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Recent developments in computer modelling, materials characterisation and experimental validation with respect to crash dynamics

E. Deletombe* , D. Delsart, J. Fabis, B. Langrand, R. Ortiz

4th Triennial Cabin and Fire Safety Research Conference - Lisbon2004

INTRODUCTION

Civil concern : Mobility is a key factor for worldwide economic sustainable growth

Defence concern : Preserve/reduce the military structures vulnerability against new operation/battle fields situations

1 – Development of new concepts for civil transport, e.g. : very large transport capacity aircraft, flying wing, buried engines …

2 – Increase transport network density, propose modular/combined transport strategies, e.g. : generalisation of helicopter use, tilt rotors, … etc,

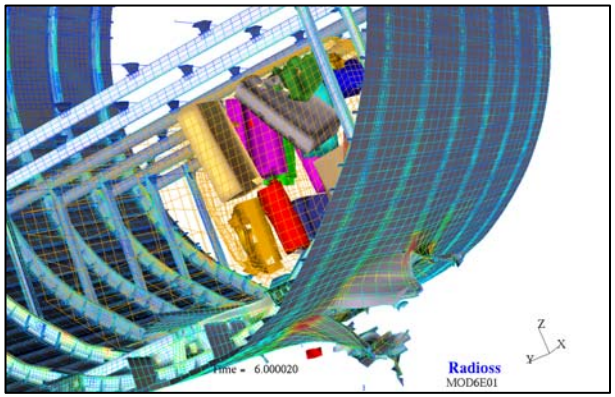
3 – Progressive but massive introduction of composites or high performance metallic materials, etc,

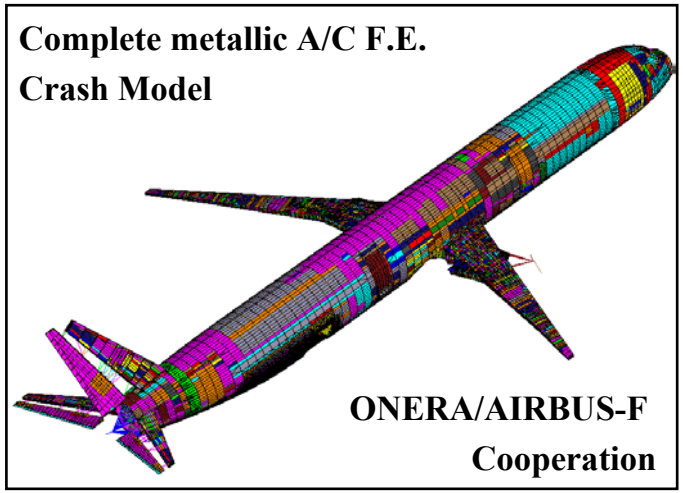
4 – Other economic parameters : reduction of the operational costs (maintenance, repair, etc) and improvement of the manufacturing process.

… at equal safety level.

Induced Constraints for Research in the Structures and Materials Field

1 – Safety and accident consequence minimization have always been a central and major issue for air transport industry (redundancy, creep and fatigue, stability, extreme loads : crash, collisions, ditching, impacts, fire, icing, etc),





2 – Now : societal and environmental constraints added (pollution and noise, energy, economic performance, etc) : in structural terms, it leads to the proposal of new shapes/concepts, and to adaptive, very-light, flexible, reusable, or smart structures.

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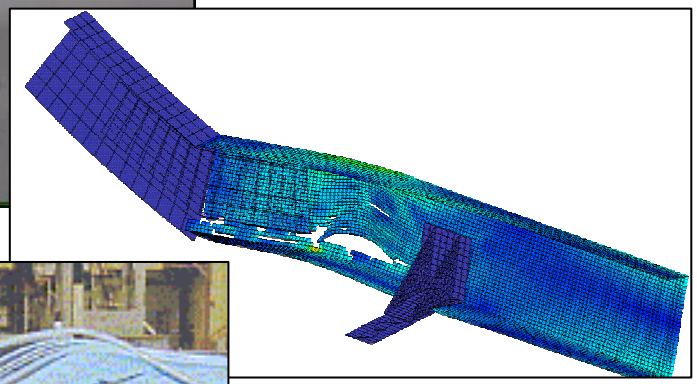
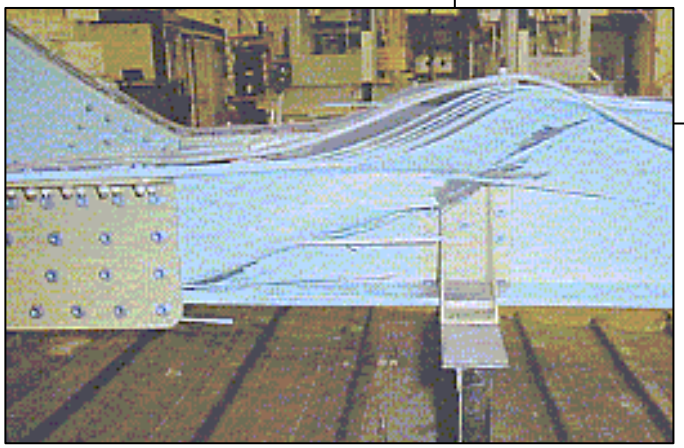
Cooperative Research : Common DRSC Research Lab. ONERA/LAMIH (CNRS Valenciennes) - ONERA/DLR Joint Team and Common R&T Programmes

Contribute to the production/development of innovative knowledge and technologies for Safe Structure Design, with a more particular interest in :

- Physics and Continuum Mechanics,
- Numerical Modelling and Structural Analysis,
- Aeronautics and Process Engineering





EU CRASURV

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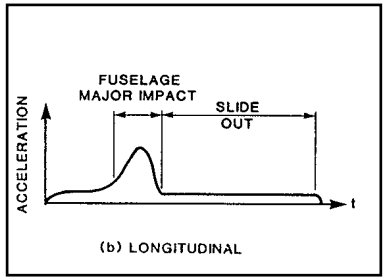
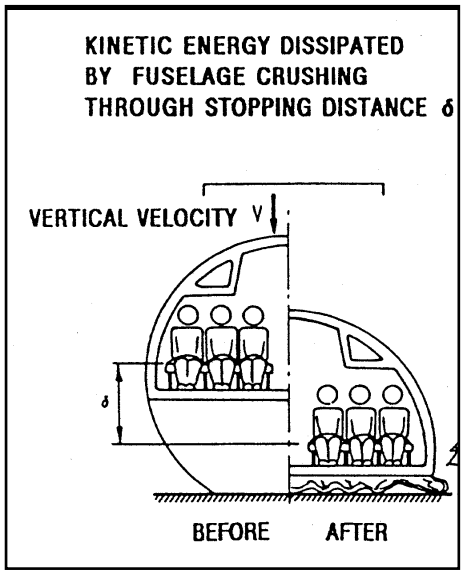
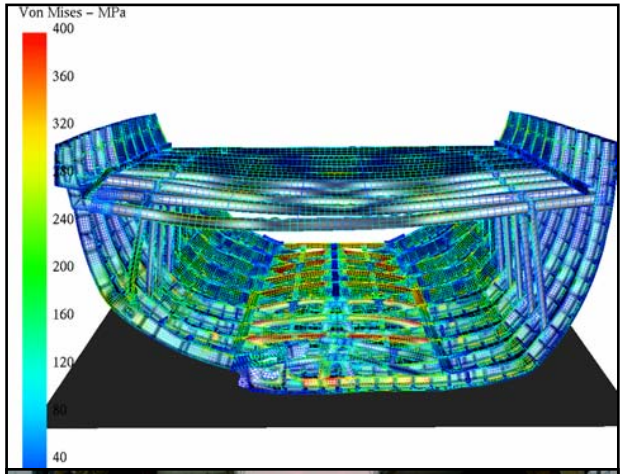
Objective : INCREASE PASSIVE SAFETY

Meaning : IMPROVEMENT OF STRUCTURAL BEHAVIOUR AGAINST EXTREME LOADS

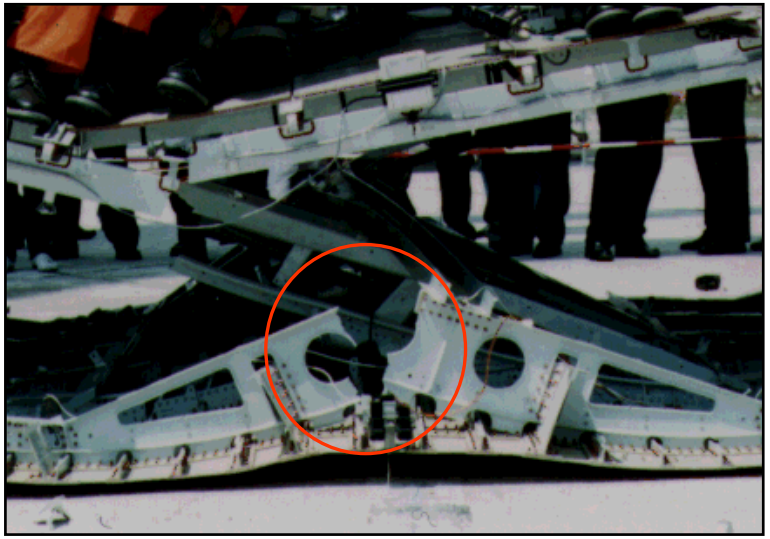
Method : BETTER UNDERSTANDING AND PREDICTION OF THE DYNAMIC BEHAVIOUR AND RUPTURE OF MATERIALS AND ASSEMBLIES







