Challenges in Modelling of Shock Initiation and Performance of Insensitive High-Explosives

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Foto: Försvarsmakten/David Gernes

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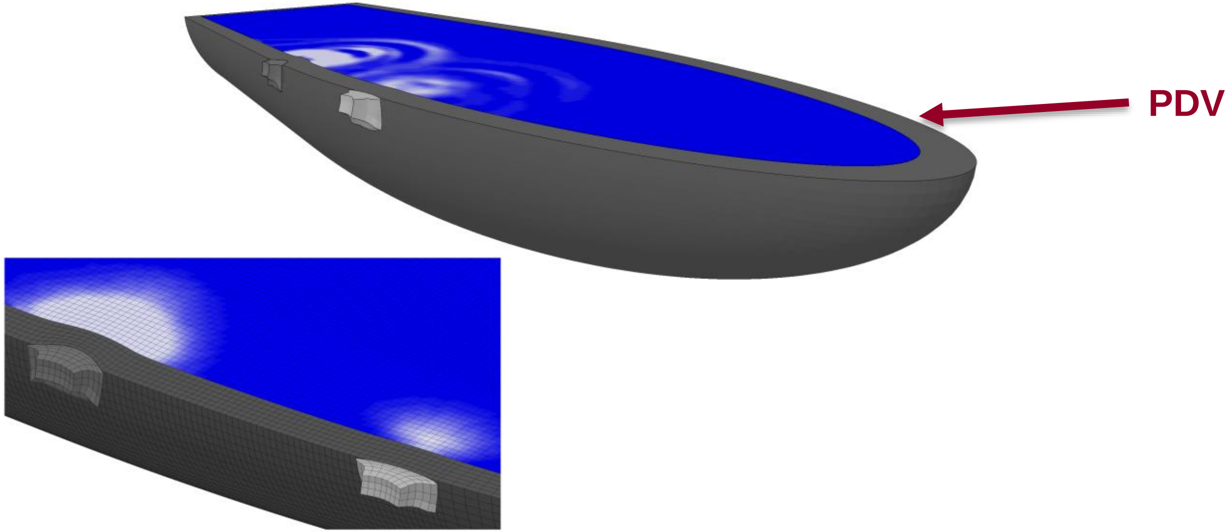
Motivation and purpose

Motivation

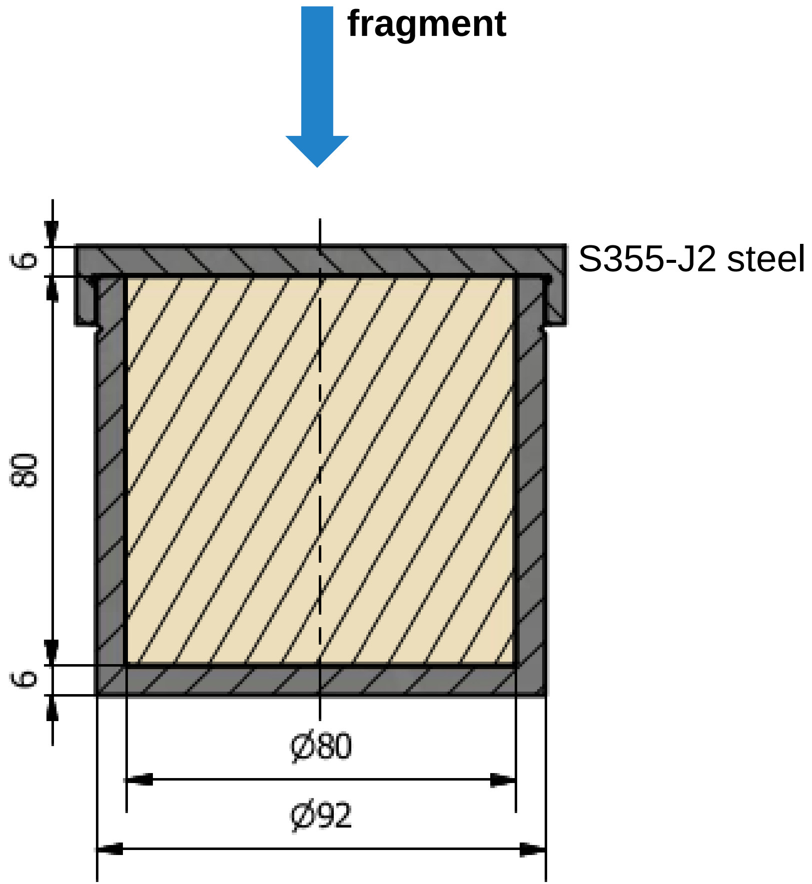
- How can calibrated reactive burn models be tested?
- How can PDV instrument be utilized in an FI setup?



