Audition to the Final Exam - XXXIII Cycle

«Structural Health Monitoring based on Piezoelectric transducers: a Carbon Fiber Automotive Component Application case»

Coordinator: ***Prof. Luca Goglio***
Tutor: ***Ing. Massimiliana Carello***

Candidate: ***Ing. Lorenzo Sisca (s252437)***

18th December 2020

Aims and Scope

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Objective of the work:

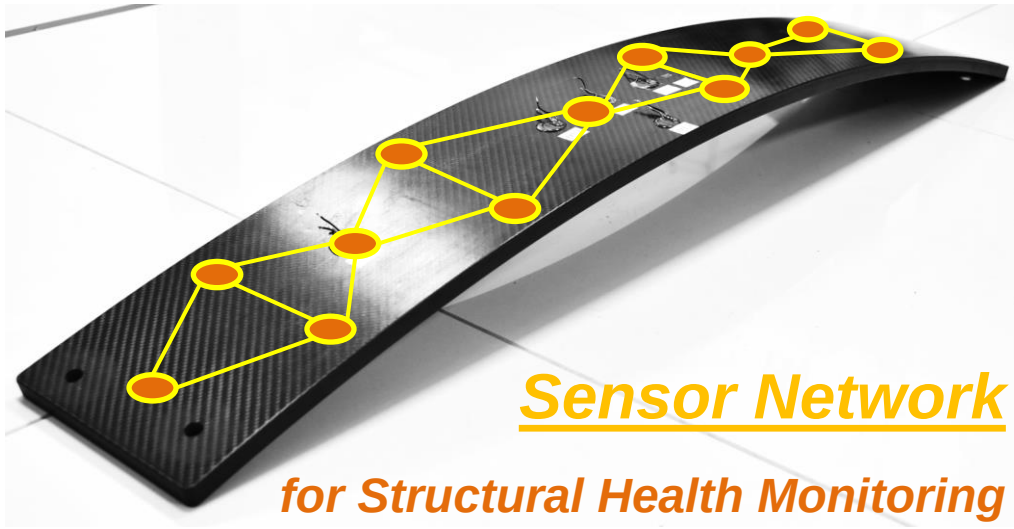
*Develop a **Structural Health Monitoring (SHM) system***

*based on Piezoelectric transducers in order to assess **Predictive Maintenance***

*on **a Carbon Fiber Component** for the Automotive sector.*

Key Concepts:

- *Could the **SHM Technology** be applicable to this Automotive component ?*
- *Does **Piezo response change** with different conditions of the structure ?*
- *Which is the **Excitation Frequency** most sensitive to Damage for this component ?*
- *Do the **known Damage Index Algorithms** apply in all conditions of the structure ?*
- *Is there **a preferred Damage Index** Algorithm ?*
- *Could the **Sensor Network positioning** be designed a-priori?*



SHM & Predictive Maintenance

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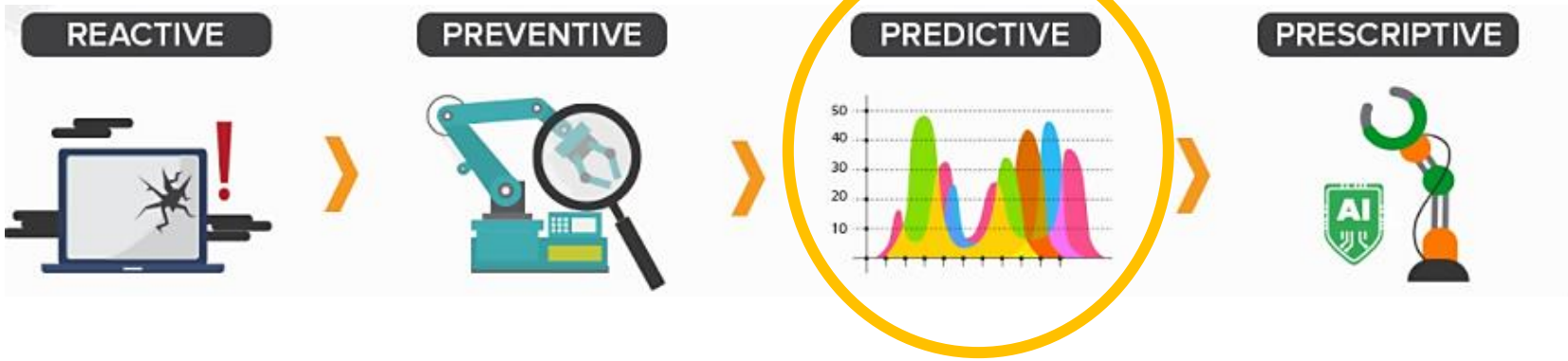
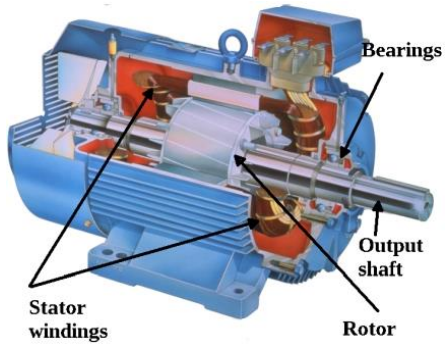
Maintenance Strategies:

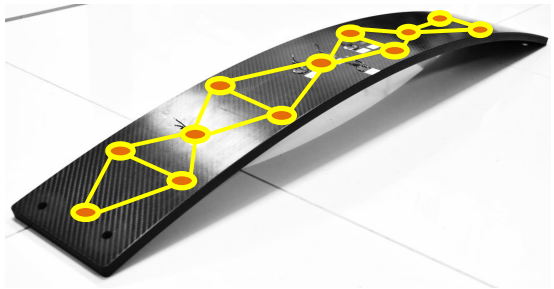




Electric Motor

Monitoring

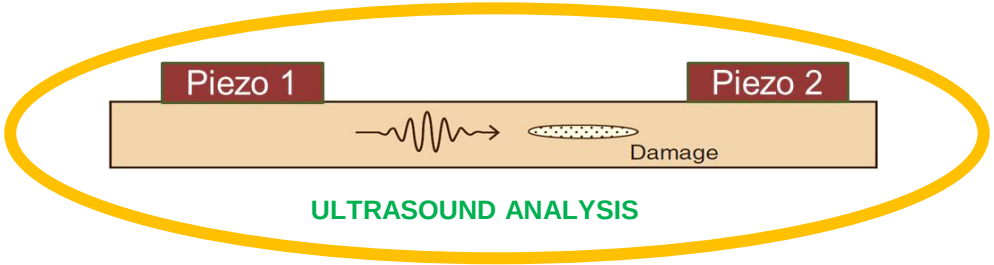
PASSIVE



Leaf-Spring CFRP Suspension

Monitoring

ACTIVE-PASSIVE



Academic & Industry about SHM

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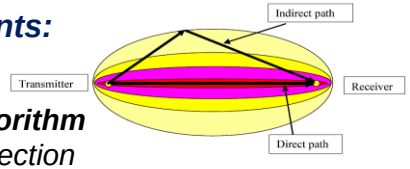
Bibliography

Papers & Projects on:
- *Phisics of Guided Lamb waves*
- *Non-Destructive Testing*
- *Damage Detection Algorithms*

Literature Contents:



e.g. ***RAPID Algorithm*** *for Damage Detection*

Academic Conferences:

- ***Italy*** *(EWSHM, CSHM-8, ICASHM)*
- ***Europe*** *(ICESHM, EURODYN, ICCS23 & MECHCOMP6, HeaMES, CST)*
- ***America*** *(SHM-NDT, SPIE)*

Research Projects:

Imperial College London

SI&HM

NDTonAIR
H2020 Marie-Curie European Network

ReMAP
Real-time Condition-based Maintenance for Adaptive Aircraft Maintenance Planning

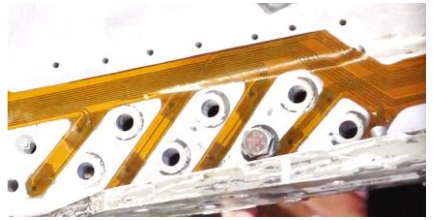
Flugwissenschaftliche Vereinigung Aachen
Structure Health Monitoring (SHM) of the FVA 29 Mast

Benchmark

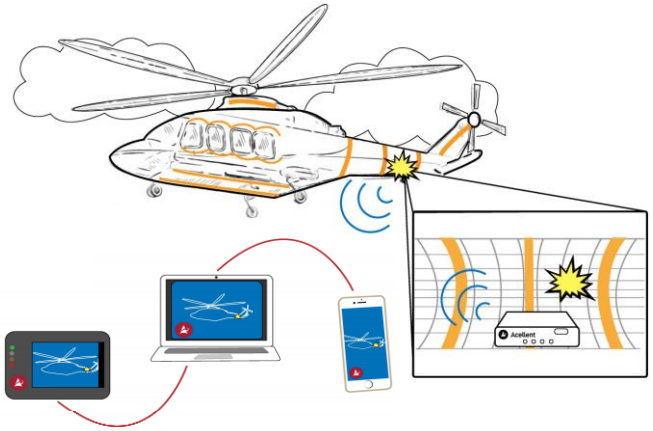
Products & Solutions for:
- *Sensor network application*
- *Softwares for Data Management*
- *Electronic System*

Acellent

Sensors SMART Layers:



Rotorcraft Monitoring:



Patents

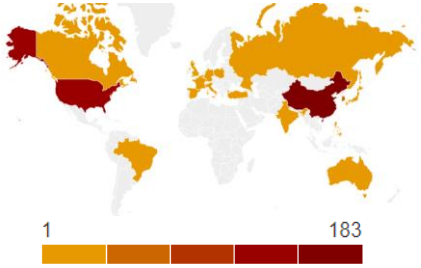
Intellectual Property on:
- *Sensor network definition*
- *Sensors Integration*
- *Data Treatment*

PATENT INSPIRATION

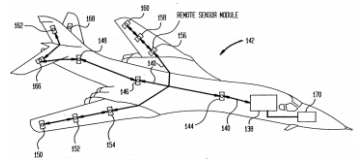
Espacenet Patent search

- **Keywords used:** *"Structural Health Monitoring"*
- **Applicant name:** *"Acellent"*
- **IPC Codes:** *"Physics", "Performing Operations; Transporting"*

Landscape Scenario:
China, America

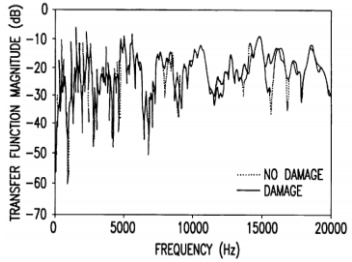


Oldest Patents:



150 citing **US6006163 (1999)**

245 citing **US5195046 (1993)**



Academic & Industry about SHM

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Bibliography	*Benchmark*	*Patents*
Papers & Projects on: • *Phisics of Guided Lamb waves* • *Non-Destructive Testing* • *Damage Detection Algorithms*	**Products & Solutions for:** • *Sensor network application* • *Softwares for Data Management* • *Electronic System*	**Intellectual Property on:** • *Sensor network definition* • *Sensors Integration* • *Data Treatment*

*Only for **SAFETY Critical Components***

→ ***NO AUTOMOTIVE APPLICATIONS***

→ *SENSOR IS TO BE FITTED ON THE APPLICATION*

→ *NO UNIFIED METHODOLOGY TO EVALUATE THE DAMAGE*

→ *NO INFORMATIONS FOR POSITIONING SENSORS*

→ *FEW APPLICATIONS ON WORKING COMPONENTS*

What to investigate?

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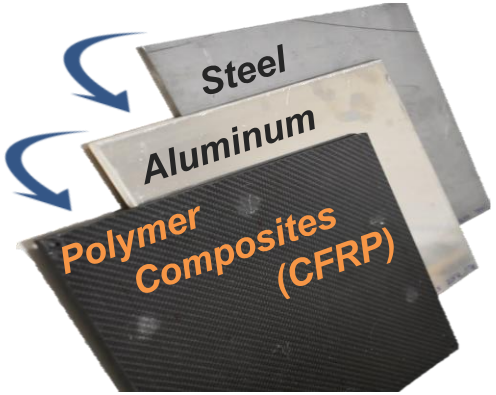
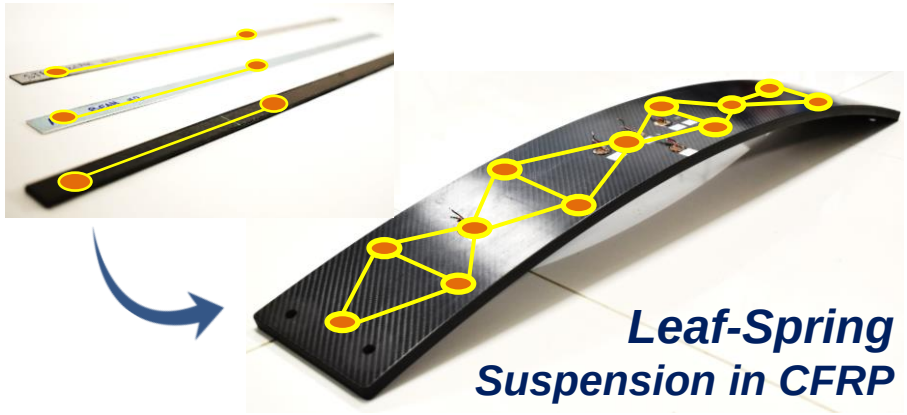
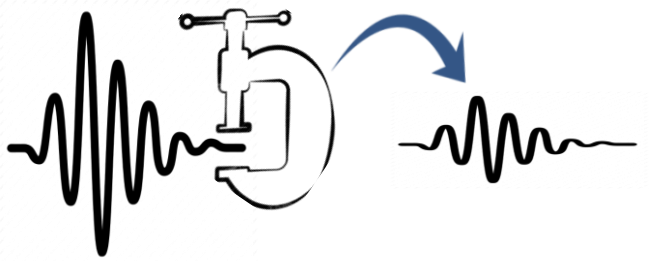
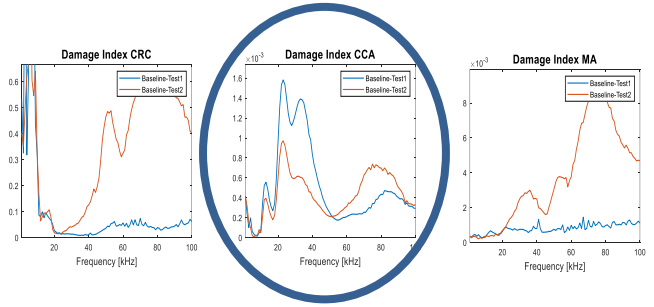
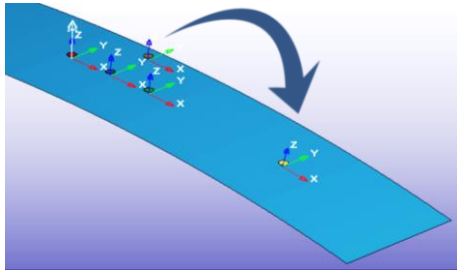
- ***Sector change*** – *effective applicability for Automotive application*
- ***Materials investigation*** – *SHM adaptation on different materials used in automotive*
- ***From specimen to component*** – *methodology applied to automotive component case*
- ***Influence of stress conditions*** – *evaluation in both free and stressed configuration*
- ***Damage Index selection*** – *Processing algorithm definition for damage detection*
- ***Sensor Positioning via Simulation*** – *Virtual methodology to design a-priori the Sensor Network*