CEAT 1995 CRASH TEST ON AN A/C METALLIC FUSELAGE SECTION



EU TIM-CRASH

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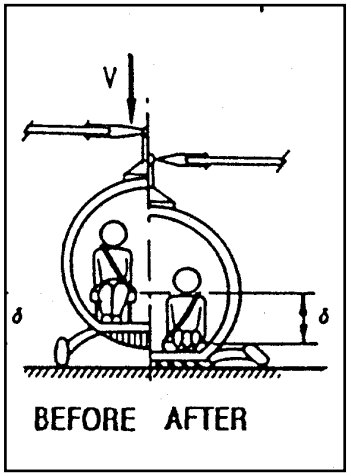
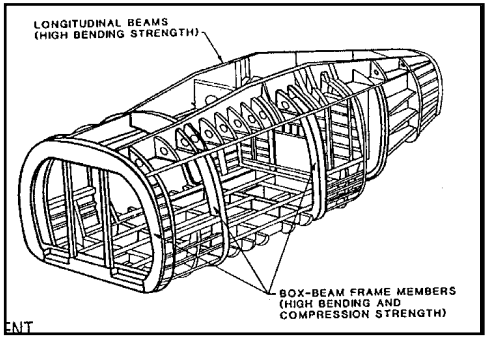
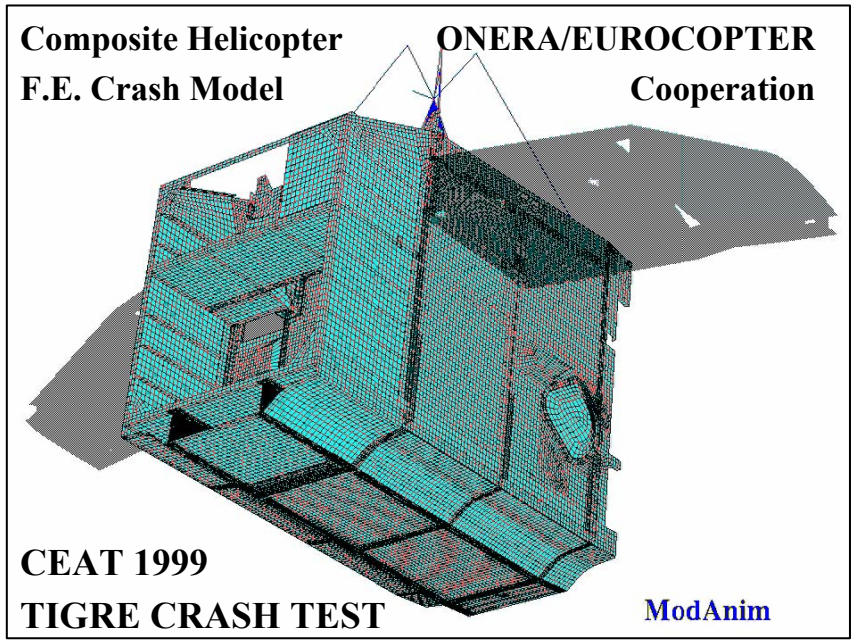
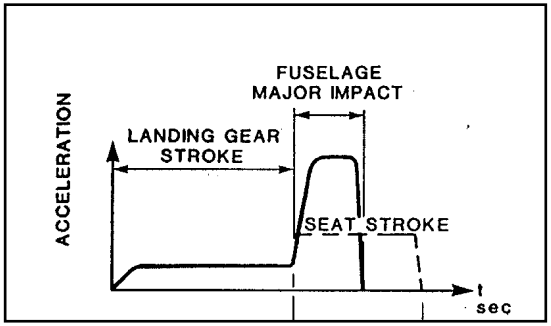
Safety Criteria : STRUCTURAL INTEGRITY / HUMAN TOLERANCE

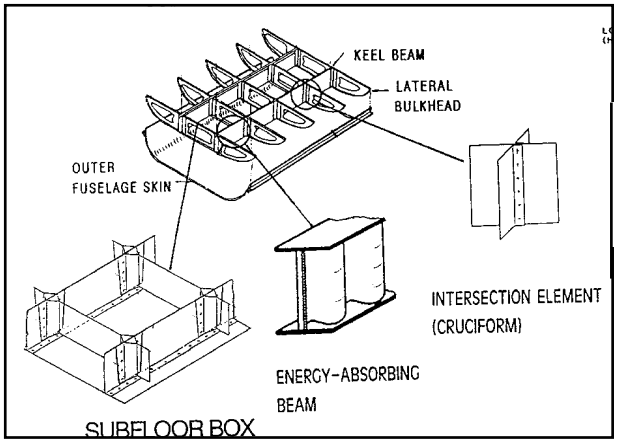




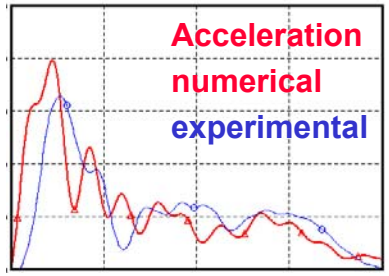
Composite Frame Integrity







Composite underfloor energy absorbing efficiency



Composite Helicopter
Fuel tanks
Energy absorbers
Riveted Joints

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DYNAMIC CHARACTERISATION AND MODELLING OF NON-LINEAR AND FAILURE BEHAVIOUR OF MATERIALS

…

F.E. CRASH SIMULATIONS

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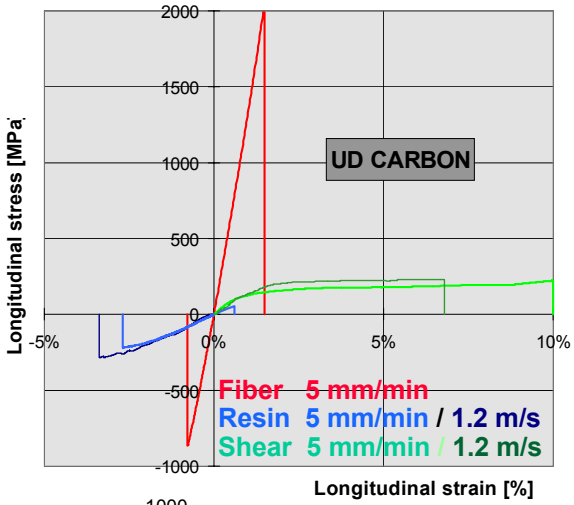
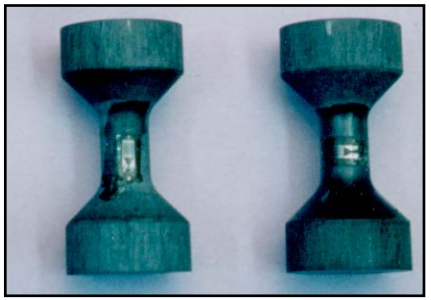
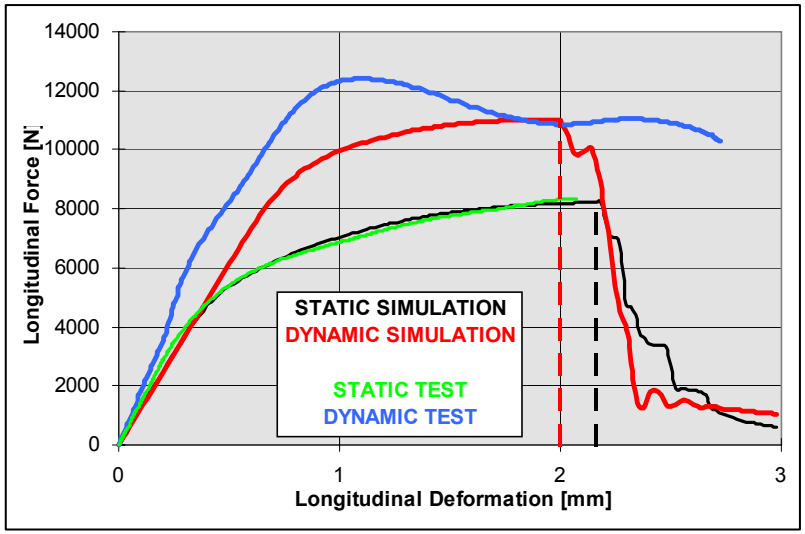
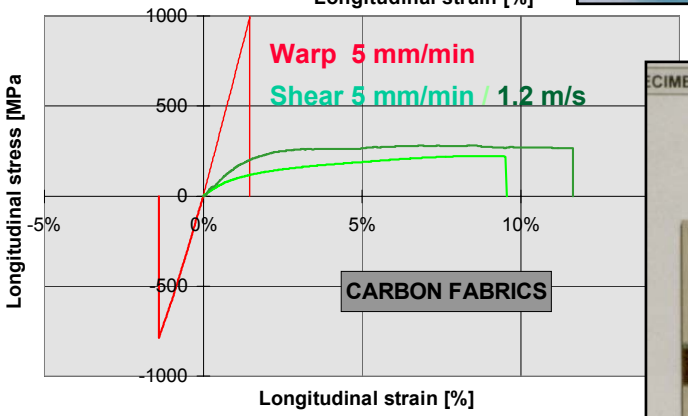
DYNAMIC CHARACTERISATION AND MODELLING OF NON-LINEAR AND FAILURE BEHAVIOUR OF MATERIALS

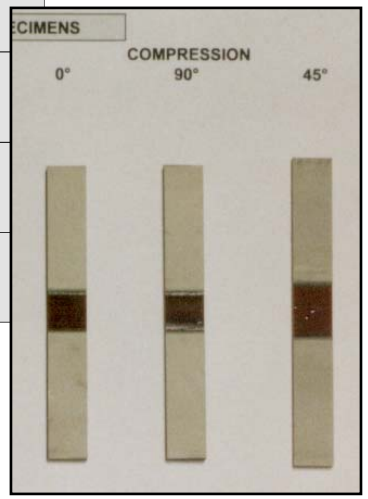
ONERA 3D STRAIN RATE DEPENDENT COMPOSITE PLY MODEL

