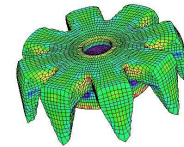
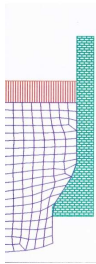
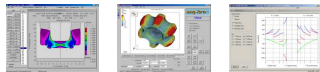


EESYFEA Simulation und Technology to support tool design



*Dr. Gerhard H. Arfmann, Dr. Michael Twickler
CPM GmbH, Herzogenrath*



Introduction

History

Since the 1980's CPM develops simulation systems.

1981 IBM PC



Typical work
environment
of an engineer

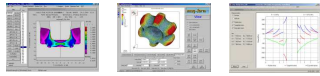


Wikipedia



Idea:

The „CA“engineer



Introduction

History
Since
1981



operations simulation systems.

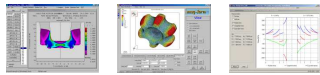


Wikipedia

Development of a „simple to use“
simulation system
to simulate metal forming and tool
layout on personal computers



The „CA“engineer



Introduction

Basic Developments FEA (2D)

Element Types

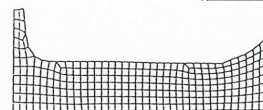
Contact Algorithm

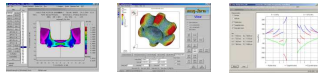
Solver for equation systems

Meshing Methodes

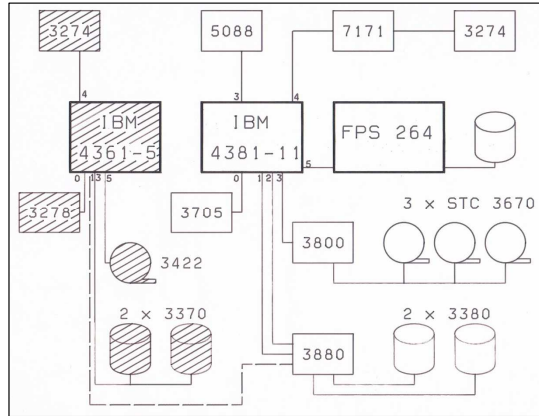
Material Laws and Data

Simple User Interface



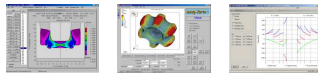


Introduction



Leistung	ca.. 60 MFLOPS
Vergleich	
Core i7,	
3,47 GHz, 83,2 GFLOPS	
6 Kerne	

Development environment in the 1980's



Introduction

First Prototype of an FEA System to be used on PC CAPS-Finel V1.0 (1989)

2D Axis-symmetric, 2D plane

Integrated Modelling, Simulation and Post-processing in a single System

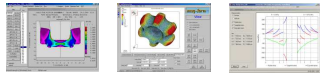
Simple interaction by a "question and answer" dialog

Rigid-plastic material law

Thermal – mechanical simulation

Automatic Meshing

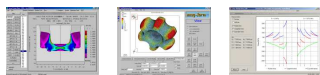
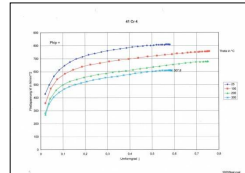
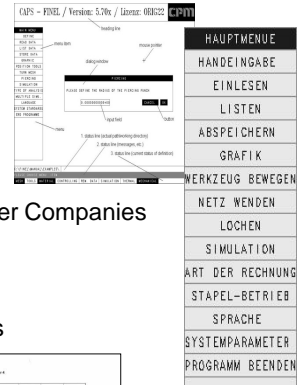




Introduction

Next Steps

- Development of a graphical interface
- Development project with German Fastener Companies
- Improvement of technological modules
- Simple handling of Multi-station processes
- Elastic tooling
- Microstructure
- Material Data



Introduction

Next steps -2-

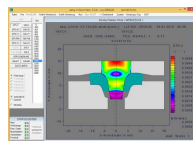
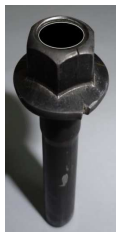
- New friction laws
- Failure analysis
- 3D Applications
- 3D Toolbox

Friction

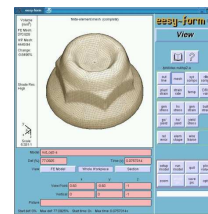
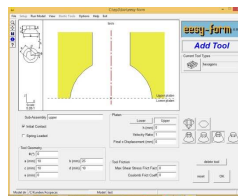
Coulomb $F_r = \mu \cdot N$

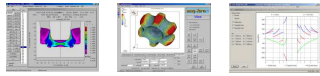
Max. shear stress $\tau = m \cdot k$

Combined Coulomb / max. shear stress

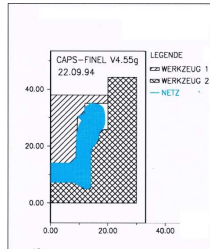


New „easy“ Windows Design (easy-2-form, easy-form)

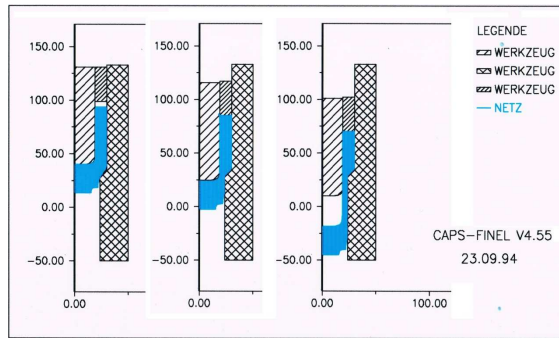




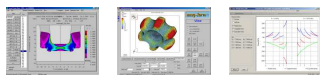
Introduction



Simulation of folding 1994

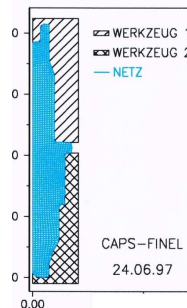
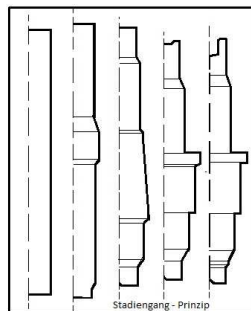


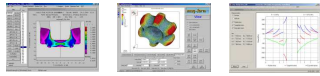
Tooling with spring



Introduction

Automatic simulation of multi station processes

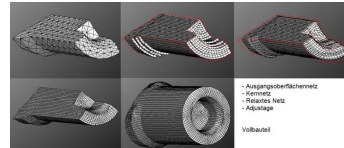




Introduction

Next steps -3-

Push of 3D Simulation using



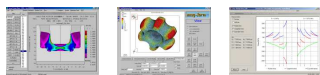
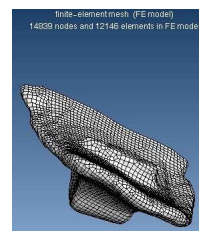
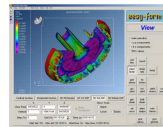
- Ausgangsoberflächennetz
- Autom.
- Relantes Netz
- Adaptive
- Vorbauzeit

- Automatic meshing and re-meshing of Hexahedral elements

- Elastic-plastic Material law

- Interfacing with CAD

-



Introduction

Next steps -4-

More and better technological modules

Contact,
Friction,
Folding,
...)

