Tungsten carbide projectiles impacting tungsten carbide targets

Dynamic characterisation of materials

TNO

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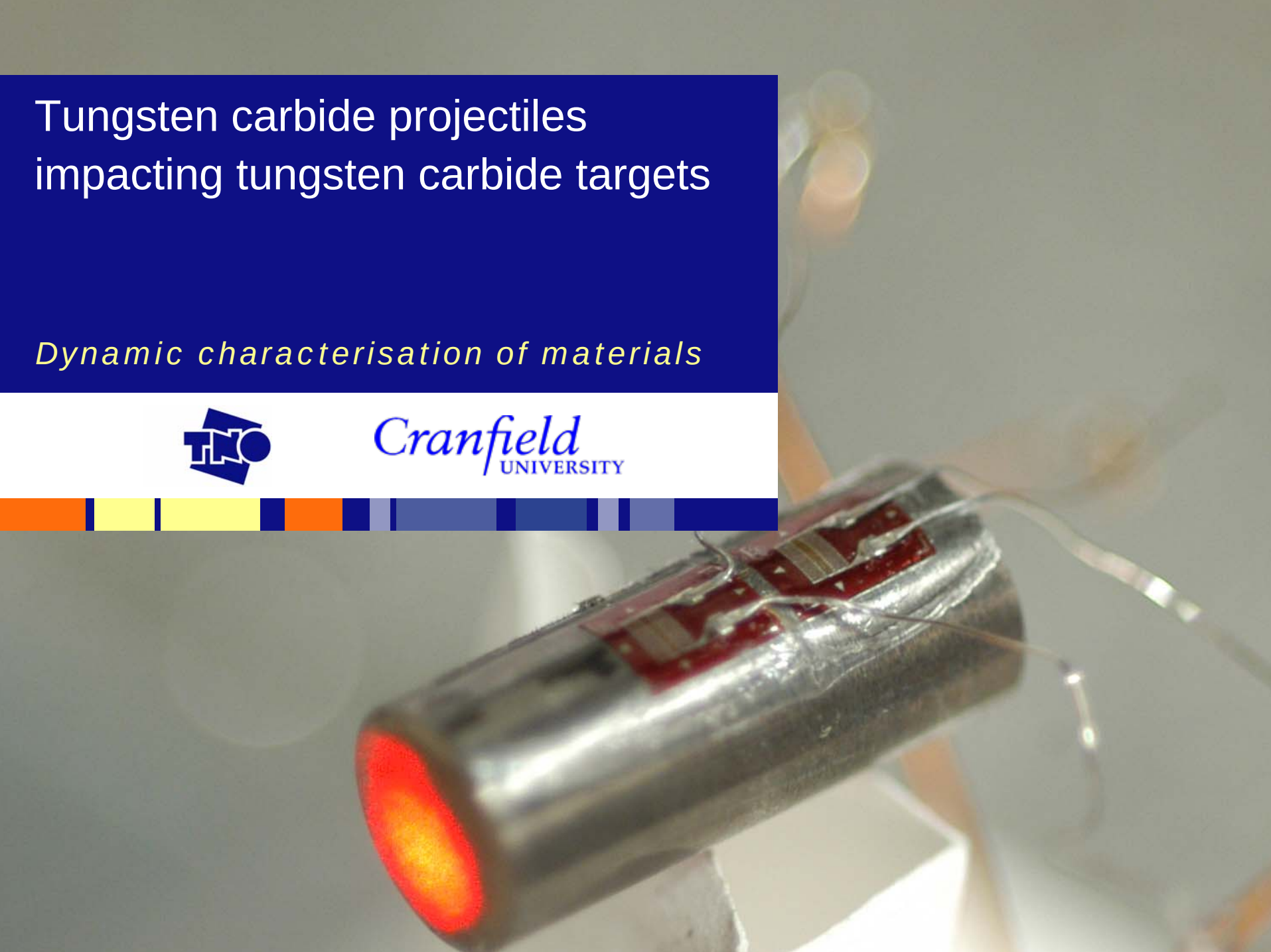

Acknowledgements

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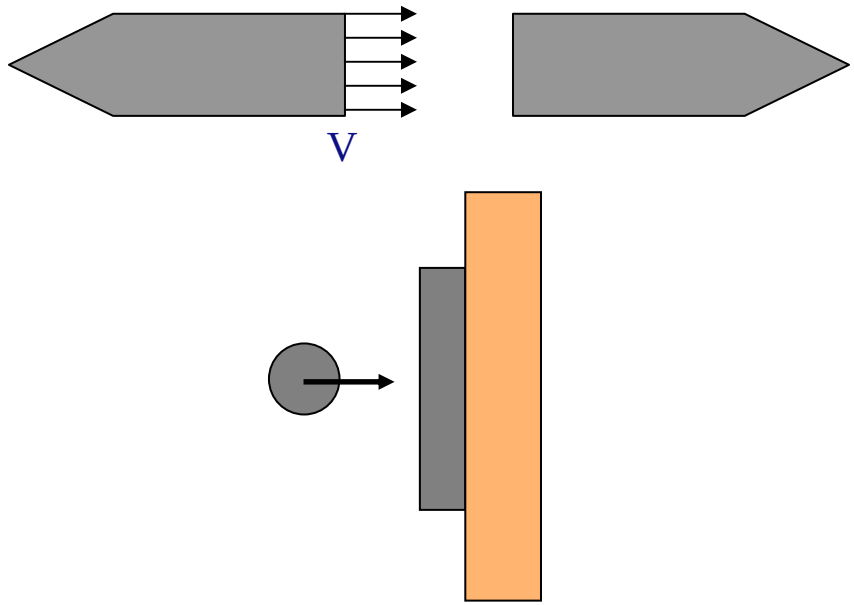