Charge fabrication

Charge design

- Simple geometry
- < 1 kg of explosive
- Extension of charge should cover expected run-distances



Charge fabrication

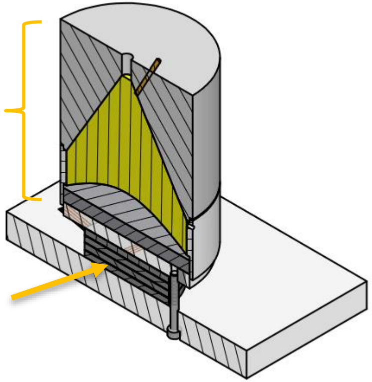
material	lot no.	amount (%, weight)
RDX, class 1 (≈200 μm)	20152213	59
RDX, class 5 (≈45 μm)	20152214	5
Aluminium, type II (≈12-18 μm)	-	20
HTPB polymer	20109025	7.34
BKF (antioxidant)	CHASME0801	0.10
DOA (plastiziser)	BCBM5175V	7.34
Dantocol (bonding agent)	200578	0.26
TPB (curing catalyst)	B08L23	0.02
IPDI (curing agent)	950325	0.95

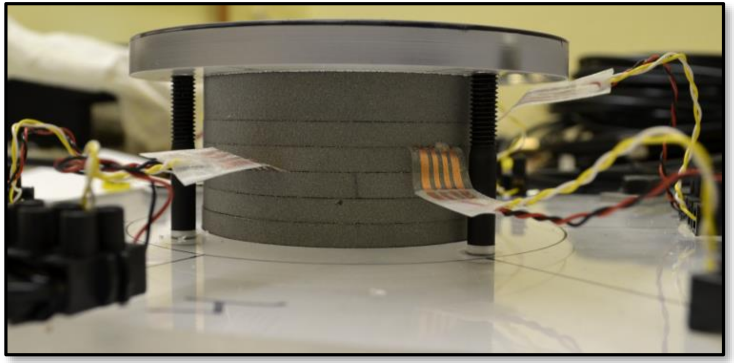
- Cast directly in casing ρ=1.65 g/cm^3
- Cast-cured body extends above top.
- Machined to obtain minimal surface roughness
- Lid is screwed on and “pushed” against explosive to minimize risk of cavities

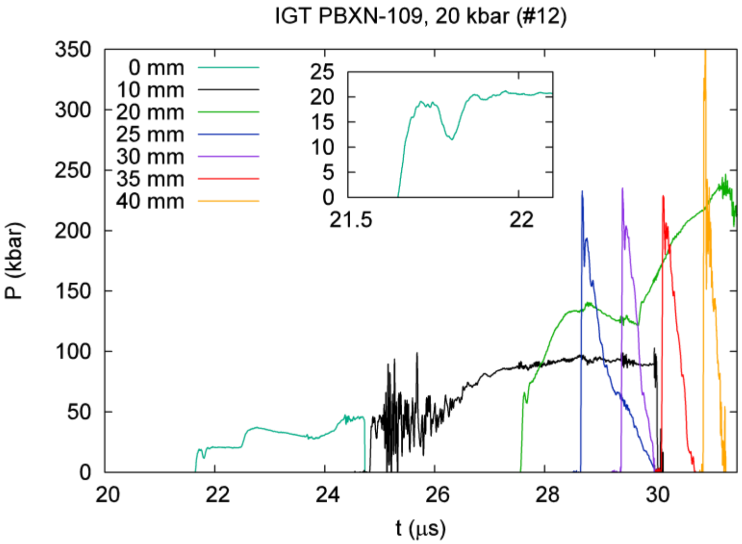
Reactive burn calibration

Instrumented Gap Test

Thin manganin gauges measure pressure over time in the explosive during build-up to detonation.





