

A photograph of a desk with technical drawings and a metal tool. The desk is covered with several sheets of paper. One prominent sheet is light blue with a technical drawing of a rectangular part. Another sheet is white with a grid pattern and some handwritten notes. A metal tool, possibly a punch or a die, is lying on the blue sheet. The background is a dark surface, possibly a desk or a table.

“Simulation for process and die design in forging”

Presented by

Dr. G.H. Arfmann
CPM GmbH, Herzogenrath, Germany

Korea Metal Week 2007
Seoul, 26.10.2007



“Simulation for process and die design in forging”

History and fields of business of CPM

Industrial applications of Simulation

Conclusion

Korea Metal Week 2007
Seoul, 26.10.2007



“Simulation for process and die design in forging”

History and fields of business of CPM

Korea Metal Week 2007
Seoul, 26.10.2007

History of CPM

CPM was founded in 1987 in Aachen, Germany as a spin-off of the University of Technology of Aachen – one of the biggest and best in its field in Europe.

CPM worked on software solutions in the field of metal forming in general.

In 1990 CPM moved to Herzogenrath, Germany and changed its focus to technology and simulation in forging.

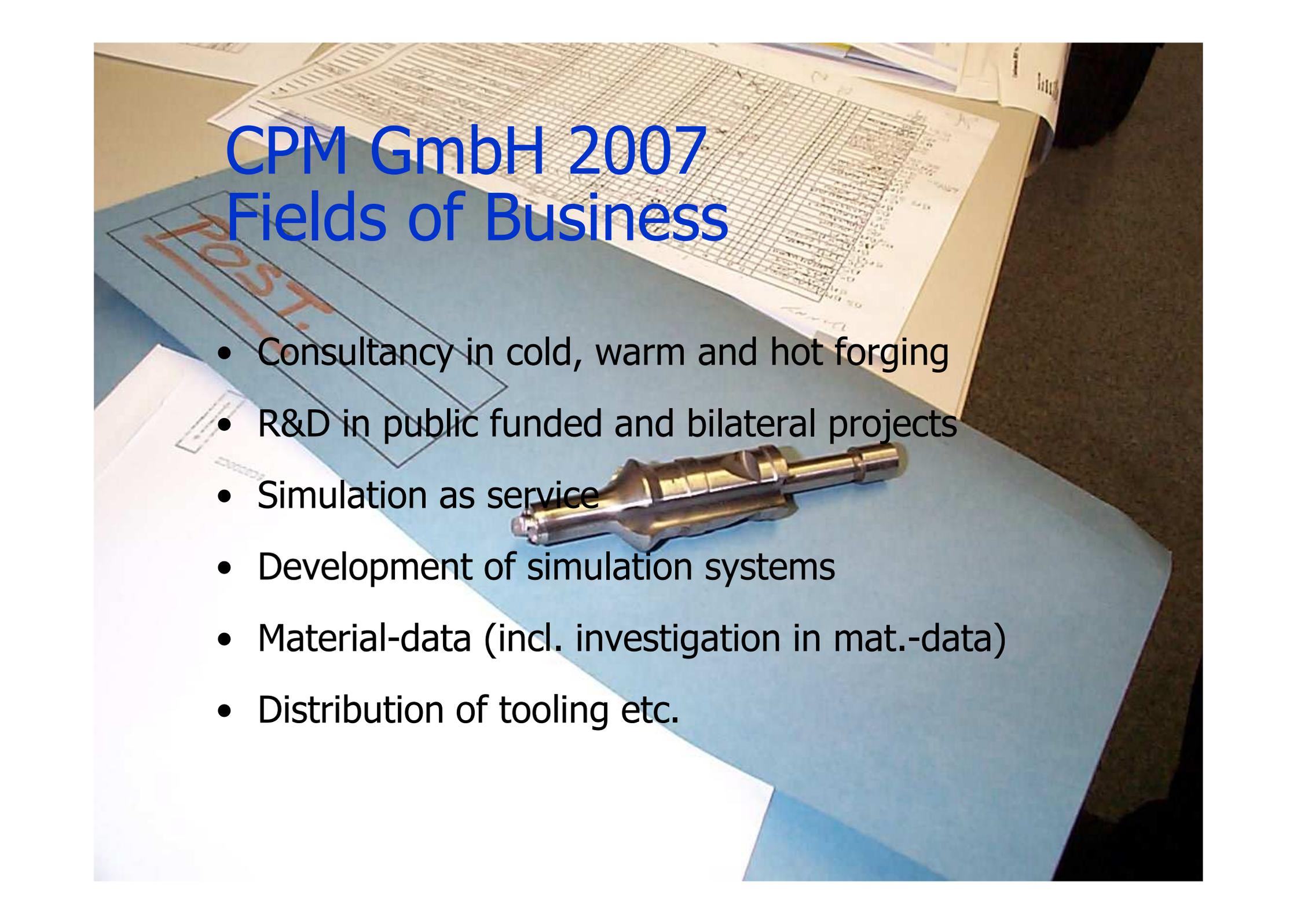
CPM provides engineering service to forging companies worldwide.

A photograph of a desk with a blue folder, a metal tool, and a grid paper. The folder is open, showing a grid paper with some handwritten notes. A metal tool, possibly a drill bit or a similar component, is lying on the folder. The text "CPM GmbH 2007" is overlaid in blue on the folder.

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Business of

CPM Gesellschaft für Computeran-
wendung, Prozeß- und Material-
technik mbH

The background of the slide is a photograph of a desk. On the desk, there is a blue folder with the word 'POST' written on it in orange. Several papers are scattered around, including one with a grid pattern. A metal tool, possibly a drill bit or a similar industrial component, is lying on the blue folder. The overall scene suggests a technical or engineering workspace.

CPM GmbH 2007 Fields of Business

- Consultancy in cold, warm and hot forging
- R&D in public funded and bilateral projects
- Simulation as service
- Development of simulation systems
- Material-data (incl. investigation in mat.-data)
- Distribution of tooling etc.

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- Consultancy in cold, warm and hot forging

Example: Spark Plug

Problem : Cracking because of wrong adjustment





eesy-2-form Vers. 2.81x Liz.:ORIG36

File Pre Pre-ELAST Graphic-Workpiece Graphic-Tool Run Run-ELAST --> Database System Hardcopy-Type EXIT

choice of increment

- 0
- 25
- 50
- 75
- 100
- 125
- 150
- 175
- 200
- 225
- 250
- 275
- 300
- 325
- 350
- 375
- 400
- 425
- 430

Export of
workpiece contour
as IGES-File



LEFT mouse button:
graphic options

RIGHT mouse button:
display of node
coordinates

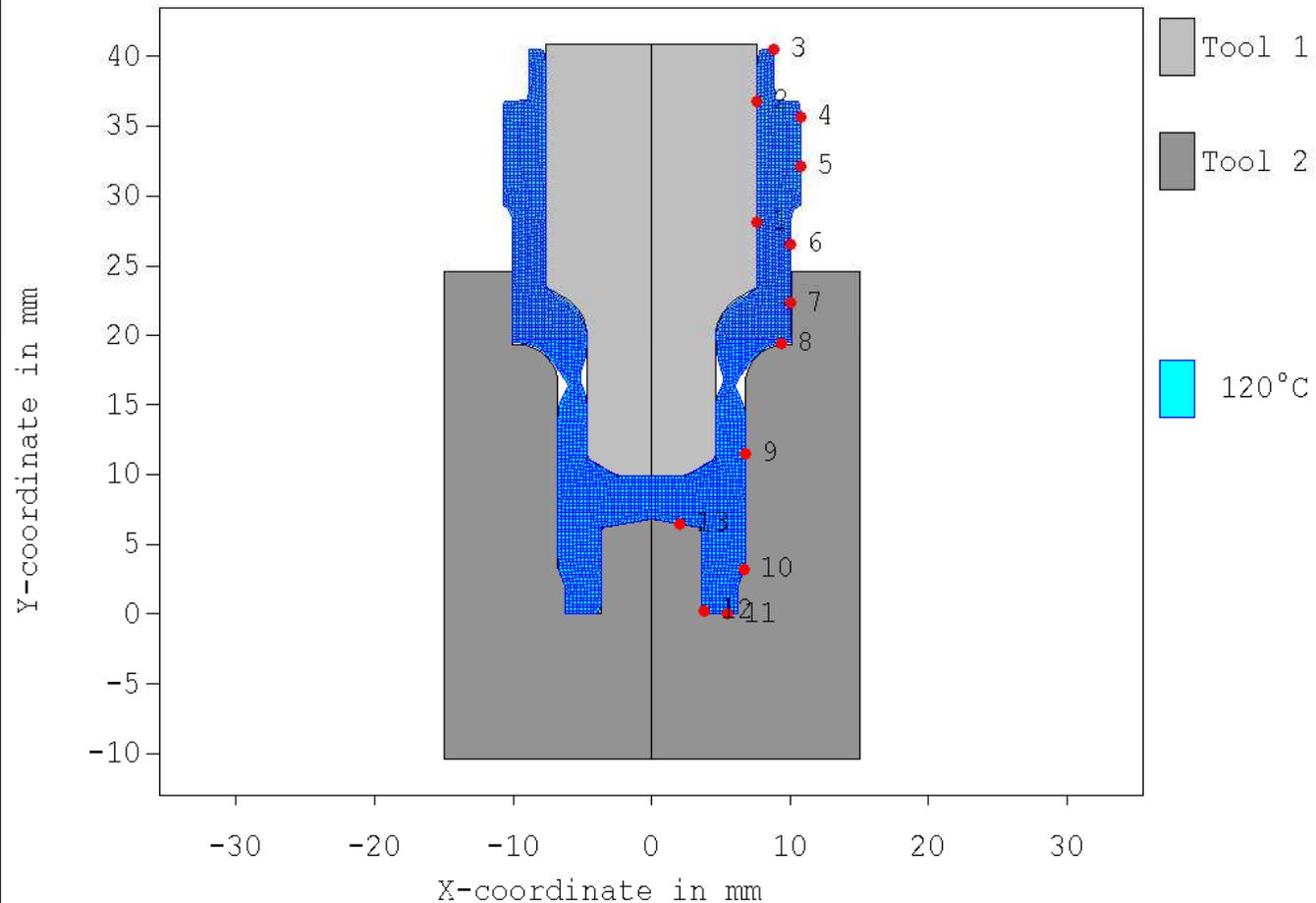
GEOMETRY (WORKPIECE)

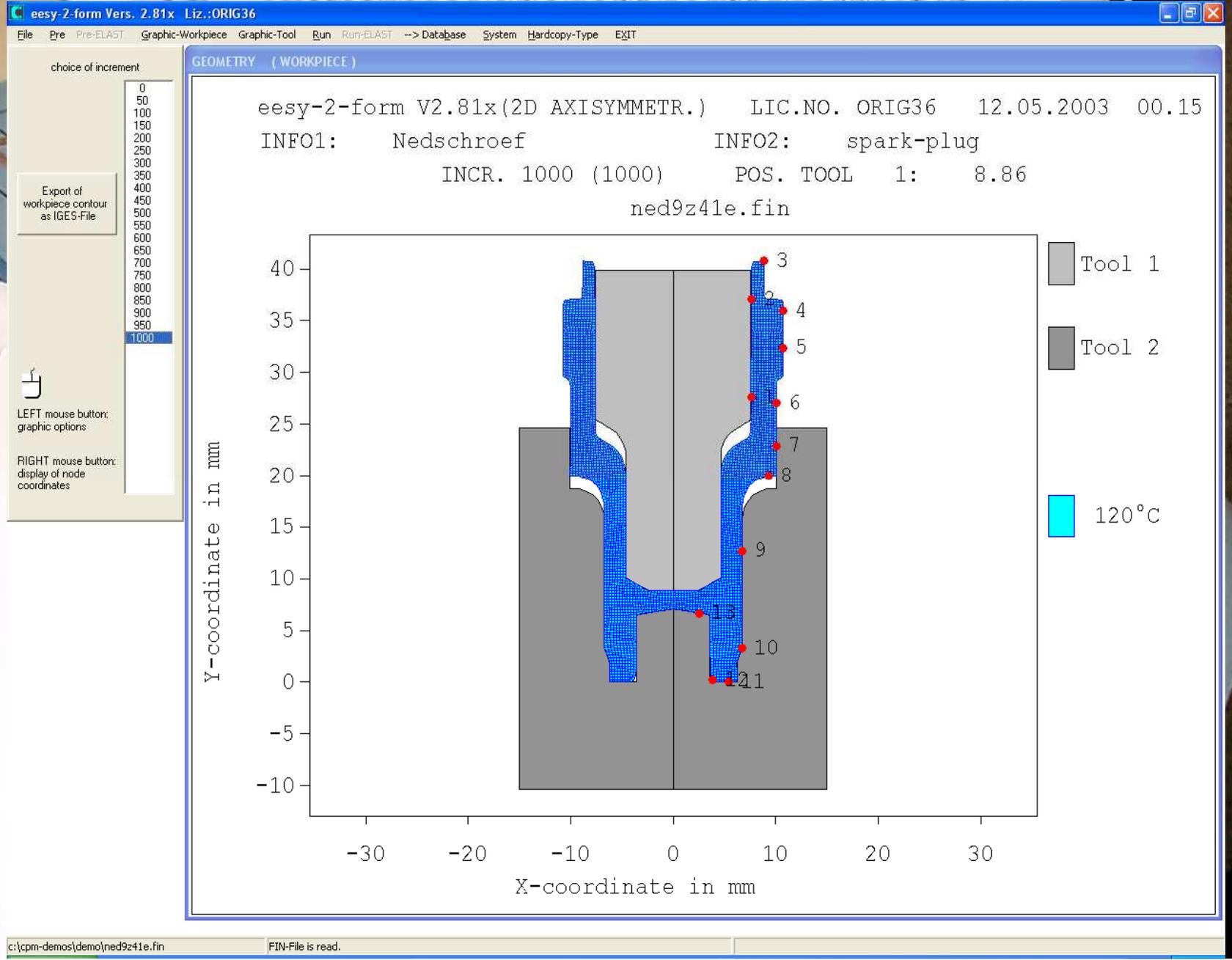
eesy-2-form V2.81x(2D AXISYMMETR.) LIC.NO. ORIG36 12.05.2003 00.14

INFO1: Nedschroef

INFO2: spark-plug

ned9a41e.fin





R&D in public funded and bilateral projects

Verbesserte Verfahren der Gewindeherstellung

3D Simulation

Forgenet

Ecologically Optimised Cold Forging

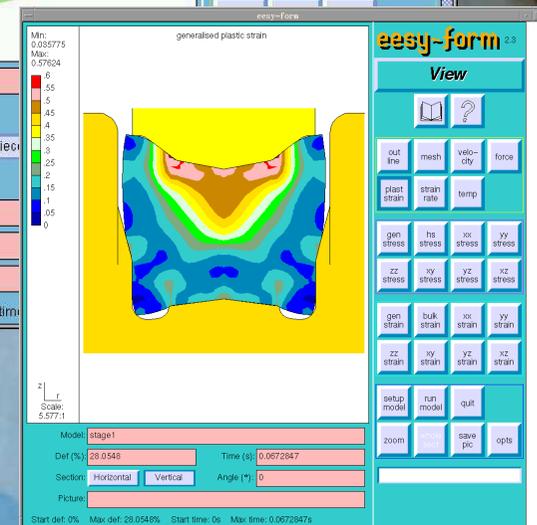
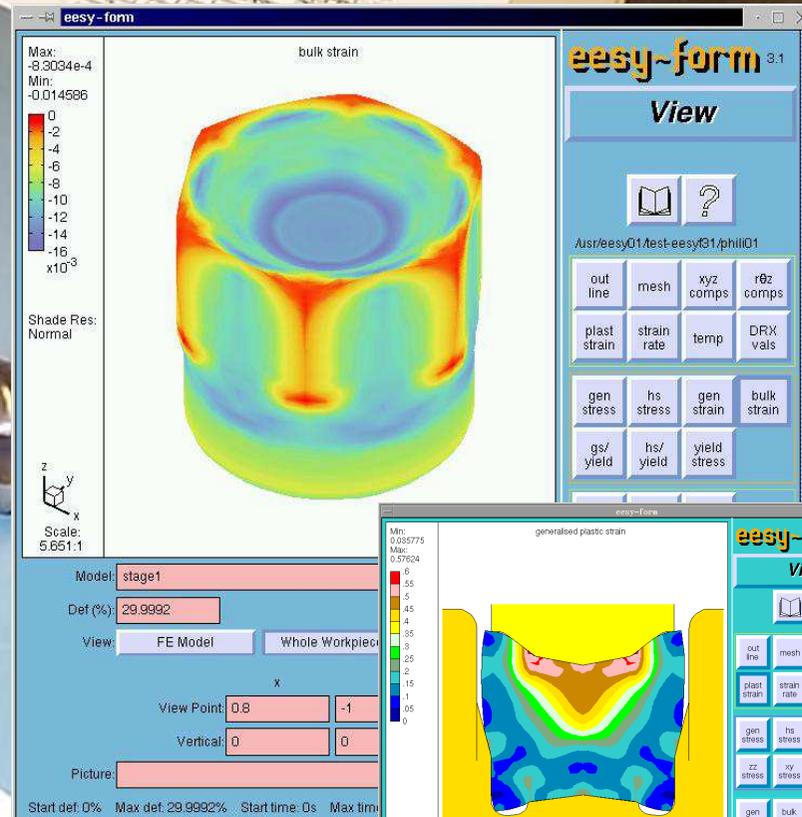
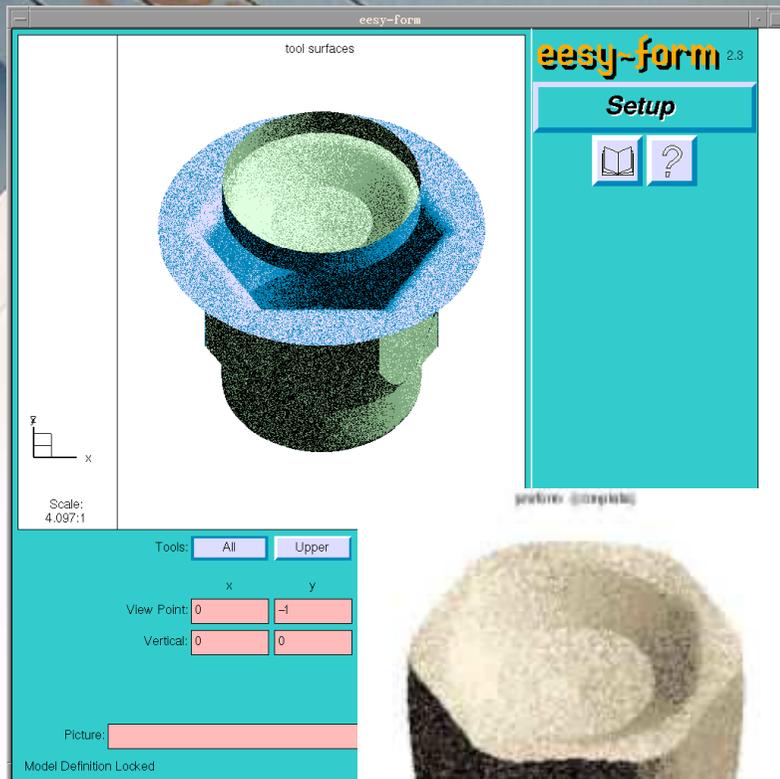
Yield Stress Strain Curves

