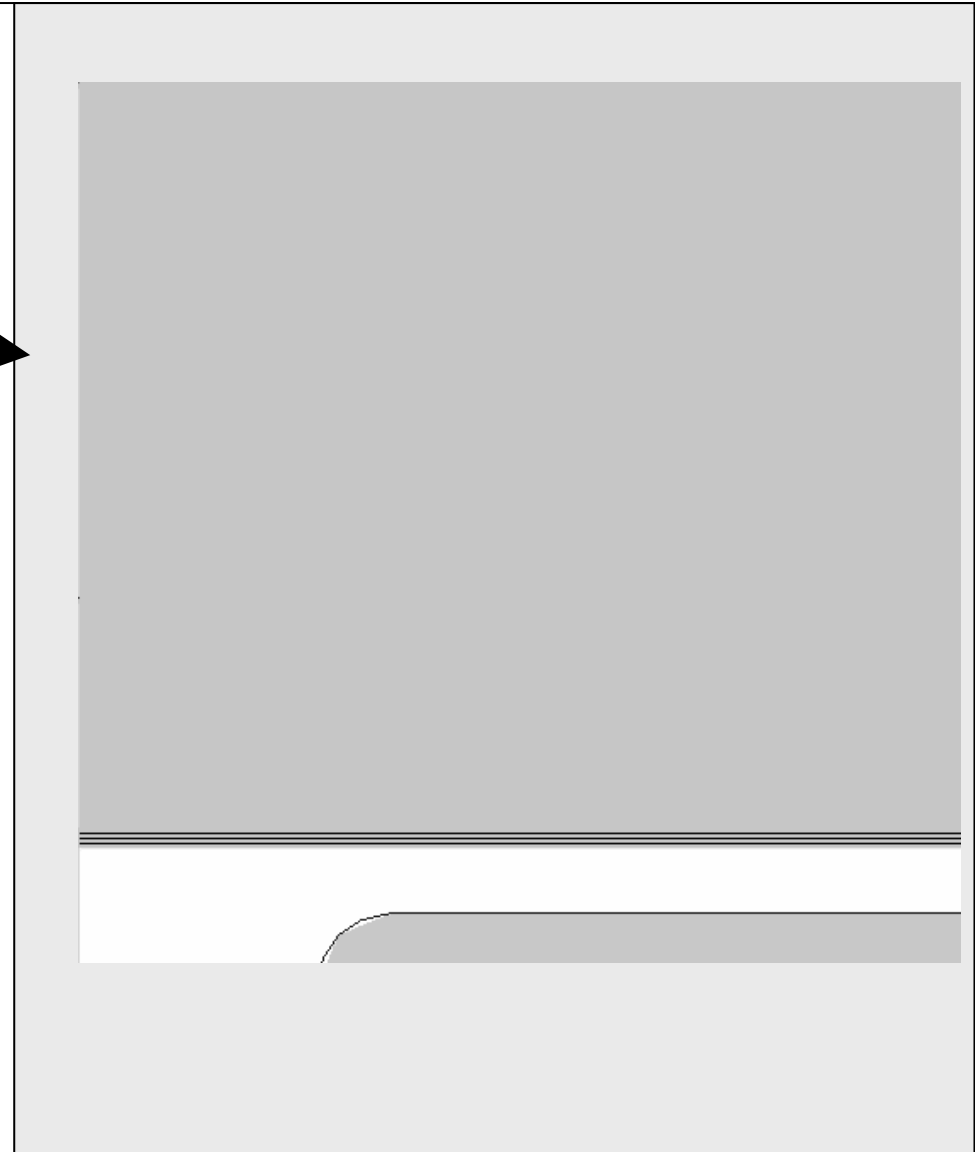
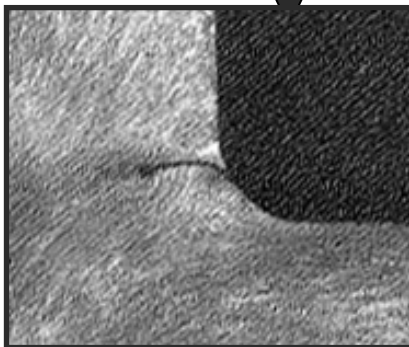
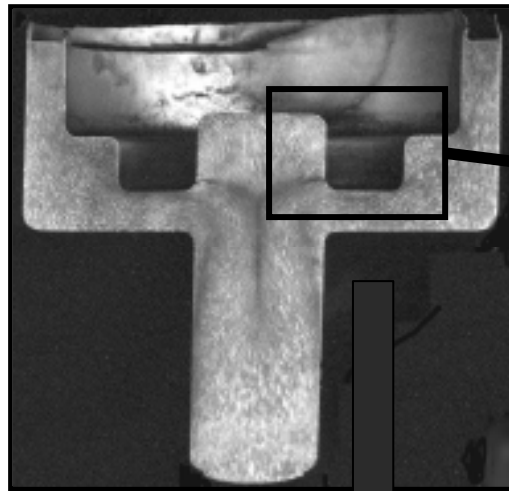


The simulation shows exact location of the defects

Prediction of the flow-through defect by means of simulation in QForm2D

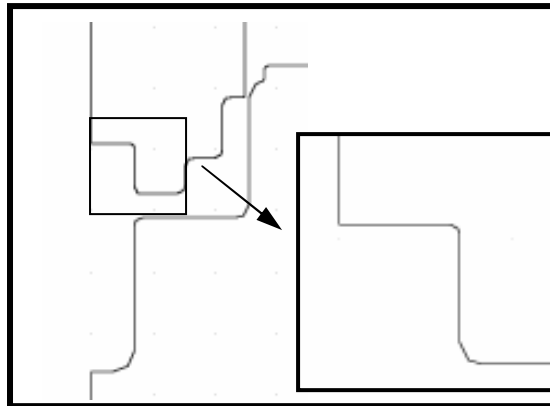


Prediction of the flow-through defect by means of simulation in QForm2D

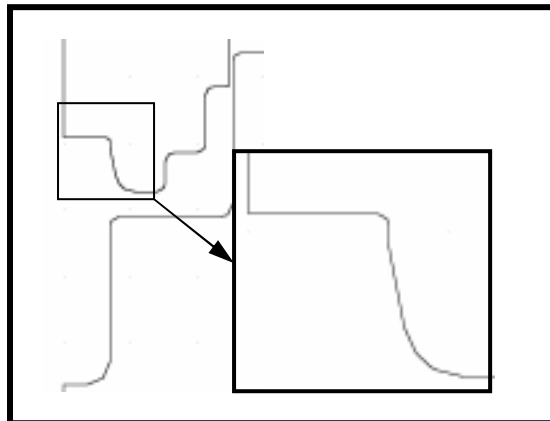


Prediction of the flow-through defect by means of simulation in QForm2D

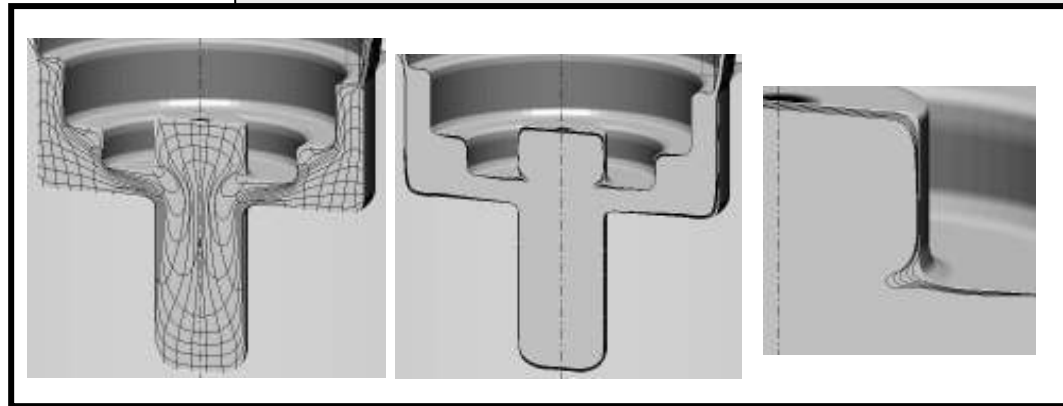
Initial die design



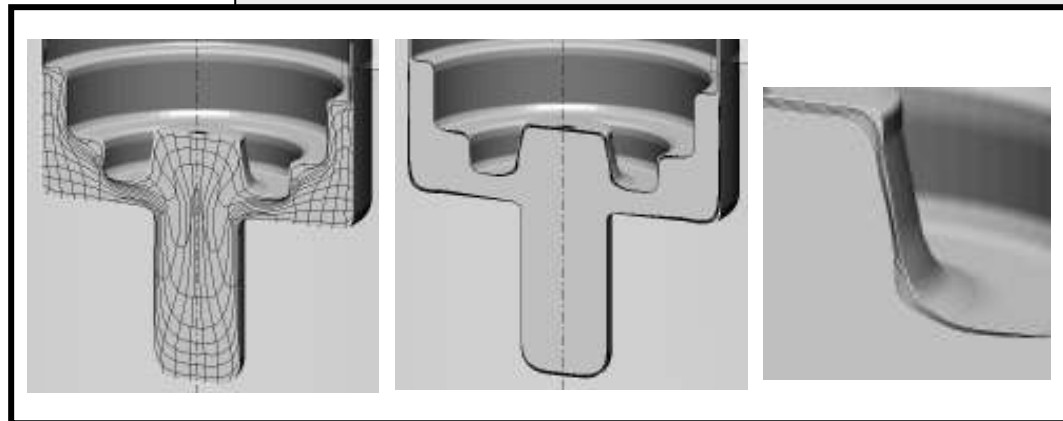
Modified die design



Flow-through defect



The forged part without flow-through defect



Prediction of the flow-through defect by means of simulation in 3D

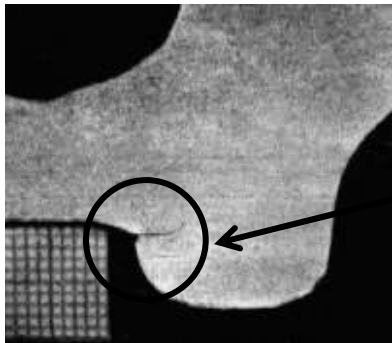
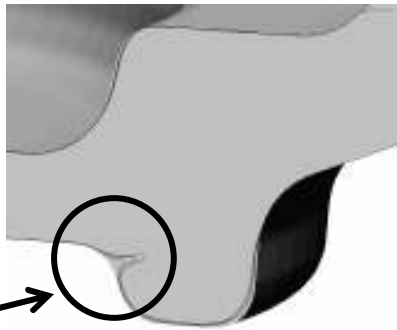
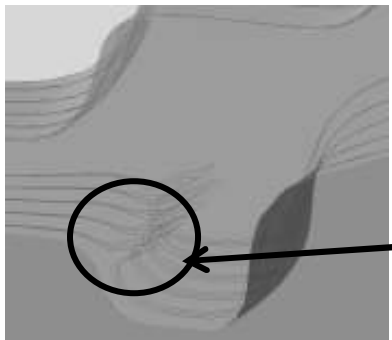