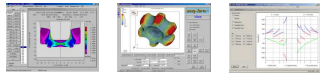


**Additional System easy-DieOpt for
Design and optimization of tooling systems**

Local Description of friction



**Additional analysis of
local surface properties -> Tribo-system**



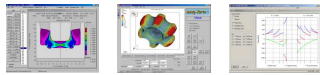
Introduction

Example of complex cold forging operations



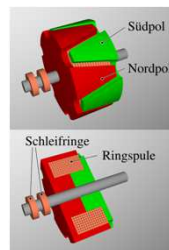
(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler
Hong Kong Fastener Association Seminar –Advanced tool design, 10.07.2015, Shenzhen, Guangdong, PR China

13

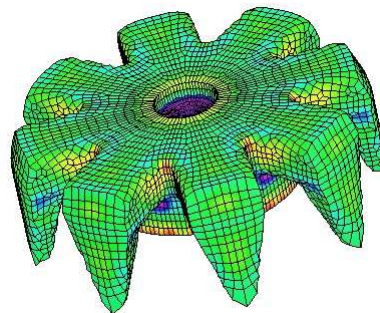


Introduction

Example of complex cold forging operations



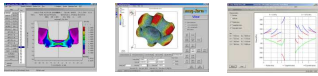
(Claw pole motor – Wikipedia)



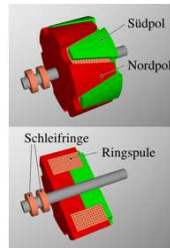
Claw

(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler
Hong Kong Fastener Association Seminar –Advanced tool design, 10.07.2015, Shenzhen, Guangdong, PR China

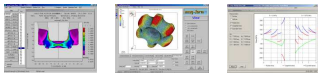
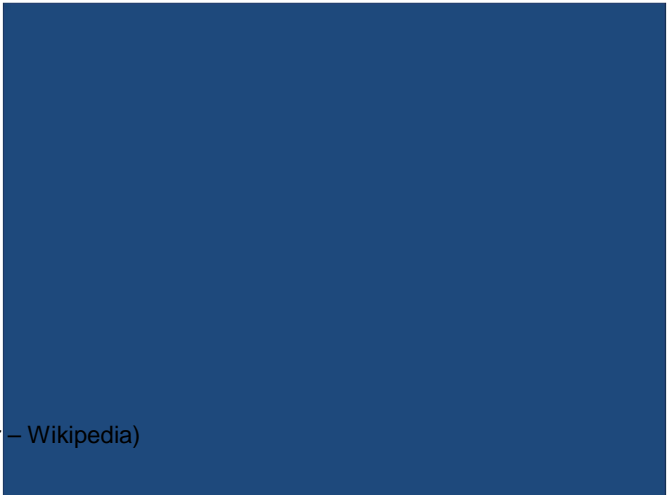
14



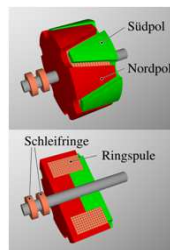
Introduction



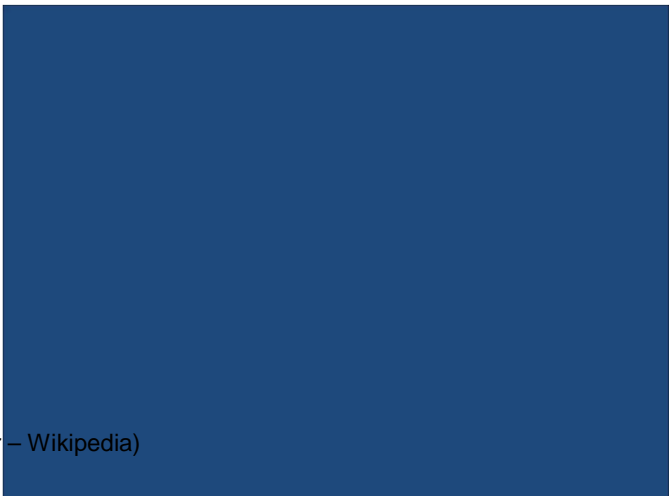
(Claw pole motor – Wikipedia)

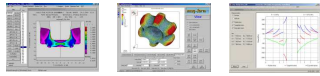


Introduction



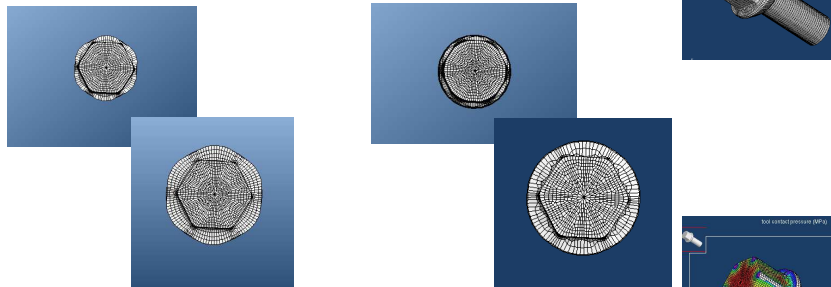
(Claw pole motor – Wikipedia)



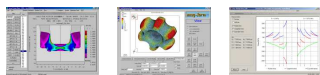
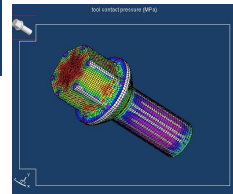


Introduction

Example of complex cold forging operations



To avoid a „flower“ shape



Introduction

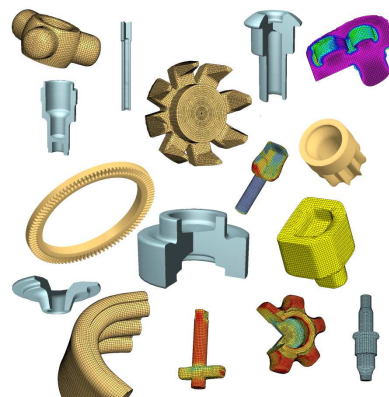
This was a small overview
about what can be done in
simulation today.

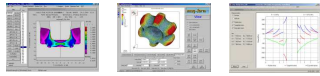
But besides the forming
sequence the

tool design

is decisive for a good
productivity.

In the following is shown
how
**Simulation can help with
Tool design**

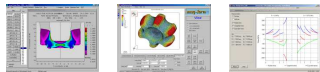
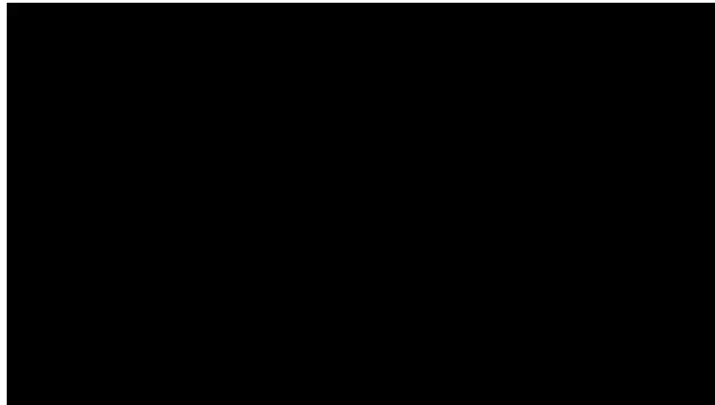