Introduction

- In ballistic impacts events → strong interaction between dynamic behaviour of projectile and armour
- Lots of work is done in characterising and modelling armour materials

- However, characterising the dynamic behaviour of Armour Piercing (AP) projectiles is equally important

- Problems:
  - **dynamic** material testing is difficult
  - only small samples of material are available (projectile cores)
  - validation experiments for FE modelling with AP projectiles often involve ‘complex’ armour systems (incl. ceramics)

Overview of total research program

EOS, hardening

- Analysing the composition of AP core material (SEM)
- ‘Standard’ dynamic material tests with material, closely resembling real AP core material: Flyer plate impact testing (*poster TB058*)

1

Failure behaviour

- Special designed dynamic experiments with real AP cores
- Special designed dynamic experiments with simulant material
- Goal: well defined, ‘simple’, experiments (*this presentation*)

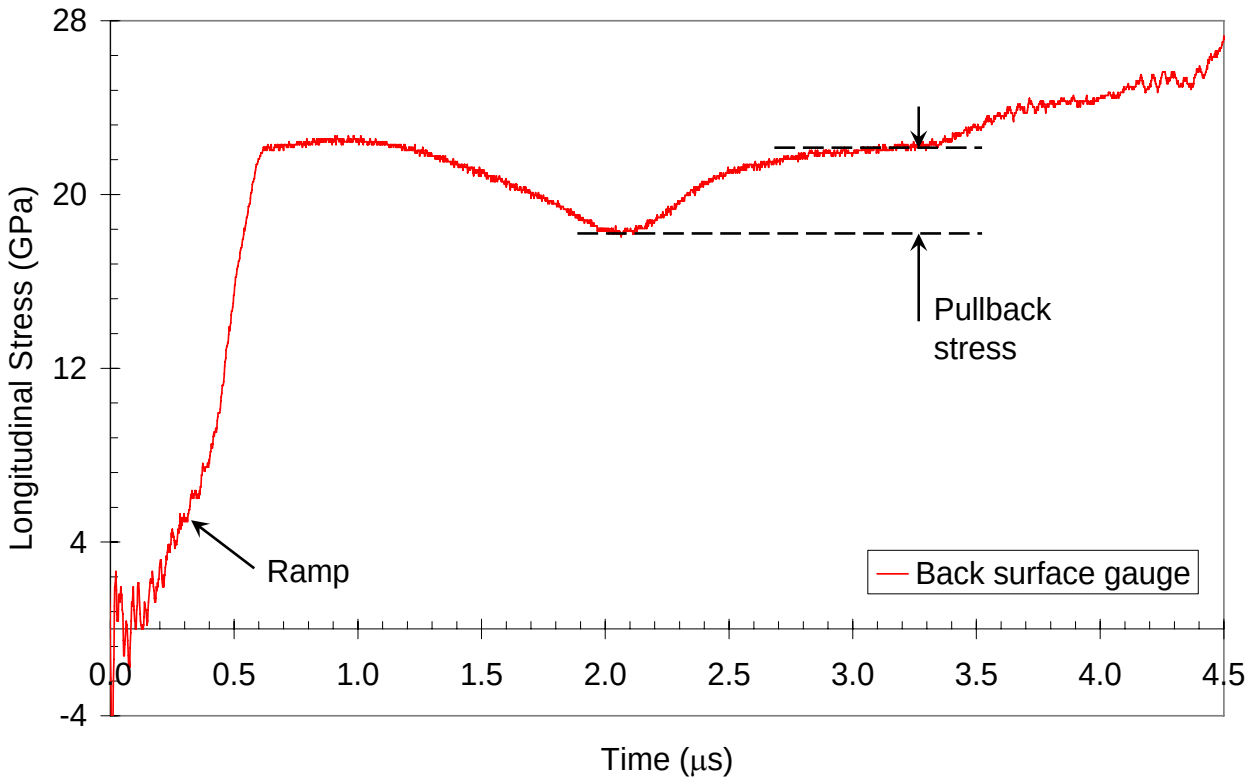
2

Total material model

- Use the results of step 1 (direct engineering) together with the results of step 2 in order to reverse engineer the dynamic material model for the AP core material (*ongoing research*)