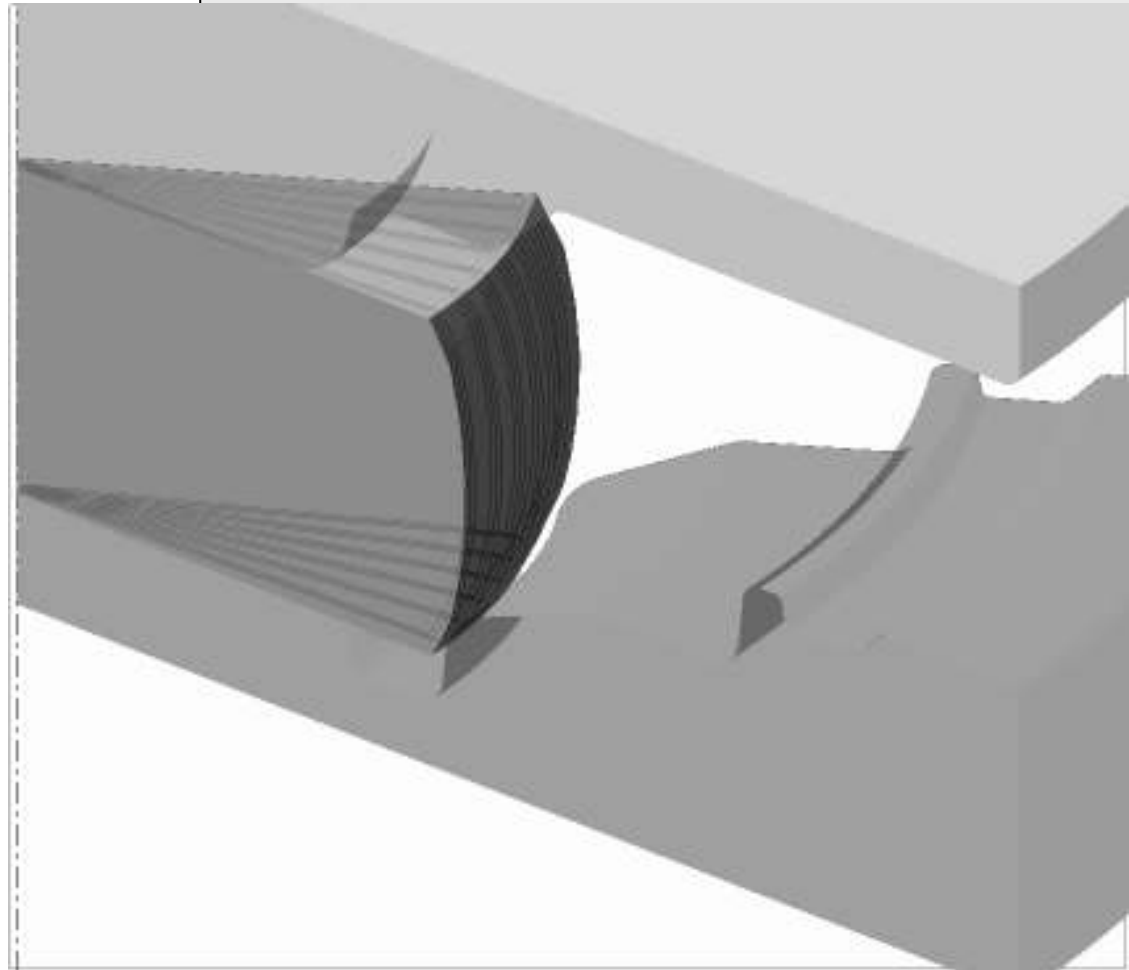
Photo with defect



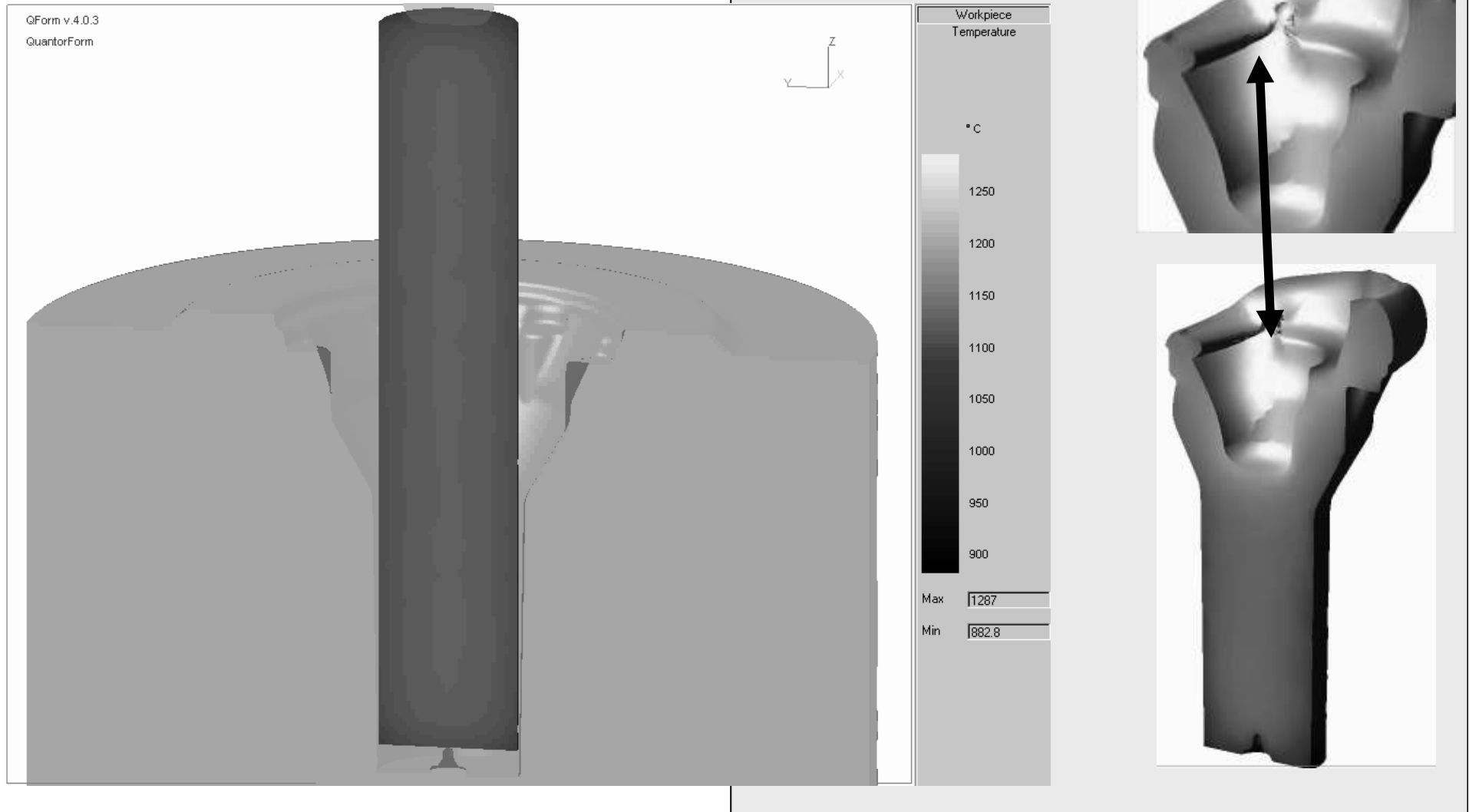
QForm2D



QForm3D



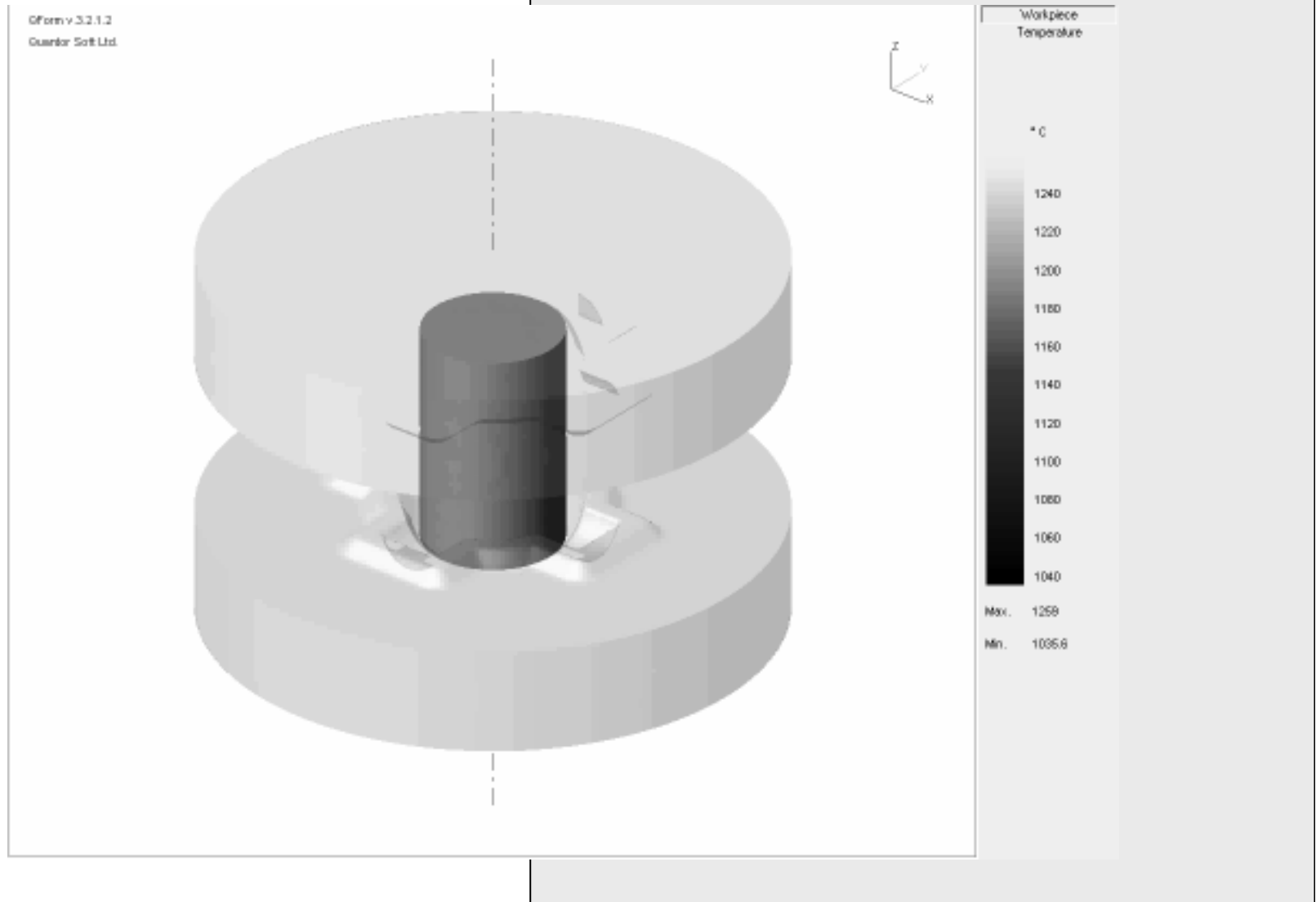
Instability in forging



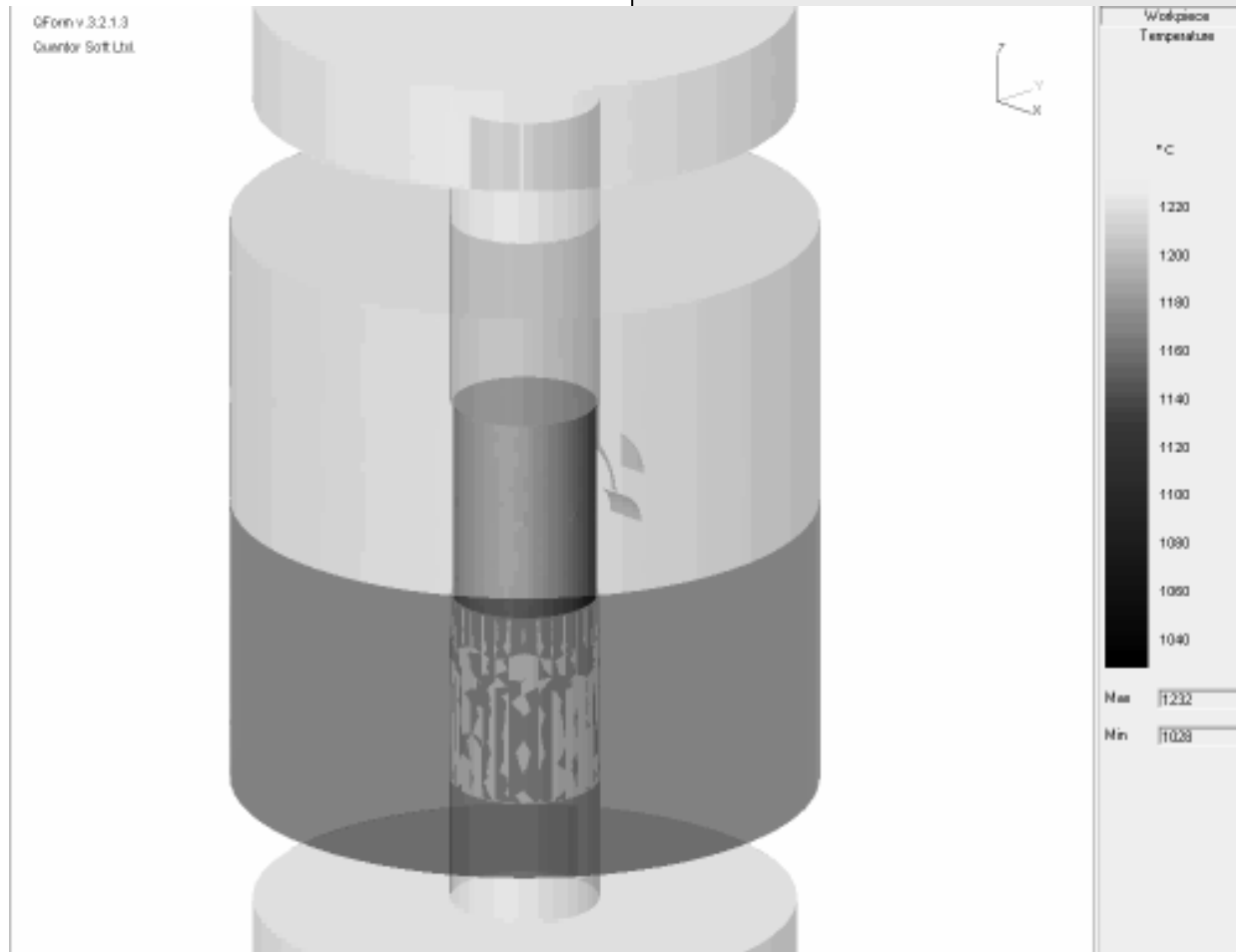
Multiple tools sets

Next >>

Conventional forging with flash




Flashless forging



25-35% material saving

Solving technological problems using QFORM3D

- 1. Filling the dies at lower load**
 - 2. Saving the material**
 - 3. Prediction of material flow defects**
 - 4. 3-tools-simulation**
 - 5. Positioning and gravity**
- 

Third blow – closed die – defect is detected

The screenshot displays the QForm v.4.0.3 software interface. The main window shows a 3D simulation of a workpiece being forged in a closed die. The workpiece is a curved, cylindrical component. The die is a light-colored, U-shaped mold. The simulation is running, and the workpiece is shown in a dark gray color. The interface includes a menu bar (File, Case, Action, View, Graphs, Tracked points, Measurement, Options, Utilities, Help) and a toolbar with various icons for simulation control. On the left side, there is a playback control panel with buttons for 'Playback', 'Step number' (249), 'Step size [s]', 'Current time [s]' (0.0860), and 'Work[kJ]' (52.8779). Below the playback panel is a 'Simulation' section with a 'Record' button and a '30 from 30' indicator. A list of simulation processes is shown, including 'bending(3D)', 'upsetting(3D)', 'mould (3D)', and 'finish form(3D)'. The 'mould (3D)' process is currently selected. At the bottom of the interface, there are buttons for 'Edit parametr', 'Apply', and 'Cancel'. The main 3D view area has a coordinate system (X, Y, Z) and a scale bar. The workpiece is positioned within the die. The software version 'QForm v.4.0.3' and 'QuantorForm' are displayed in the top left of the 3D view area. The status bar at the bottom shows 'Final position' and 'NUM'.