Modeling of Metal forming based on microstructure for micro-alloyed steels in multi-station forging operations

Aluminum parts for Automotive applications

Development of simulation systems

Example of a 3D application



Development of simulation systems

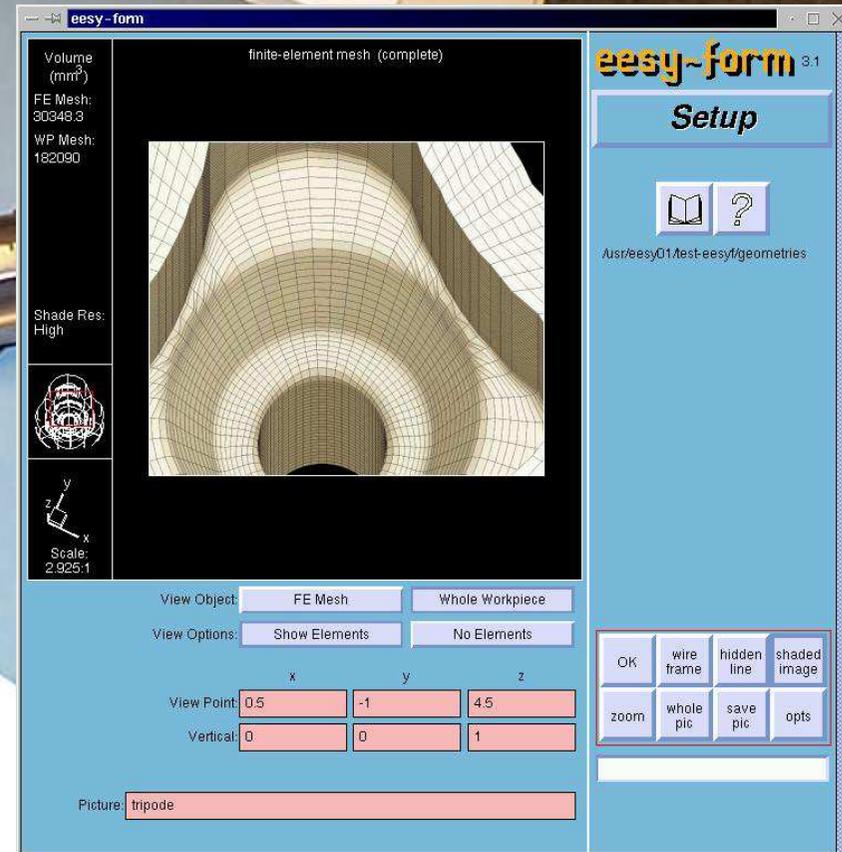
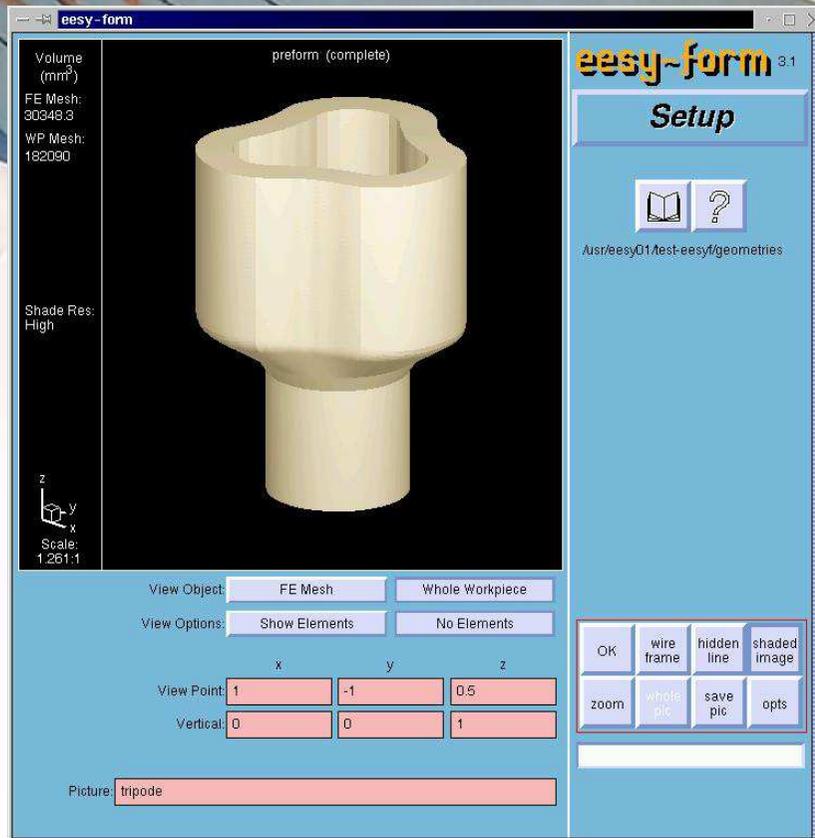
Example of a 3D application

The image displays the eesy-form 3.1 software interface, which is used for finite element simulation. It features several windows and panels:

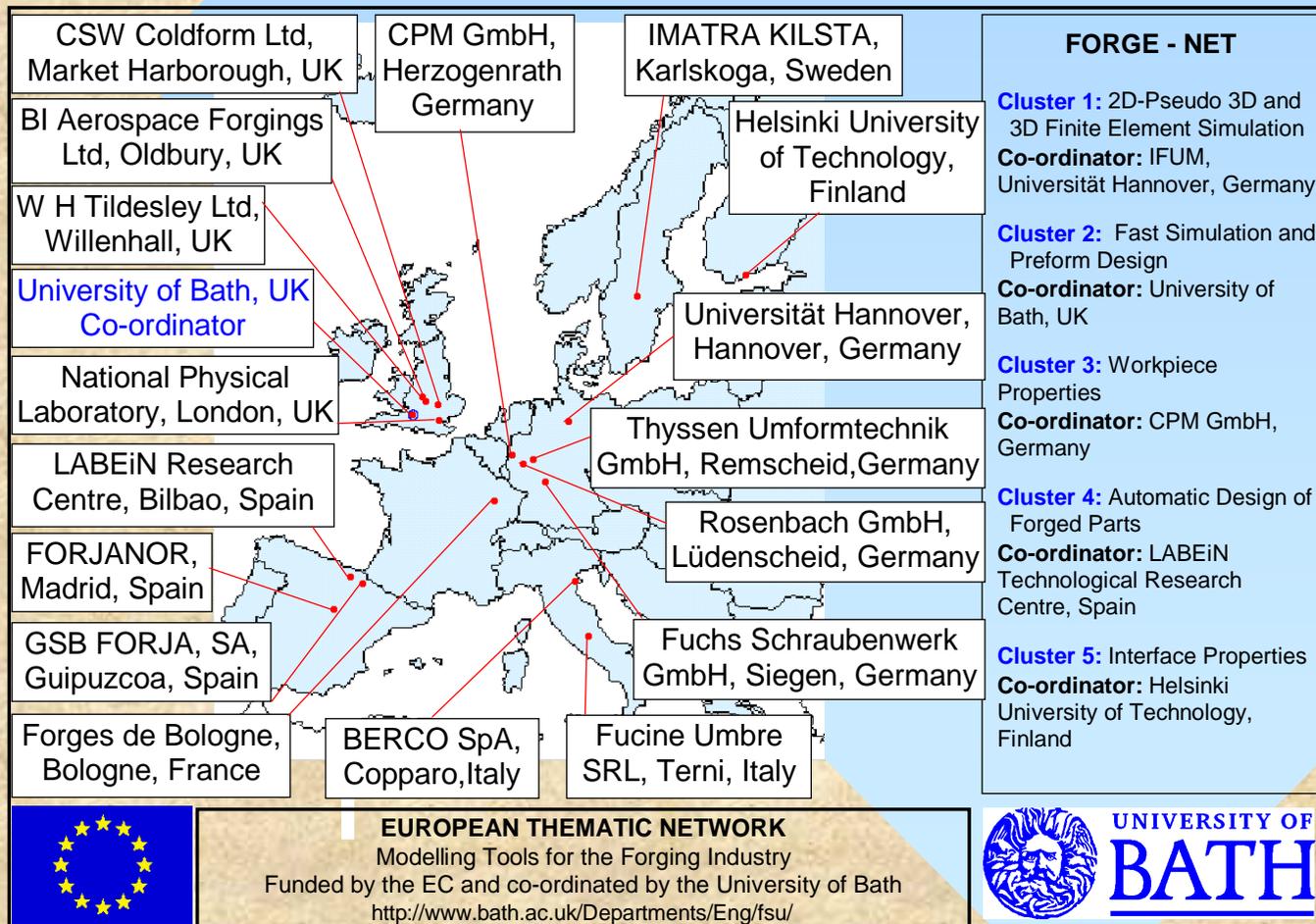
- Left Panel (Properties):** Displays simulation parameters for the finite-element mesh (complete).
 - Volume (mm³): 115.057
 - FE Mesh: 1380.69
 - WP Mesh: -1.167%
 - Change: -1.167%
 - Shade Res: Medium
 - Scale: 5.805:1
- Top-Left Window (View):** Shows a 3D perspective view of the finite element mesh of a bolt-like component. The title bar indicates "eesy-form 3.1" and "View".
- Top-Right Window (Setup):** Shows a cross-sectional view of a preform and tool. The title bar indicates "eesy-form 3.1" and "Setup". It includes a "run model" button and a "view result" button.
- Bottom-Left Window (View):** Shows a stress/strain analysis of the bolt. The title bar indicates "eesy-form 3.1" and "View". It displays a color-coded stress distribution on the bolt, with a legend on the left showing values from -0.84996 to 0.14952. The legend also includes a scale of $\times 10^{-1}$. The window includes a "View" menu and a "Picture" button.
- Bottom-Right Window (View):** Shows a stress/strain analysis of the bolt. The title bar indicates "eesy-form 3.1" and "View". It displays a color-coded stress distribution on the bolt, with a legend on the left showing values from -0.84996 to 0.14952. The legend also includes a scale of $\times 10^{-1}$. The window includes a "View" menu and a "Picture" button.

Development of simulation systems

Example of a 3D application



R&D in public funded and bilateral projects: Forgenet



CSW Coldform Ltd,
Market Harborough, UK

CPM GmbH,
Herzogenrath
Germany

IMATRA KILSTA,
Karlskoga, Sweden

BI Aerospace Forgings
Ltd, Oldbury, UK

Helsinki University
of Technology,
Finland

W H Tildesley Ltd,
Willenhall, UK

University of Bath, UK
Co-ordinator

Universität Hannover,
Hannover, Germany

National Physical
Laboratory, London, UK

Thyssen Umformtechnik
GmbH, Remscheid, Germany

LAbEiN Research
Centre, Bilbao, Spain

Rosenbach GmbH,
Lüdenscheid, Germany

FORJANOR,
Madrid, Spain

GSB FORJA, SA,
Guipuzcoa, Spain

Fuchs Schraubenwerk
GmbH, Siegen, Germany

Forges de Bologne,
Bologne, France

BERCO SpA,
Copparo, Italy

Fucine Umbre
SRL, Terni, Italy



EUROPEAN THEMATIC NETWORK
 Modelling Tools for the Forging Industry
 Funded by the EC and co-ordinated by the University of Bath
<http://www.bath.ac.uk/Departments/Eng/fsu/>



**UNIVERSITY OF
BATH**

R&D in public funded and bilateral projects

Innovative processes in producing screws (Aluminium) (MWM-TV-NRW)

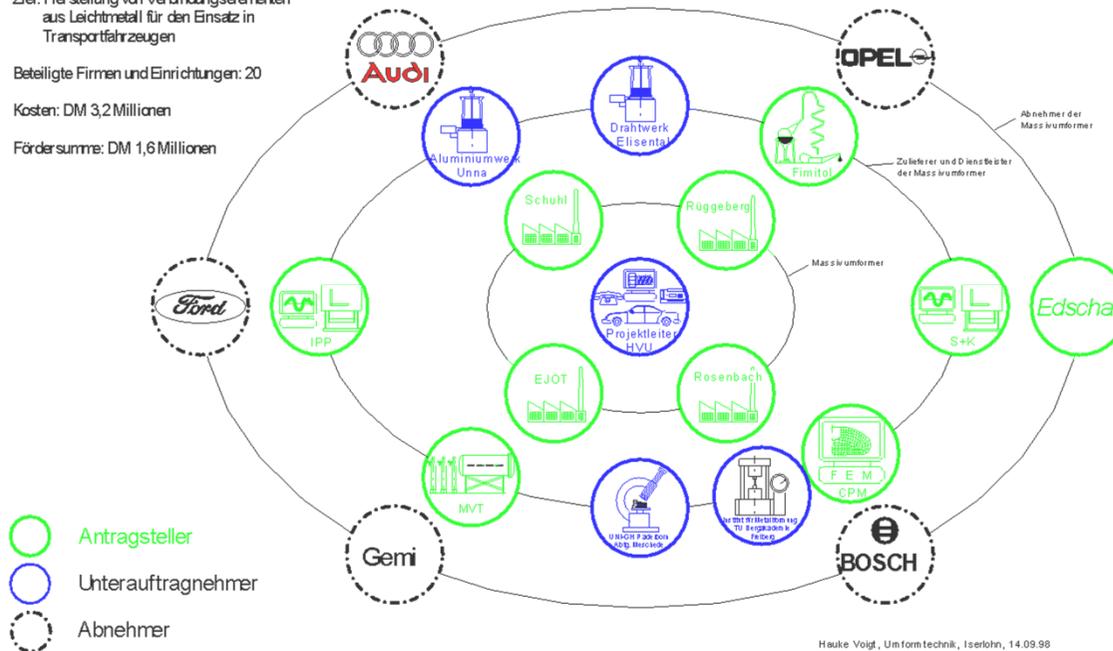
Vom Ministerium für Wirtschaft, Mittelstand, Technologie und Verkehr des Landes NRW gefördertes
Verbundprojekt "Innovative Fertigungsverfahren in der Schraubenindustrie"

Ziel: Herstellung von Verbindungselementen aus Leichtmetall für den Einsatz in Transportfahrzeugen

Beteiligte Firmen und Einrichtungen: 20

Kosten: DM 3,2 Millionen

Fördersumme: DM 1,6 Millionen



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- **Tasks to solve:**
 - Garde of aluminium
 - History before forging (casting, drawing, heat-treatment)
 - Forging technology
 - Progression
 - Tooling
 - Tool Coating
 - Lubrication
 - Handeling
 - Heat-treatment
 - Coating

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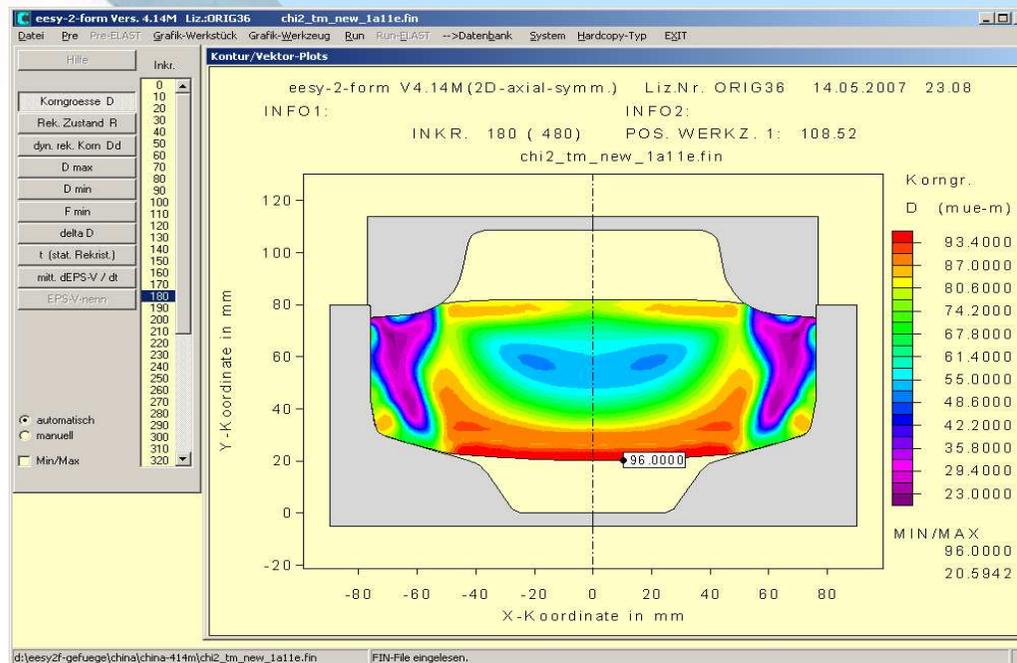
R&D in public funded and bilateral projects