Tool Design Task - generel



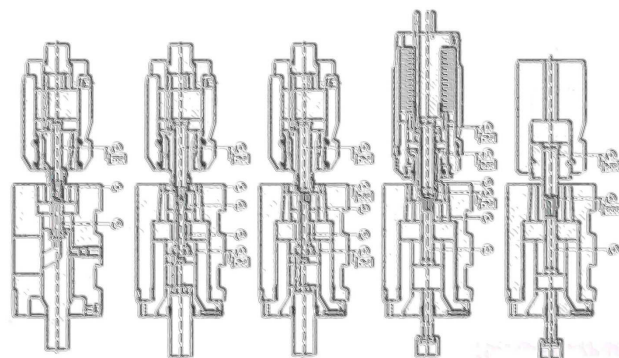
Spark Plug



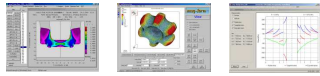
Tool Design Task - generel



Spark Plug



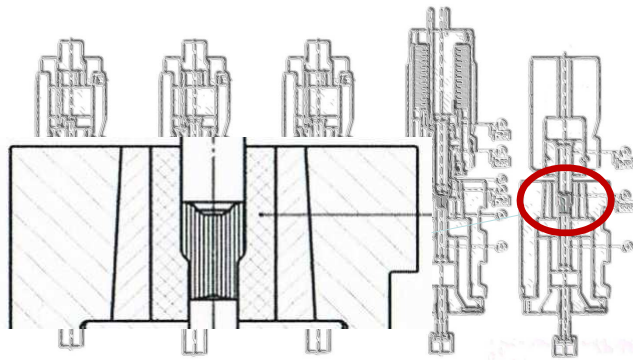
The idea how to make the tool design may be known in general.



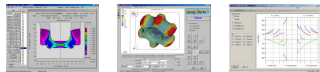
Tool Design Task - genel



Spark Plug



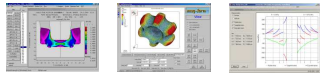
How to do in detail ?



Tool Design Task

The presentation will show you examples how to systematically design the tooling using simulation and calculation systems.

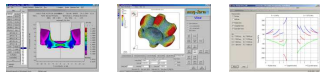
1. Analysis of punches
2. Analysis of a die insert (Carbide)
3. Design of an extrusion die
4. Example of a practical applications



Tool Design Task

The presentation will show you examples how to systematically design the tooling using simulation and calculation systems.

1. Analysis of punches
2. Analysis of a die insert (Carbide)
3. Design of an extrusion die
4. Example of a practical applications

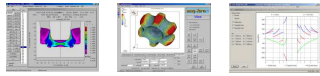


Tool Design Task – Analysis of punches



Examples of punch failure

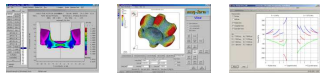




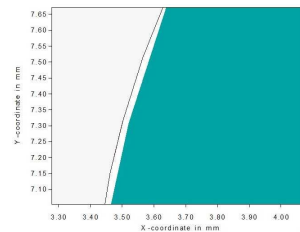
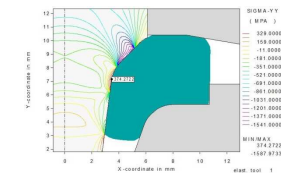
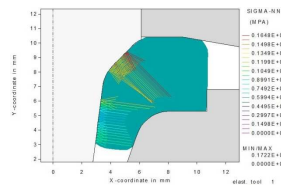
Tool Design Task – Analysis of punches



Punch failure during
production of a
valve spring retainer

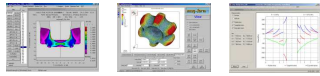


Tool Design Task – Analysis of punches

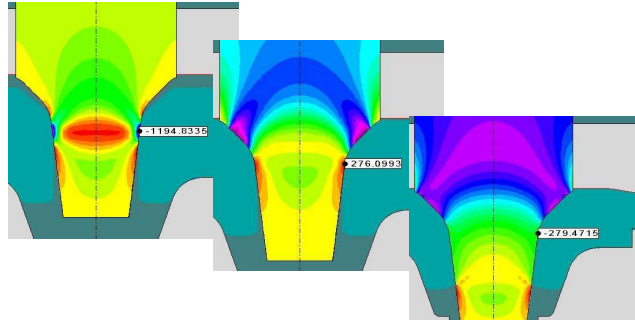


Analysis
Pressure on the surface
Alternating axial
stresses in the punch
and explanation
Loss of contact
during forming
(no oil or air enclosure)

Punch failure during production of a retainer

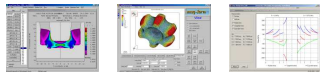


Tool Design Task – Analysis of punches

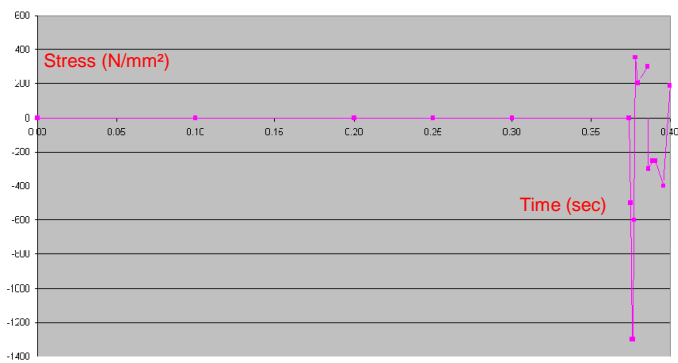


Alternating Stresses

Failure due to fatigue

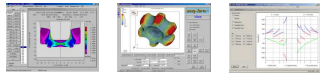


Tool Design Task – Analysis of punches

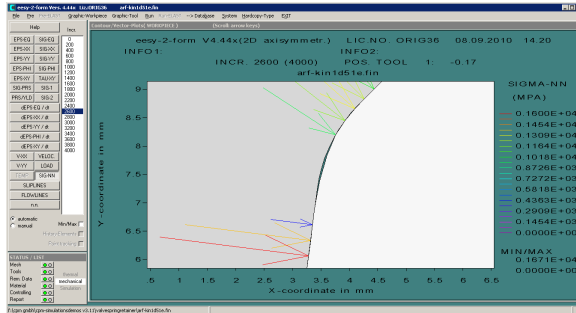


Alternating Stresses in due time

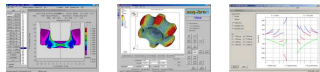
Failure due to fatigue



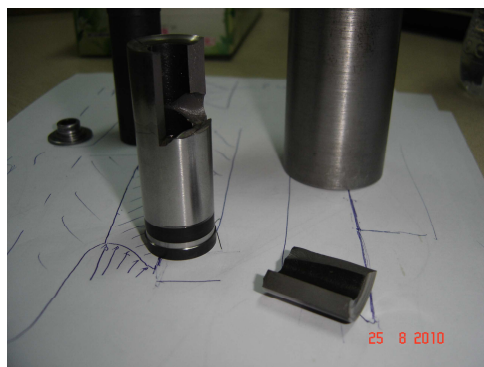
Tool Design Task – Analysis of punches



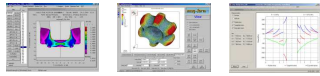
Reason for the stress situation:
the material flow during the forming.
(Temporarily no contact – gap some 1/100 mm)



