Numerical and experimental study on the high strain rate deformation of tubes for perforating gun applications

IPS-16-32

Mihaela Cristea
Maurizio Bellingardi
Davide Gallina

2016 International Perforating Symposium, Galveston

Modelling the survivability tests:

Is steel characterization the *key factor* for reliable swelling predictions?
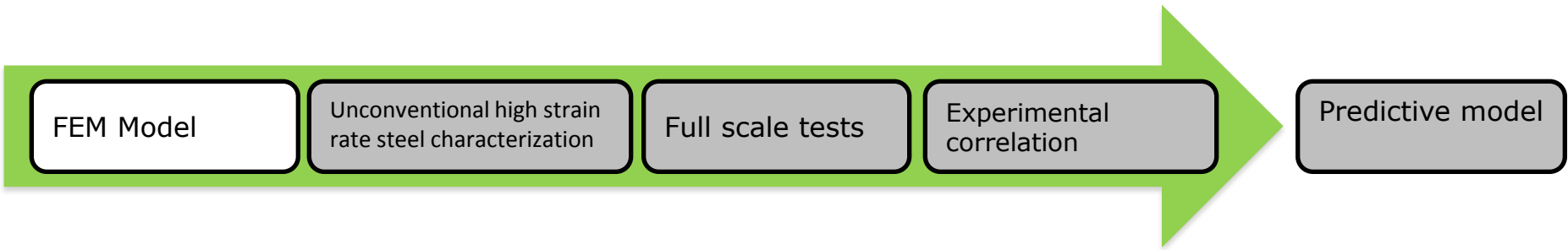
Modelling the survivability tests

FEM Model → Unconventional high strain rate steel characterization → Full scale tests → Experimental correlation → **Predictive model**

# Need for a tool able to predict the swelling of the gun carrier

3D model of a gun carrier with 3 shaped charges

Each section modelled as follow:
1. **Steel gun carrier**: Johnson-Cook (J-C) plasticity model, obtained from experimental tests at high strain rates;

2. SC: **casing** and **liner**: J-C material/damage model*;

3. **Explosive**: Jones-Wilkins-Lee (JWL) equation of state*.

Sequential detonation of 3 charges (5 ms delay)