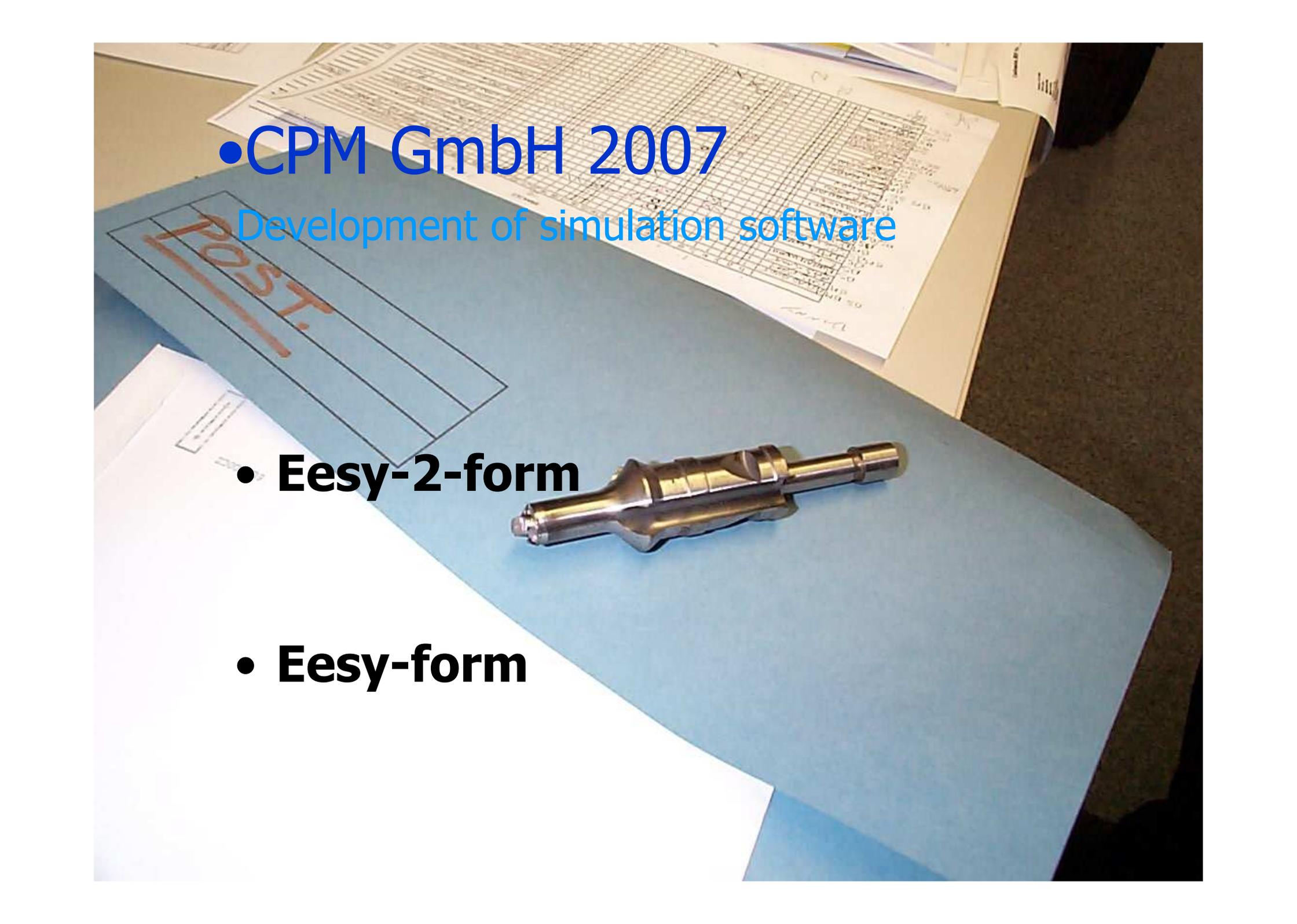
Ecologically Optimized Cold Forging

- no phosphate
- coated wire
- new oils
- tool surface treatment
-

R&D in public funded and bilateral projects

Modeling of Metal forming based on microstructure for micro-alloyed steels in multi-station forging operations



A photograph of a desk with a blue folder, a metal tool, and various papers. The folder has 'POST.' written on it. A metal tool, possibly a drill bit or a similar tool, is lying on the folder. There are several papers scattered around, including one with a grid pattern.

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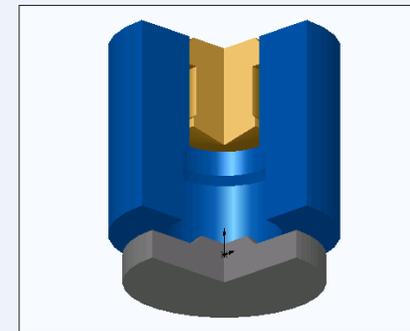
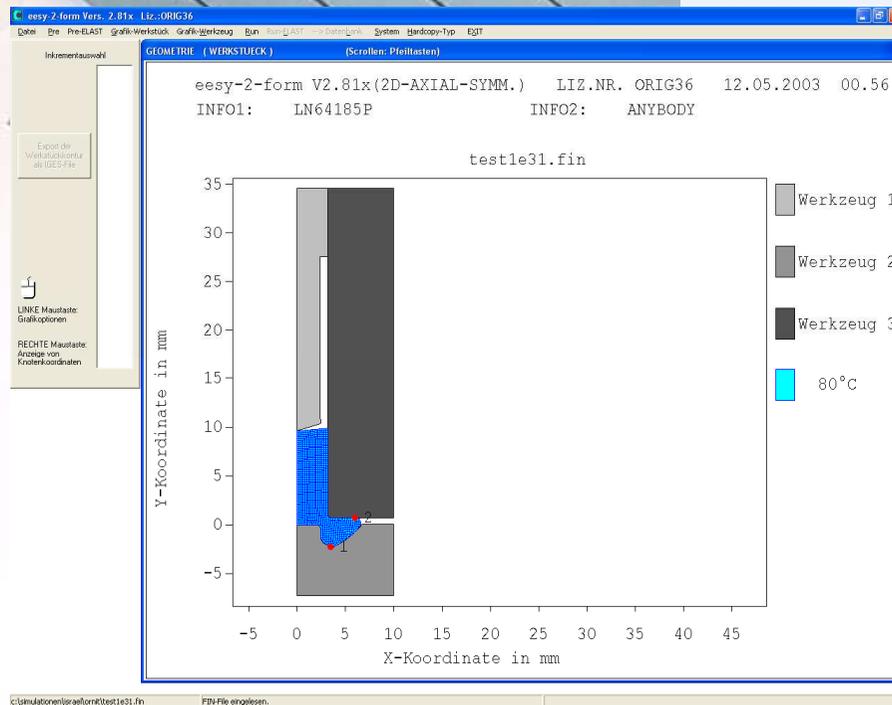
Development of simulation software

- **Easy-2-form**

- **Easy-form**

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easy-2-form

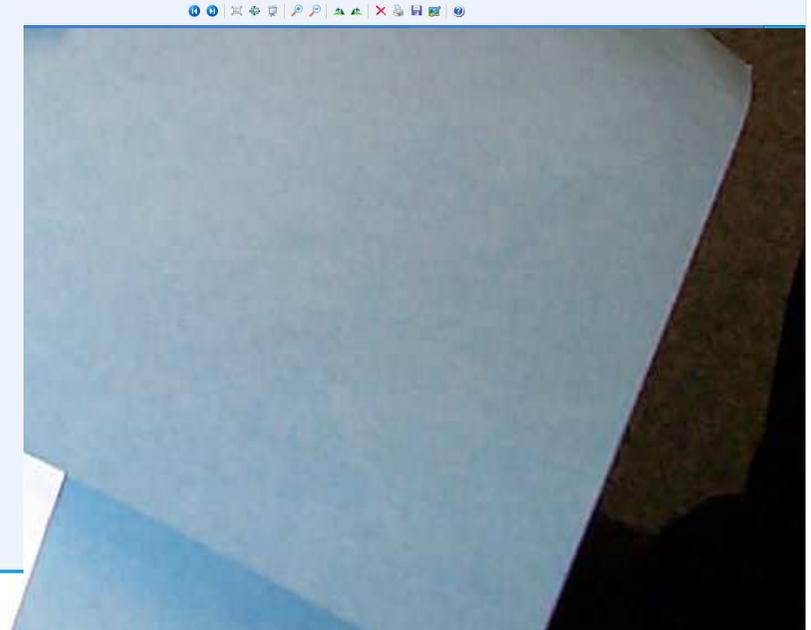
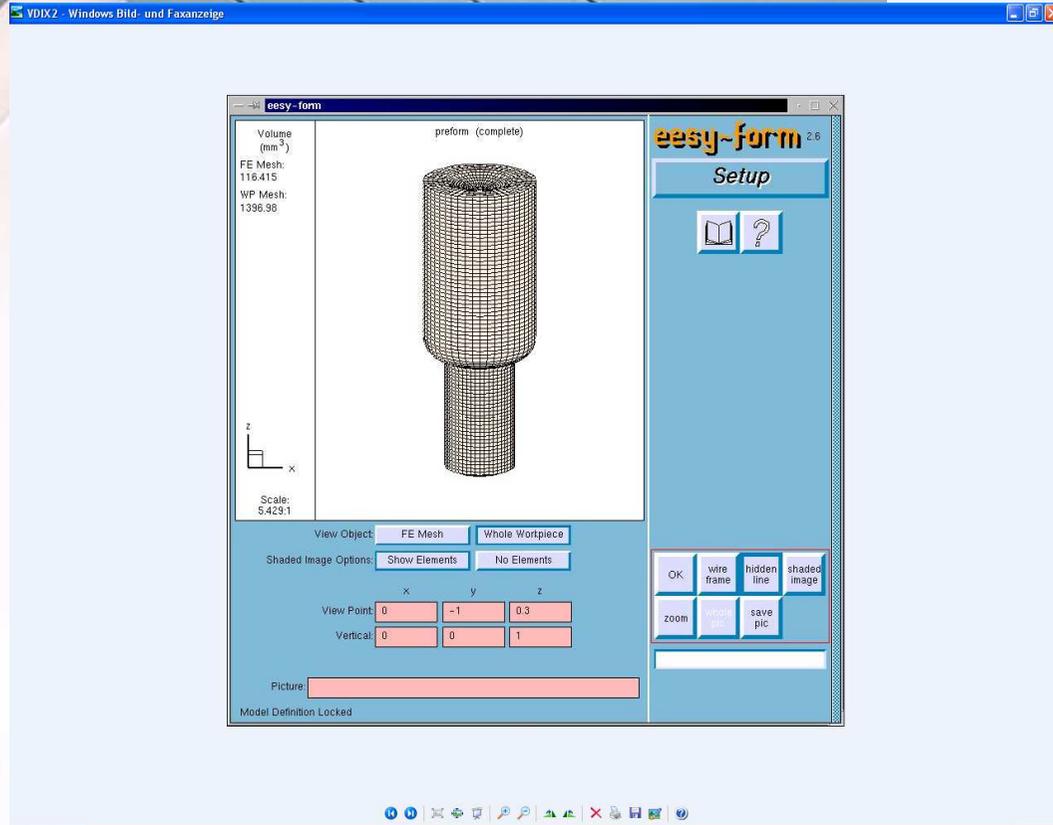
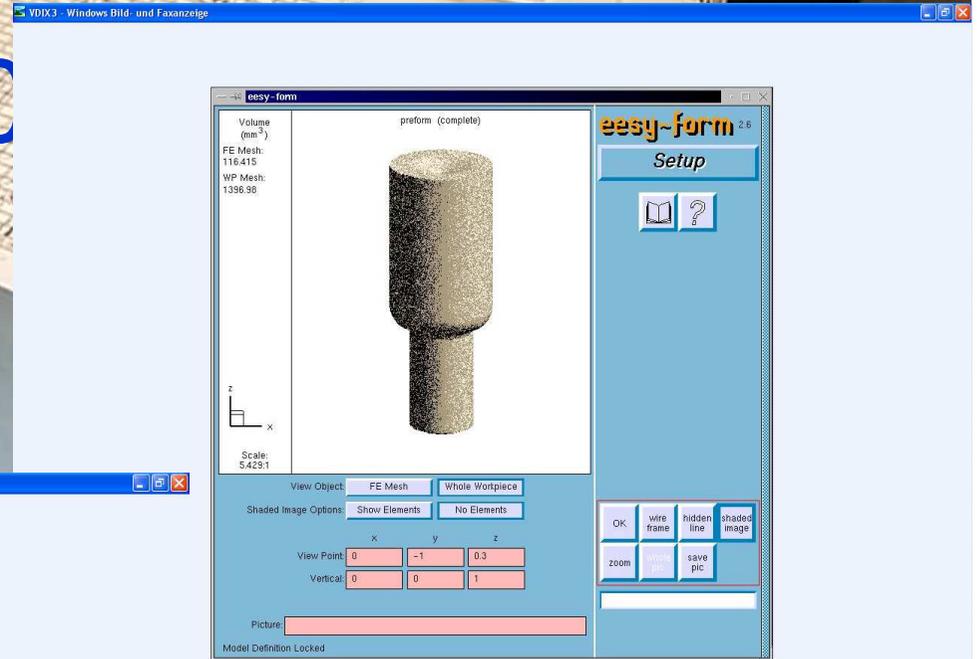


springloaded - Windows Bild- und Faxanzeige

Windows taskbar icons including Start, Run, and application icons.

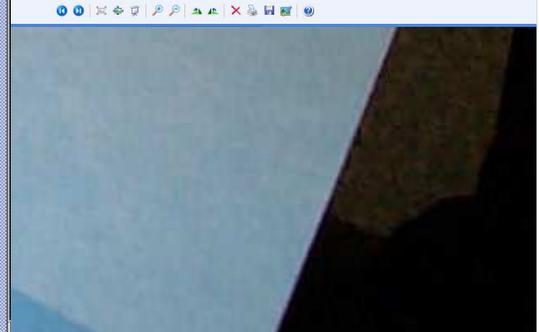
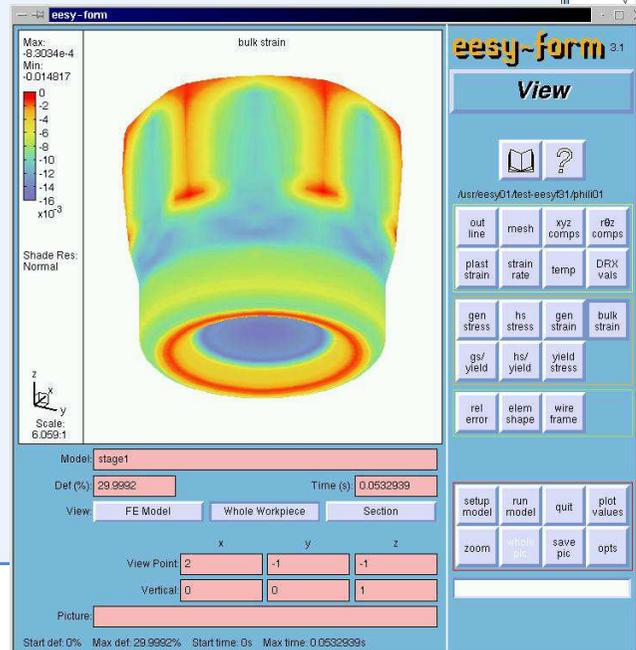
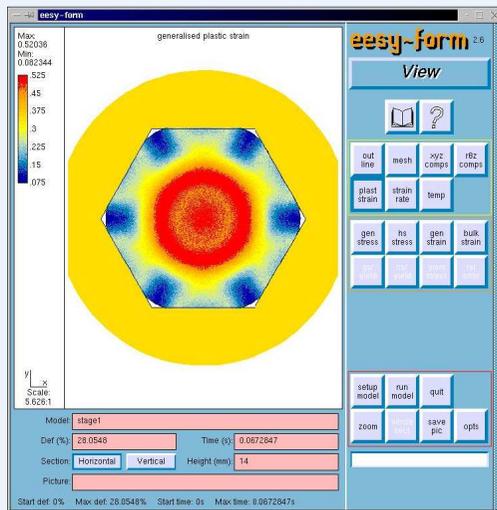
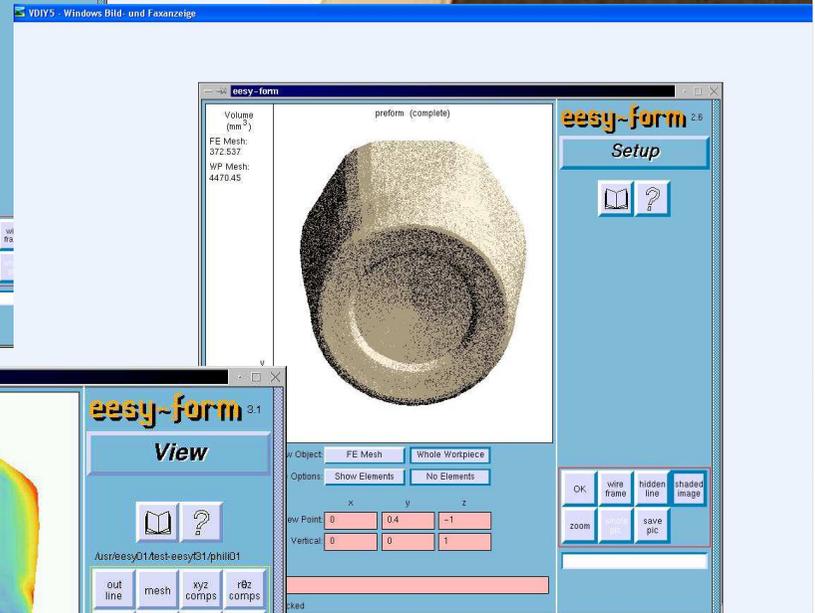
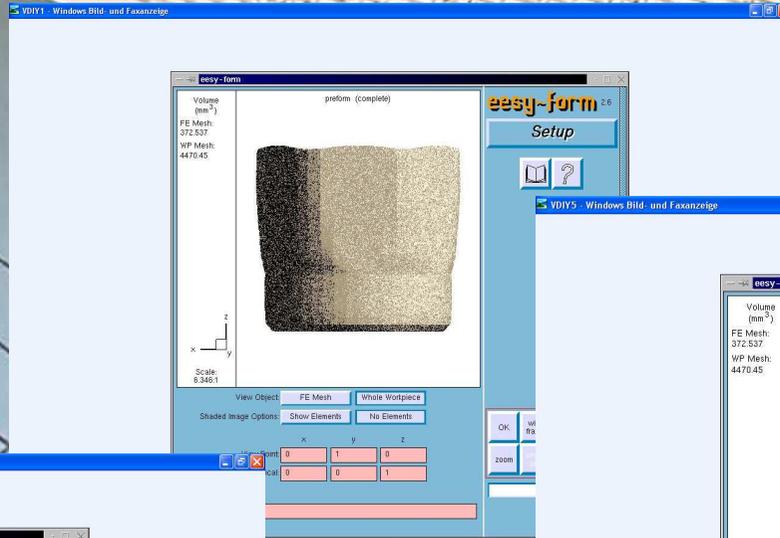
• CPM GmbH 20

