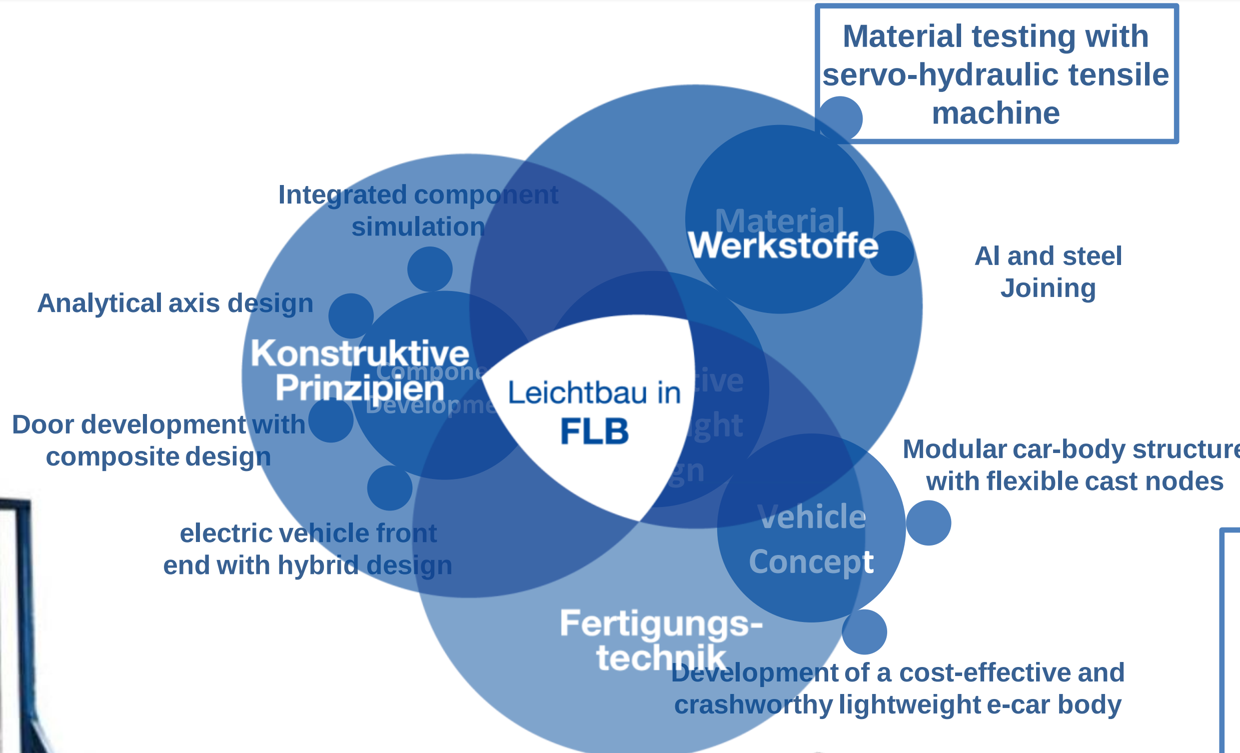
Numerical stress wave analysis in LS-DYNA and force measurement at strain rates up to 1000 /s of a high speed tensile machine

Prof. Xiangfan Fang and Dr. Jie Li

Institute of Automotive Lightweight Design
University of Siegen, Germany

Research and Development at FLB, Uni. Siegen



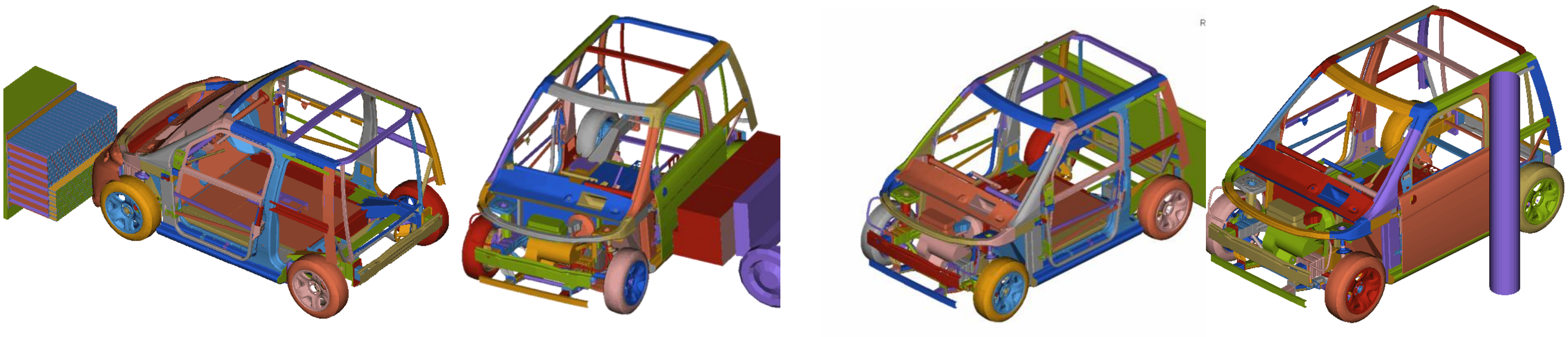
Body development at FLB: StreetScooter City Car