3

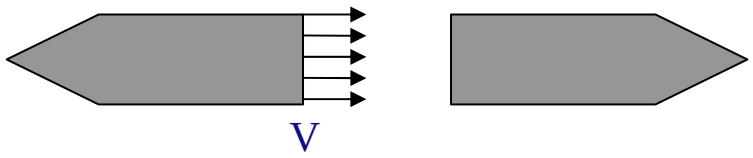
Step 1: flyer plate testing



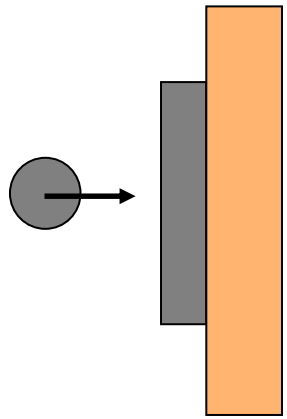
- "Shock response of a cemented Tungsten Carbide" (poster TB058)
- Measured: EOS (shock), Hugoniot Elastic Limit, Dynamic Spall Strength

Step 2: Specialized experiments

- Core to core experiments
- Acceleration of a AP core (in reverse orientation) onto an identical stationary core



- Sphere to disc experiments
- Sphere of ‘simulant’ AP core (WC) material impacting ‘simulant’ (WC) target
- Target: 6 mm WC with 12 mm polycarbonate backing

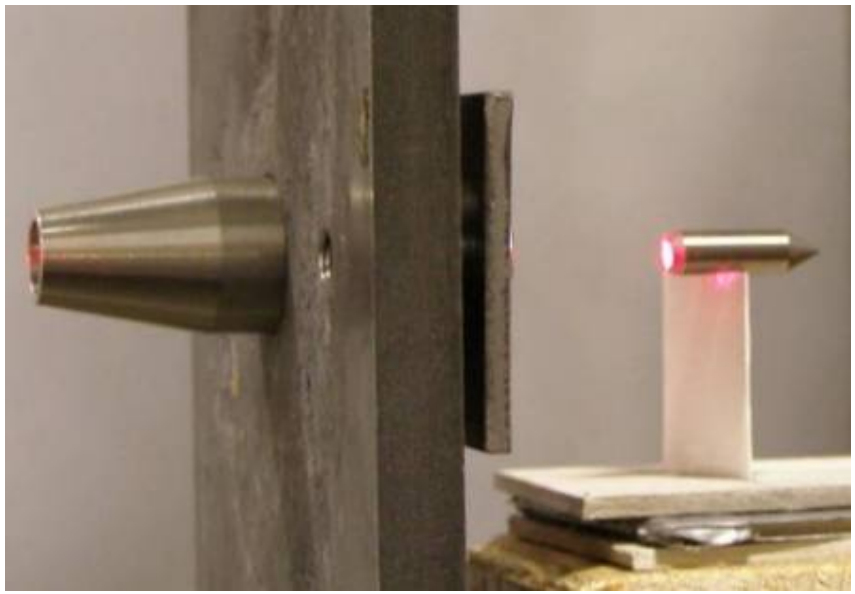


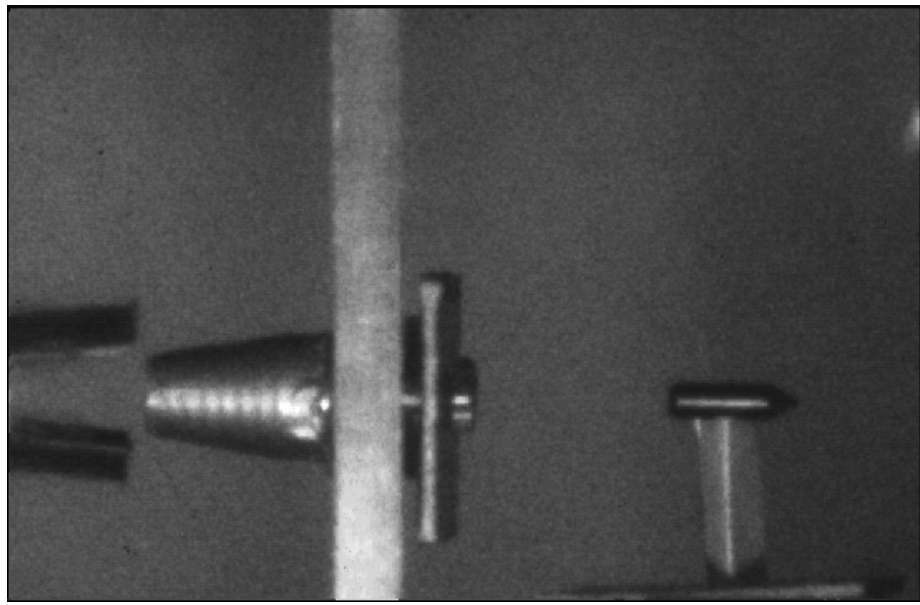
Goal: break-up of WC material with a ‘simple’ experimental set-up

Use the results of the experiments to reverse engineer the failure model

Step 2: Specialized experiments: Core to Core

- Acceleration of a AP core (in reverse orientation) onto an identical stationary core
- Acceleration in a sabot
- Velocity regime: 250 - 500 m/s
- Fragments are captured and collected afterwards for SEM analysis
- Occasionally strain measurements are performed on the stationary core