easy-form



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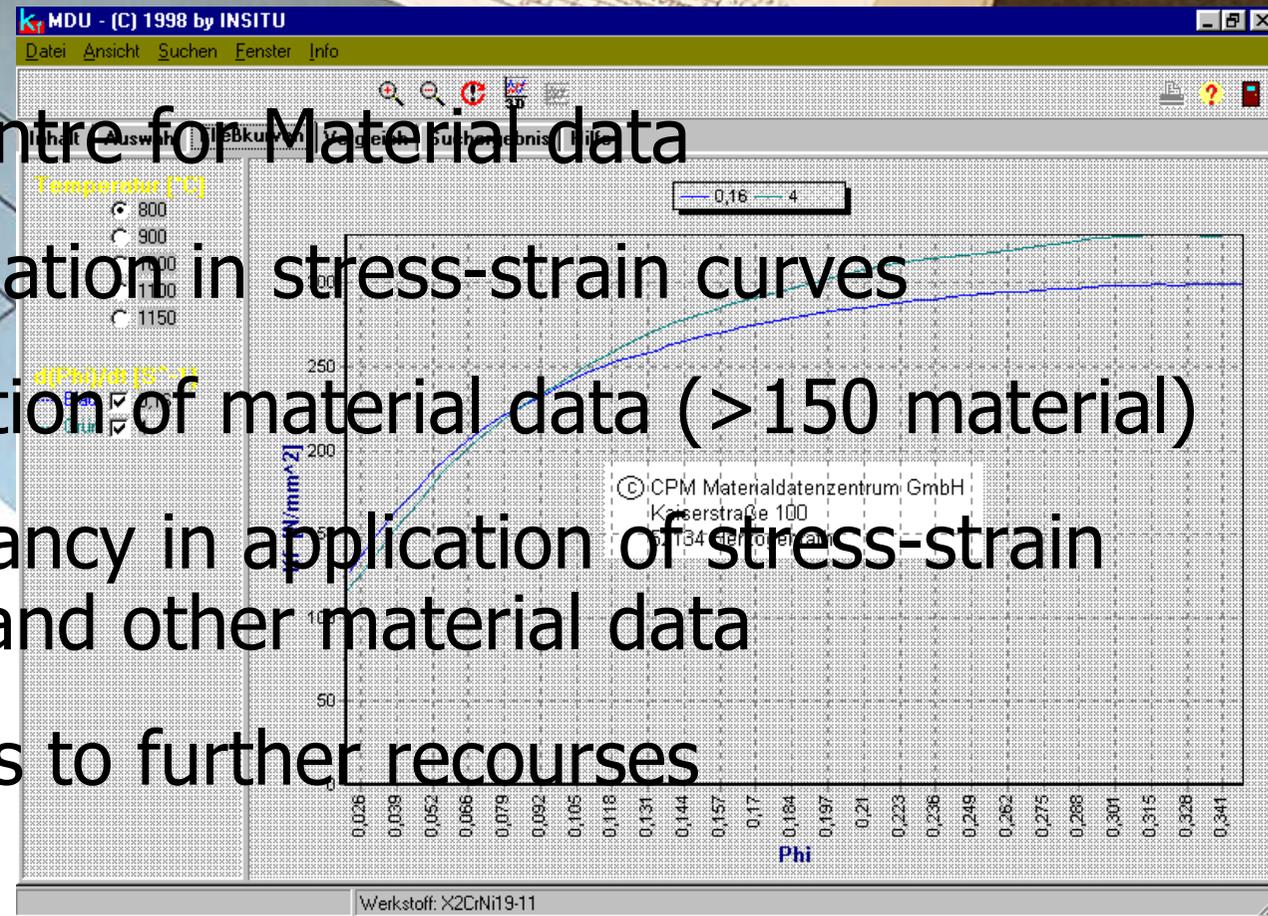
easy-form



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Material data

- Data centre for Material data
- Investigation in stress-strain curves
- distribution of material data (>150 material)
- Consultancy in application of stress-strain curves and other material data
- Contacts to further recourses



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Distribution of Tooling/etc.

- Tooling of TNP for Cold-forging, Korea
Standard tools und Specials
- Special punches (6-lobe,...), Korea
- Dosing-systems of Serte, Italy
- Tooling of Eurotool, Italy
- Tooling of "CG", Taiwan
- Export of special tooling from Germany
- Inspection machines from Italy

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Distribution of Tooling/etc.



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Distribution of Tooling/etc.



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Partners

- **India King Impex, India**
- **Chang Chi Metal, Taiwan**
- **Chang Chi Metal + partners, China**
- **Chierichetti, Italy**
- **Consultec, Brazil**
- **COMTESA, Spain**
- **Jin-A Commerce, Korea**
- **Extrusion Process System, Singapore, Malaysia, Ind.**
- **Memsan, Turkey**
- **Jury Lavrinenko, Russia**
- **Johnson Machines and Tooling, UK + Ireland**
- **Nedschroef, Begium + Worldwide**



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Spectrum of clients

- **Companies producing cold, warm and hot forged parts**
- **Universities**

Companies in the range of small and medium size enterprises up to large companies in international business

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- **CPM Gesellschaft für Computeranwendung, Prozeß- und Materialtechnik mbH
Kaiserstraße 100
D-52134 Herzogenrath**

E-mail: CPM@CPGMBH.COM

www.cpmgmbh.com

Tel.: +49-2407-95940

Fax +49-2407-959466

- **Agent in Korea
Jin-A Commerce, Seoul**

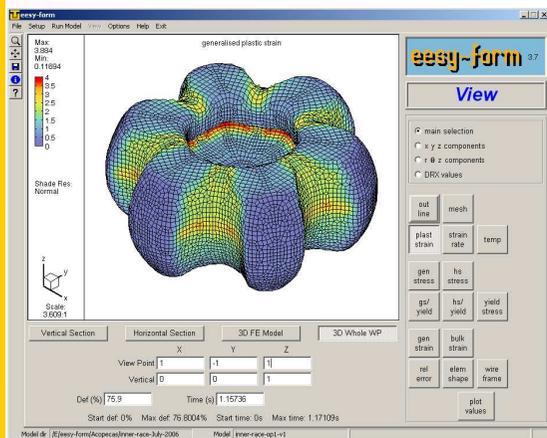


“Simulation for process and die design in forging”

