SPALLATION OBSERVED IN HARD METALS DURING TAYLOR-IMPACT-TESTS

Frank Bagusat, Torsten R. Lässig, Siegfried Pfändler, Martin Sauer

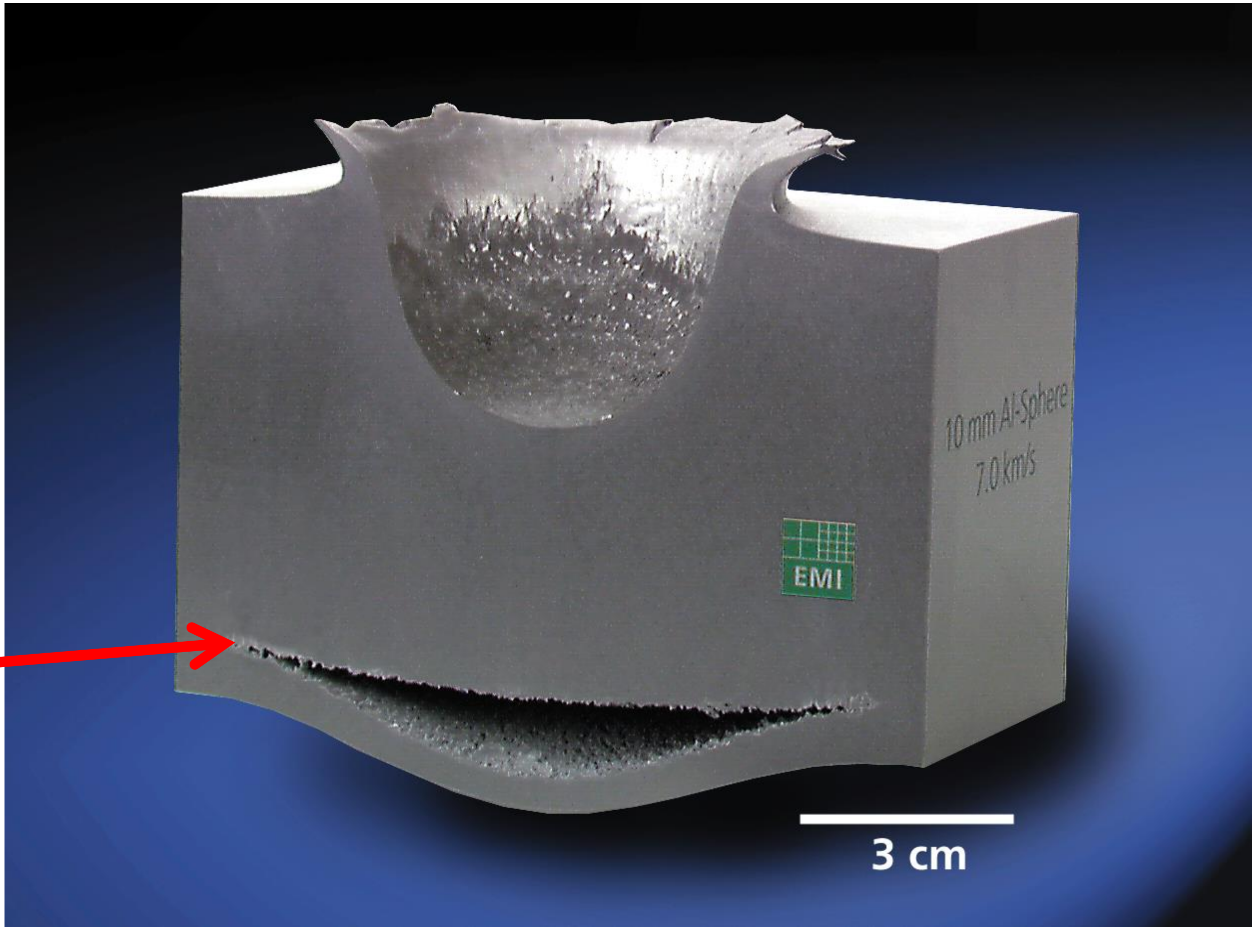
Fraunhofer

EMI

04.09.2018

Example of Spallation
Sphere Impact

Aluminum target, impacted by an aluminum sphere of 10 mm diameter at 7 km/s

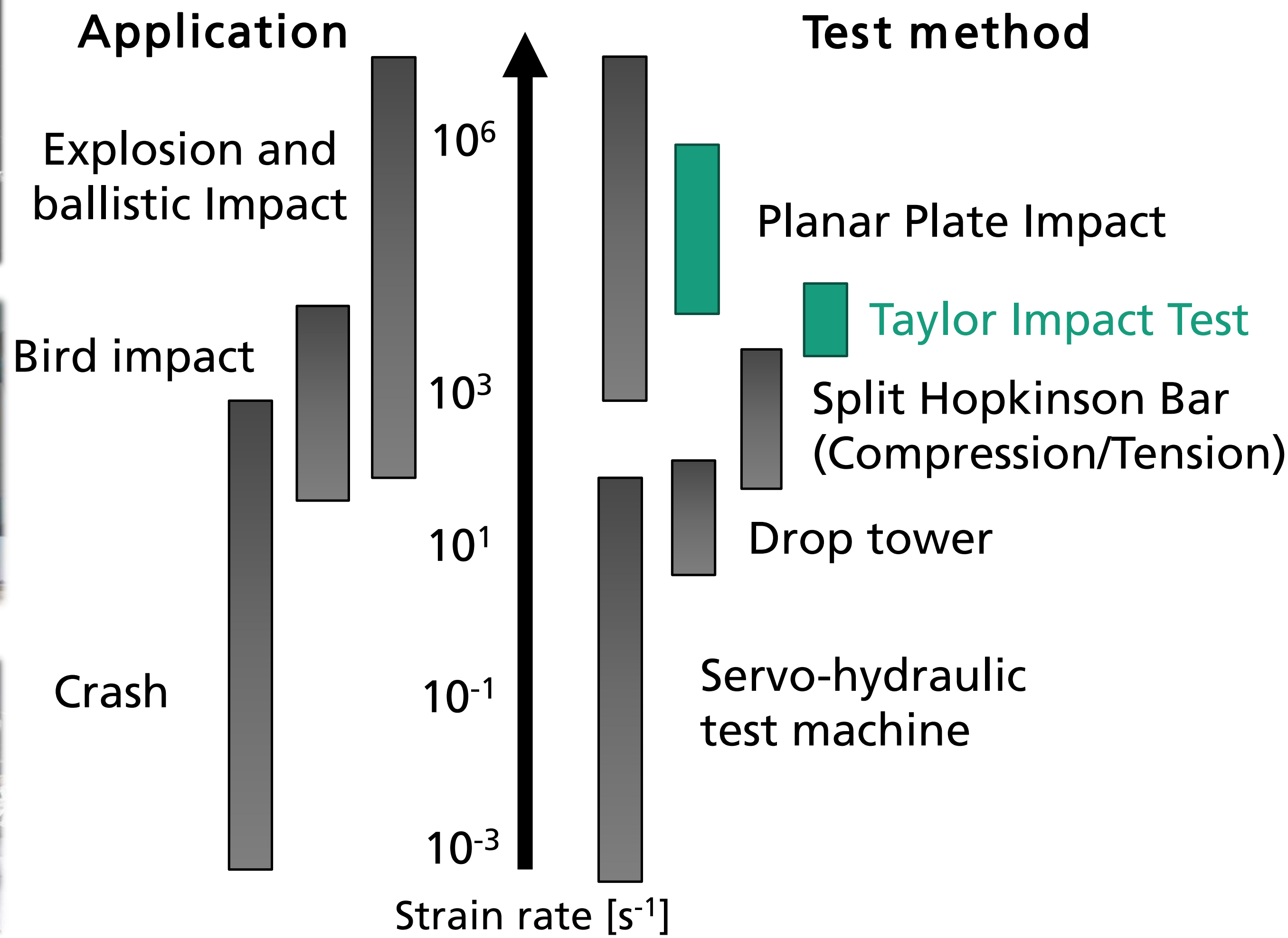


spall crack;