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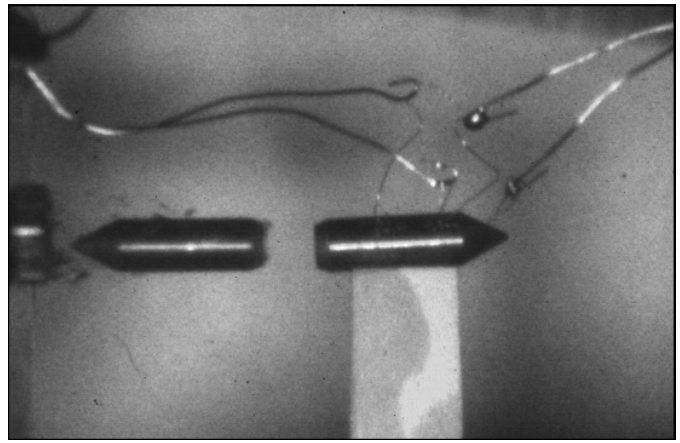
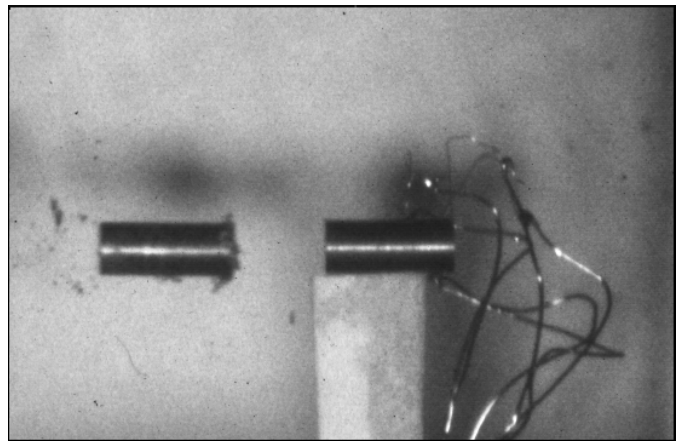
Specialized experiments: Core to Core

- Benefits:
  - Experiments with real core material
  - Only one material is used → only one material needs to be modelled
  - Highly dynamic event (impact velocity up to 500 m/s)
  - Simple small geometry → FE models small and quick

(straight cilinders from AP cores with the use of spark erosion)





Specialized experiments: Core to Core

- Results:
  - Projectiles rapidly erode at impact surface followed by fragmentation along length

