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2016 LATIN AMERICA PERFORATING SYMPOSIUM, BUENOS AIRES

SLAP2016
SIMPOSIO LATINOAMERICANO DE PERFORATING

High strain rate mechanical and fracto-mechanical steel characterization for perforating gun simulation model

SLAP-16-22

October 20th

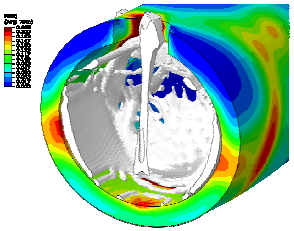
PRESENTER: Mihaela Cristea & Maurizio Bellingardi - TENARIS

Topic of this presentation

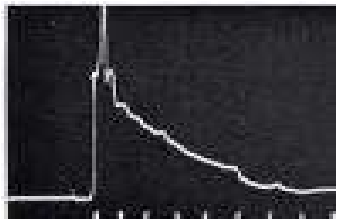
Is steel characterization the *key factor* for reliable swelling predictions and/or potential gun carrier failure?

Survivability test conditions: Events

Detonation



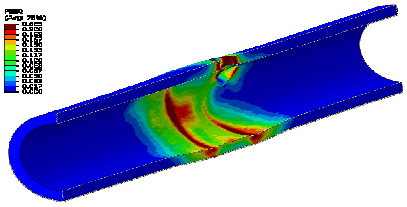
Perforating Needle



Gas Pressure Wave & Impact of Casing on inside carrier wall

Phenomena under investigation: Cracking / Failure

1. Swelling



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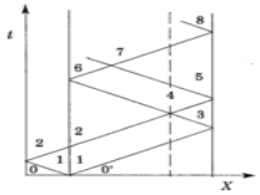

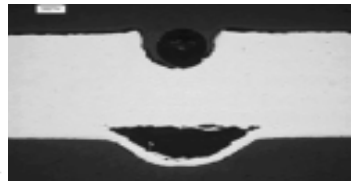

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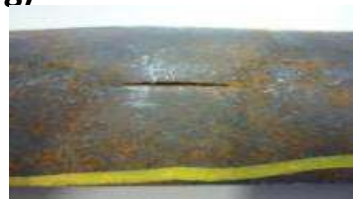


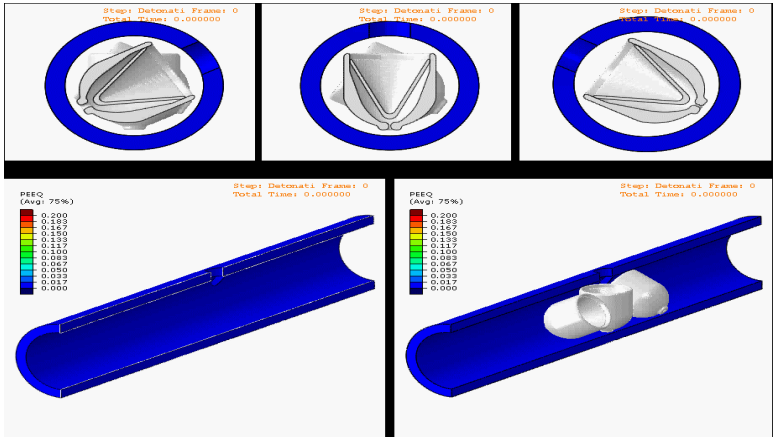
EVENTS

TIME

Tool for gun carrier swelling prediction

IPS-16-32 - Numerical and experimental study on the high strain rate deformation of tubes for perforating gun applications