spall region

Strain Rate Regimes and Applications
Test Methods

http://www.airnation.net

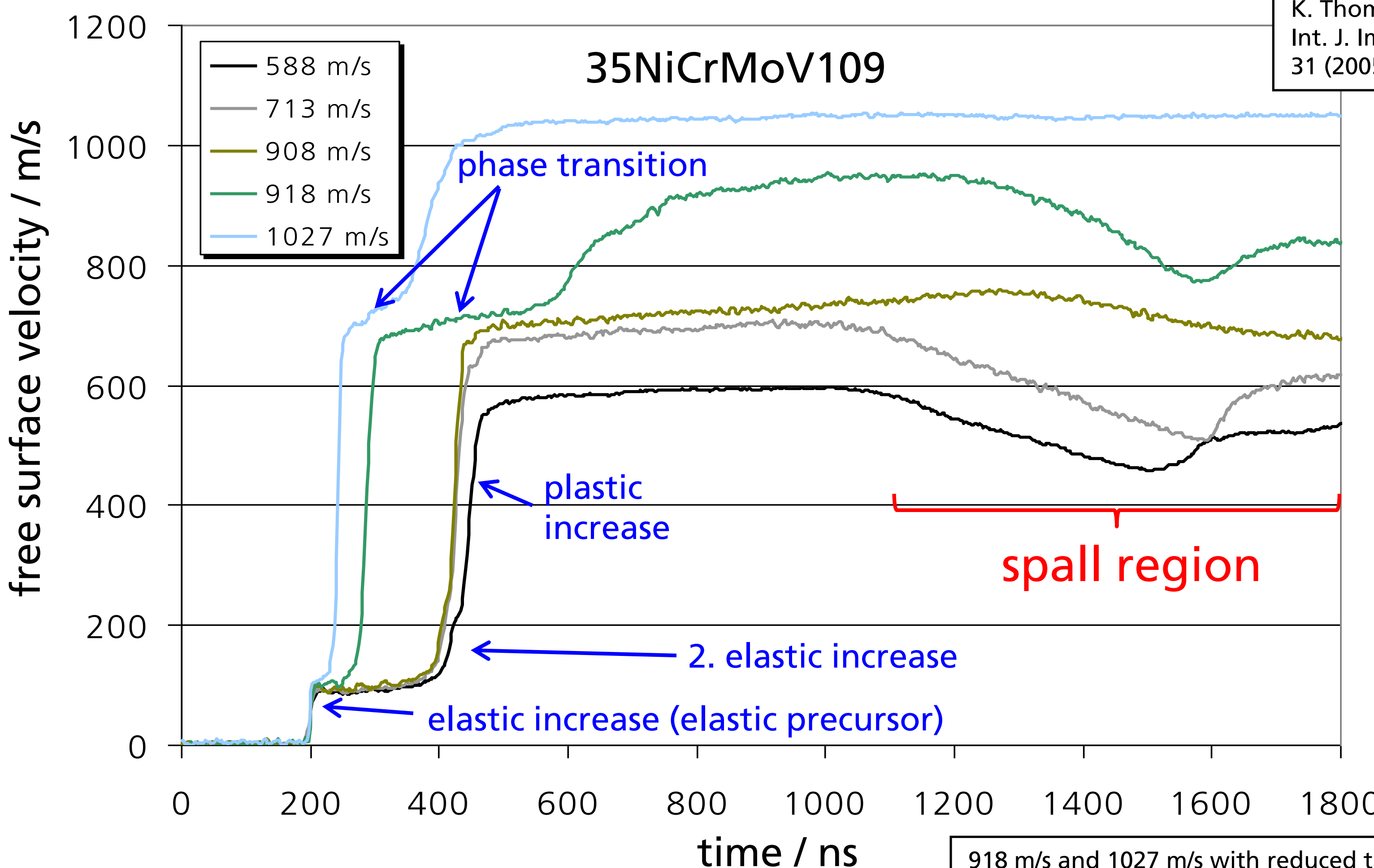


Fraunhofer EMI

Planar Plate Impact Test

VISAR signals

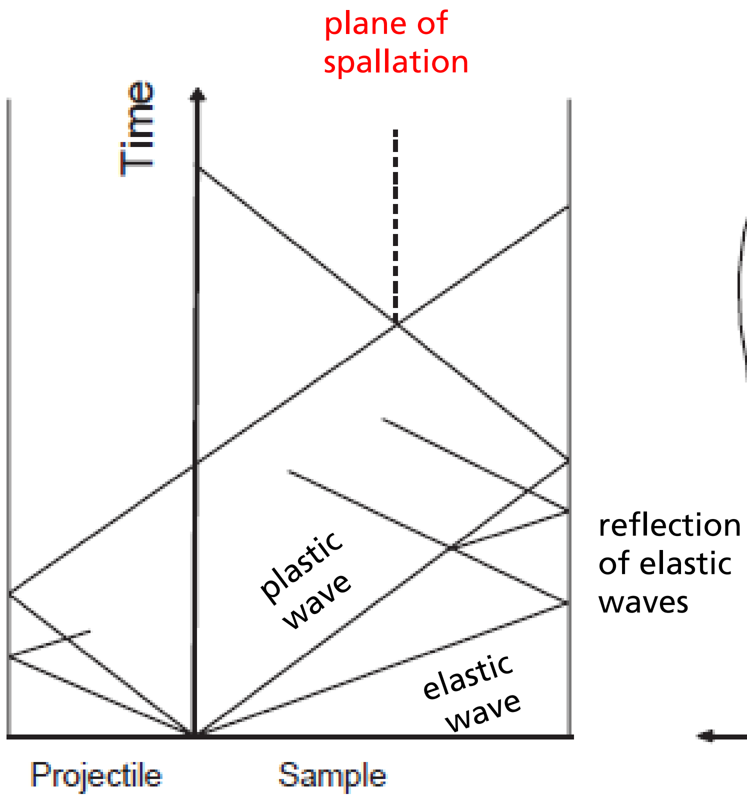
I. Rohr, H. Nahme,
K. Thoma
Int. J. Impact Eng.
31 (2005), p. 401-433