4th blow – closed die – defect is still in the critical area

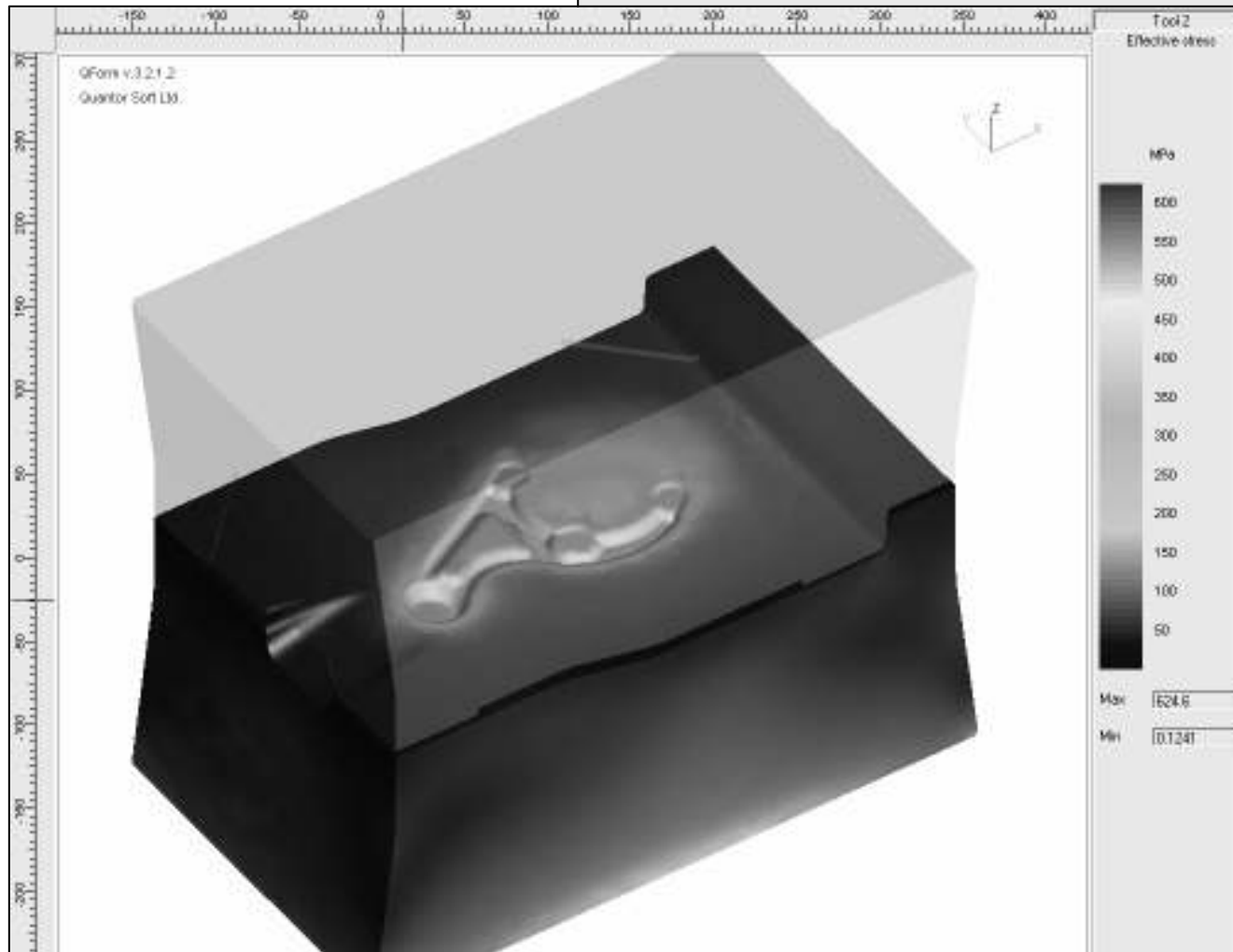
The screenshot displays the QForm v.4.0.3 software interface. The main window shows a 3D model of a forged part with a defect. The interface includes a menu bar (File, Case, Action, View, Graphs, Tracked points, Measurement, Options, Utilities, Help), a toolbar, and a playback control panel. The playback panel shows the current step number (80) and a progress bar. The simulation data table is as follows:

Simulation	
Step number	80
Step size [s]	
Current time [s]	0.0359
Work[kJ]	5.8564
Record	30 from 30
Iteration	
Norm 1	
Norm 2	

The 3D view shows the part with a defect. The temperature scale on the right indicates a maximum temperature of 1030°C and a minimum of 883.5°C. The simulation is currently at step 80, and the part is in the 'finish form' stage. The defect is still present in the critical area.

Increasing the die life

Die stress in solid die block



Next >>

Gear forging simulation

- **Simulated in Half Section on QForm**

QForm v.4.1.6
QuantorForm
gear.qfm
Action 1



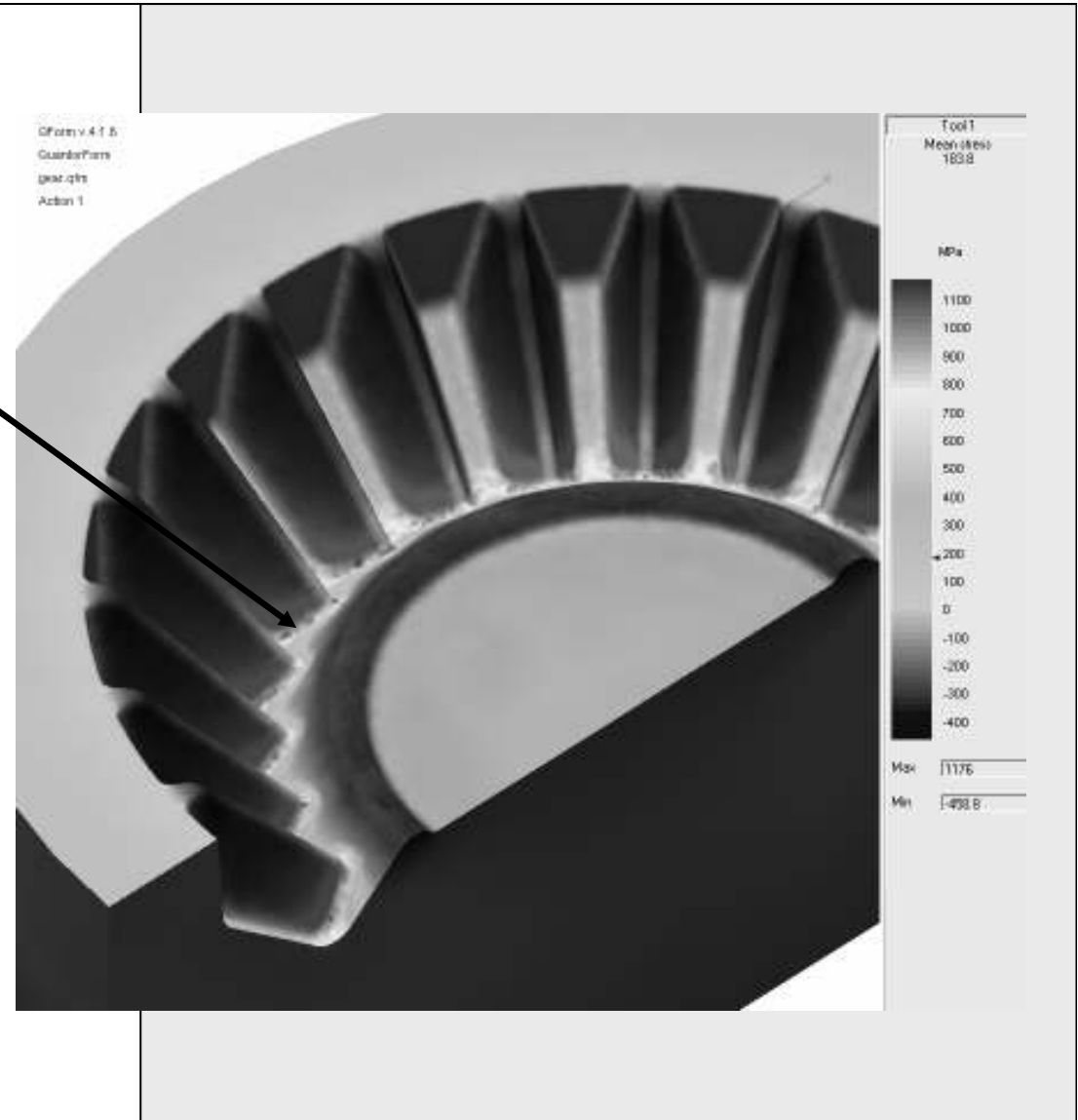
Die crack

- **23 Toothed Gear with Finish-Forged Teeth for Combined Harvester PTO Application**
- **Dies Cracking After Around 400 Parts**
- **Improvement Needed for Production Quantities**



Die stress in solid die block

- **Maximum Stress Shown Where Dies Were Cracking**



Split die instead of solid die block

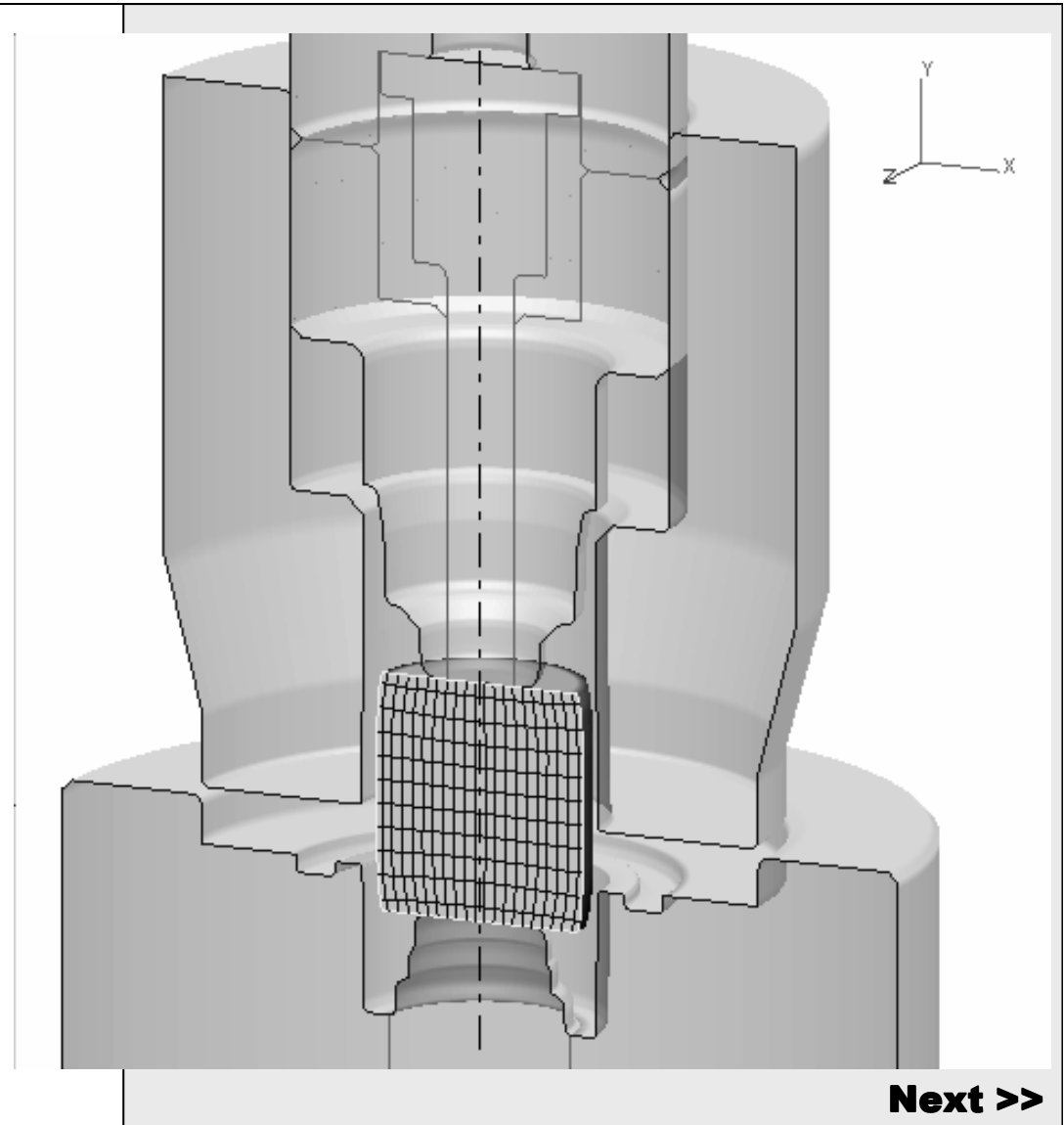
- **“Inserted” Die Now Machined**
- **To Trial on Next Production Batch**