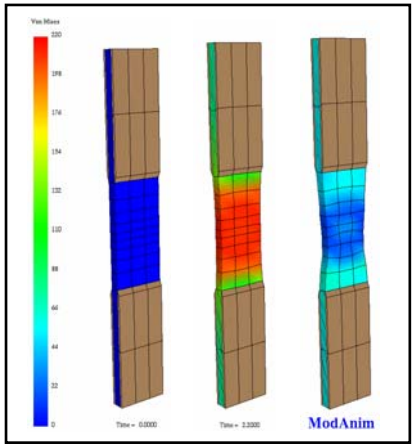












MODEL VALIDATION

+/-45° Tension

Carbon fabrics

<u>Static</u> : 5 mm/min

<u>Dynamic</u> : 4 m/s

COMPOSITE MATERIALS DYNAMIC CHARACTERISATION FOR MODEL IDENTIFICATION

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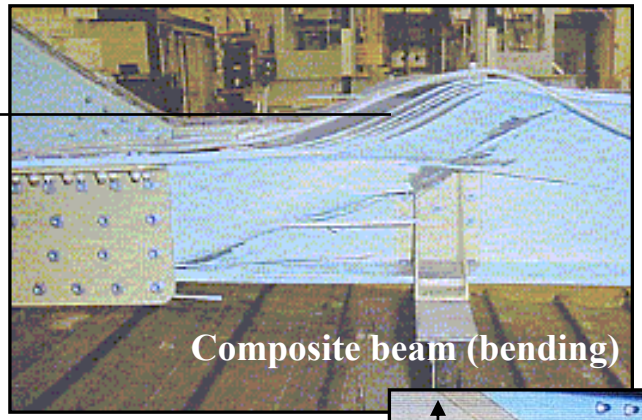
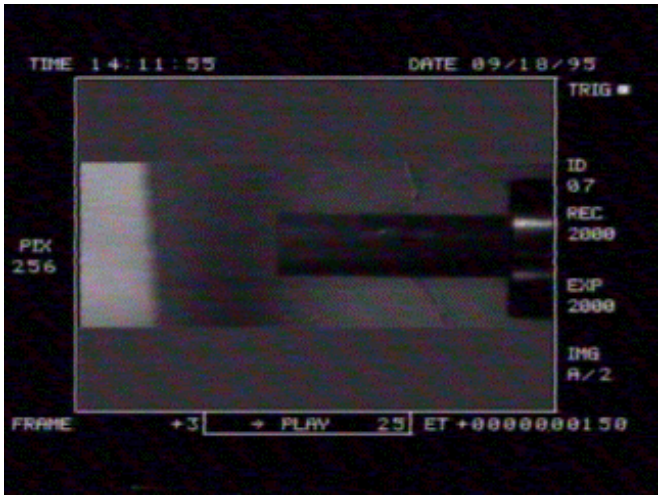
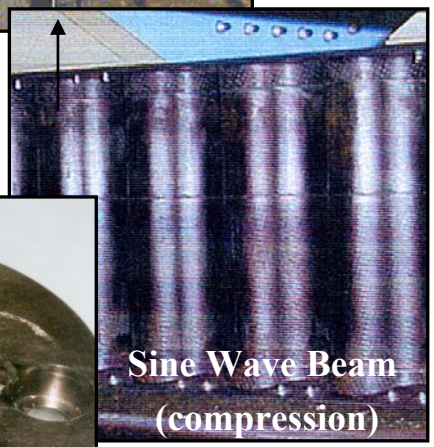
COMPLEX FAILURE MODES







Delamination

Fragmentation

Crush (energy absorption)

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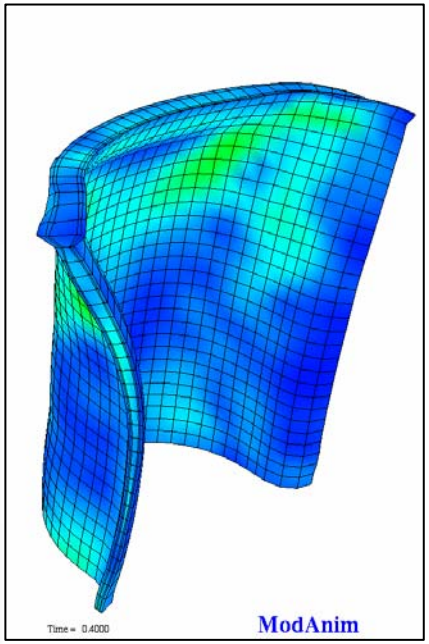
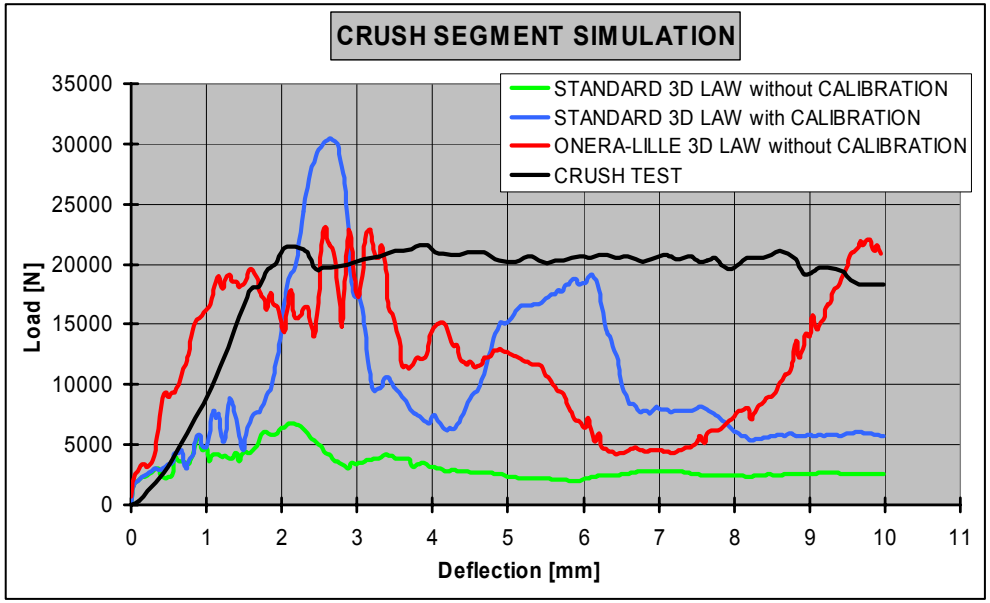
DYNAMIC CHARACTERISATION AND MODELLING OF NON-LINEAR AND FAILURE BEHAVIOUR OF MATERIALS

COMPOSITE SINEWAVE BEAM FOR CRASH ENERGY ABSORPTION (LAMINATE + TRIGGER)



SIMPLIFIED COMPOSITE HALF "TUBE" FOR MODEL VALIDATION

"RESEARCH" MODEL … CPU TIME !!!!!



NO MATERIAL DATA CALIBRATION …

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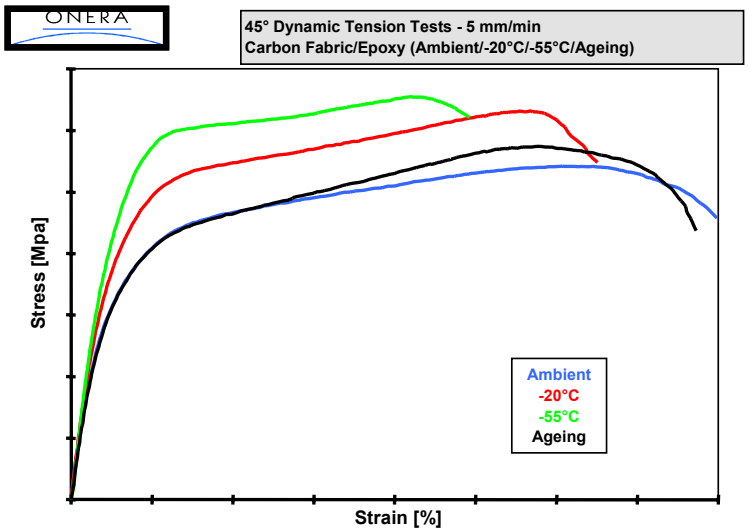