Research Activity Pillars

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Electronic System

- ***Piezoelectric Excitation*** *(-10/+10 V, 1-100 kHz)*
- ***Piezoelectric Acquisition*** *(100 mV, 1 MS/s)*
- ***Digital Commutation*** *(for Actuator selection)*

Data Processing

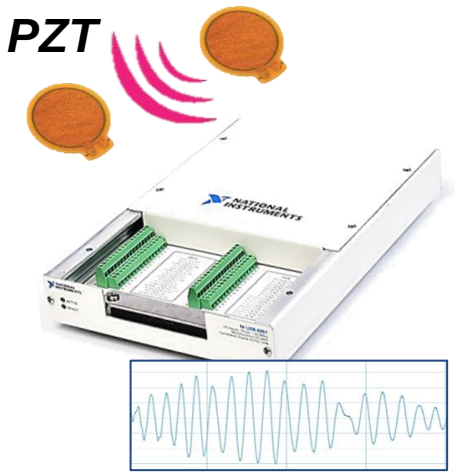
- ***Big Data Management*** *(1μs step → $5 \cdot 10^4$ @1 kHz)*
- ***TXT/Folder Formatting*** *(Organized Architecture)*
- ***Process during acquisition*** *(Average, Low-pass Filter, Damage Indexes and plots)*

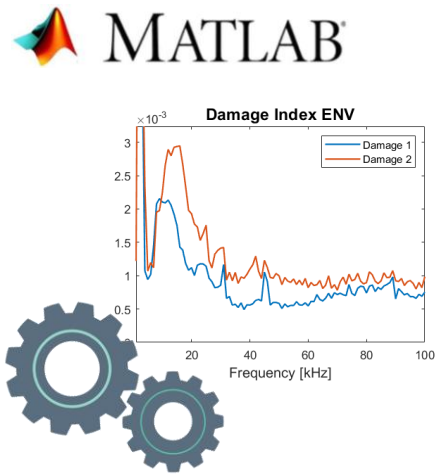
Experimental Tests

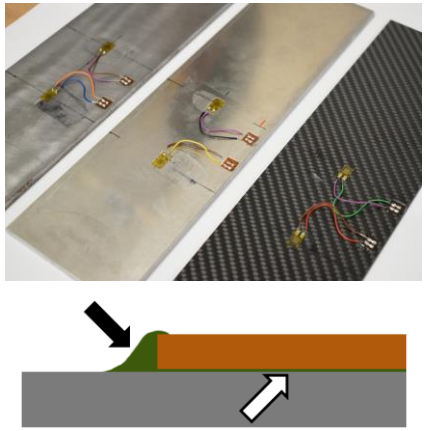
- ***Specimens case*** *(Beam, Plate, Simulacrum)*
- ***Component case*** *(Automotive Leaf Spring)*
- ***Test Configurations*** *(Stressed and Damaged)*

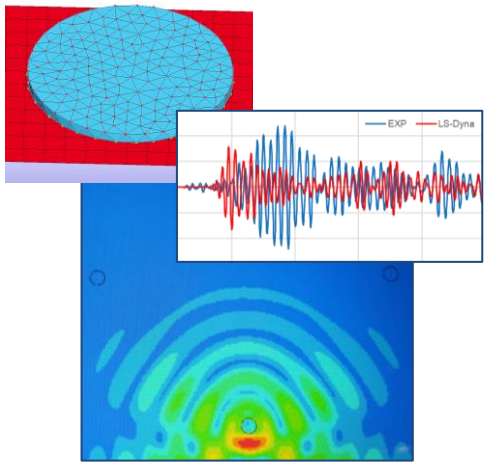
Virtual Correlation

- ***Piezoelectric Modelling*** *(Voltage-Motion Analogy)*
- ***Structures Modelling*** *(NO Damage, NO Stresses)*
- ***Vibration Results*** *(Consideration for Piezo Positioning)*









Electronic System: Roadmap

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From sensor…

… to System Setup

Sensor

- Piezoelectric circular patch suitable for SHM
- PI DuraAct covered by kapton for flexibility

Hardware/Software

- Matlab to control National Instruments I/O module
- Multifunction device with Sample rate 1 MS/s

Hardware/Software Setup

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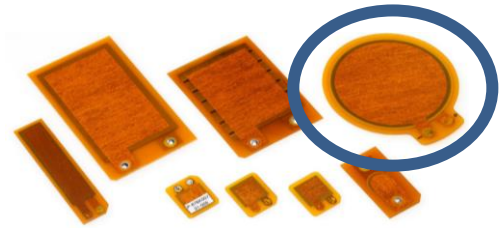
Piezoelectric patch



DuraAct Transducer Specifications

- ***Shape of Piezoceramic***

→ ***Circular:*** *diameter 10 mm,*
→ ***Plate:*** *thickness 0,20 mm*

- ***Voltage Excitation Limits***

→ ***Range:*** *Min.-100 V, Max.+400V*
→ ***Frequency:*** *Max. 1000 Hz*

Multifunction I/O

NI USB-6259 (Spring Terminals)

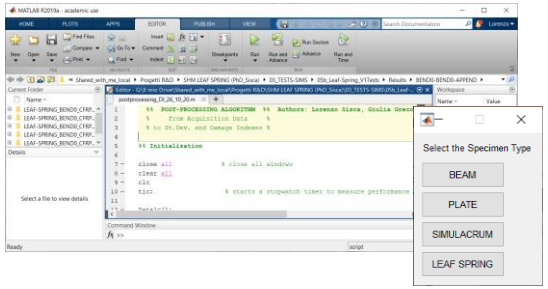
- ***Output chans for Actuators:***

→ ***Update rate:*** *1 MS/s*
→ ***Range:*** *-10/+10V*

- ***Input chans for Sensors:***

→ ***Sample rate:*** *1 MS/s*
→ ***Range:*** *-10/+10V*
→ ***Acquisition:*** *10 times of Output*

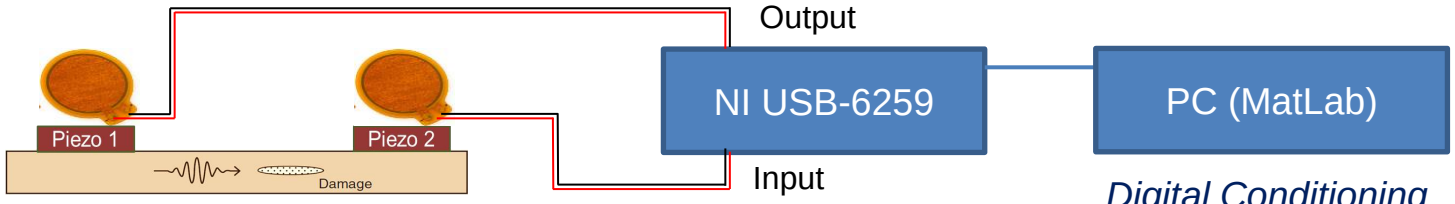
Programming



Data Acquisition Toolbox *to control NI Devices*

- ***MatLab control up to 1 MS/s Update/Sample rate***
  → *able to define actuation waves up to 100 kHz*
- ***Digital Data Low-Pass Filtering***
  → *Signal repeatability up to 100 kHz*
- ***Implementation of Damage Index Algorithms***
  → *On-line / Off-line Processing*

Measurement Chain:



Actuator/Sensor | *Data Acquisition* | *Digital Conditioning + Data Processing*

Data Processing: Roadmap

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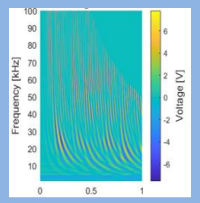
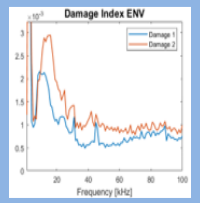
From Voltage signal…

… to Damage information



Data acquisition

- Algorithms for different Frequency ranges
- Data storage and visualization



Damage Index

- Selection of Processing methods from Literature
- Specific DI for each Frequency, material and structure

Data Acquisition

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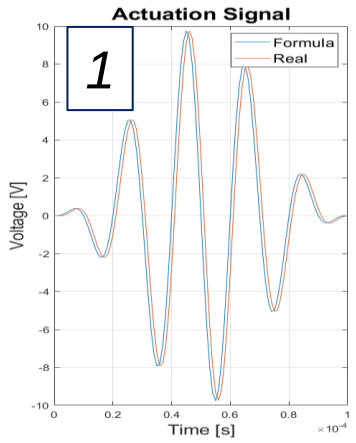
Sending at 1 MS/s the burst signal in Voltage from the Output channel — 1

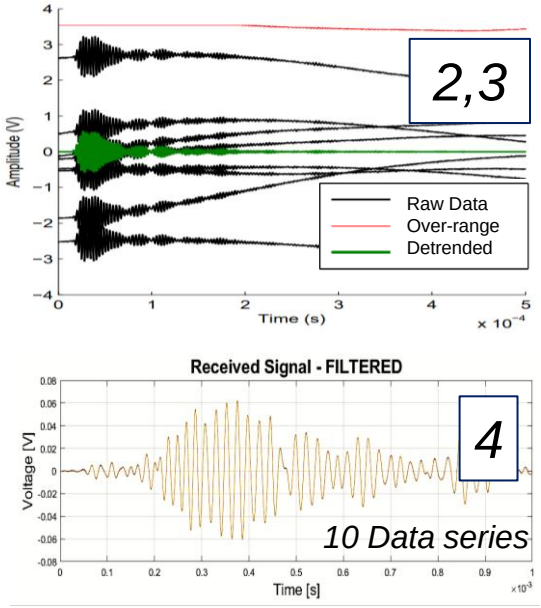
Acquiring at 1 MS/s the response signal in Voltage from the Input channel — 2

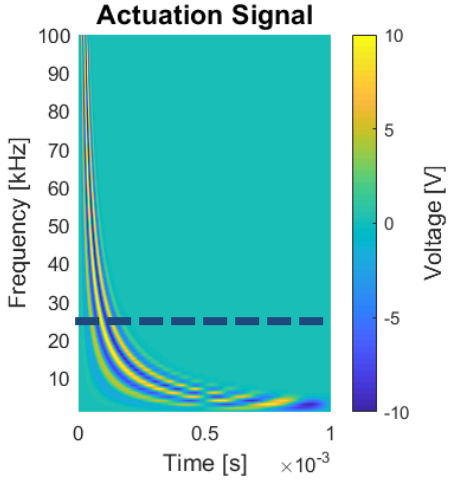
Correcting the raw signal trend by Matlab post-processing (detrend function) — 3

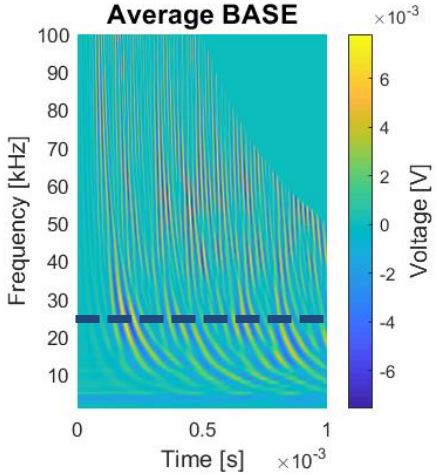
Filtering by Matlab post-processing (Lowpass filter) — 4