Frankfurt Auto Show 2011

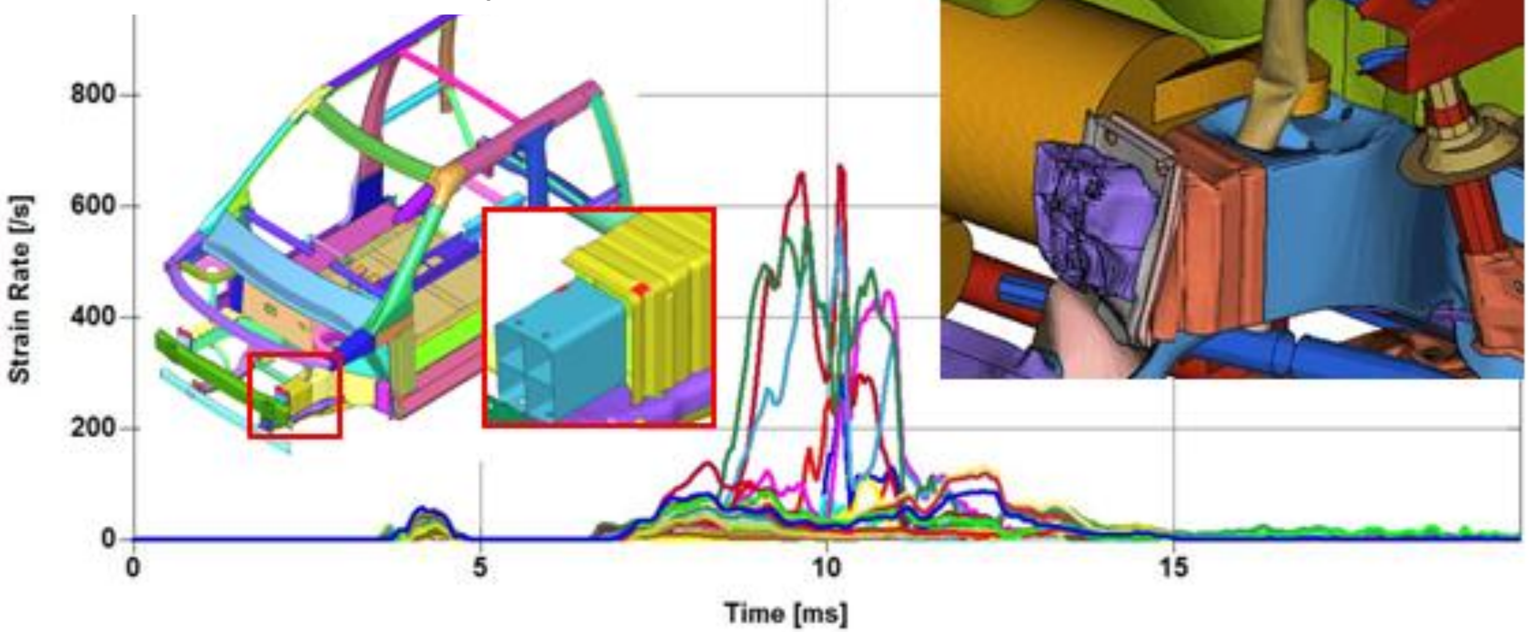
Deutsche Post in Bonn, 79 Cars

Cost-effective Body Structure for an E-vehicle, Xiangfan Fang, Jie Li, Stefan Kurtenbach, ATZ - Automobiltechnische Zeitschrift, May 2014.

Mat. Data for Crash Simulation at Strain Rates up to 10^3 /s

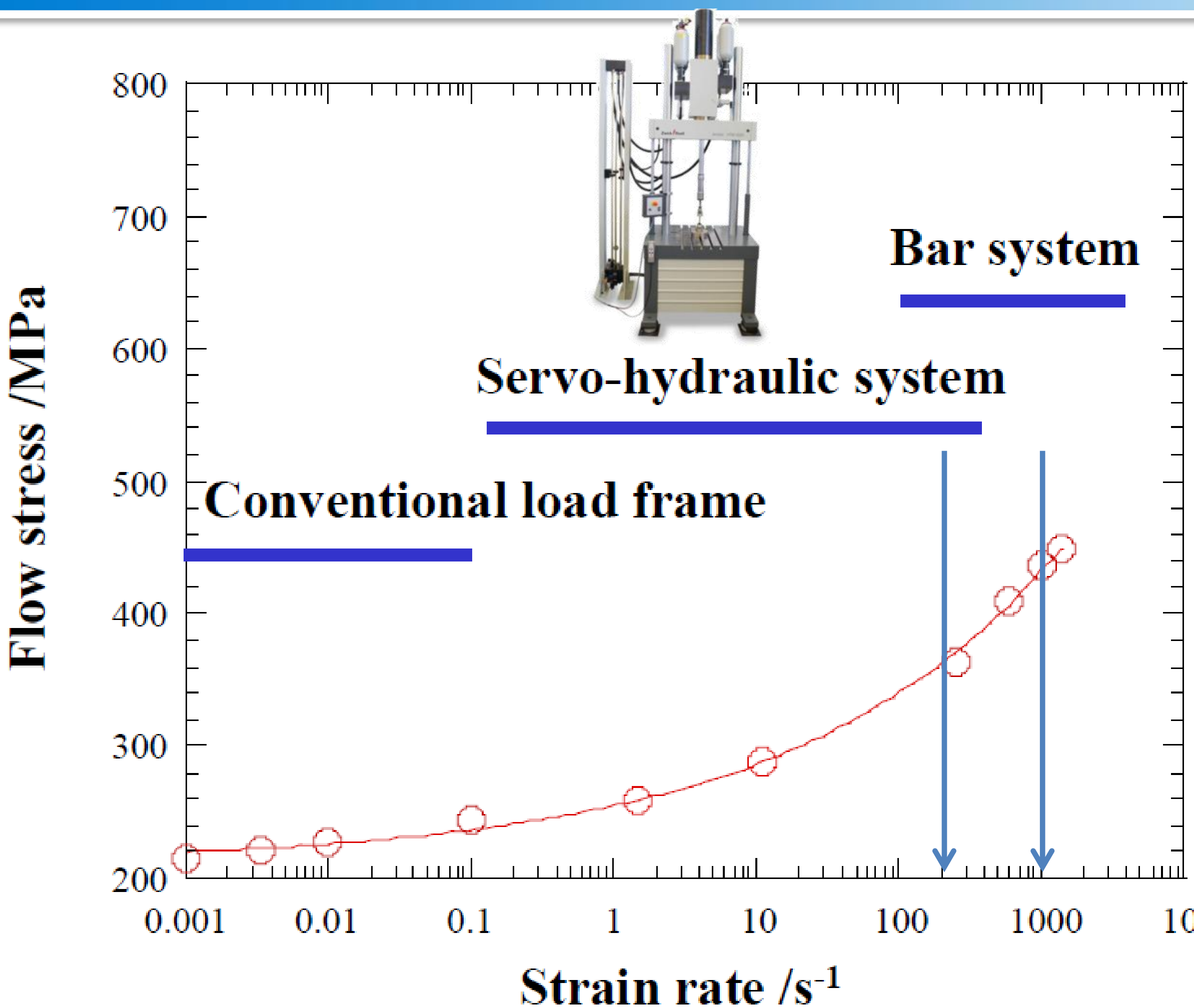


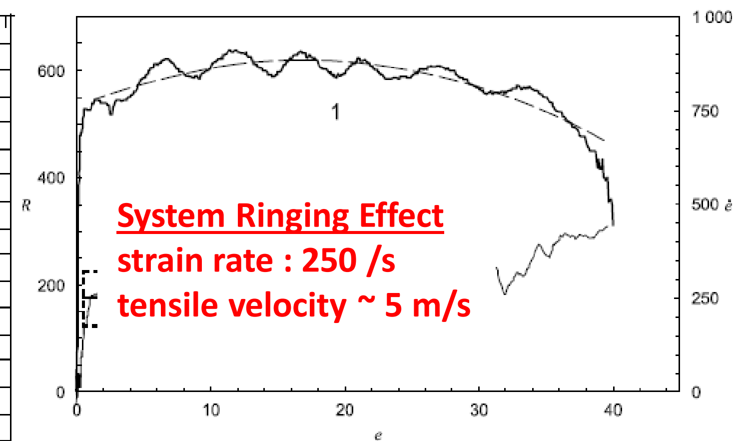
Plastic deformation at strain rates ~ 1000/s

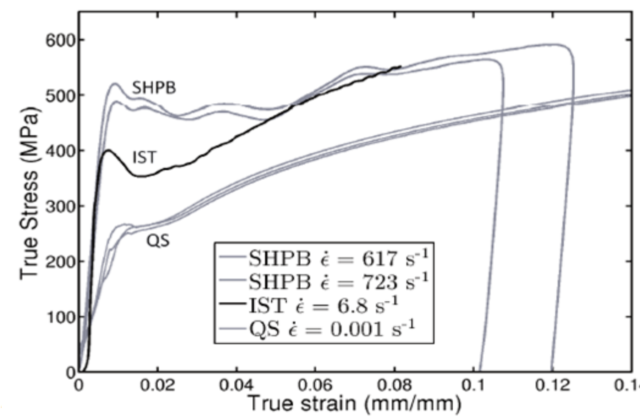


Cost-effective Body Structure for an E-vehicle, Xiangfan Fang, Jie Li, Stefan Kurtenbach, ATZ - Automobiltechnische Zeitschrift, May 2014.