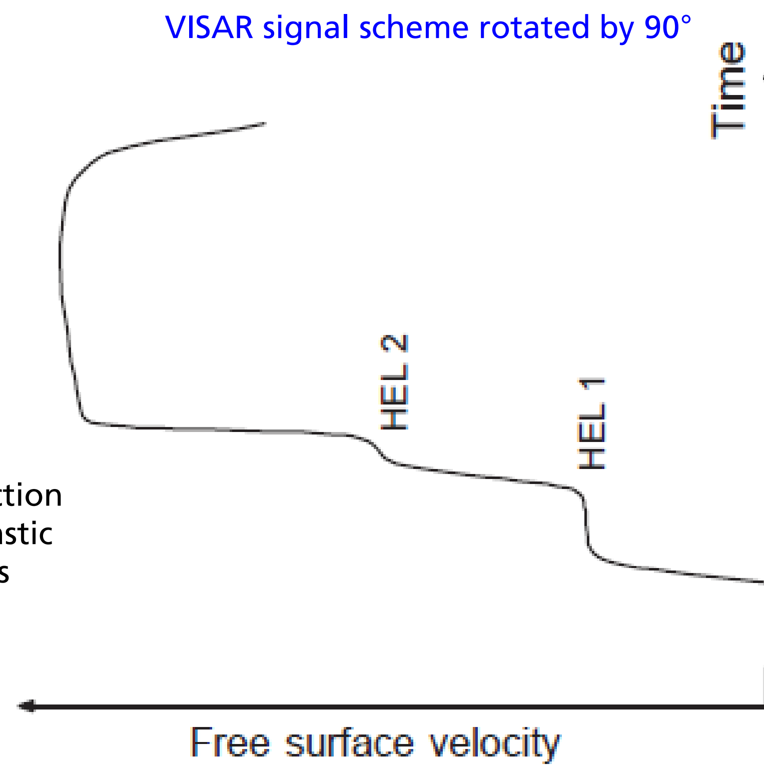


918 m/s and 1027 m/s with reduced target thickness

Fraunhofer
EMI

Planar Plate Impact Test
Wave processes



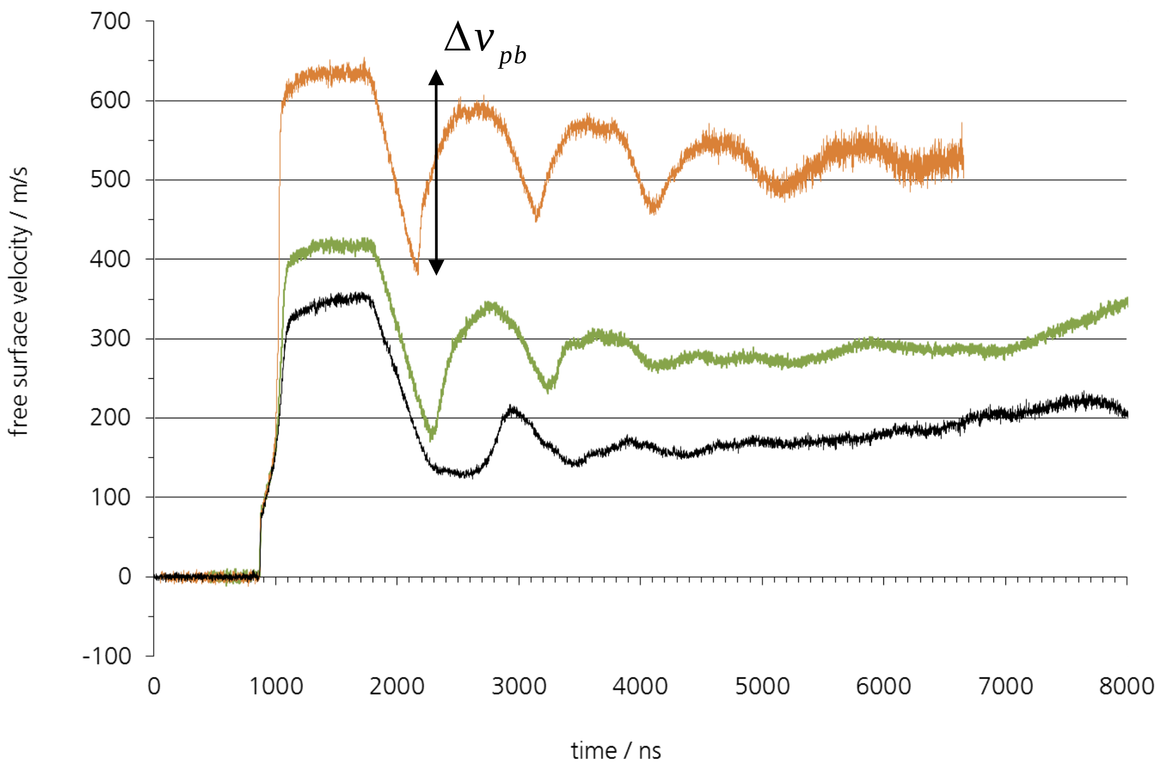


I. Rohr, H. Nahme, K. Thoma, Int. J. Impact Eng., 31 (2005), p. 401-433

Fraunhofer EMI

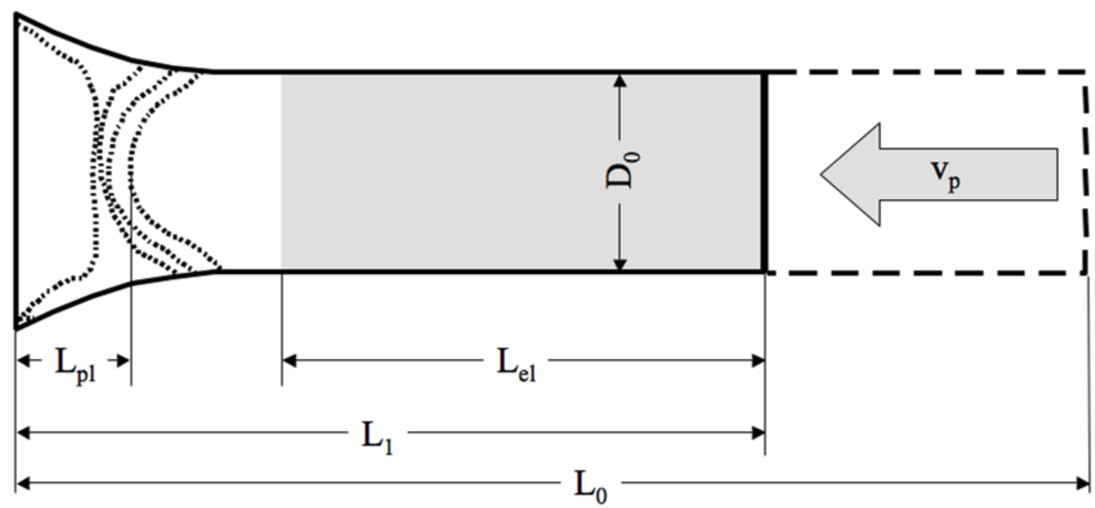
Spallation in Planar Plate Impact Tests

$$f_t^{dyn} \approx \frac{1}{2} \rho c \ \Delta v_{pb}$$



Classical Taylor Test
Determination of yield stress according to Taylor (1948)