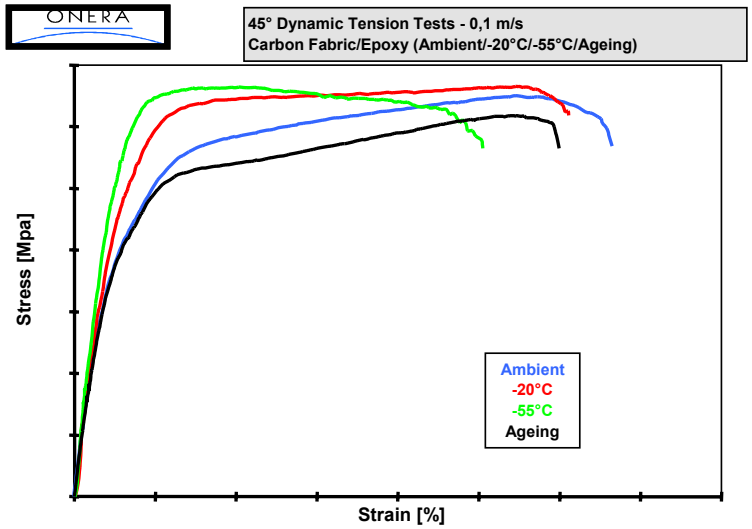

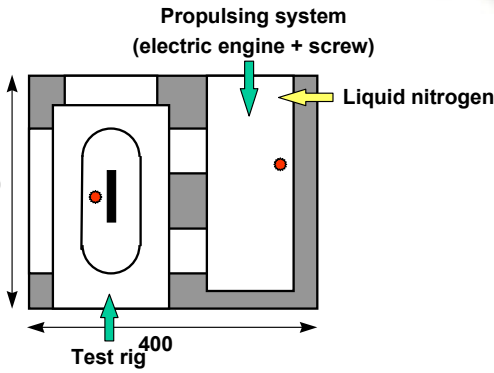

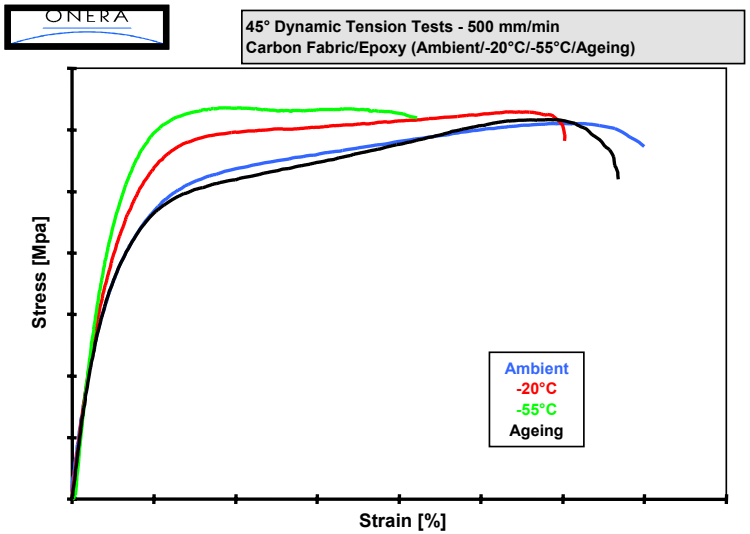

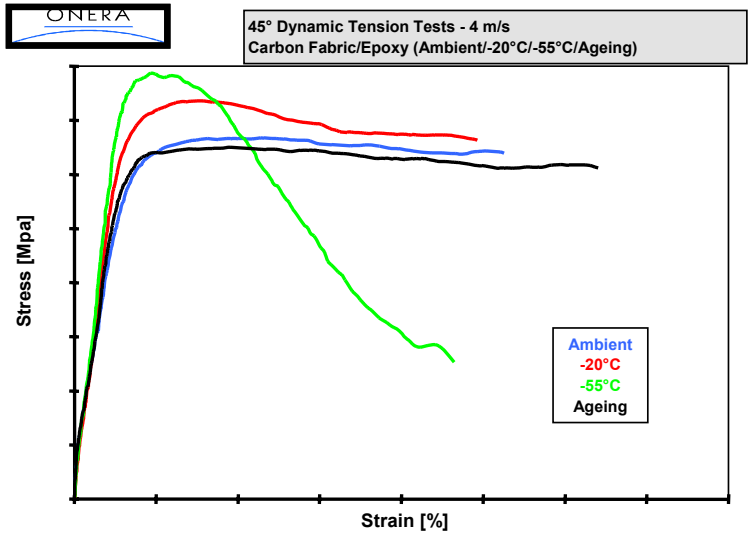

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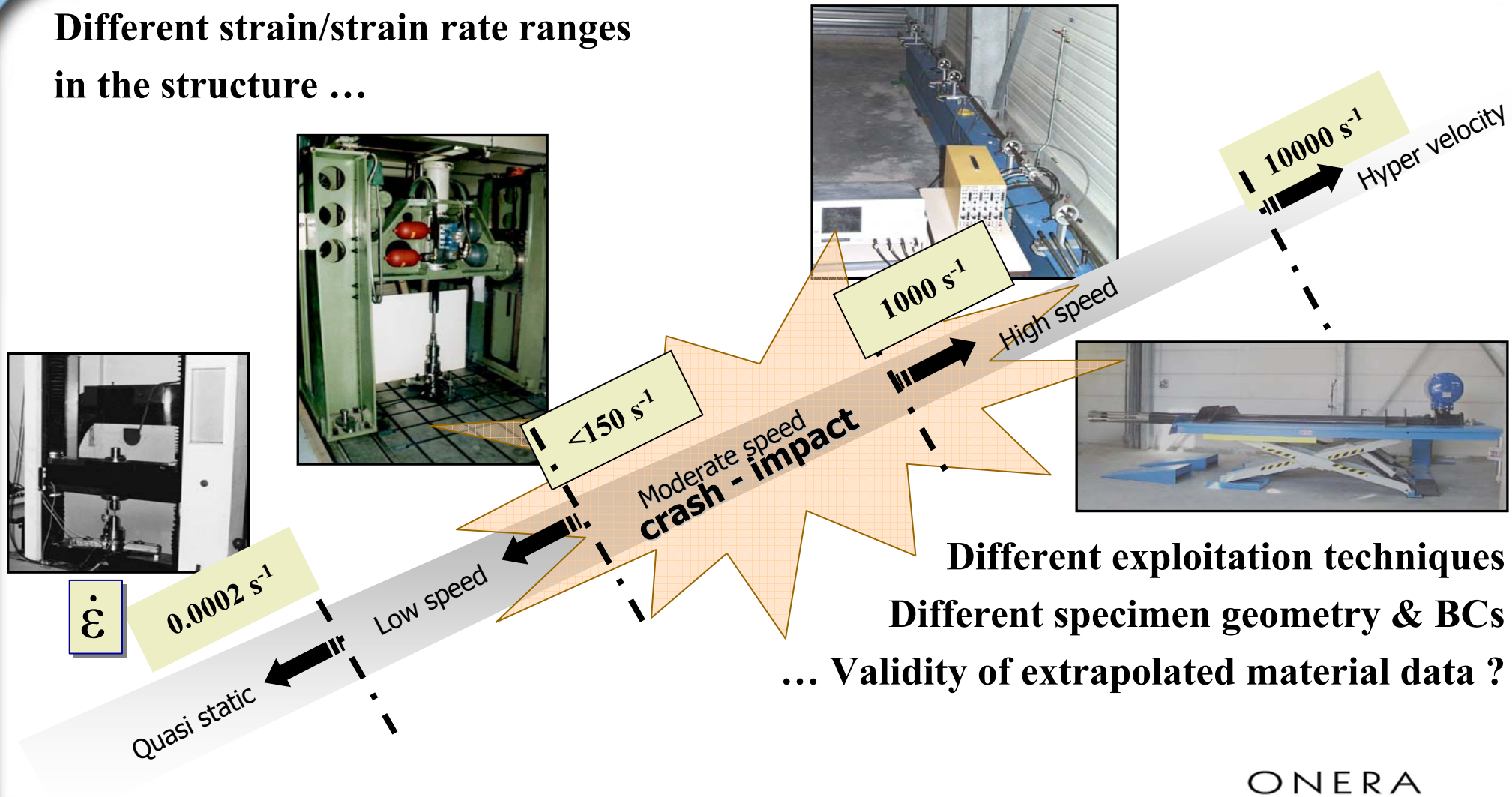
DYNAMIC CHARACTERISATION AND MODELLING OF NON-LINEAR AND FAILURE BEHAVIOUR OF MATERIALS

Different strain/strain rate ranges in the structure …



Different exploitation techniques

Different specimen geometry & BCs

… Validity of extrapolated material data ?

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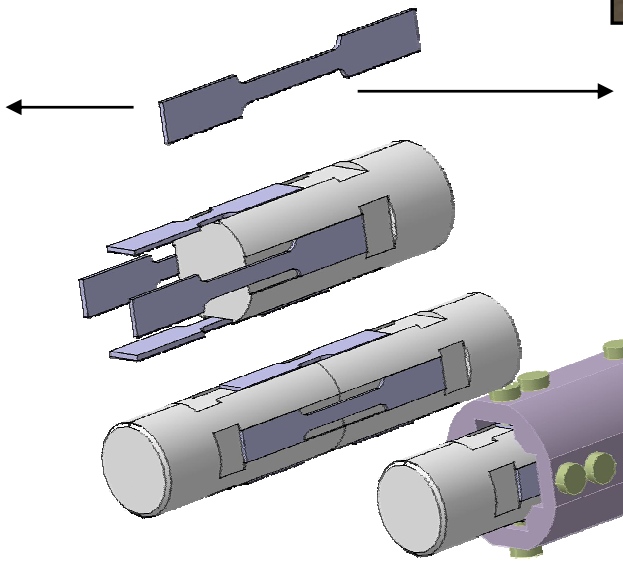
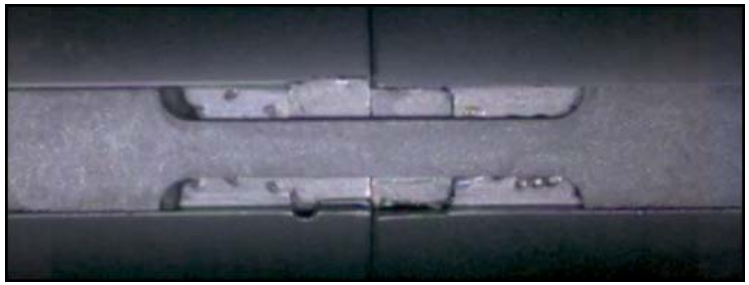
OVERLAPPING of ONERA Hydraulic Jack and LAMIH Hopkinson Bars

Same specimen geometry

Strain Gauges
+ Optical extensometer





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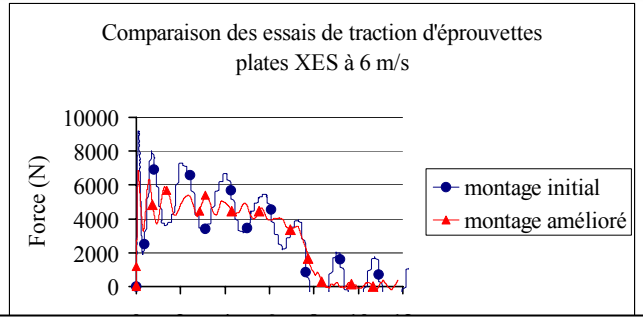
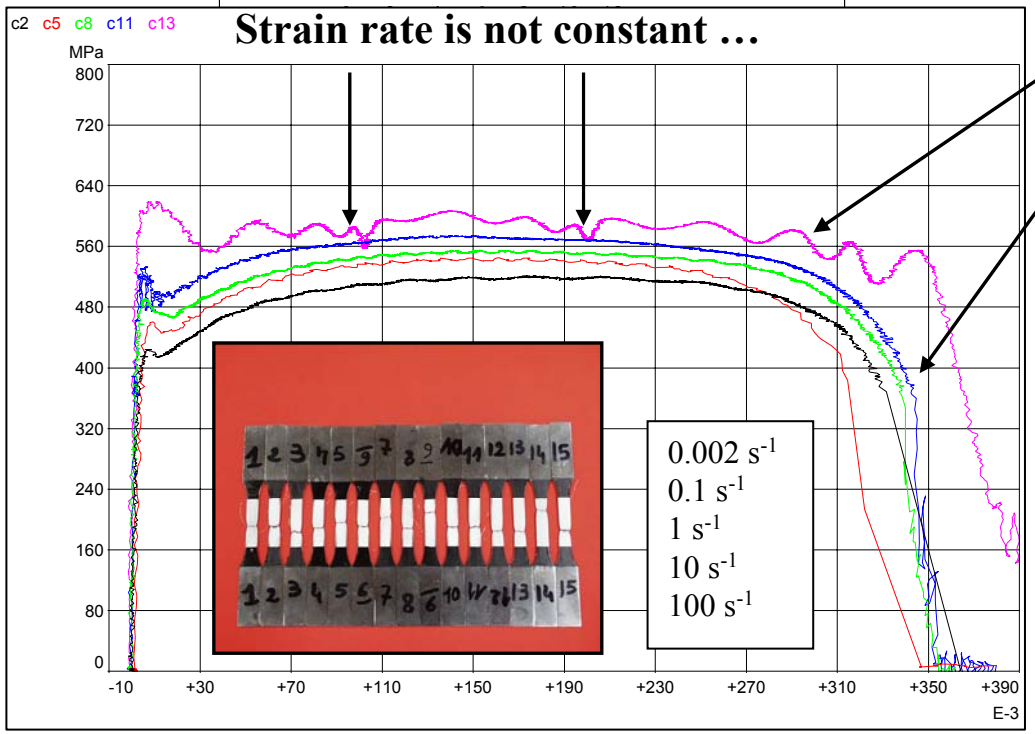
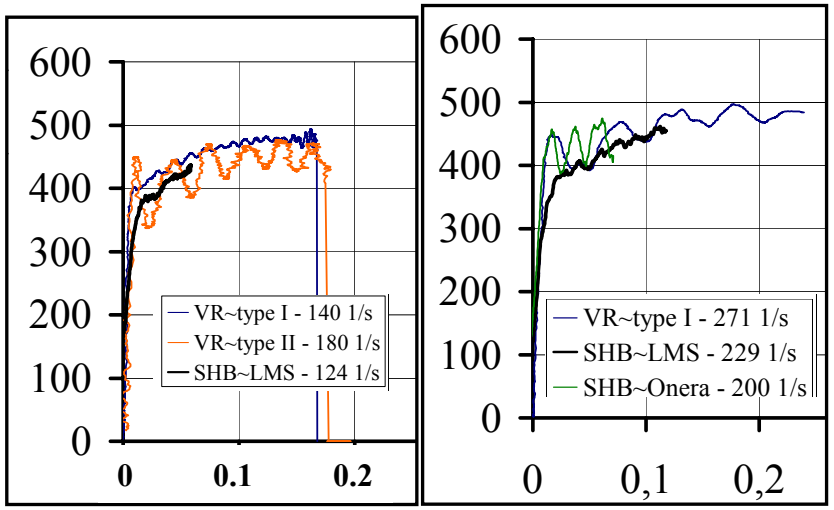