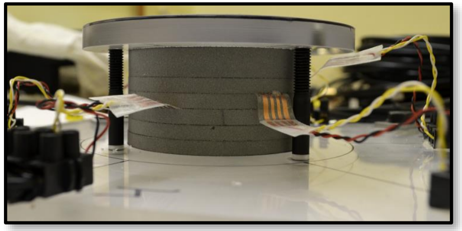


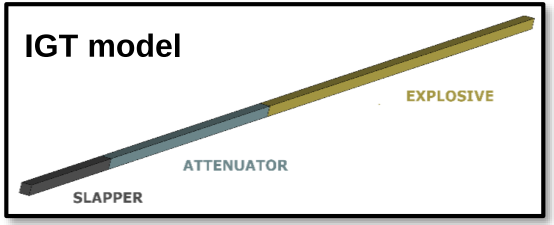
Long run-distances are challenging!

Shock initiation - calibration strategy

Burn rate equation

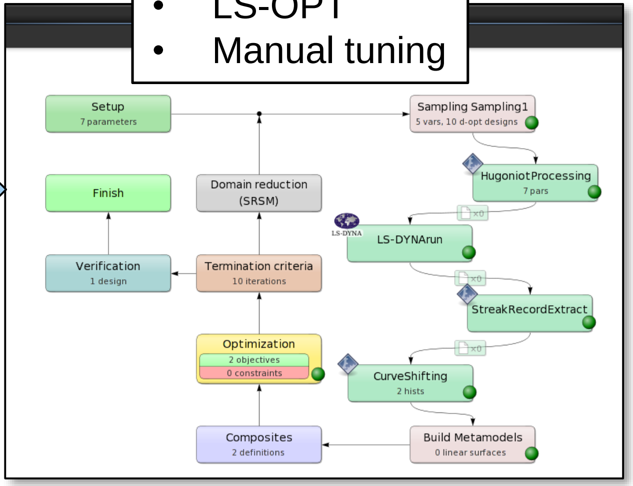
$$\frac{\partial F}{\partial t} = freq(1-F)^{frer}\left(\frac{V_0}{V} - 1 - ccrit\right)^{eetal} + grow1(1-F)^{es1}F^{ar1}p^{em} + grow2(1-F)^{es2}F^{ar2}p^{en}$$

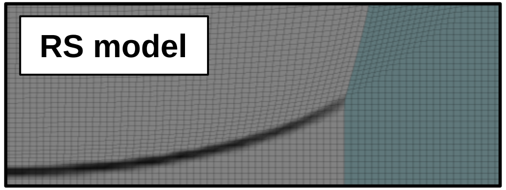


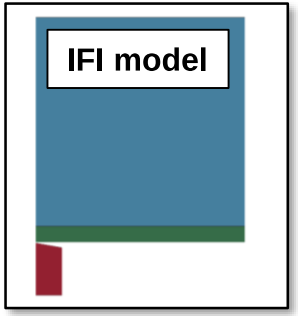


Optimisation:

- LS-OPT
- Manual tuning



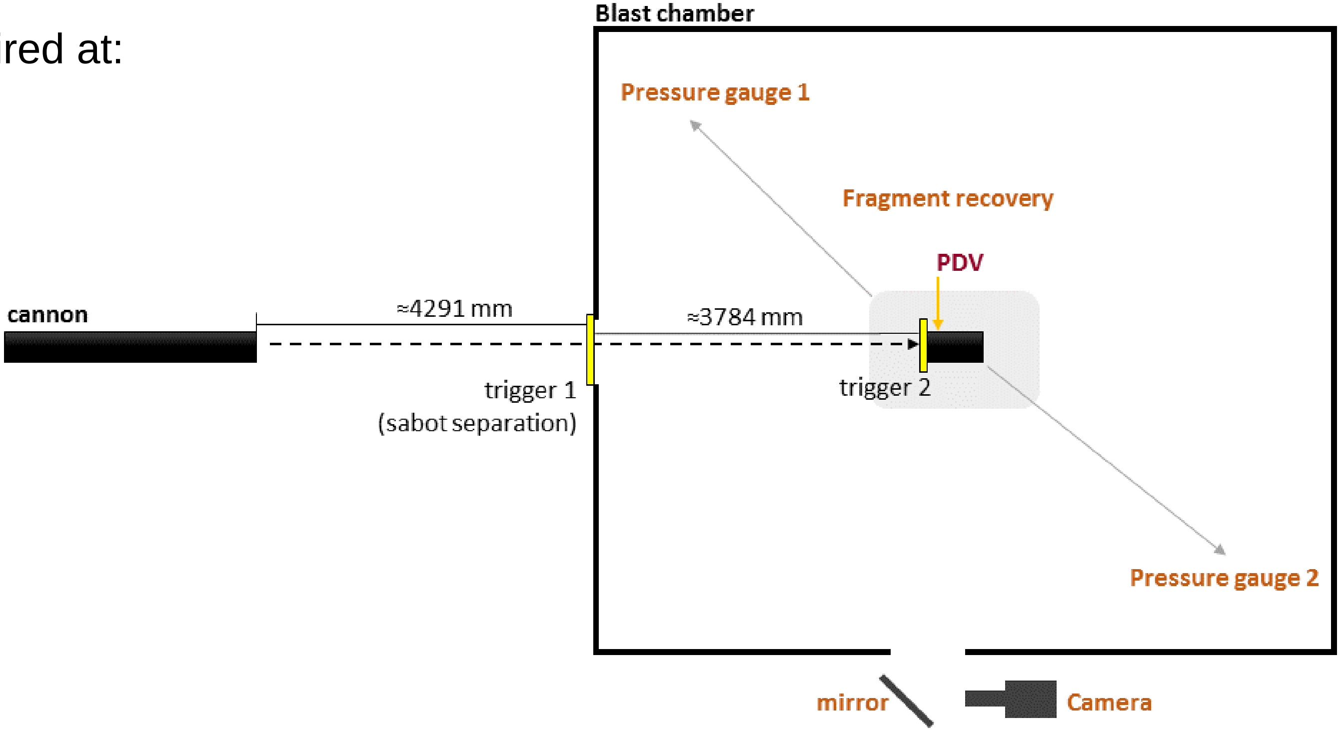


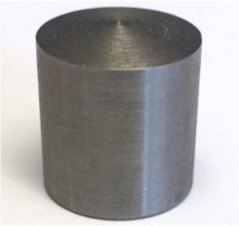


Instrumented fragment impact test

Fragment was fired at:

1. **1306 m/s**
2. **1819 m/s**
3. **2125 m/s**



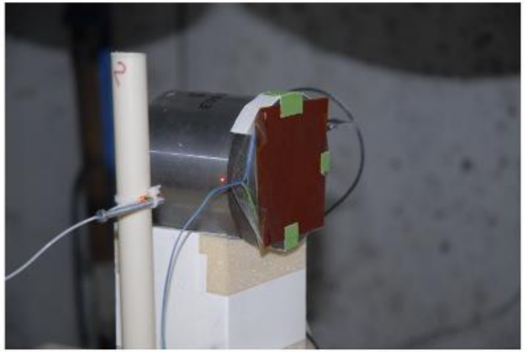


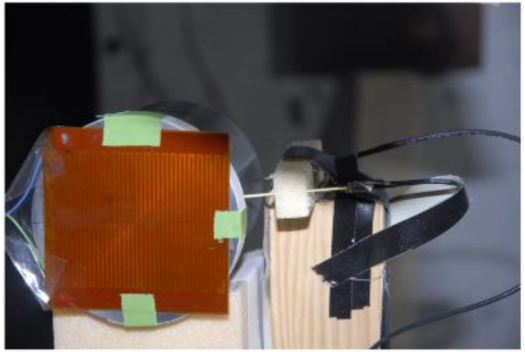
STANAG fragment

FOI

Diagnostics

- High-speed video
- PDV
- Charge fragment analysis
- Blast pressure measurements