$$\sigma_Y^T = \frac{\left(L_0 - L_{pl}\right)\rho v_p^2}{2\left(L_0 - L_1\right)\ln\left(L_0 / L_{pl}\right)}$$



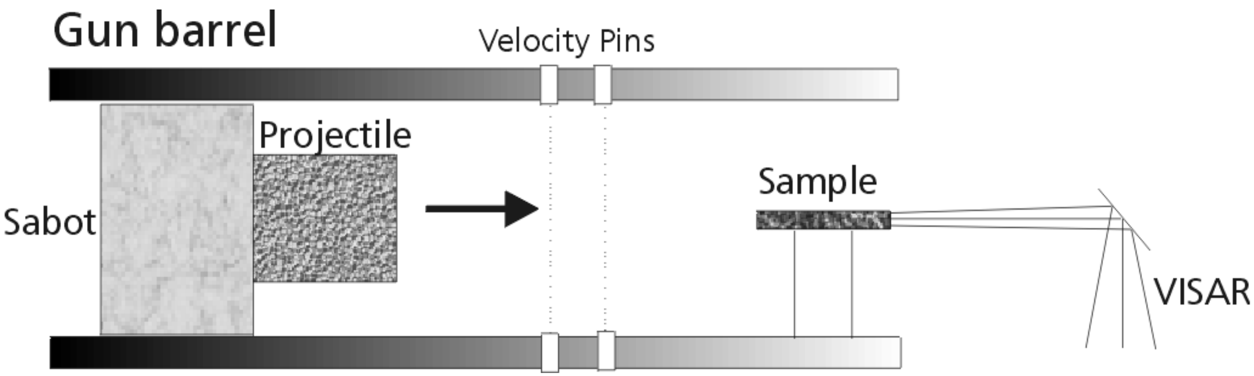
Assumptions:

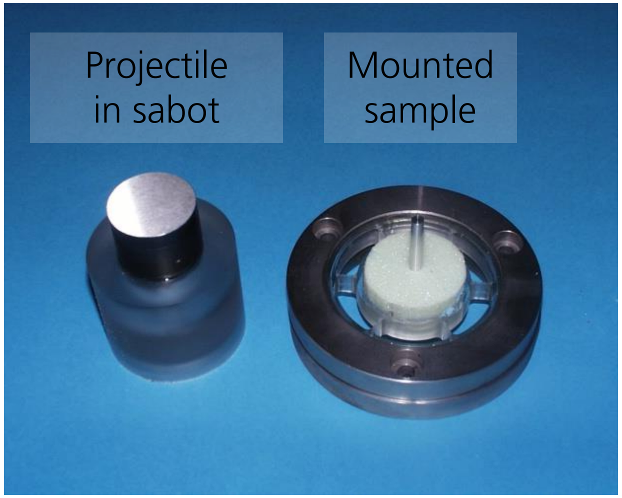
- Constant velocities of plastic front and rod end
- Homogeneous deformation over cross section
- Strain rate as approximate global value

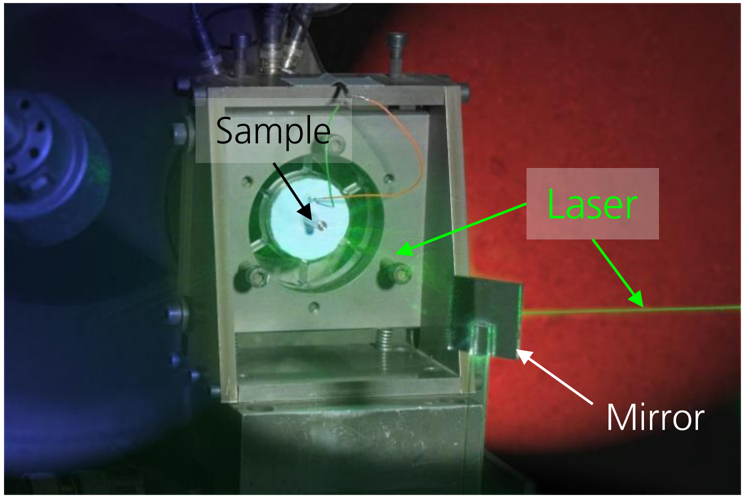
G. Taylor, Proc. Royal Soc. London A, 194 (1948) p. 289-299