High Strain Rate Tensile Test: The state of the art







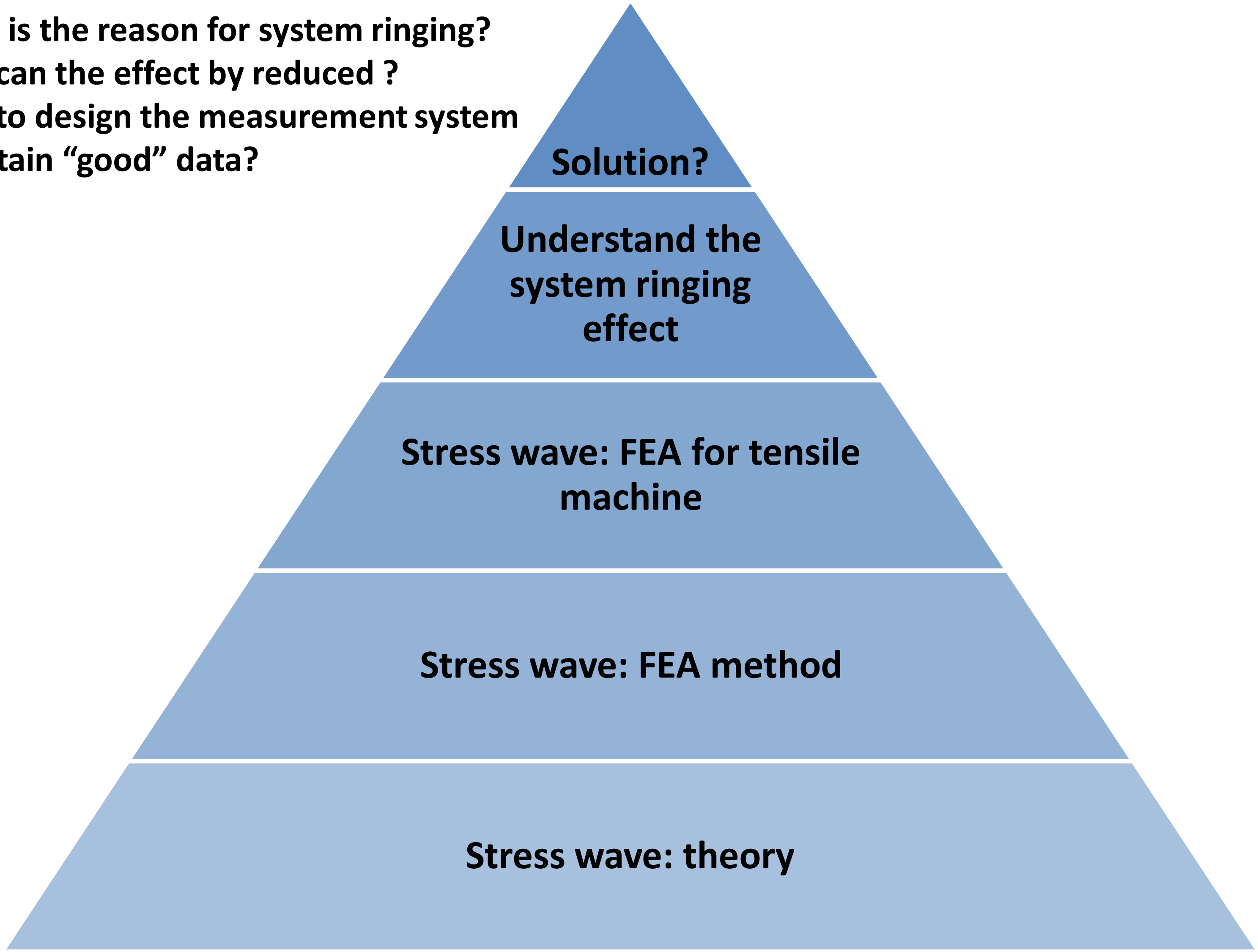
System Ringing Effect: great challenge for force measurement between 2 m/s and 20 m/s.

Borsutzki M, Cornette D, Kuriyama Y, et al. (2005) Recommendations for Dynamic Tensile Testing of Sheet Steels. Intern. Iron and Steel Institute
International Organization for Standardization (2011) Metallic materials -- Tensile testing at high strain rates -- Part 2: Servo-hydraulic and other test systems; ISO 26203-2.

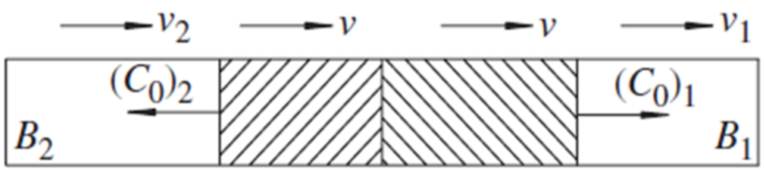
FLB approach to the “system ringing effect”

FLB
Lehrstuhl für Fahrzeugleichtbau
UNIVERSITÄT SIEGEN

- What is the reason for system ringing?
- How can the effect by reduced ?
- How to design the measurement system to obtain “good” data?

