

Politecnico di Milano *...since 1863...*

 POLITECNICO DI MILANO



SIGMA Lab: focus on experimental capabilities

(November 2015)

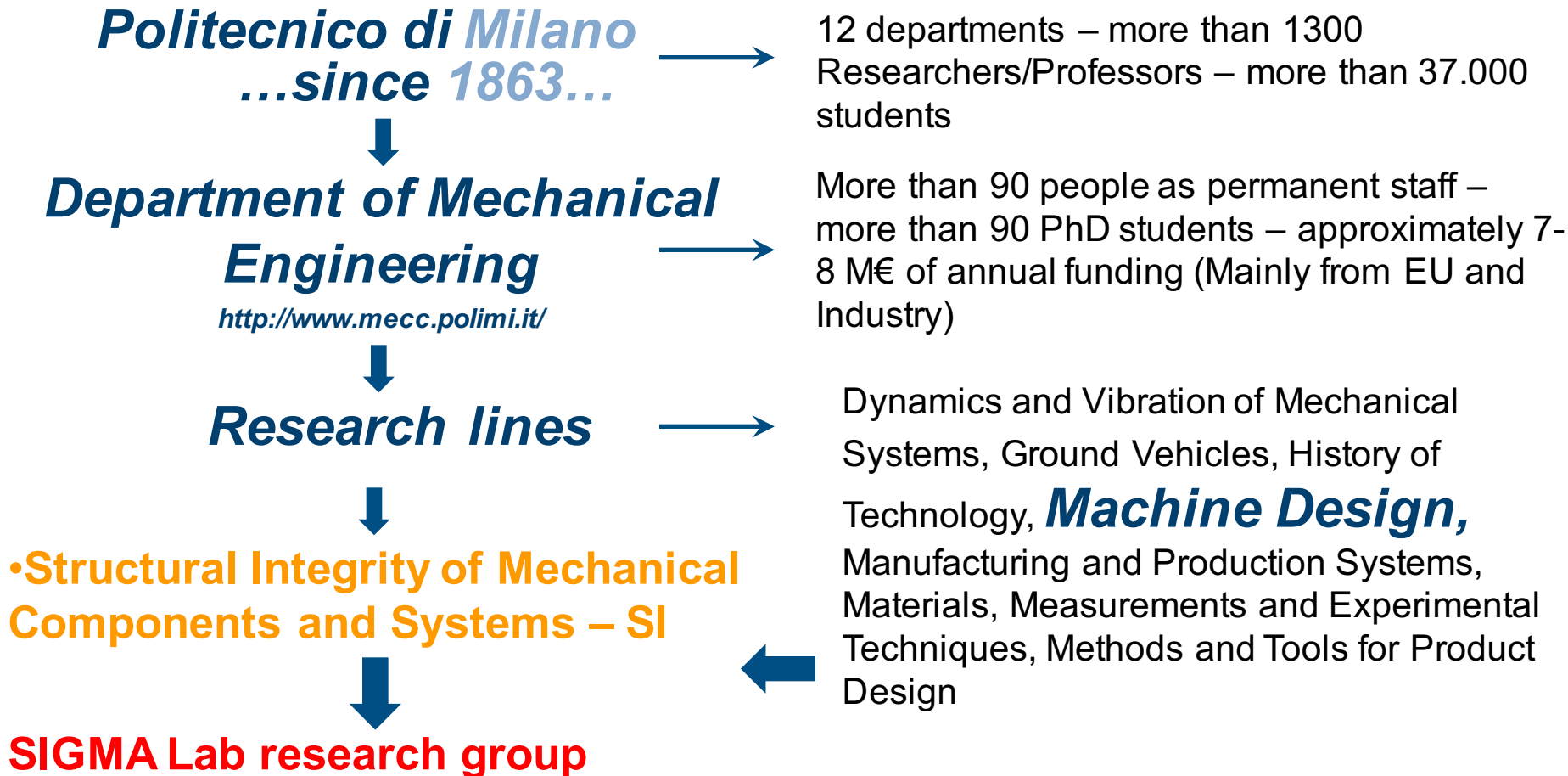
SIGMALab

POLITECNICO DI MILANO, ITALY

DIPARTIMENTO DI MECCANICA



Structure Impact proGnosis Monitoring MAterial LABoratory





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Ph.D. graduate student

Alessio Beligni

Ph.D. graduate student



Our mission:

Main aim of the research team is an advanced engineering approach for the **assessment, new design and optimization of mechanical and aerospace components**. Research activities and topics concern with several aspects related to:

- **assessment and optimization** of components under spectrum loads and extreme loads (ballistic damage, etc.);
- **monitoring, diagnosis and prognosis** of critical structures, under fatigue loads and impact loads;
- **application of novel approaches in structural integrity design** (flaw tolerant approach, vulnerability, etc.).

Experimental investigations and numerical-analytical investigation allow to individuate models able to simulate components under contingent-extreme loads in order to optimize their behavior.



Our vision: a reference team for tailored assessment of critical components under extreme conditions

More than 15 years of challenging research activities with academic and industrial partners and customers (included security and defense).

ACCADEMIC



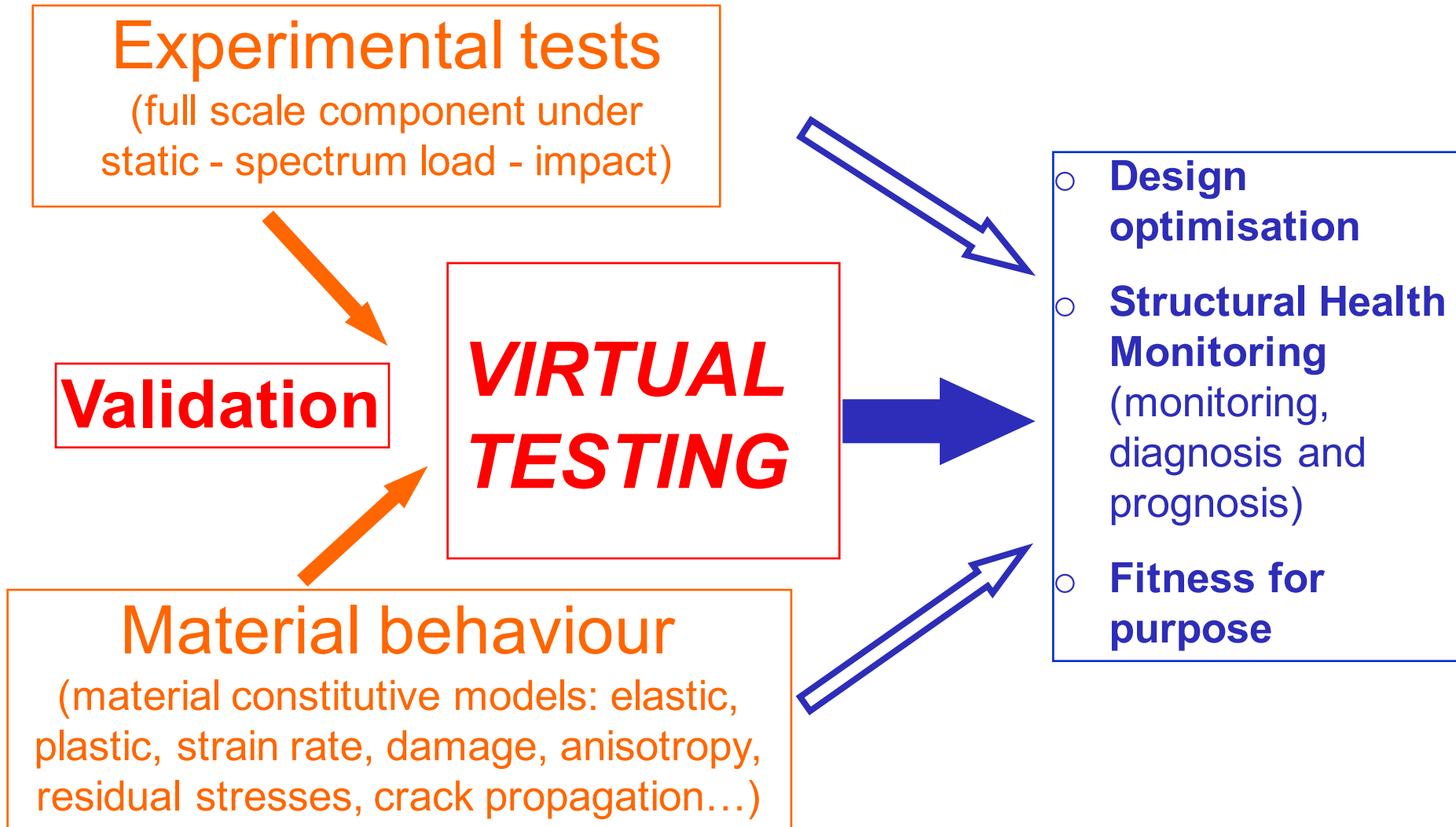
INDUSTRIAL



RESEARCH - ISTITUTIONAL



A multidisciplinary and complete approach:





Mainly focused on aerospace components:

Full scale tests on metallic and composite components under

- ultimate static loads
- fatigue spectrum loads
- impact (low and high velocity)

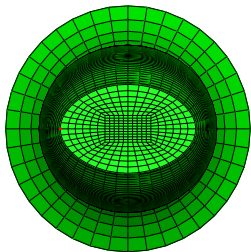
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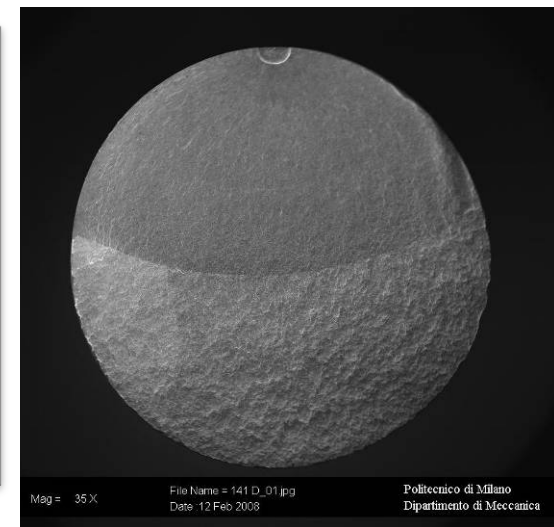
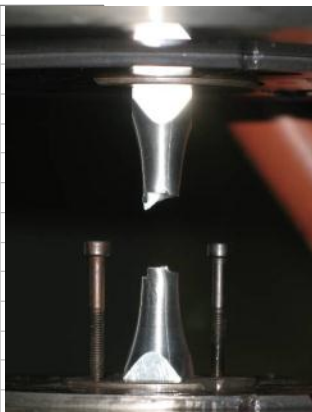
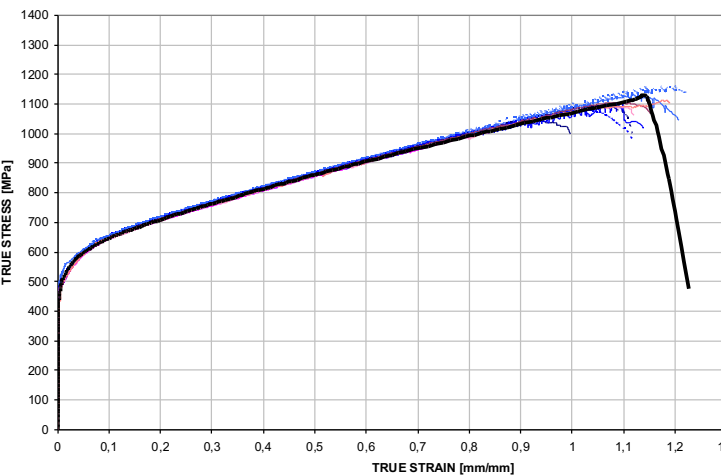
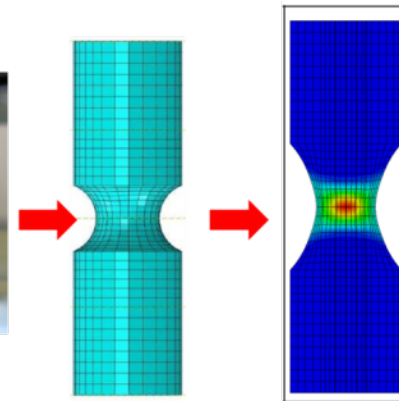
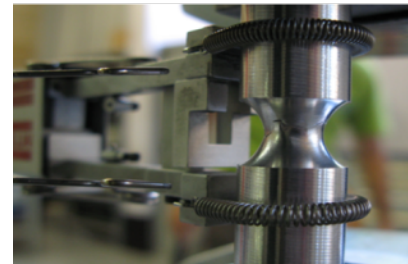
Material constitutive models:

- elastic/plastic
- anisotropy
- strain rate
- damage/failure
- flaw tolerant
- residual stresses
- crack propagation
- micro-indentation
- delamination
- ...



COM Simulation - Abaqus/Explicit Version 6.11 - Modulo 10 (M10) in corso sempre controllato 2008

Modulo 10 (M10) in corso sempre controllato 2008
Oggetto: Modulo 10 (M10) in corso sempre controllato 2008
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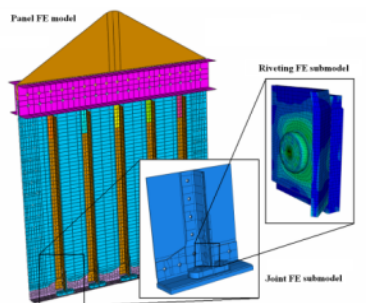
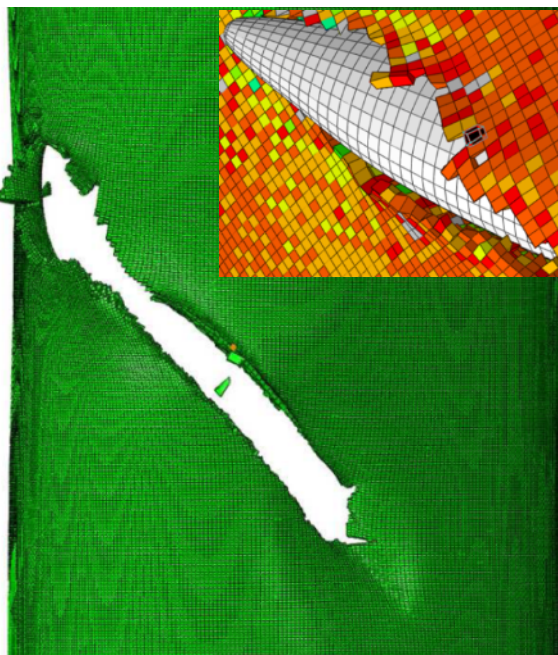
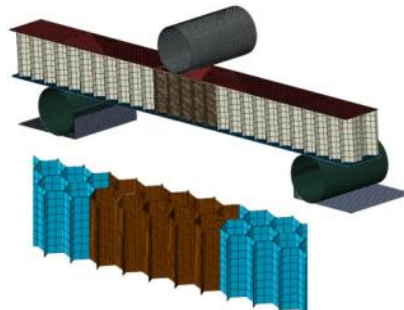
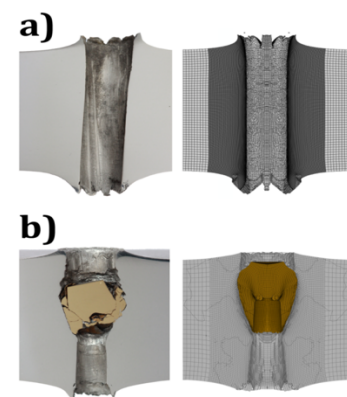
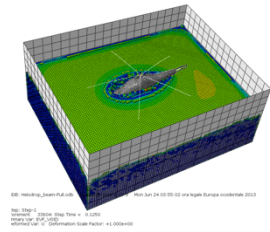
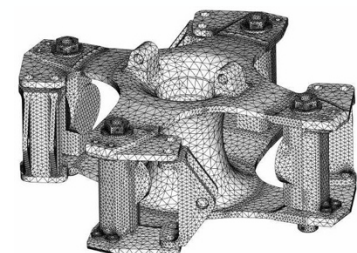
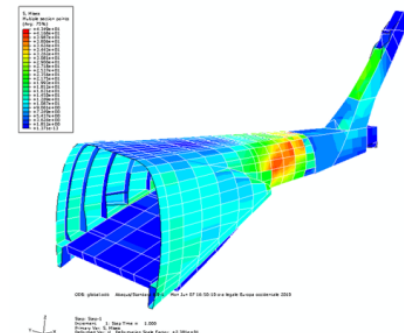
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Politecnico di Milano
Dipartimento di Meccanica