XES Steel – Dynamic Jack - Elasto viscoplastic behaviour

Damage and rupture

Conventional stress/strain curve



Aluminium – SHB vs DHJ

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NON LINEAR BEHAVIOUR AND FAILURE OF ASSEMBLIES

…

PREDICTION OF STRUCTURAL RUIN MODES

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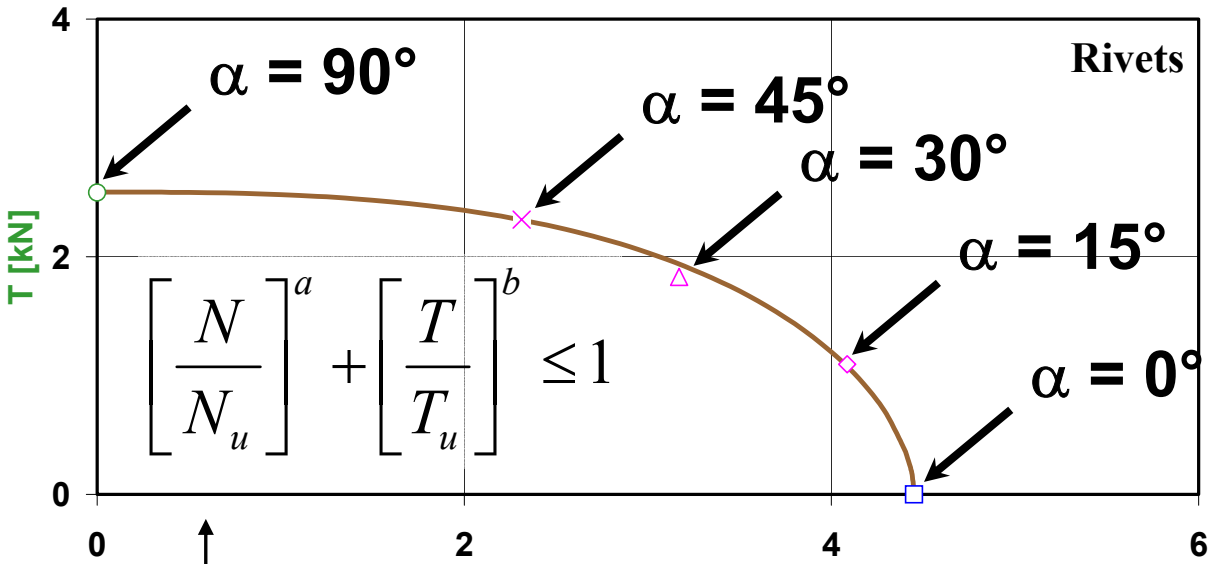
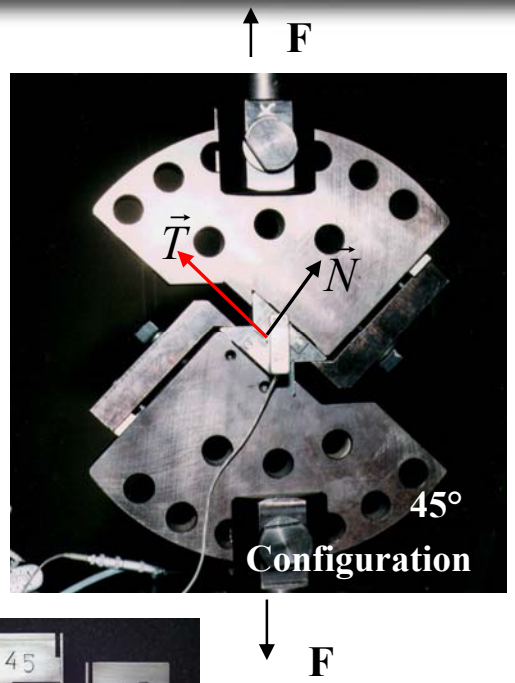
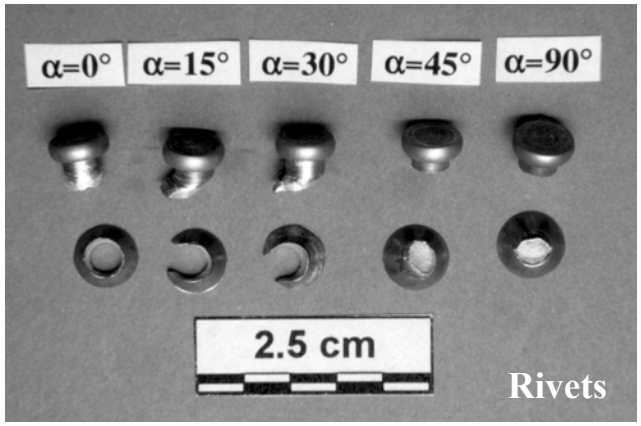
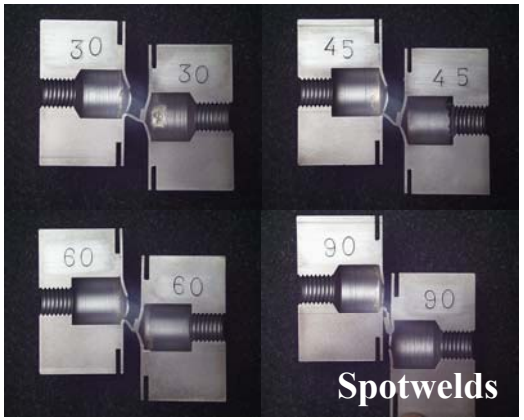
NON LINEAR BEHAVIOUR AND FAILURE OF ASSEMBLIES









ARCAN TEST PROCEDURE : STATIC MULTIAXIAL TESTING OF FIXATIONS

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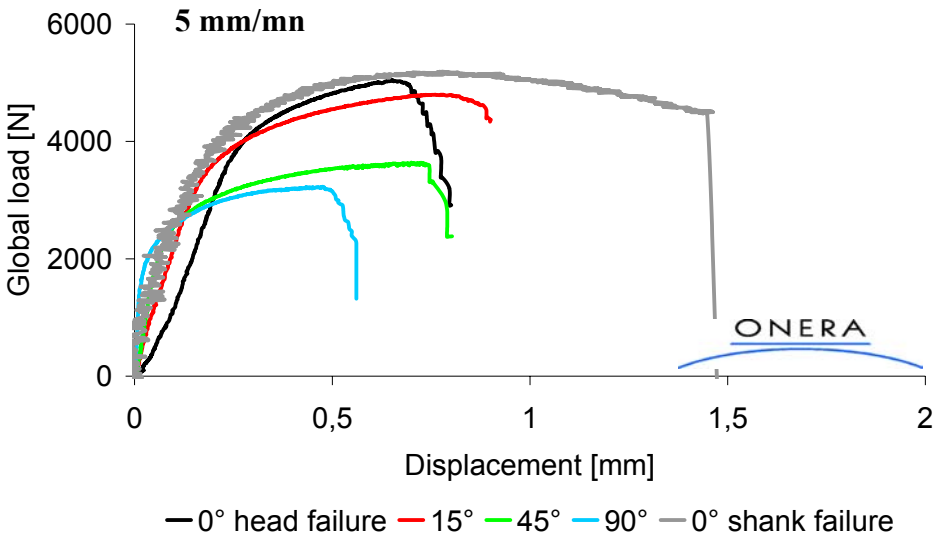
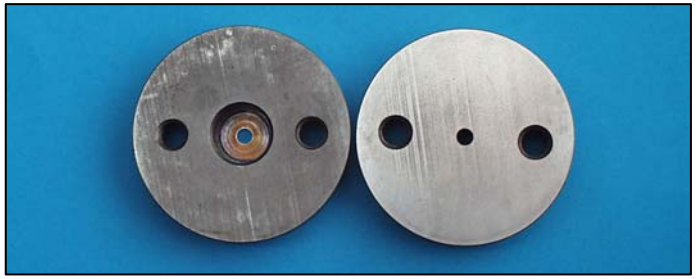
NON LINEAR BEHAVIOUR AND FAILURE OF ASSEMBLIES

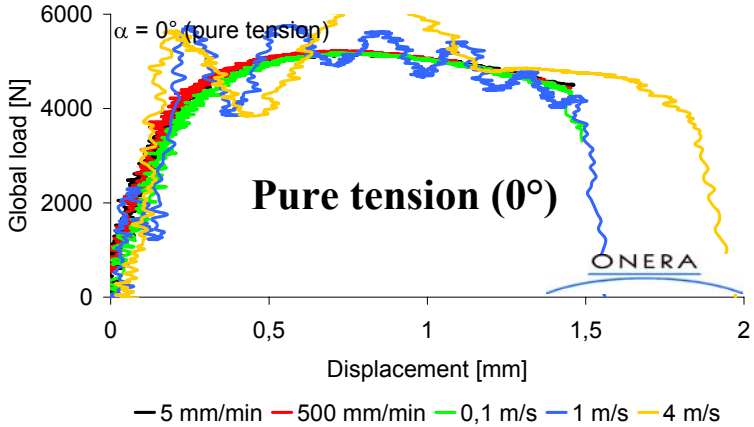


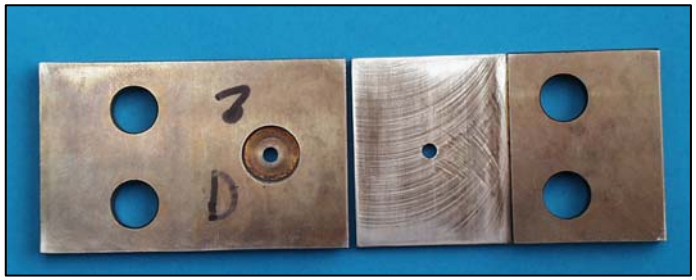
V_{imp} = {5mm/min, 500mm/min, 0.1m/s, 1m/s, 4m/s}

