PERMAS
Users' Conference
Stuttgart 2018

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PERMAS User Conference 2018

Non-linear plastic analysis

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Agenda

1. Introduction to MAHLE Filtersysteme
2. Explanation of the problem
3. Linear static analysis
4. Non-linear plastic analysis
5. Comparison of analysis types
6. Summary

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MAHLE worldwide

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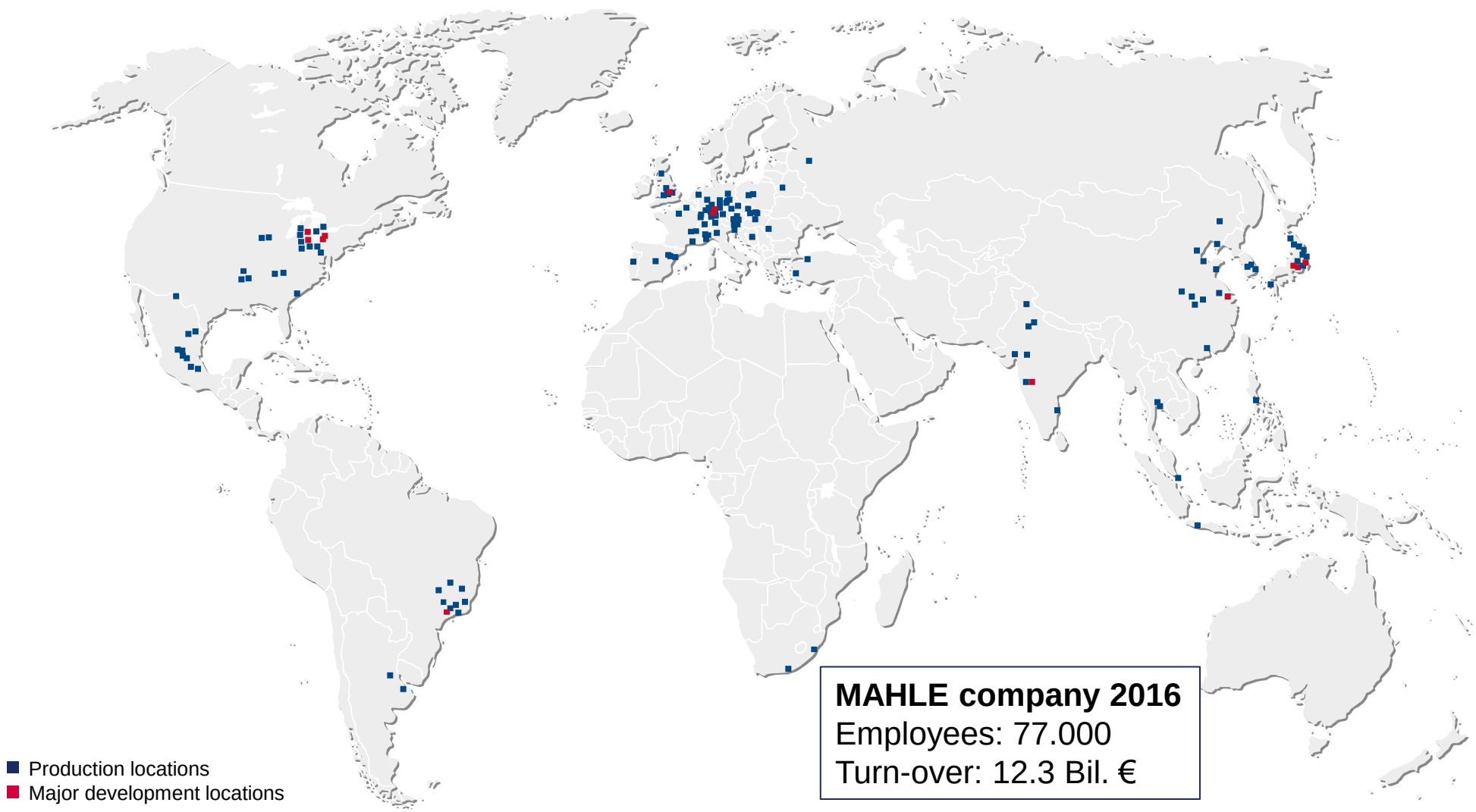

MAHLE company 2016
Employees: 77.000
Turn-over: 12.3 Bil. €

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MAHLE in Germany

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- Production locations
- Major development locations

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Product portfolio

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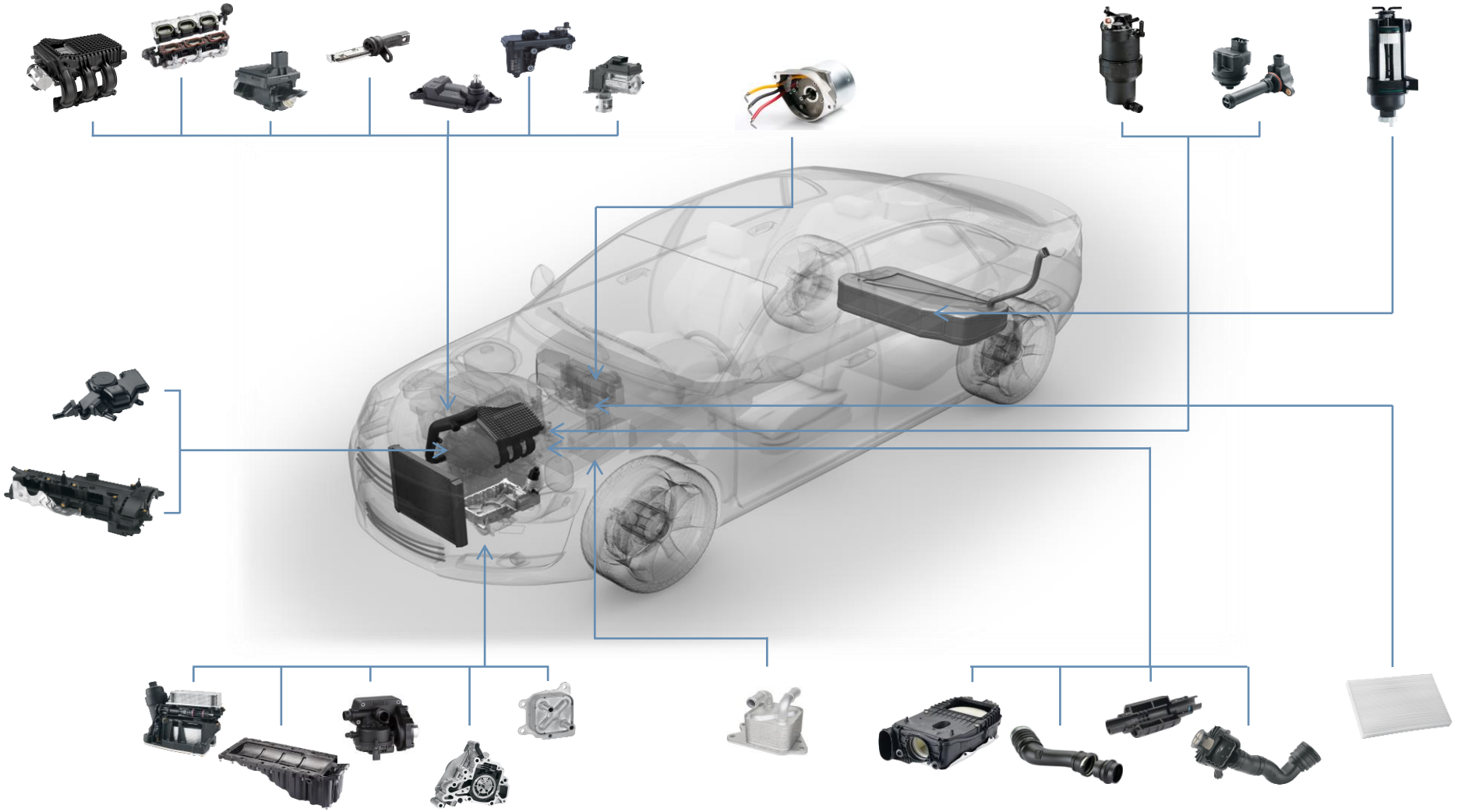