Swelling predicted as permanent plastic deformation on the steel carrier

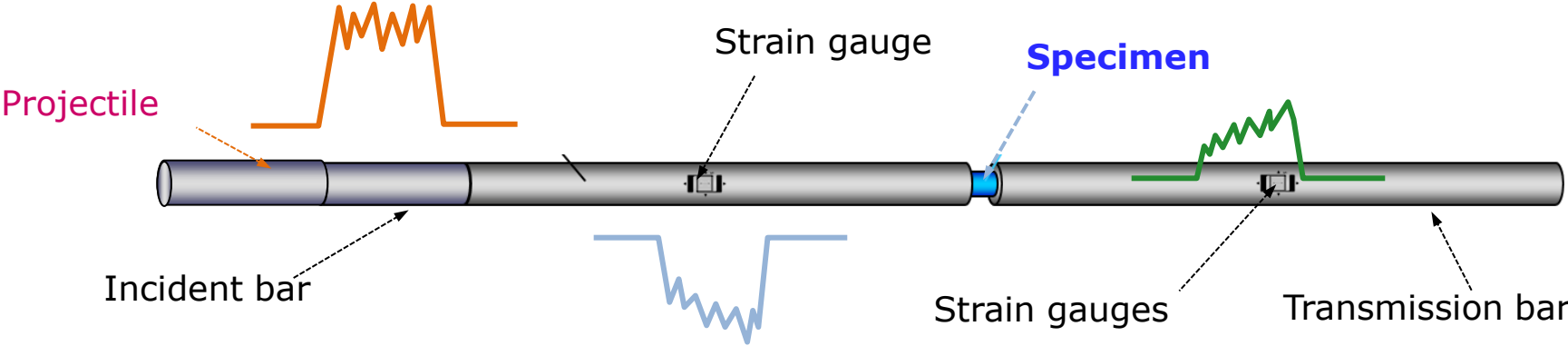*literature data

More info

IPS-16-32
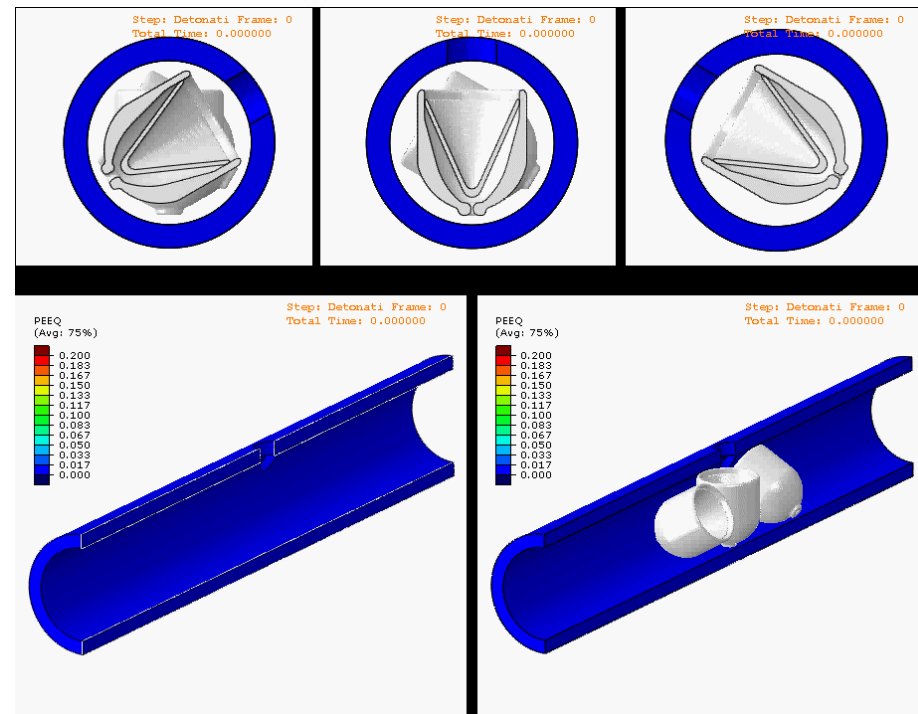
Need for experimental high strain rate tests for proper steel characterization

Tests methodology: Split Hopkinson bar test (SHBT)

The reflected and transmitted waves are analysed to reconstruction based on the two
The projectile hits the incident bar generating a compressive wave train
- Partly reflected waves and reconstruction based on the two signals the dynamic material behaviour of the specimen is obtained. bars

Specimens machined from Perf Gun Carrier Material

Projectile

Strain gauge

Specimen

Incident bar

Strain gauges

Transmission bar
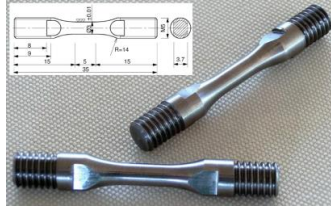
Johnson-Cook (J-C) constitutive model

Stress = (Plasticity)(Log. of strain rate)(Temperature)

A, B, n   C, ε_0 m

FEM vs. Experimental traction force

Test 1
Test 2
Test 3
FEM

Force (N)

Strain rate: 10^3 s^{-1}

Displacement (mm)