$$\dot{\varepsilon}_{max} \approx 1200\ s^{-1}$$



Dynamic pure tension test – 0°





Dynamic pure shear test – 90°

DYNAMIC PROCEDURE : CHECK SENSITIVITY IN 0° AND 90° CONDITIONS

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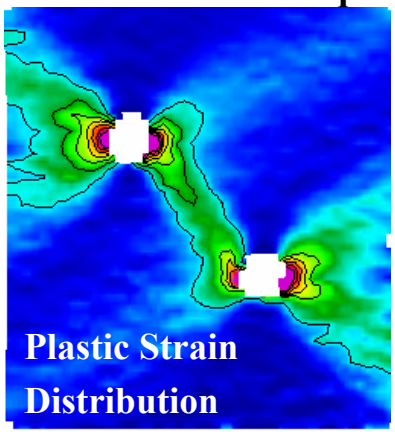
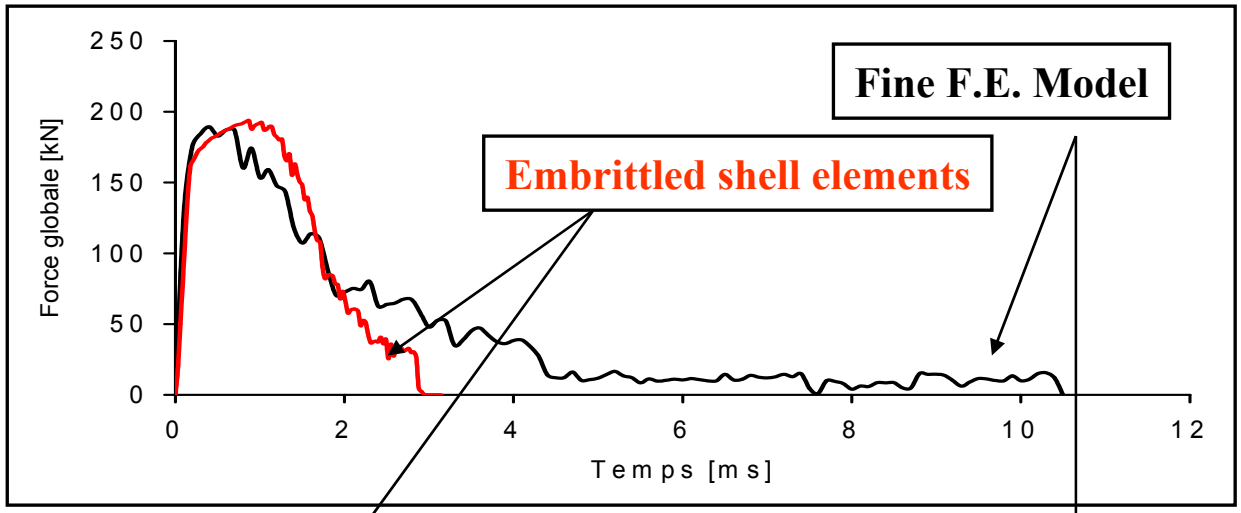
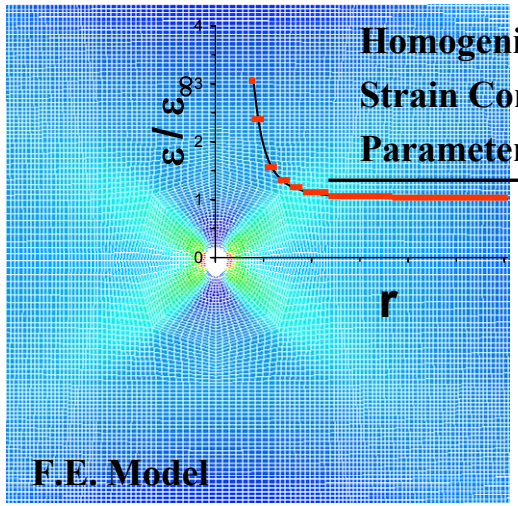
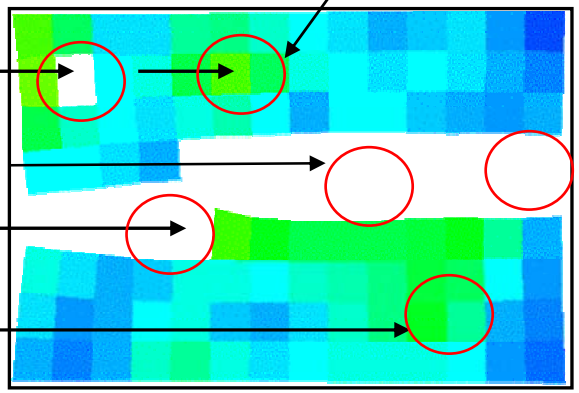
NON LINEAR BEHAVIOUR AND FAILURE OF ASSEMBLIES

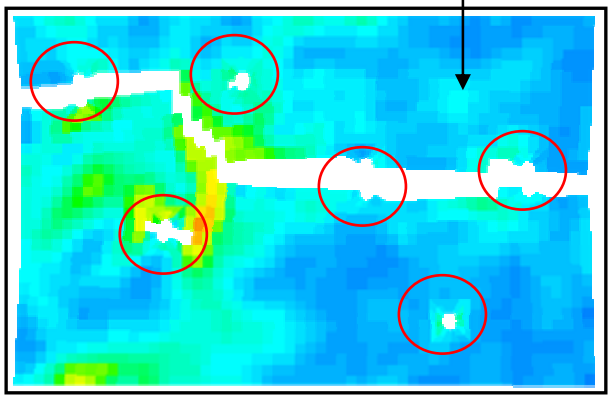
Experimental Image Correlation Technique











RUPTURE OF PERFORATED PLATES WITHOUT MATERIAL MODEL CALIBRATION
(JOHNSON-COOK + GURSON MODEL)

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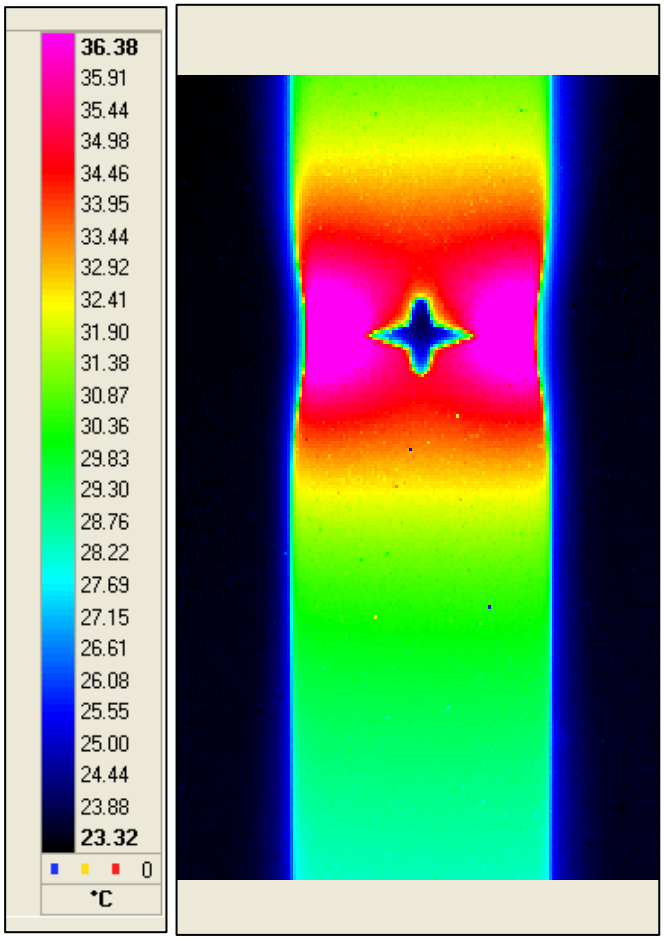
NON LINEAR BEHAVIOUR AND FAILURE OF ASSEMBLIES

Perforated plate (steel) - 500 mm/mn



TEMPERATURE FIELD
INFRARED HIGH SPEED CAMERA

CURRENT WORKS AND PERSPECTIVES :

- **COMPOSITE PERFORATED PLATES,**
- **DYNAMIC CHARACTERISATION OF COMPOSITE MATERIALS,**
- **FRICTION STIR WELDING ASSEMBLIES,**
- **SPOTWELDS,**
- **ETC**

ONERA

FLUID/STRUCTURE INTERACTIONS

…

REALISTIC F.E. STRUCTURAL MODEL SOLICITATION …

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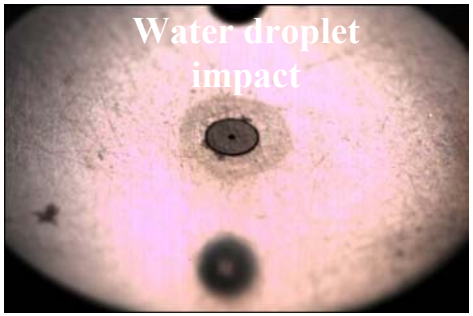
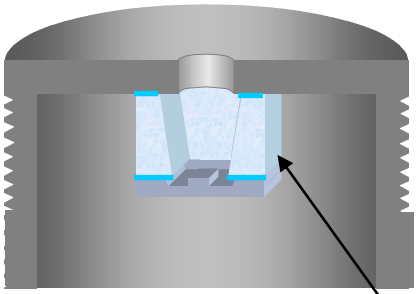
FLUID/STRUCTURE INTERACTIONS