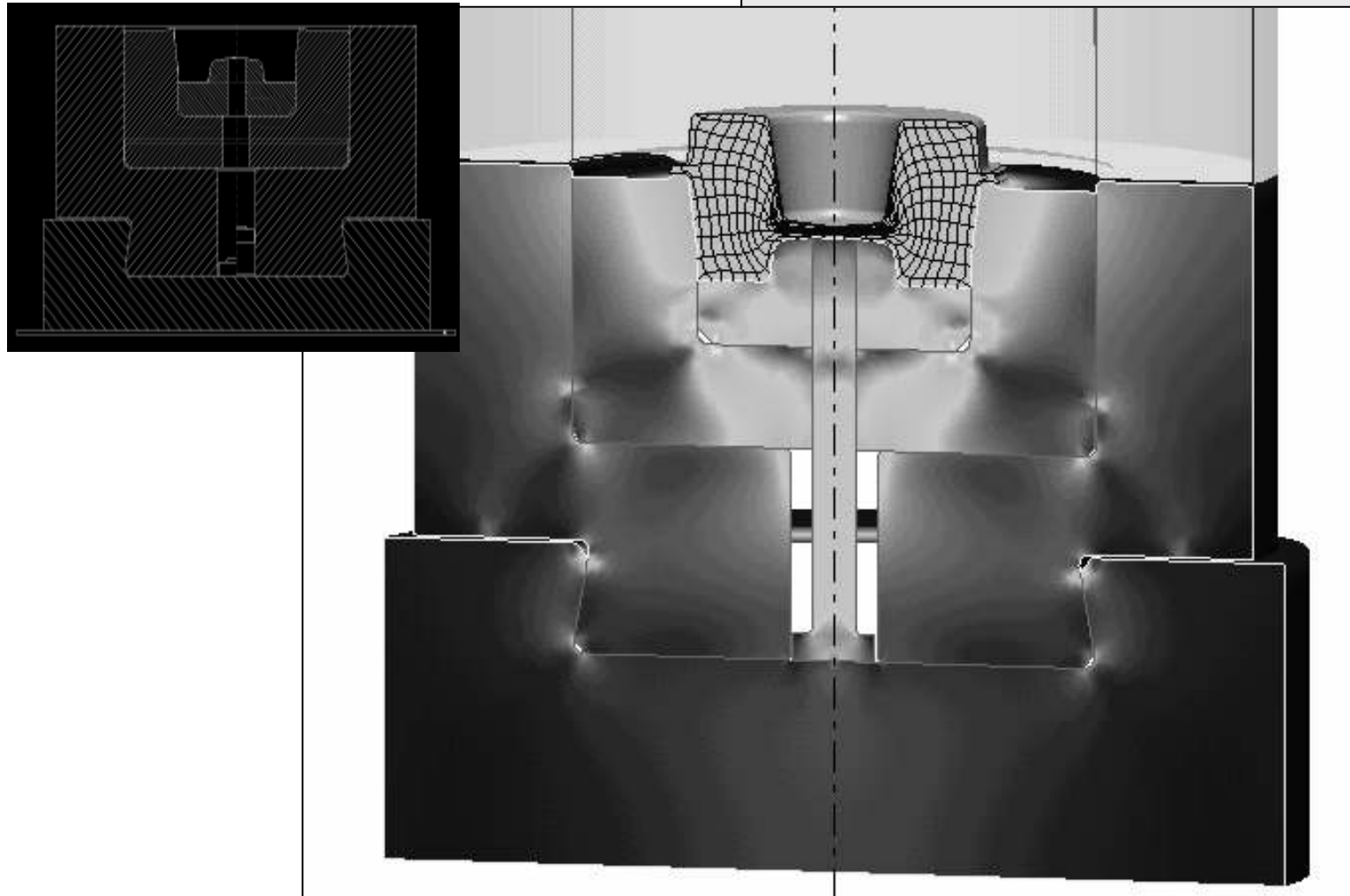
- **Potential Improvement in Die Life: At Least 150%**
- **Potential Cost Saving: ~£2000 (approx 4 dies)**