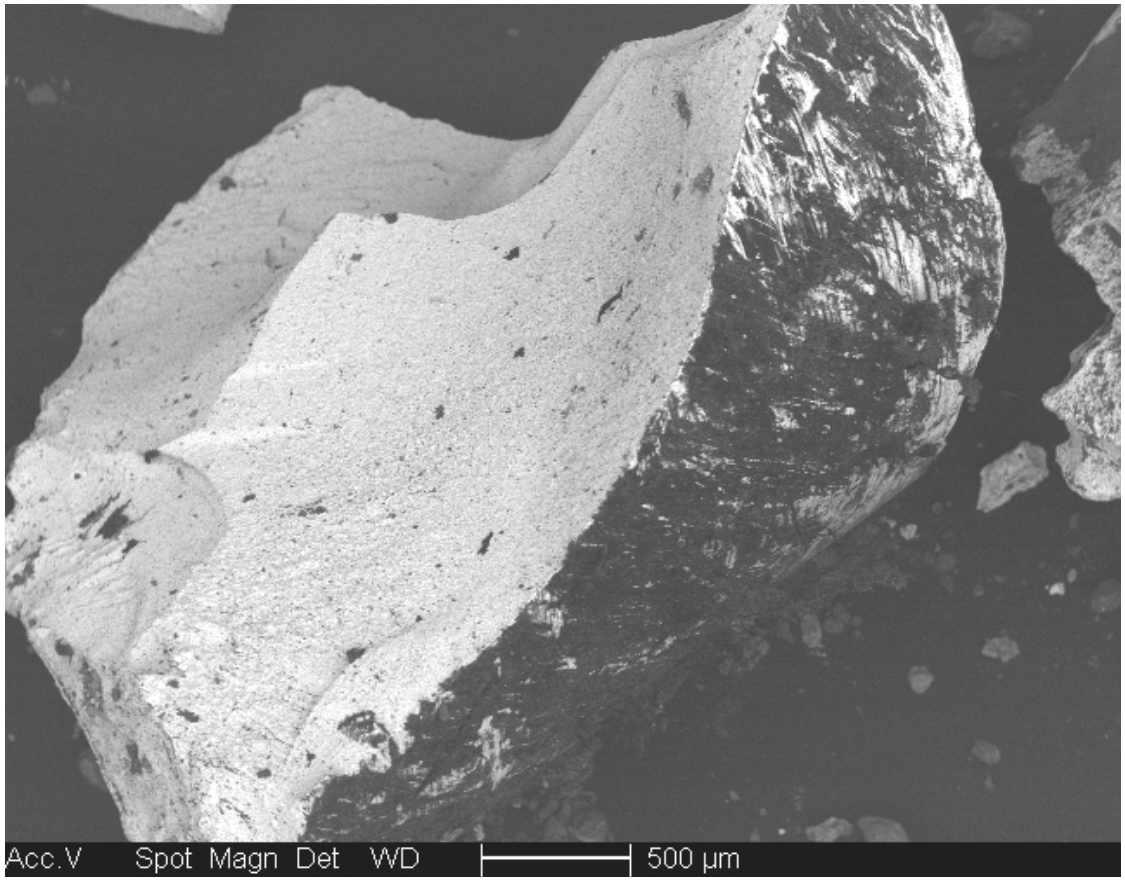
v = 250 m/s

v = 370 m/s

v = 500 m/s

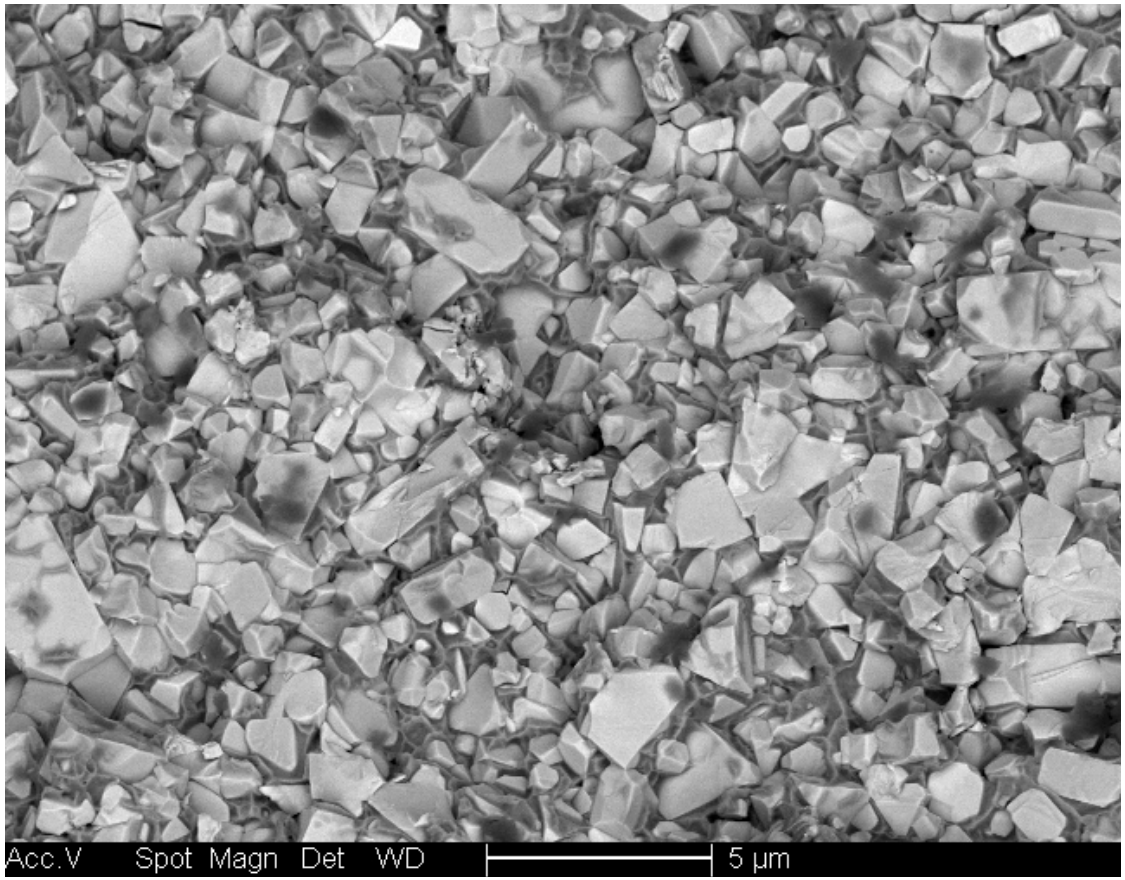
- Comminution of material increases with impact velocity
- Complete fragmentation of cores with v = 500 m/s