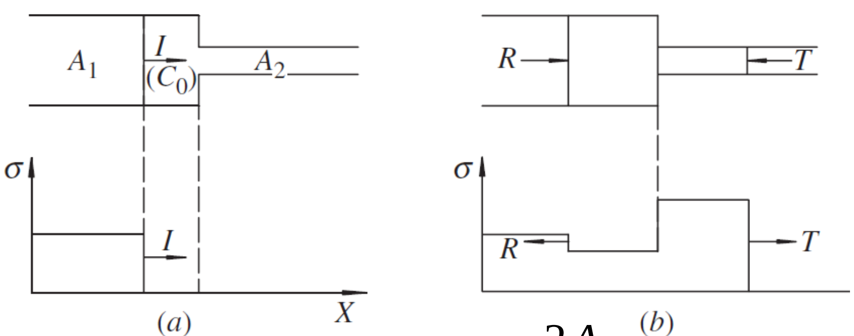


Stress wave: Theory and FEA



$$\sigma = -(1/2)\rho_0 C_0 (v_2 - v_1)$$

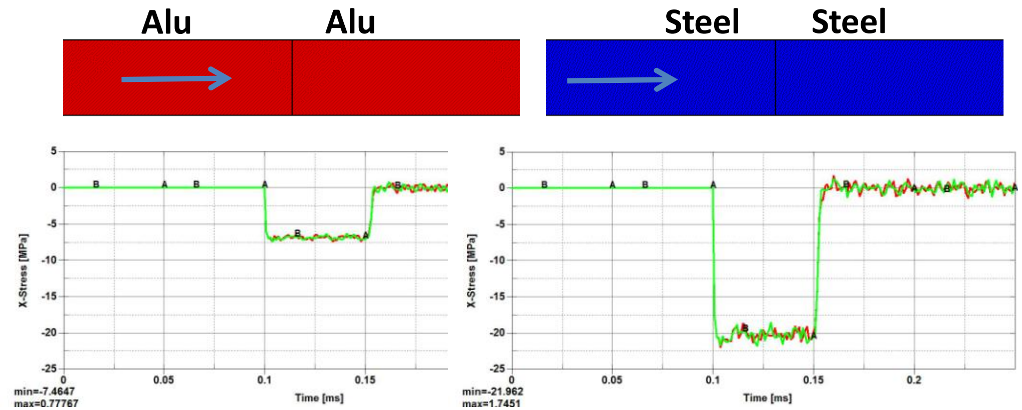
$$v = \sqrt{\frac{E}{\rho}}$$



$$\sigma_T = \sigma_i \frac{2A_1}{A_1 + A_2}$$

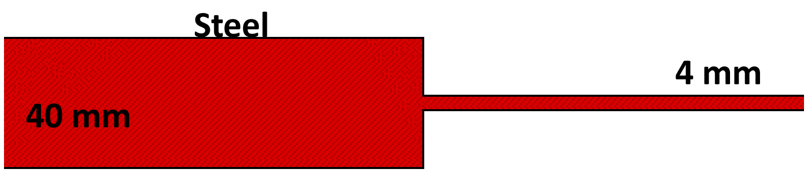
$$\sigma_R = \sigma_i \frac{A_2 - A_1}{A_2 + A_1}$$

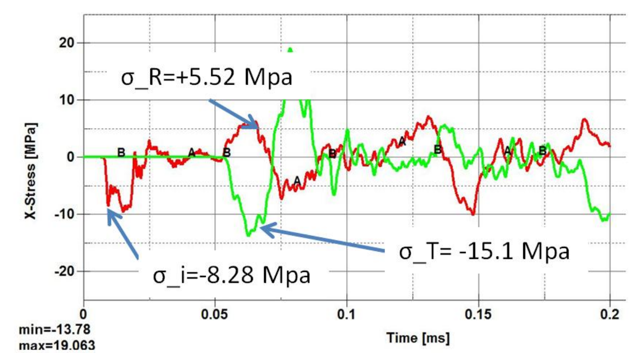
Wang L (2007) **Foundations of Stress Waves**, illustrated edition. Elsevier Science



X Stress (MPa)	
FEA	Theory
7.0	6.87

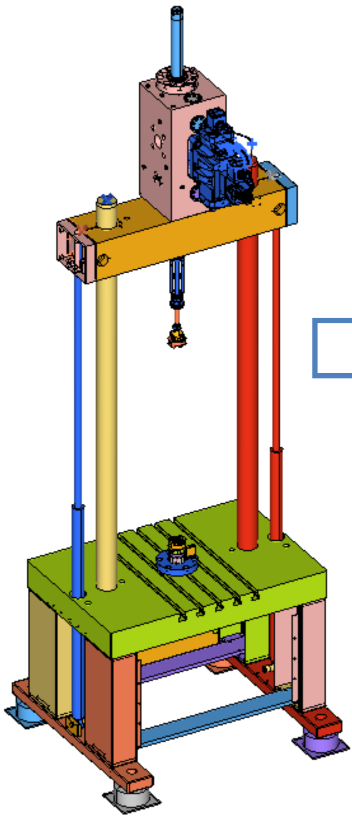
X Stress (MPa)	
FEA	Theory
20.27	20.30



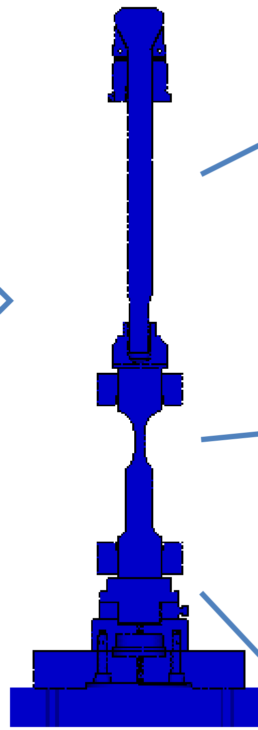


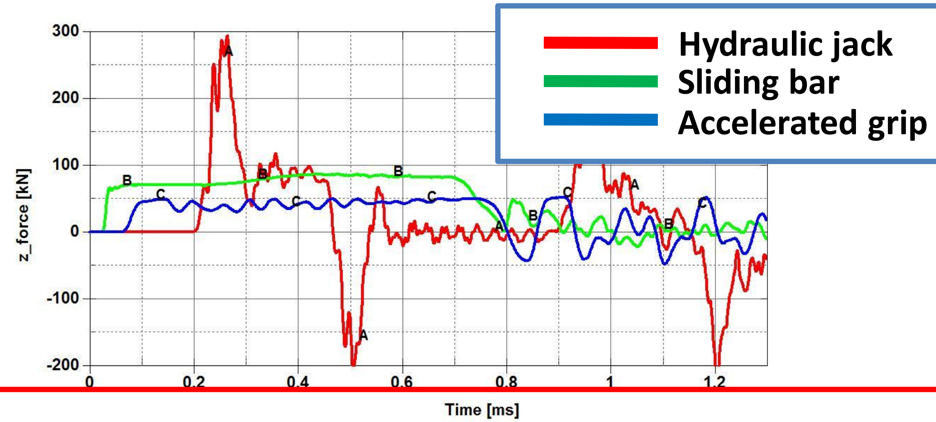
Stress wave: FEA for HTM 5020 (Zwick)

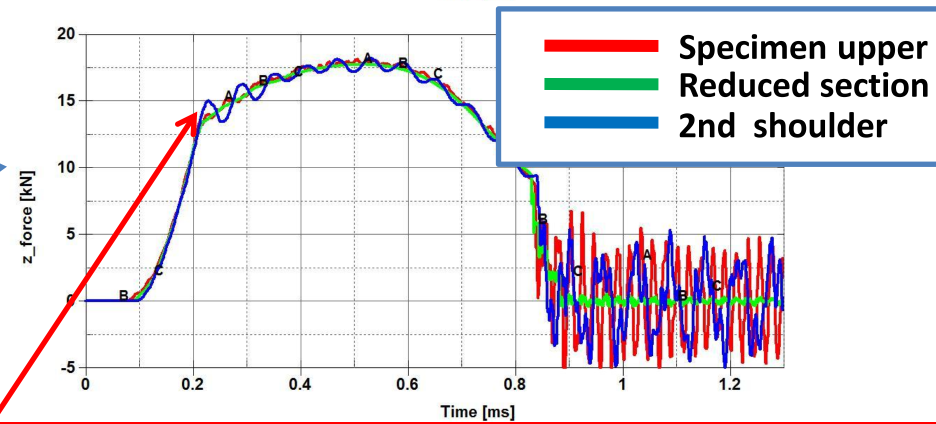
CAD of HTM 5020 (provided by Zwick)