Complex die assemblies

**Pre-stressed dies with
inserts and pegs**

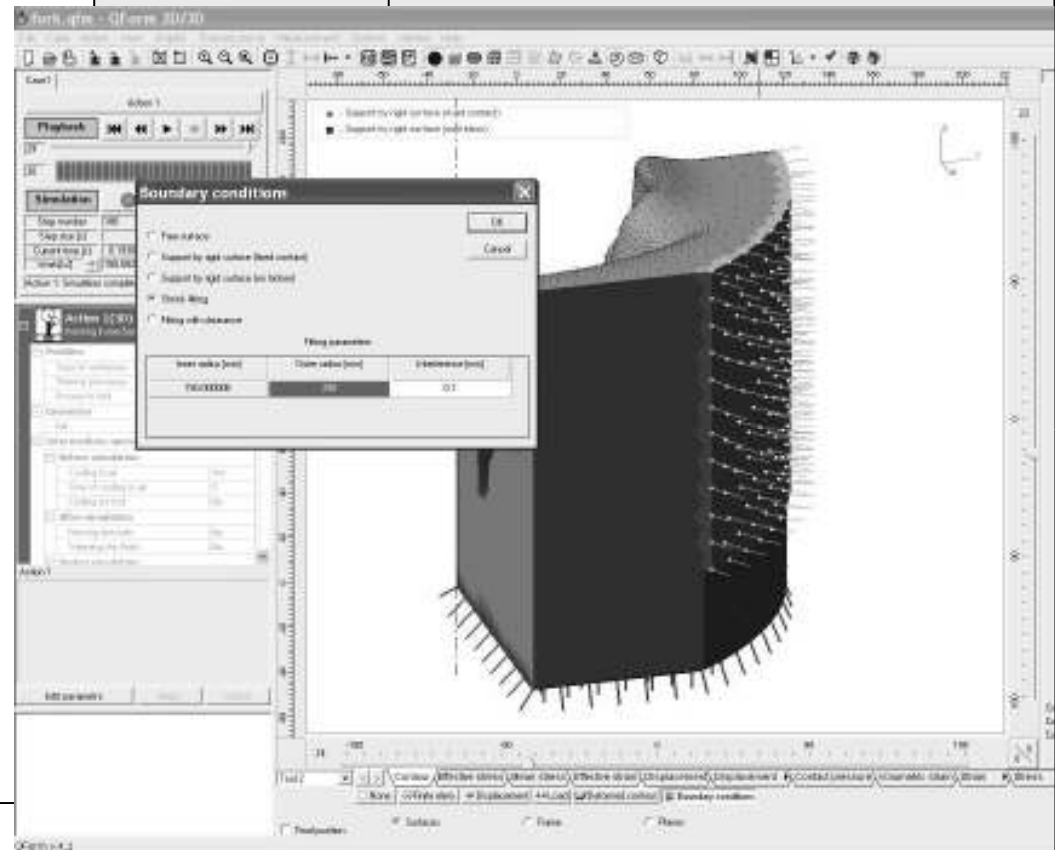


Effective stress distribution in assembled die

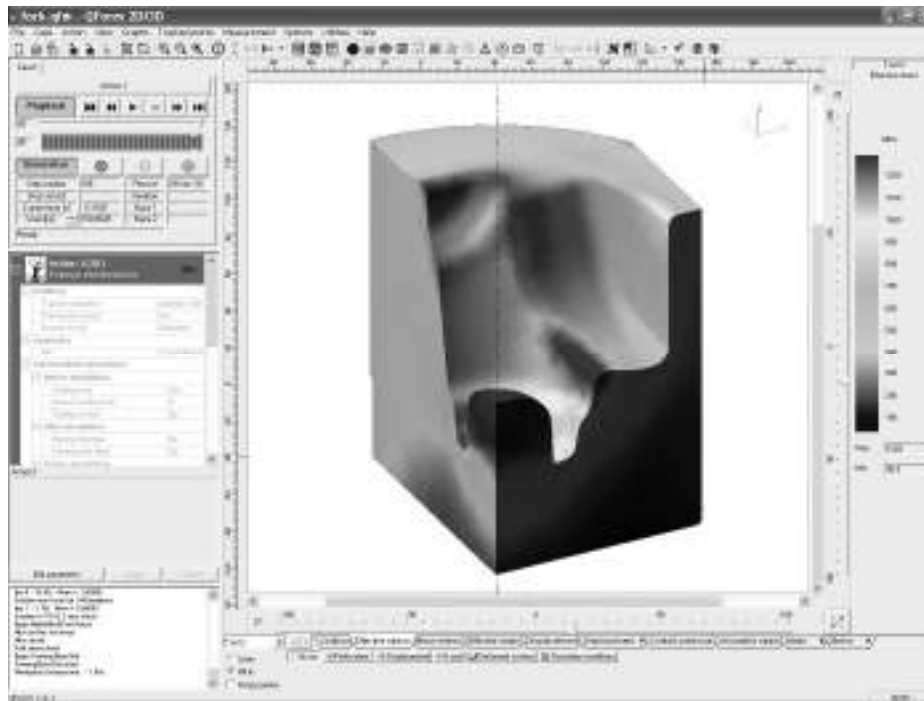


Next >>

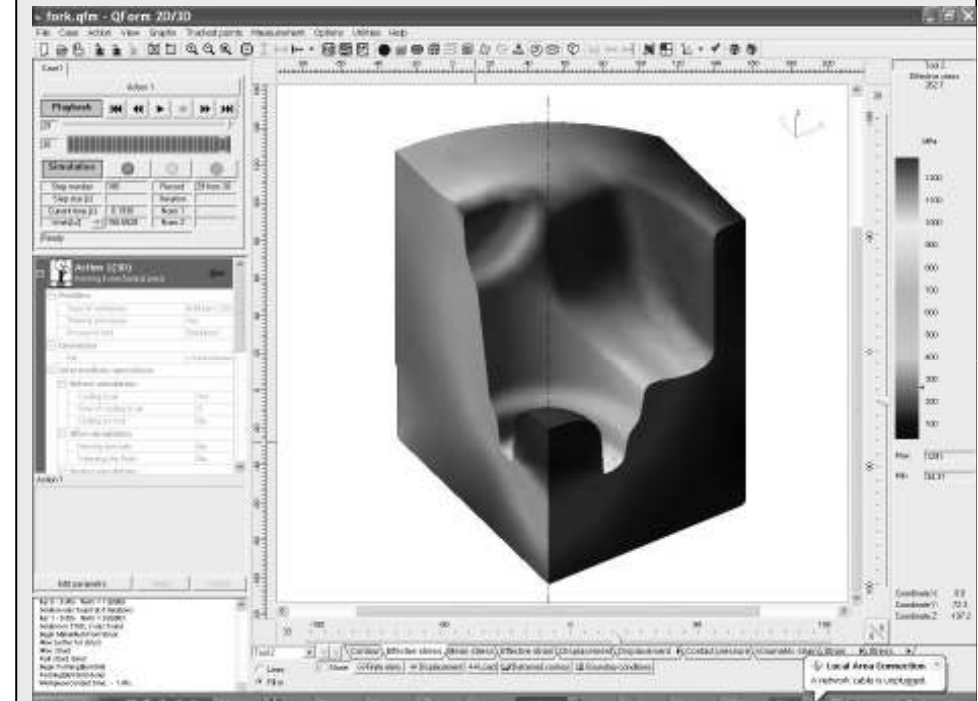
Shrink ring for the dies in 3D



The effect of shrink fitting for the dies

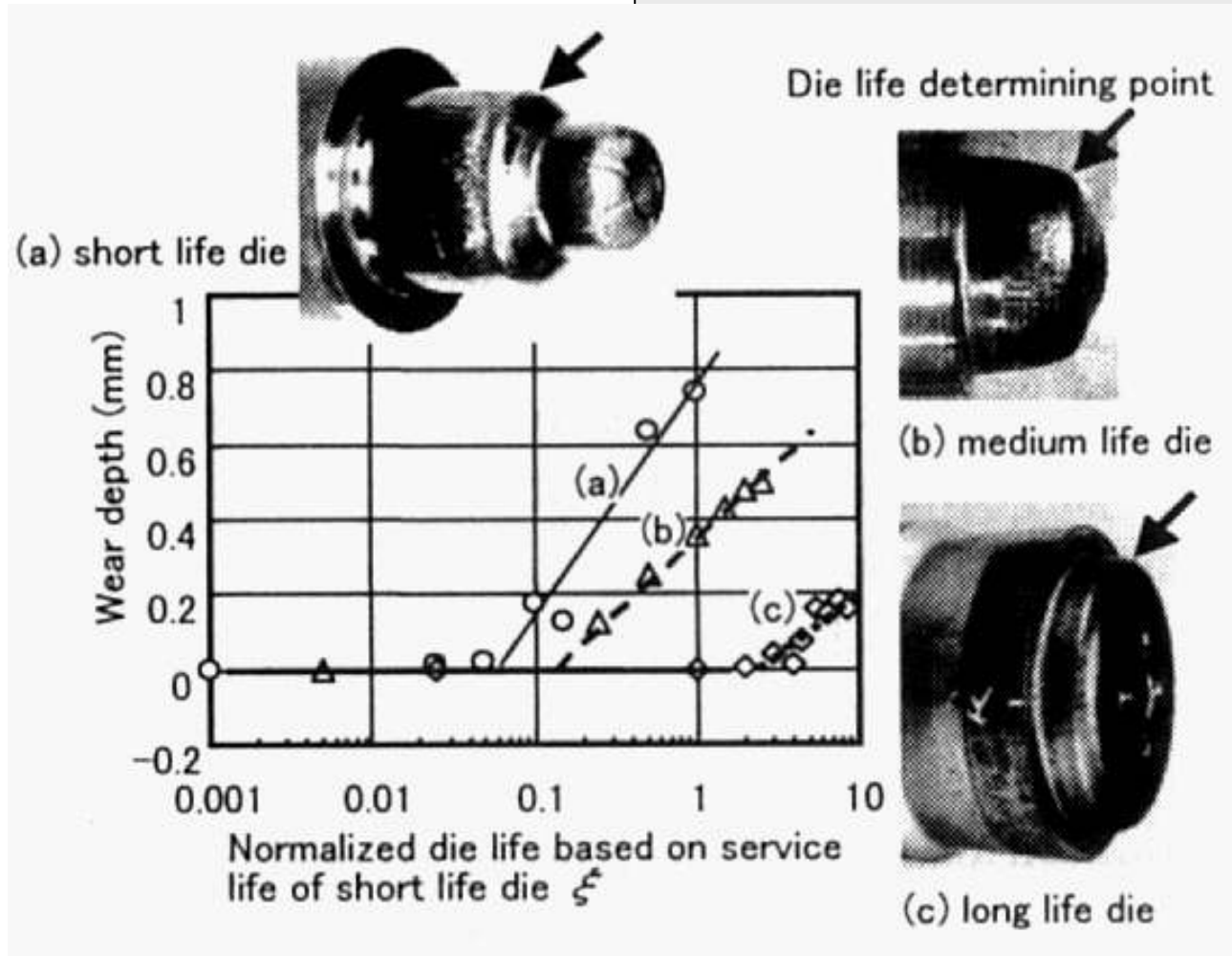


Effective stress distribution with free lateral surface

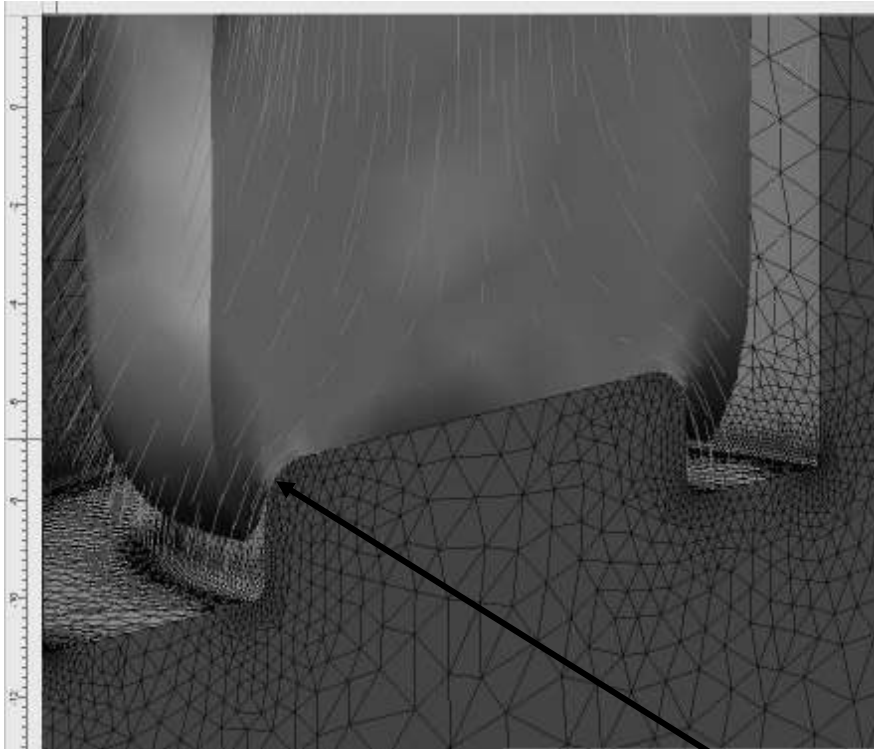


Effective stress distribution with shrink fitting

Die wear prediction



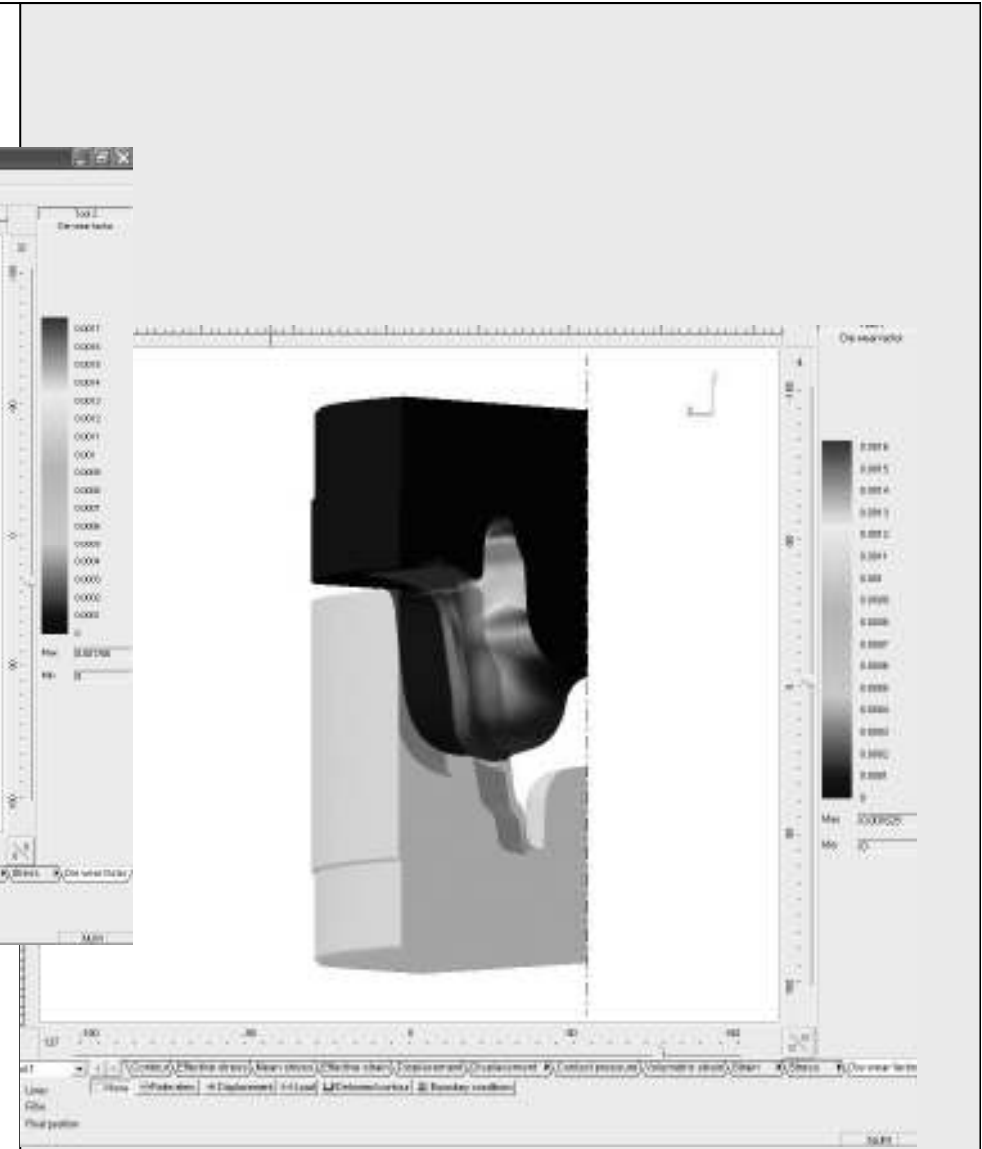
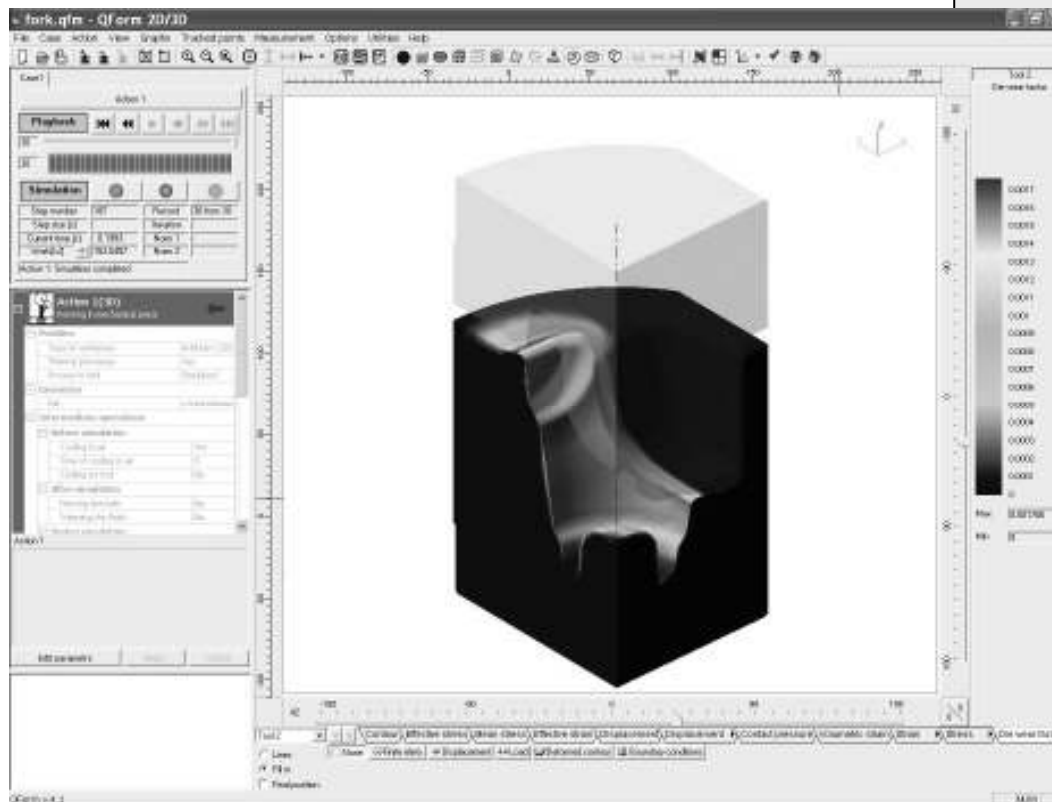
Die wear prediction



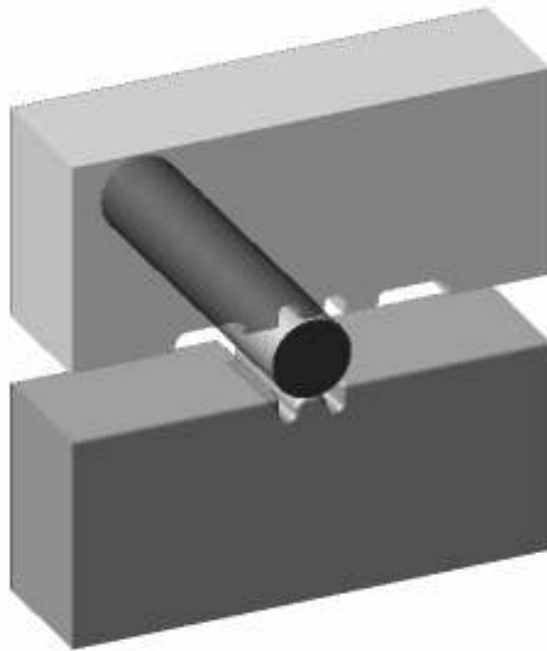
Die wear depends on:

- Contact traction
- Relative sliding velocity on a die surface
- Yield stress of the die material
- Time of the contact

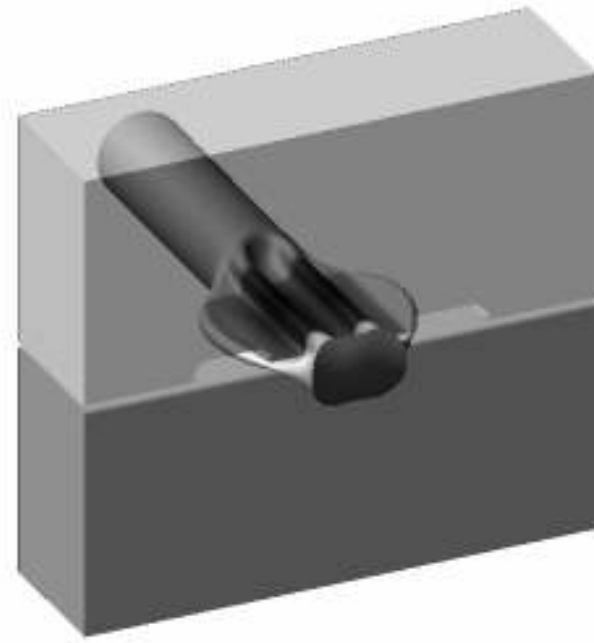
Die wear prediction: relative die wear factor distribution



1 Comparing the results of the predicted die wear distribution with the experiment



a.



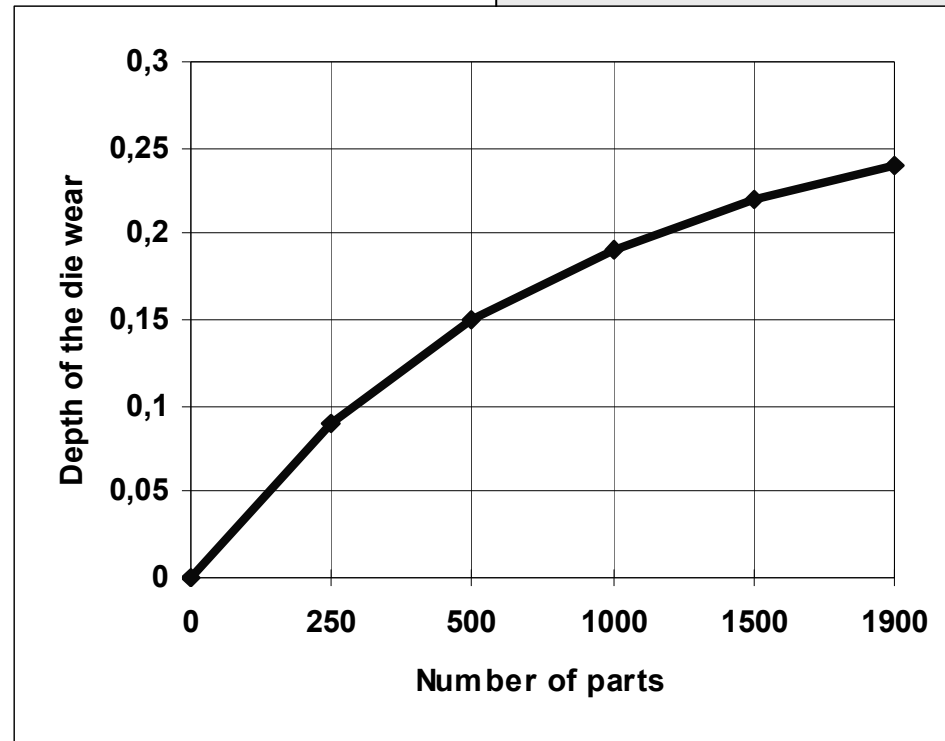
b.