5 sines Hanning modulated signal at 1-100 kHz









1 Frequency

100 Frequencies
1 - 100 kHz
(at 1 kHz step)

Data Processing

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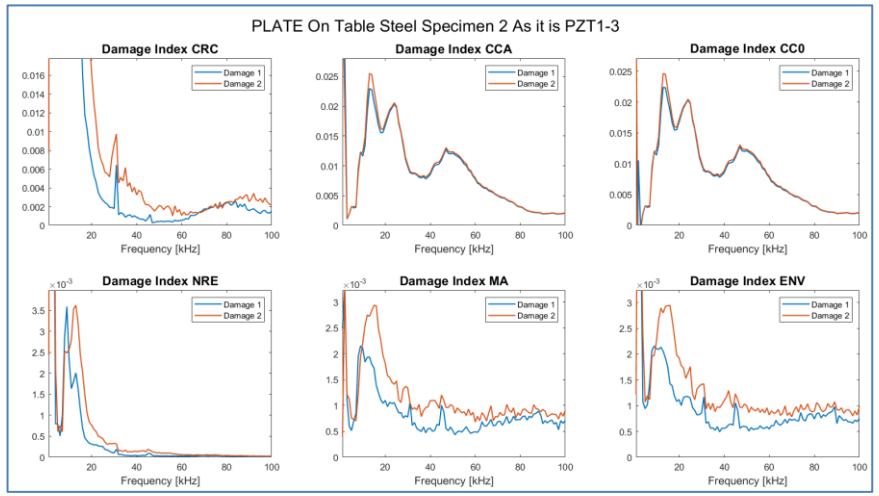
Literature Algorithm Models*

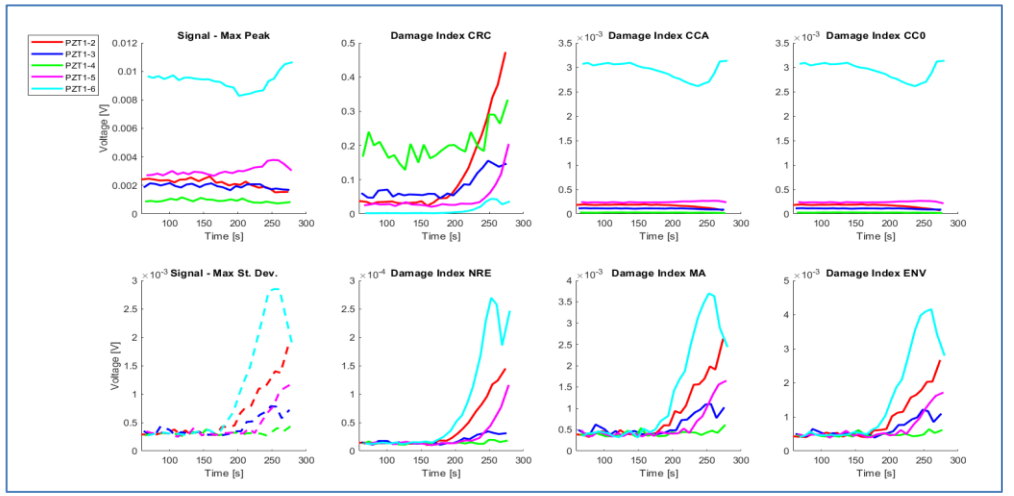
DI name	Comments	Definition
CCA	MATLAB based implementation of the maximum of the correlation	$1 - \max(xcorr[x_{ij}(t), y_{ij}(t)])$
CC0	MATLAB based implementation of the zero-lag correlation	$1 - xcorr[x_{ij}(t), y_{ij}(t)](0)$
CRC	MATLAB-based implementation of the correlation coefficient	$1 - corrcoeff[x_{ij}(t), y_{ij}(t)]$
NRE	Normalized residual energy	$\int_0^T \left(x_{ij}(t) - y_{ij}(t)\right)^2 dt$
MA	Maximum amplitude of the difference	$\max[x_{ij}(t) - y_{ij}(t)]$
ENV	Maximum envelope of the difference	$\max[ENV(x_{ij}(t) - y_{ij}(t))]$

Off-line Processing	On-line Processing (Real-Time)
Specimens and Leaf Spring	*Leaf Spring*
Baseline vs. Test1/Test2	*Baseline vs. Real-Time Data*
100 Frequencies (1-100 kHz)	*1 constant Frequency (X kHz)*
1 Piezo couple	*5 Piezo couples*
6 Damage Index	*6 Damage Index*
Max. Voltage and St. Dev.	*Max. Voltage and St. Dev.*

Off-line Processing



On-line Processing (Real-Time)



* *Nazih Mechbal, Marc Rebillat.* ***Damage indexes comparison for the structural health monitoring of a stiffened composite plate.*** *8th ECCOMAS Thematic Conference on Smart Structures and Materials (SMART 2017), Jun 2017, Madrid, Spain. pp.436-444. ffhal-01592996*

Data Processing

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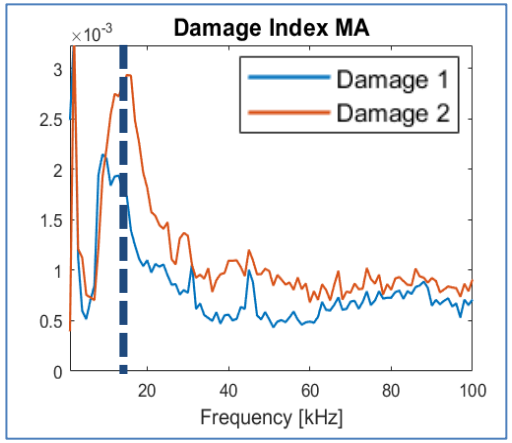
Off-line Processing	On-line Processing (Real-Time)
Specimens and Leaf Spring	Leaf Spring
Baseline vs. Test1/Test2	Baseline vs. Real-Time Data
100 Frequencies (1-100 kHz)	1 constant Frequency (X kHz)
1 Piezo couple	5 Piezo couples
6 Damage Index	6 Damage Index
Max. Voltage and St. Dev.	Max. Voltage and St. Dev.

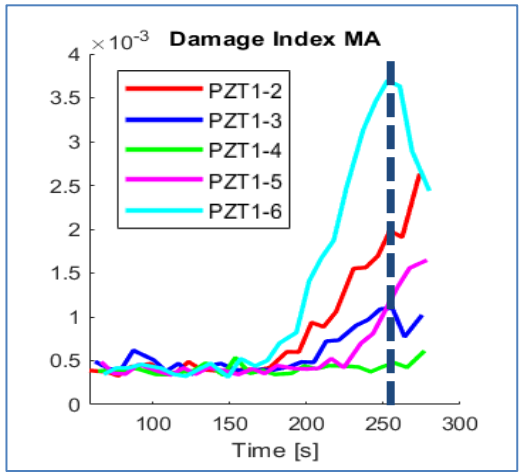
Off-line Processing



Objective:

Evaluation of frequencies more sensitive to damages for each Damage Index algorithm model

On-line Processing (Real-Time)



Objective:

Evaluation of each Piezo couple real-time behavior for each Damage Index algorithm model

* *Nazih Mechbal, Marc Rebillat.* ***Damage indexes comparison for the structural health monitoring of a stiffened composite plate.*** *8th ECCOMAS Thematic Conference on Smart Structures and Materials (SMART 2017), Jun 2017, Madrid, Spain. pp.436-444. ffhal-01592996*

Experimental Tests: Roadmap

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From specimen…

… to component

Damage definition

- 2 mm surface damage
- 4 mm through thickness damage

Repeatable *Damage*

Beam *(2 Piezo)*

- 3 materials (steel, aluminum, CFRP)
- SHM evaluation

1D *NO Load*

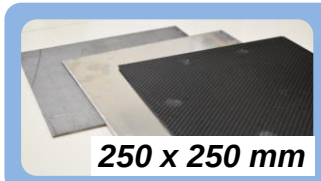
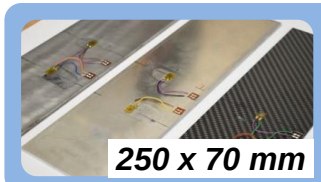


Plate *(4 Piezo)*

- 3 materials (steel, aluminum, CFRP)
- SHM evaluation

2D *NO Load*



Simulacrum *(3 Piezo + 2 Strain-Gages)*

- 3 materials (steel, aluminum, CFRP)
- SHM evaluation + Bending

2D *Bending Load*

Leaf Spring *(6 Piezo + 2 Strain-Gages)*

- 1 material (CFRP)
- SHM evaluation + Bending

Curved 2D *Bending Load*

Test Configurations: Off-line

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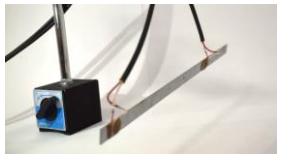
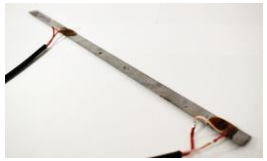
Beam

300 x 12 x 2 mm

Appended



On Table



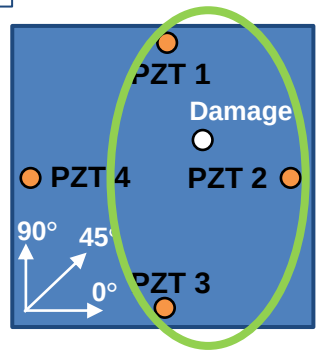
Clamped

PZT1-2
SHM Test each configuration

Plate

250 x 250 x 4 mm

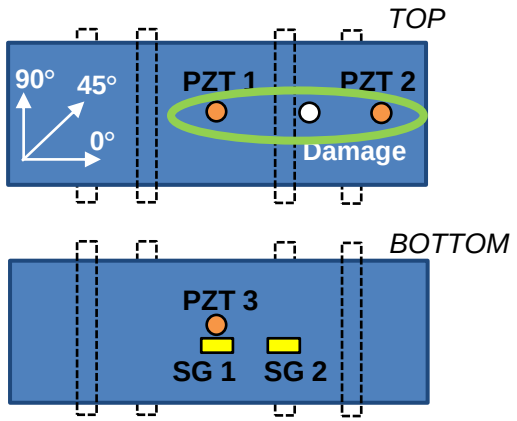
On Table



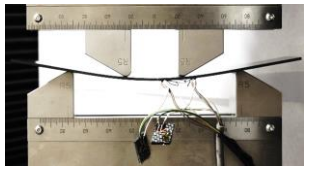
PZT1-2, 1-3, 1-4
SHM Test

Simulacrum

250 x 70 x 4 mm



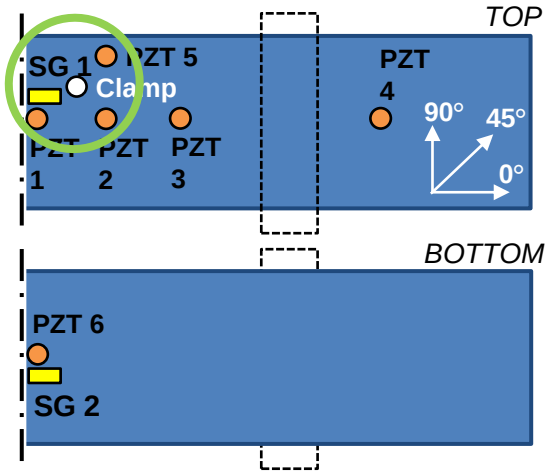
Bending



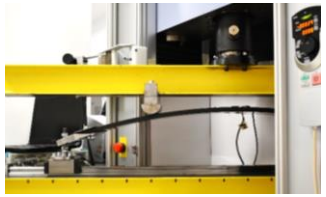
PZT1-2, 1-3
SHM Test each step

Leaf Spring

1000 x 150 x 15 mm



Bending



PZT1-2, 1-3, 1-4, 1-5, 1-6
SHM Test each step

Damage

<u>For specimens</u>
Damage 1 (Surface):
Pre-hole d.2 mm
Damage 2 (Volume):
Passing hole d.4 mm

<u>For Leaf Spring</u>
Clamp: *locally increasing stiffness*

Mechanical Tests

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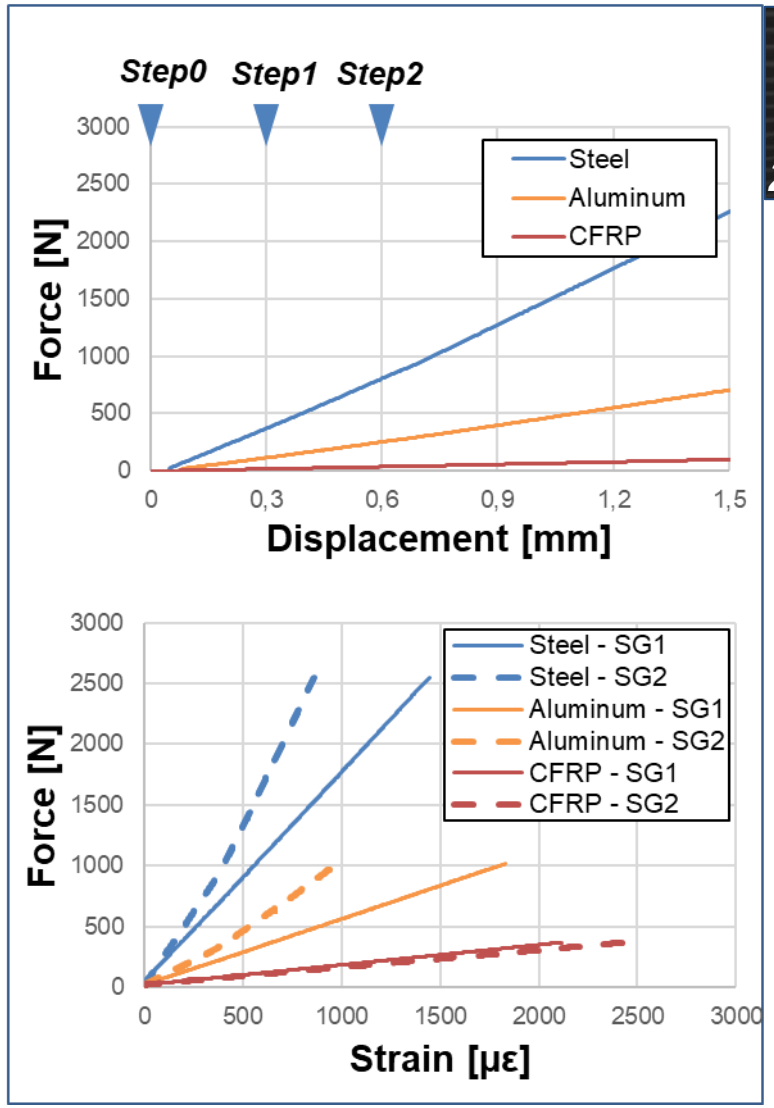
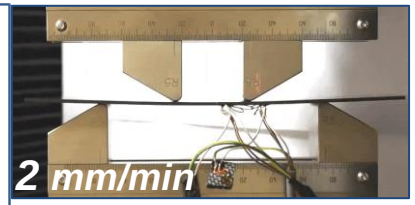
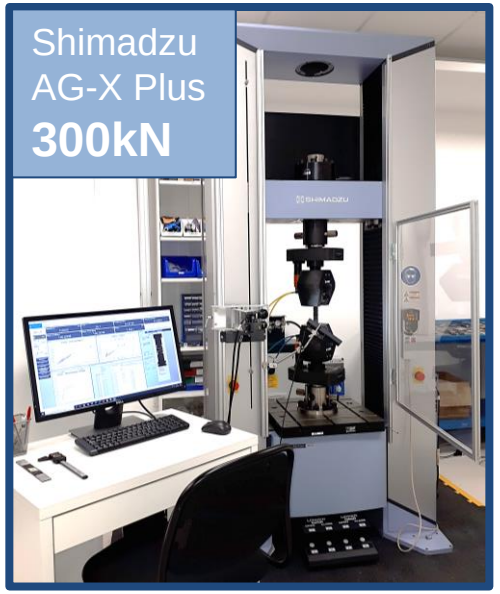
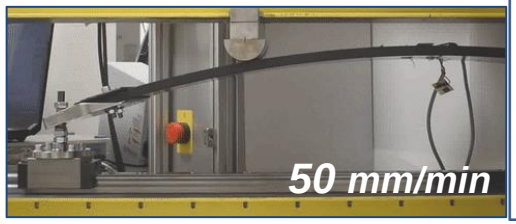
Simulacrum