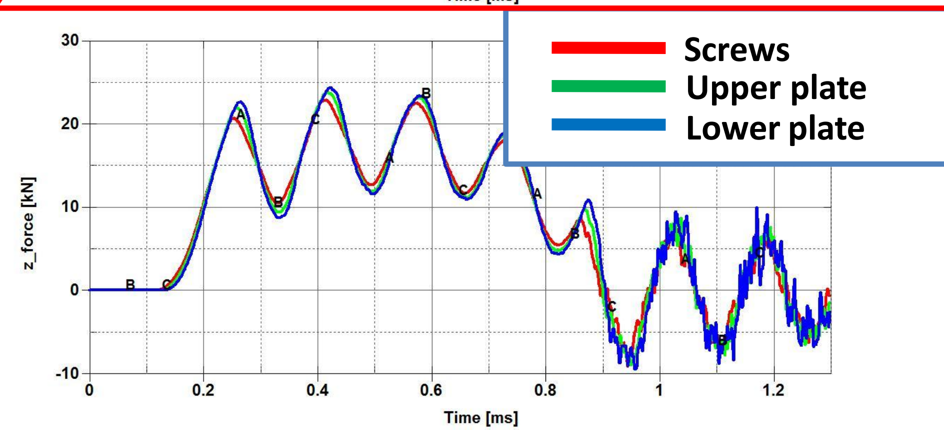


Stress wave simulation in LS-DYNA



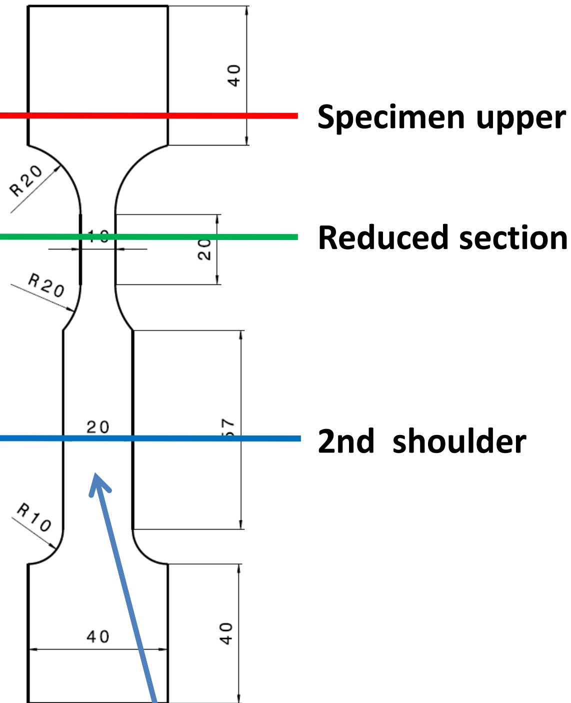


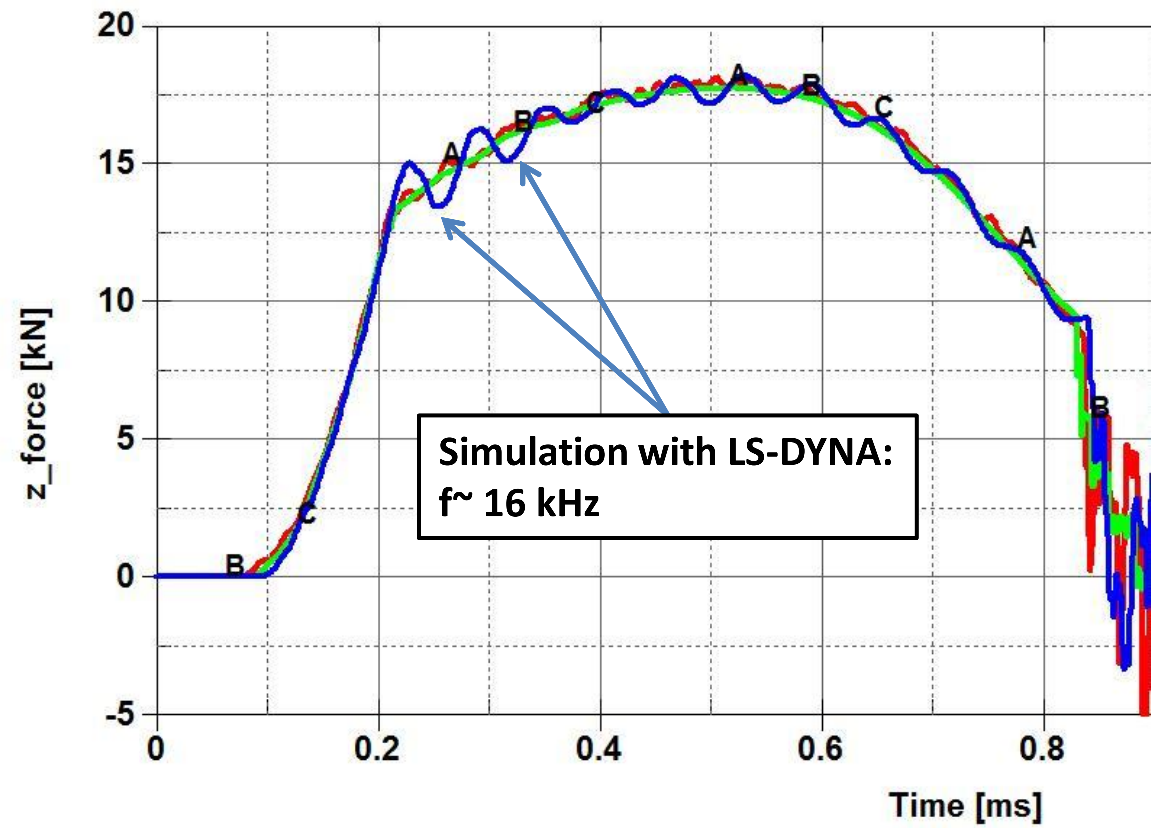




Stress Wave effect <u>negligible</u> within the <u>new</u> Specimen!
-> Frequency analysis
-> additional test to confirm