Product portfolio

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- **Filtration**
  - Air filter modules
  - Complete air induction systems
  - Fuel filter modules
  - Oil filter modules
  - Cabin air filters

- **Engine Peripherals**
  - Air intake modules
  - Cylinder head covers
  - Oil mist separators
  - Controlled oil and water pumps
  - Oil coolers
  - Activated carbon canisters
  - Mechatronic systems (BX)

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Explanation of the problem

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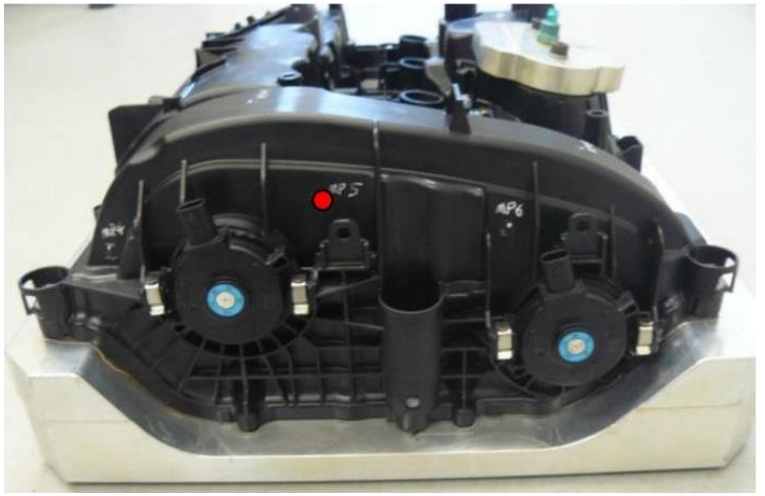
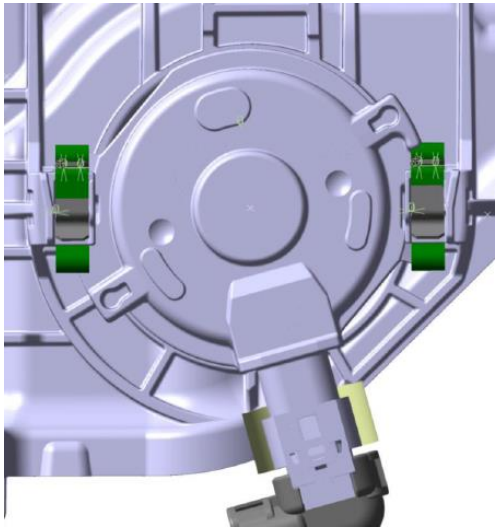
- Cylinder head cover system
  - Cylinder head cover
  - 2 actuators for the cam shaft control
    - Mounted/arrested by two springs (bajonett system)
    - Quick-change system for service cases
- Requirements for the system (for the springs)
  - Safety against unwanted dismount
  - Generate axial pre-tension between actuator and cover (min. required force F_{REQ})
- The springs are also part of the MAHLE supplier volume





Loading situation

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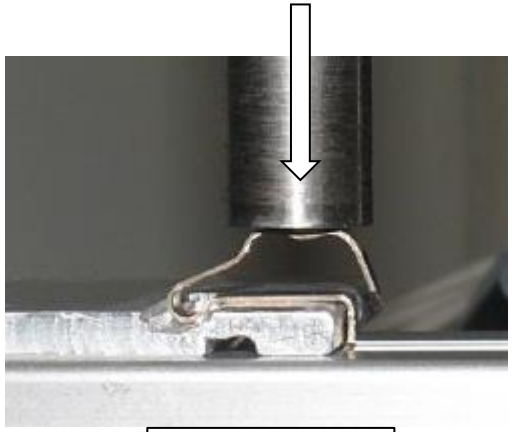
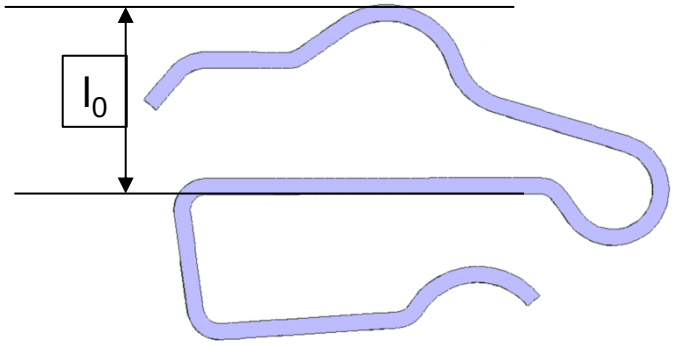
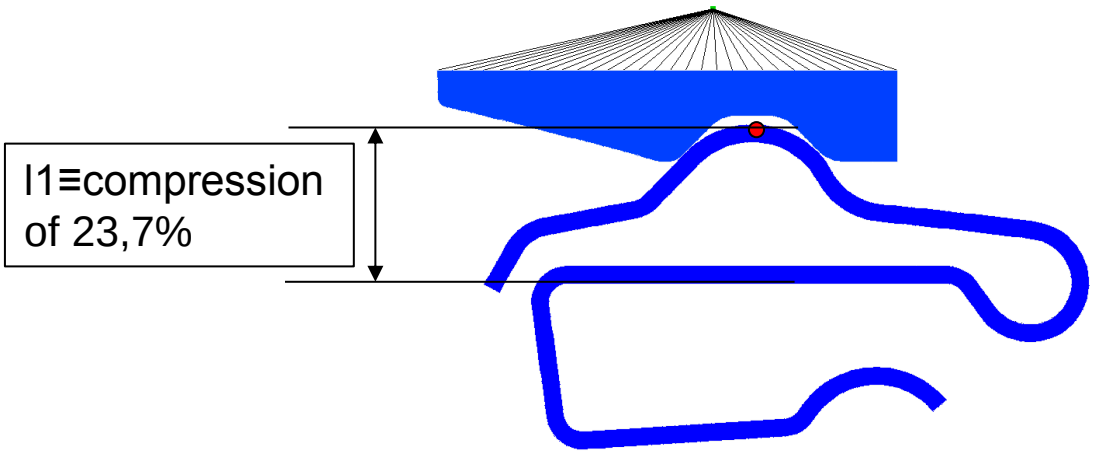
- Specific spring characteristics:
  - Initial opening width l_0
  - Mounted opening width l_1 (≡ 23,7% compr.)
    - Spring must deliver reaction force F_{REQ}
- Testing on Zwick test bench