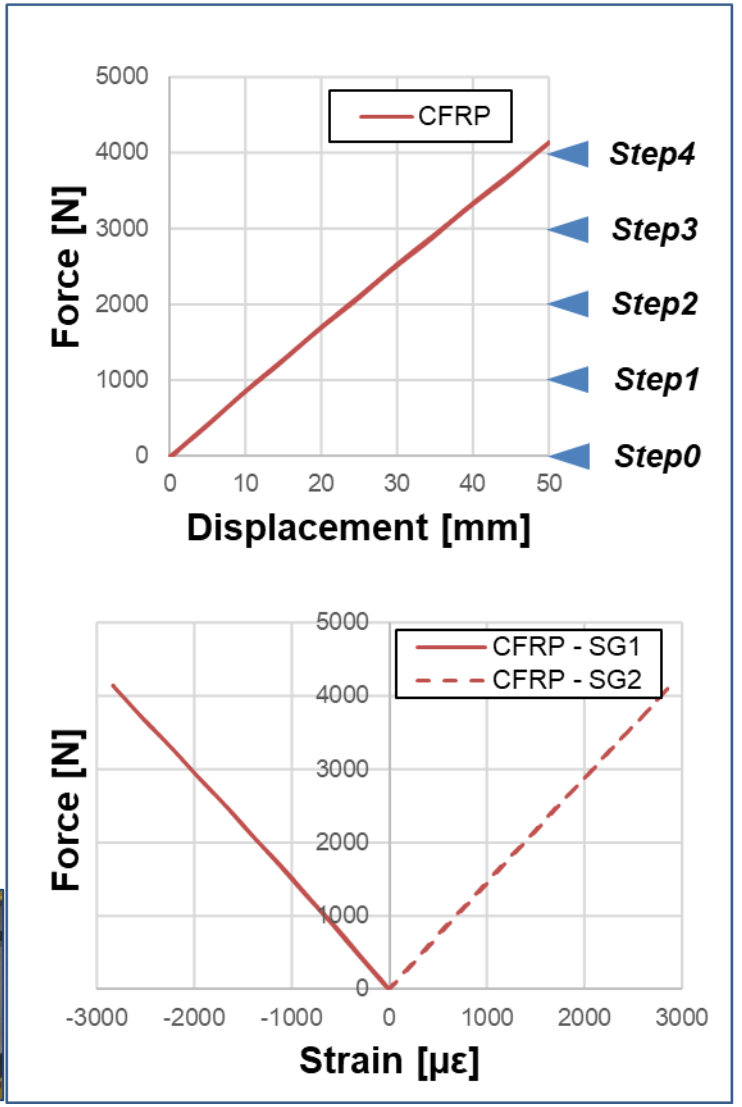








Leaf Spring



SHM Off-line Results: Specimens

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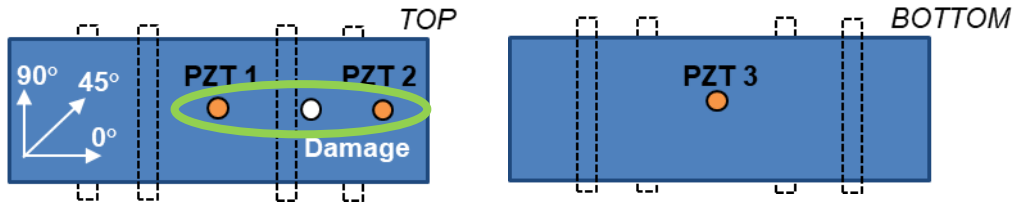
*Example of Data Acquisition for **CFRP Simulacrum***



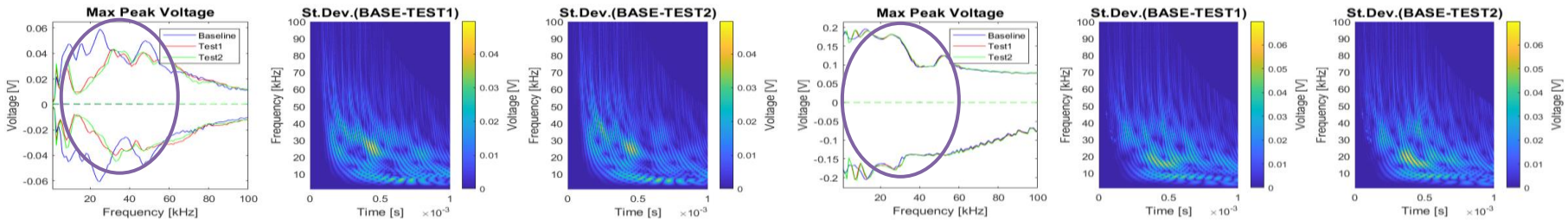
BASE: BEND0
TEST: BEND1
TEST2: BEND2

Observations:

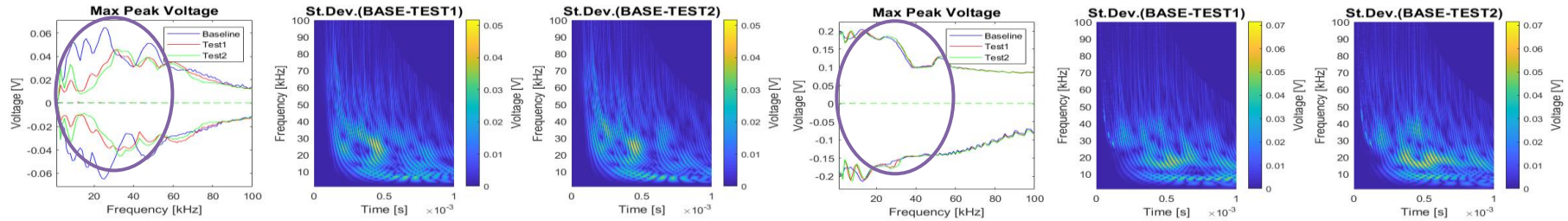
- *Sensor 2 is more affected from Bending than Sensor 3*
- *Difficult to understand the information about Damage*
- *Necessary the Damage Index Algorithms*

PZT1-2 | **PZT1-3**

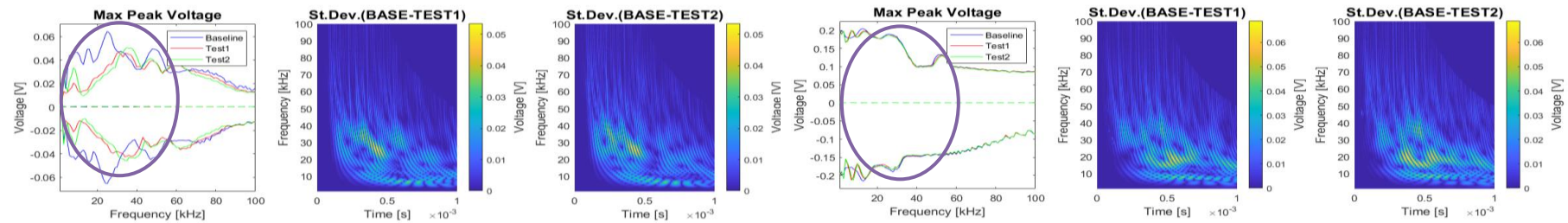
NO DAM



DAM1



DAM2



SHM Off-line Results: Specimens

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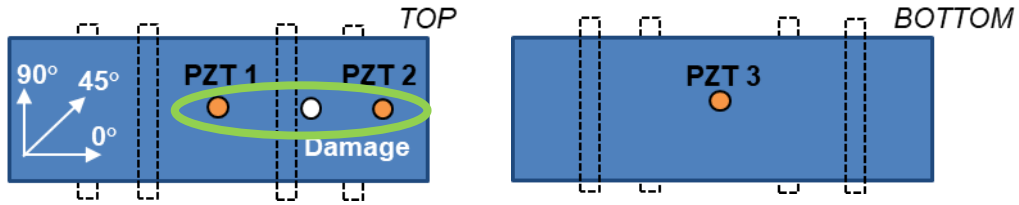
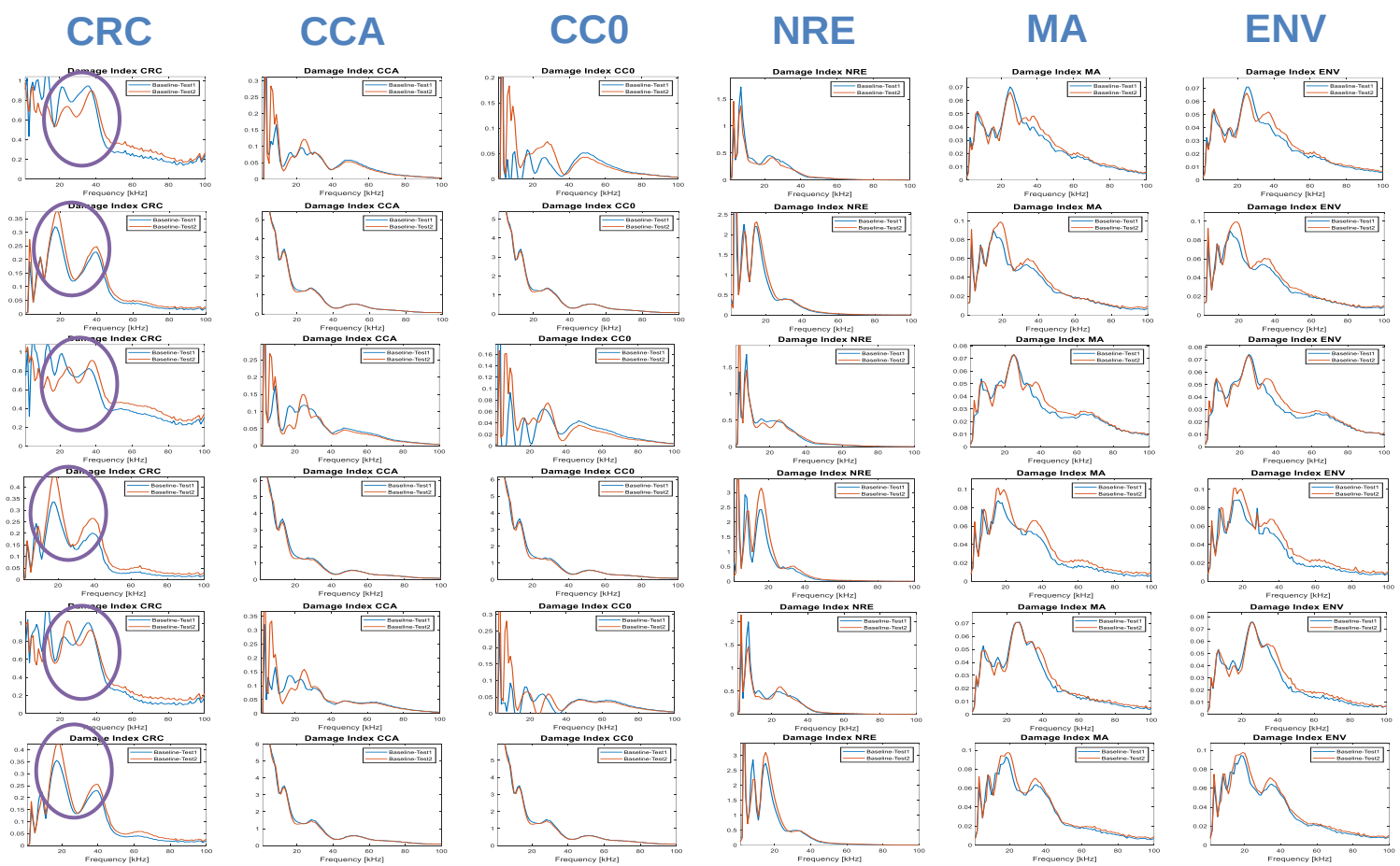
*Example of Data Processing for **CFRP Simulacrum***