New Specimen Geometry and Frequency Analysis





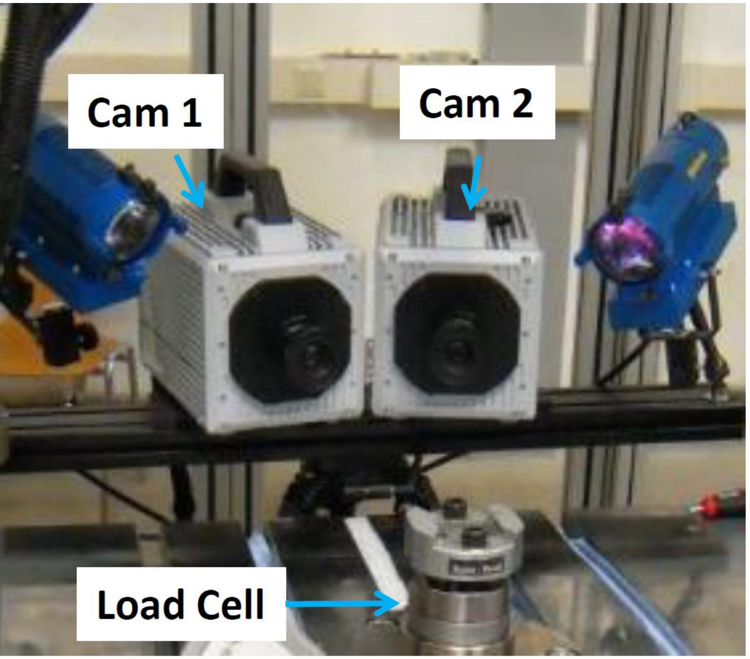
Conclusion:

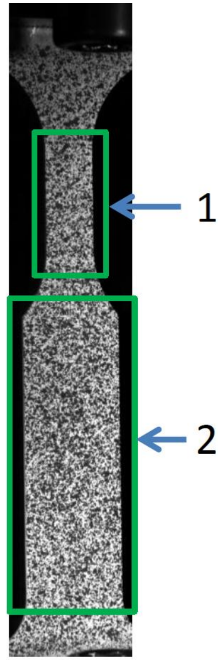
1. negletible oscillation within the reduced section of the specimen
2. very little oscillation within the 2nd shoulder with f~ 16 kHz

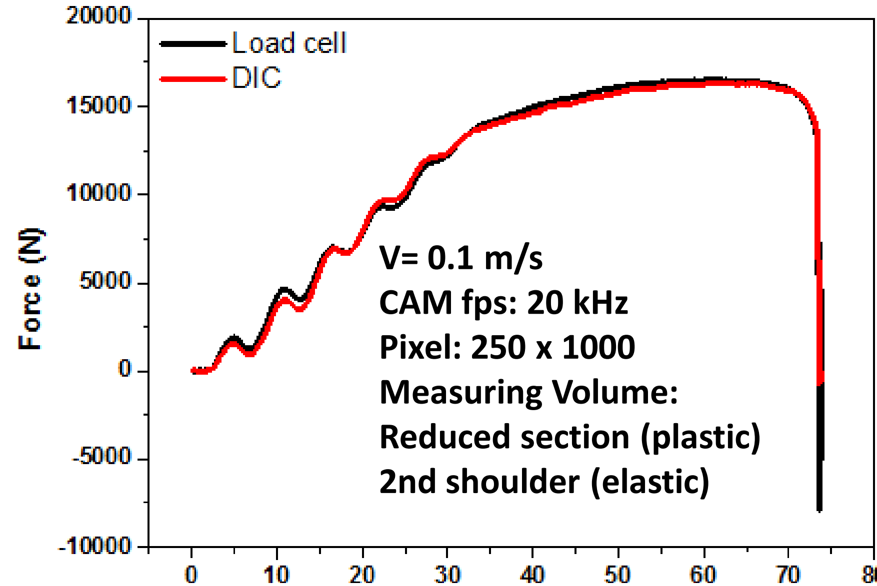
> Force measurement with elastic strain of the 2nd shoulder?

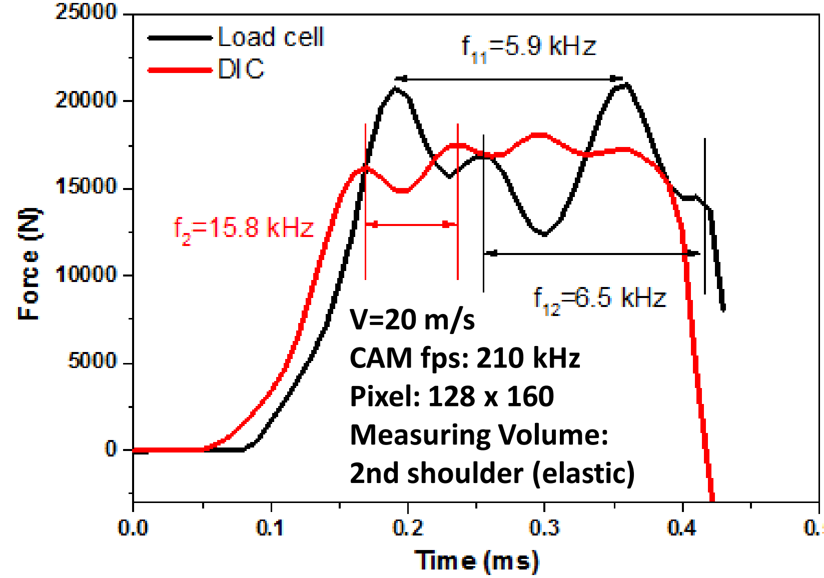
F= e_elastic x width x thickness x E?

DIC force with ARAMIS, Experiments









F_DIC= e_elastic x width x thickness x E

$$f = \frac{1}{2L}\sqrt{\frac{E}{\rho}}$$

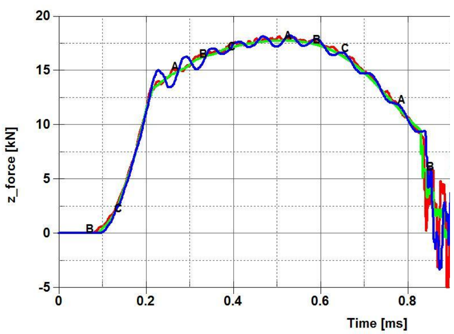
E=210 GPa,
ρ= 7.85E-6 kg/mm^3
L=149 mm
=> f= 17. 4 kHz

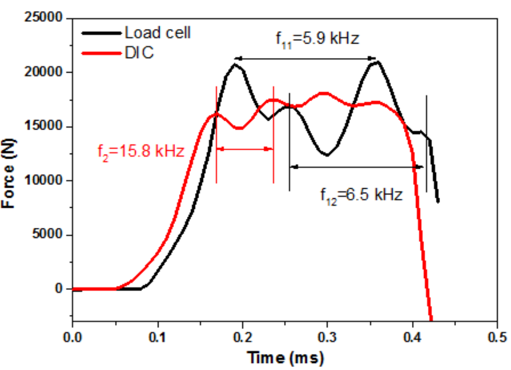
Published in "Experimental Mechanics"
Li J, Fang X (2014) Exp Mech 54:1497–1501