The conditions of the experiment: round bar 13mm,
steel AISI 1030, temperature 1100-1150 degrees C

The experimental results of the die wear evaluation are obtained by Dr. Jan Cermak, Czech Technical University in Prague

1

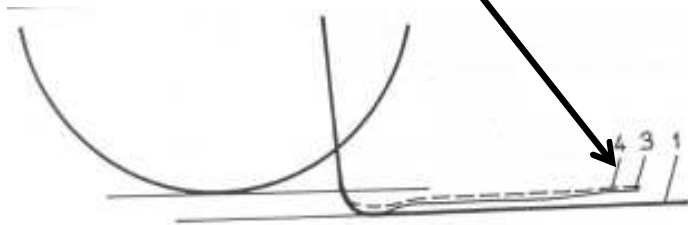
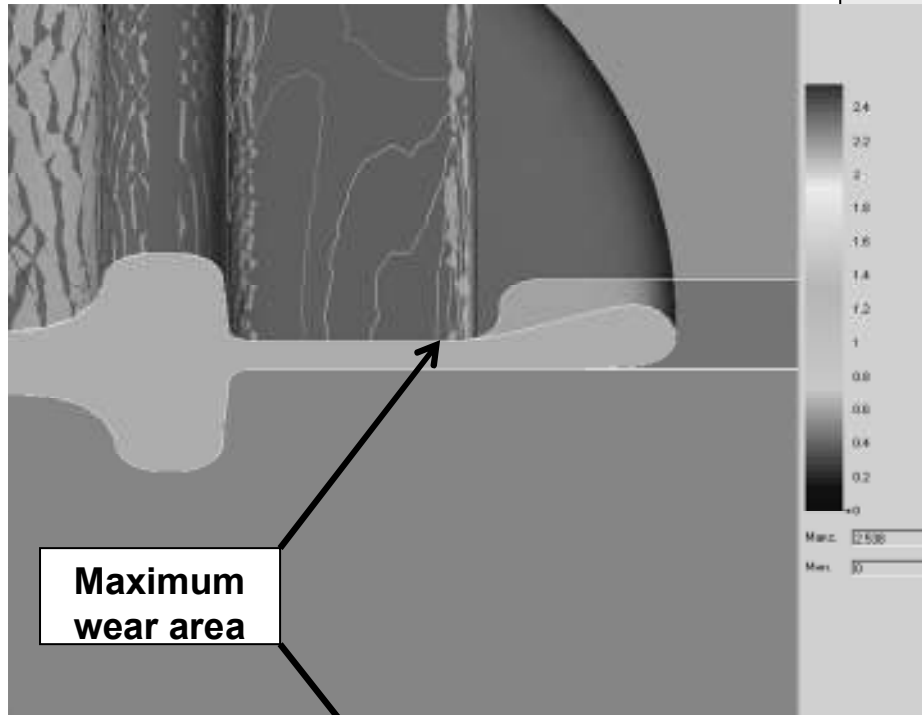
The experimental evaluation of the abrasive wear



The maximum depth of the die wear (mm) versus the number of the forged parts (the upper die)

1

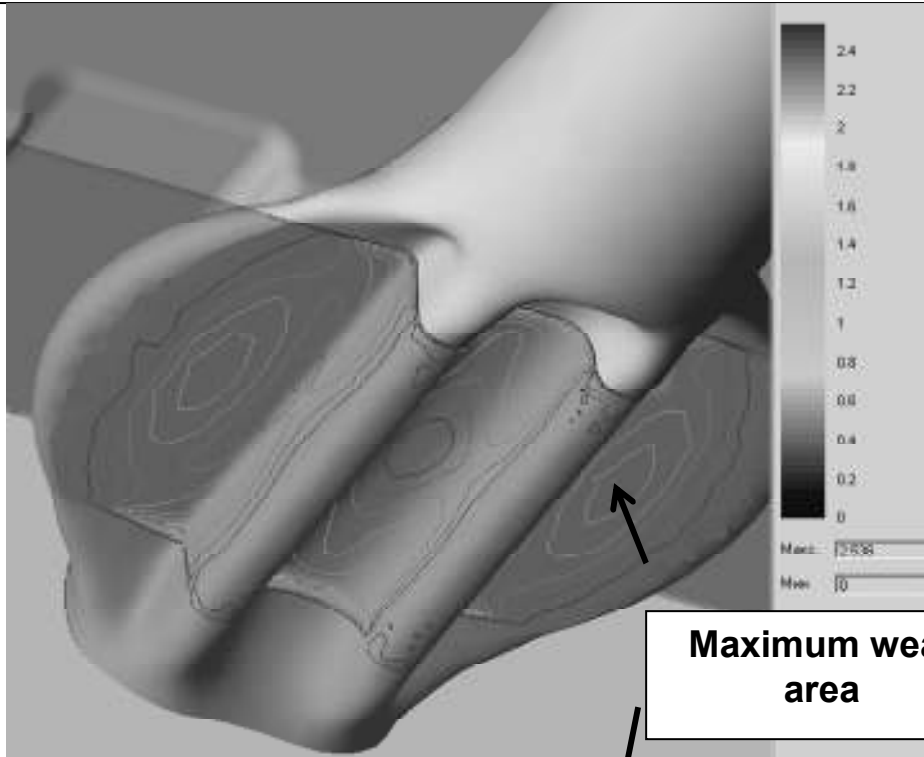
Abrasive wear distribution *10⁻¹ mm of the upper die



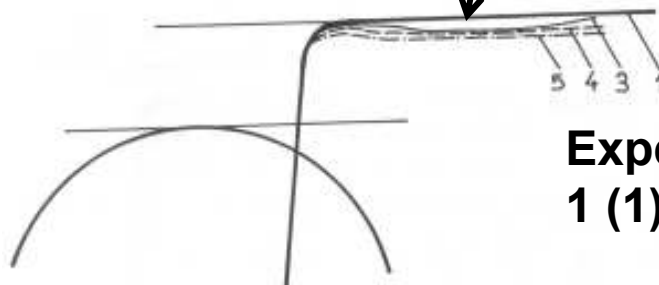
Experimental measurement after:
1 (1), 500 (2), 1000 (3), 1500 (4) and 1900 (5) parts.

1

Abrasive wear distribution *10⁻¹ mm of the lower die



Simulation results

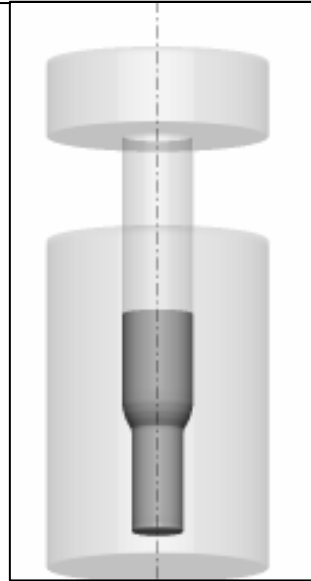


Experimental measurement after:
1 (1), 500 (2), 1000 (3), 1500 (4) and 1900 (5) parts.

3

Initial technology of cold forging of the bolt

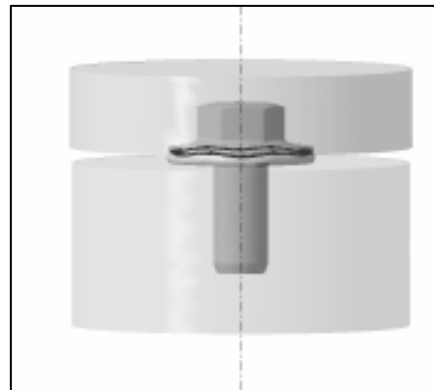
1st action



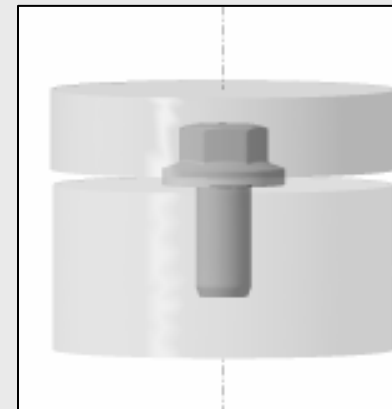
2nd action



3rd action

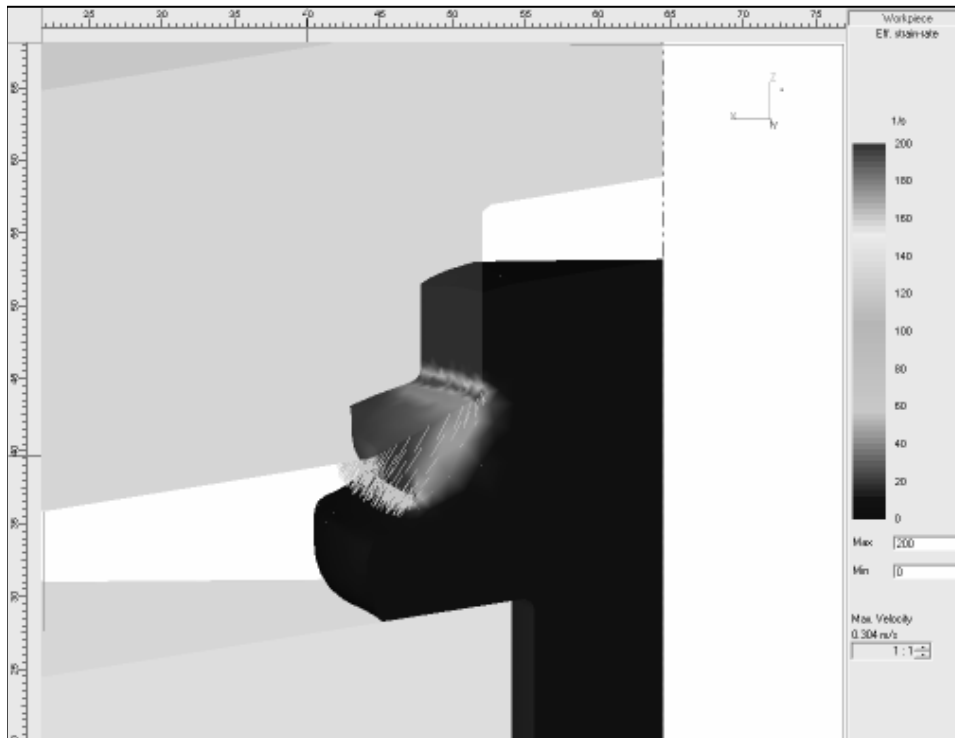


Trimming



3

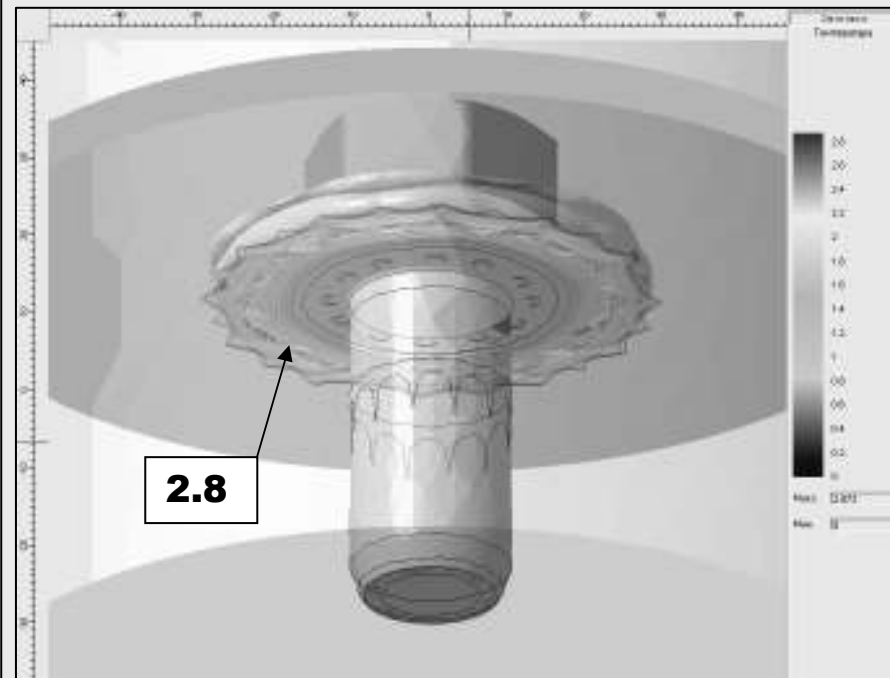
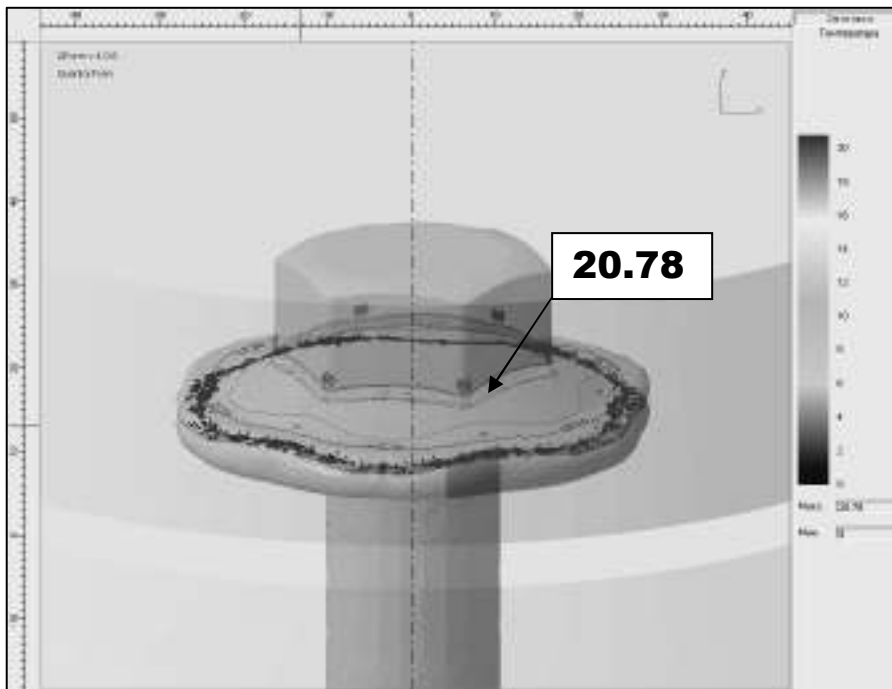
Initial technology of cold forging of the bolt



Intensive sliding of forged material under the upper die at the 3rd action of the initial technology