Test bench



Unmounted situation



Mounted situation

Testing results (acc. to specification)

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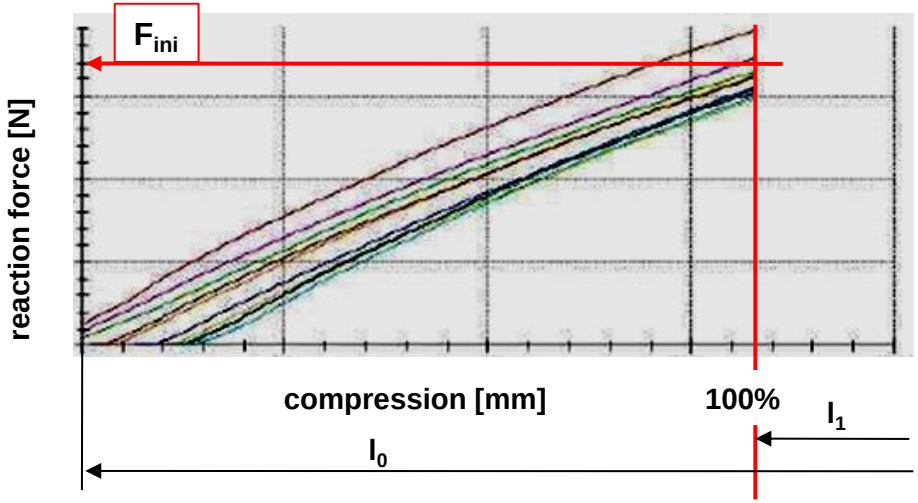
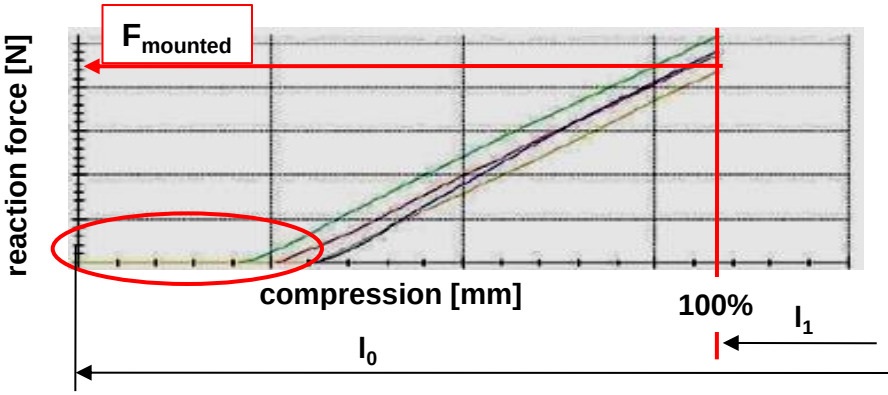
MAHLE testing
New spring



Results (spring compressed to l1):
- $F_{ini} > F_{REQ}$
- F_{ini}=32,1N

MAHLE testing
Return spring



Results (spring compressed to l1):
- $F_{mounted}$ ≈ 73,8% F_{ini}
- $F_{mounted}$=23,7N
- Plastification of the spring („initial/free“ opening width of a return spring is smaller than of a new spring)

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Real life situation

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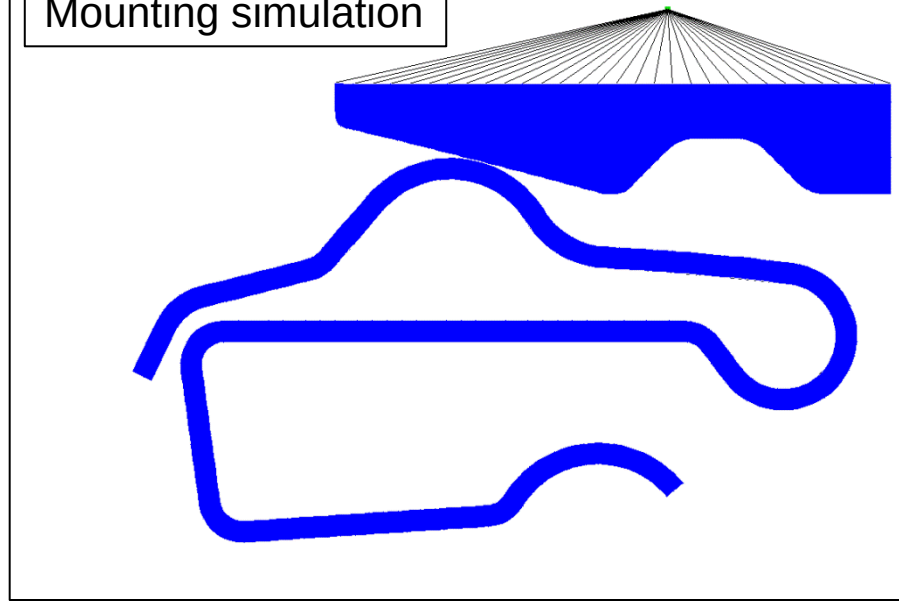
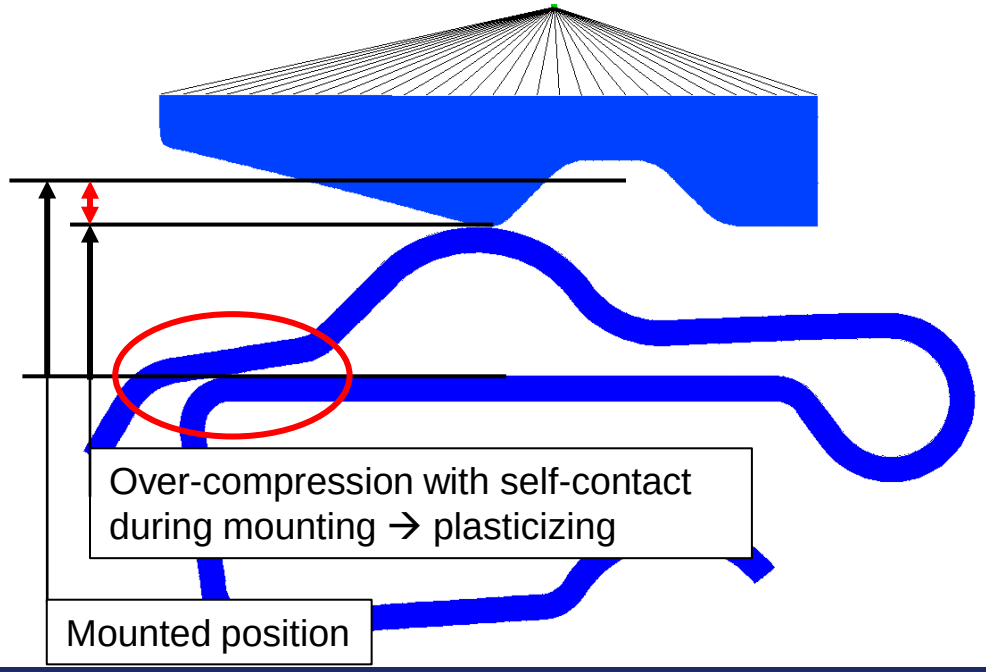
- Over-compression during mounting → the spring is highly plasticized and loses a lot of its original power
- In the mounted position the spring is not able to deliver the required force ($F_{mounted} < F_{REQ}$)