Is the Simulation correct? -> Further Validations

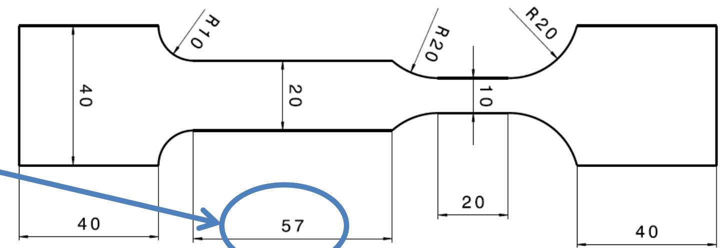
Simulation with LS-DYNA
16 kHZ

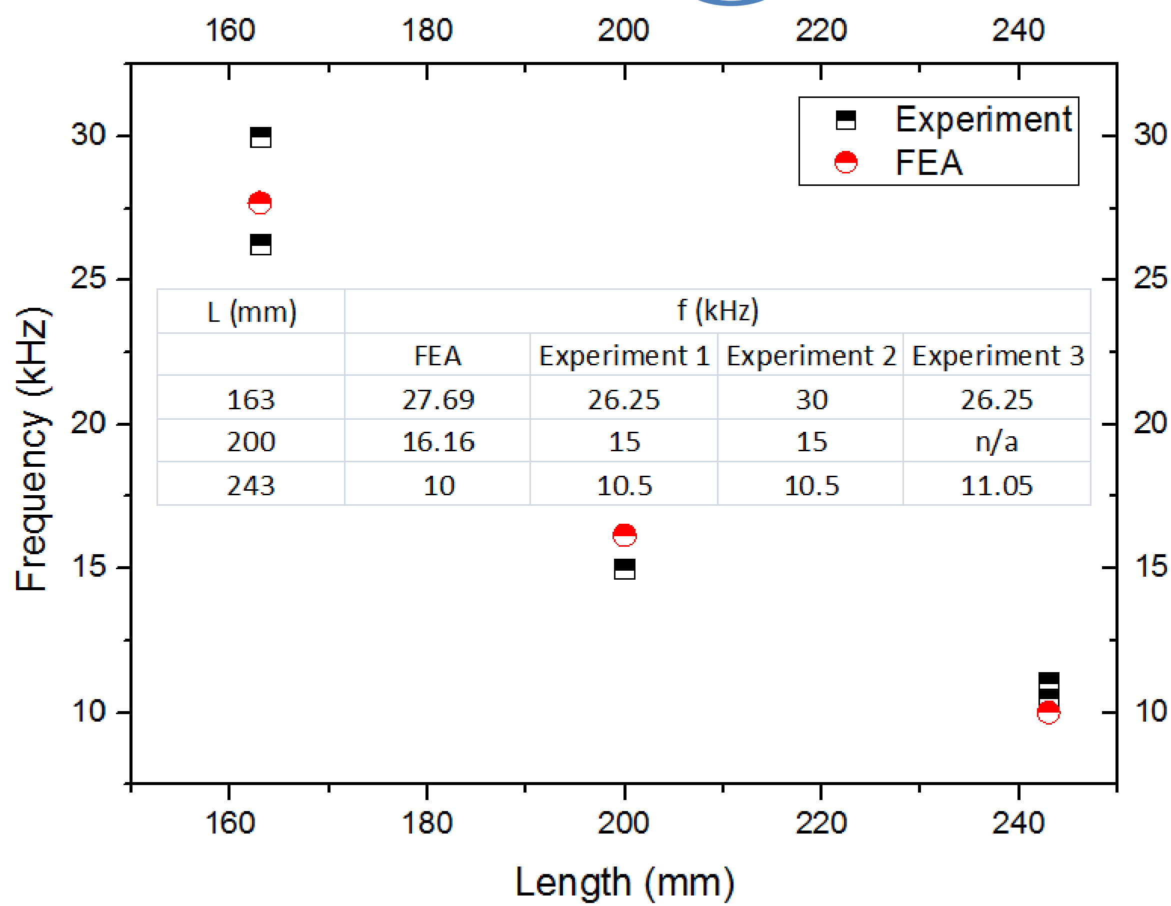
DIC Experiment: 15.8 kHZ





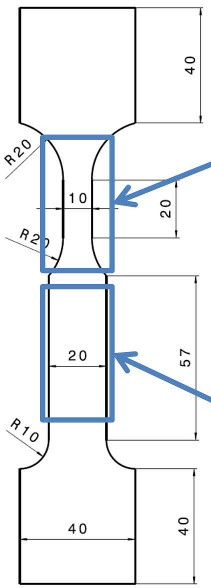
Additional Experiments with different Specimen Length (L)





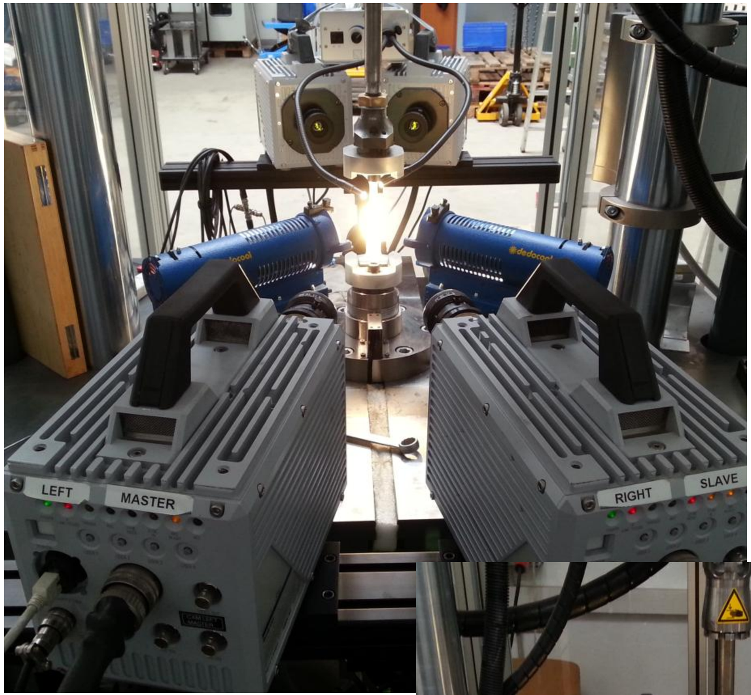
L (mm)	f (kHz)			
	FEA	Experiment 1	Experiment 2	Experiment 3
163	27.69	26.25	30	26.25
200	16.16	15	15	n/a
243	10	10.5	10.5	11.05

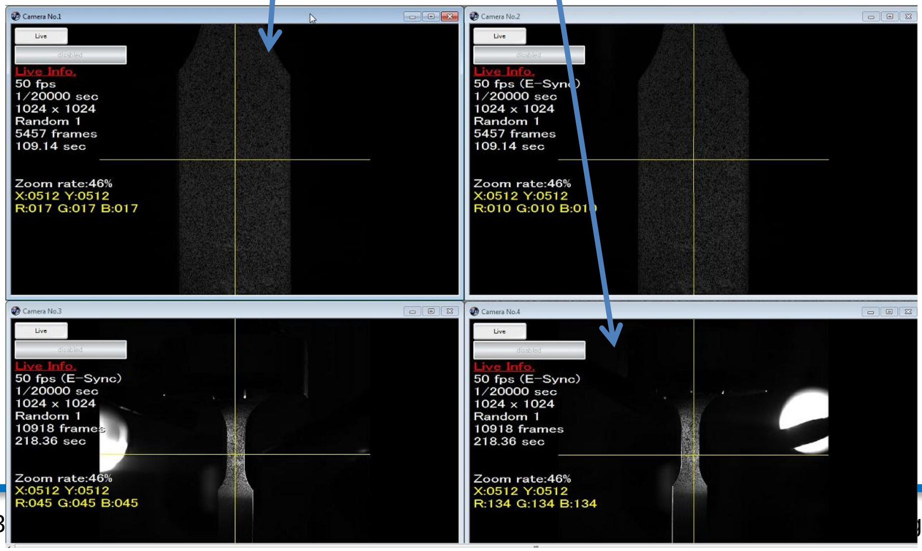
strain-stress measurement at 10^3 /s, 2x 3D DIC measurement