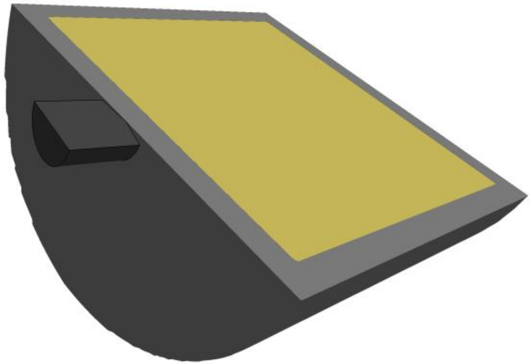


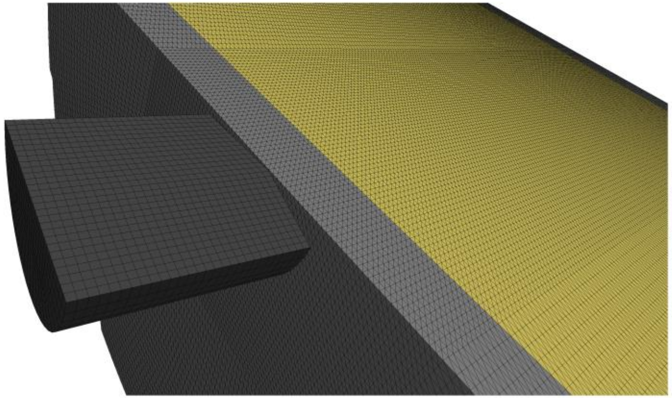
Model description

Modelling

3D explicit finite element model in LS-Dyna

- ALE – projectile in Lagrange, charge in Euler
- 2nd order advection
- Penalty-based contacts
- 0.5 mm element size
- Monitoring wall expansion at PDV and probe positions