EMI Setup for Modified Taylor-Impact Test (MTT)

Inverse impact – anvil on rod

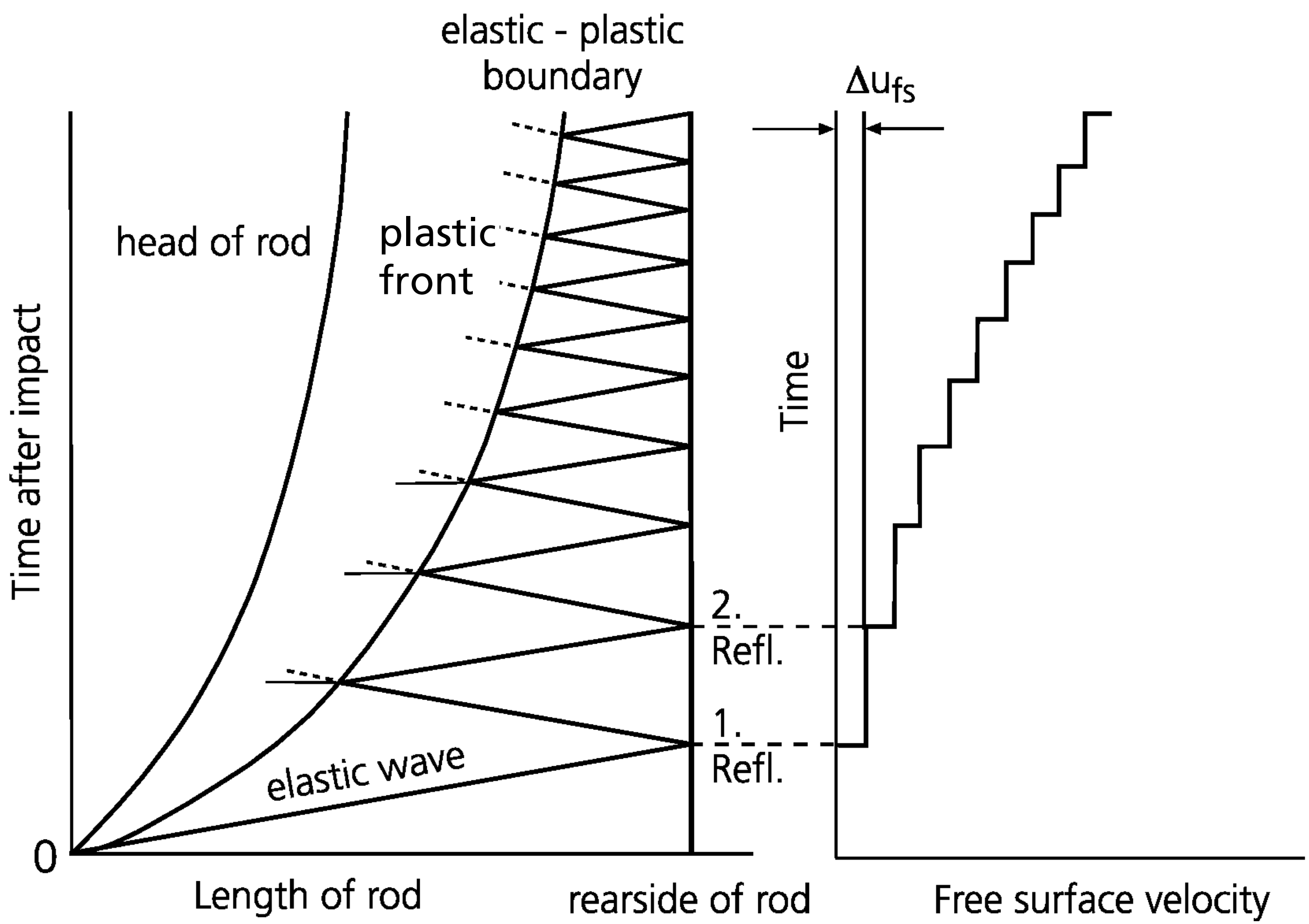






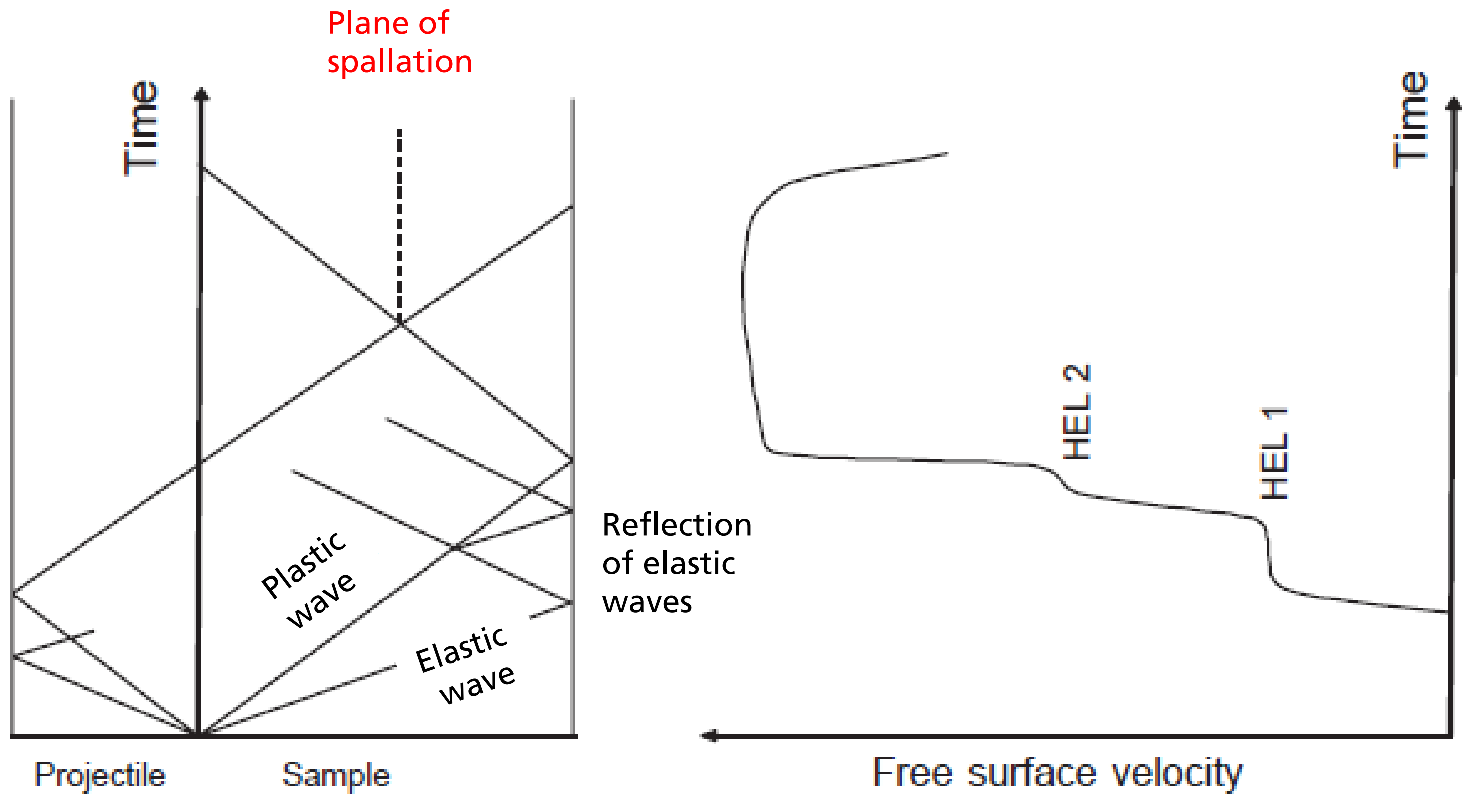
G. Kuscher, PhD-Thesis, RWTH Aachen/Fraunhofer EMI, 1985
I. Rohr, H. Nahme, K. Thoma, J. Phys. IV France, 110 (2003), p. 513-518
I. Rohr, H. Nahme, K. Thoma, Int. J. Impact Eng., 31 (2005), p. 401-433