Industrial applications of Simulation

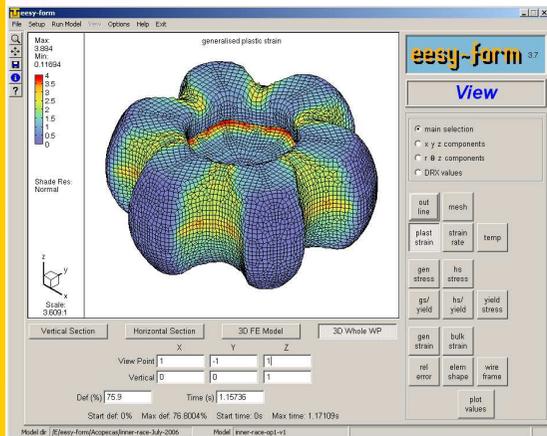
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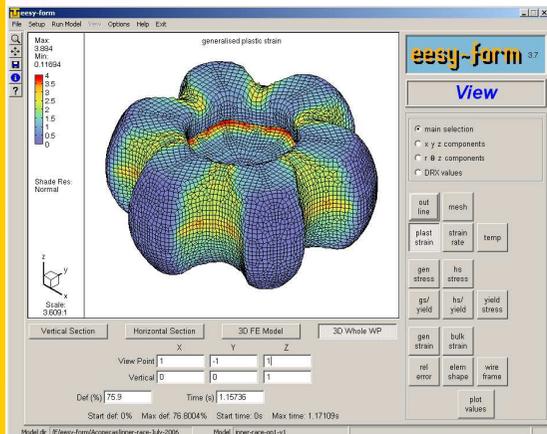
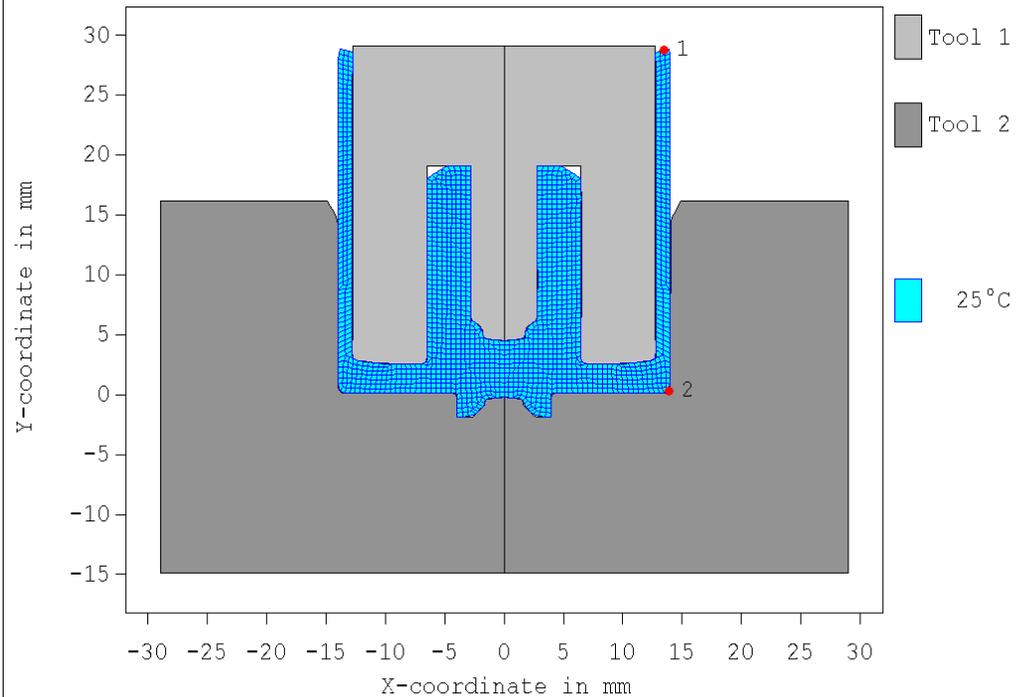
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```
eesy-2-form V2.85x(2D AXISYMMETR.) LIC.NO. ORIG36 11.06.2003 11.39  
INFO1: dia 17 t 4.5 ty2 INFO2: mesh 0.3  
INCR. 600 ( 600) POS. TOOL 1: 4.50  
arf-core_lb21e.fin
```



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Principle of Process Design Work

Product drawing

Empirical process design

Testing on the machine

Re-design

Development cycle

© AE Engineering



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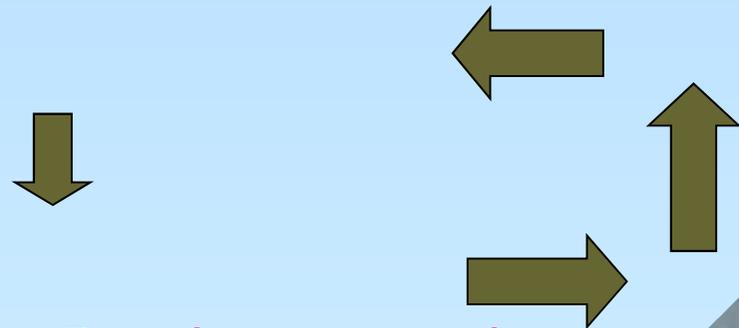
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Principle of Process Design Work

This development cycle is very cost intensive
and covers a lot of uncertainties

Testing on the machine

Re-design



Development cycle

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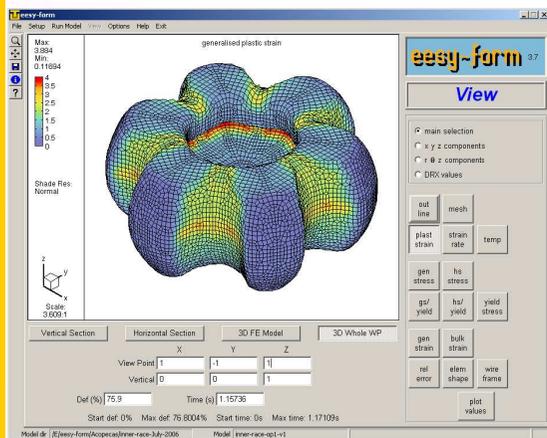
Besides reducing the costs of the product development
Simulation can help

- To develop specific product properties
- To analyze the product application
- To train production and engineering personal
- To explain production tasks to a customer during common development
- To build up technological „know why“
-



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Examples of application

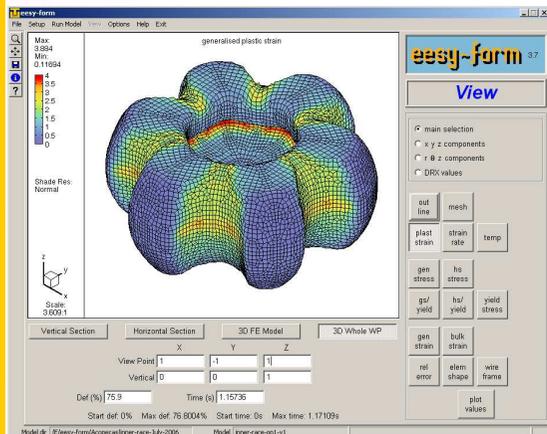


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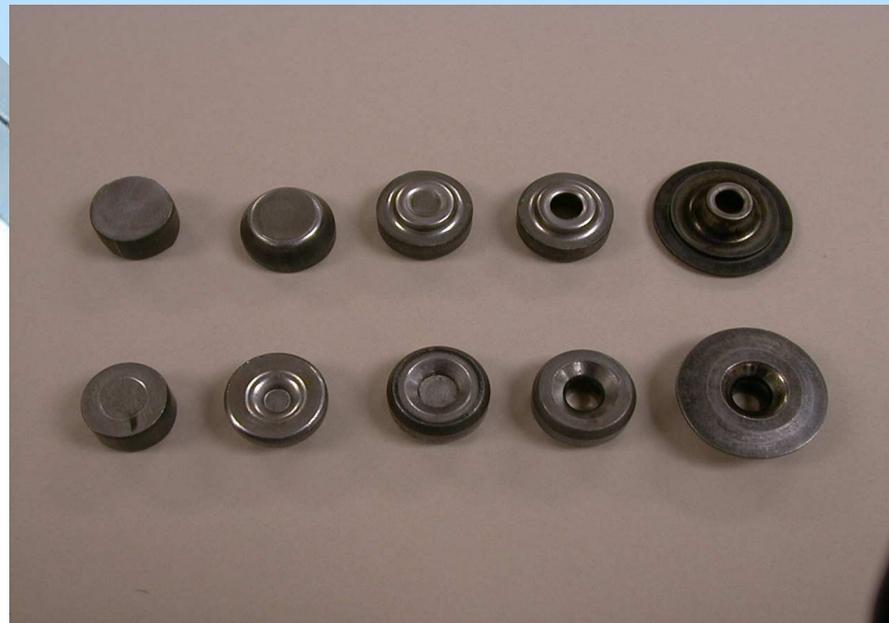
Examples of application

- Tool failure in production of a valve spring retainer
- Folding of material
- Failure of punch because of contact problems
- Cracking of a screw head do to tangential stress
- Die failure
- Die design
- Forming station with spring loaded die
- Difficult tool design for a combined forward and backward extrusion
- Microstructure prediction in forging



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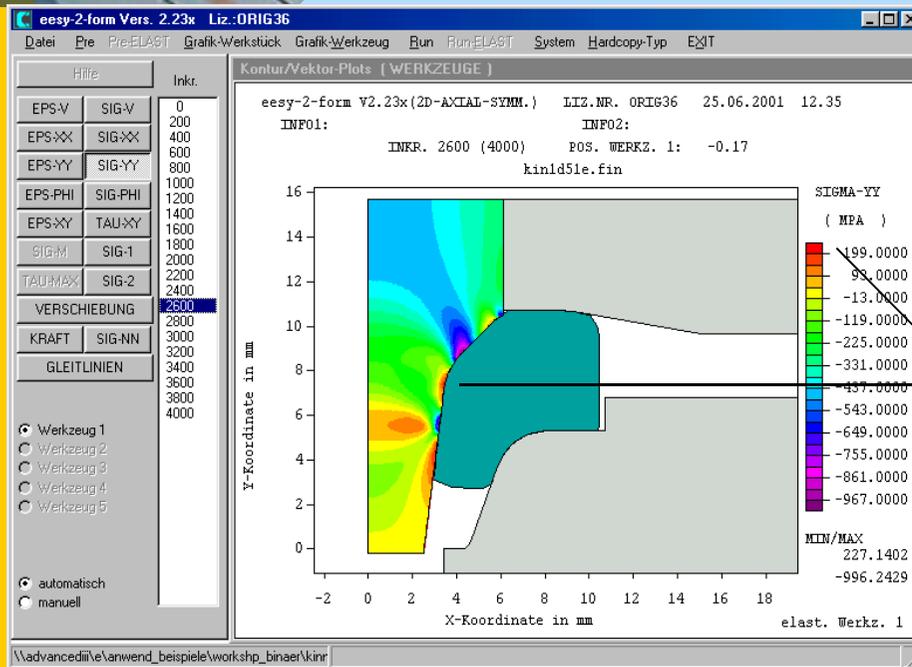
Tool failure in production of a valve spring retainer



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Tool failure in production of a valve spring retainer

- Searching for Failure of punch



High stresses!



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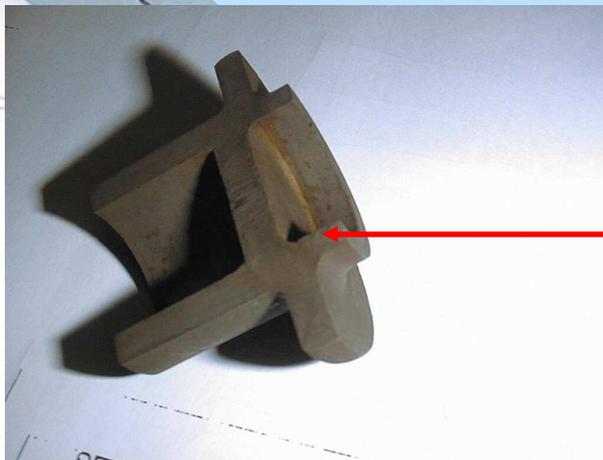
Tool failure in production of a valve spring retainer



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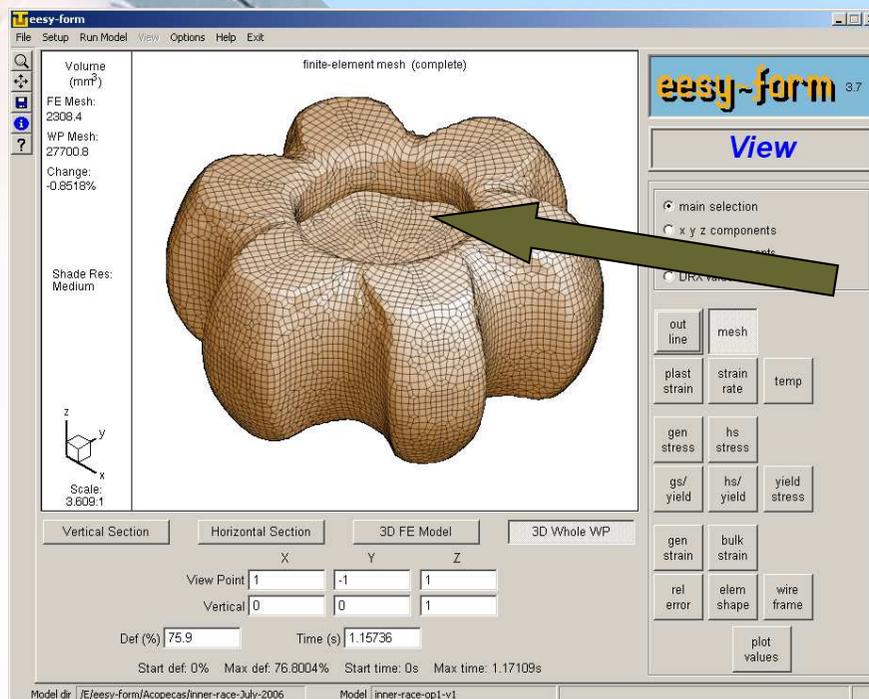
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Folding of material



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Folding of material



Folding / Underfilling

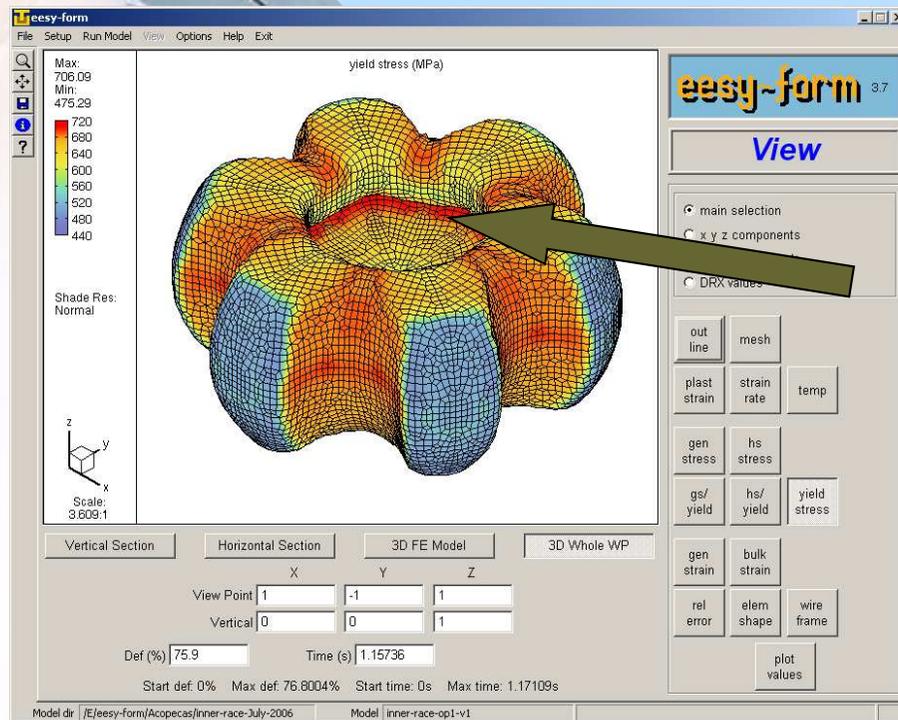
on an inner race



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Folding of material



Folding / Underfilling

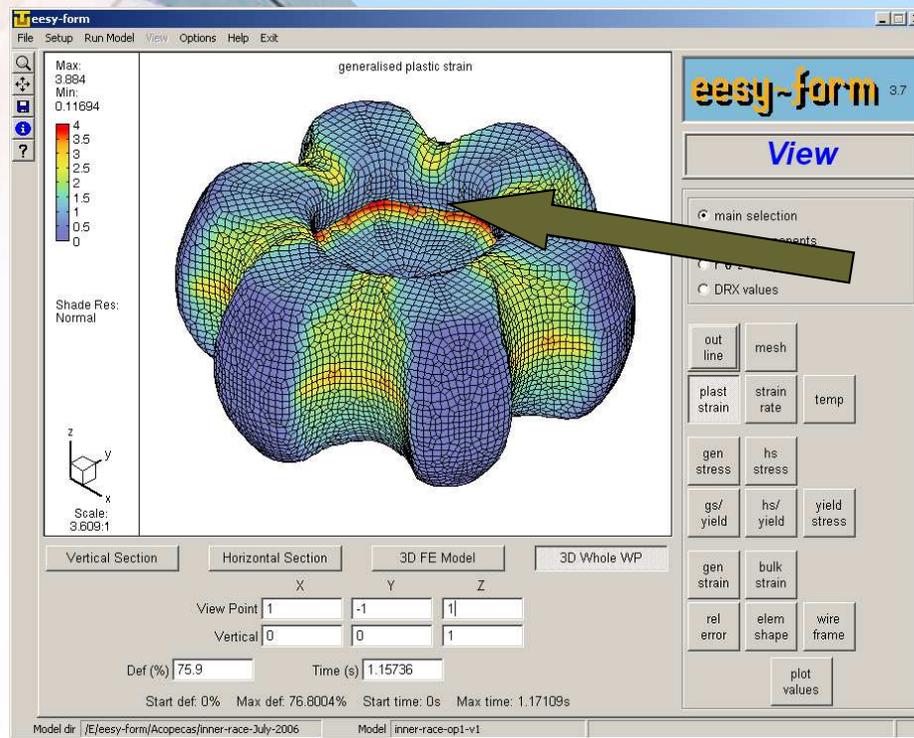