Mounting simulation





The complete actuator mounting process must be taken into account as well as plasticizing of the spring:

→Linear elastic analysis not appropriate anymore

→Nonlinear, plastic analysis is required

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Linear elastic analysis with contact update
Model set up

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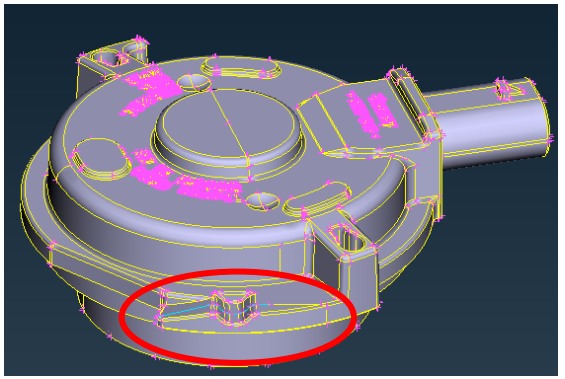
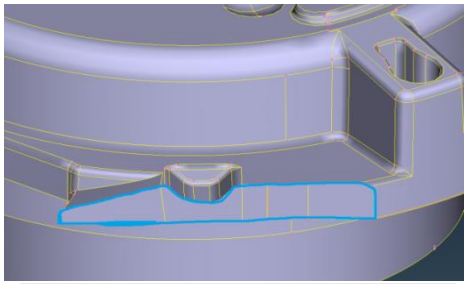
- Neglecting the rotation of the actuator during mounting → straight displacement only
- HEXA8, PENTA6 (30.000 elements)
- $CONTACT UPDATE along two surfaces
  1. spring – blade
  2. spring self-contact
- $PRESCRIBE for blade displacement
- $SUPPRESS for spring fixation
- $MATERIAL=steel

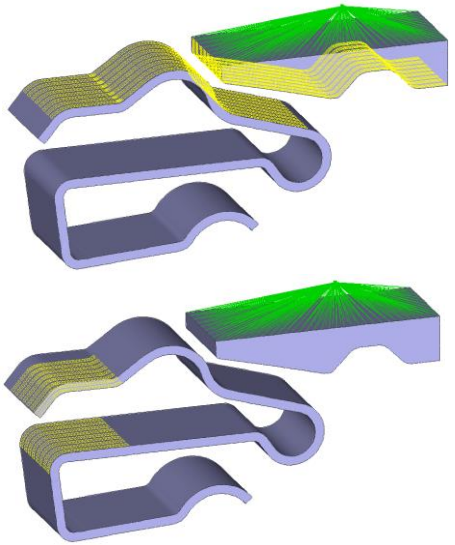
→ **Basic model for all types of simulations**

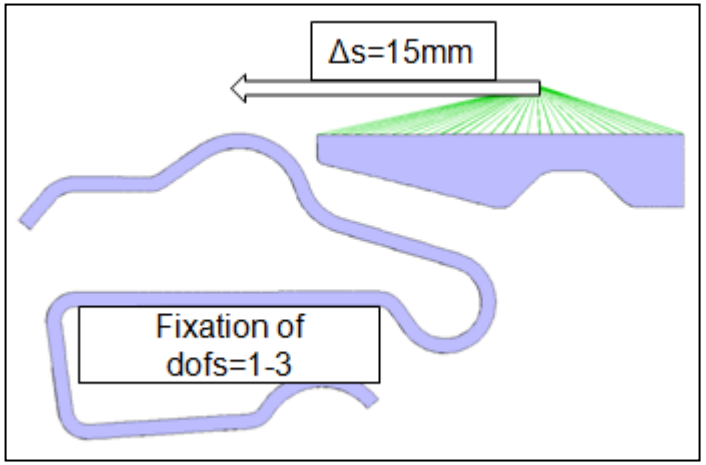


1. Actuator model



2. Simplification for analysis





3. Run nonlinear plastic analysis

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Linear elastic analysis with contact update
Results