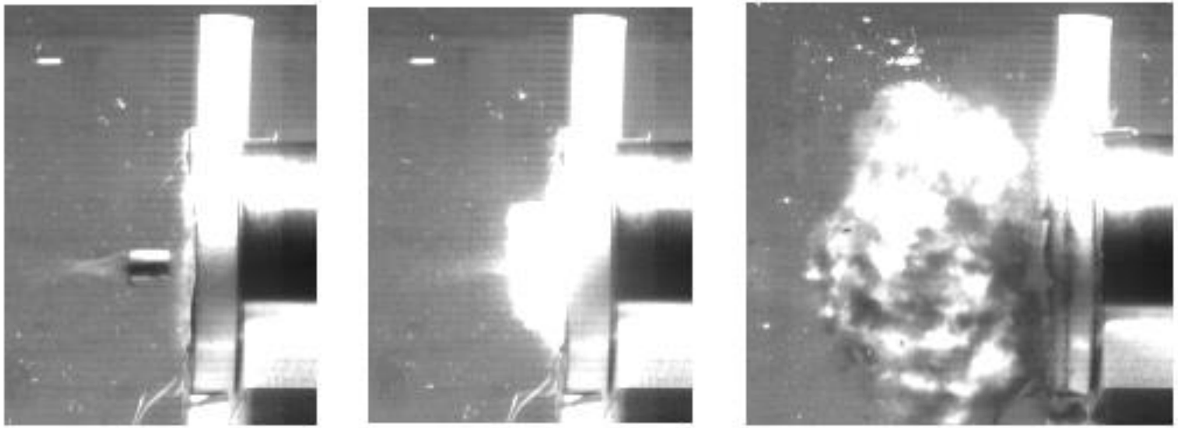




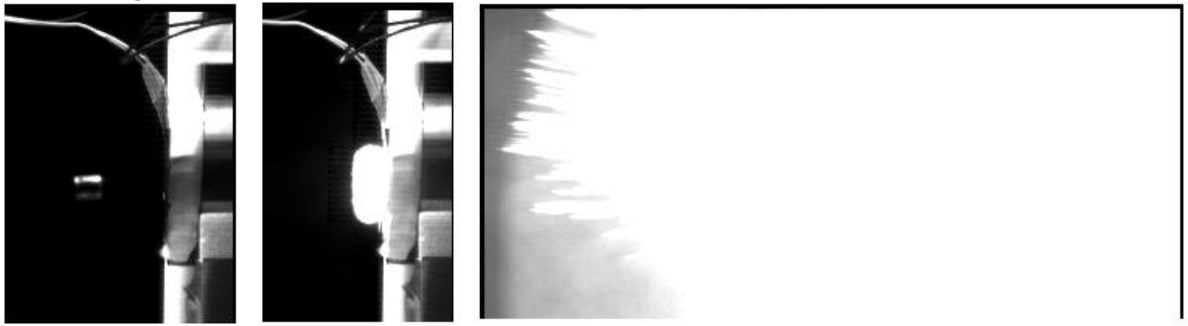
Results

Instrumented fragment impact test (IFI)

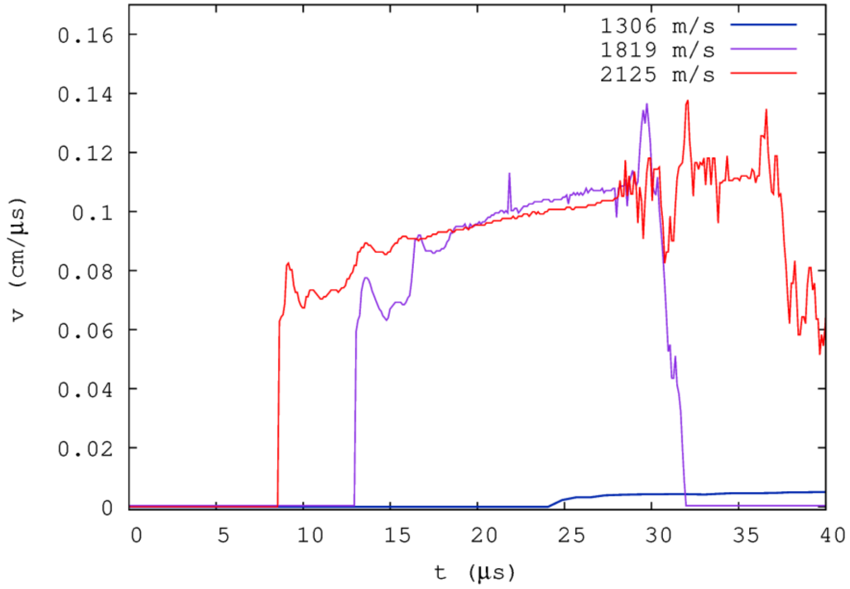
1306 m/s



1819 m/s



Instrumented fragment impact test (IFI)

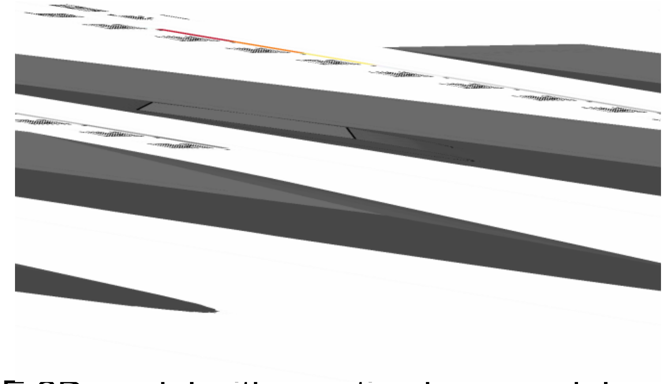


overall assessment

test	v_f	response
4	1306 m/s	NOGO
7	1819 m/s	delayed detonation
8	2125 m/s	detonation