on an inner race



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Folding of material



Folding / Underfilling

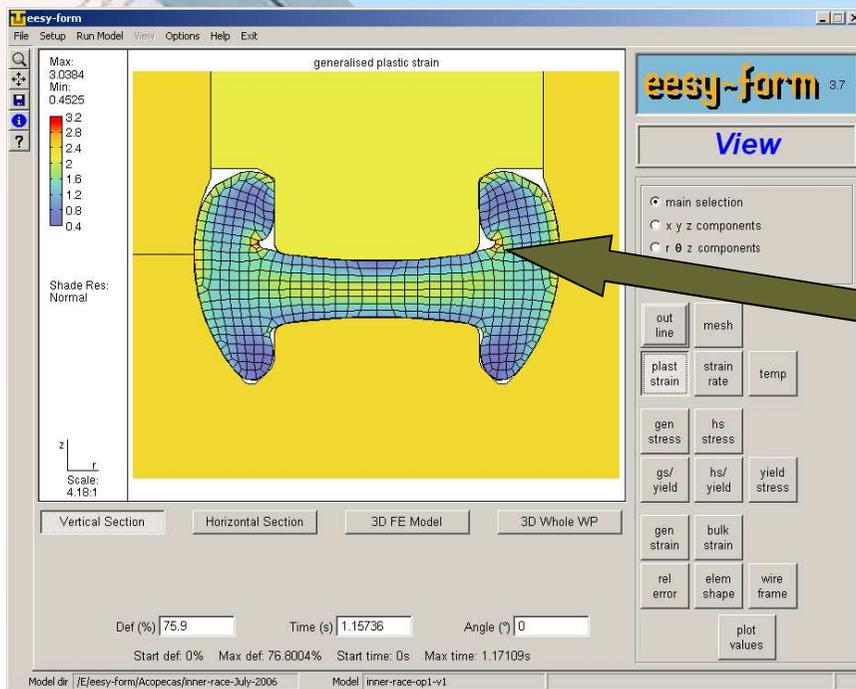
on an inner race



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Folding of material



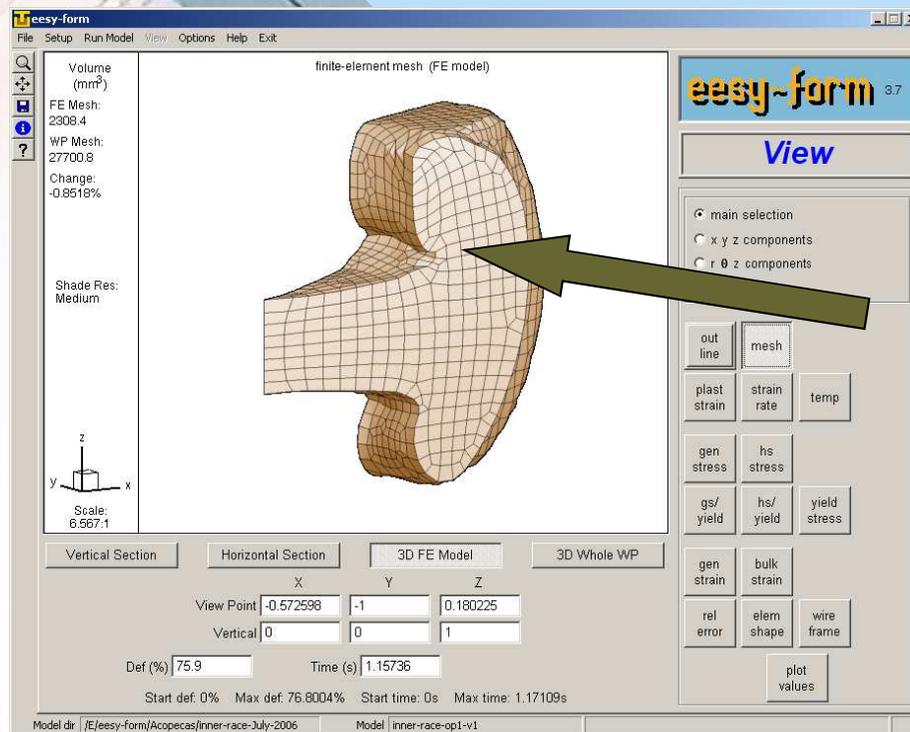
Folding / Underfilling
on an inner race



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Folding of material



Folding / Underfilling

on an inner race



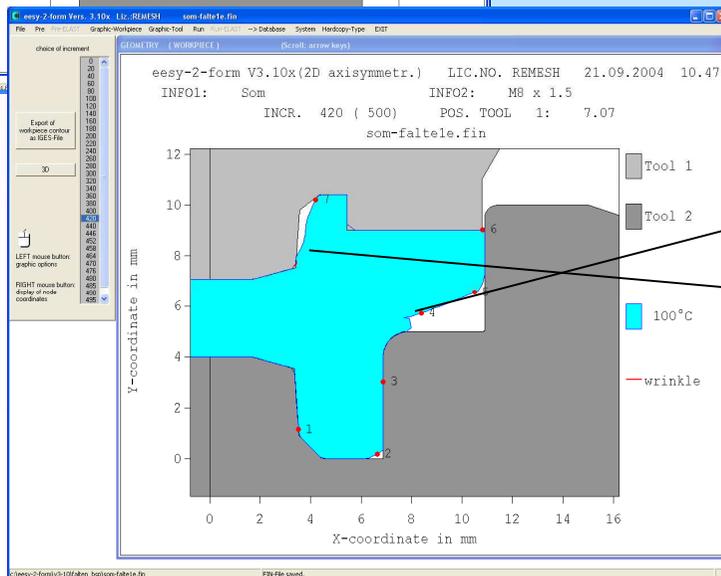
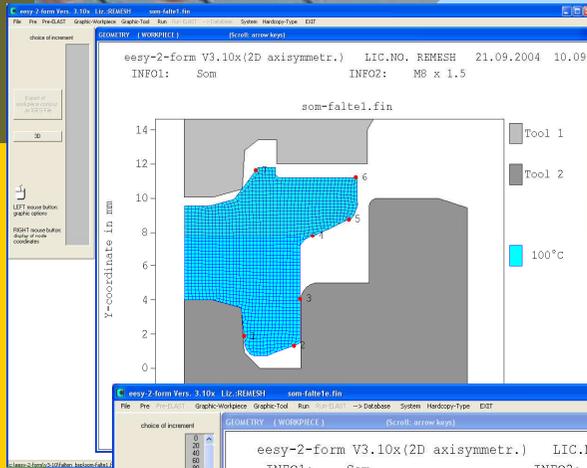
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Folding of material

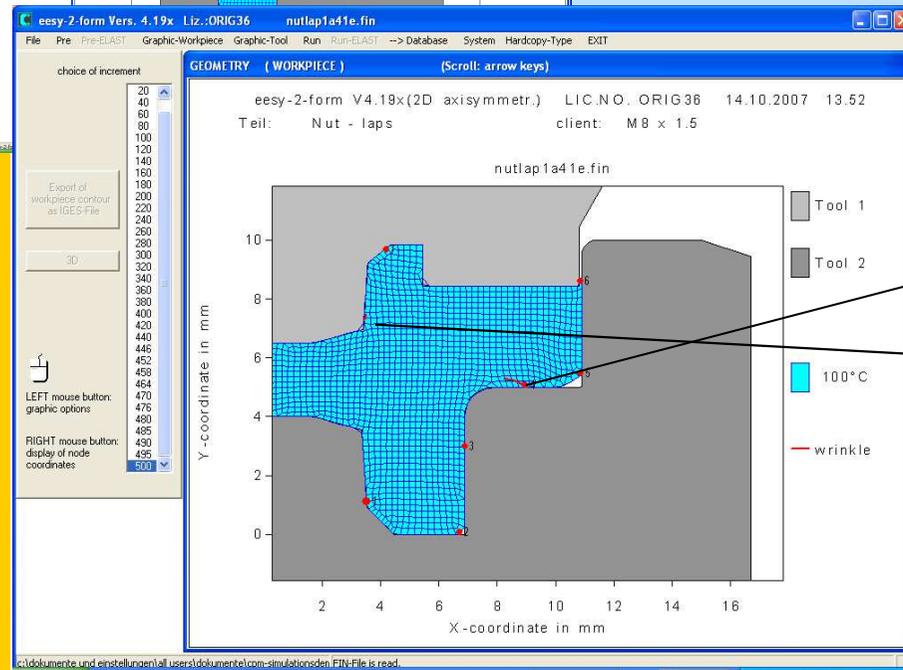
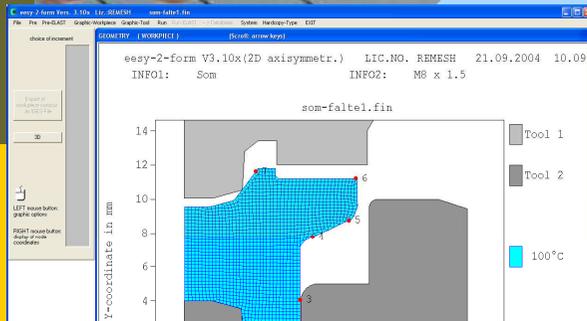
Folding at nut in

- Surface and
- Thread area



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Folding of material



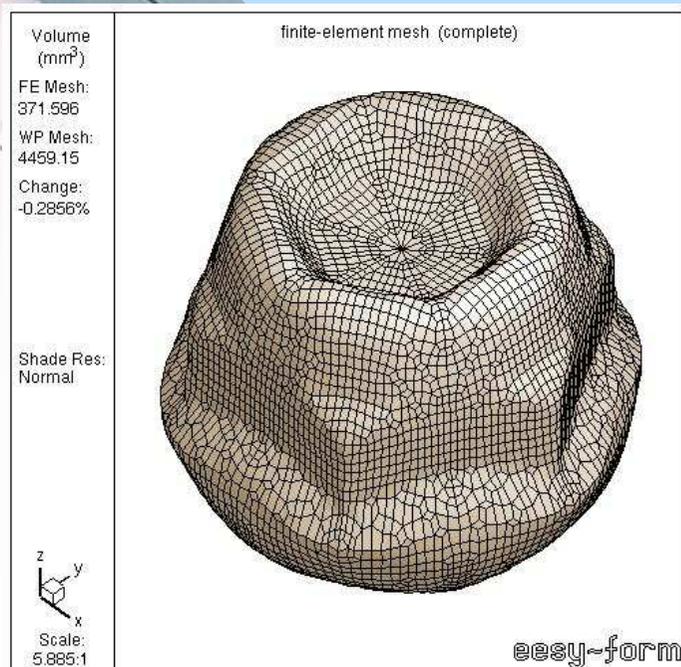
Folding at nut in

- Surface and
- Thread area



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Failure of punch because of contact problems

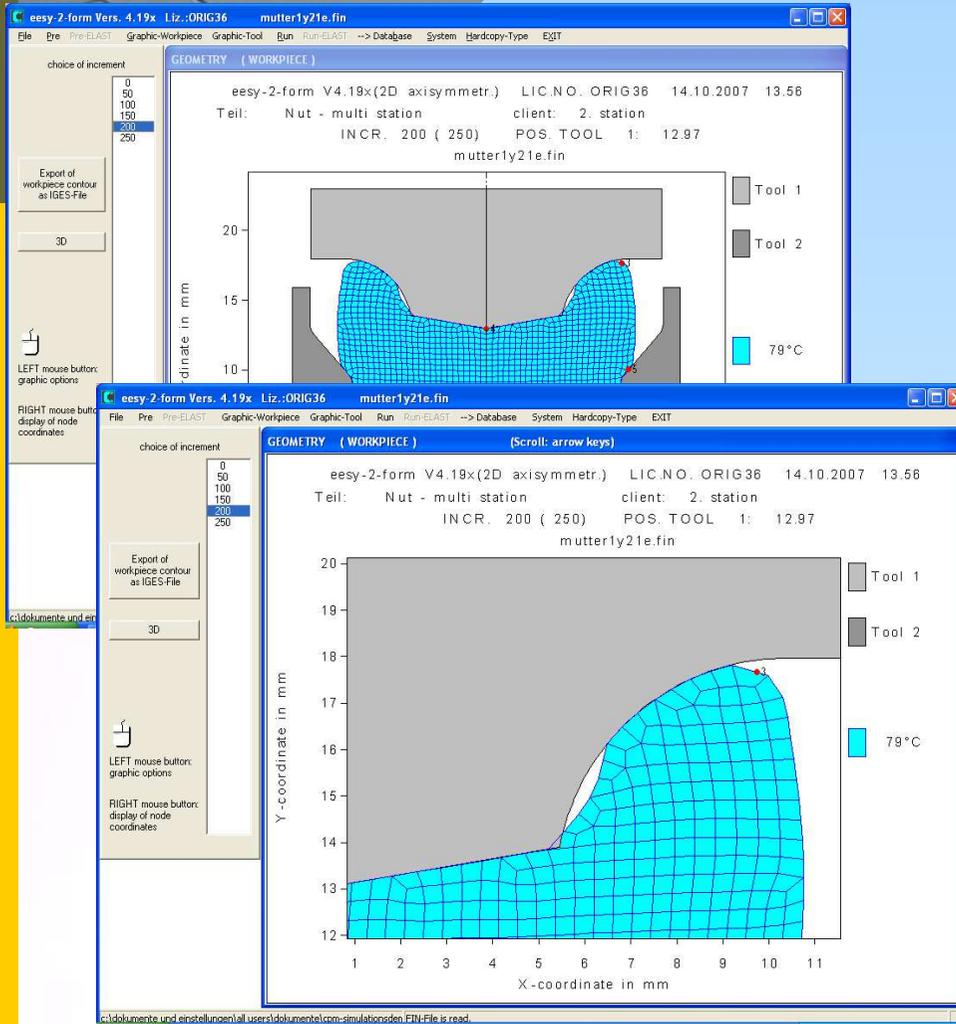


Flansh nut 2nd. Station



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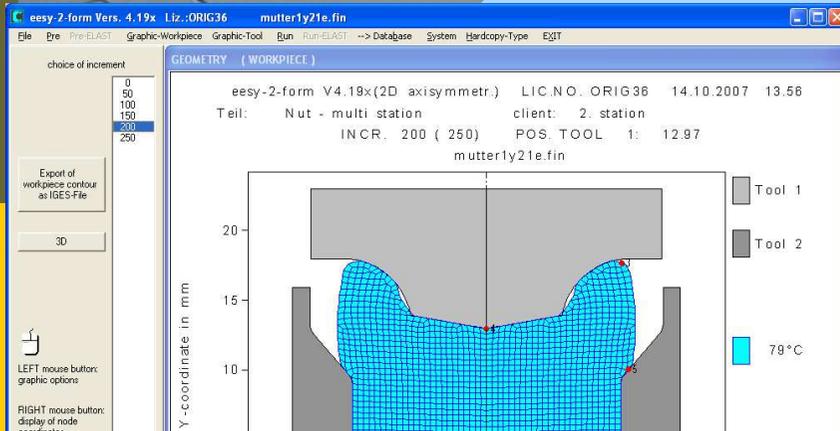
Failure of punch because of contact problems

Flansh nut 2nd. Station

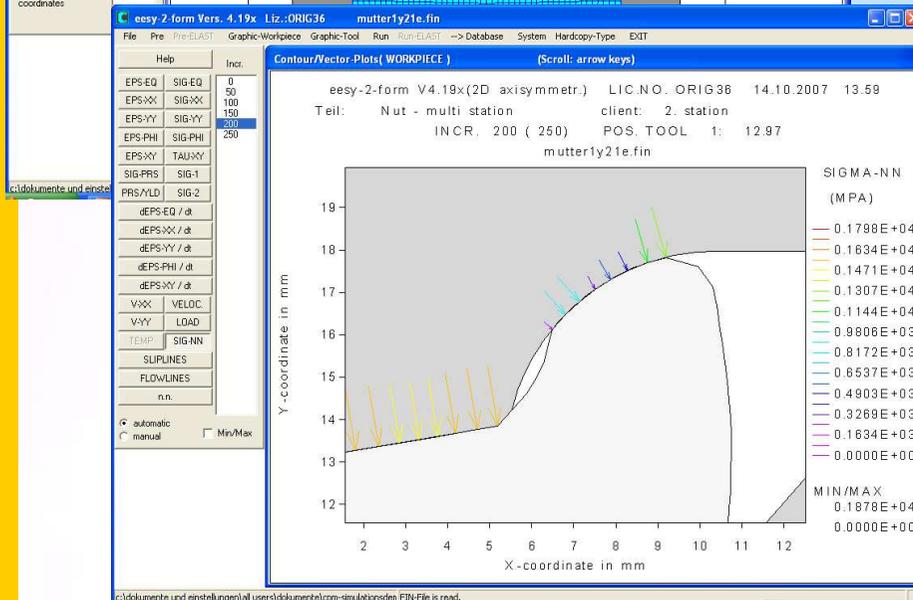
Non sufficient contact between punch and material!



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Failure of punch because of contact problems



Flansh nut 2nd. Station

inhomogeneous stress situation!



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Failure of punch because
of contact problems

Failure of a punch in another
nut making process due
to the same reason



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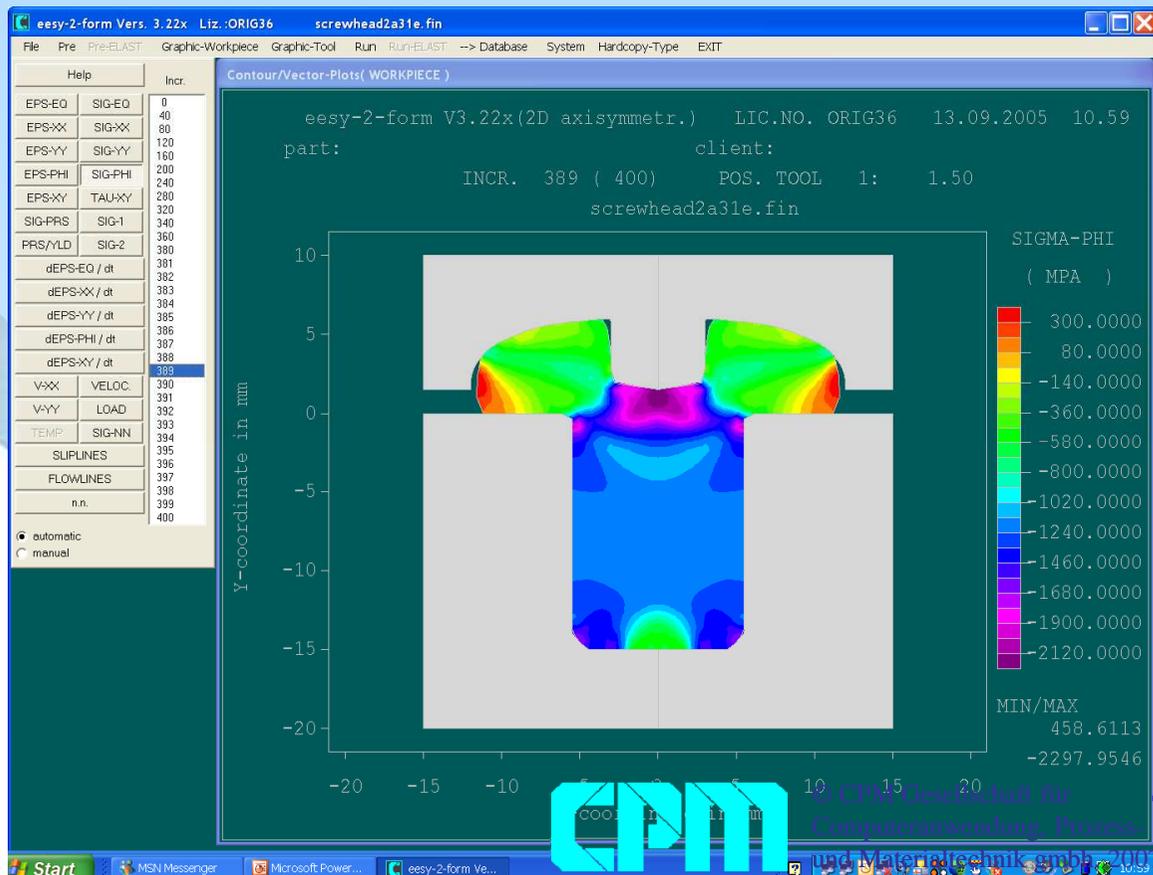
Cracking of a screw head do to tangential stress



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Cracking of a screw head do to tangential stress



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Die failure



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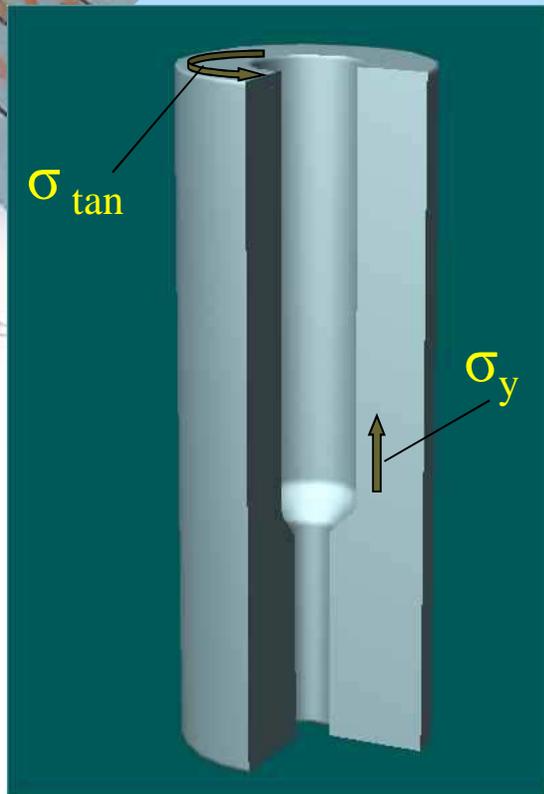
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Die failure



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Die failure

Principle of Die Design

σ_{\tan} : critical for axial crack

σ_y : critical for horizontal crack



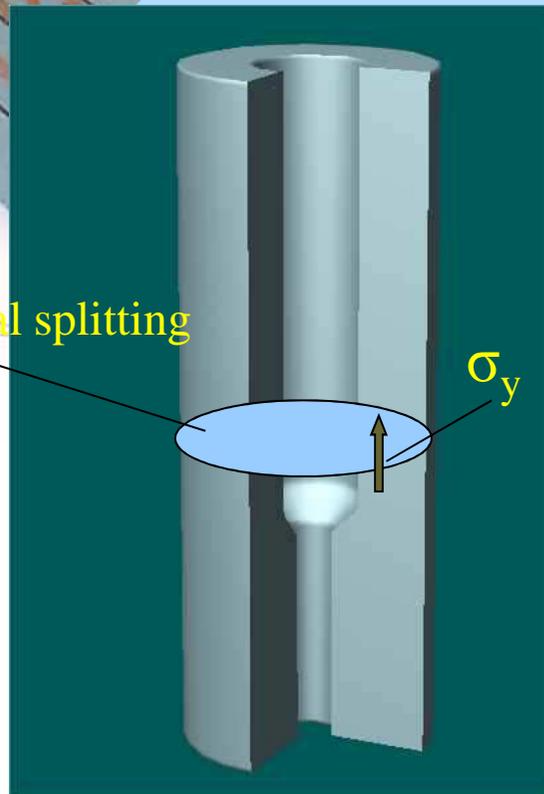
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Die failure

Principle of Die Design

Horizontal splitting



σ_y

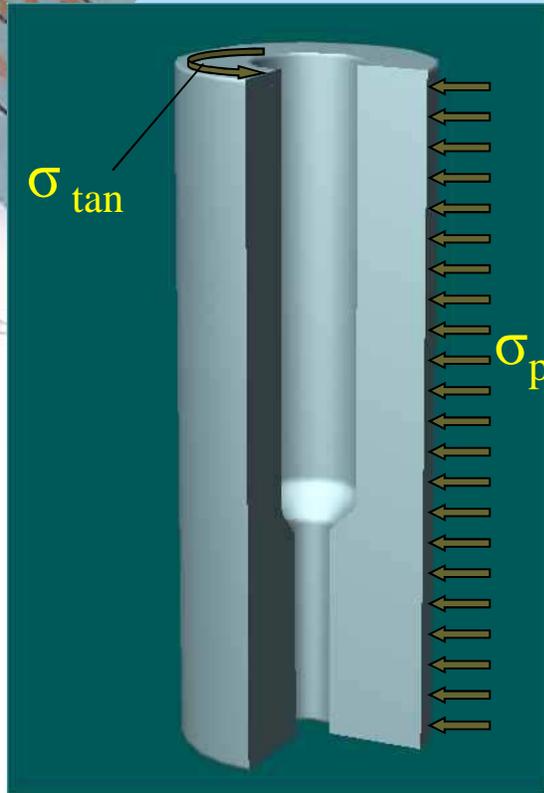
σ_y : critical for horizontal crack

➔ horizontal split of the insert



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Die failure

Principle of Die Design

σ_{tan} : critical for axial crack

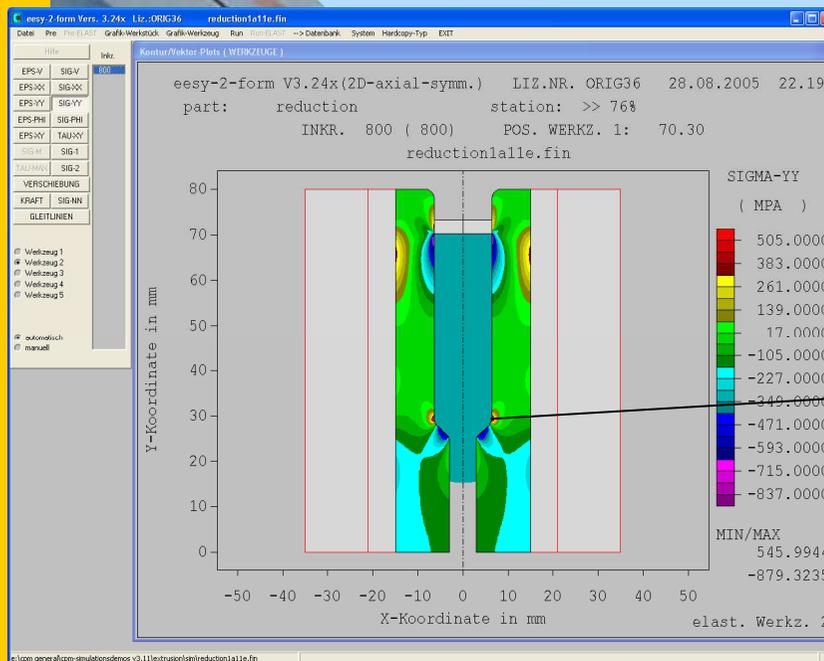
➔ Pre-stressing of the insert



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Die failure