Stress

Strain

Conventional tests
10^3 s^{-1}
10^4 s^{-1}
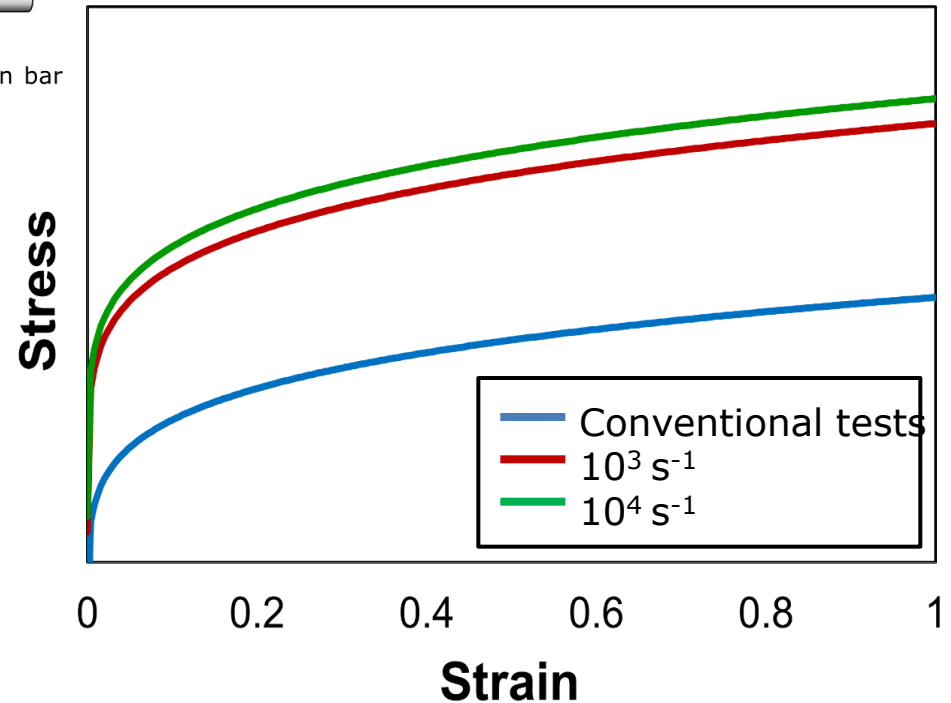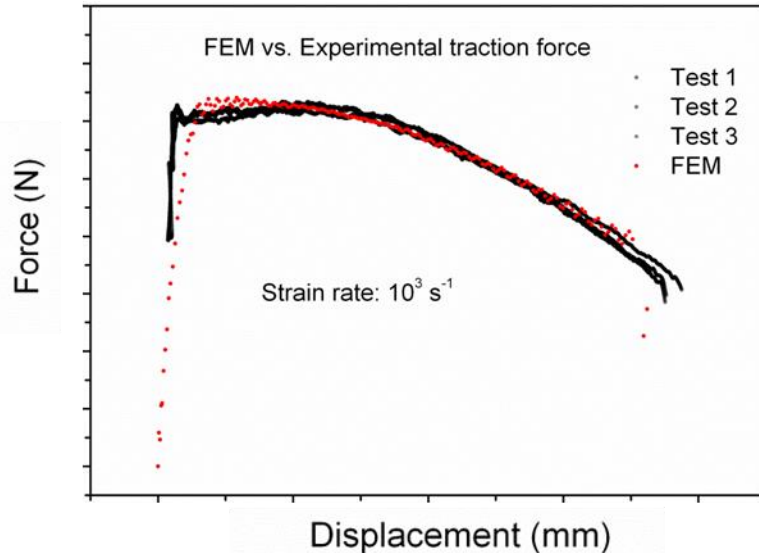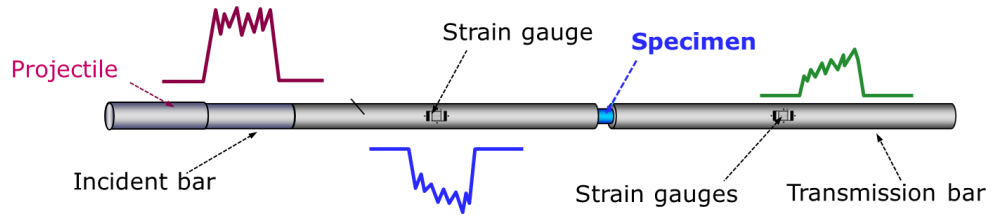
In order to calibrate the J-C model's parameters, FEM inverse analysis onto the experimental curves up to a discrepancy within about 5% have been carried out.

FEM Model → Unconventional high strain rate steel characterization → Full scale tests → Experimental correlation → Predictive model