MTT: Wave Propagation in Impacted Rods



I. Rohr, H. Nahme, K. Thoma, J. Phys. IV France, 110 (2003), p. 513-518

Planar Plate Impact Test
-> Spallation also possible in case of MTT?



I. Rohr, H. Nahme, K. Thoma, Int. J. Impact Eng., 31 (2005), p. 401-433

HSS Steel Spall Cracking in Modified Taylor Test

Taylor Rod, HSS Steel, 6 mm diameter, 62.8 mm length, marked with black dots, impacted at 208 m/s

HSS Steel Spall Cracking in Modified Taylor Test

Taylor Rod, HSS Steel, 6 mm diameter, 62.8 mm length, marked with black dots
Elastic wave velocity c_L 5200 m/s
Impacted by hardened C45 steel projectile at 208 m/s
Observation: Shimadzu HPV-X high-speed video camera, 1 frame/µs,
and VISAR velocity measurement at the free end.

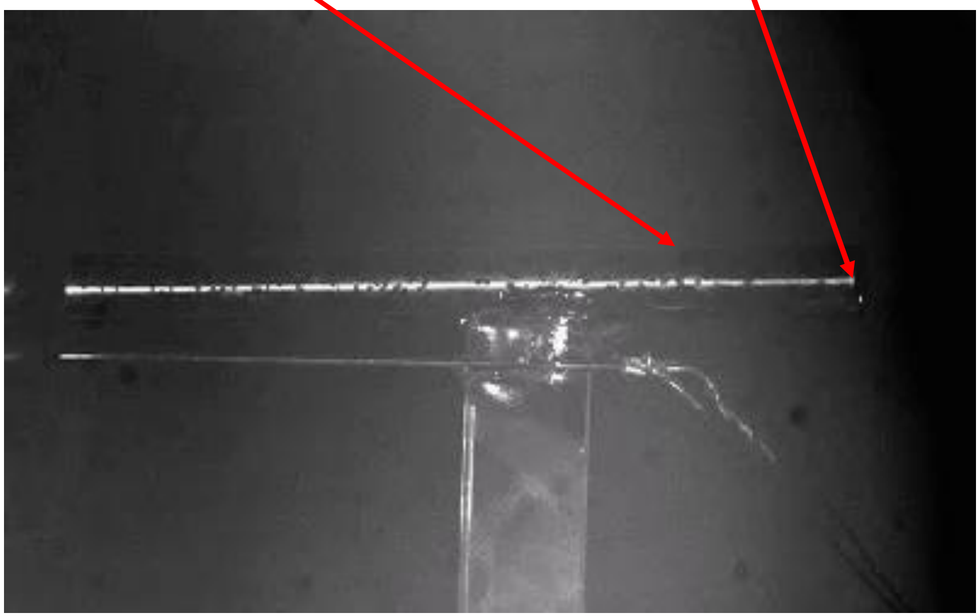
First orthogonal crack (spall) visible 18 µs after impact where release waves from the front and the free end meet