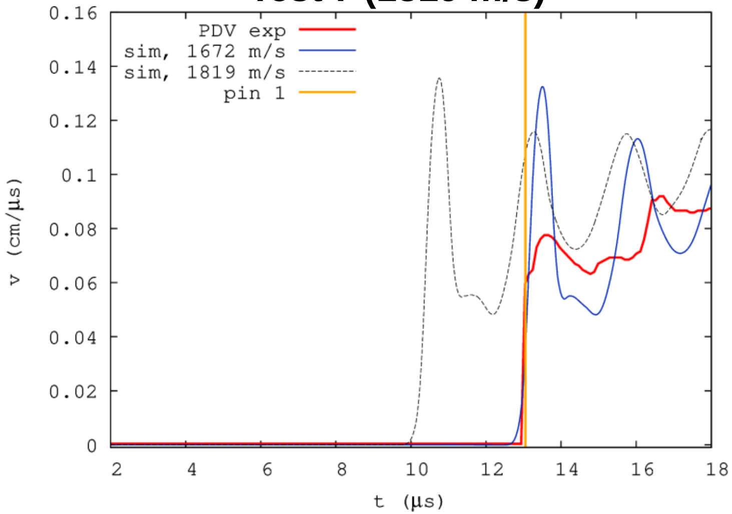
PDV – powerful tool for quantifying response, especially for IHE.

IFI for model validation



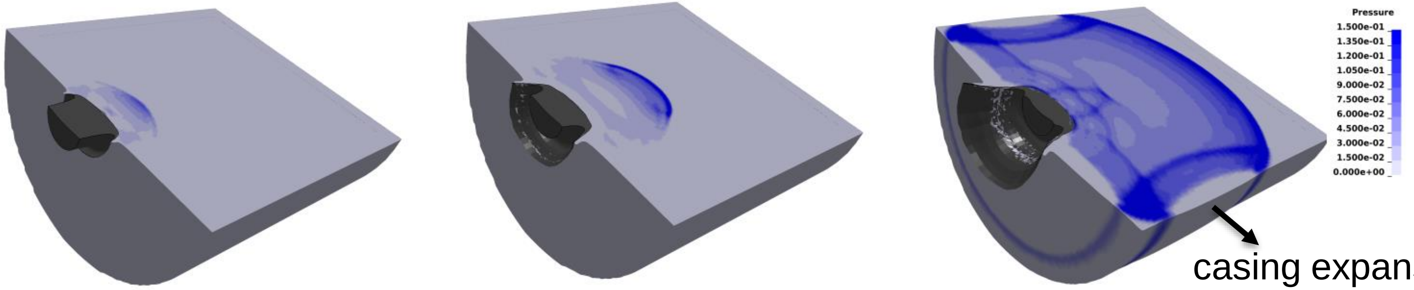
ALE 3D model with reactive burn model

Test 7 (1819 m/s)



Detonation occurs a bit too early in model..

Pressure field at 4 µs, 8 µs and 14 µs after impact.