BASE: BEND0
TEST: BEND1
TEST2: BEND2

NO DAM — PZT1-2, PZT1-3
DAM1 — PZT1-2, PZT1-3
DAM2 — PZT1-2, PZT1-3



Observations:

- *Different absolute values for Damage Index Results*
- *Difficult to select the frequency sensitive to Damage*
- *Necessary a comparison between Damage Index algorithms at each frequency*

SHM Off-line Results: Specimens

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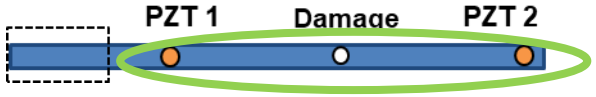
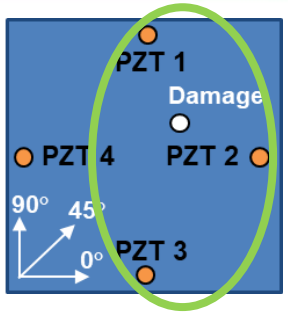
Percent Increment of Damage Indexes

Beam

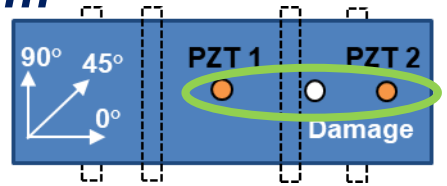


BASE: NO DAM
TEST: DAM1
TEST2: DAM2

Plate

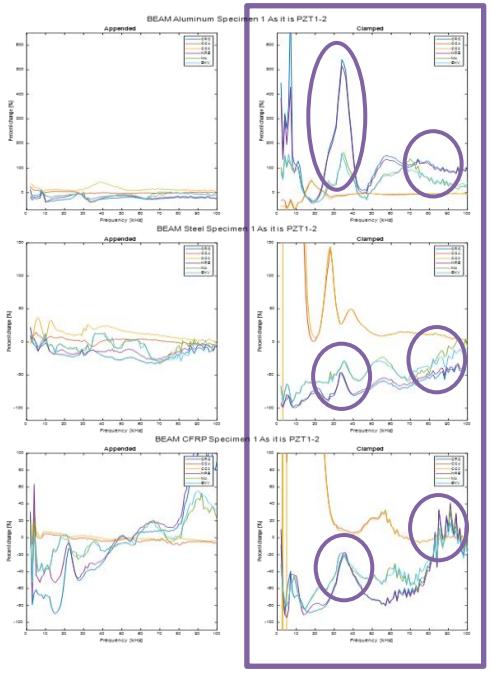


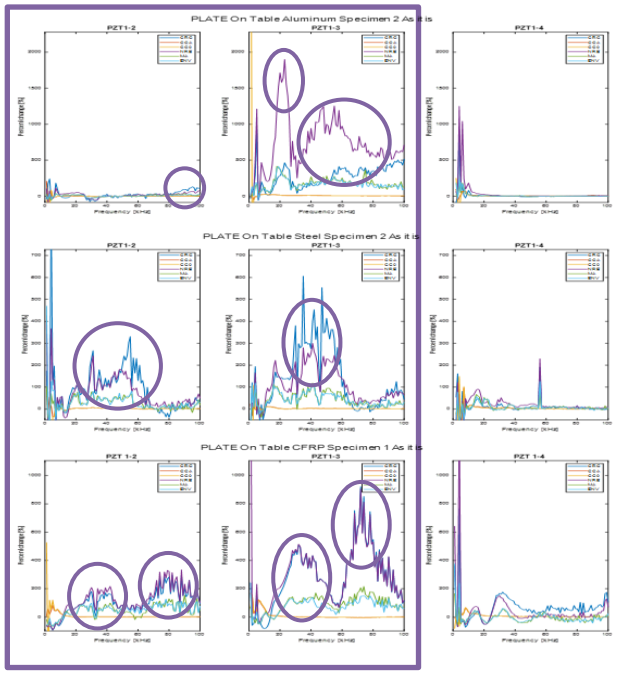
Simulacrum

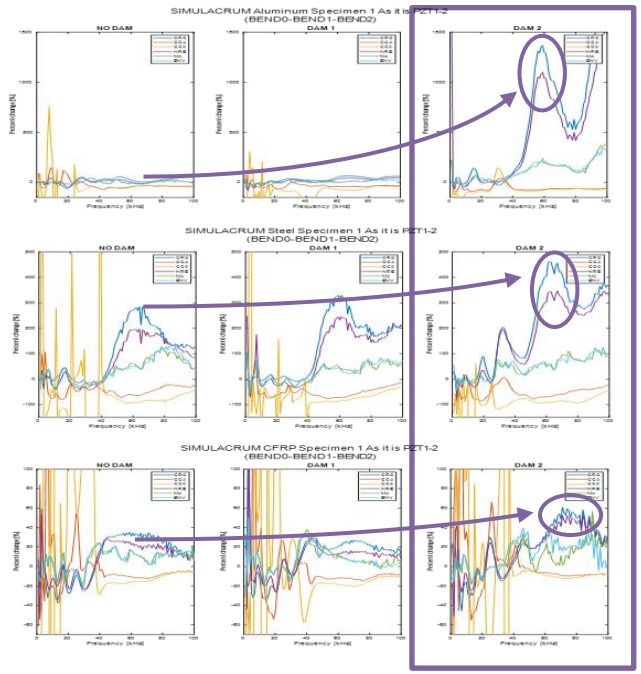


BASE: BEND0
TEST: BEND1
TEST2: BEND2

	Appended	Clamped	PZT 1-2	PZT 1-3	PZT 1-4	NO DAM	DAM1	DAM2
ALU								
STEEL								
CFRP								







CRC
CCA
CC0
NRE
MA
ENV

Damage Index increases with Stress (Clamped)

Sensitive Freq: 35, 90 kHz

Damage Index increases for the piezo couples on damaged path

Sensitive Freq: 35, 90 kHz

Damage Index increases with Stress (Bend 2) and Damage (DAM2)

Sensitive Freq: 75 kHz → Leaf Spring

SHM Off-line Results: Leaf Spring

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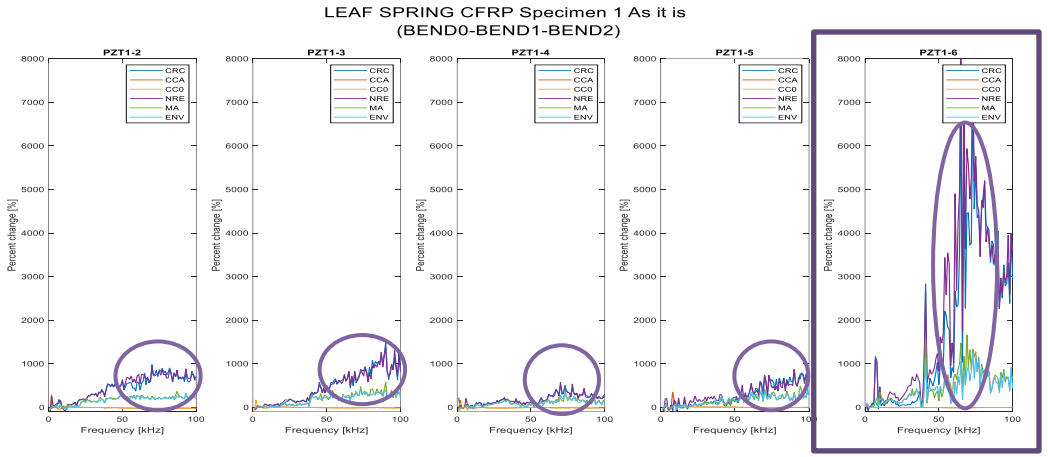
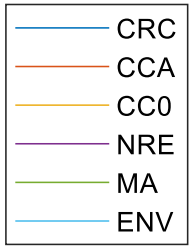
Evaluation of Bending Static Loading effect on the Damage Index

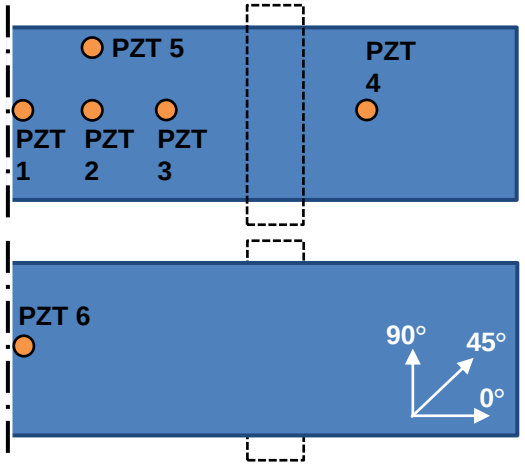
For Example:

PZT 1-2 **PZT 1-3** **PZT 1-4** **PZT 1-5** **PZT 1-6**

BASE: BEND0
TEST: BEND1
TEST2: BEND2







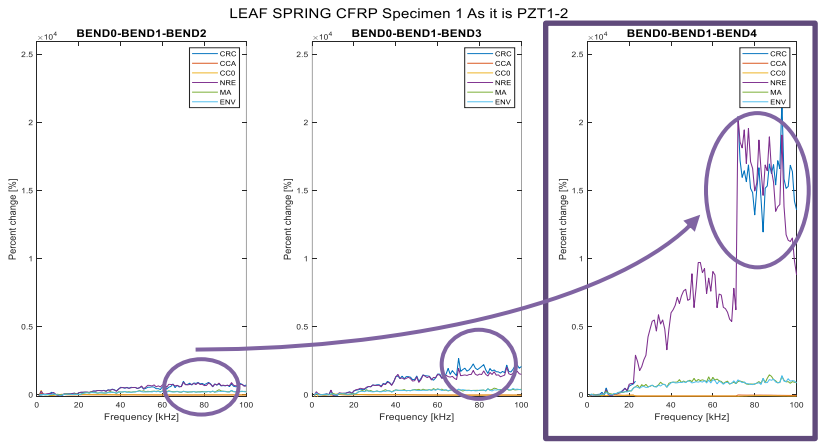
For Example:

PZT 1-2

BASE: BEND0
TEST: BEND1
TEST2: BEND2

BASE: BEND0
TEST: BEND1
TEST2: BEND3

BASE: BEND0
TEST: BEND1
TEST2: BEND4



Observations:

- ***Bending Step 2*** *shows a Damage Index higher than Bending Step 1 for all Piezo couples*
- *Piezo couple* ***PZT 1-6 (bottom)*** *is the most sensitive to Bending Loading*
- *Sensitive* ***Frequency 75 kHz***

- *Each Piezo couple shows a* ***great increasing*** *of Damage Index* ***with Bending Load***
- *The most sensitive Damage Index Algorithms are* ***CRC and NRE***

SHM On-line Results: Leaf Spring

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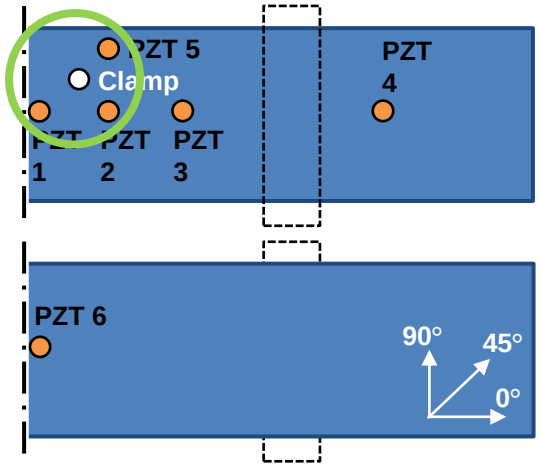
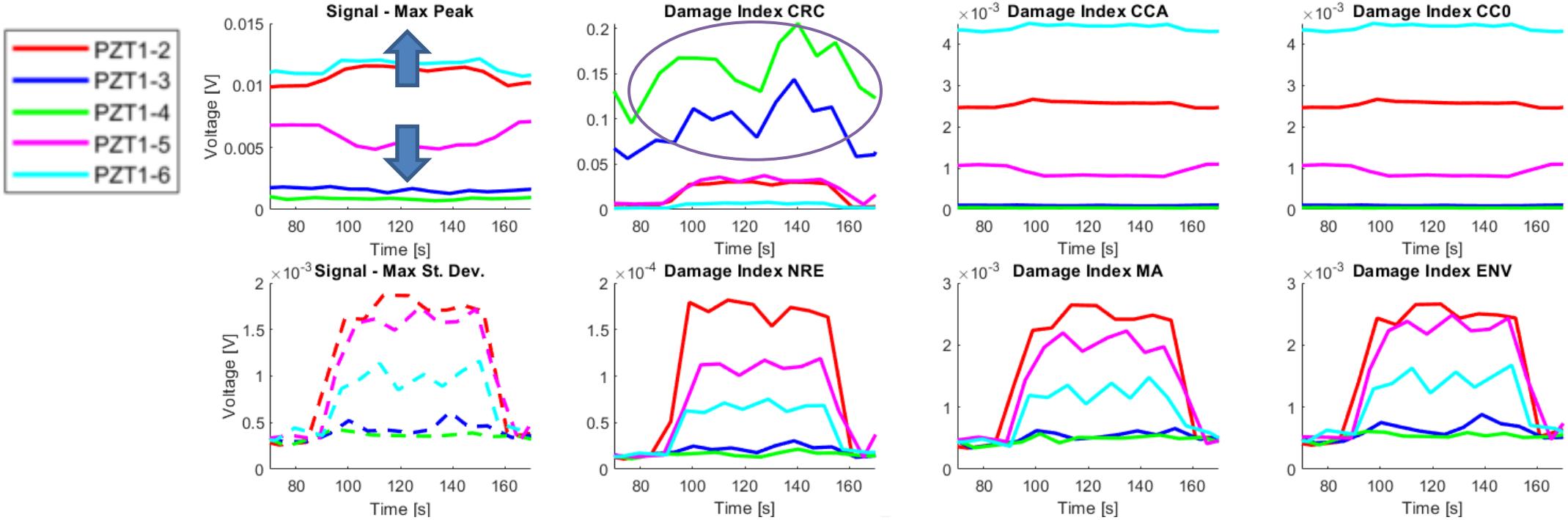
Leaf Spring Static condition
Clamp applied after baseline