Tool Design Task – Analysis of punches



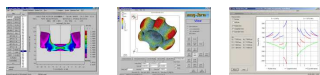
Fatal failure of a punch



Tool Design Task – Analysis of punches



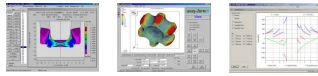
Fatal failure of a punch



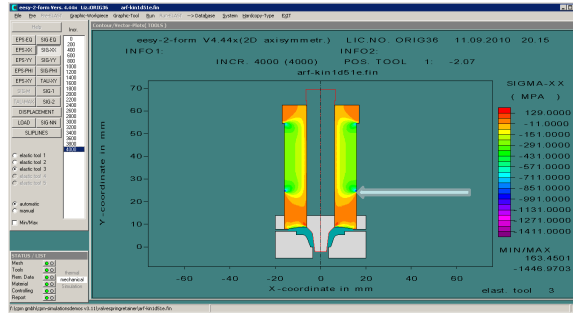
Tool Design Task – Analysis of punches



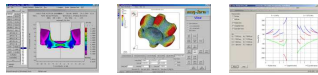
Crack Initiation



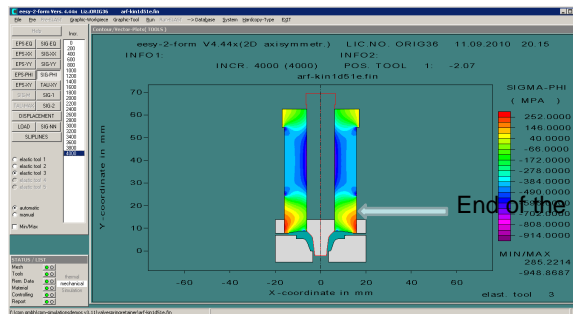
Tool Design Task – Analysis of punches



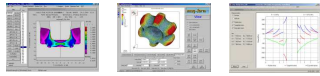
Stress concentration at the point of crack initiation (Sig xx)



Tool Design Task – Analysis of punches



Positive tangential stress below the contact point

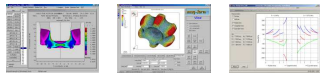


Tool Design Task – Analysis of punches



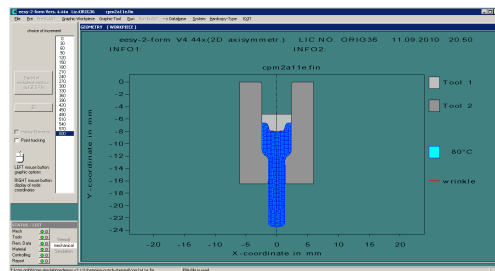
Punch failure during
production of spark plug

Picture from a similar case (Picture ICFG Workgroup Simulation)

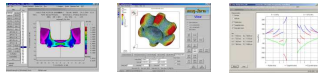


Tool Design Task – Analysis of punches

Failure of punch during extrusion

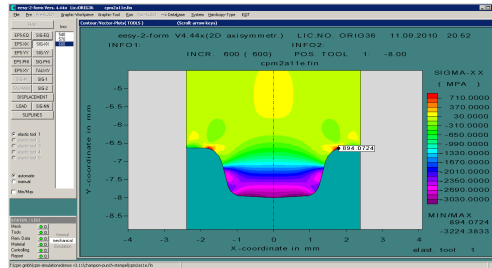


Punch failure during
production of spark plug



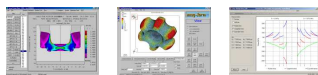
Tool Design Task – Analysis of punches

Failure of punch during extrusion



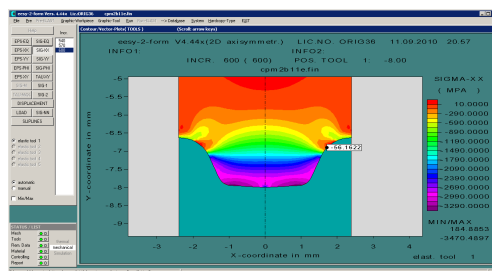
Punch failure during production of spark plug

High local positive radial stress -> punch failure



Tool Design Task – Analysis of punches

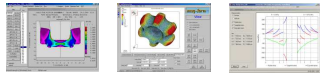
Failure of punch during extrusion



Punch failure during production of spark plug

No concentration of positive radial stress after

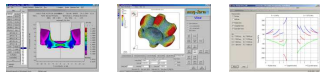
Changing the radius -> no failure



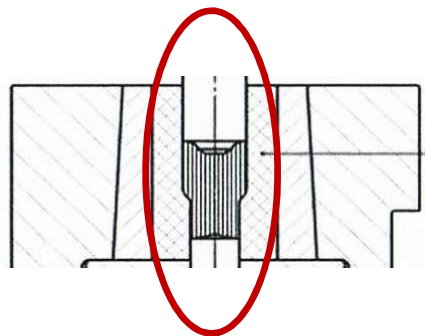
Tool Design Task

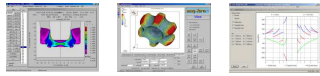
The presentation will show you examples how to systematically design the tooling using simulation and calculation systems.

1. Analysis of punches
- 2. Analysis of a die insert (Carbide)**
3. Design of an extrusion die
4. Example of a practical applications



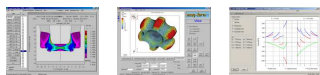
Tool Design Task – Analysis of a die insert – carbide insert





Tool Design Task – Analysis of a die insert – carbide insert

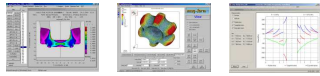
Horizontal split
(breakage)
due
to axial stresses



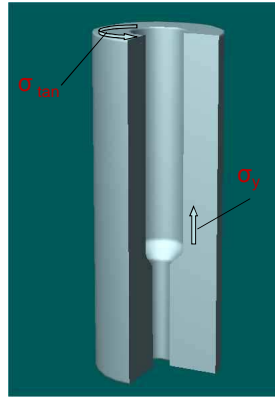
Tool Design Task – Analysis of a die insert – carbide insert

Fatal cracking
due to
overloading



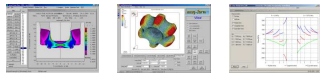


Tool Design Task – Analysis of a die insert – carbide insert

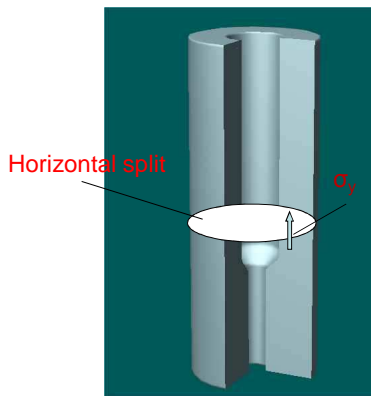


σ_{tan} : critical for axial crack

σ_y : critical for horizontal crack



Tool Design Task – Analysis of a die insert – carbide insert



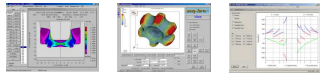
σ_y : critical for horizontal crack



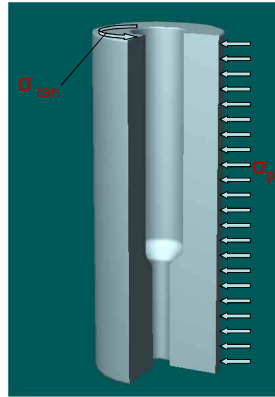
horizontal split of the insert

to avoid





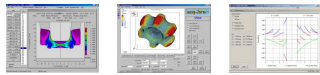
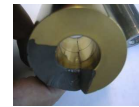
Tool Design Task – Analysis of a die insert – carbide insert