3D model of a gun carrier with 3 shaped charges

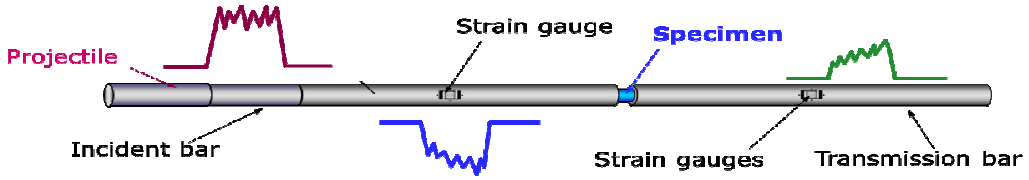


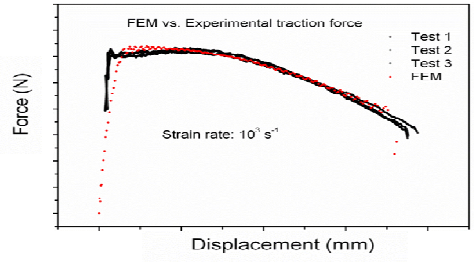
Johnson-Cook (J-C) constitutive model

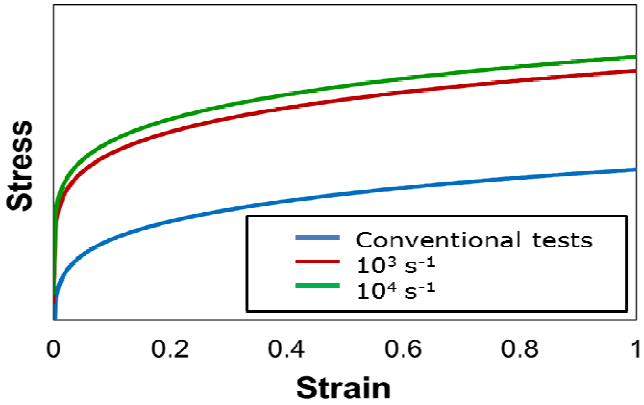
Stress = (Plasticity)(Log. of strain rate)(Temperature)

A, B, n — C, ε_0 — m

Tests methodology: Split Hopkinson bar test (SHBT)







Survivability test conditions: Events

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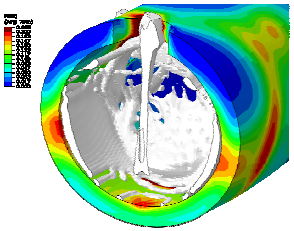

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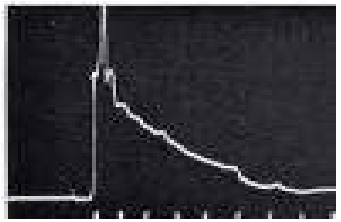

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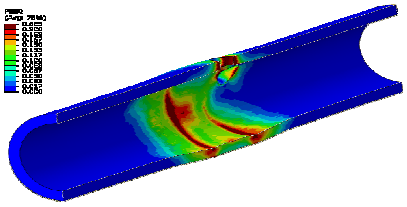

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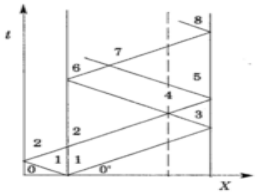