Elastic wave arrives at free end 12 µs after impact

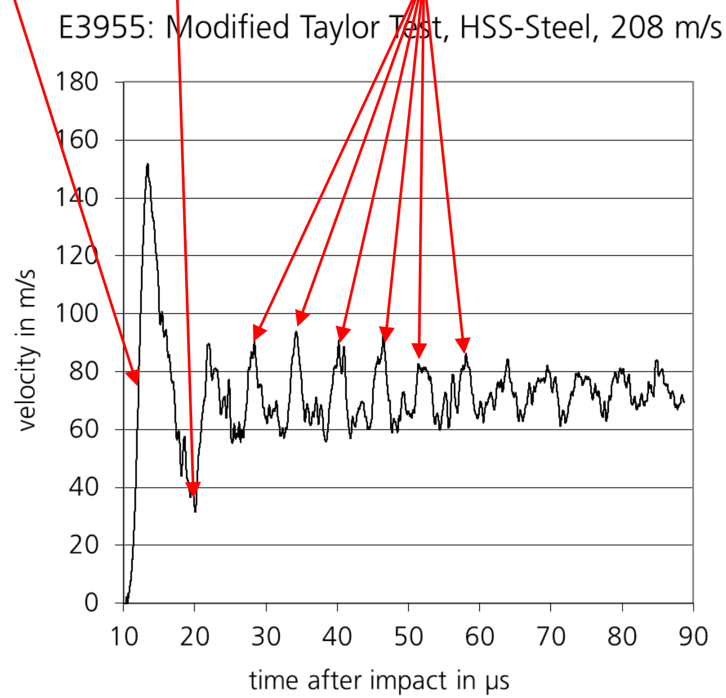
Elastic wave arrives

Spall signal arrives

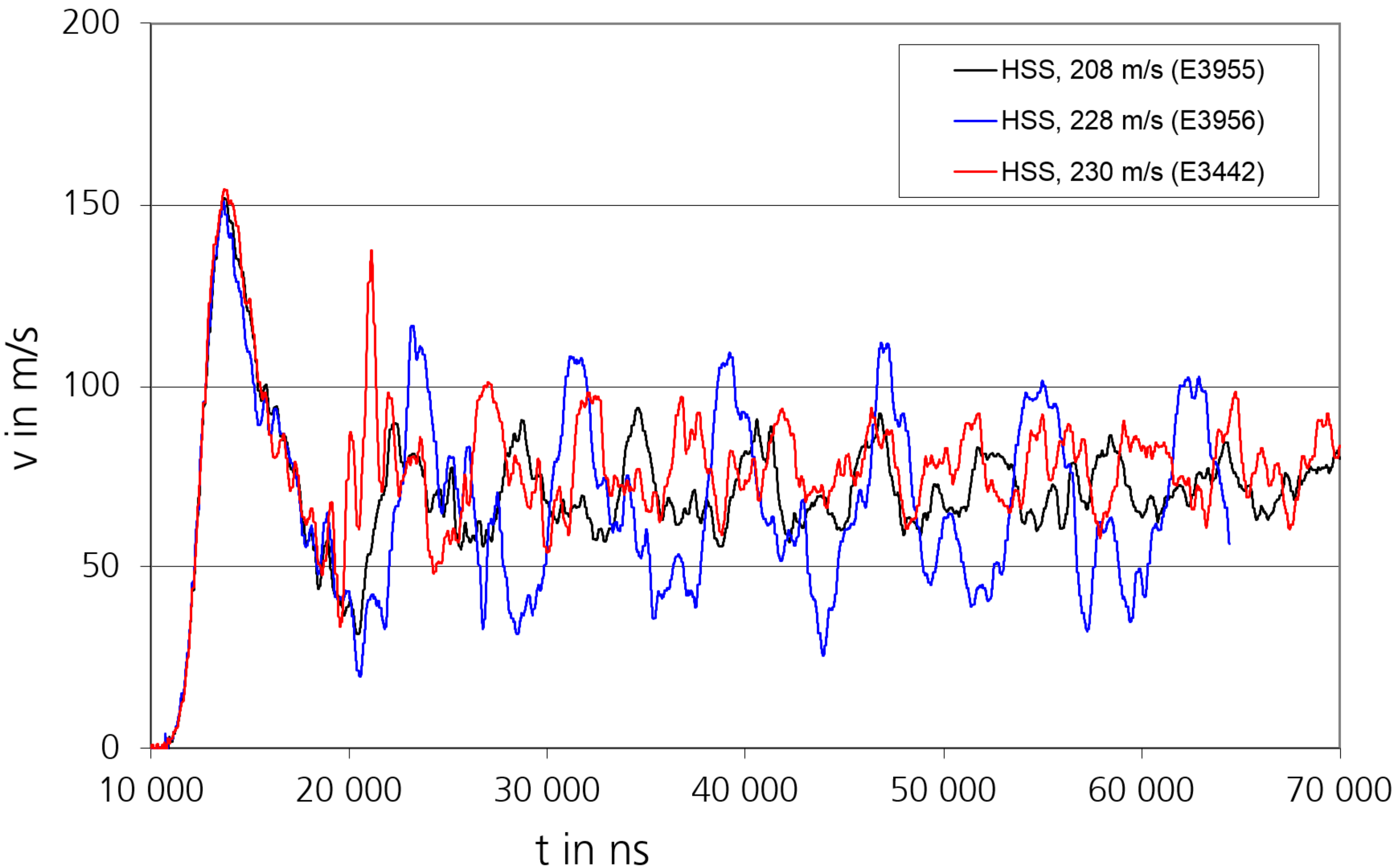
Elastic oscillations in the spalled fragment



Video showing 128 frames from -12 µs to 116 µs



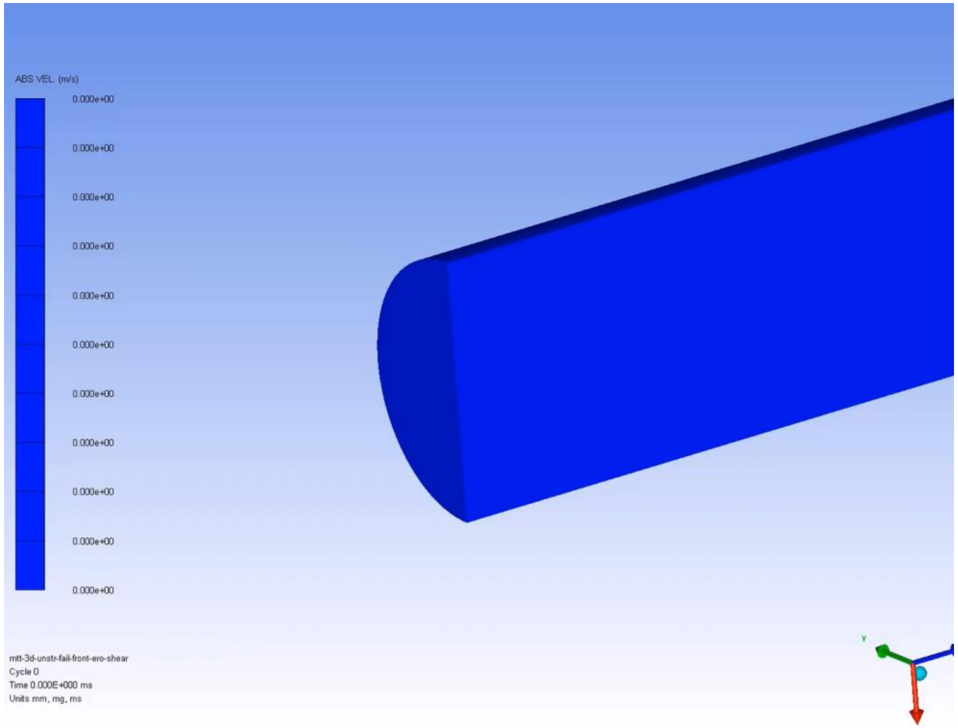
Comparison of 3 Similar Tests with HSS Steel