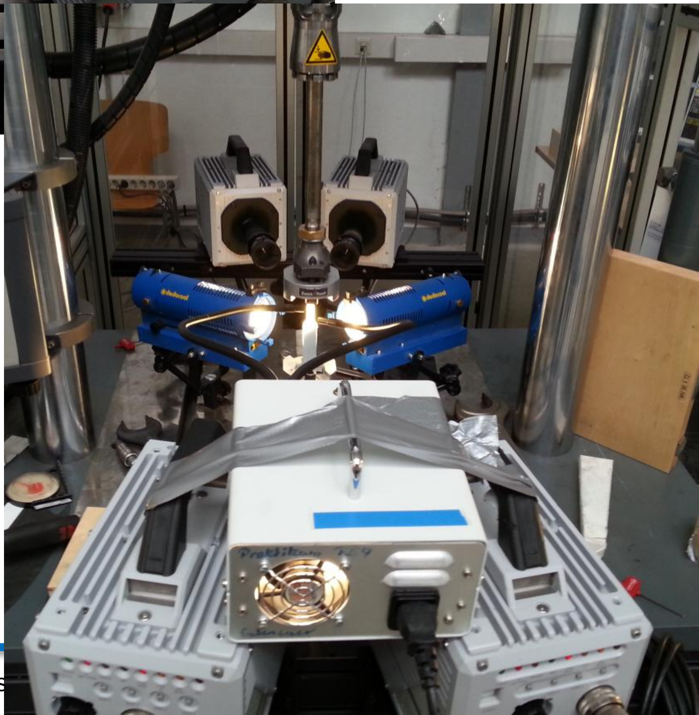


1. 3D DIC with 2 SA 5 Camera
plastic deformation
strain measurement

2. 3D DIC with 2 SA 5 Camera
elastic deformation
force measurement
stress measurement

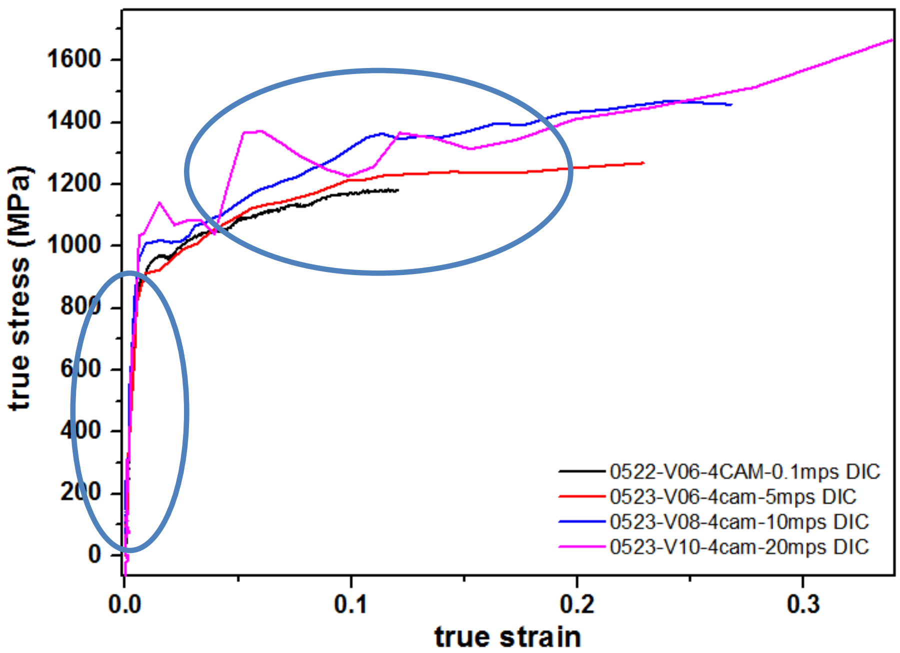




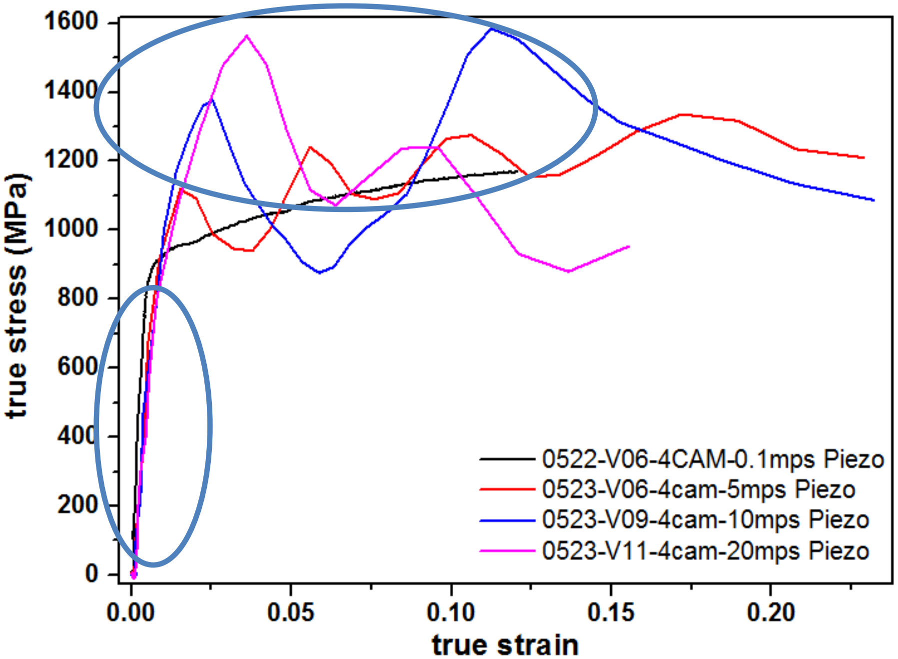


Results, all-optical and conventional method

all-optical stress strain determination



conventional method with piezoelectric load cell



<u>conclusion:</u>
negligible oscillation up to 10 m/s
much lower oscillation at 20 m/s
-> can be further reduced with better specimen geometry and changes on test equipment!

Conclusion and Acknowledgement

Solution!

√ Additionally validated

√ Understand the system ringing effect

√ Stress wave: FEA for tensile machine

√ Stress wave: FEA method

√ Stress wave: theory

- ***Zwick Roell*** for CAD of HTM5020
- ***GOM*** for tech. Support
- ***Photron Europe*** for tech. Support
- **DFG** for funding