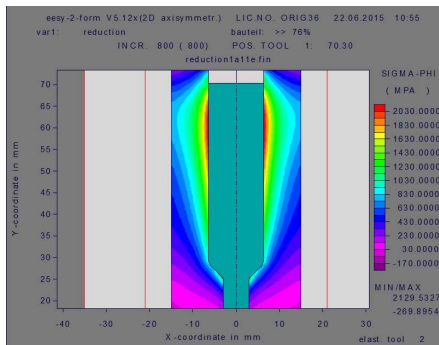
σ_{tan} : critical for axial crack

⇒ Pre-stressing of the insert

to avoid

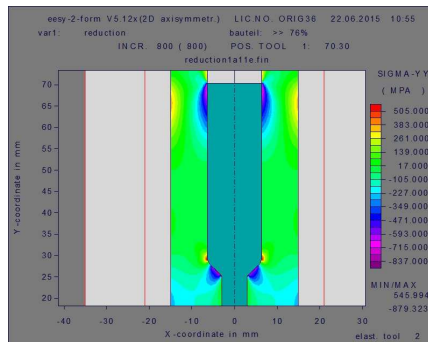


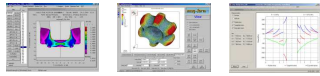
Tool Design Task – Analysis of a die insert – carbide insert



Axial stress to be avoided by split

Tangential Stress to be compensated by pre-stressing

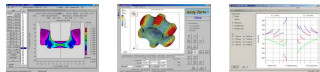




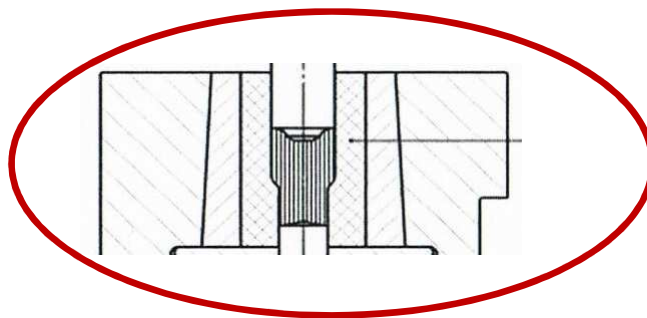
Tool Design Task

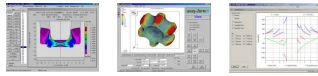
The presentation will show you examples how to systematically design the tooling using simulation and calculation systems.

1. Analysis of punches
2. Analysis of a die insert (Carbide)
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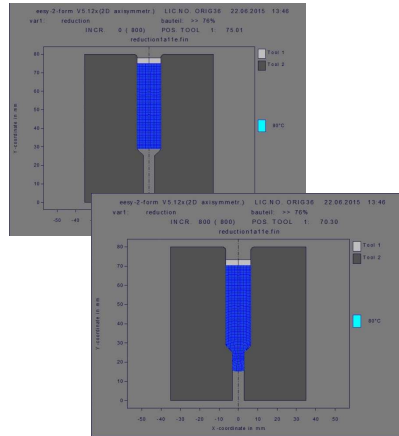


Tool Design Task – Design of an extrusion die





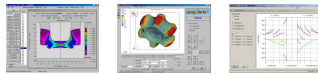
Tool Design Task – Design of an extrusion die



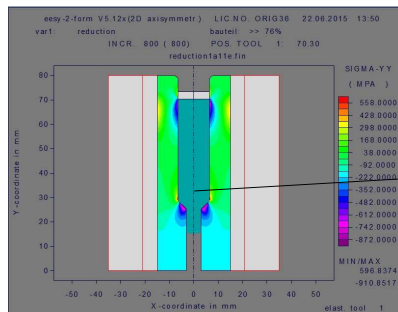
Simulation of an
extrusion

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Tool Design Task – Design of an extrusion die

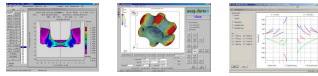


- Avoiding of failures (elastic analysis of the insert with FEM)

Splitting of the die
due to high axial
stresses

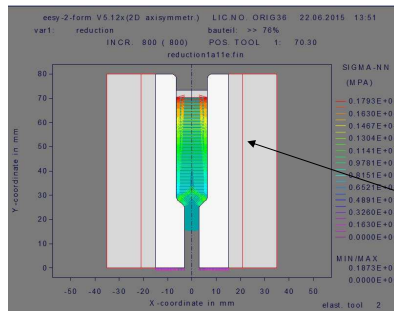
(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler

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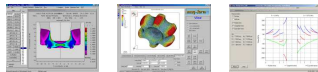


Tool Design Task – Design of an extrusion die

Tool design

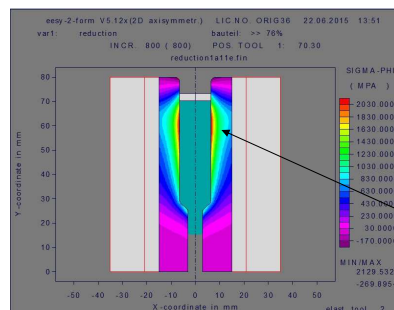


Die insert without pre-stressing

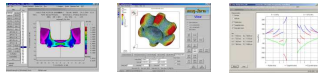


Tool Design Task – Design of an extrusion die

Tool design

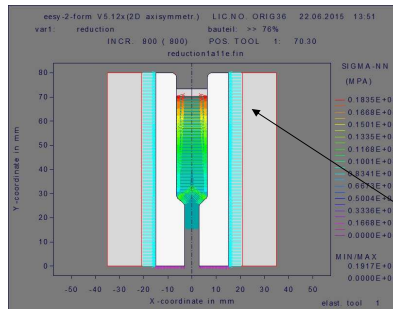


Positive stress in the die without pre-stressing

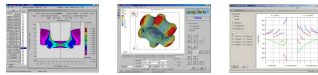


Tool Design Task – Design of an extrusion die

Tool design



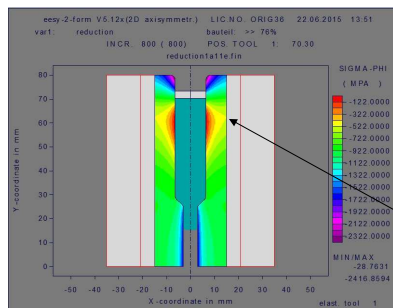
Die with pre-
stressing (900
MPa)



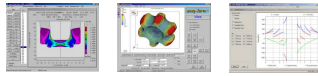
Tool Design Task – Design of an extrusion die

- Design of a cold forming process

Tool design



Pressure in the die
with pre-stressing

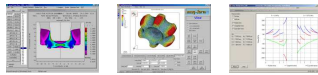


Tool Design Task – Design of an extrusion die

Procedure

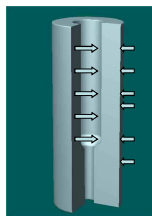
After the FEM analysis of the part an optimal design layout is calculated with the die-design system

The results (diameters, interferences etc) are provided to the FEM code with integrated die-design software



Tool Design Task – Design of an extrusion die

System to calculate and optimize the pre-straining in a die



easy-DieOpt Vers. 2.04 License for: 11-CPM GmbH, Herzogenrath, Germany

File 2-RING-SYSTEM (cold) 2-RING-SYSTEM (warm) 3-RING-SYSTEM 4-RING-SYSTEM Language System EXIT