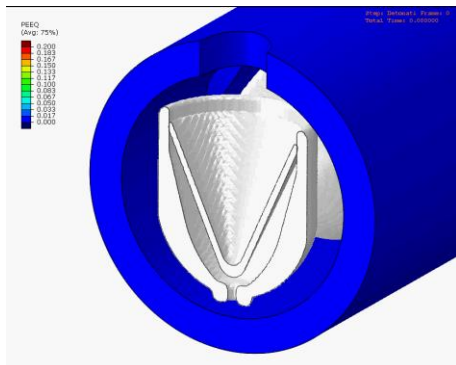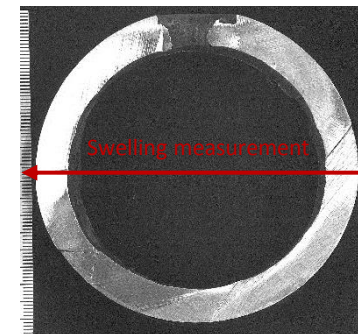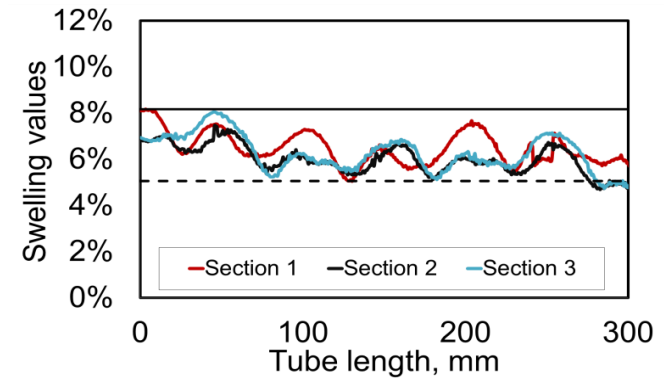**Need for experimental measurements of local strain deformation and overall swelling**

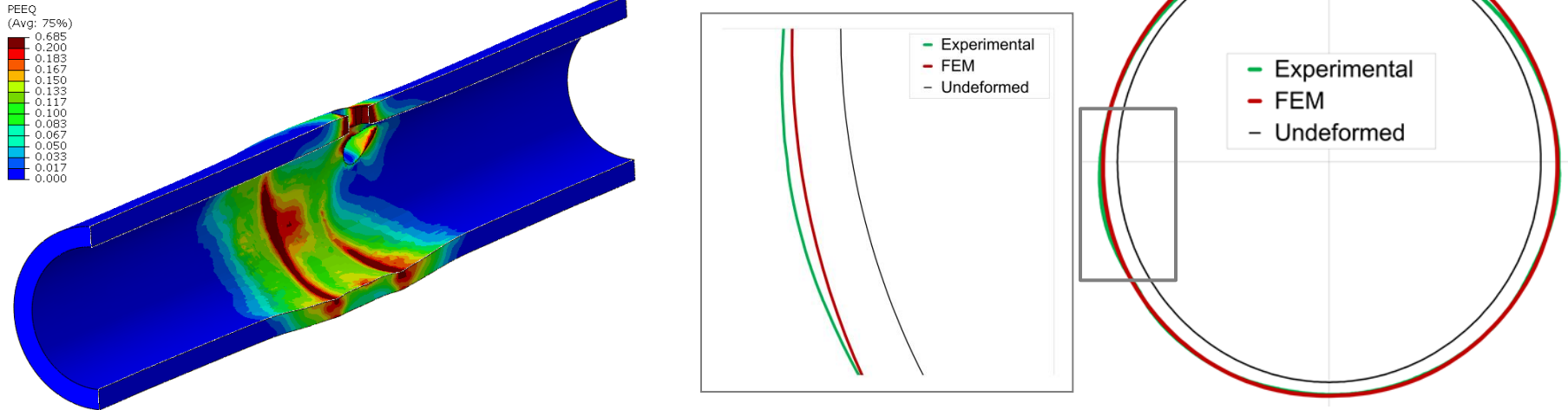**Local** strain deformation measurement at the max. impact angle determined by FEM model

Overall swelling measurement sections

More info

IPS-16-32

FEM Model → Unconventional high strain rate steel characterization → Full scale tests → Experimental correlation → Predictive model

Local and overall post mortem deformation vs numerical analysis results

PEEQ
(Avg: 75%)
0.685
0.200
0.183
0.167
0.150
0.133
0.117
0.100
0.083
0.067
0.050
0.033
0.017
0.000

— Experimental
— FEM
— Undeformed

	Measurement Position	Experimental value	FEM value
Overall swelling	Location with max. value	8.3%	8.0%
Local deformation	70°	10.3 %	10.2 %
	55°	5.1 %	6.5 %

Thanks for your attention