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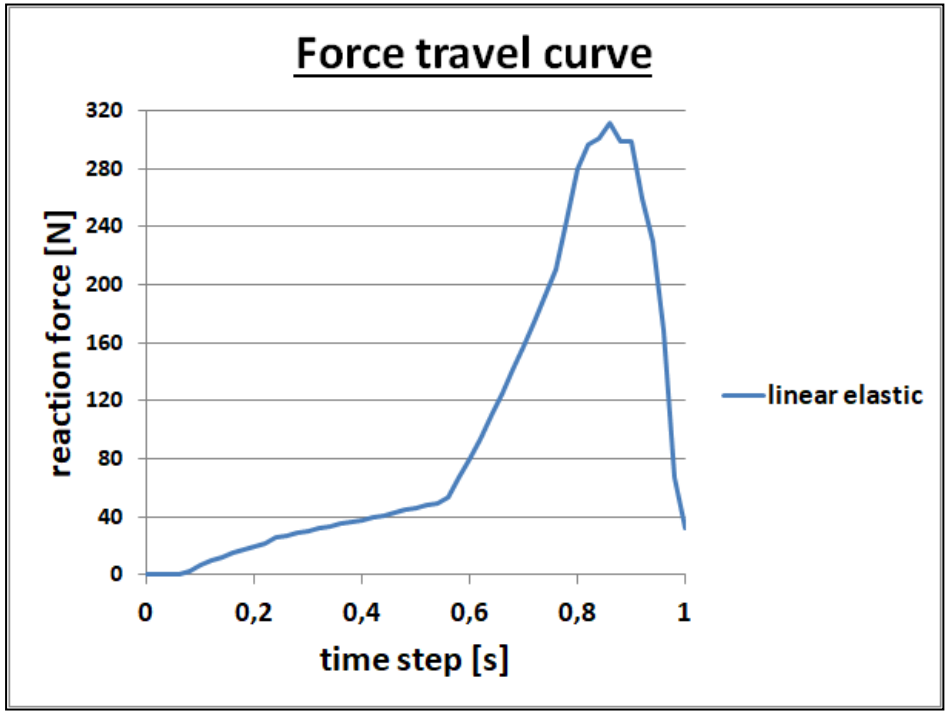
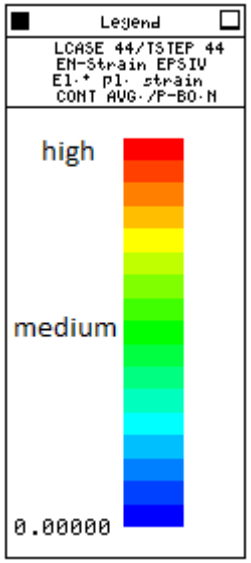
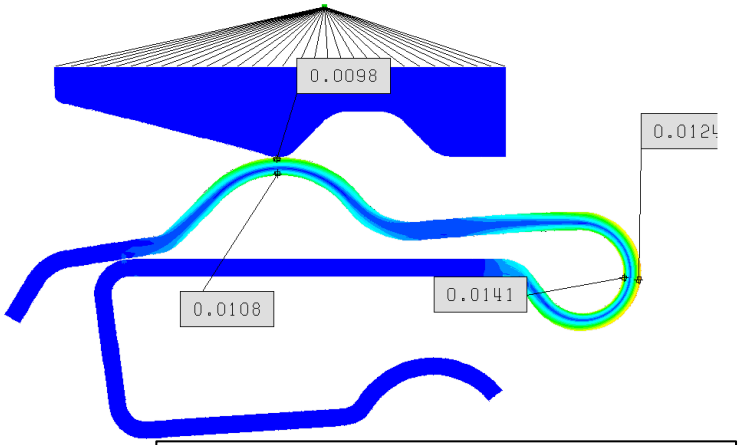
```
     Host: PCL3NB2 / Linux-x86_64-3.10.0-514.10.2.el7.x86_64
2*4 cores Intel(R) Xeon(R) CPU E5-2637 v4 @ 3.50GH / 251.77 GiByte
```

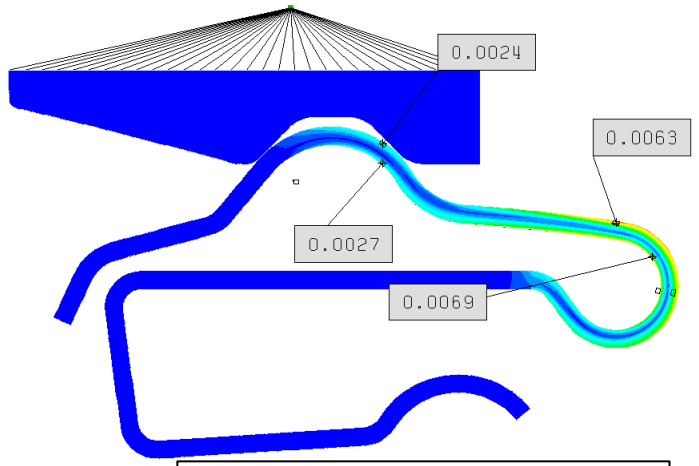
- UCI: STATIC
- Computing time: t=716s ≈ 12min
- Strains in [-]







Strains during over-compression



Strains in mounted position

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Plastic analysis with contact update: Basic simulation results

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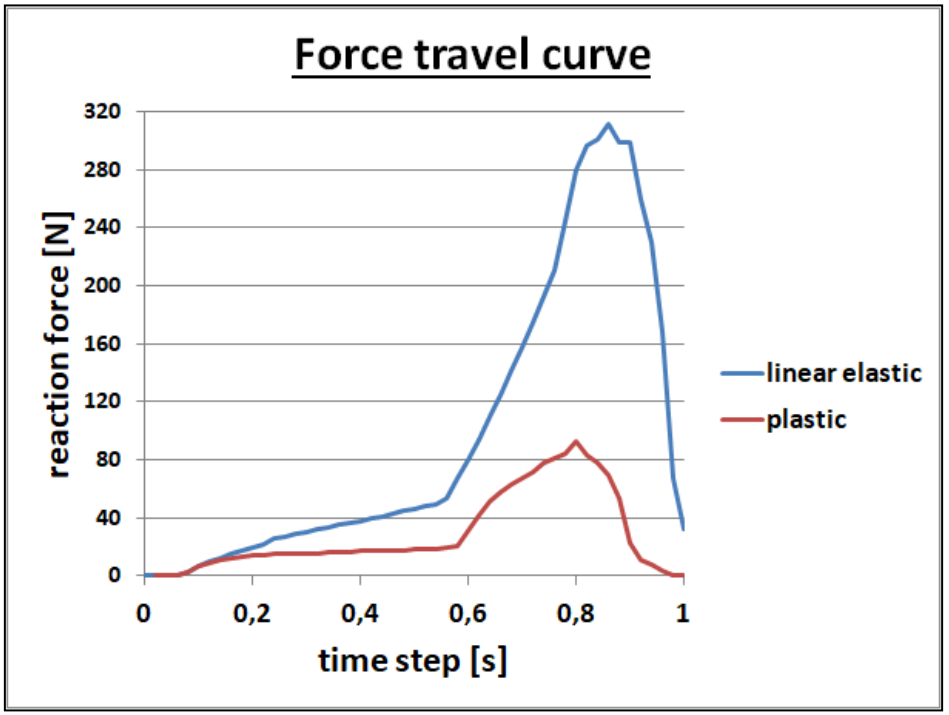
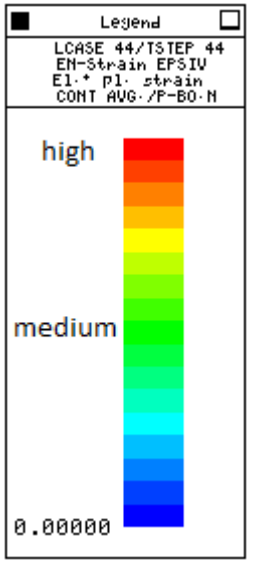
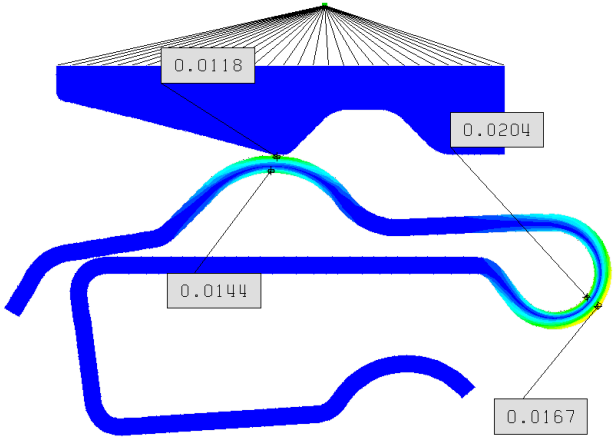
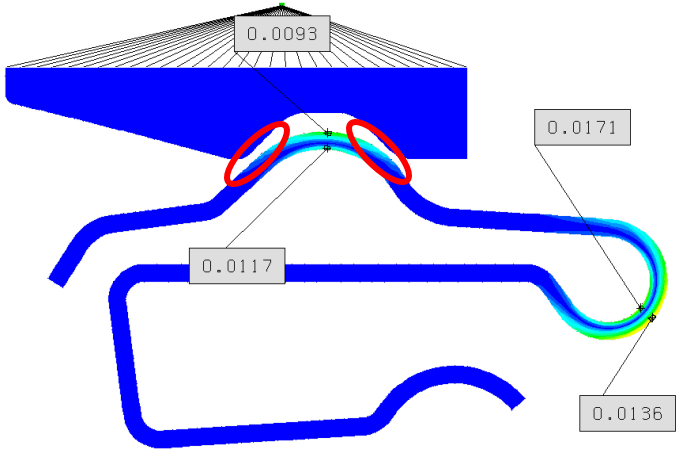
- UCI: NLMATERIAL NLGEOM=YES
- Computing time: t=742s ≈ 12,5min
- Strains in [-]
- No contact anymore between spring and blade