3-RING-SYSTEM License for: 11-CPM GmbH, Herzogenrath, Germany

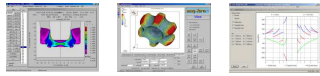
	Insert	Sleeve	Casing
Material name	G55	X40CrMoV51	X40CrMoV51
Material number		1.2344	1.2344
Young's modulus [MPa]	450000	216000	216000
Poisson's ratio [-]	0.25	0.28	0.28
Tensile strength [MPa]		1900.0	1670.0
Yield strength [MPa]		1700.0	1470.0
Tempering temp. [°C]		550	600
Equivalent stress [MPa]	1462.7	1530.0	1323.0
Tangential stress [MPa]	0.0	571.1	899.6

Inner diameter Di: 12.83 mm
 Outer diameter Da: 70.00 mm
 Fitting diameter D1: 23.00 mm
 Interference S1: 0.169 mm
 Fitting diameter D2: 42.00 mm
 Interference S2: 0.168 mm
 Inner pressure Pi: 1462.7 MPa
 Fitting pressure P1: 958.9 MPa
 Fitting pressure P2: 423.4 MPa
 Taper angle (for D1): 1.0 °
 Axial movement: 4.94 mm

Contraction (-) / Expansion (+): of Di 0.070 mm of Da 0.154 mm
 Assembly: (Casing + Sleeve) <- Insert
 (Insert + Sleeve) -> Casing
 Without intermediate corrections

New calculation Optimization (Interference) Optimization (Complete) Optimization (S1,D2,S2 only) Help Graphic

22.06.2015 14:40



Tool Design Task – Design of an extrusion die

Interface

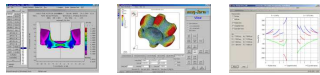
EESY-DieOpt

EESY-2-form

(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler

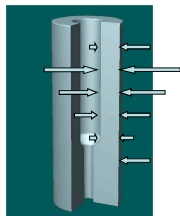
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Tool Design Task – Design of an extrusion die

Principle



New method for die design

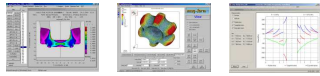
$$\text{Pre-stress} = f (P_1(t,y); d_1(y); y; \dots)$$

P_1 – inner pressure, d_1 – inner diameter, t – time (increment), y – axial location

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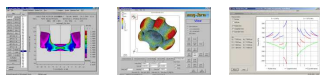
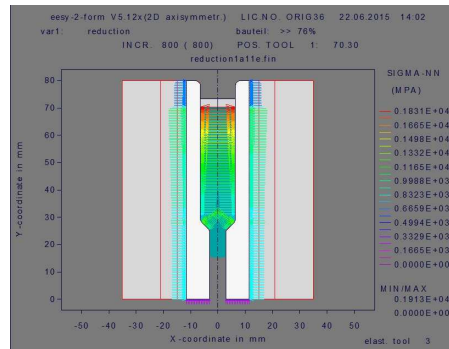
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Tool Design Task – Design of an extrusion die

The pre-stress on the insert shows a distribution now

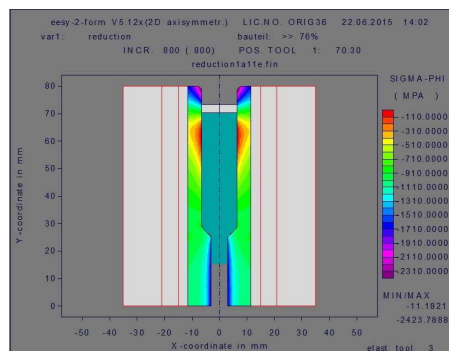


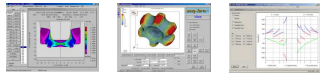
Tool Design Task – Design of an extrusion die

The stress distribution in the insert is different, too.

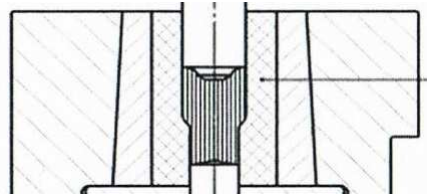
In this case the result is ok.

Otherwise the engineer has to make changes in the design again.





Tool Design Task – Design of an extrusion die



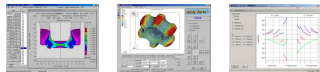
Final design:

inner dia: 12.83 mm
outer dia: 70.00 mm

fitting dia: 23.00 mm
interf.: 0.169 mm

fitting dia 2: 42.00 mm
interf: 0.168 mm

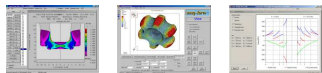
Mat insert: G55
Mat sleeve: SKD61 HRC 54
Mat body: SHD61 HRC 50



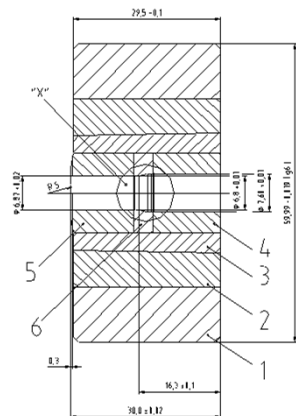
Tool Design Task

The presentation will show you examples how to systematically design the tooling using simulation and calculation systems.

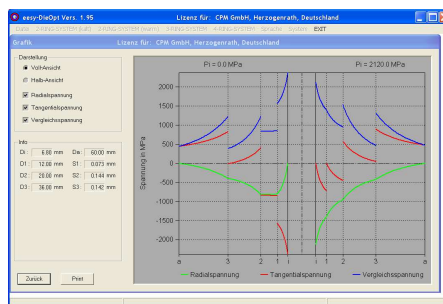
1. Analysis of punches
2. Analysis of a die insert (Carbide)
3. Design of an extrusion die
- 4. Example of a practical applications**



Tool Design Task – Design of an extrusion die



- Even complex design could be realised

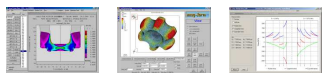


(c) WALLRAM

(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler

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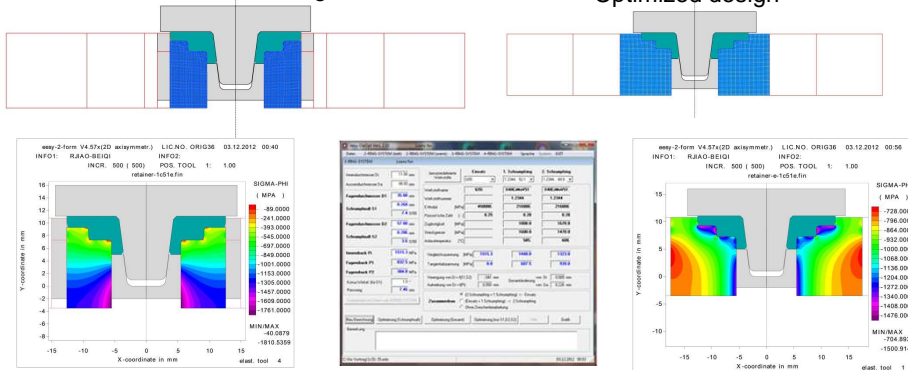
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Tool Design Task – 1st Example of practical applications

Conventional design

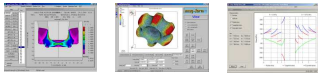
Optimized design



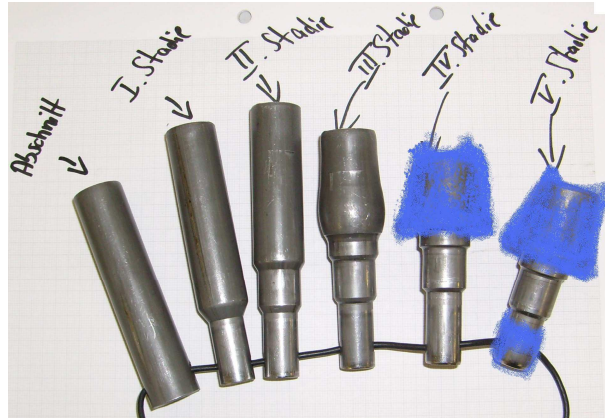
(c) 2015 Dr. Gerhard H. Arfmann, Dr. Michael Twickler