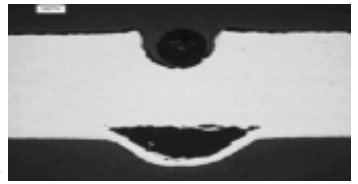

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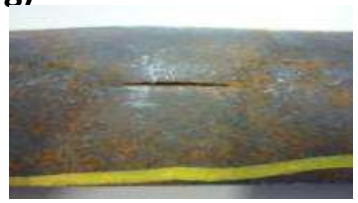
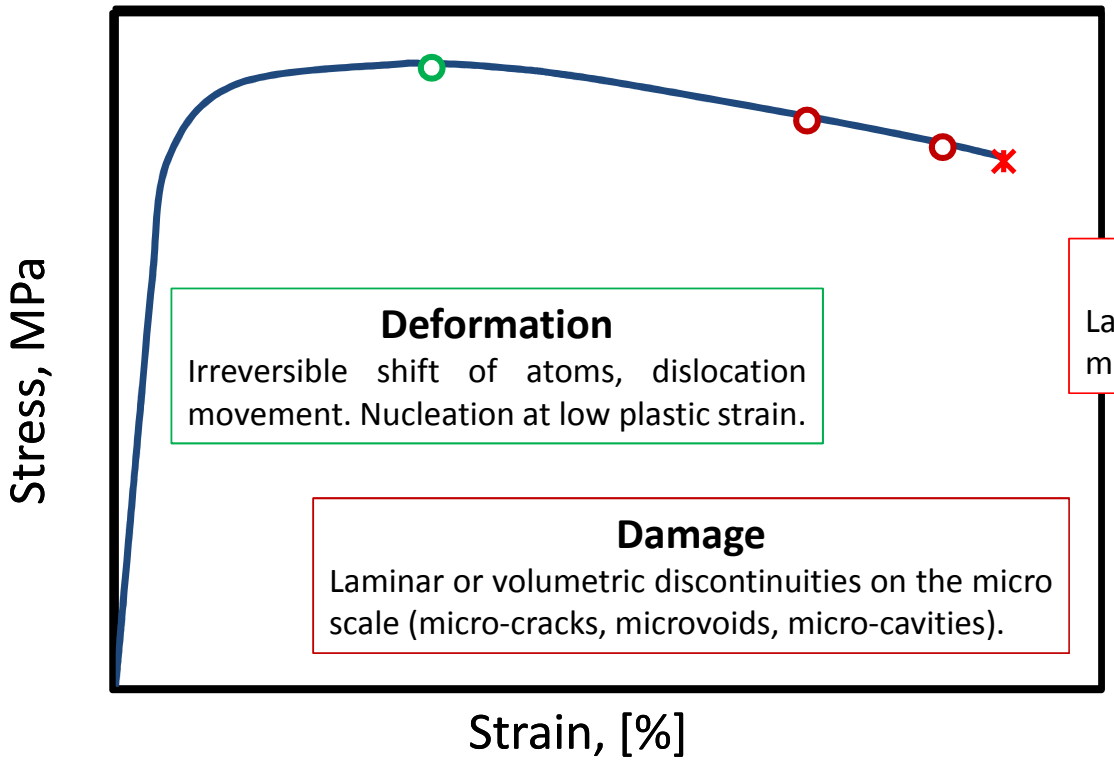


EVENTS

TIME

Material behavior: Deformation – Damage - Fracture



Deformation
Irreversible shift of atoms, dislocation movement. Nucleation at low plastic strain.

Damage
Laminar or volumetric discontinuities on the micro scale (micro-cracks, microvoids, micro-cavities).

Fracture
Laminar discontinuities/cracks on the macro scale leading to global failure .