- Avoiding of failures (elastic analysis of the insert with FEM)
Splitting the die to avoid too high axial stresses

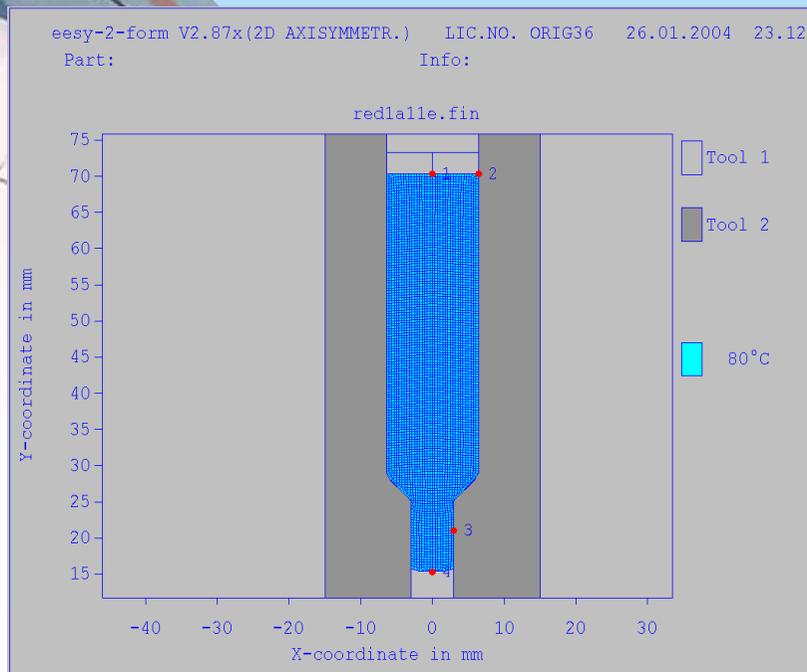


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Die design

Pre-straining of dies

to avoid axial die
breakage



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Die design

Calculation of Die Layout

esy-DieOpt Vers. 1.92 Lizenz für: CPM GmbH, Herzogenrath, Deutschland

Datei 2-RING-SYSTEM (kalt) 2-RING-SYSTEM (warm) 3-RING-SYSTEM 4-RING-SYSTEM Sprache System EXIT

3-RING-SYSTEM Lizenz für: CPM GmbH, Herzogenrath, Deutschland

	Einsatz	1. Schrumpring	2. Schrumpring
Innendurchmesser Di	12.80 mm	1.2344, 56.0	1.2344, 49.9
Aussendurchmesser Da	70.00 mm		
Fugendurchmesser D1	23.00 mm		
Schrumpmaß S1	0.187 mm		
	8.1 0/00		
Fugendurchmesser D2	43.00 mm		
Schrumpmaß S2	0.178 mm		
	4.1 0/00		
Innendruck Pi	1621.9 MPa		
Fugendruck P1	1062.1 MPa		
Fugendruck P2	434.8 MPa		
Konus-Winkel (für D1)	1.0 °		
Pressweg	5.36 mm		

	Einsatz	1. Schrumpring	2. Schrumpring
Werkstoffname	G55	X40CrMoV51	X40CrMoV51
Werkstoffnummer		1.2344	1.2344
E-Modul [MPa]	450000.	216000.	216000.
Poisson'sche Zahl [-]	0.25	0.28	0.28
Zugfestigkeit [MPa]		2050.0	1670.0
Streckgrenze [MPa]		1850.0	1470.0
Anlasstemperatur [°C]		520.	600.
Vergleichsspannung [MPa]	1621.9	1757.5	1396.5
Tangentialspannung [MPa]	0.0	695.4	961.7

Verengung (-) / Aufweitung (+): von Di 0.012 mm von Da 0.171 mm

Zusammenbau

- (2.Schrumpfung + 1.Schrumpfung) <- Einsatz
- (Einsatz + 1.Schrumpfung) -> 2.Schrumpfung
- Ohne Zwischenbearbeitung

Neu Berechnung Optimierung (Schrumpmaß) Optimierung (Gesamt) Optimierung (nur D2) Hilfe Grafik

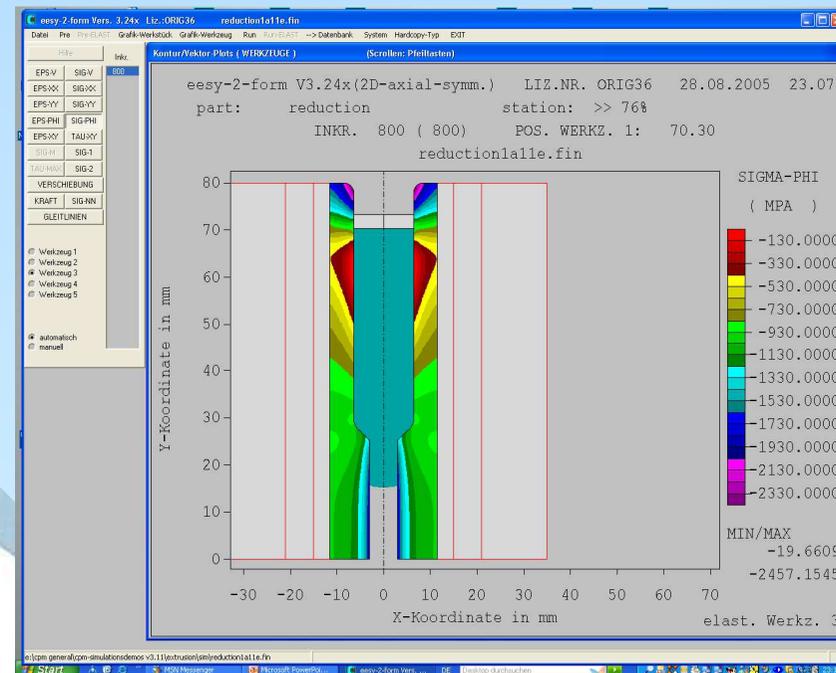
D:\jesy-dieopt\Layouts\cfc.edo



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Die design

The stress distribution in an insert with pre straining optimisation



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Punch die to form
torx recesses.

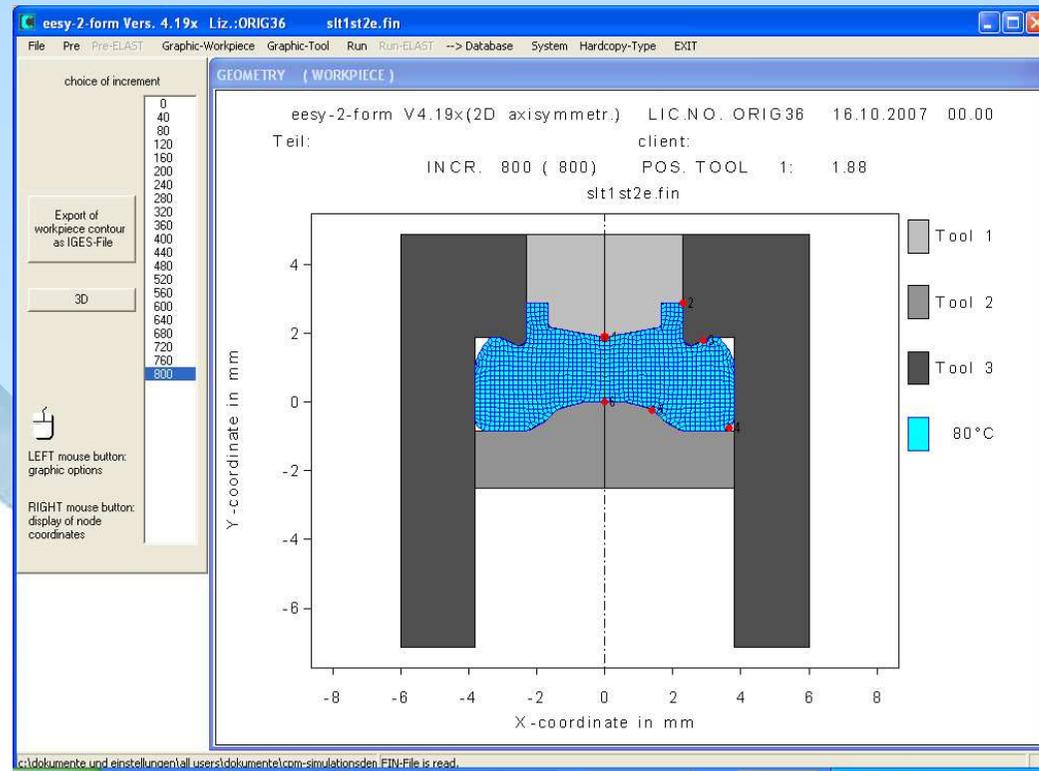
After systematic
optimization such a
punch produces
more than
2.000.000 parts!



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Forming station with spring loaded die

Layout of the spring loaded die system for a complex operation



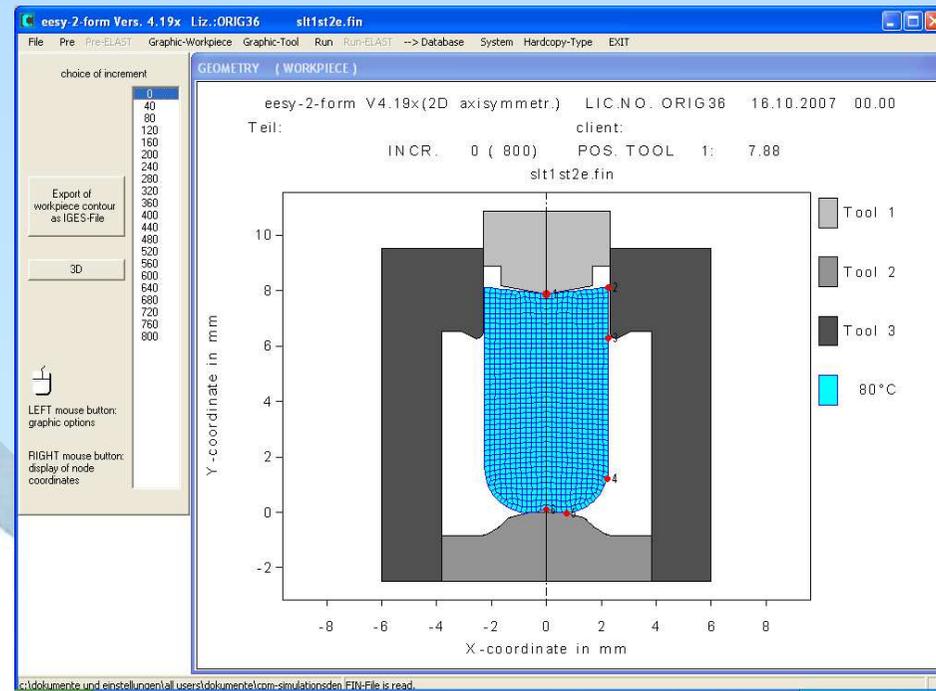
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Forming station with spring loaded die

Layout of the spring loaded die system for a complex operation

Initial position



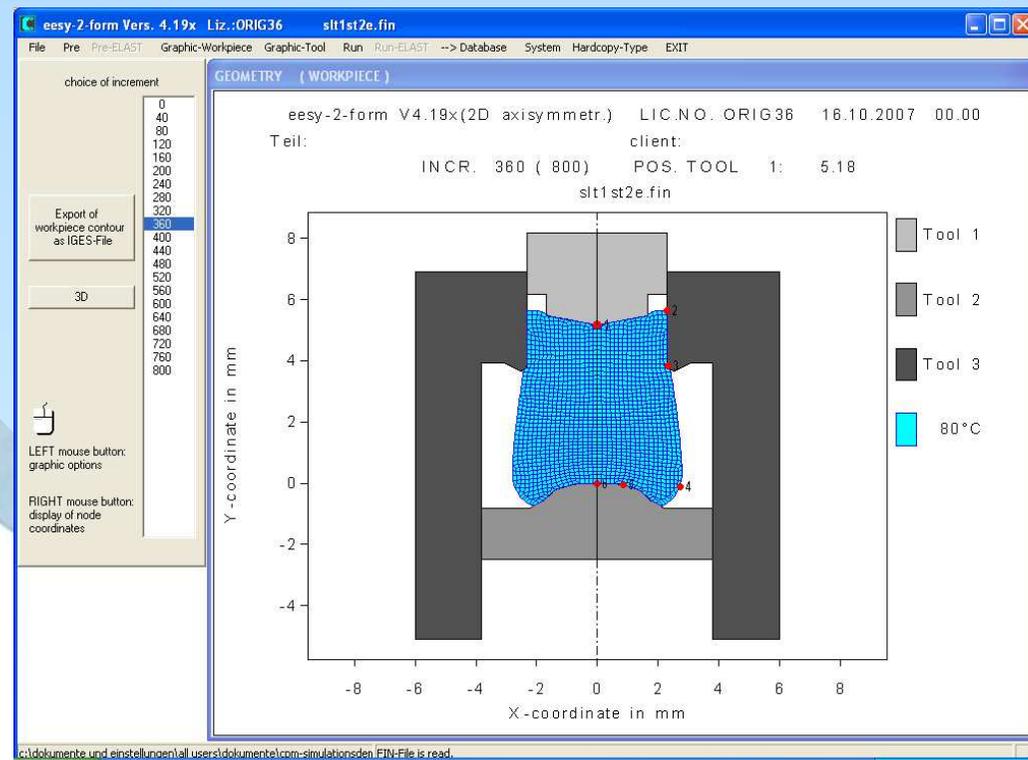
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Forming station with spring loaded die

Layout of the spring loaded die system for a complex operation

Die starting to slide

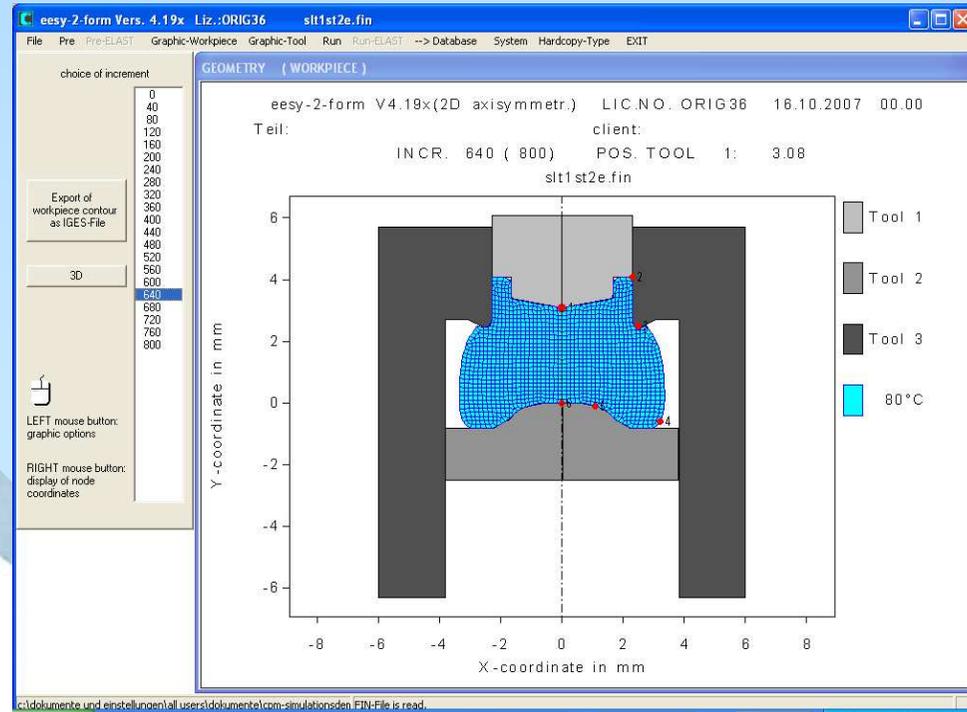


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Forming station with spring loaded die

Layout of the spring loaded die system for a complex operation

Die sliding