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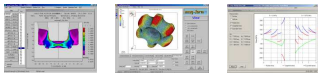
Hong Kong Fastener Association Seminar –Advanced tool design, 10.07.2015, Shenzhen, Guangdong, PR China



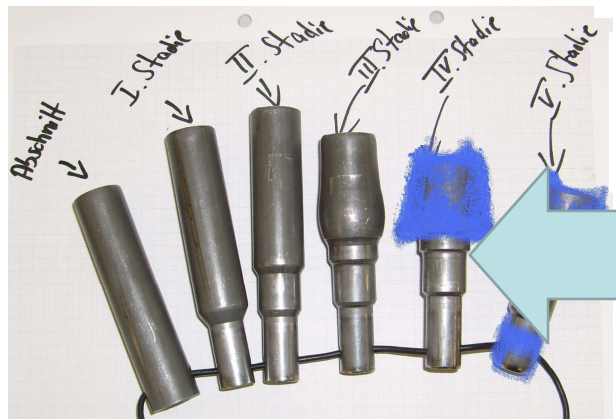
Tool Design Task – 2nd Example of practical applications



5 station
cold forging
process

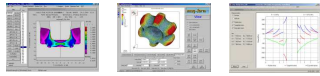


Tool Design Task – 2nd Example of practical applications

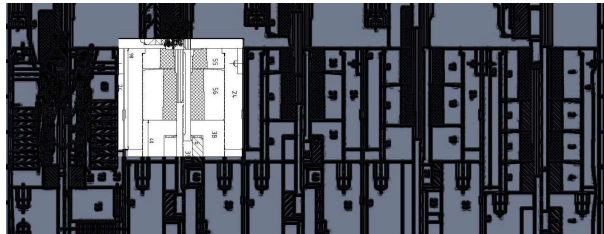


5 station
cold forging
process

Location of the
problem in the
tooling

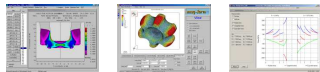


Tool Design Task – 2nd Example of practical applications



5 station
cold forging
process

Initial tool design in operation 4

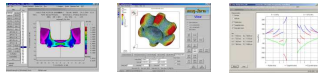


Tool Design Task – 2nd Example of practical applications

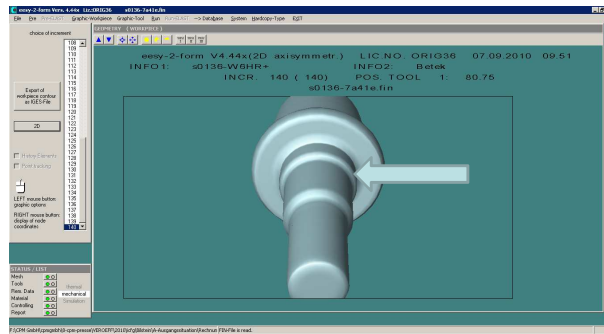


5 station
cold forging
process

Premature failure
of the die

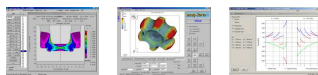


Tool Design Task – 2nd Example of practical applications



5 station
cold forging
process

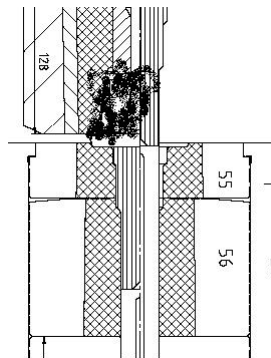
Forming in operation 4



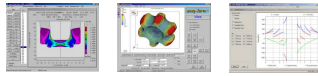
Tool Design Task – 2nd Example of practical applications

Initial design of the
die in operation 4

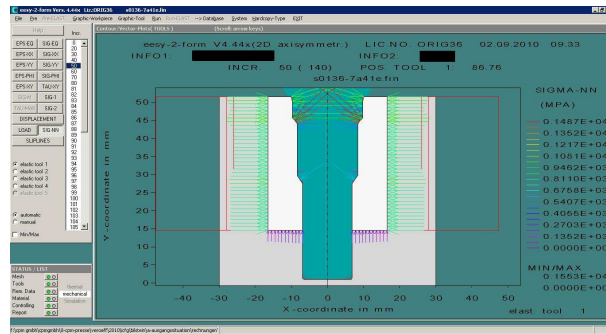
(Carbide –
pre-stressed by
one ring)



5 station
cold forging
process

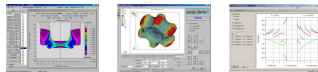


Tool Design Task – 2nd Example of practical applications

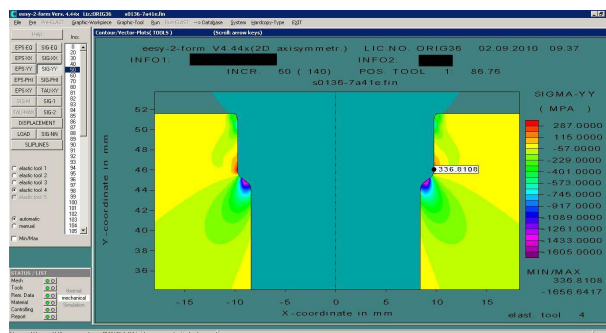


5 station
cold forging
process

Distribution of pressure in the die

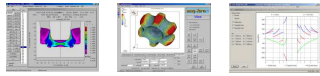


Tool Design Task – 2nd Example of practical applications



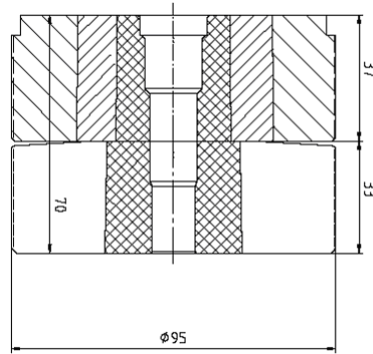
5 station
cold forging
process

Positive stress in the carbide → failure

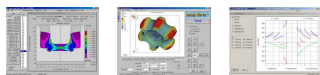


Tool Design Task – 2nd Example of practical applications

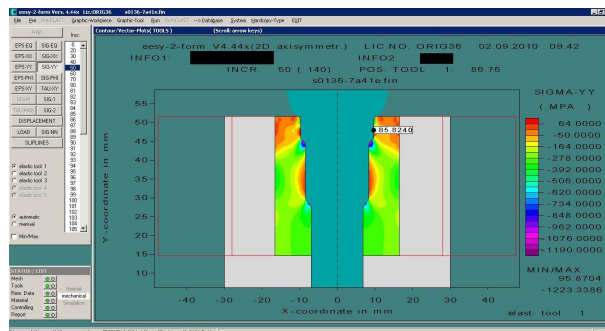
New design of the die in operation 4
(Carbide – pre-stressed by two rings)