Dealing with material or components containing cracks

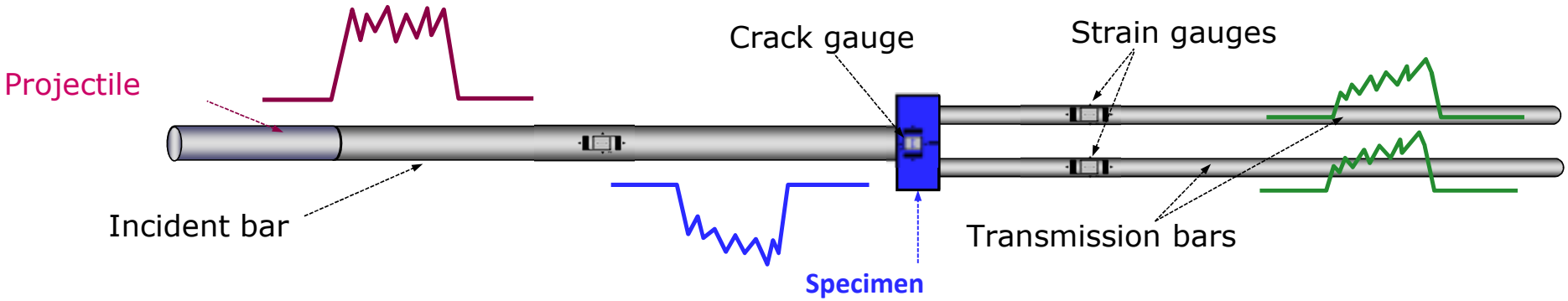
⬇

Material fracture toughness

Damage (“*l'endommagement, comme le diable, invisible mais redoutable”)* describe evolution of **degradation** phenomena on the microscale from initial (undamaged or pre-damaged) state up to creation of a **crack** on the mesoscale (material element).

Experimental $J_I D_{INITIATION}$

Initiation dynamic fracture toughness



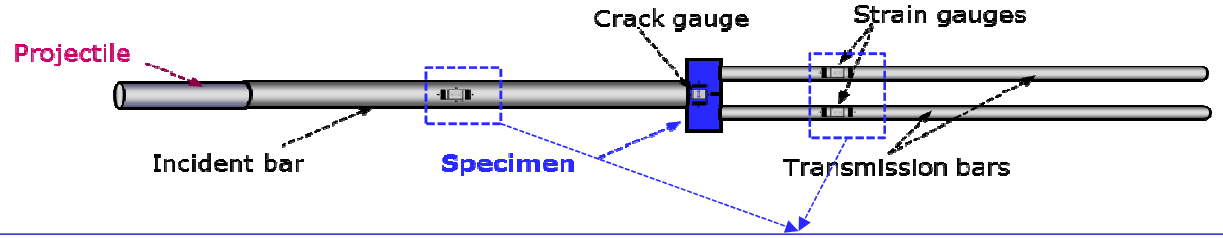
The dynamic loads (stress waves) are measured using instrumented bar using high strain gages

Dynamic fracture toughness $J_I^D{}_{init}$ is function of the **load** applied during the test and the **fracture time** t_f

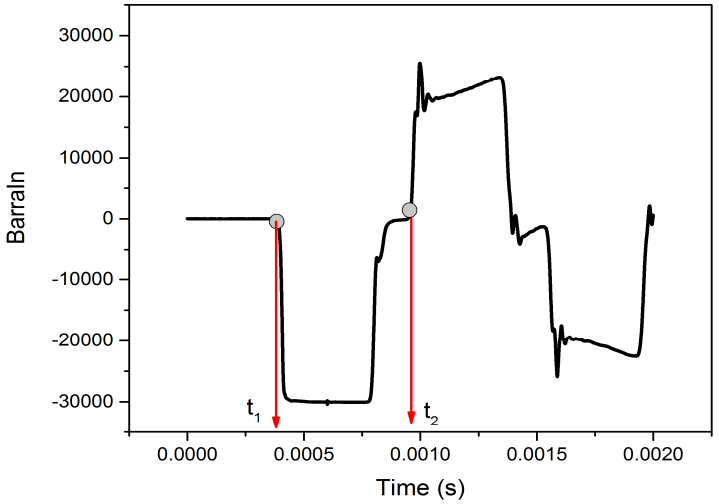
The fracture time can be measured by means of **fracture gage** or by means of **DIC** (Digital Image Correlation)