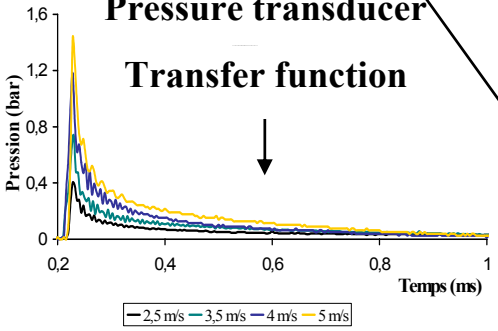
F.E. ANALYSIS OF F/S PROBLEMS



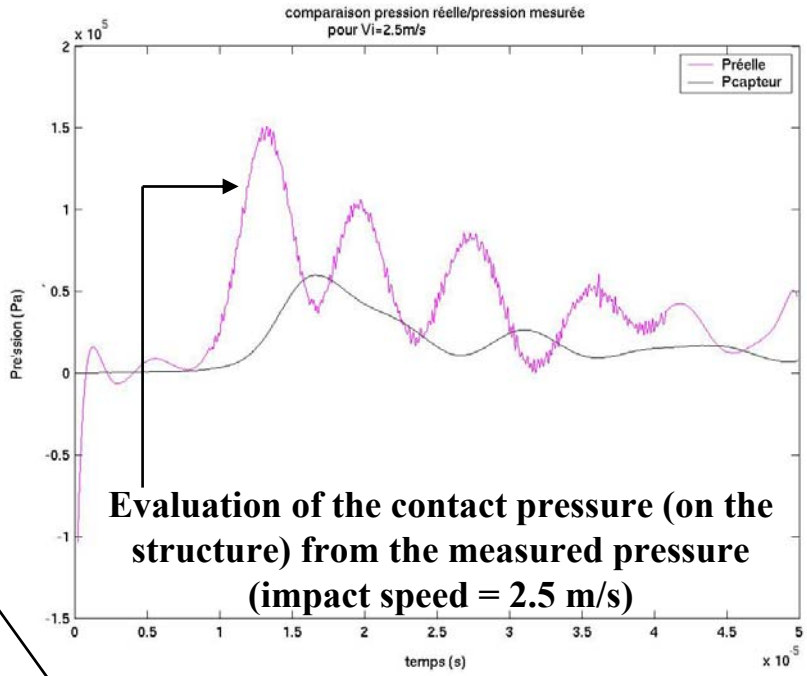


Pressure transducer

Transfer function



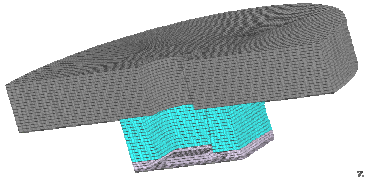
EXPERIMENTAL DATABASE
(FLUID DENSITY, IMPACT SPEED, …)



Evaluation of the contact pressure (on the structure) from the measured pressure (impact speed = 2.5 m/s)

TRANSDUCER CHAMBER FULL OF WATER

Numerical evaluation of the transfer function (transducer geometry, manufacturer data, F.E. model)



$$P_{struct}(t) = H(x(t), \dot{x}(t), \ddot{x}(t), t)$$

$P_{struct}(t)$: contact pressure

$x(t)$: membrane displacement

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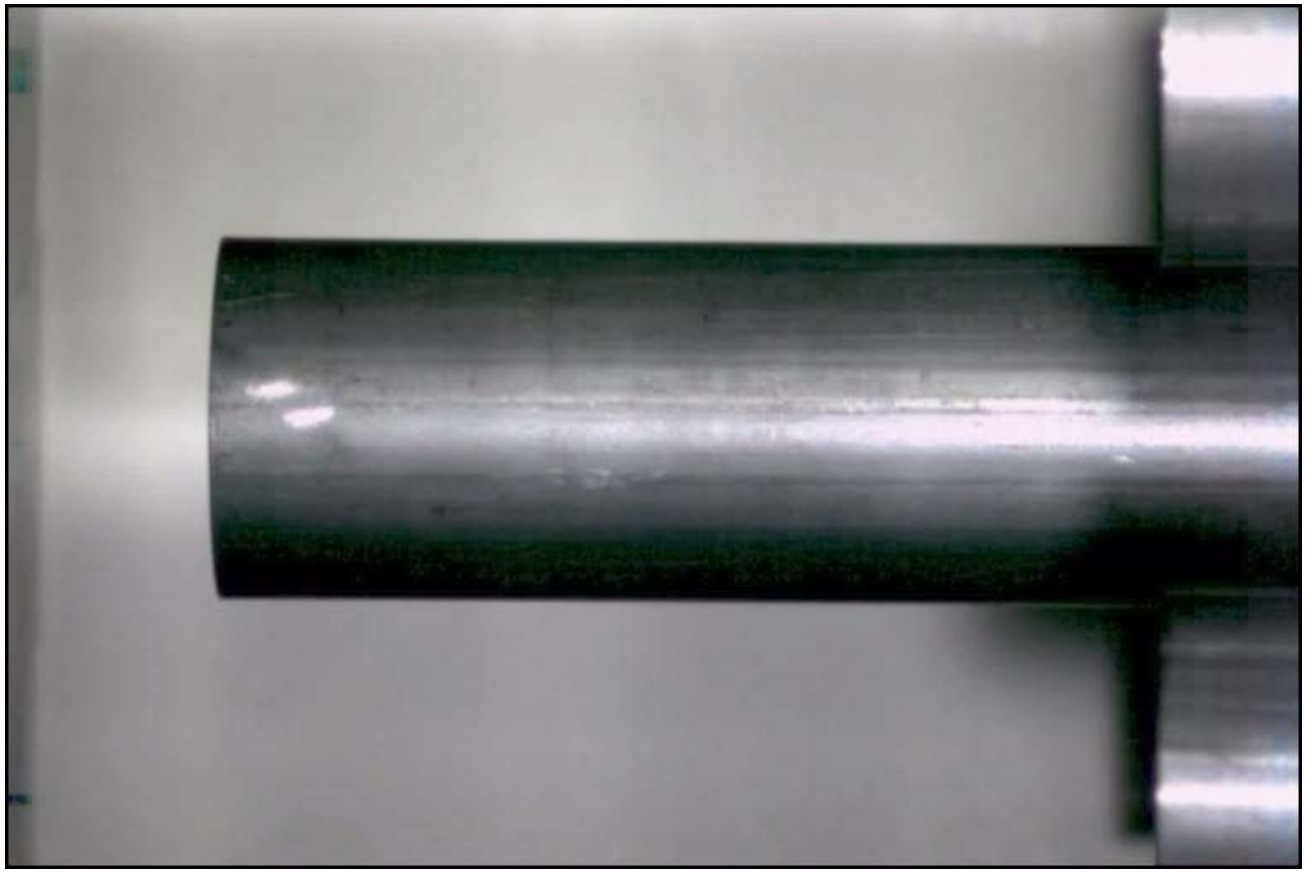
VALIDATION AGAINST STRUCTURAL COMPONENTS



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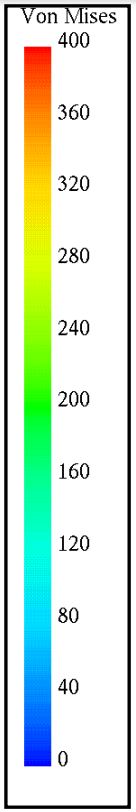
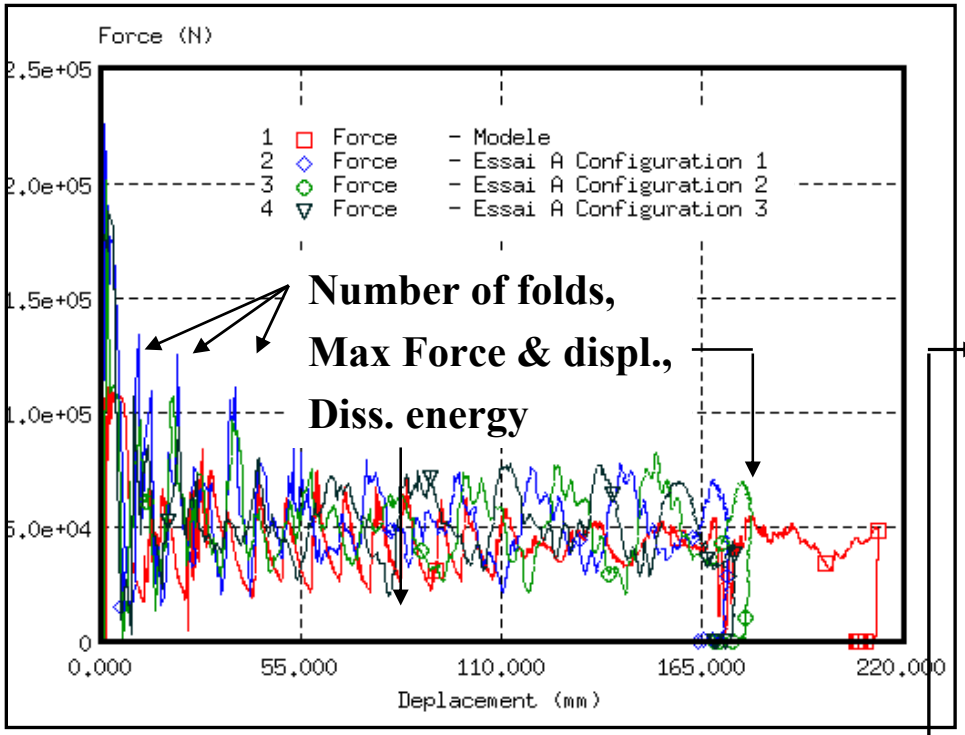
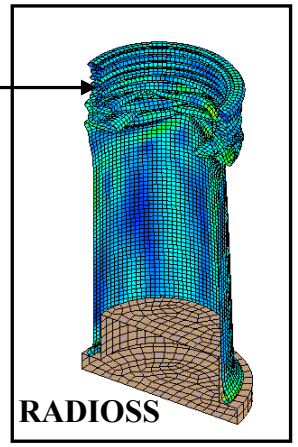
VALIDATION AGAINST STRUCTURAL COMPONENTS







ONERA DROP TOWER :

Controlled/guided trajectory < 20 m/s

Modular impactor size and mass < 200 kJ (1 T)

2 m x 2 m test area (piezo-electric load cells)

Etc …

Contact

Boundary cond.