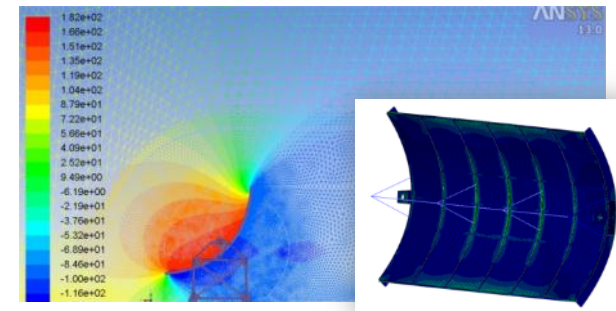
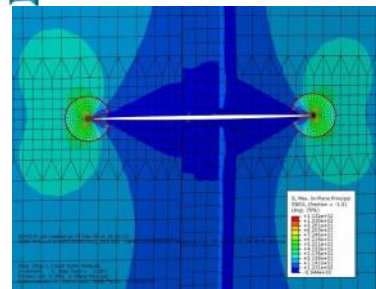
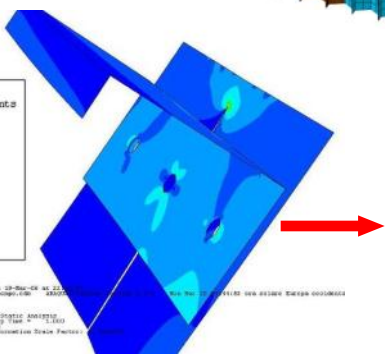
Finite Element Analysis:

- non linear analysis
- sub-modelling and remeshing technique
- advanced material characterization
- multiphysics simulation



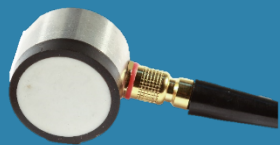
Mesh
Multiple section points
Ve. Crit.: 75%

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#3	2.00e+02
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Model-Based SHM system methodology

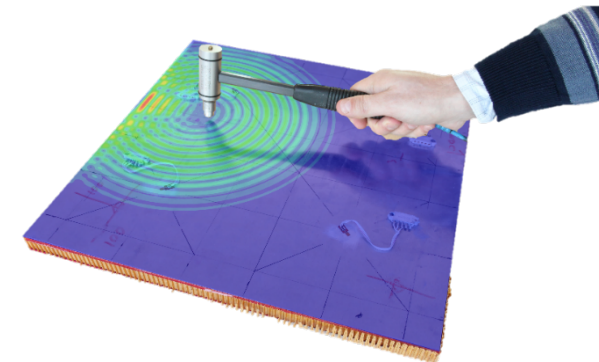
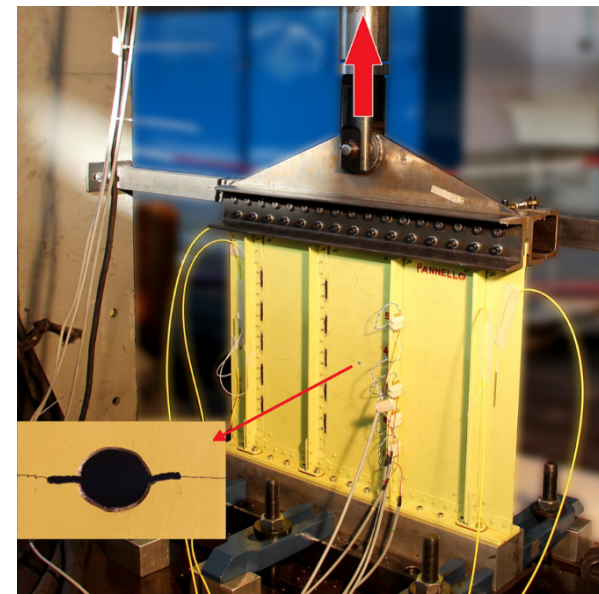
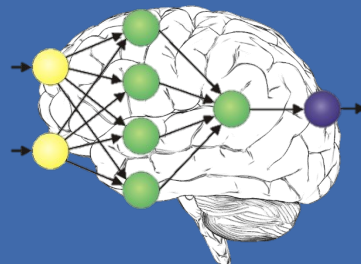
Sensors provide a signal dependent on damage to be interpreted.



Numerical models provide simulated experience for signal interpretation.



Signal processing tools combine numerical and sensor data to provide damage diagnosis.



Damage diagnosis and prognosis
Impact monitoring



SIGMALab is active in several research topics but conventionally we have created **three main research programmes**. Each area develops original and advanced technology platforms at the state of the art in order to deliver the best solutions for challenging problems. The areas merge in several activities.

Structural integrity under extreme load

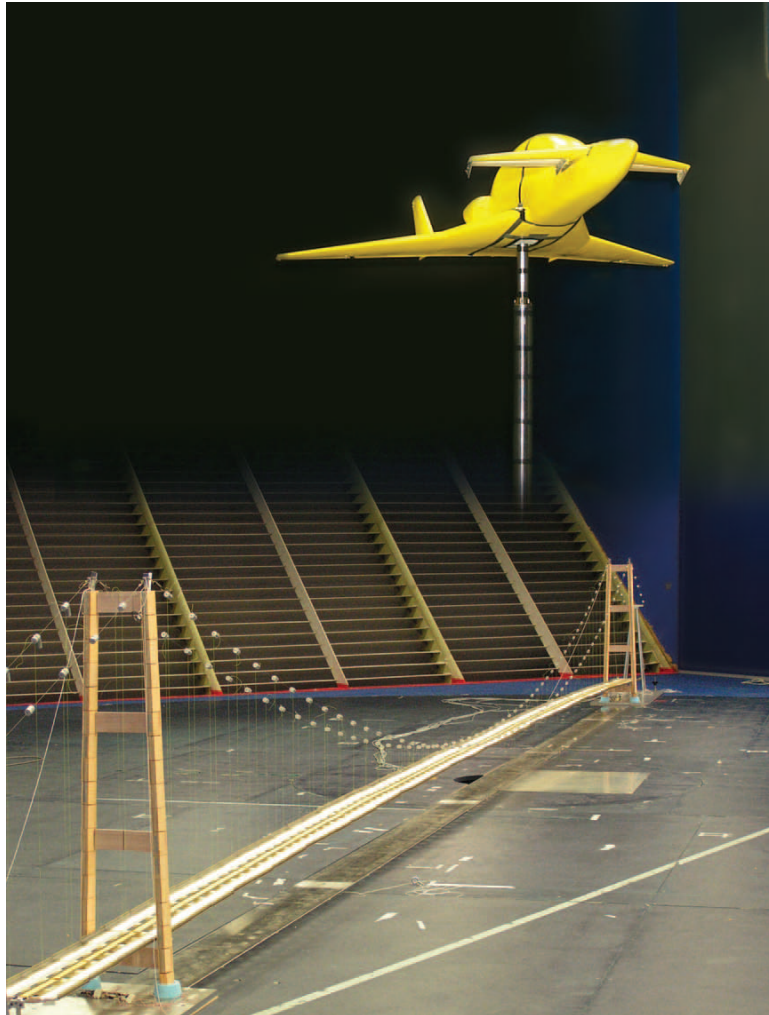
- *Large deformation and failure, impact, explosion, crack, delamination, etc*
- A deep investigation both in practical aspect and state of the art
- Material calibration
- Numerical and analytical modelling
- Experimental testing
- Validation of the modelling approaches
- Definition of a predictive methods
- Sports Engineering

Structural Health Monitoring and prognosis

- Investigation of different state of art sensor technologies for SHM
- Numerical and analytical modelling for SHM system training
- Machine learning and pattern recognition for diagnosis
- Bayesian filters and Monte-Carlo methods for prognosis
- Experimental SHM verification and performance qualification

A new entry for SIGMALab research topic: **Energy**. SIGMALab team is working in order to provide dedicated solutions both for O&G and sustainable energy





Aeronautical Test Section

Max wind velocity: **55 m/s**

Turbulence index: **<0.1%**

Test area section: **4x3.84m**

Length: **6m**

Special features:

- Traversing system to perform wake measurements.
- Several model supports in order to vary the incidence angle.
- 2.5m diameter turntable.

Civil Test Section

Max wind velocity: **16 m/s**

Turbulence index: **<2%**

Test area section: **13.84m x 3.84m**

Length: **35m**

Special features:

- Passive or active turbulence generators to simulate the atmospheric boundary layer (IT>25%).
- Specific device for the twisted flow generation.
- 13m diameter turntable.

Internet site:

www.windtunnel.polimi.it



Structures Facility Laboratories

- Laboratories for full scale components tests (static and fatigue): aeronautic and helicopter components, railway axles and bogie frames, cable dynamics (with test rig span length 40 m), etc; about 2000 m² of laboratories (max height: 8 m); oleodynamic system (210 bar / 284 l/min)
- Laboratory for high temperature mechanical behaviour of materials (creep, LCF, HCF).
- Laboratory for microstructural characterization, equipped with metallographic samples preparation, optical microscope, hardness and micro-hardness measurements.
- Gear transmission laboratory, equipped for performance and durability tests.
- Laboratories for simulation, optimization and control of manufacturing system
- Geometrical metrology laboratory with highly controlled thermal and vibration conditions (CMM, LMM, surface roughness measuring systems).
- Laboratories for virtual reality and augmented reality technologies and tools (systems for motion capture, head mounted display, rapid prototyping machines).
- Laboratories for haptics and reverse engineering (3 and 6 DOF haptics devices, optical 3D scanner).
- Mechatronics laboratories (drives, biomechanics, test rig for control systems)
- InTenso patented test rig, designed to measure the location of gravity centre and inertia tensor of rigid bodies.
- Horizontal axis steel drum (RuotaVia) for testing suspension systems, tyres, rims, braking systems or rail wheels.
- Rotor dynamics test-rig.
- Robotics laboratory.