SEM pictures recovered fragments after impact



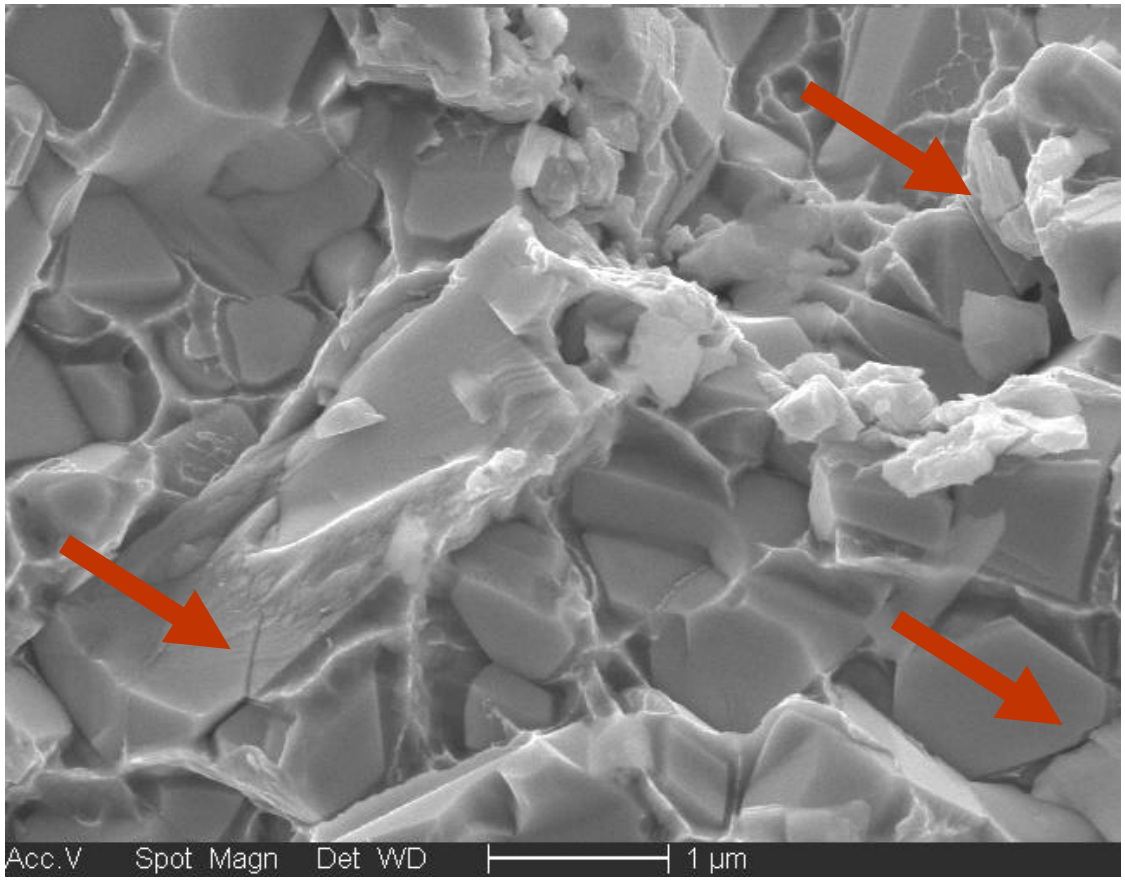
33 x magnification

SEM pictures recovered fragments after impact



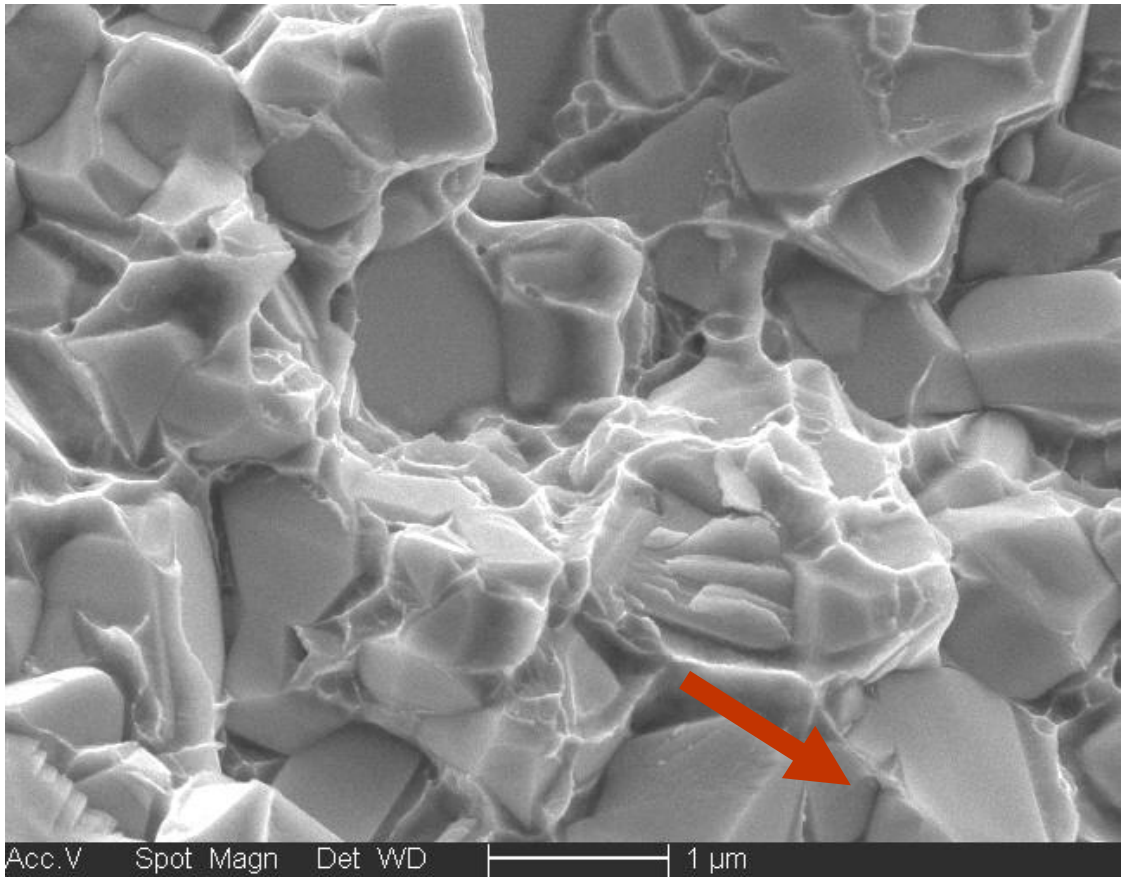