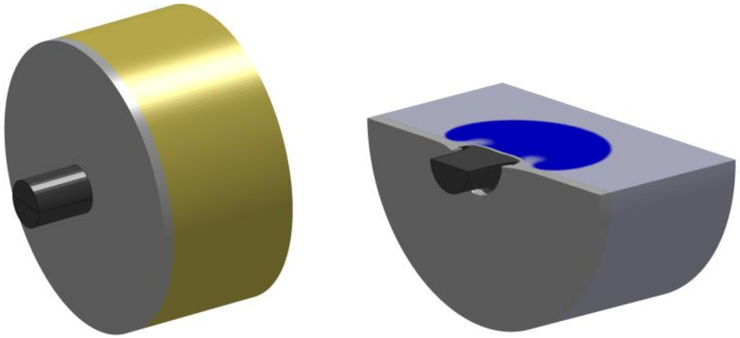


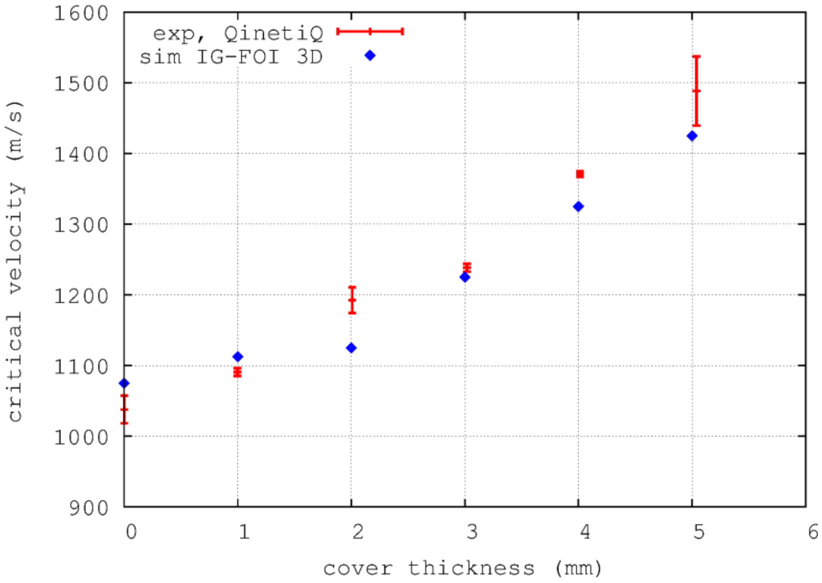
casing expansion velocity

Recalibration and validation

Critical fragment velocity is included in the set of calibration data – fair agreement can be achieved against FI, IGT, critical diameter and D(d).

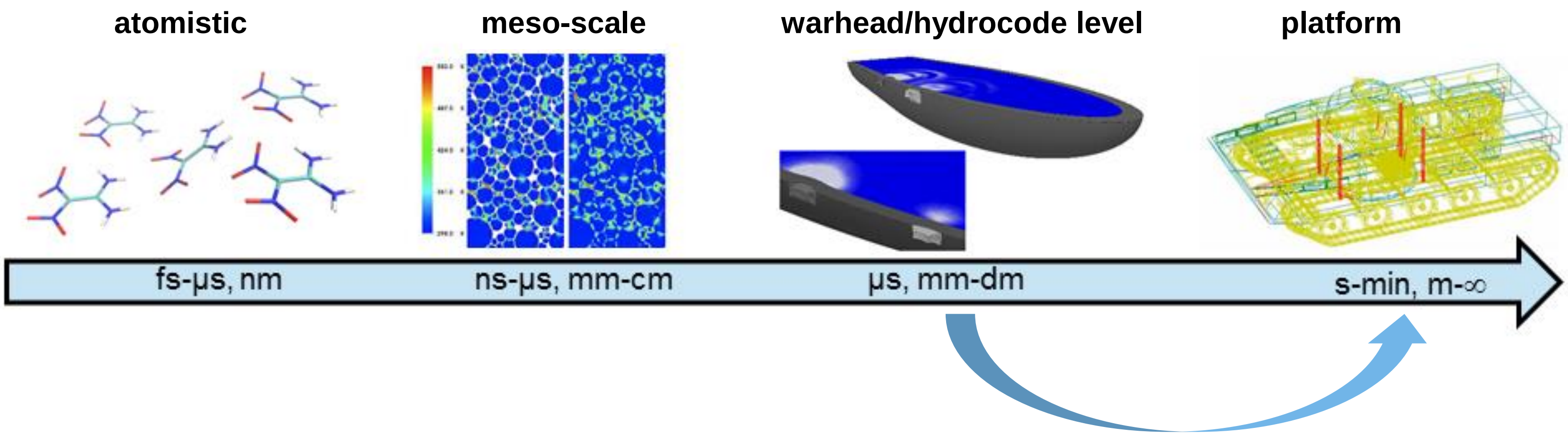
How does this parameter set perform when fragment geometry and casing material and thickness is altered?





Model shows satisfactory agreement, and can be utilized in various assessments.

Application of physical initiation models



Semi-smart interface that:

- starts simulations
- vary parameters
- finds critical velocities
- generates data-tables which can be read by platform-level programs

Thanks

for your attention!