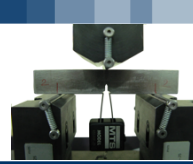
Structures Facility set-up, instrumentation and devices

Special set-ups for full-scale component testing:

- 25 servo-hydraulic actuators (max force 1000 kN).
- 5 electrodynamic shakers (max force 25 kN).
- 10 Controller for servo-hydraulic actuators: single and multichannels (MTS 407, MTS Flex Test IIIm, MTS Aero GT, MTS Flex Test SE,).
- Constraint systems with treaded holes or grooves.
- Frames for full scale tests.
- Pressure transducers - Temperature transducers - Displacement transducer - Rotation transducer – Accelerometers - System for data analysis - Load cells - Systems for strain gages measurements acquisition (up to 90 strain gauges channels for static acquisition with a single device) ...

Certification of personnel:

- NDT qualification according to EN 473, ISO 9712 and SNT-TC-1° in:
- Testing by electrical resistance strain gauges (level 1 and 2).
- Metallographic testing (level 2 – ferrous alloy, steels, cast irons, copper alloys, light and ultra-light alloys).
- Liquid penetrant testing, PT (level 2).
- Ultrasonic testing, UT (level 2).
- Magnetoscopy, MT (level 2).



Material Facility Laboratories

Testing machines:

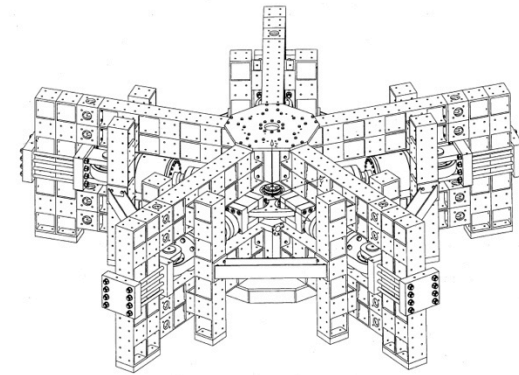
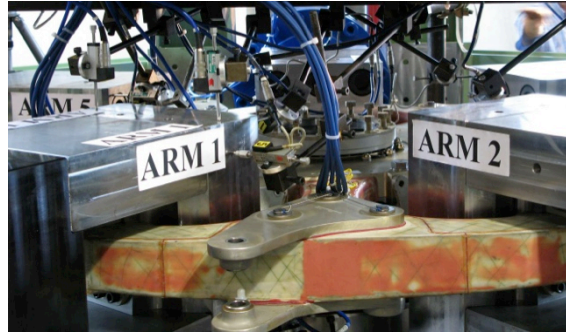
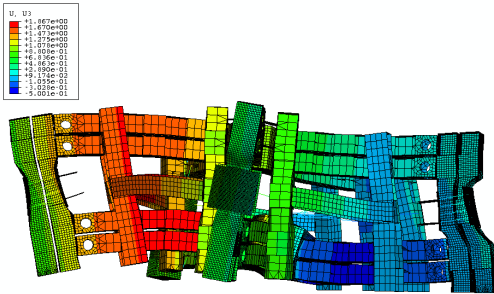
- 1 Tri-axial MTS 809 (axial, 250 kN, torsion, 2000 Nm, pressurization) hydraulic testing machine.
- 1 electromechanical testing machines MTS RT 100(capacity 100 kN).
- 1 electromechanical testing machines MTS RF 150(capacity 150 kN).
- 3 hydraulic testing machines MTS 810 (capacity 100 kN) with devices for controlled temperature tests (-129° C/1200° C).
- 1 hydraulic testing machine INSTRON 8501 (capacity 100 kN).
- 1 hydraulic testing machine SHENCK Hydropulse (capacity 250 kN).
- 3 resonant bending testing machines RUMUL CRACKTRONIC (capacity 160 Nm).
- 1 resonant axial testing machine RUMUL TESTRONIC 100 (capacity 100 kN).
- 3 rotating bending testing machines (ITALSIGMA).

Other instrumentations:

- Scanning Electron Microscope with EDS and EBSD systems.
- X-ray diffractometer for residual stress measurements on materials.
- Instrumentation for mechanical and thermal measurements.



Static test of the AW101 composite MR/H: *Set-up of the test and assessment by analysis of the test rig in case of actuator breakdown*

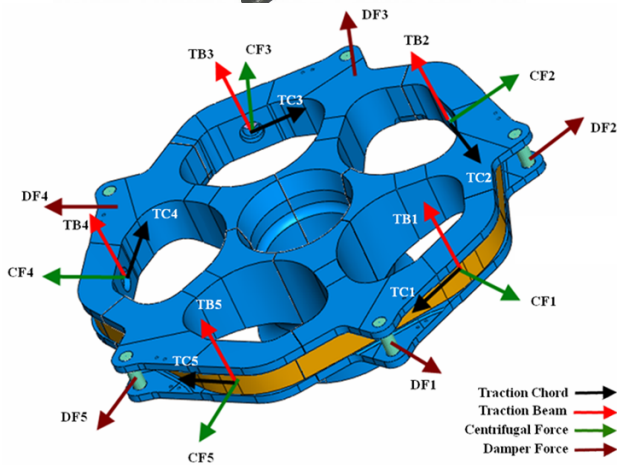


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1
CDB: Trave-es101-4nod1-accorciato-final-u.odb ABAQUS/STANDARD Version 6.6-3 Sun May 20 19:23:17 1
Step: Step-3, Linear Static Analysis
Increment: 11, Step Time = 1.000
Primary Var: U, U3
Deformed Var: U, Deformation Scale Factor: *3.000e+03





Safe life - Fail safe – Residual static test: Set-up of the test, NDT inspection



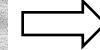
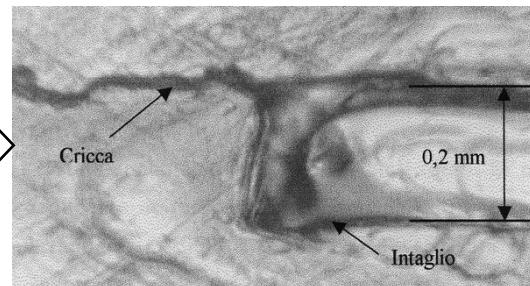
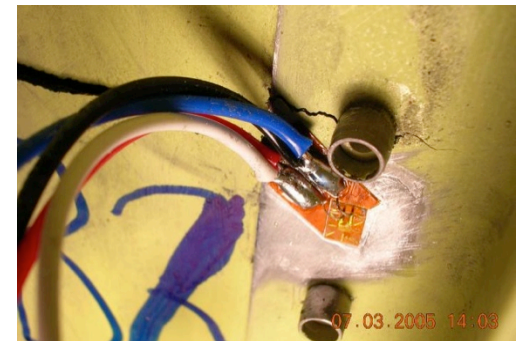
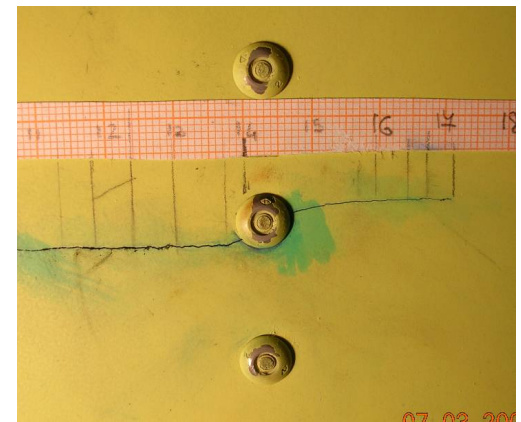
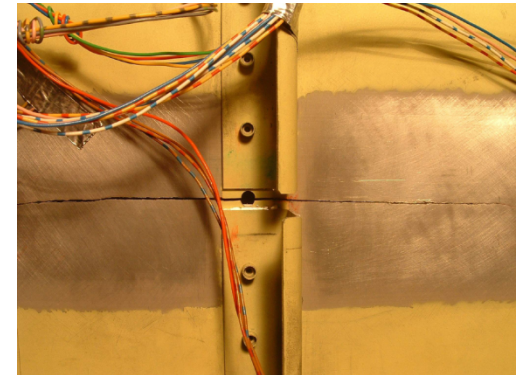


Fatigue and damage tolerance assessment of aluminium panels: metallic panels AW 101