5.000 x magnification

SEM pictures recovered fragments after impact



20.000 x magnification, v = 500 m/s

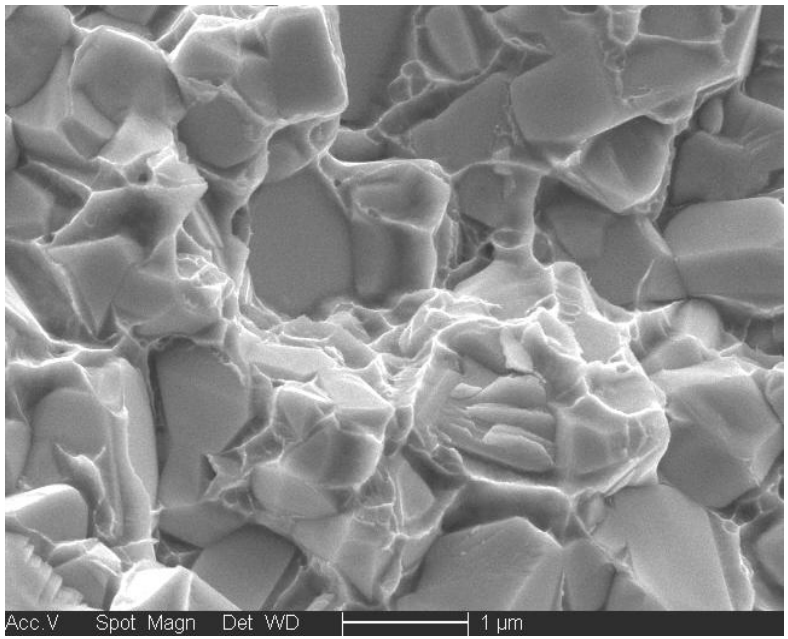
SEM pictures recovered fragments after impact