Observations:

- *Clamping is **successfully detected by Sensors 2, 5, 6***
- ***CRC Algorithm** is also sensitive for the other Sensors far from clamp*
- ***The signal Amplitude** increases for Sensors 2 (0°) and 6 (bottom), decreases for Sensor 5 (45°)*



SHM On-line Results: Leaf Spring

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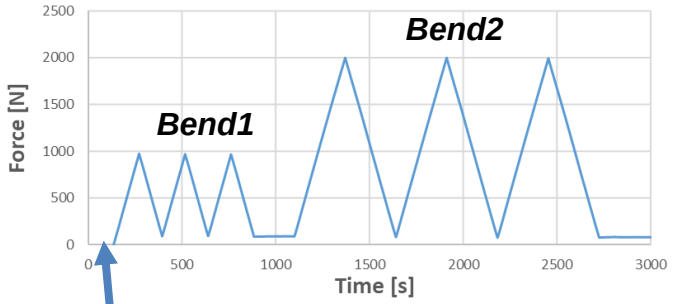
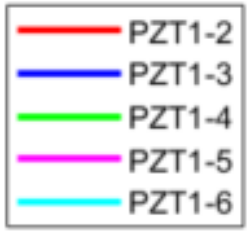
Cyclic loading (5mm/min)

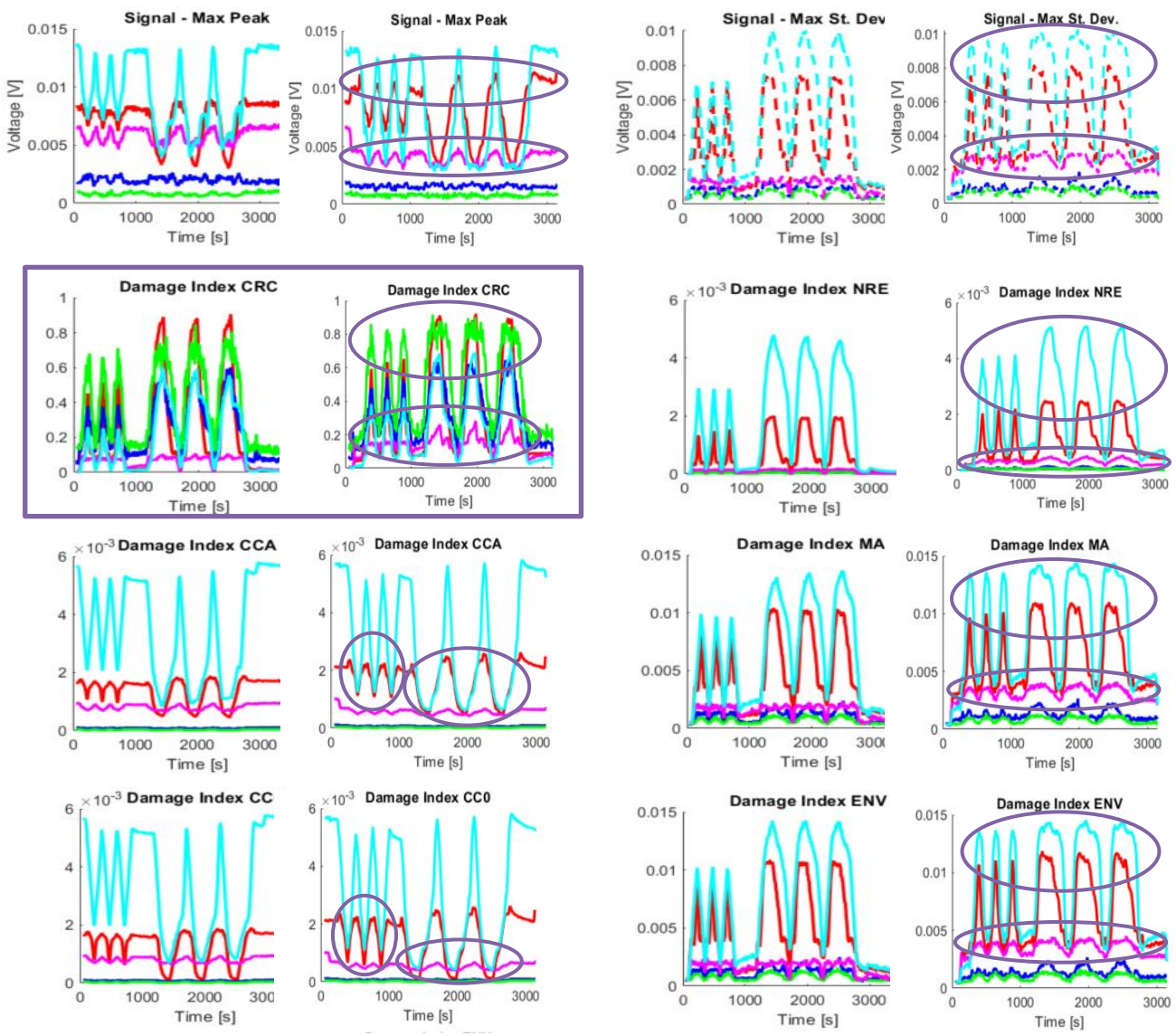


Clamp applied after baseline



Observations:

- *All Damage Index Algorithms show **great variations with cyclic loading***
- *The clamping is **successfully detected by Sensors 2, 5, 6***
- ***CRC Algorithm** is also sensitive for the other Sensors far from clamp*



Virtual Simulations: Roadmap

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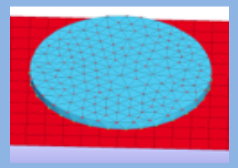
From sensor modelling…

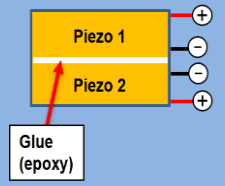
… to Sensor Positioning

PZT Modelling



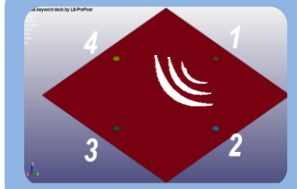
- Piezoelectric effect simulation
- Meshing techniques

Voltage-Displacement Conversion



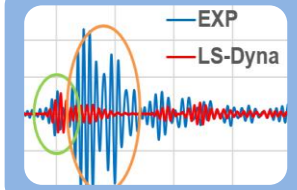
- Correlation with special test Piezo-to-Piezo
- Voltage from virtual Displacement

Vibrational Models



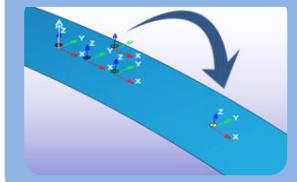
- Piezoelectric patches positioning
- Specimen Model setup

Numerical-Experimental Correlation



- Voltage Signal Comparison EXP-SIM
- First waves and Edge reflections

Indication for Sensor Positioning



- Voltage Signal Comparison EXP-SIM

Piezo Modelling and Correlation

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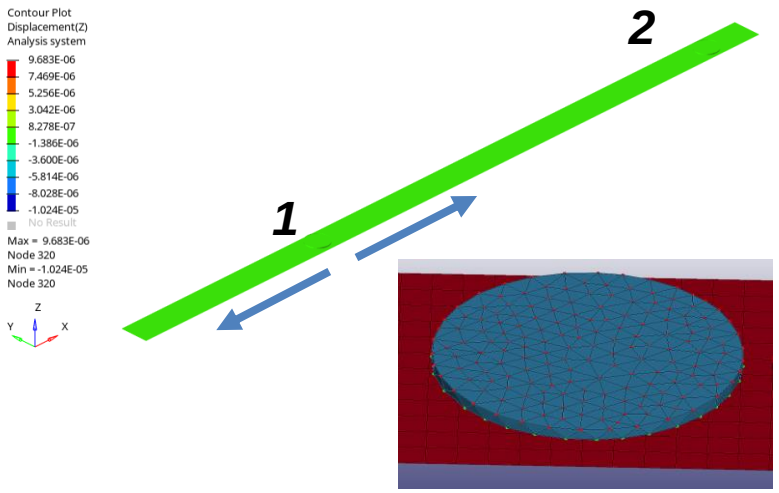
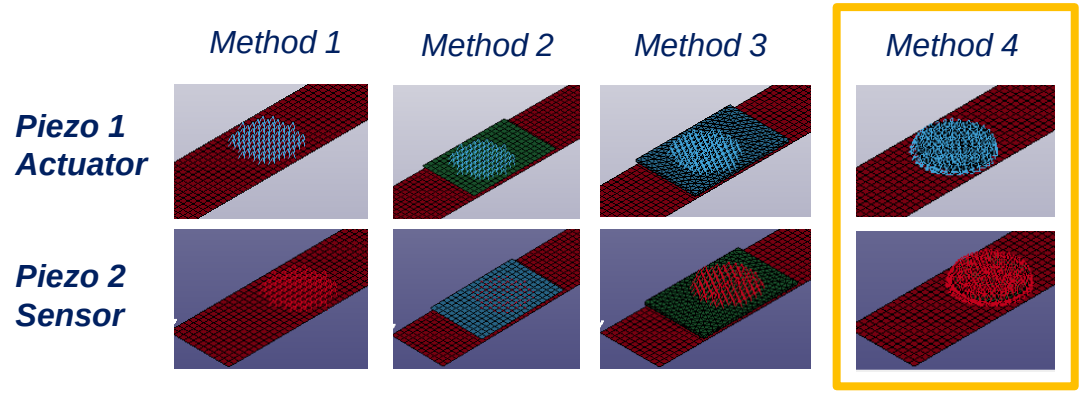
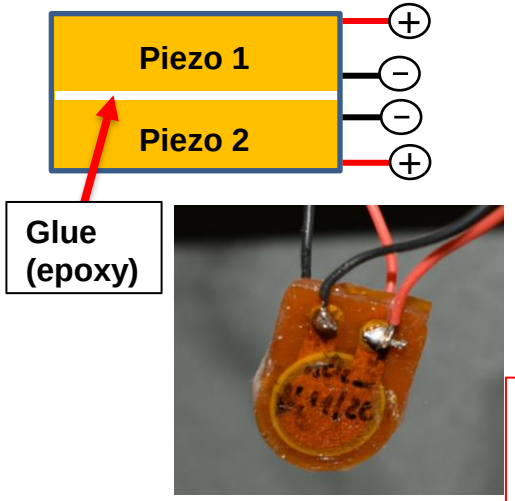
Modelling Methodology based on Beam specimen





Beam	Piezo	Input Keyword	Output Keywords	Glue
Shell 2D	Solid 3D	Prescribed motion	Displacement → Nodout Force → Nodefor Piezo Contact Force → Recforc	None

Special test Piezo-to-Piezo to correlate the Sensor Signal:



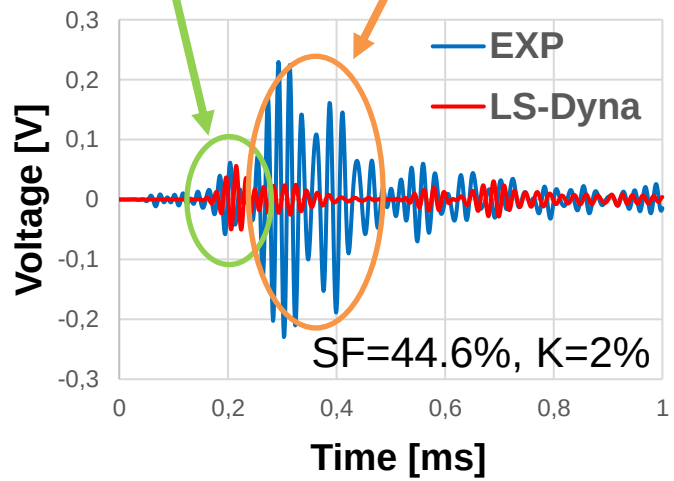
Piezo 1		Piezo 2		
Input [V]	Input [mm]	Output [mm]	Output [V]	Output [V]
10	SF·4 10^{-6}	1.6·10^{-7}	6E-2	6E-2
			SIM	EXP

$\Delta TH[mm] = \mathbf{SF}*4E\text{-}7*U\ [V]$
SF = Scale Factor
for Actuator correlation

$U = \mathbf{K}*\Delta TH[mm]/4E\text{-}7$
K = Coefficient
for Sensor correlation

First Wave
Good Correlation

Edge Reflection
Not important



FEA Results

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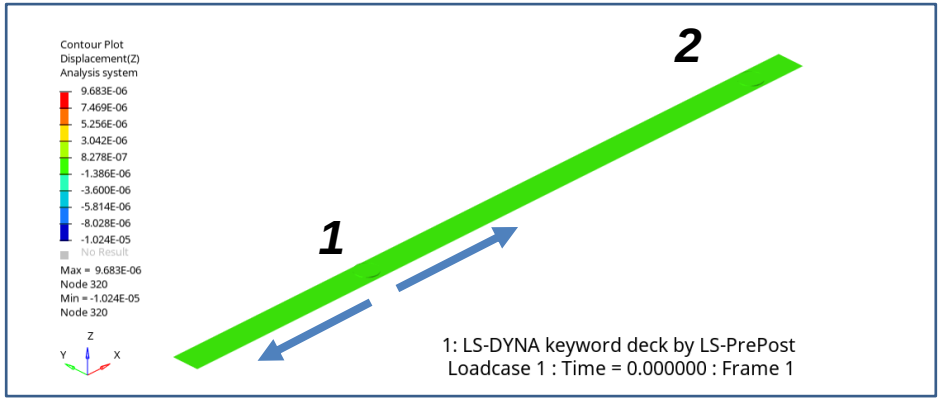
Simulated Configurations:

- Free condition (no Clamps, no Bending)
- Health condition (no Damage)
- 3 frequencies for each model (25,50,75 kHz)

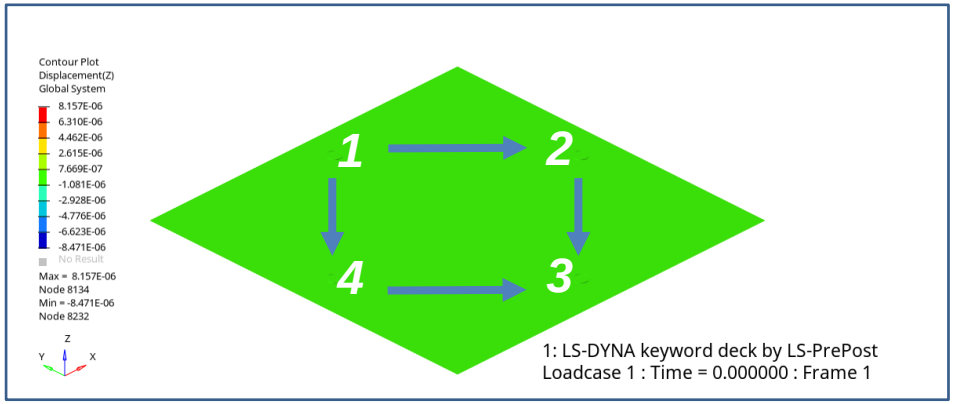
Visualization:

- z-displacement for specimens
- 1st principal stress (normal) for Leaf spring

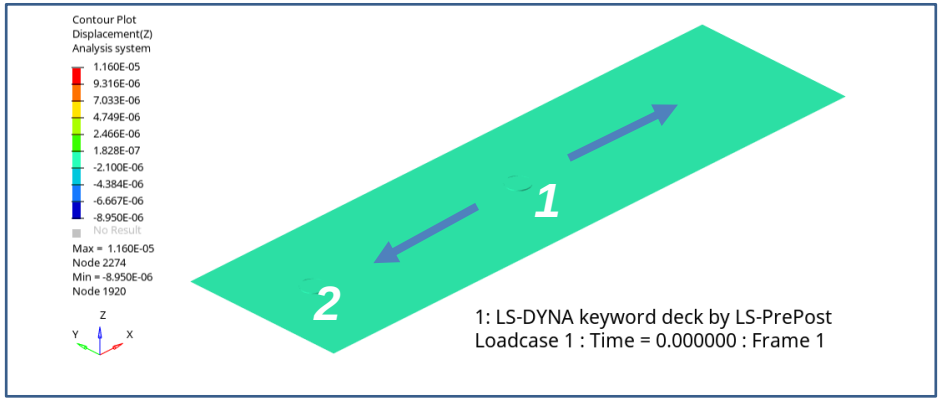
Beam



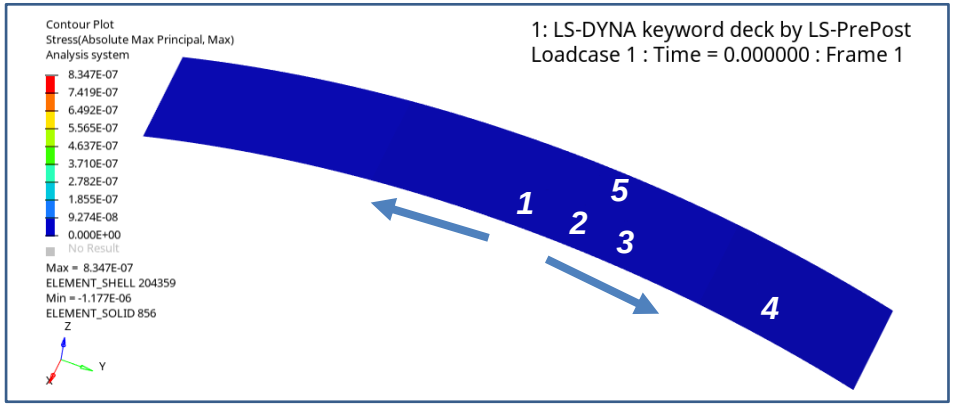
Plate



Simulacrum



Leaf Spring



SHM correlation: Leaf Spring

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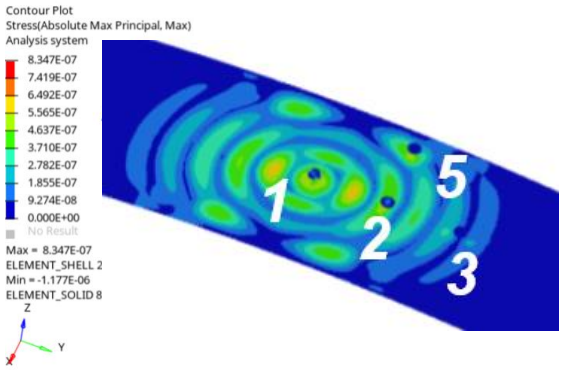
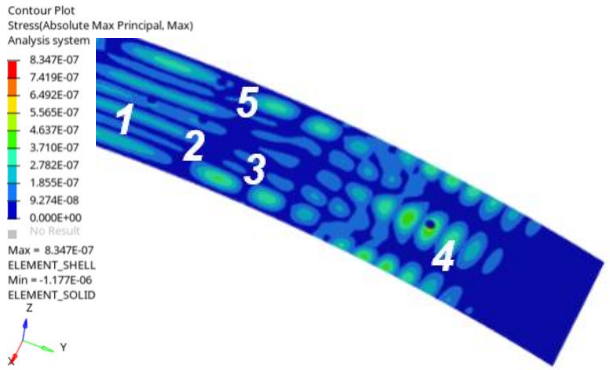
Wave behavior on Sensors PZT 2,3,5 Closer to Actuator:

Directionality due to CFRP Orthotropy

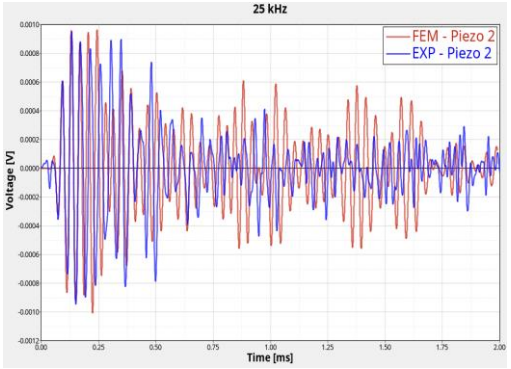


Wave behavior on Sensor PZT 4 Far from Actuator:

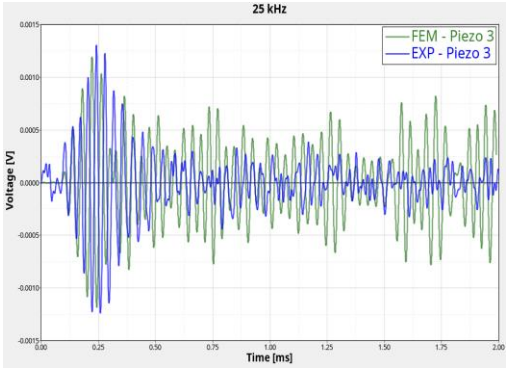
Wave arrival with a delay (Time of Flight)



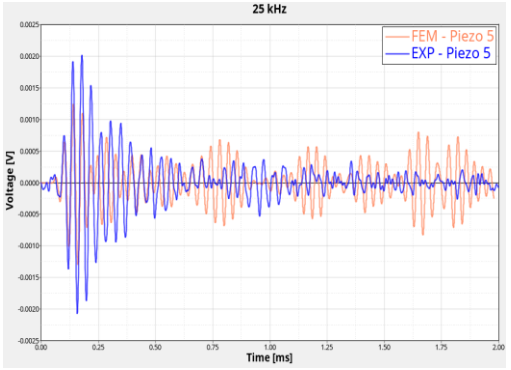
PZT1-2 – Distance 55mm 0°



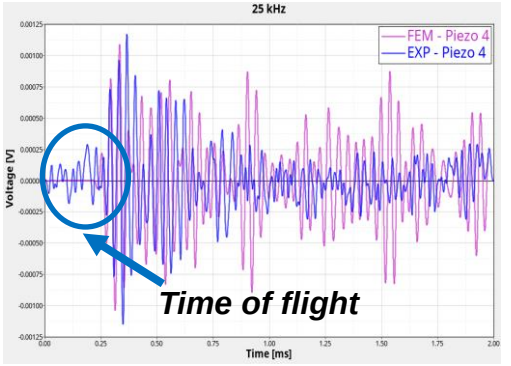
PZT1-3 – Distance 110mm 0°



PZT1-5 – Distance 55mm 45°



PZT1-4 – Distance 305mm 0°



Good Voltage Amplitude Correlation for all Sensors

Sensor Network design a-priori is possible!

Final Remarks

The following results can be highlighted:

- ***SHM Technology has been successfully applied to Automotive component***
- ***Piezo Sensor response changes with materials, stress condition and damage type***
- ***Frequency of 75 kHz is the most sensitive to Damage and bending load for Leaf Spring***
- ***Damage Index Algorithms need fine tuning and lots of experimental data***
- ***Damage Index values must be linked to Strain measurements***
- ***CRC is the preferred Algorithm to monitor Damage and bending load for Leaf Spring***
- ***Simulation of structure has been found to be a support for the Sensor Network design***

Applicability of SHM on CFRP Automotive components is possible !

Internal Project

Application of SHM system on leaf spring suspension of a real vehicle

PI2MAP Project

"Piezoeletric sensors Integration on composite MAnufacturing Process for predictive MAintenance on structural composite Parts"

in collaboration with:
SFC Compositi S.r.l., Beond S.r.l., FRAP S.p.a., MEC S.r.l. ***(Italian Partners)***
FRACTAL Technologies GmbH, Rollax GmbH ***(German Partners)***

Period:

April 2020 – April 2022

Objectives:

Develop an electronic system to identify critical damaging during the operation of smart components, aiming a predictive maintenance protocol

PhD Courses

Ing. Lorenzo Sisca
Audition to the Final Exam - XXXIII Cycle

Code	Internal PhD Course	Type	Exam date	Points	Hours
01SHGRO	*Acoustics and Vibroacoustics in Transportation Engineering (didattica di eccellenza)*	Hard	8/2/2018	13.33	10
01SCWRO	*Giunzioni strutturali : progettazione, processi e tecnologie*	Hard	6/11/2018	50.00	30
01SIQRO	*Material Fastening and Joining Research (didattica di eccellenza)*	Hard	9/7/2018	40.00	30
01REPIW	*Modellizzazione avanzata di problemi strutturali con elementi finiti*	Hard	14/6/2018	50.00	30
02JEIRP	*Programmazione degli esperimenti industriali*	Hard	20/6/2018	41.67	25
01SFURV	*Programmazione scientifica avanzata in matlab*	Hard	13/4/2018	26.67	20
01LEXRP	*Strumenti e tecnologie per lo sviluppo del prodotto*	Hard	8/5/2018	41.67	25
01RISRO	*Public speaking*	Soft	15/2/2018	6.67	5
01QORRO	*Writing Scientific Papers in English*	Soft	21/3/2018	20.00	15
01RRPRO	*Lean startup and lean business for innovation management*	Soft	24/7/2018	33.33	20
01SWPRO	*Time management*	Soft	22/2/2019	2.67	2

External Training Activity	Type	Activity Date	Hours
AUTOTEQ 5G Conference 2020 *- Tecnologie embedded, connettività 5G e cybersecurity nel settore [...]*	Hard	2/12/2020	14
ALTAIR Virtual ATCx Composites *- A Complete Composite Workow for all Industries*	Hard	2/12/2020	6
ATT Angelantoni Test Technologie *- Webinar Corso Base Tecnici Prove Ambientali Simulate*	Hard	18/11/2020	6
MODCOMP FINAL EVENT 2020 Webinar *- Novel engineered fibre-based materials for technical, high value [...]*	Hard	29/9/2020	2
Orbit Express *- Training su banca dati brevettuale*	Hard	16/9/2020	1
MCM-SAVE Web Edition*. Strumentazione di misura, big data, software, IoT. Dal processo al manifatturi [...]*	Hard	3/7/2020	6
LabVIEW FPGA *- National Instruments Online Training Course*	Hard	13/4/2020	4
LabVIEW Real-Time 1 *- National Instruments Online Training Course*	Hard	13/4/2020	4
LabVIEW Core 2 *- National Instruments Online Training Course*	Hard	12/4/2020	4
LabVIEW Core 1 *- National Instruments Online Training Course*	Hard	12/4/2020	4
DIMEAS - Corso di Formazione *per l'utilizzo di ZwickRoell Retroline Schenck RSA100 con Software [...]*	Hard	29/1/2020	4
Structural Health Monitoring: A Machine Learning Perspective *- October Friday Seminars of DISEG*	Hard	4/10/2019	6
AUTOTEQ 5G Conference 2019 *- Tecnologie embedded, connettività 4G-5G e cybersecurity nel sett [...]*	Hard	20/6/2019	7
EATC/AVK Seminar *- Discover the Potential of Thermoplastic Composites*	Hard	27/5/2019	10
Trasferimento Tecnologico *e Valorizzazione dei risultati della ricerca scientifica*	Soft	20/11/2018	6
Multiplier Event del progetto S.T.R.E.E.T. *Sustainable Transport Education for Environment and Touri [...]*	Hard	30/5/2018	4
JEC WORLD 2018 Seminar *- Automotive: how to change the production scale?*	Hard	6/3/2018	3
DIMEAS - Corso di Formazione *per l'utilizzo del sistema DANTEC DYNAMICS DIC (Digital Image Corre [...]*	Hard	1/2/2018	4
Workshop on MICROMECHANICS*, MODELLING AND FAILURE OF COMPOSITES - PoliTO/Purdue ''Joint [...]*	Hard	15/12/2017	4