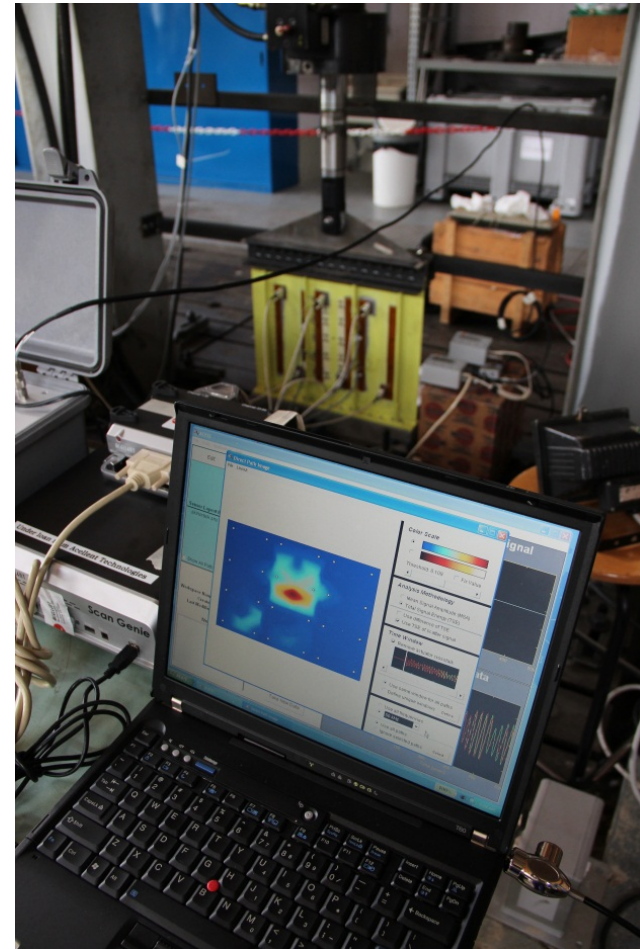
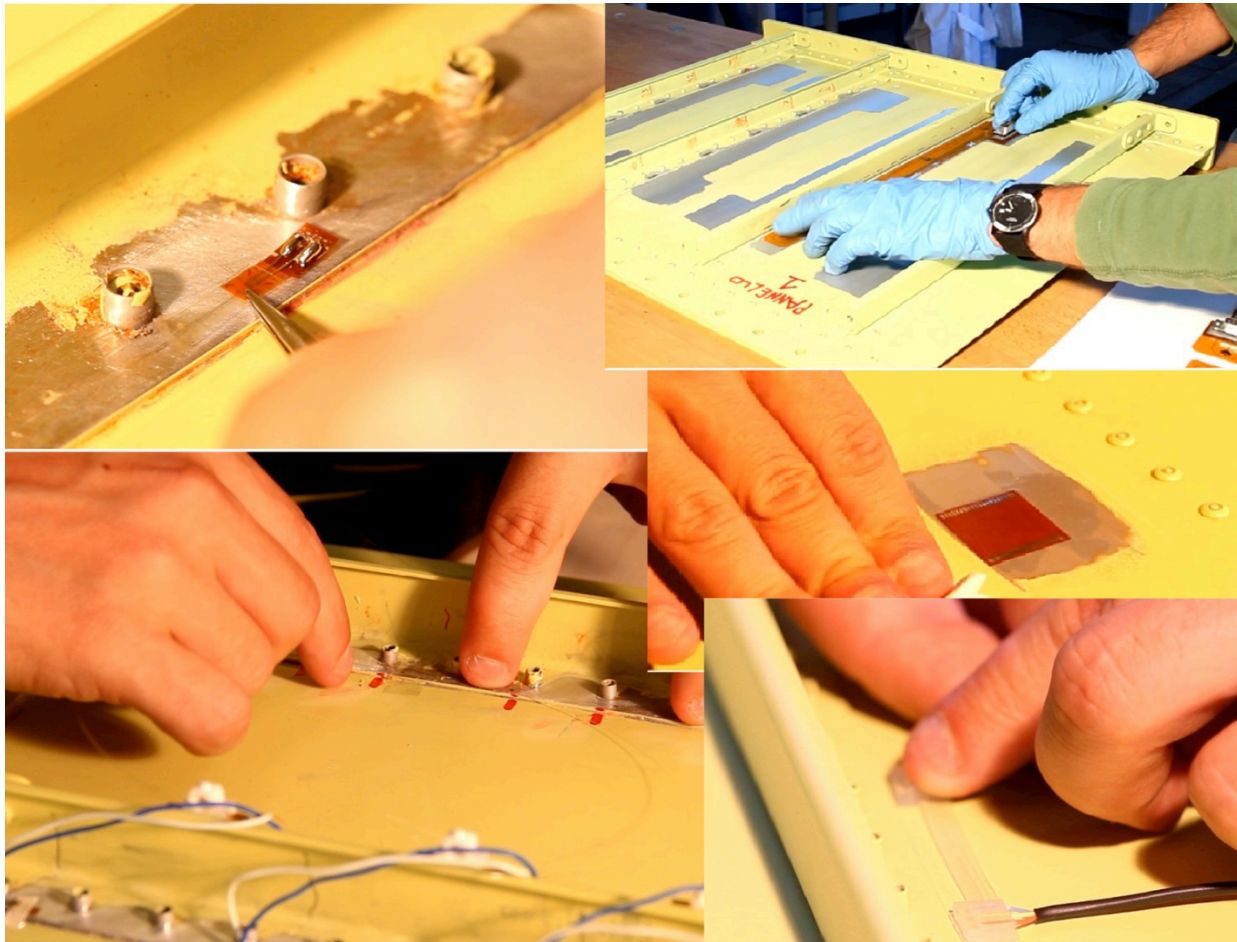
Fatigue evaluation of Al-Li panels belonging to the rear modular joint - **damage tolerance** behaviour due to artificial crack (on the skin with different configurations) during fatigue load

Complete set-up, design and manufacturing of the test rig, strain gauges and crack gauges acquisition



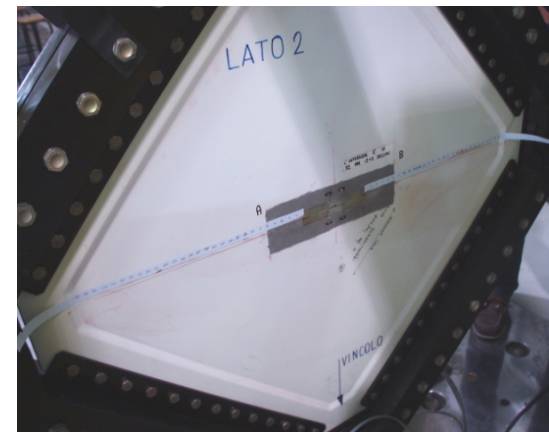
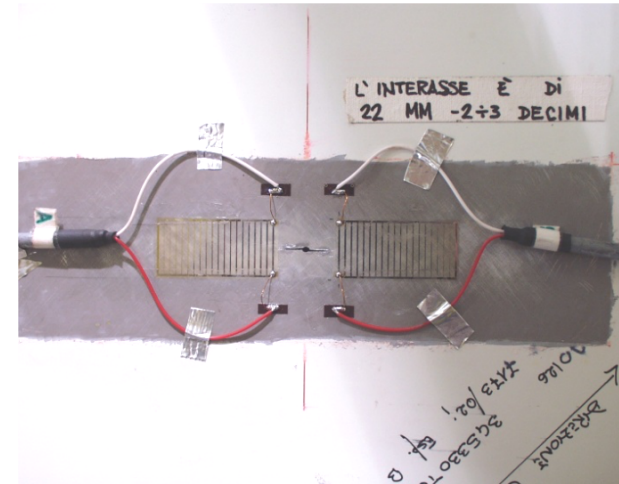
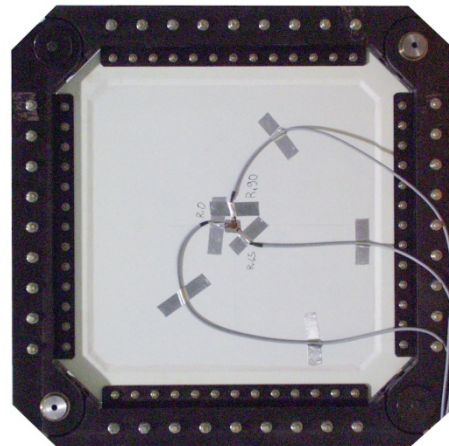
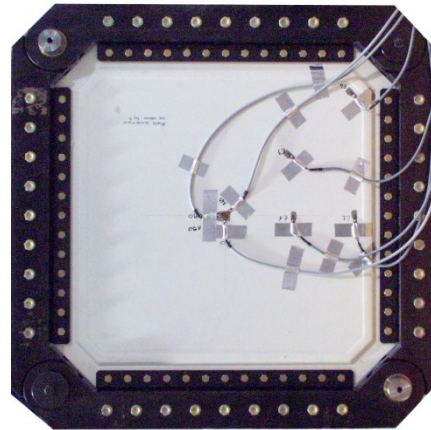
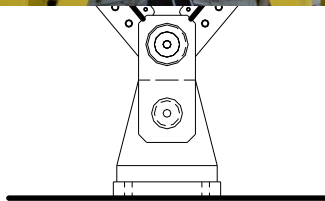