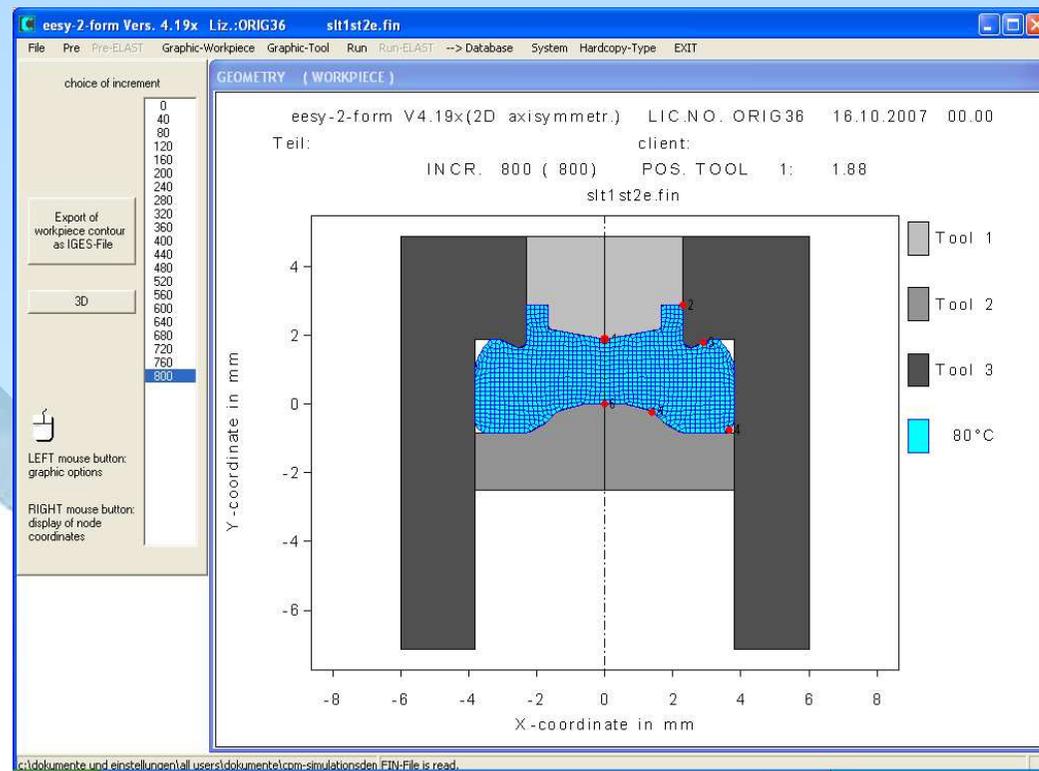
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Forming station with spring loaded die

Layout of the spring loaded die system for a complex operation

Final position

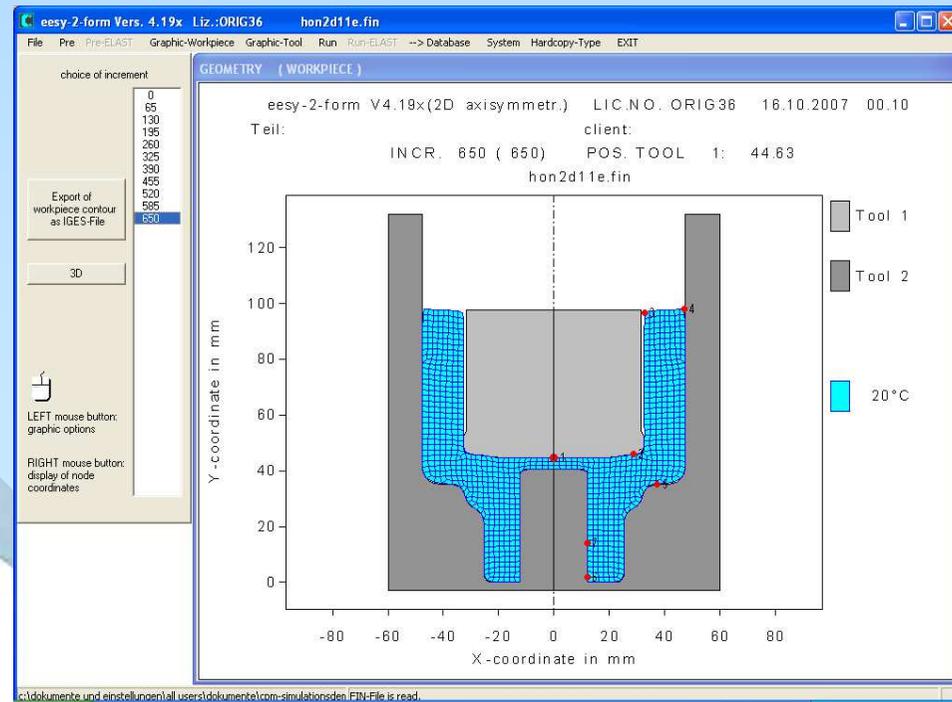


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Difficult tool design for a combined forward and backward extrusion

Extreme deformations during extrusion with tight tolerances



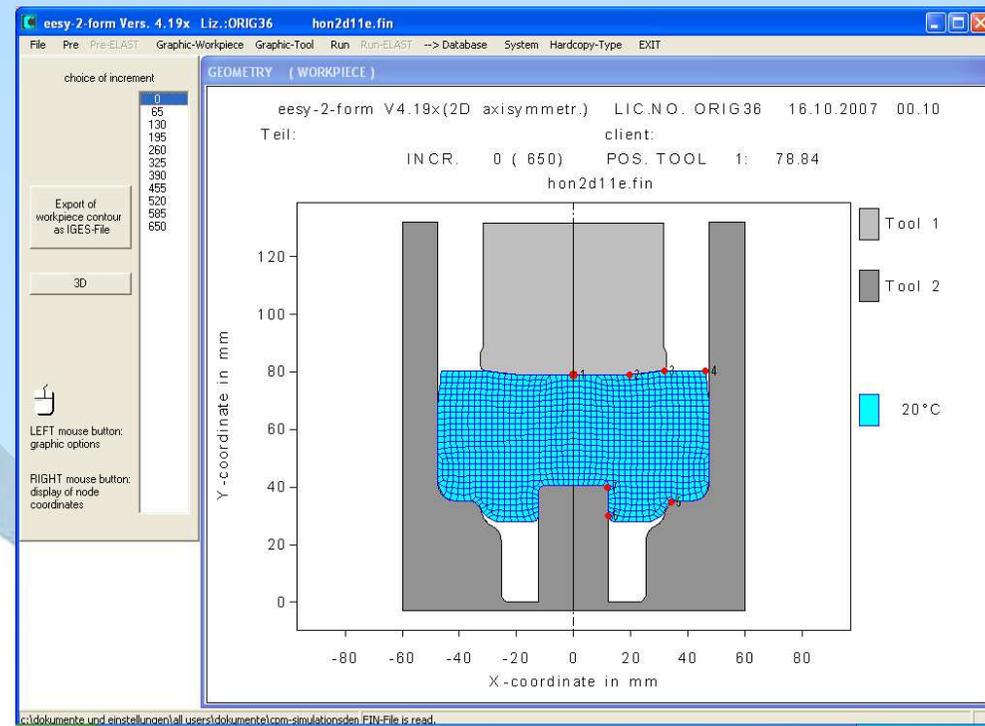
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Difficult tool design for a combined forward and backward extrusion

Extreme deformations during extrusion with tight tolerances

Initial position



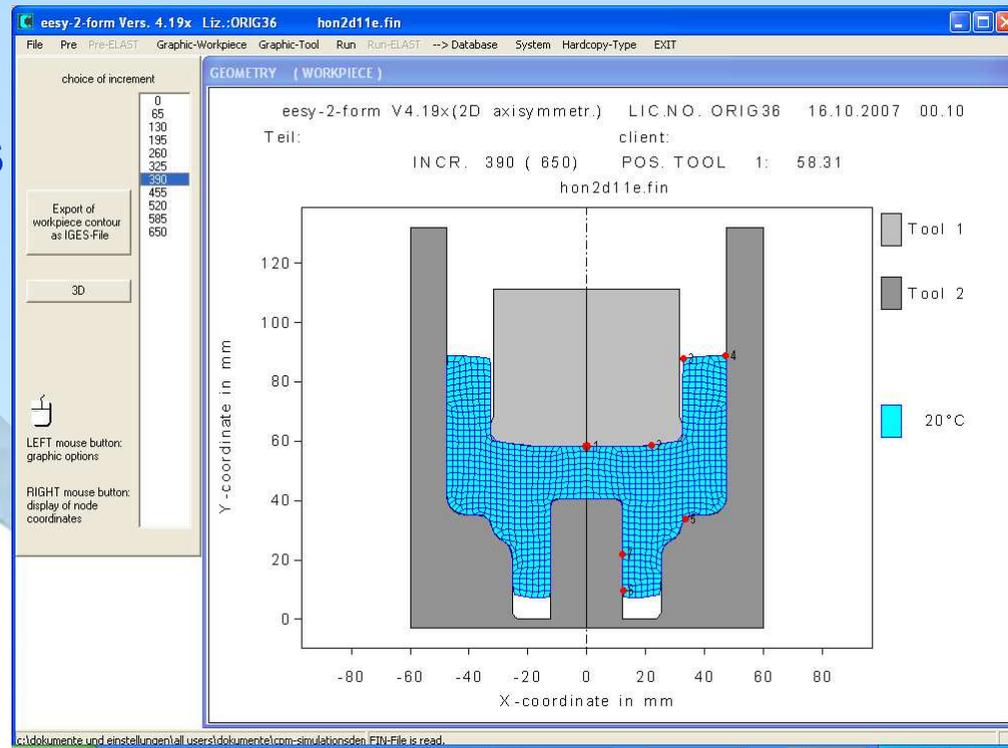
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Difficult tool design for a combined forward and backward extrusion

Extreme deformations during extrusion with tight tolerances

intermediate position



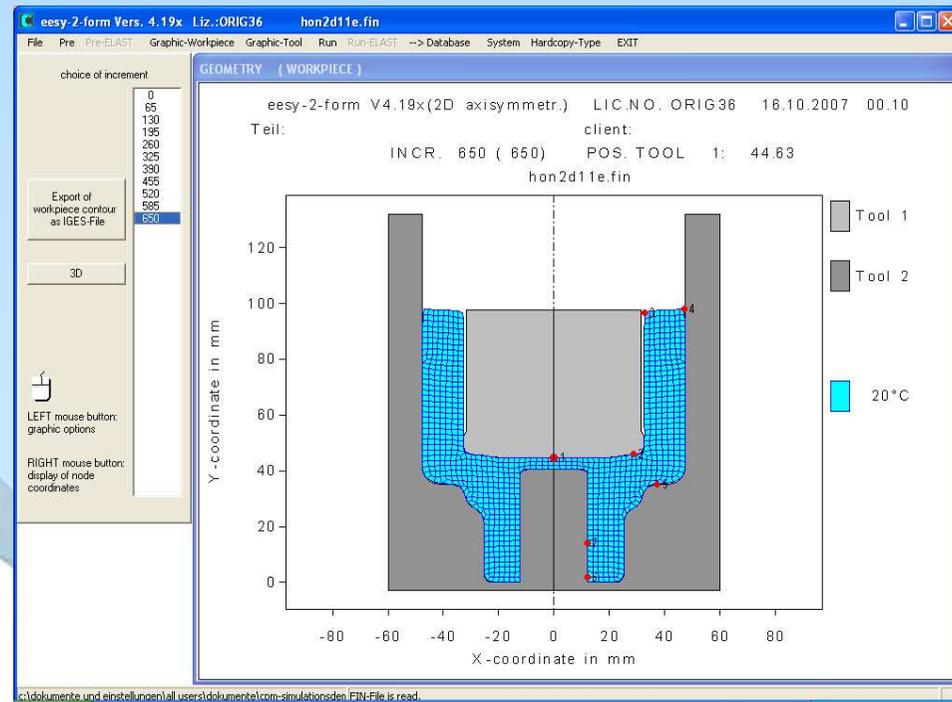
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Difficult tool design for a combined forward and backward extrusion

Extreme deformations during extrusion with tight tolerances

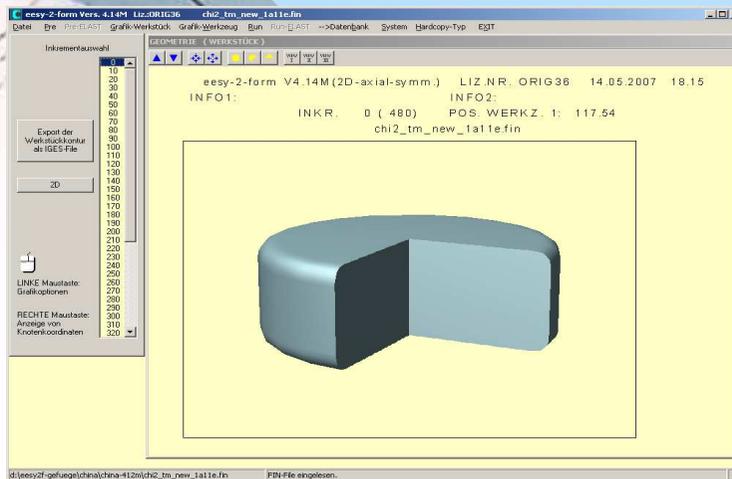
Final position



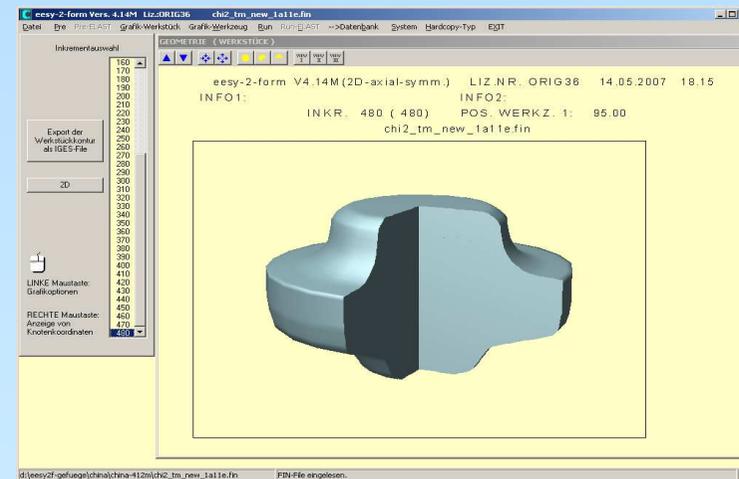
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Microstructure prediction in forging



Initial blank

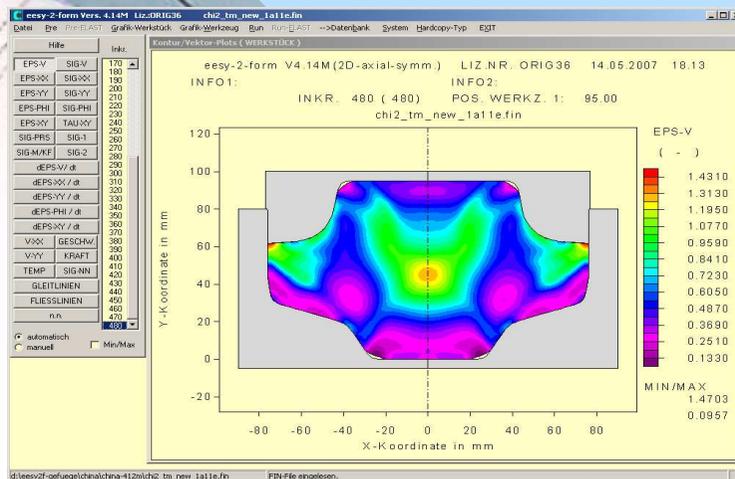


Final shape

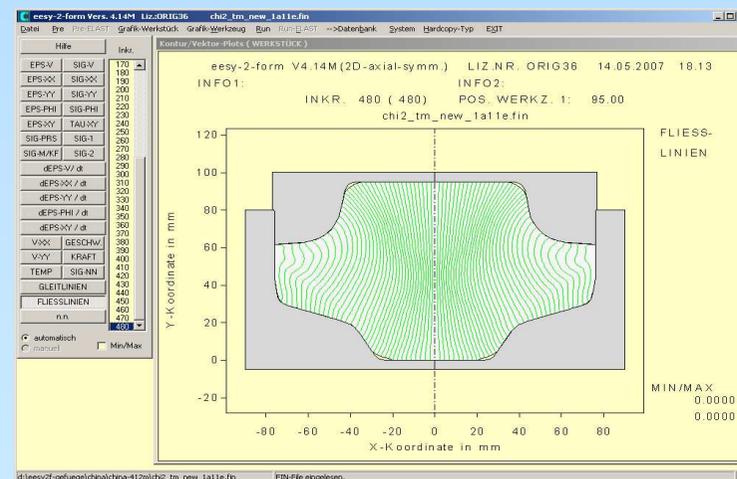


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Microstructure prediction in forging



Distribution of strain



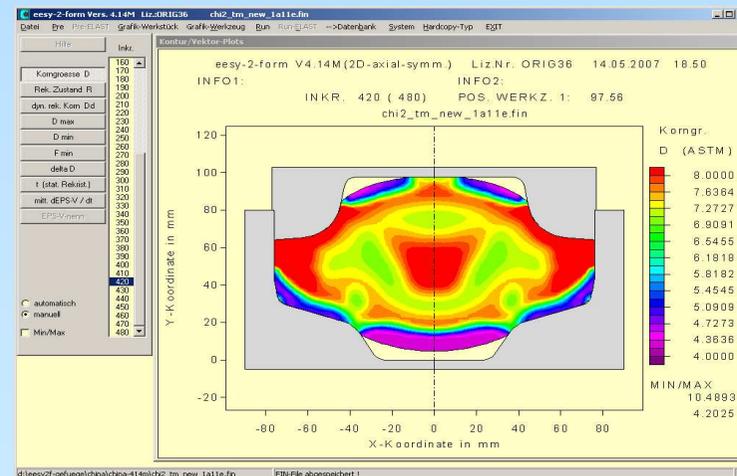
Fibre distribution



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Microstructure prediction in forging

- Grain size
- degree of re-cristallisation
- dynamic re-crist. fraction
- static re-crist. fraction
- grain-groth
- timing and recovering



Aims of simulation

Gain size distribution



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“Simulation for process and die design in forging”

Conclusion

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Seoul, 26.10.2007

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Conclusion

Most of the daily problems in design of a metal forming process can be supported by today simulation technology.

Some special application need further development still.

Simulation is generally established as a design tool.

Hurry up to not miss the train .. But choose your simulation partner carefully he has to be expert in forging as well!



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Thank you for your attention !

**You are most welcome to contact
CPM or Jin-A.**

**Like this bird knocking at my door
at a Hotel in China in the early
morning.....**

**I do not know whether he wanted
support or knowledge or
simulation....**



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