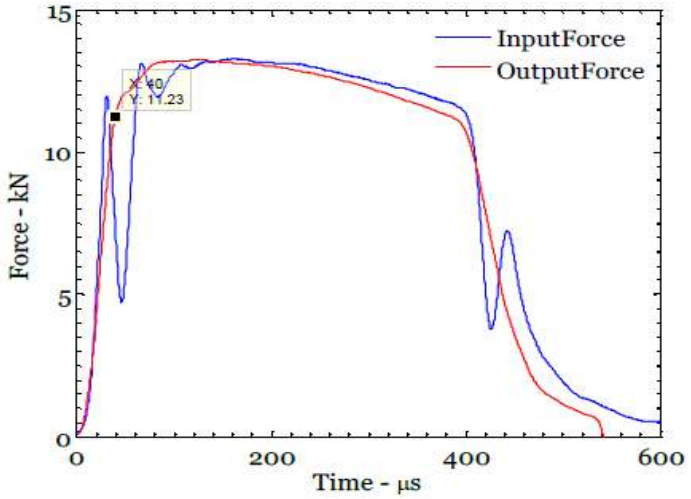
Experimental $J_I D_{INITIATION}$

Load vs. time



By means of strain gages positioned on the incident and transmission bars, specimen geometry, cross section, sound propagation rate and Young's modulus of the equipment bars is it possible to obtain forces and stress vs. time.

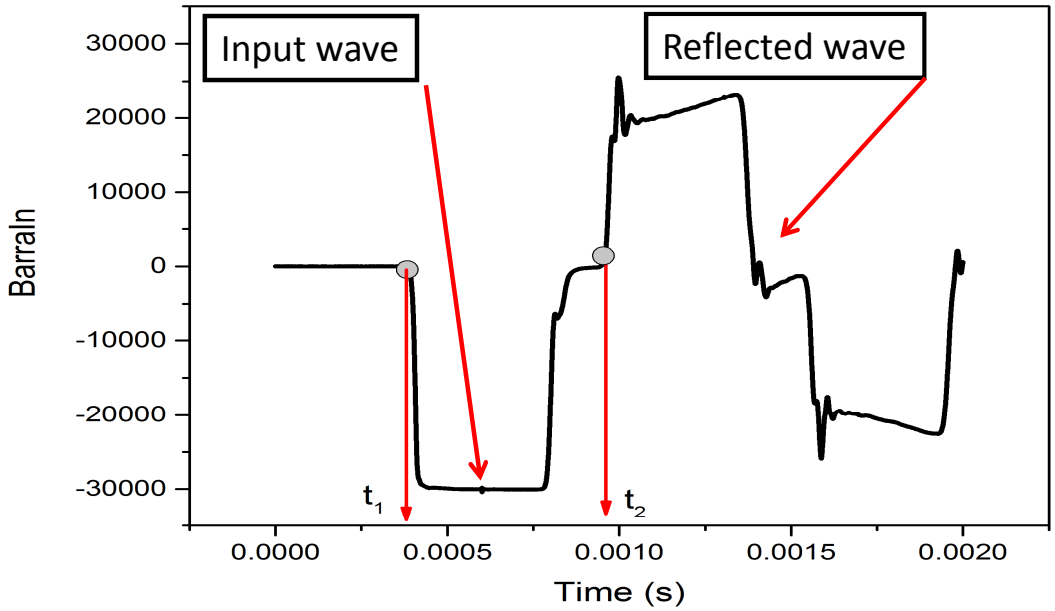




Experimental $J_I D_{INITIATION}$

Fracture time: t_{start}

Signals Synchronization: input-reflected waves. Using the signal vs. time diagrams of the actual input and first reflected wave signals.