Fatigue tests of pre-cracked metallic panels for **SHM**: Complete test design and set-up, design and manufacturing of the test rig, assessment of several sensors technologies (strain gauges, fiber Bragg, CVM, crack gauges, smart layer)



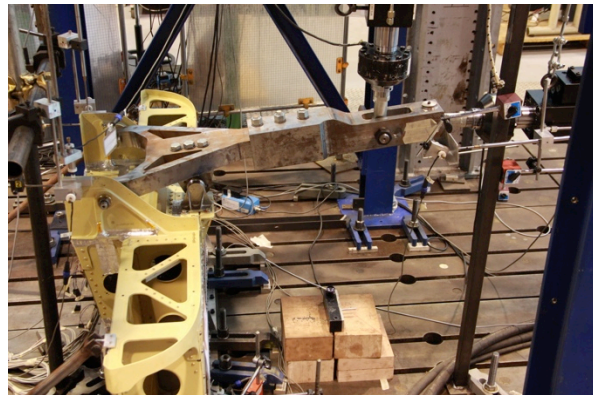
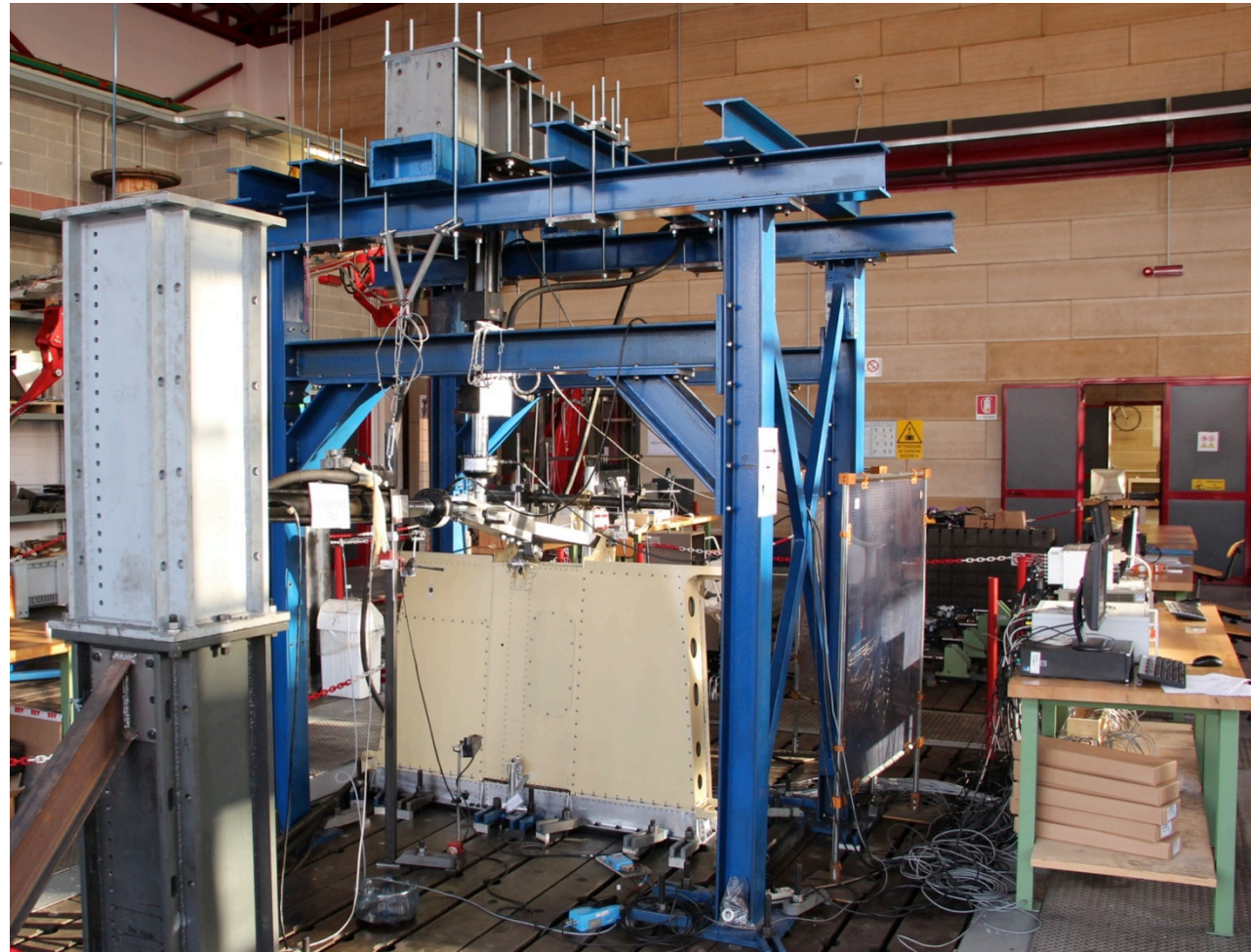
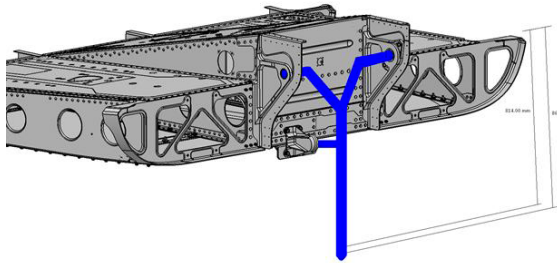


Shear fatigue tests on Al-Nomex fuselage sandwich panels: *complete set-up, design and manufacturing of the test rig, strain gauges and crack gauges acquisition*





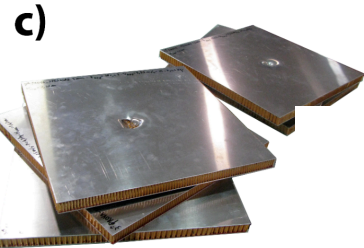
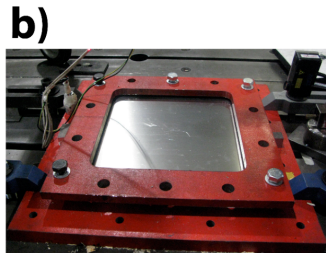
AW 169 Nose Landing Gear Installation Static Test: set up of the test, design and manufacturing of test rig and dummy landing gear.



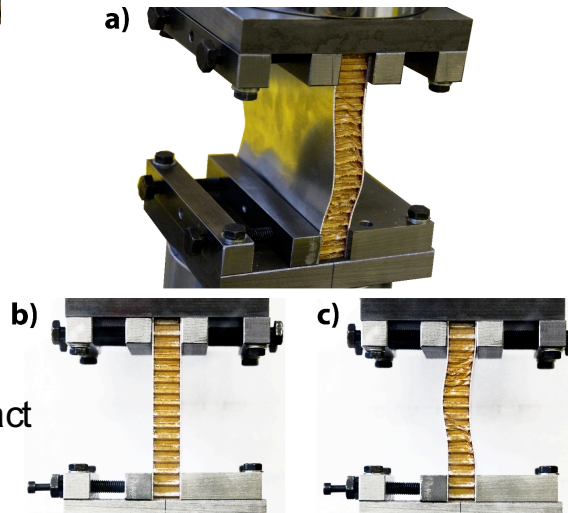
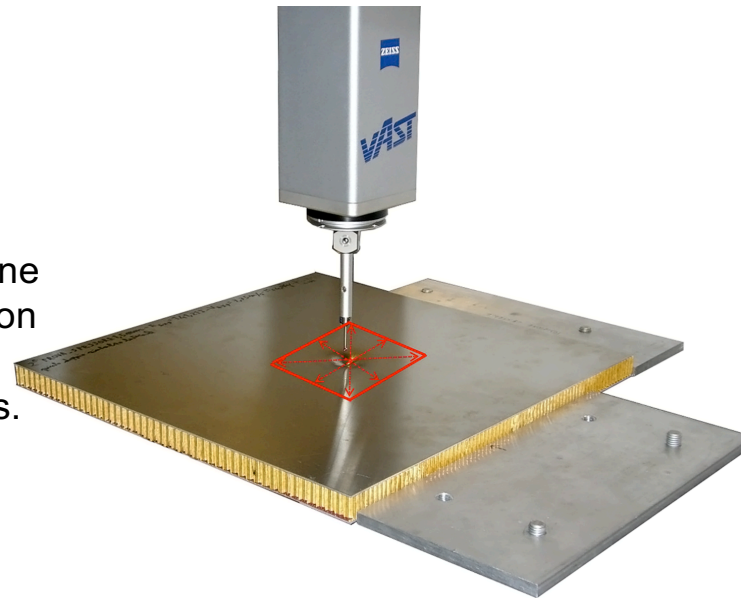
Impact and CAI test: Complete set-up, design and manufacturing of the test rigs.