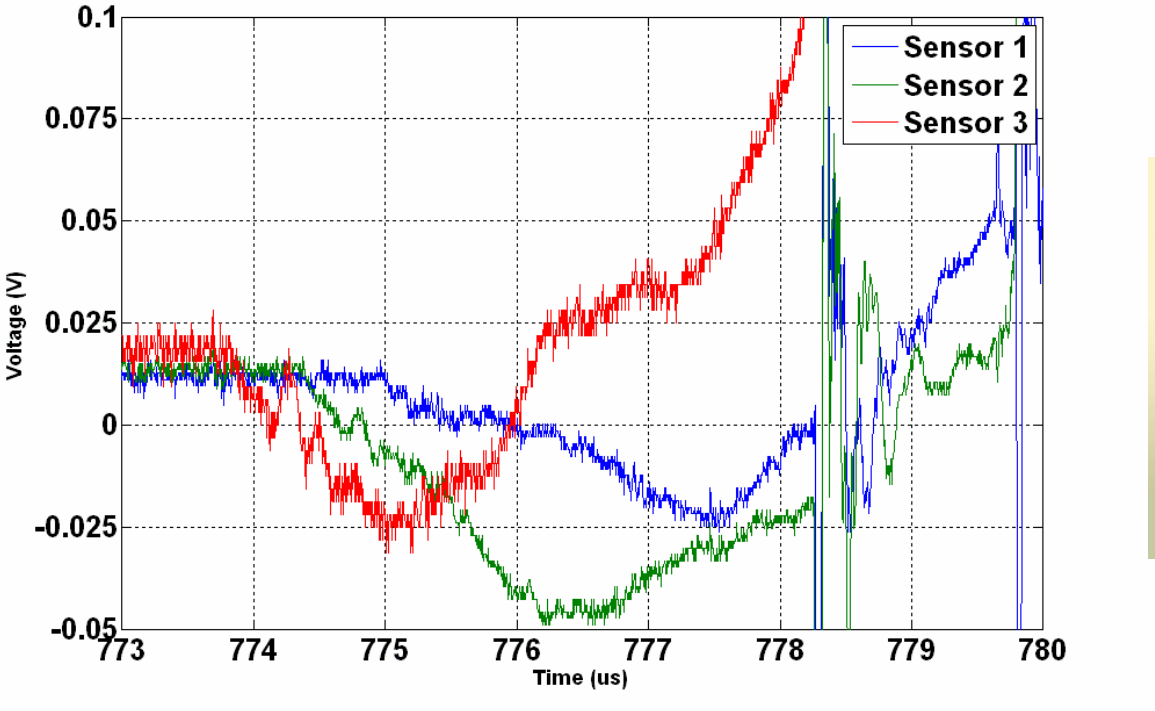
20.000 x magnification, v = 250 m/s

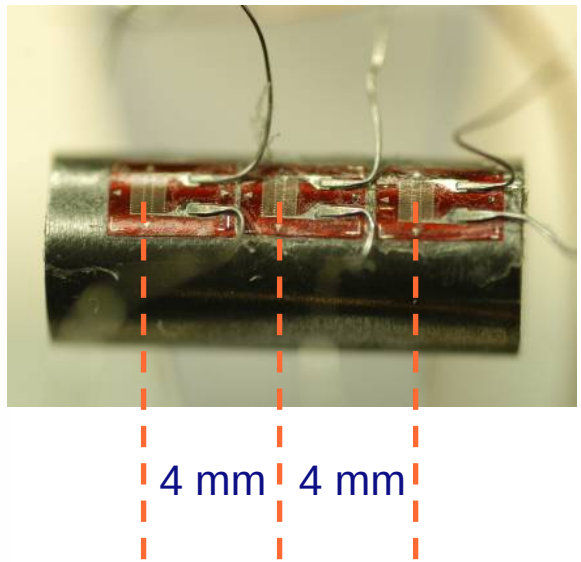
SEM pictures recovered fragments after impact

- Failure dominated by trans-granular failure in Co-matrix
- Trans-granular failure seems to be more brittle at higher impact velocities
- Inter-granular failure is rare



Results strain gauges





- Successful measurements of strain for approximately 4 µs
- Measured wave velocity corresponds well with measured EOS

Summarizing

EOS, hardening

- Analysing the composition of AP core material (SEM)
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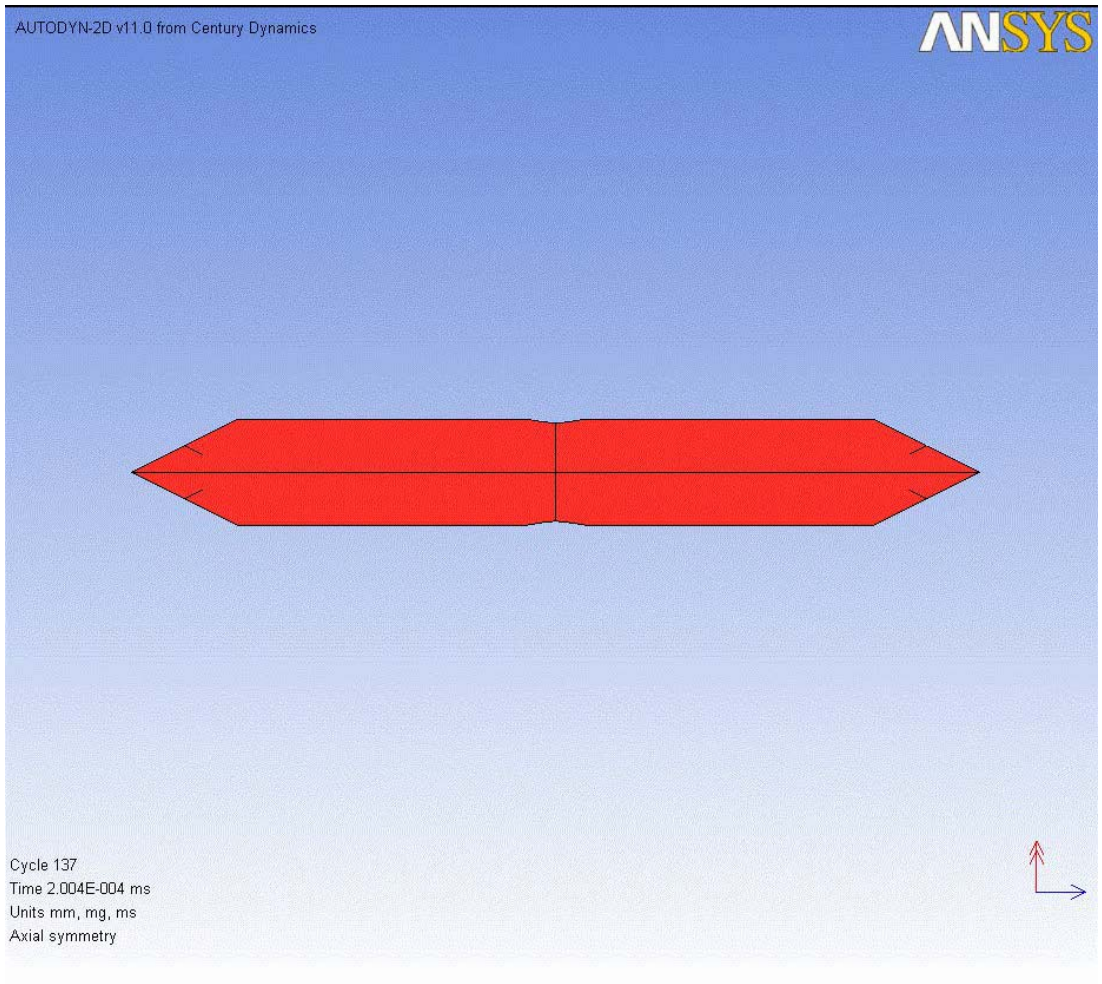
Step 3, *in progress*



Thank you for your attention

Questions … ??

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