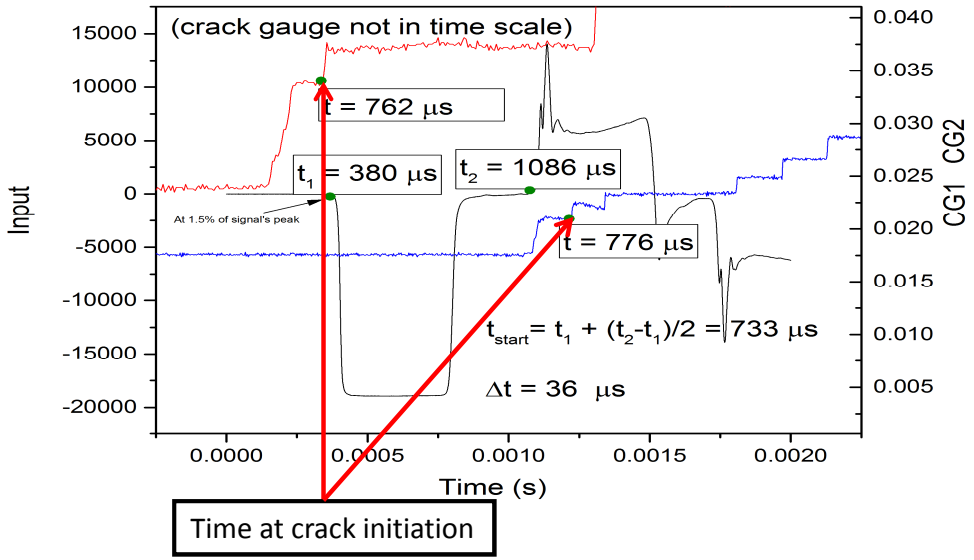
The time-points t_1 and t_2 corresponding to the wave front of the input and reflected signals can be measured.

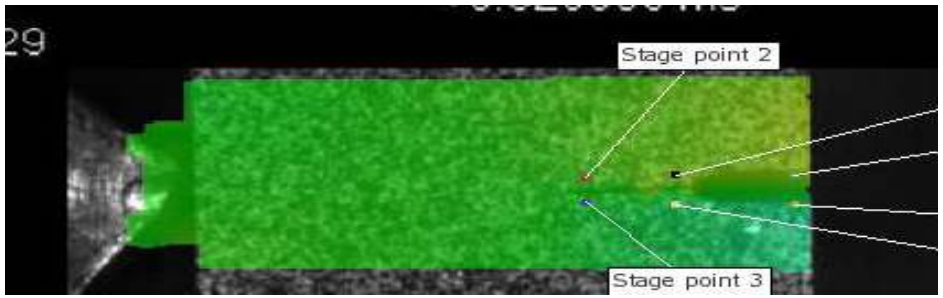
The time shift from the zero of the time acquisition is given by the formula:

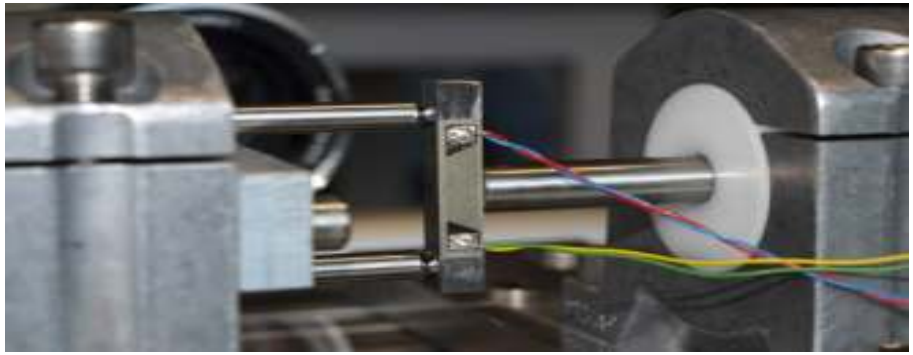
$$t_{start} = t_1 + \left((t_2 - t_1) / 2 \right)$$

Experimental $J_I D_{INITIATION}$

Fracture time: t_{init}







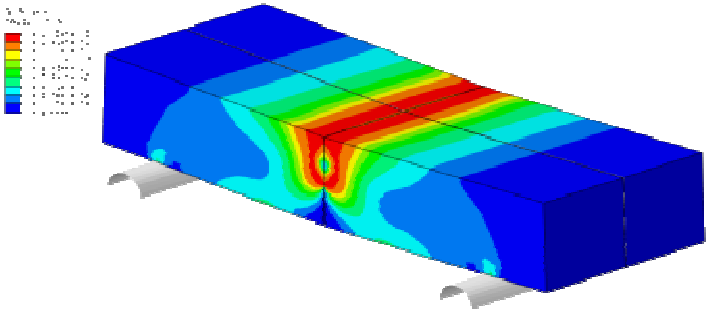
For each crack gauge, the time at which the crack is considered to start is the point in time corresponding to the first "macro" step of the gauge signal. The very first tiny ones correspond to the pre-crack opening.