1) (a) test rig for the drop test; (b) focus on the rigid frame for panel grounding and (c) examples of sandwich panel specimens after impact tests.



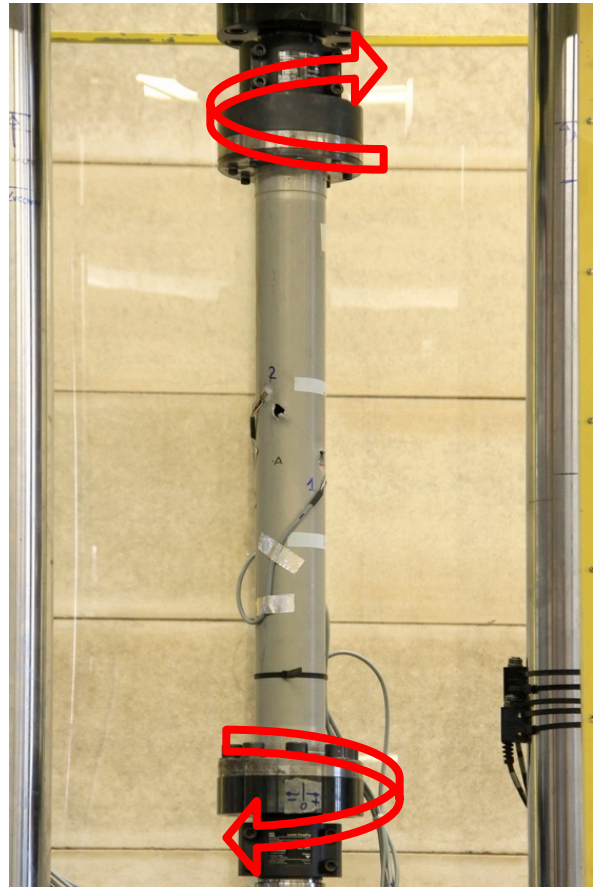
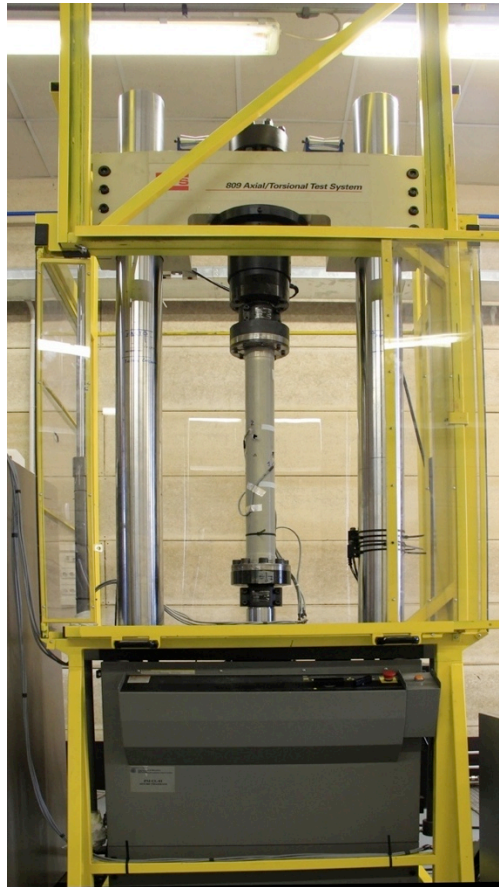
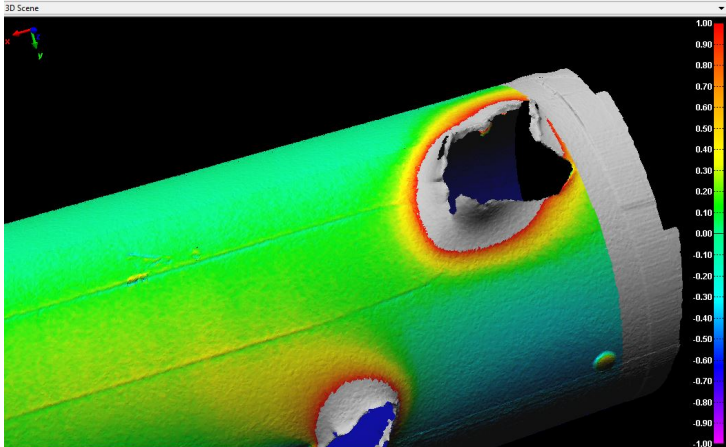
2) Coordinate measure machine with the indication of the profile measured paths.



3) Compression After Impact (CAI) test, (a) Prospective view of a sandwich panel specimen and the gripping system during a compression test, (b) orthogonal view of an uncompressed panel and (c) orthogonal view of a compressed panel.

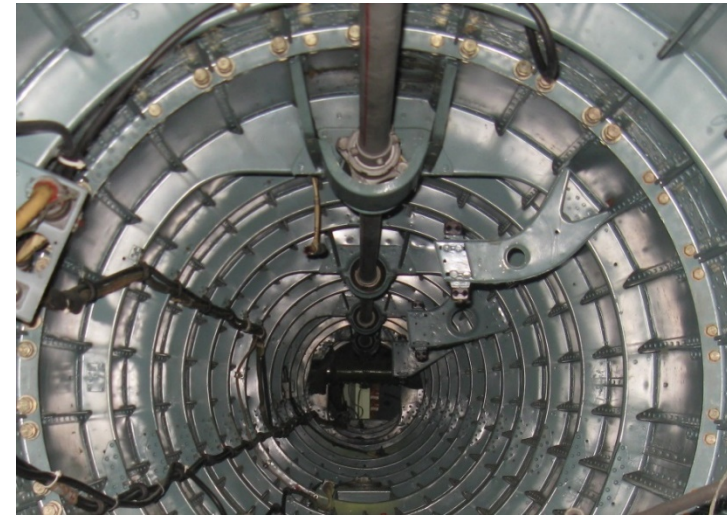
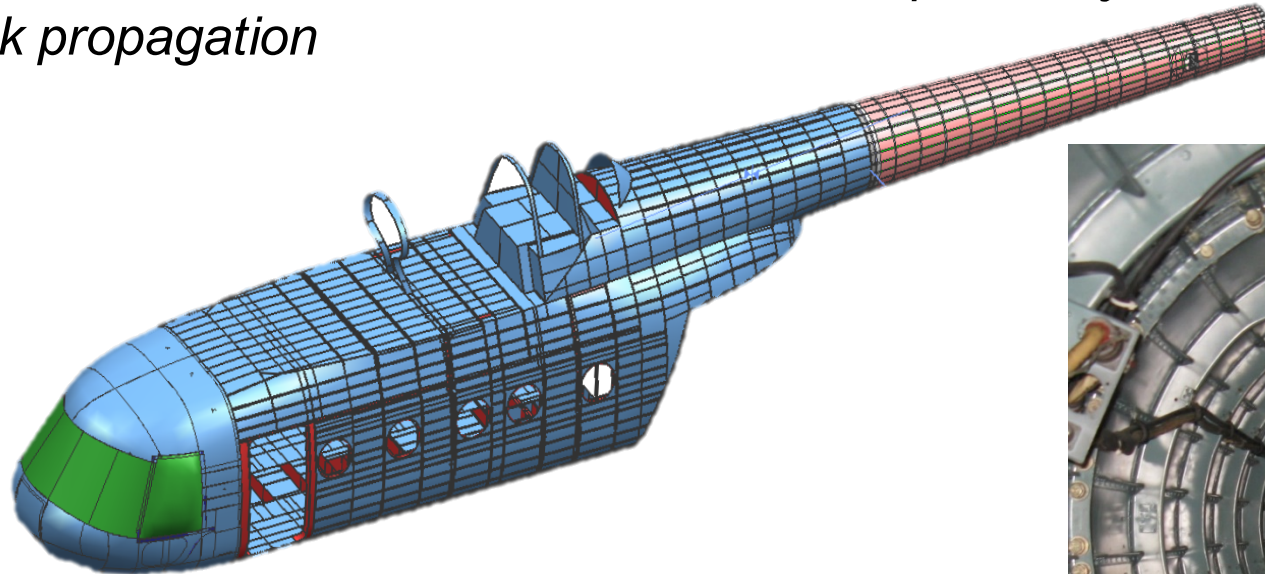


