

## Modeling and simulation of carbon black filled elastomer damper using LS-DYNA.

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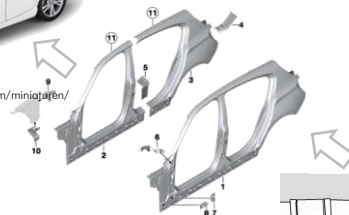
LS-DYNA Forum, Bamberg, October 6-8, 2014

1

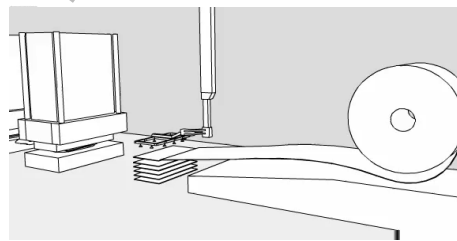
## How it's made?



Source: <http://www.bmw-amold.com/miniaturen/>



Source: <http://www.leebsmann24.com/>



Source: <http://www.bmwgroup.com/>

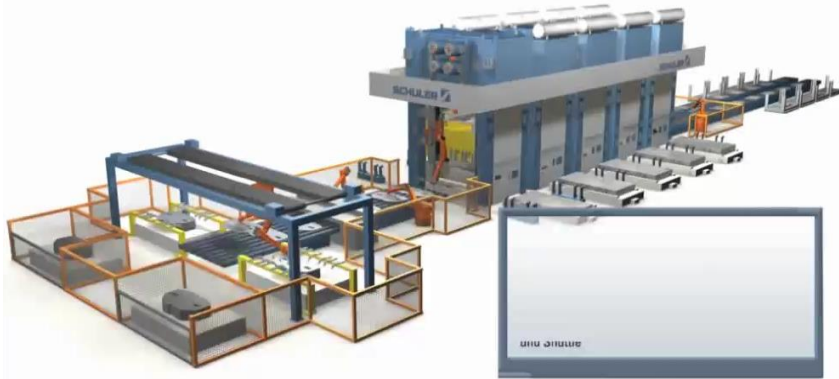
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"Modeling and simulation of carbon black filled elastomer damper using LS-DYNA."  
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2

# The servo press



Source: <http://www.schulergroup.com/>

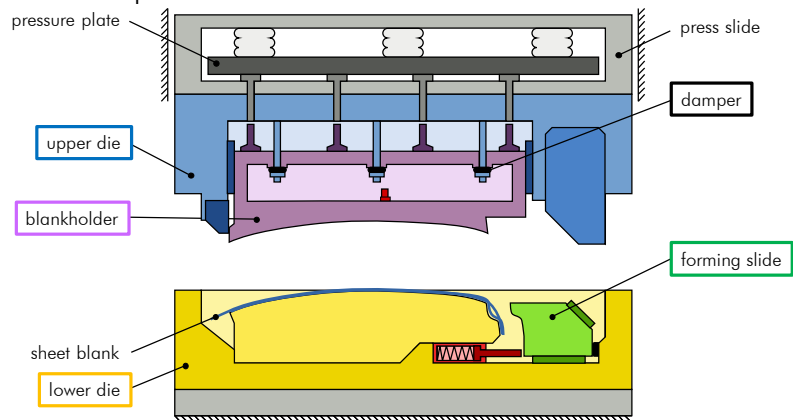
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3

# The automotive tool

## ■ Main components:



## ■ A real tool is made of up to 3000 components!

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4

# Agenda

- Background
- The elastomer damper
- Methods
- Experiments
- Simulations
- Results and comparison
- Conclusion and outlook

# The elastomer damper

- Black carbon filled elastomer:



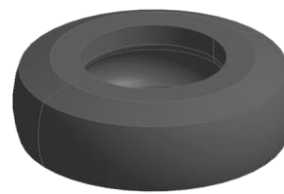
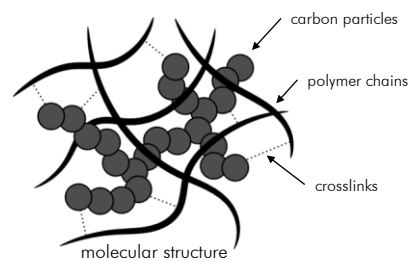
natural or synthetic rubber  
Source: www.wikipedia.org



black carbon particles  
Source: www.wikipedia.org



vulcanization



final elastomer damper  
Source: www.ace-ace.com/

## The damper: 1<sup>st</sup> issue: complex form

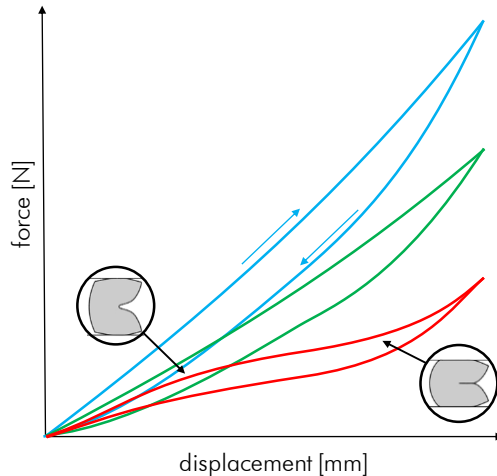
- Simple form:



- Ring form:



- Ring form with cut-out:



## The damper: 2<sup>nd</sup> issue: lack of material

- to address different material deformation states typically following tests are carried out:



uniaxial tension



uniaxial compression



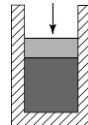
biaxial



planar shear



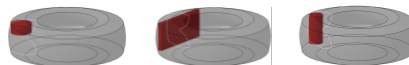
simple shear



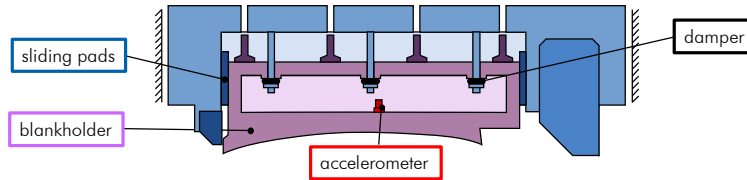
volumetric tests

Source: <http://www.axelproducts.com>

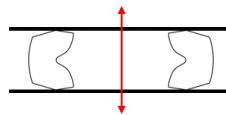
- but there were no specimen samples of the damper material available → only raw material, which differs in stiffness
- thermal treatment of raw material is unknown (confidential)
- cutting samples from damper limited due to small size (but was also carried out)



## Simplifying the problem

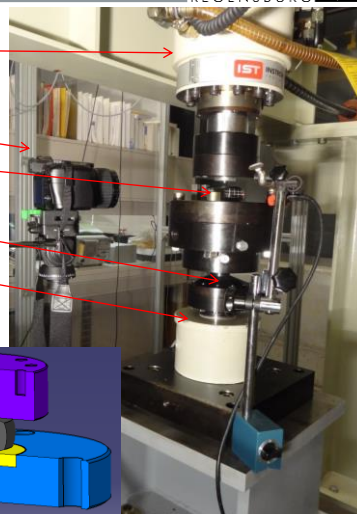
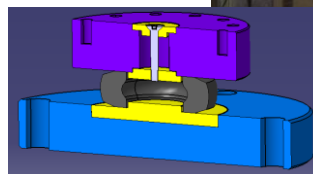
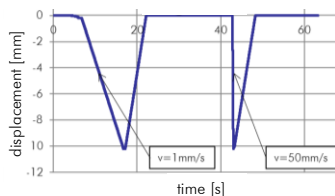


- due to the fact that the blankholder is vertically constrained (sliding pads) and its mass is distributed on several dampers, its displacement can be very well approximated considering **only axial response of the dampers:**



## Experiments

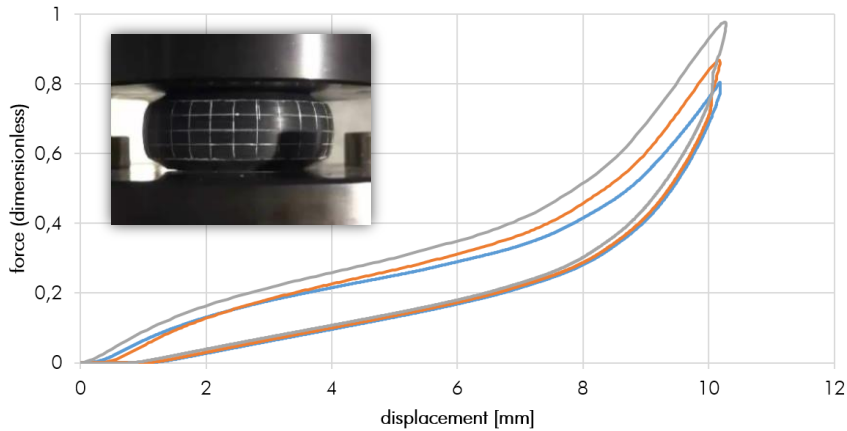
- Hydropulse system
- Video camera
- Elastomer damper
- Spherical joint
- Force transducer
- Excitation, displacement-controlled:



# Experiments results

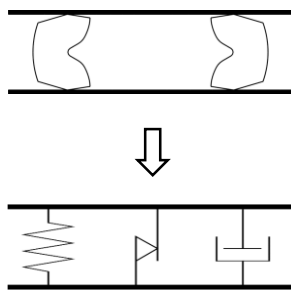
- Hysteresis force-displacement curves in compression:

— vel = 1 mm/s — vel = 50 mm/s — vel = 100 mm/s

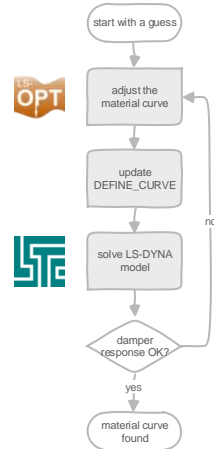


# Possible solutions

- 1-D rheological model:

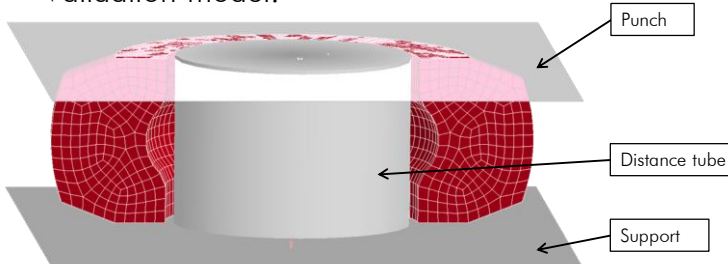


- reverse engineering:



# Experiments validation

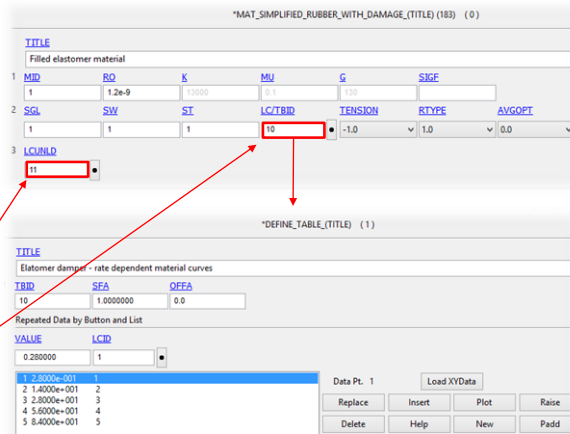
- Validation model:



- Impose motion with displacement curve: BOUNDARY\_PRESCRIBED\_MOTION\_RIGID\_BODY
- Element formulation: constant stress solid element
- Contact: Self contact and steel-rubber with friction

# Material model

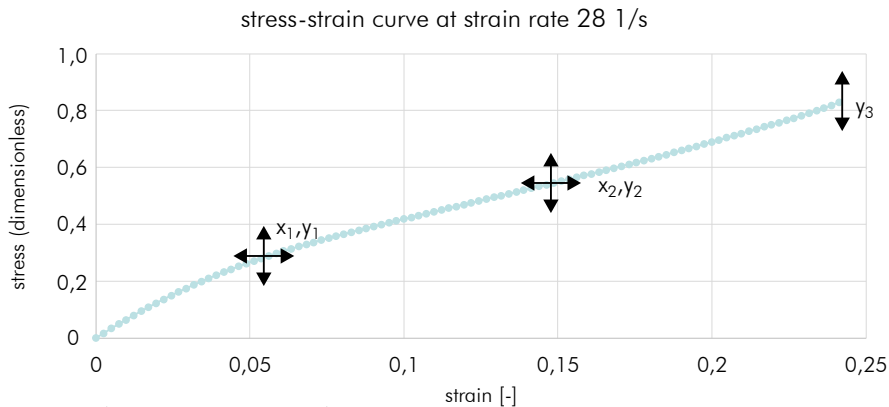
- Material: MAT\_183\_SIMPLIFIED\_RUBBER\*
- tabulated, based on Ogden functional
- only uniaxial tensile/compressive test results needed
- assumes incompress.
- Inputs:
  - Unloading curve
  - Table with family of loading curves defined for discrete strain rates



\* Source: Du Bois: „A simplified approach to the simulation of rubber-like materials under dynamic loading“ (2003)

# Input curve parameterization

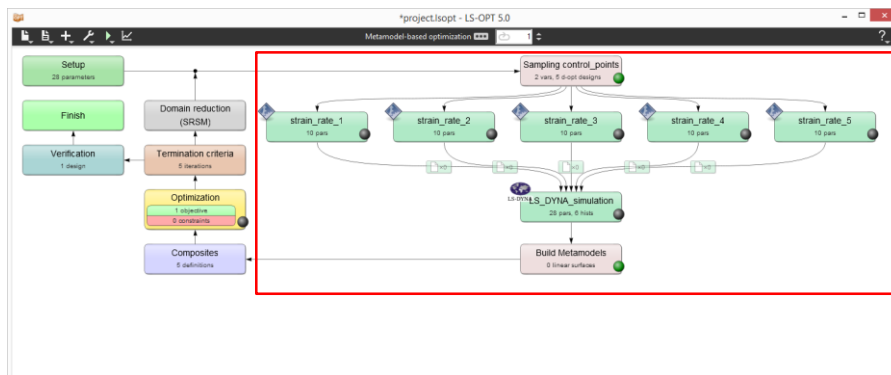
- Parameterization of the stress-strain curve of the damper material with a cubic Hermite spline\*:



\* Source: K. Witowski, LS-OPT Support - Curve mapping example

# Optimization with LS-OPT

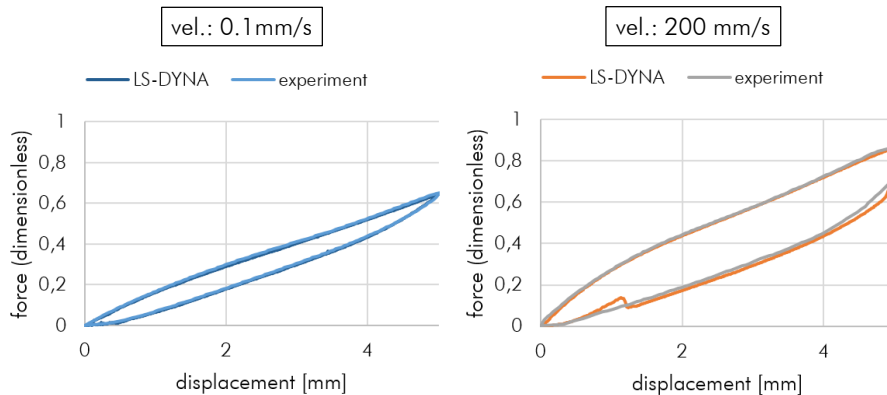
- LS-OPT scheme:





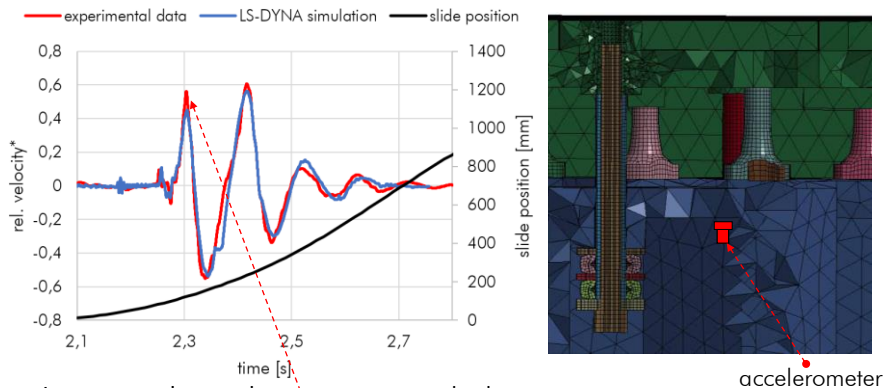
## Simulation results

- Strain results at different strain rates with corresponding force-displacement curves:



## Results and comparison

- Comparison of blankholder's velocity:

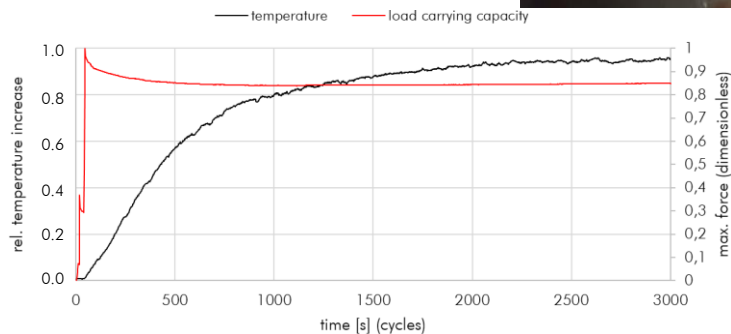


- In general good agreement with the experiment
- Still some deviations

\*highpass, cutoff freq.: 5 Hz, lowpass: 1000 Hz

## Temperature dependence

- temperature sensor fixed with elastic band
- Elastomer damper pre-stressed at 3 mm
- Excitation with a sine curve (freq.: 1 Hz, amplitude: 6 mm), path-controlled



## Conclusions and outlook

- LS-OPT can be used to guess the unknown simplified material curve
- The LS-DYNA damper model describes the strain rate dependency correctly
- Thanks to LS-DYNA simulation the forming tool designer can:
  - get a deeper insight into the tool
  - do fatigue life prediction
  - reduce the mass of the tools, thus saving money
- Next steps:
  - Implement the temperature dependency
  - Develop the 1-D rheological model of the damper
  - Finish the complete LS-DYNA forming tool model
  - Automate the modeling process