Hours:

HARD SKILLS	170(Int.) + 93(Ext.)
SOFT SKILLS	42(Int.) + 6(Ext.)
TOTAL	***311***

Points:

HARD SKILLS	263.33(Int.) + 93(Ext.)
SOFT SKILLS	62.67(Int.) + 6(Ext.)
TOTAL	***425***

Scientific Production

Ing. Lorenzo Sisca
Audition to the Final Exam - XXXIII Cycle

2020

1. Carello, M., Ferraris, A., Airale, A.G., Messana, A., **Sisca, L.**, de Carvalho Pinheiro, H., Reitano, S., 2020. *Experimental Characterization of Piezoelectric Transducers for Automotive Composite Structural Health Monitoring*. Presented at the WCX SAE World Congress Experience. https://doi.org/10.4271/2020-01-0609
2. de Carvalho Pinheiro, H., Russo, F., **Sisca, L.**, Messana, A., De Cupis, D., Ferraris, A., Airale, A.G., Carello, M., 2020. *Advanced Vehicle Dynamics through Active Aerodynamics and Active Body Control*. Presented at the Proceedings of the ASME IDETC/CIE 2020, Virtual, Online. https://doi.org/10.1115/DETC2020-22290
3. de Carvalho Pinheiro, H., Castro dos Santos, P.G., **Sisca, L.**, Scavuzzo, S., Ferraris, A., Airale, A.G., Carello, M., 2020. *Dynamic Performance Comparision between In-Wheel and On-Board Motor Battery Electric Vehicles*. Presented at the Proceedings of the ASME IDETC/CIE 2020, Virtual, Online. https://doi.org/10.1115/DETC2020-22306
4. de Carvalho Pinheiro, H., Russo, F., **Sisca, L.**, Messana, A., De Cupis, D., Ferraris, A., Airale, A.G., Carello, M., 2020. *Active Aerodynamics through Active Body Control: Modelling and Static Simulator Validation*. Presented at the Proceedings of the ASME IDETC/CIE 2020, Virtual, Online. https://doi.org/10.1115/DETC2020-22298
5. Messana, A., **Sisca, L.**, Ferraris, A., Airale, A.G., Carello, M., 2020. *Lightweight Design of a Multi-Material Suspension Lower Control Arm*. Presented at the Proceedings of the ASME IDETC/CIE 2020, Virtual, Online. https://doi.org/10.1115/DETC2020-22323
6. **Sisca, L.**, Locatelli Quacchia, P.T., Messana, A., Airale, A.G., Ferraris, A., Carello, M., Monti, M., Palenzona, M., Romeo, A., Liebold, C., Scalera, S., Festa, A., Codrino, P., 2020. *Validation of a Simulation Methodology for Thermoplastic and Thermosetting Composite materials considering the effect of Forming process on the Structural performance.* MDPI, Special Issue Polymers, 12(12), pp. 2801. https://doi.org/10.3390/polym12122801
7. **Sisca, L.**, Virgillito, E., Ferraris, A., Airale, A.G., Carello, M., 2020. *Influence of Freeze-Thaw Aging on the Impact Performance of Damped CFRP Materials for Automotive applications*. Journal of Sandwich Structures and Materials, SAGE Publications ***(submitted and waiting for revision).***

2019

8. Carello, M., Bertipaglia, A., Messana, A., Airale, A.G., **Sisca, L.**, 2019. *Modeling and Optimization of the Consumption of a Three-Wheeled Vehicle*. Presented at the WCX SAE World Congress Experience. https://doi.org/10.4271/2019-01-0164
9. de Carvalho Pinheiro, H., Ferraris, A., Galanzino, E., **Sisca, L.**, Carello, M., Airale, A., Messana, A., 2019. *All-wheel drive electric vehicle modeling and performance optimization*. SAE TECHNICAL PAPER SERIES. https://doi.org/10.4271/2019-36-0197
10. de Carvalho Pinheiro, H., Messana, A., **Sisca, L.**, Ferraris, A., Airale, A.G., Carello, M., 2019. *Torque Vectoring in Electric Vehicles with In-wheel Motors*, in: Uhl, T. (Ed.), Advances in Mechanism and Machine Science, Mechanisms and Machine Science. Springer International Publishing, pp. 3127–3136. https://doi.org/10.1007/978-3-030-20131-9_308
11. de Carvalho Pinheiro, H., Messana, A., **Sisca, L.**, Ferraris, A., Airale, A.G., Carello, M., 2019. *Computational Analysis of Body Stiffness Influence on the Dynamics of Light Commercial Vehicles*, in: Uhl, T. (Ed.), Advances in Mechanism and Machine Science, Mechanisms and Machine Science. Springer International Publishing, pp. 3117–3126. https://doi.org/10.1007/978-3-030-20131-9_307
12. Ferraris, A., Messana, A., Airale, A.G., **Sisca, L.**, de Carvalho Pinheiro, H., Zevola, F., Carello, M., 2019. *Nafion® Tubing Humidification System for Polymer Electrolyte Membrane Fuel Cells*. Energies 12, pp. 1773. https://doi.org/10.3390/en12091773
13. Ferraris, A., Messana, A., Multari, D., **Sisca, L.**, Airale, A.G., Carello, M., 2019. *Steering System of a Low-Consumption Vehicle: From the Dynamics Analysis to the Design of the Wheel Assembly*, in: Carbone, G., Gasparetto, A. (Eds.), Advances in Italian Mechanism Science. Springer International Publishing, Cham, pp. 91–99. https://doi.org/10.1007/978-3-030-03320-0_10
14. Ferraris, A., Messana, A., **Sisca, L.**, Santoro, F., Airale, A.G., Carello, M., 2019. *Statistical Energy Analysis SEA: A Correlation Between Virtual and Experimental Results*, in: Carbone, G., Gasparetto, A. (Eds.), Advances in Italian Mechanism Science. Springer International Publishing, Cham, pp. 211–220. https://doi.org/10.1007/978-3-030-03320-0_23
15. Messana, A., **Sisca, L.**, Ferraris, A., Airale, A.G., de Carvalho Pinheiro, H., Sanfilippo, P., Carello, M., 2019. *From Design to Manufacture of a Carbon Fiber Monocoque for a Three-Wheeler Vehicle Prototype*. Materials 12, pp. 332. https://doi.org/10.3390/ma12030332
16. Sangermano, M., Antonazzo, I., **Sisca, L.**, Carello, M., 2019. *Photoinduced cationic frontal polymerization of epoxy–carbon fibre composites*. Polymer International 0. https://doi.org/10.1002/pi.5875
17. Virgillito, E., Airale, A.G., Ferraris, A., Sisca, L., Carello, M., 2019. *Specific Energy Absorption Evaluation on GFRP Laminate Plate by Optical, Thermographic and Tomographic Analysis*. Exp Tech 43, pp. 15–24. https://doi.org/10.1007/s40799-018-0257-y
18. Messana, A., **Sisca, L.**, Getti, C., Malvindi, A., Ferraris, A., Airale, A., Carello, M., 2019. *Design, Optimization and Manufacturing of an Aluminum Wheel Rim for the IDRAkronos Vehicle Prototype*. Computer-Aided Design and Applications 16, pp. 733–741. https://doi.org/10.14733/cadaps.2019.733-741

2018

19. Amirth Jayasree, N., Airale, A.G., Ferraris, A., Messana, A., **Sisca, L.**, Monti, M., Romeo, A., Carello, M., 2018. *Complete material characterisation of thermoplastic composite laminate at forming state*. Presented at the International Symposium on Dynamic Response and Failure of Composite Materials, Ischia, Naples, Italy.
20. Messana, A., **Sisca, L.**, Getti, C.M., Malvindi, A., Ferraris, A., Airale, A.G., Carello, M., 2018. *Design, Optimization and Production of Aluminum Alloy Rim for the Vehicle Prototype IDRAkronos*. Presented at the Proceedings of CAD'18, Paris, France, pp. 112–116. https://doi.org/10.14733/cadconfP.2018.112-116

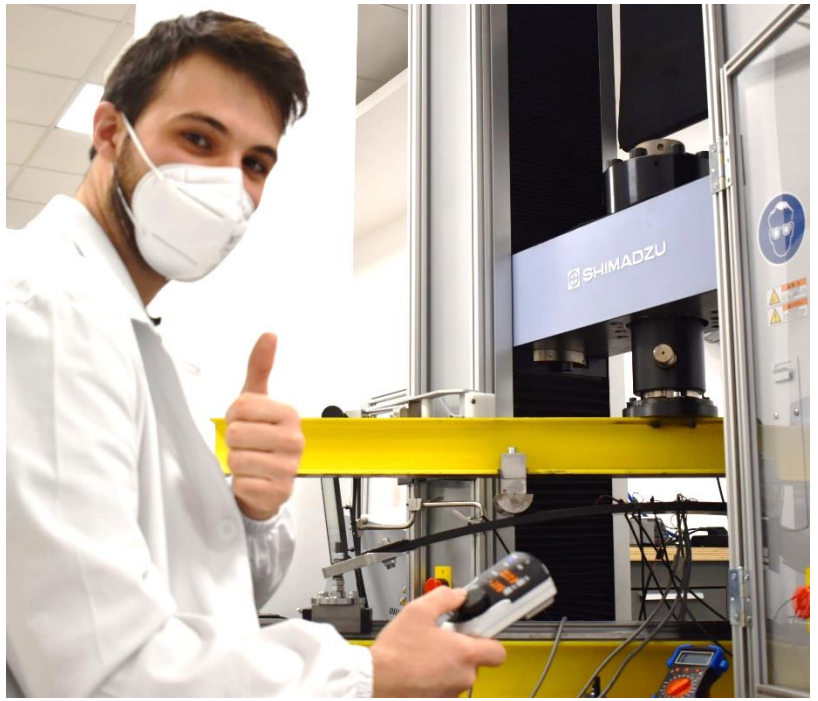
2017

21. **Sisca, L.**, Airale, A., Massai, P., Xu, S., Ferraris, A., 2017. *Function integration concept design applied on CFRP cross leaf spring suspension*. International Journal of Automotive Composites 3, 276. https://doi.org/10.1504/IJAUTOC.2017.10012546
22. Carello, M., Airale, A. G., Ferraris, A., **Sisca, L.**, Messana, A., Amirth Jayasree, N., 2017. *Process analysis for structural optimisation of thermoplastic composite component using the building block approach.* Composites Part B: Engineering 126, pp. 119–132. https://doi.org/10.1016/j.compositesb.2017.06.007
23. Messana, A., Airale, A. G., Ferraris, A., **Sisca, L.**, Carello, M., 2017. *Correlation between thermo-mechanical properties and chemical composition of aged thermoplastic and thermosetting fiber reinforced plastic materials: Korrelation zwischen thermomechanischen Eigenschaften und chemischer Zusammensetzung von gealterten thermo- und duroplastischen faserverstärkten Kunst.* Materialwissenschaft und Werkstofftechnik 48(5). https://doi.org/10.1002/mawe.201700024
24. Carello, M., Airale, A. G., Ferraris, A., Messana, A., **Sisca, L.**, 2017. *Static Design and Finite Element Analysis of Innovative CFRP Transverse Leaf Spring.* Applied Composite Materials 24(6). https://doi.org/10.1007/s10443-017-9596-6

Academic Role	Period
Esercitatore per il Corso di Meccanica delle macchine *02IHSMA (Docente Prof.ssa Gabriella Eula)*	March - June 2019
Esercitatore per il corso di Chassis design *04MSGLO (Docente Prof.ssa Massimiliana Carello)*	January 2019

Research Project	Period
PI2MAP "Piezoeletric sensors Integration on composite MAnufacturing Process for predictive MAintenance on structural composite Parts" in collaboration with: SFC Compositi S.r.l., FRACTAL Technologies GmbH, FRAP S.p.a., MEC S.r.l., Rollax GmbH, Beond S.r.l.	April 2020 - in progress
CARBOGREEN "Analisi stato dell'arte sui materiali compositi green e riciclabili, caratterizzazione sperimentale di tali materiali compositi e supporto alla definizione di carte materiale per il calcolo" in collaboration with: Sabelt S.p.a.	2019 - 2020
BITMAP "Bracci Telescopici estraibili in MAteriale composito per Piattaforme aeree" in collaboration with: MULTITEL PAGLIERO S.p.a.	2019 - 2019
ACTL_2 "Balestra trasversale in materiale composito per applicazioni automotive" in collaboration with: SFC Compositi S.r.l., MEC Engineering S.r.l., BLUE Engineering S.r.l., Proplast	2018 - 2019

Award	Description
ASME2020 DED/AVT Best Student Paper Award	The Paper "*Active Aerodynamics through Active Body Control: Modelling and Static Simulator Validation*" presented at ASME IDETC/CIE 2020 Virtual Conference has been awarded as "Best Student Paper at the 22nd AVT Conference" from the Design Engineering Division and Advanced Vehicle Technologies.
SAE2020 Best Paper with WCX	The Paper "*Experimental Characterization of Piezoelectric Transducers for Automotive Composite Structural Health Monitoring*" presented at SAE 2020 World Congress Experience (WCX 2020) has been awarded as one of the "Best papers for WCX" and has been selected to appear in SAE International Journal of Advances and Current Practices in Mobility.



Thank you for the attention!