Strains during over-compression



Strains in mounted position

Plastic analysis with contact update: Implementation of production induced plasticizing

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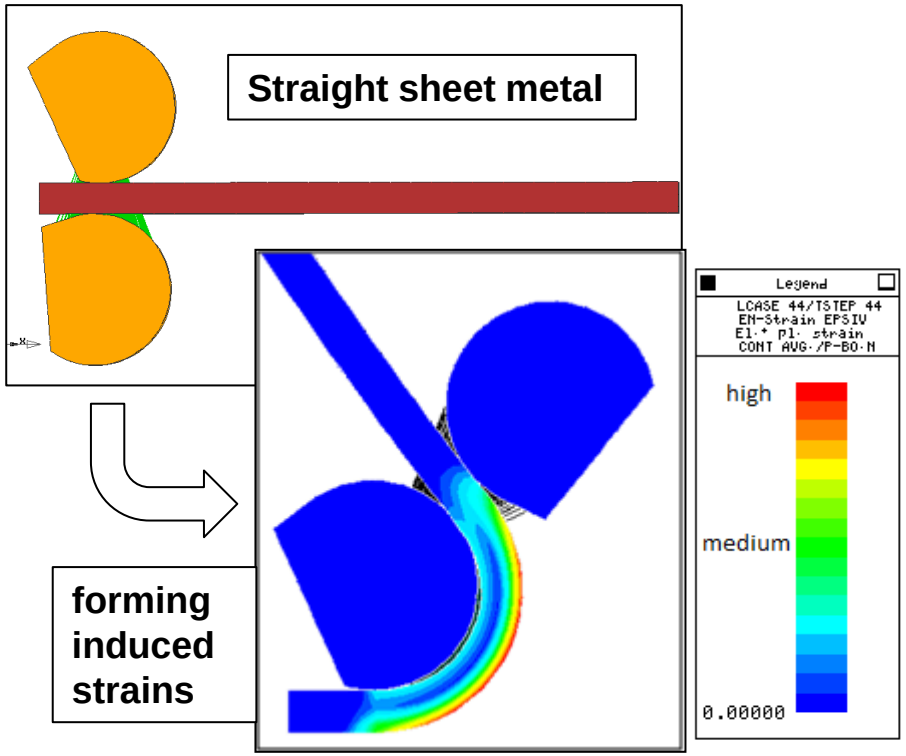
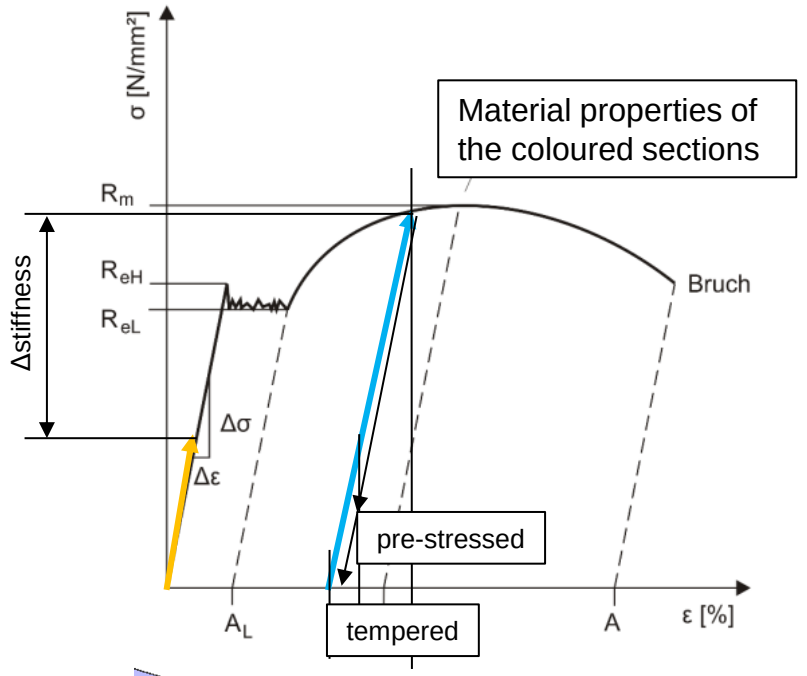
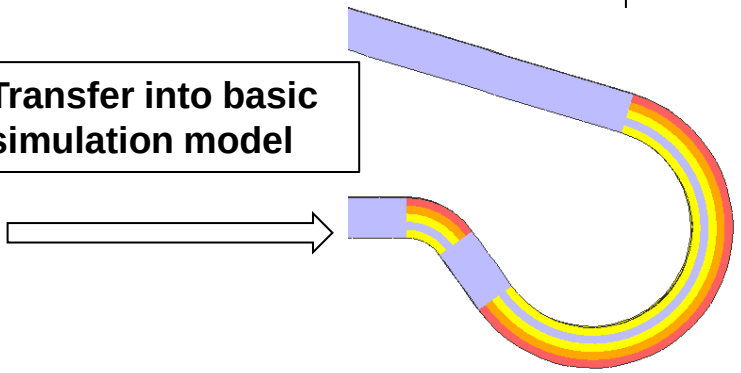
- UCI: NLMATERIAL NLGEOM=YES
- Strains in [-]