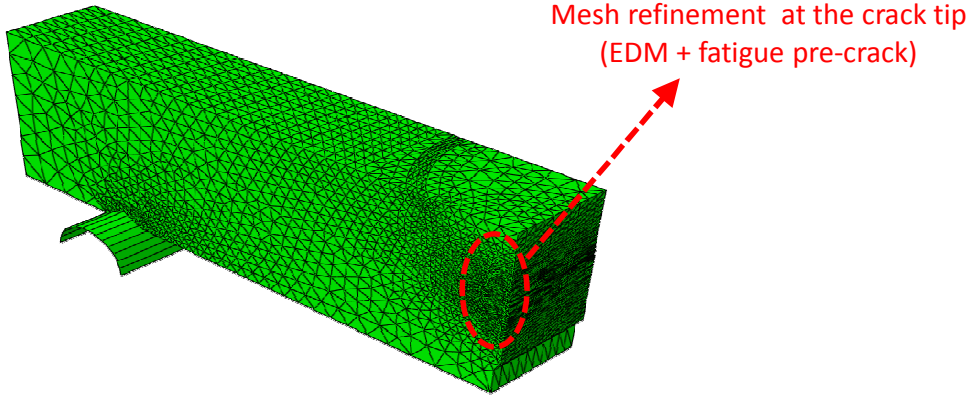
Comparison with direct measurement of the initiation time using the high speed images of the test:

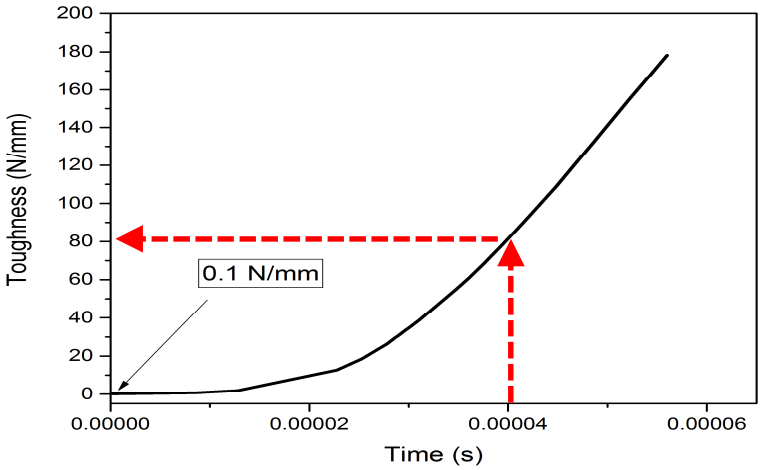
35 µs (DIC) vs. 36 µs (Crack gauge)

Numerical model for $J_ID_{INITIATION}$

3D model: due to two planes of symmetry **only a ¼** of the specimen was considered
INPUT: Experimental load vs. time obtained from strain gauge instrumented HOP







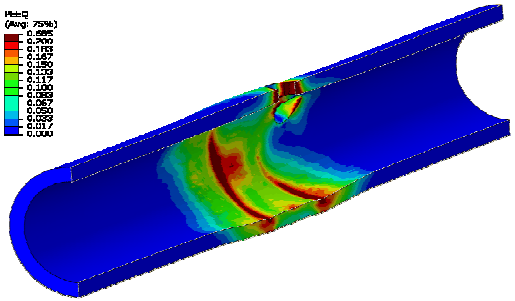
The toughness (J integral) as a function of time is calculated by the finite element model of the specimen subjected to the actual loading.