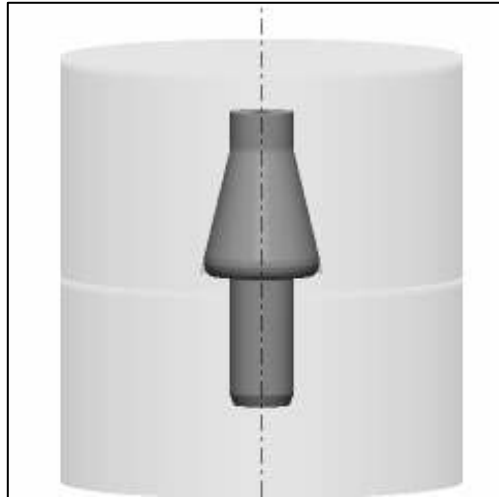
Relative die wear maximum values



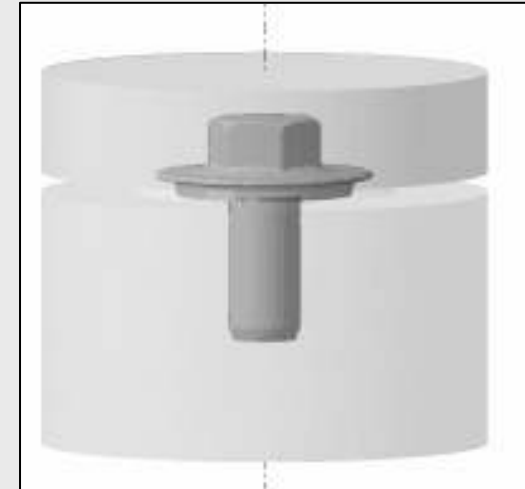
maximum die wear $w_r=20.78$ exactly on the edge of the upper die;

4

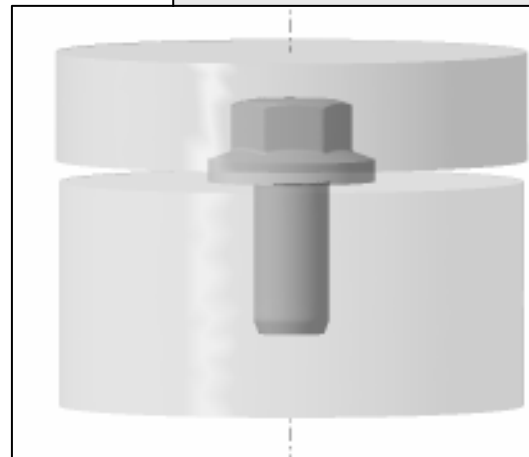
Modified technology of cold forging of the bolt



1st action



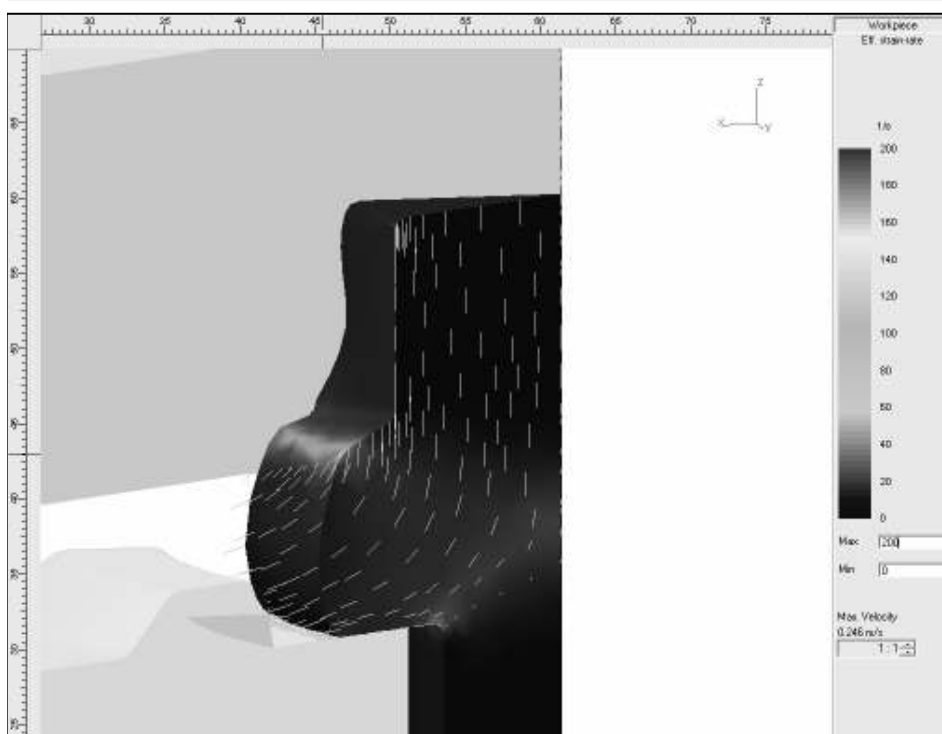
2nd action



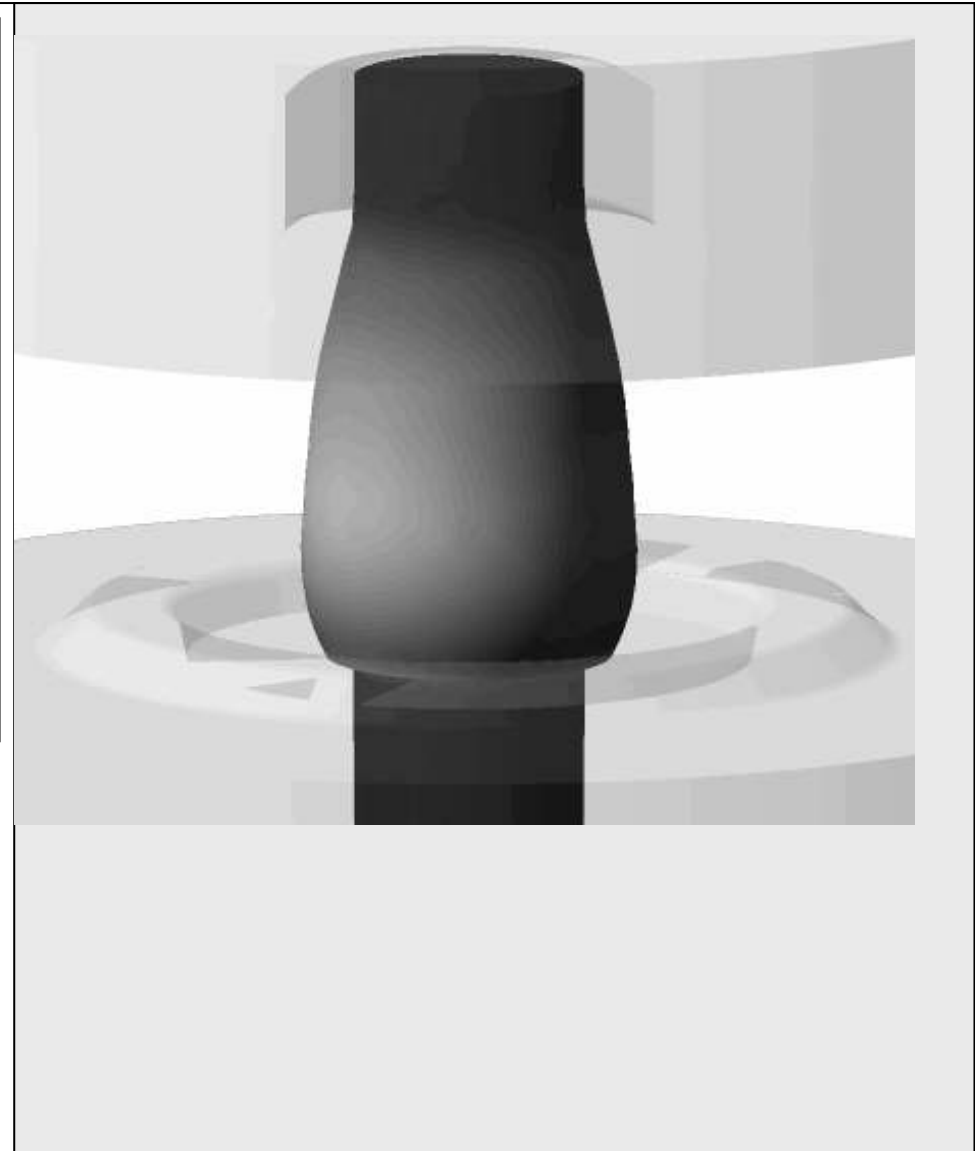
Trimming

5

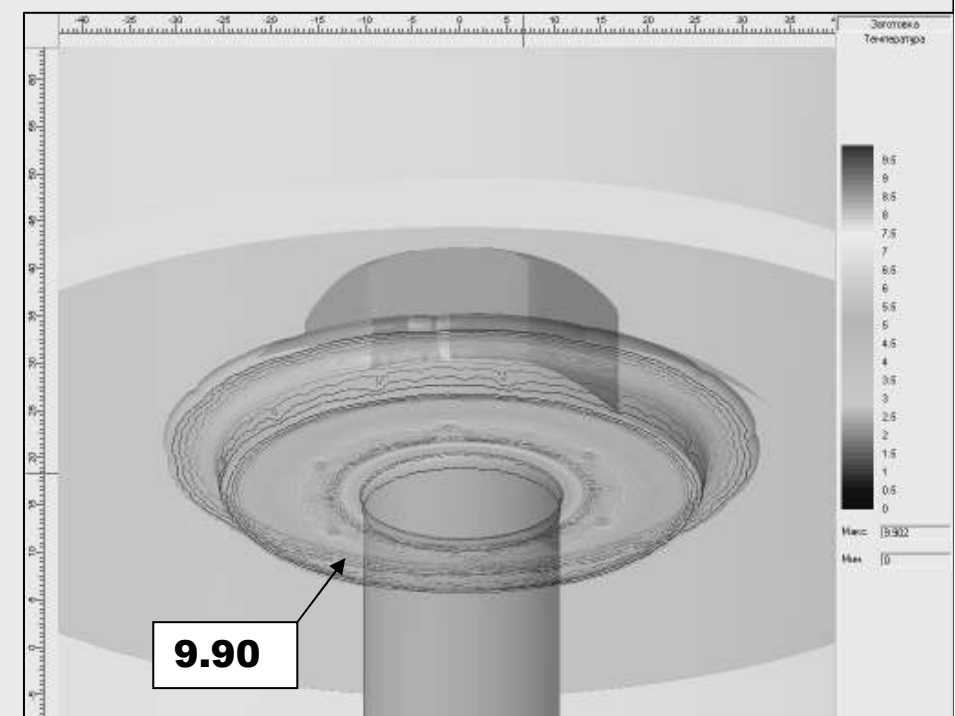
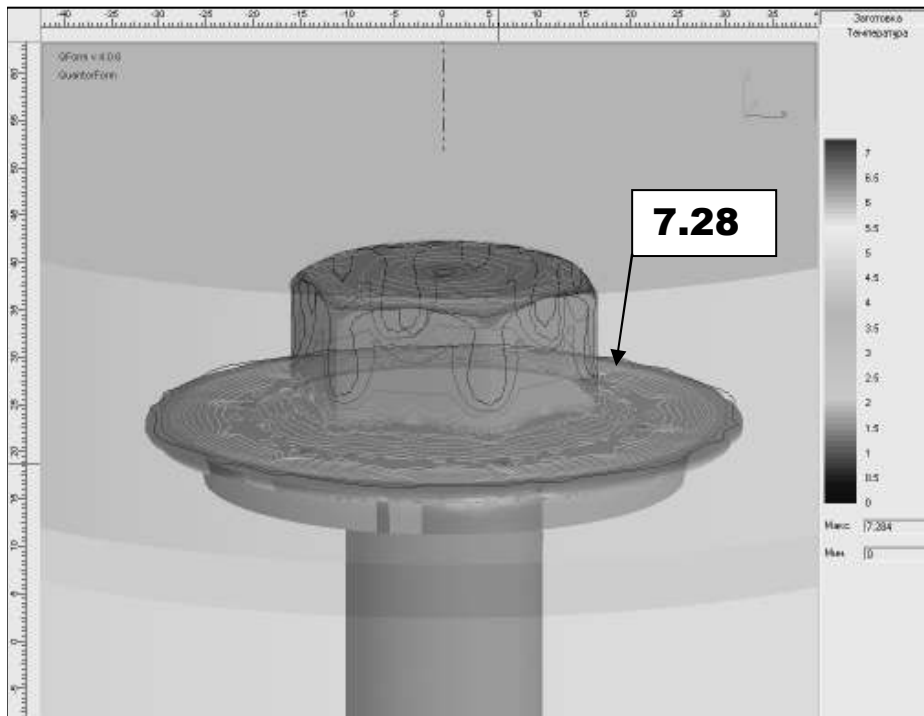
Velocity vectors and the effective strain



Filling of the die cavity for modified technology (b) with equal sliding of the material along upper and lower dies.