Transfer into basic simulation model



Grey: ε_{pl_0}
Yellow: ε_{pl_1}
Orange: ε_{pl_2}
Red: ε_{pl_3}

Plastic analysis with contact update: Forming induced strains

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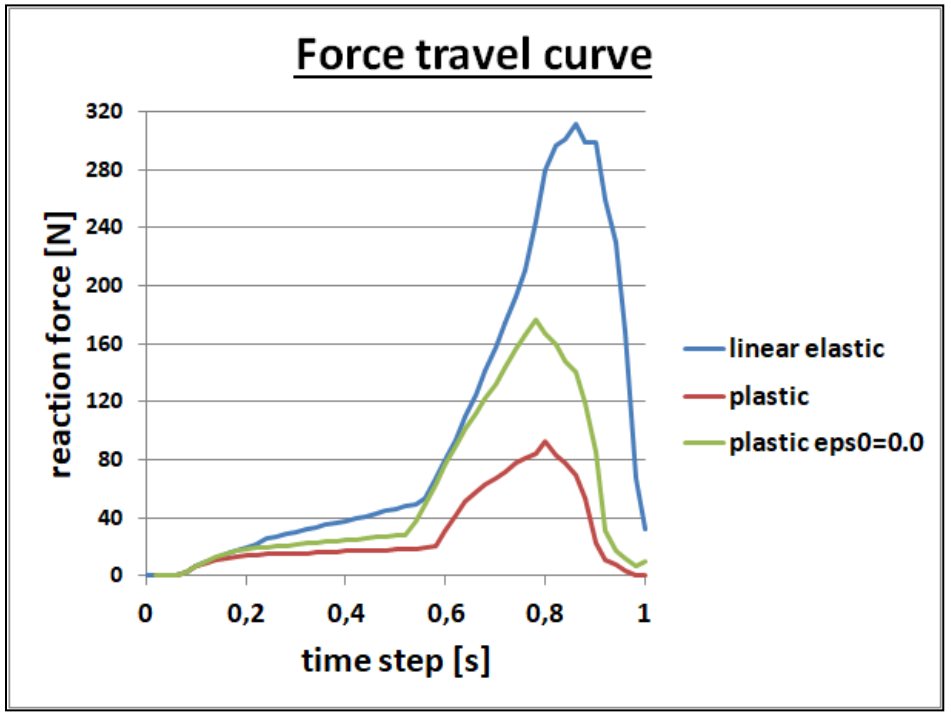
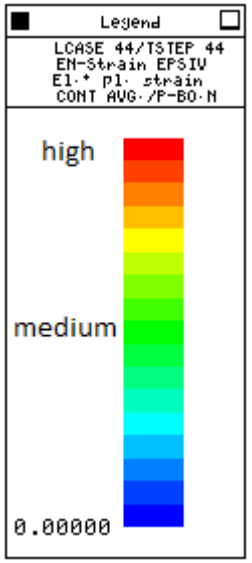
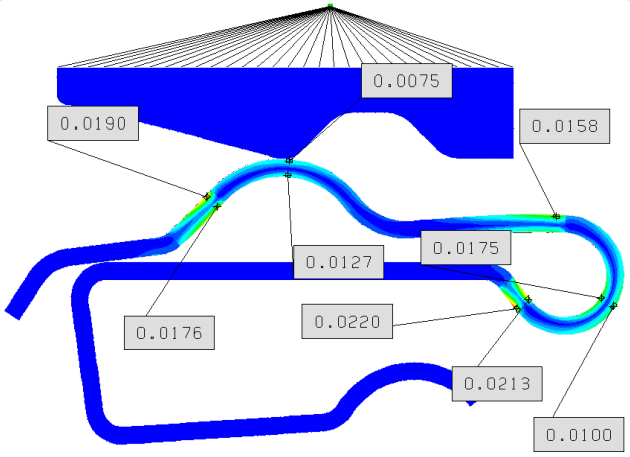
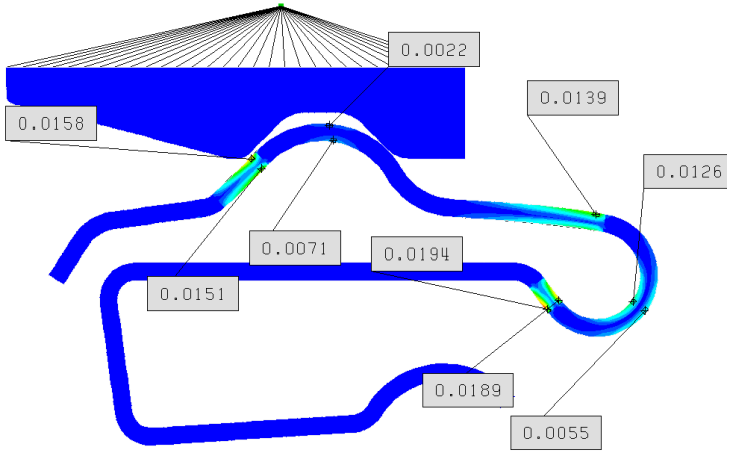
- UCI: NLMATERIAL NLGEOM=YES
- Computing time: t=862s ≈ 14,5min
- Strains in [-]







Strains during over-compression



Strains in mounted position

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Plastic analysis with contact update: Forming induced strains + milled strains