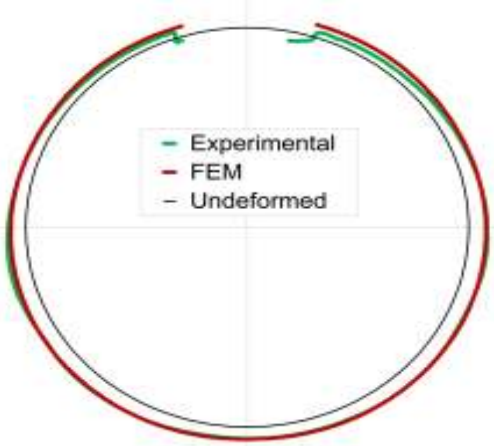
Knowing the initiation time measured with the procedure explained before the toughness at crack initiation is obtained.

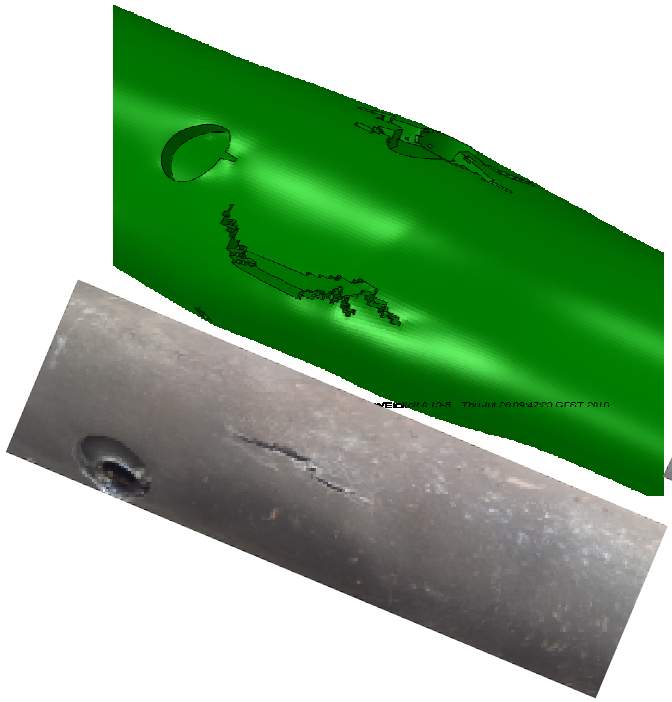
Failure predictive model

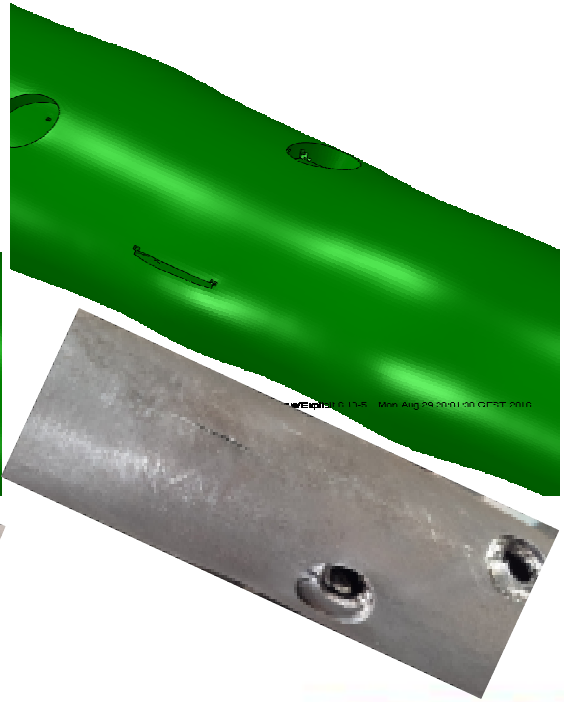
Development of the predictive model

- ✓ Local and overall deformation after full scale test - implemented
- ✓ Addition of damage & fracture toughness - on going









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QUESTIONS?
THANK YOU!

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