5 station
cold forging
process

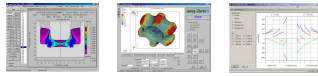


Tool Design Task – 2nd Example of practical applications



5 station
cold forging
process

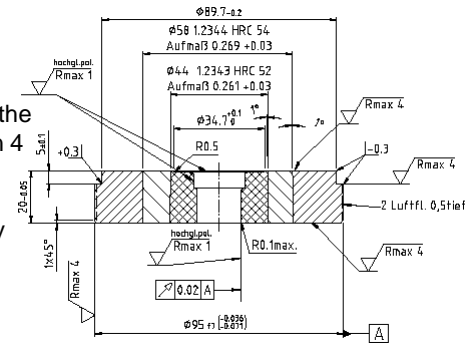
Positive stress in the carbide → failure
The carbide has to be split as well due to positive axial stresses in the lower area



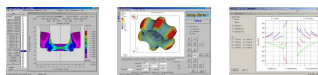
Tool Design Task – 2nd Example of practical applications

New design of the die in operation 4

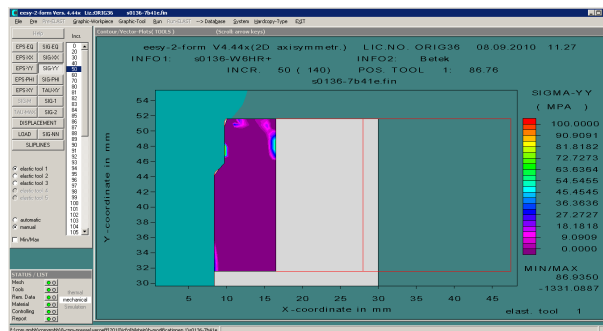
(Carbide – pre-stressed by two rings and splitted)



5 station
cold forging
process

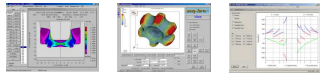


Tool Design Task – 2nd Example of practical applications



5 station
cold forging
process

Positive stress in the carbide still → failure

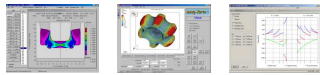


Tool Design Task – 2nd Example of practical applications



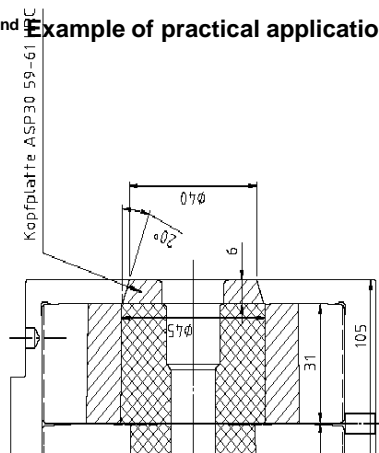
5 station
cold forging
process

Prove of the failure in practical test

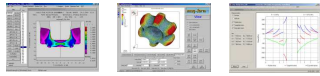


Tool Design Task – 2nd Example of practical applications

New design of the die in operation 4
(disc made out of ASP 30, Carbide split – pre-stressed by two rings)



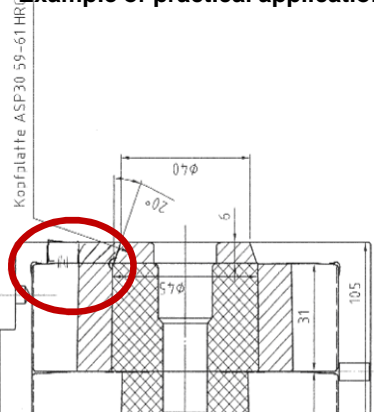
5 station
cold forging
process



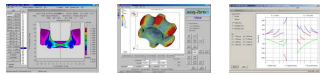
Tool Design Task – 2nd Example of practical applications

Corrected design
of the
die in operation 4

(disc made out of
ASP 30,
Carbide split –
pre-stressed by
two rings)



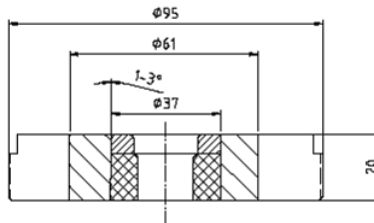
5 station
cold forging
process



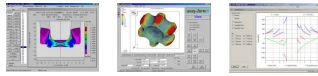
Tool Design Task – 2nd Example of practical applications

Final design
of the
die in operation 4

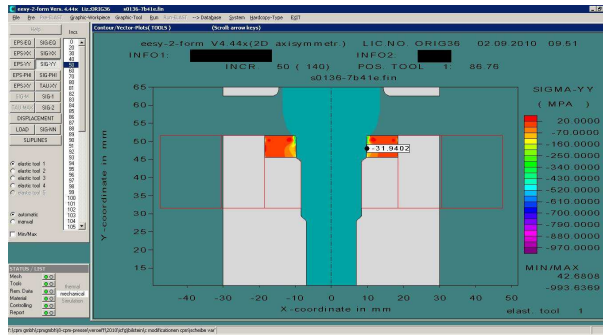
(disc made out of
ASP 30,
Carbide split –
pre-stressed by
two rings)



5 station
cold forging
process

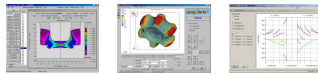


Tool Design Task – 2nd Example of practical applications

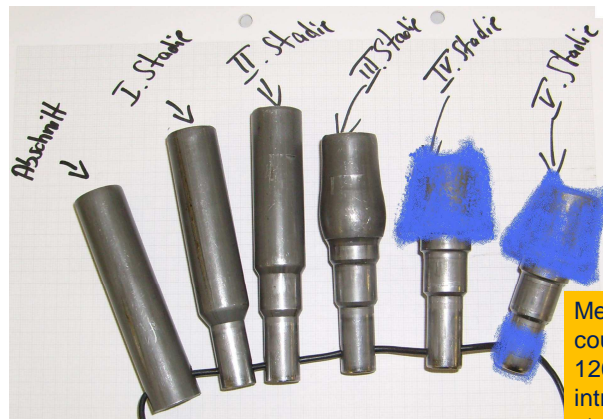


5 station
cold forging
process

Stresses are compressive now
Tool life could be improved from 1000 pieces to 25000 pieces

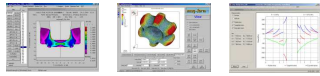


Tool Design Task – 2nd Example of practical applications



5 (6) station
cold forging
process

Meanwhile the tool life
could be improved to
120000 pieces by
introducing a further
station before # 4.



Tool Design Task – 3rd Example of practical applications



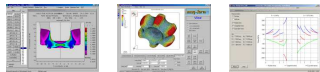
Pre-stressed punch to form
a TORX® recess

After optimization

a tool life of 2,5 Mio

was reached

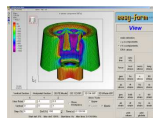
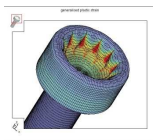
**(stable for more than
10 years now)**

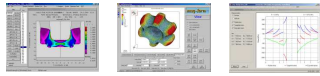


Future

Future developments

- * Integration of the simulation in the entire production chain
- * Completion of the material data needed
- * Development of further technological modules
- * Reducing the simulation systems to very specialized systems for industry sectors



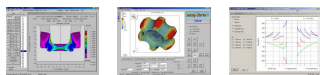


Aknowledgements

CPM is much obliged to their customers that provided relevant information to enable CPM to present successful applications of their simulation software.



Such information is very helpful to promote CPM software and the application of simulation in general by presentations like this one.



Trust in “easy” simulation



Customers are happy to work on their daily tasks
with “easy” simulation