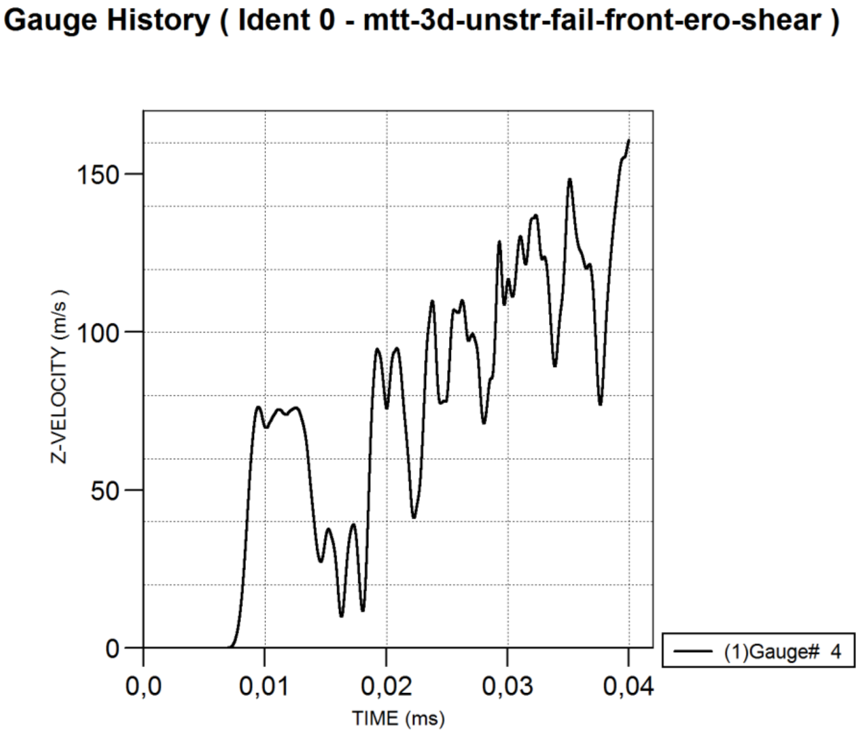


Fraunhofer EMI

Phenomenological Simulation of Taylor Test with Generic Brittle Metal

- Unloading wave from the front is triggered from failure at the rod tip
- Attempt to simulate fragmentation and unloading effect

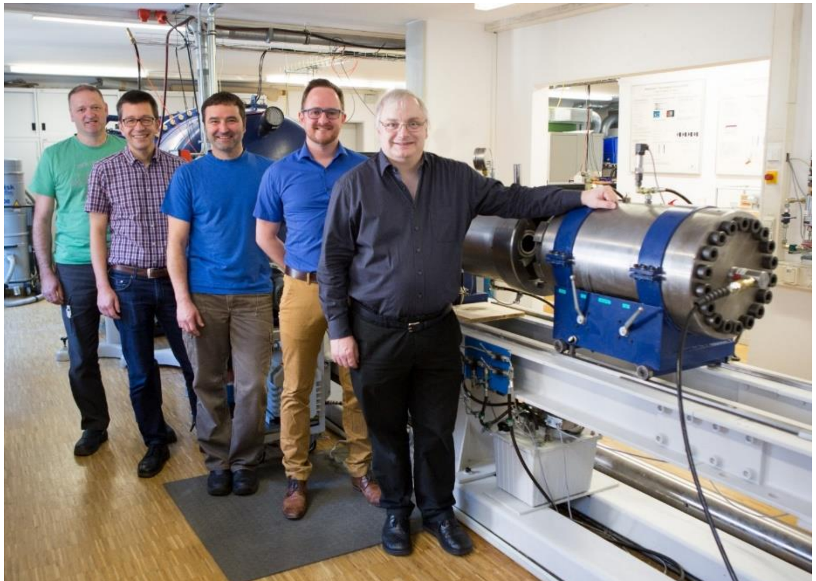


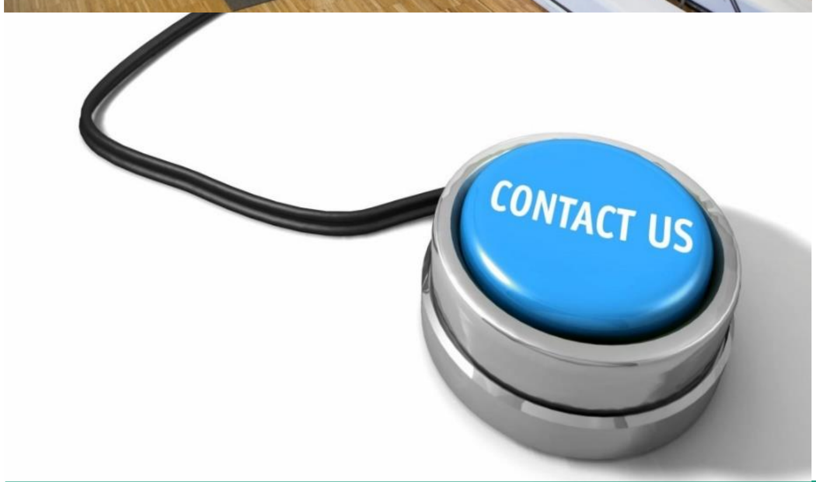


Fraunhofer EMI

Conclusions

- Modified Taylor Test method presented
- In the past, failure occurred in Taylor Tests with brittle hard metals, which made interpretation of VISAR signals difficult
- First successful use of high-speed camera (> 1 Mio frames/sec) to observe failure processes in Modified Taylor Tests at EMI
- With the help of these camera observations, the VISAR measurements can now be correlated with fragmentation processes
- Development of quantitative evaluation method is ongoing, one option is to use DIC to evaluate strains on the rod surface
- First evaluation gives spall strength (1D-stress) of about 2 GPa
- The observation might be relevant for fragmentation of penetrator rods





Materials at Highest Strain Rates Group

Contact:

Dr. Frank Bagusat or Dr. Torsten Lässig

Fraunhofer-Institut for High-Speed Dynamics
Ernst-Mach-Institut, EMI
Ernst-Zermelo-Straße 4
79104 Freiburg, Germany
Phone.: +49 761 2714-469

Frank.Bagusat@emi.fraunhofer.de

Torsten.Laessig@emi.fraunhofer.de