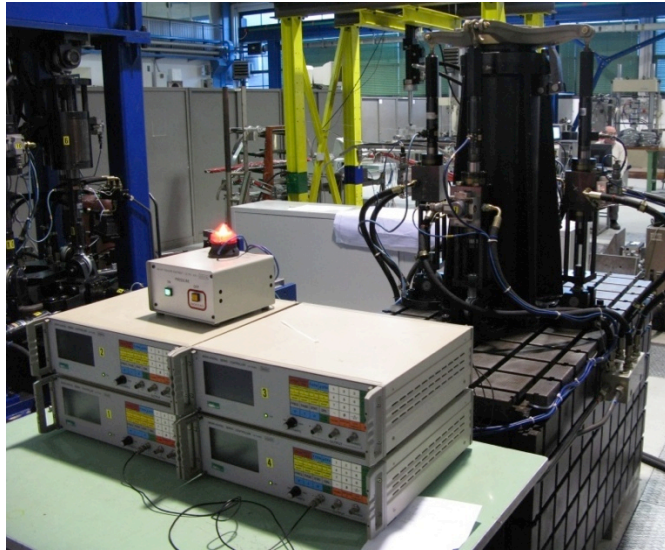
Ballistic damage tolerance tests of the T 129A tail rotor shafts: *Set-up of the test after ballistic impact tests, residual stress and laser scan measurement, strain gauges and crack gauges acquisition.*





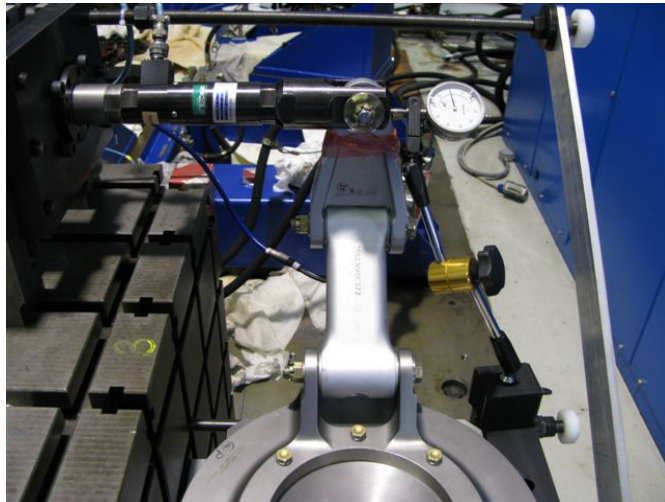
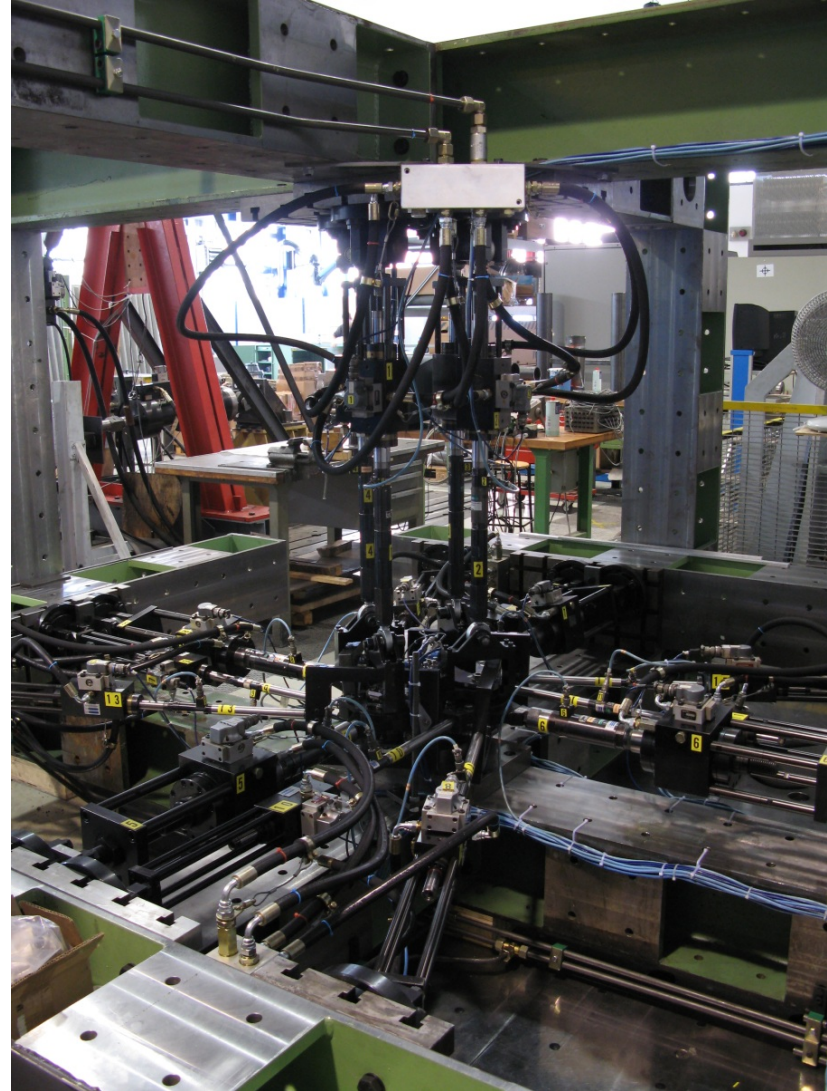
Fatigue test: *Set-up of the test, sensors acquisition and elaboration; the tail boom of a Mi-17 helicopter subject to fatigue crack propagation*





AW 109
Swashplate
Rotating
Assy
Fatigue Test

Fatigue
test of
the AW
139 tail
rotor
hub
assy



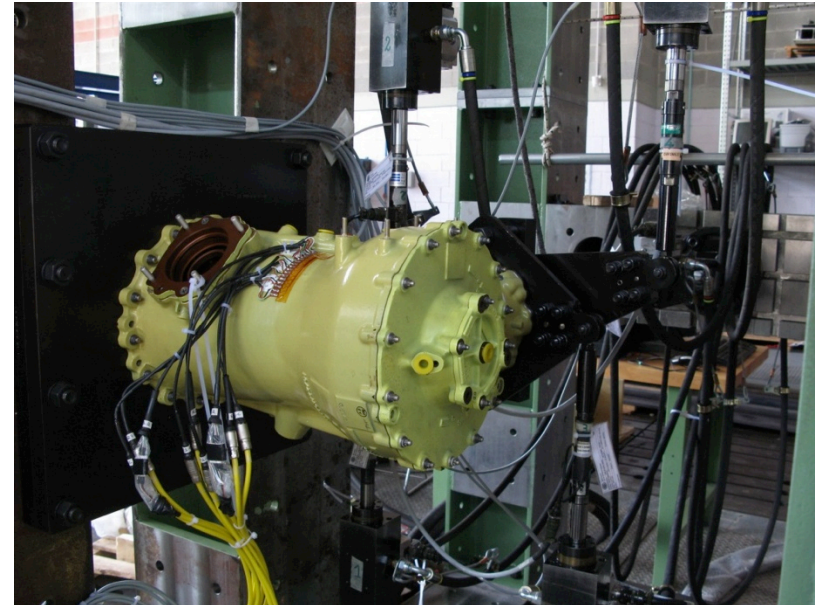
AW 139
M/R
Lower
Scissor
Lever
Fatigue
Test



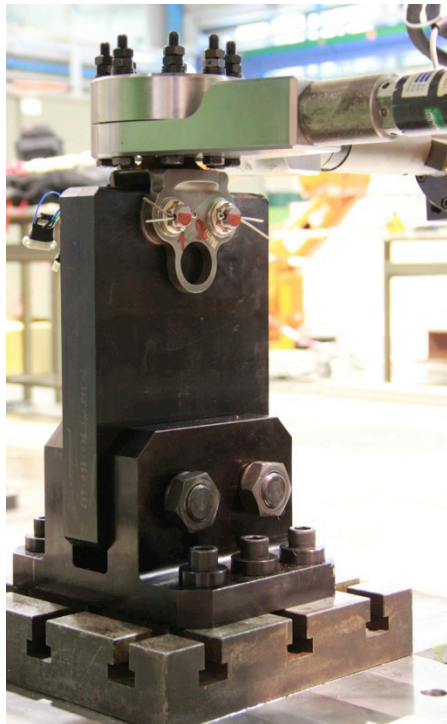
Fatigue tests of Helicopter components 2



Sea King
Tail pylon
fold joint
upper hinge
fitting
fatigue test



NH 90 Input case Fatigue test



AW 609
inboard
Spindle
Fatigue Test
(FAA
certification)

Static test
of the AW
609
composite
wing rear
spar (FAA
certification)





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The material in this presentation has been prepared by SIGMA Lab team and is general background information about SIGMA Lab's activities and expertise current as at the date of this presentation. This information is given in summary form and does not purport to be complete. SIGMA Lab retains all intellectual properties associated with the presentation

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