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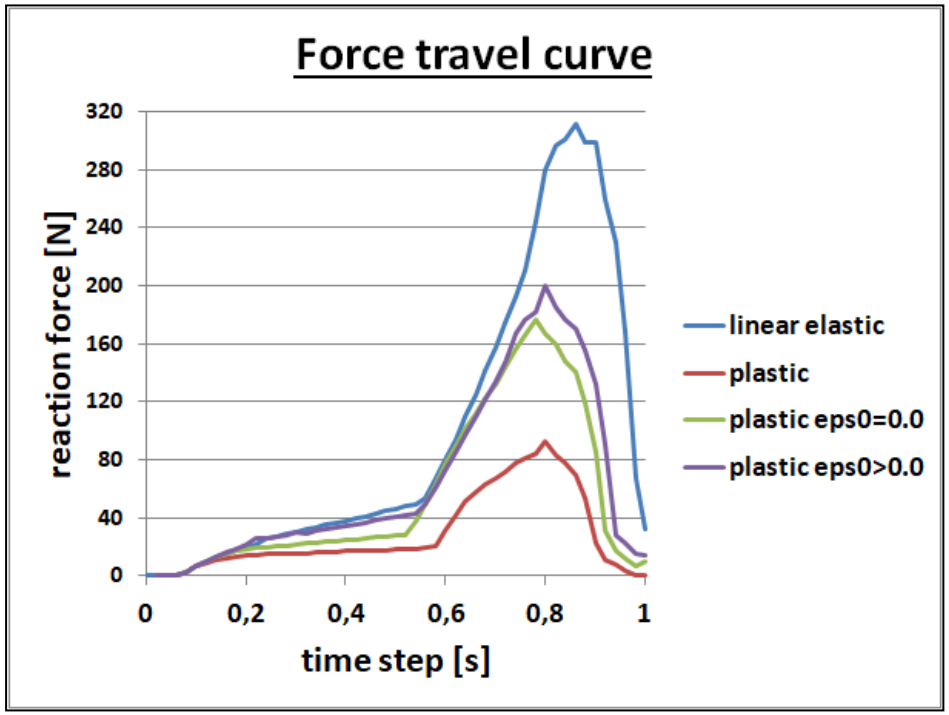
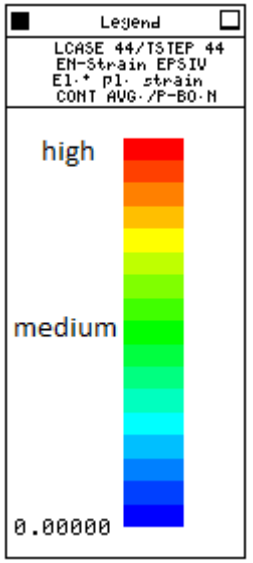
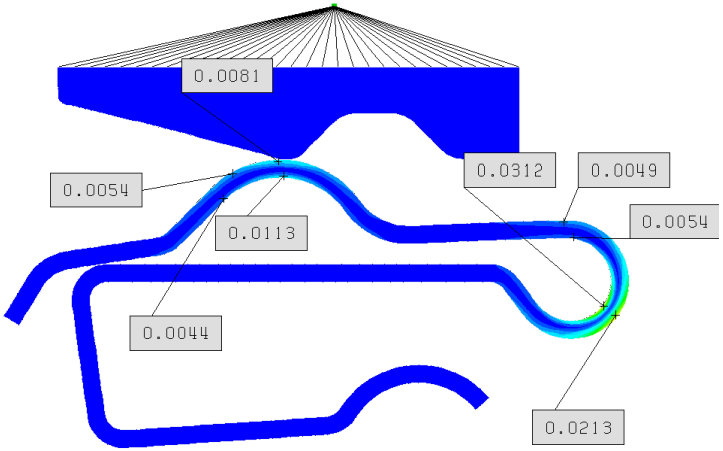
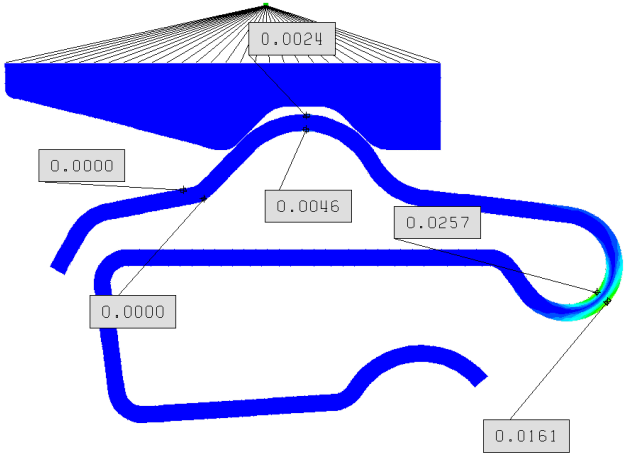
- UCI: NLMATERIAL NLGEOM=YES
- Computing time: t=889s ≈ 15min
- Strains in [-]







Strains during over-compression



Strains in mounted position

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Comparison of analysis types

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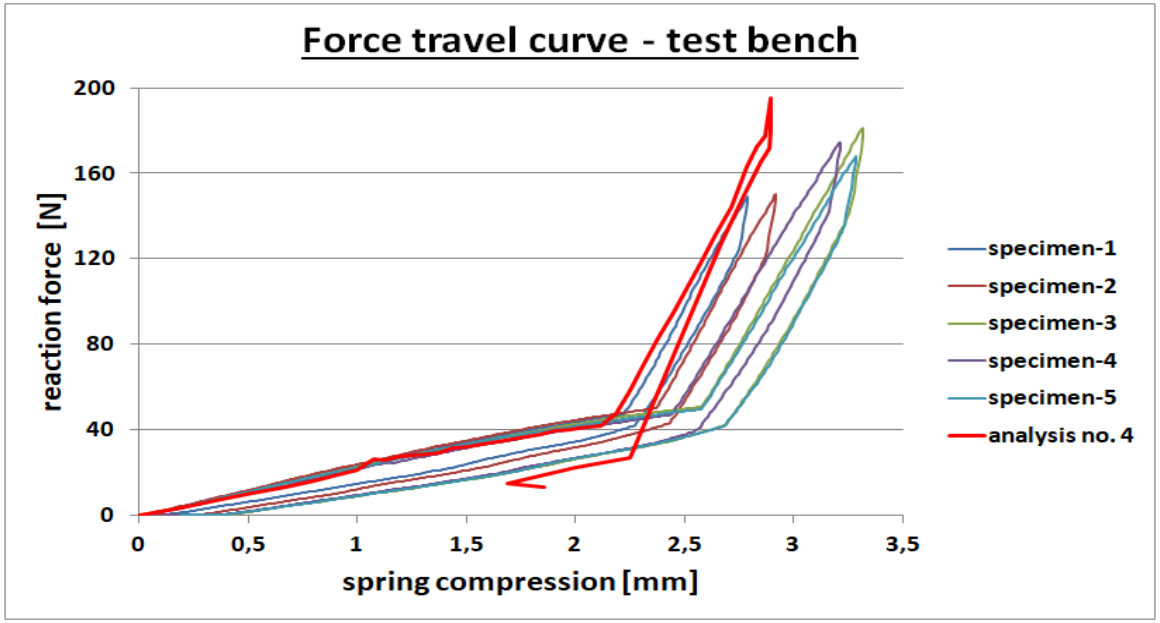
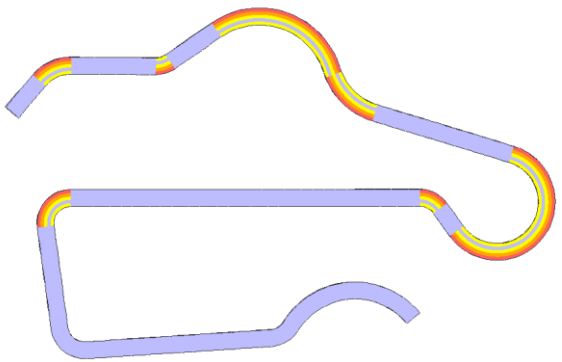
- Analysis 4 shows the best correlation between testing and simulation results
  - Inclination of curves
  - Drop after over-compression
  - Hysteresis curve
- But deviations for the
  - max. spring force
  - mounted spring force



Analysis type	Computing time [s]	Max. spring force [N]	Mounted spring force [N]
1. Linear elastic	716	311	32,1
2. Plastic	742	92,8	0
3. Plastic + forming strains	862	176	6,5
4. Plastic + forming & milling strains	889	200	14,1



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Summary

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- For parts/structures with large deformations and/or plasticizing, the linear elastic approach is not appropriate anymore
- Non-linear analysis elongates computing time about 2,5 minutes only
- Good correlation between testing and simulation results
  - Deviations still there (but, reasons are known)

Advice:

- (for metal spring) All types of process induced (plastic) strains must be taken into account
- For high(er) plasticizing zero-force-elements are needed (convergence issues)

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Questions?