Mesh size

Mat. Properties

$\dot{\varepsilon}_p$

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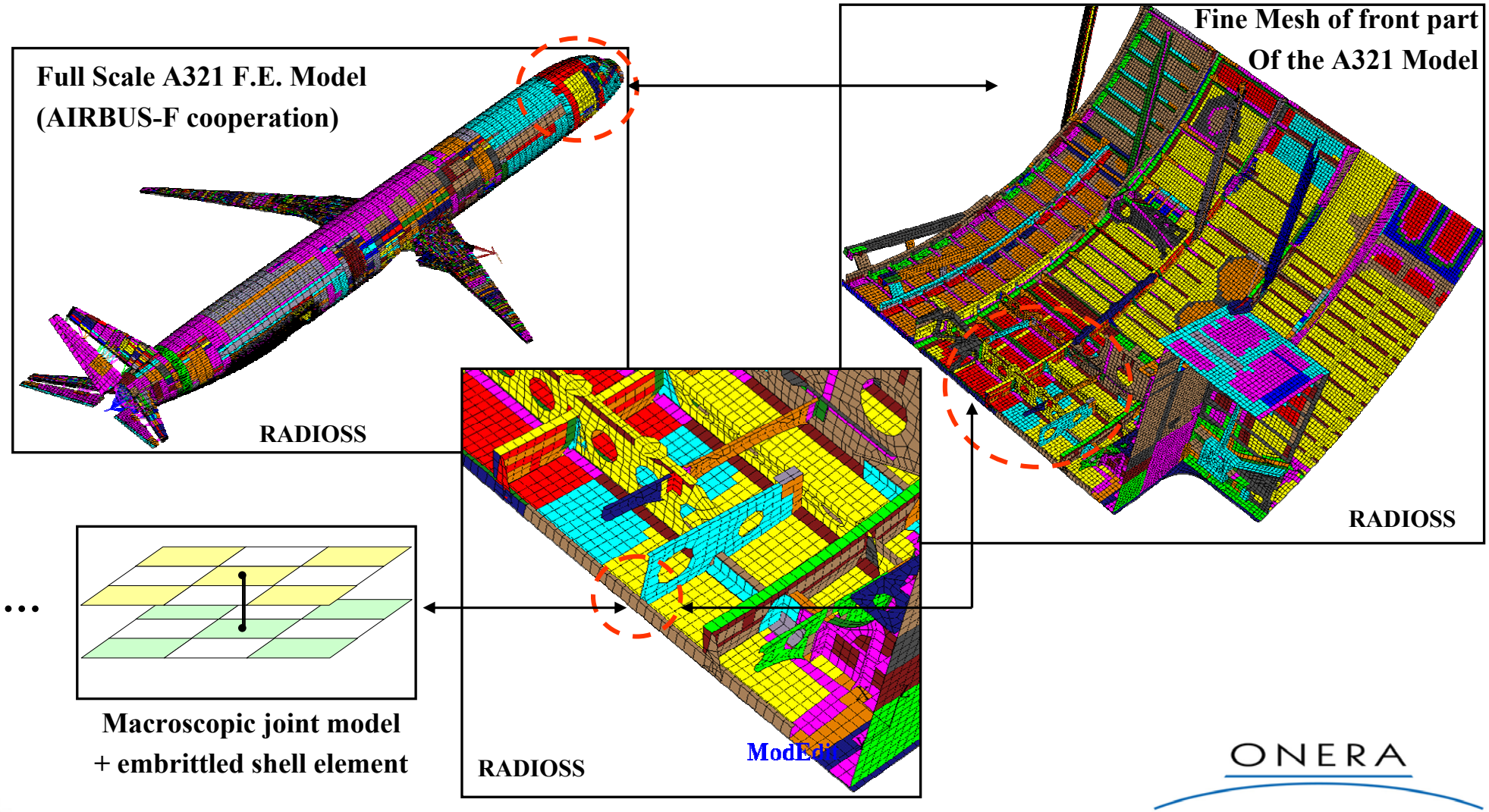
CONCLUSIONS AND PERSPECTIVES

Recent developments in computer modelling, materials characterisation and experimental validation with respect to crash dynamics

CONCLUSION AND PERSPECTIVES

Multi-scale F.E. Models



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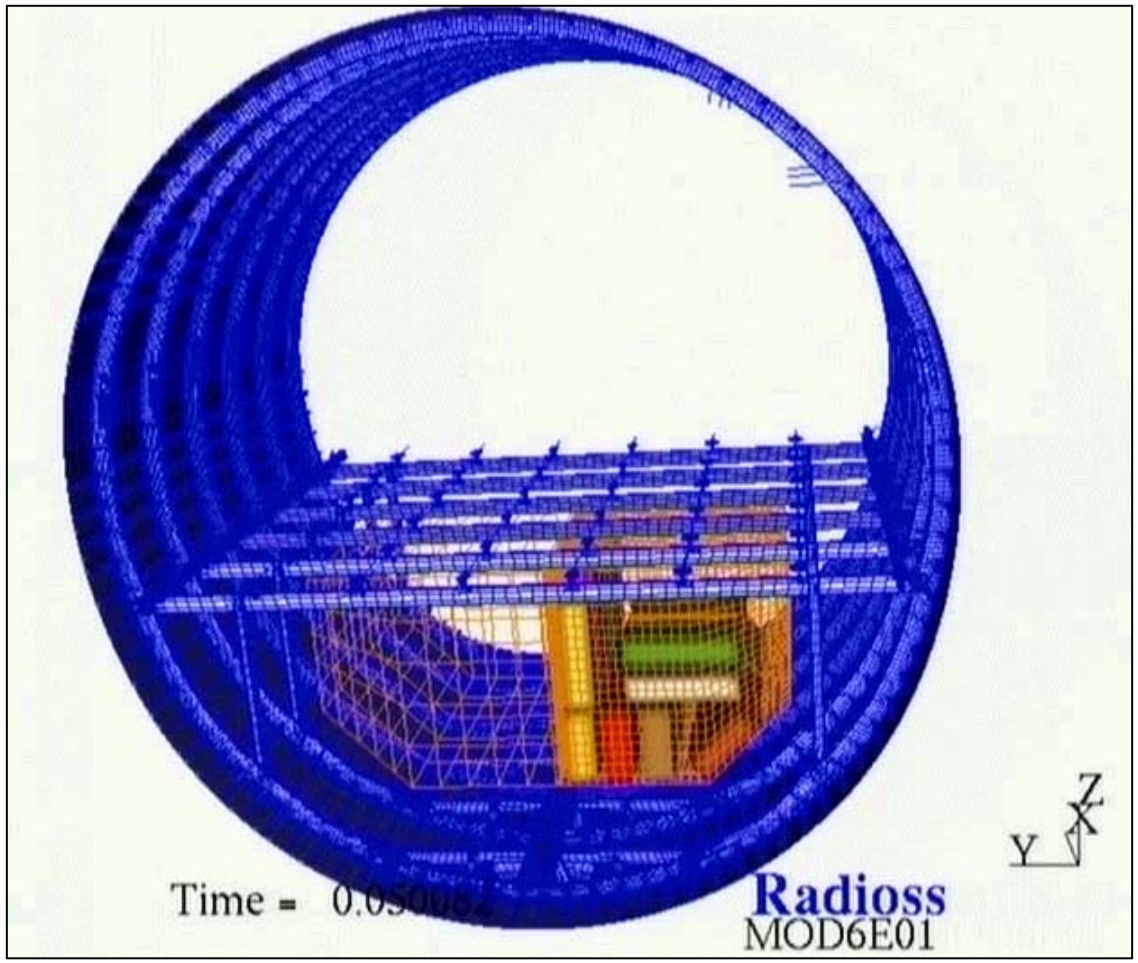
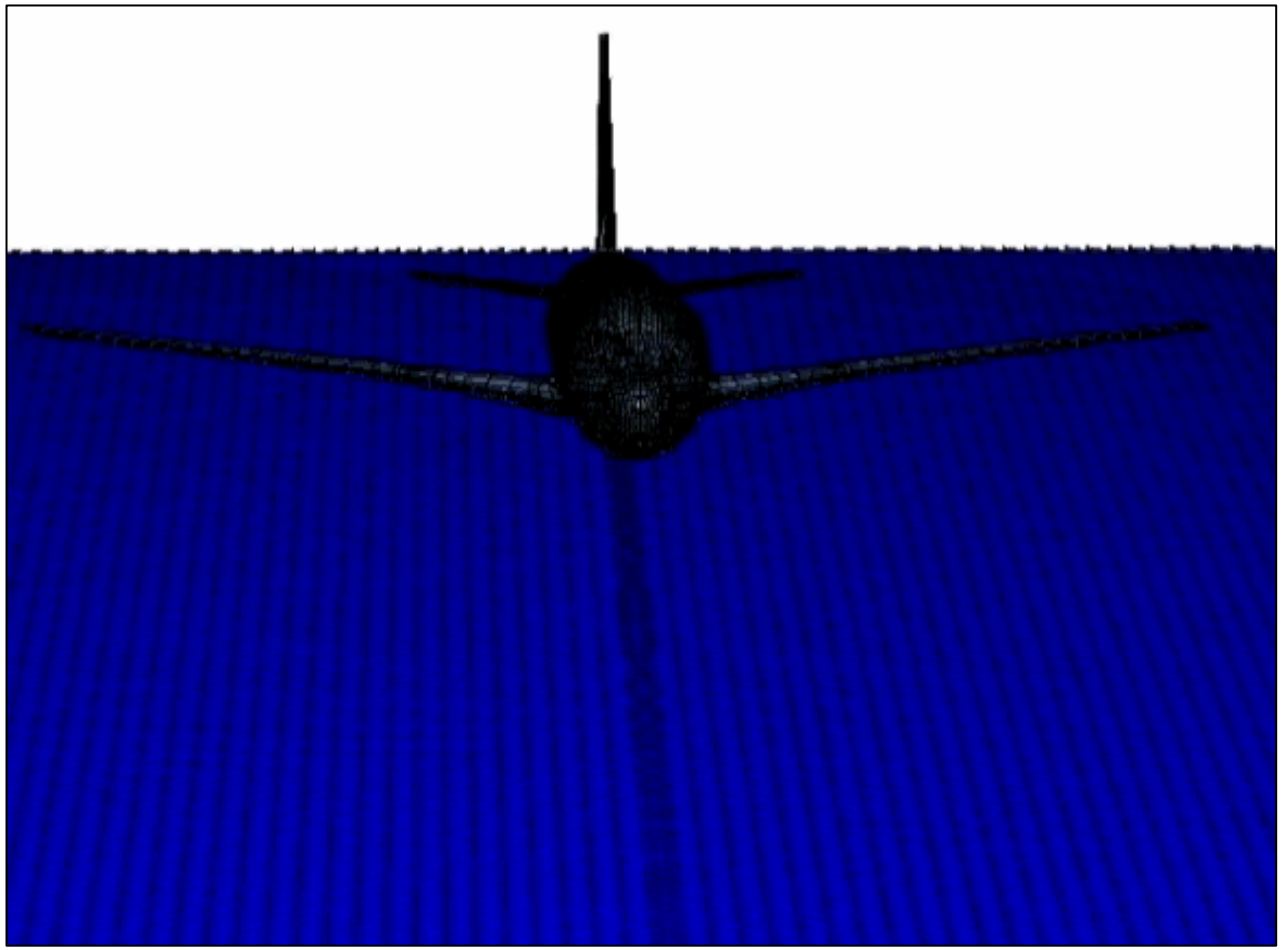
Multi-physics (Fluid + Solid + Fracture Mechanics)



Multi-physics (Fluid + Solid + Fracture Mechanics) & Multi-scale Models