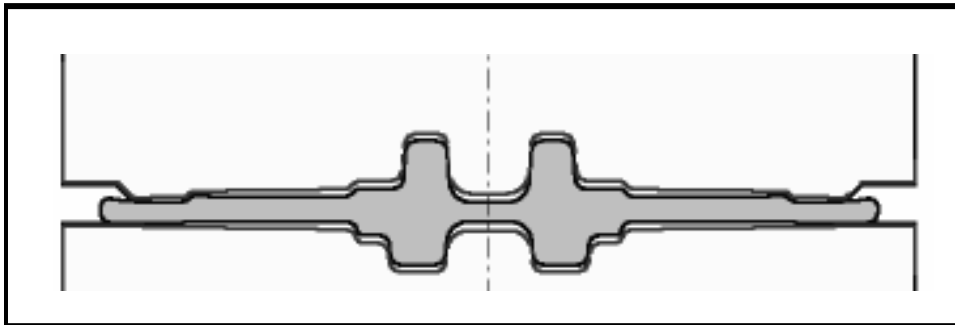
Modified technology of cold forging of the bolt



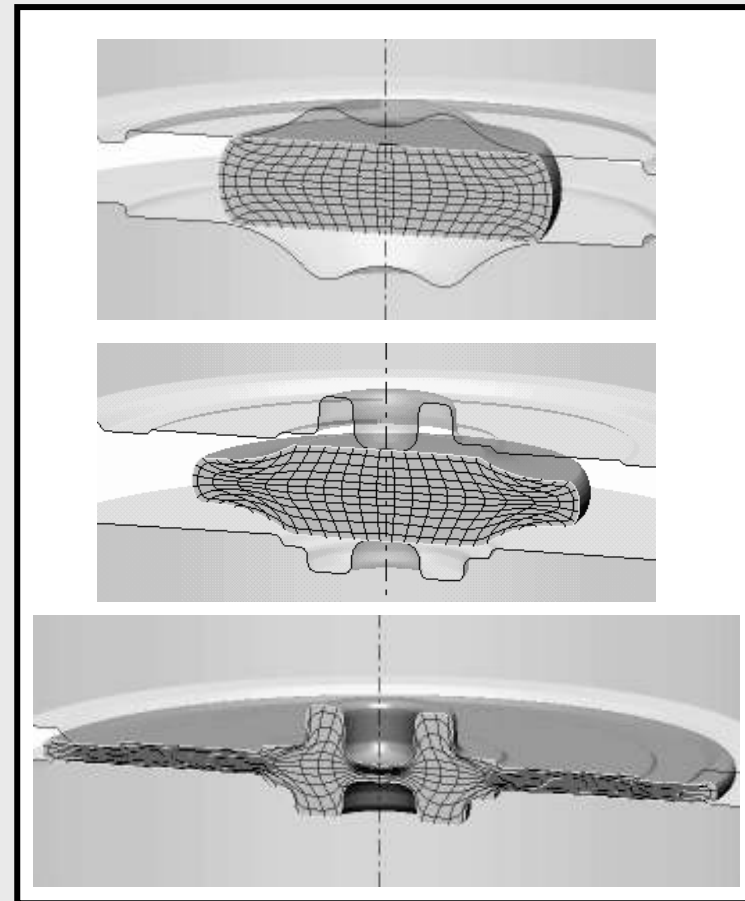
Maximum relative die wear $w_r = 9.90$ on the lower die

Elastic deflection of the dies and its compensation

Deflection of the die (magnified)

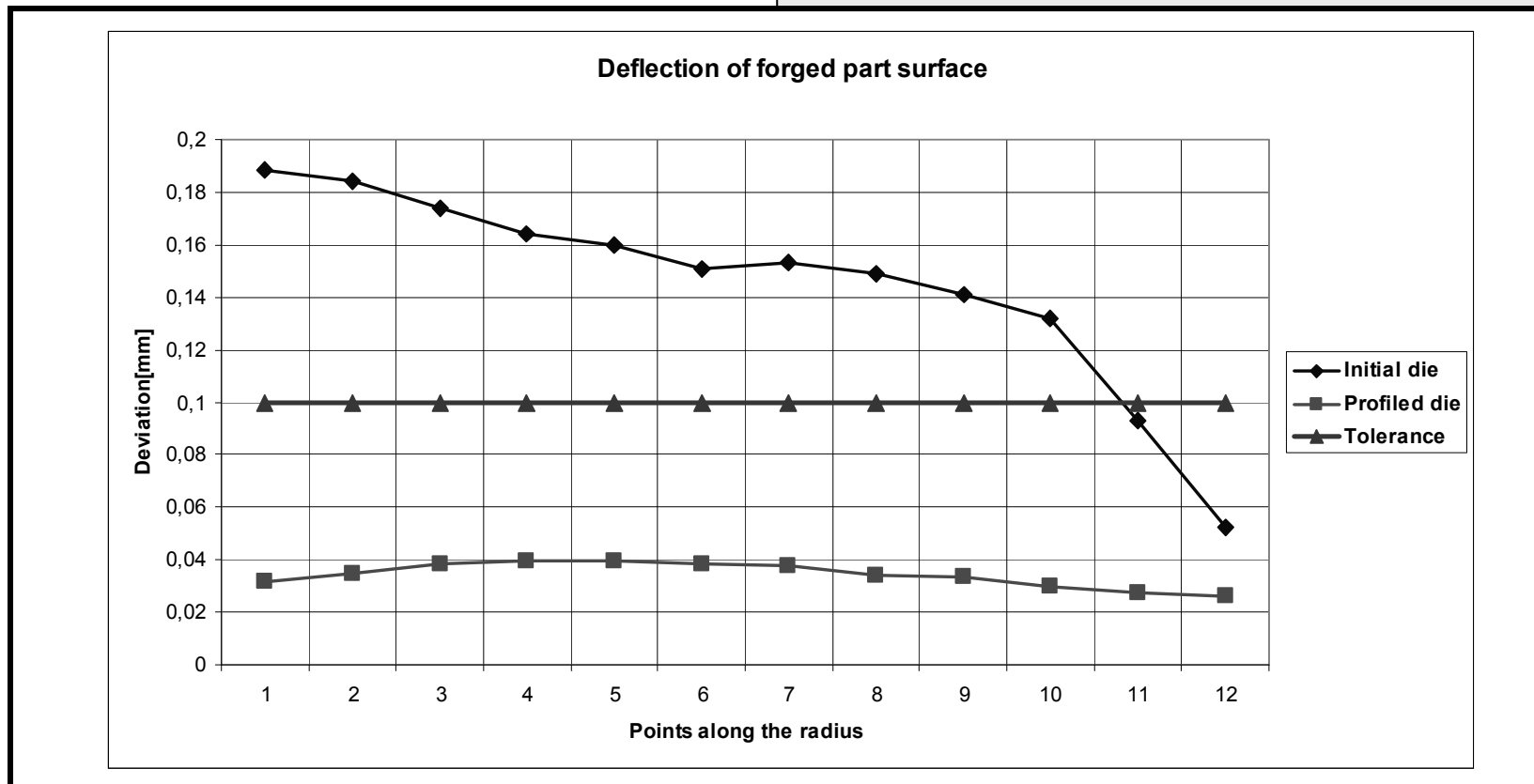


the stages of forging



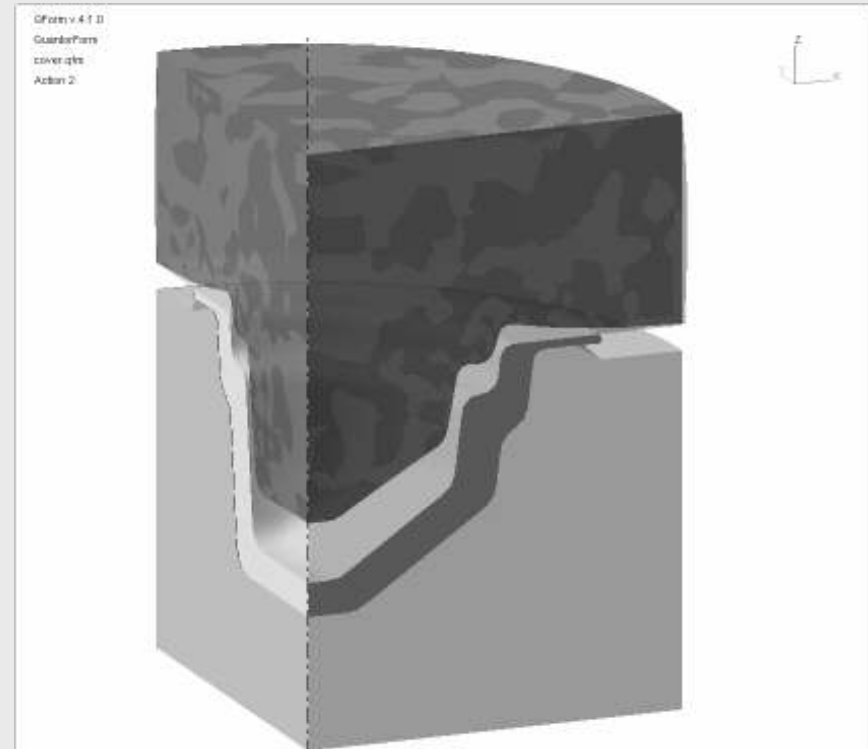
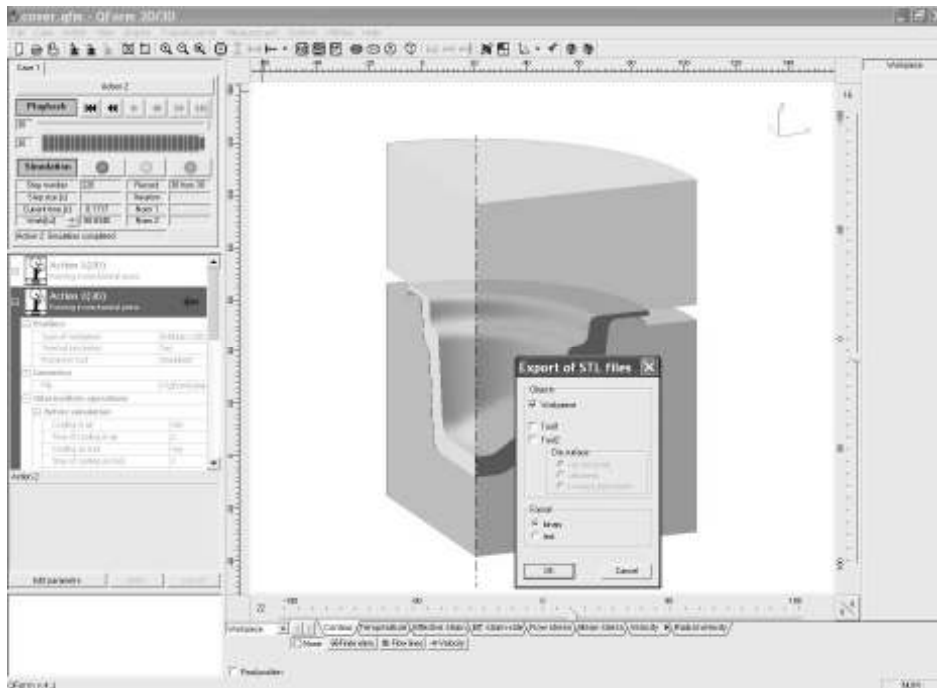
Elastic deflection of the dies and its compensation

Graphs of upper die surface deflection along the radius of the forged part for initial and profiled die shape



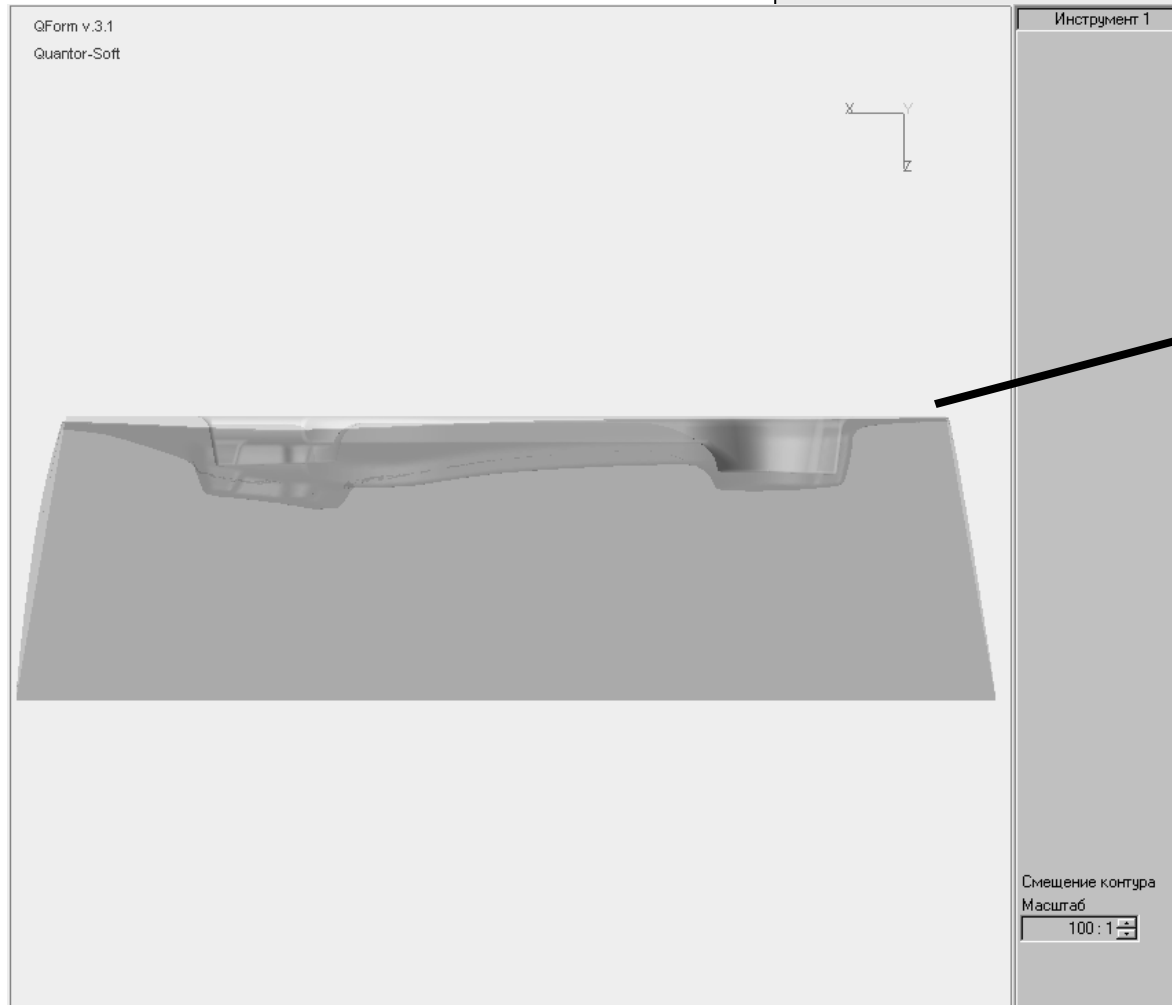
Elastic deflection of the dies and its compensation

Export of deformed and profiled shapes of the tools



Compensation of the elastic deformation of the dies

The blocker die surface deflection (magnification factor 100)



**Export of
profiled die
shape to CAD
for precise
forging**

QForm is very economically efficient

- **It is the perfect tool for die designer and forging engineer that they use in their everyday practice**
- **It saves material, tools, energy**
- **The development is fast and effective, no forging trials required for new jobs**
- **Then using QForm the forging skill is significantly improving**



QUANTOR FORM