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Project acronym: **HyPactor**

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HYPACTOR

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Content

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1. Executive summary

1.1. Description of the deliverable content and purpose

This deliverable is the third of the WP4 of HYPACTOR project. It provides the summary of results of the WP4 entitled Inspections methods.

1.2. Deviation from objectives, corrective action

N/A

1.3. Technical progress

N/A

1.4. Impact of the results

N/A

1.5. Dissemination activities

1.5.1. Publishable summary of the deliverable

The deliverable D4.10 summarizes the results of WP4 activities.

1.5.2. Dissemination activities

Public Deliverable.

2. List of figures

3. Deliverable report

3.1. Summary description of the project objectives

The main objective of HYPACTOR is to provide recommendations for Regulation Codes and Standards (RCS) regarding the qualification of new designs of COPV and the procedures for periodic inspection in service of COPV subjected to mechanical impacts.

To this aim, experimental and numerical work will be combined with feedback from experience in order to:

- Understand & characterize the relationship between the impact, the damage and the loss of performance of COPV at short term and after further pressure loads in service;
- Identify the impact conditions that produce short time failure of COPV and assess long term influence of impacts on COPV performance;
- Develop models to predict short term residual performance of the impacted COPV;
- Assess relevant (non-destructive) inspection procedures and define pass-fail criteria for COPV in service subjected to mechanical impacts;
- Disseminate the scientific knowledge and revised methodology for qualification and inspection.

The hypactor project structure is detailed below:

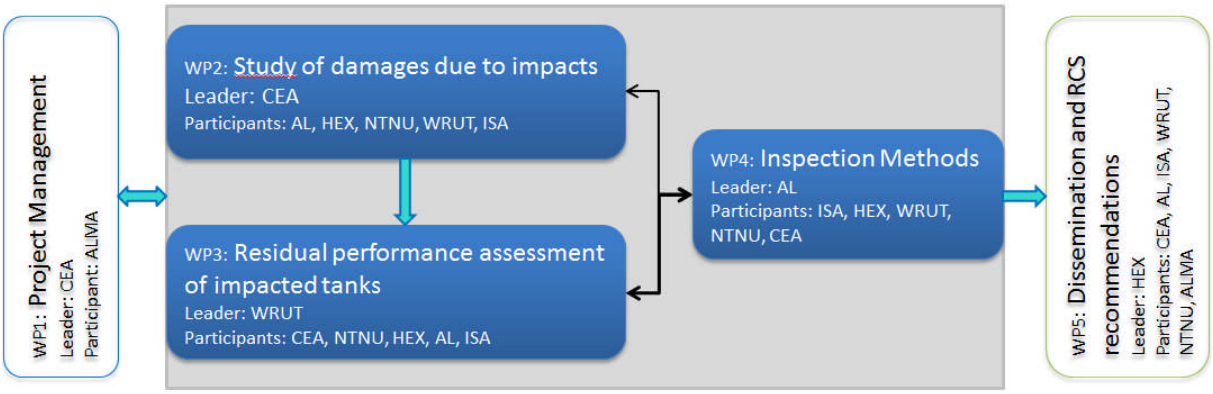


Figure 1: Hypactor project structure.

3.2. Brief description of the work performed since the beginning of the project and results achieved

During these first 18 Months, activities have mainly been focused on:

- Project management issues (templates, Quality Assurance Plan, website public/private, communication tools);
- Literature and industrial reviews on reported incidents involving high pressure cylinders and industrial constraints to perform non-destructive inspection on site;
- First testing campaigns to determine impact conditions leading to immediate failure and respective influence of load conditions (cylinder empty, gas pressure, water pressure, energy levels).
- Industrial constraints for NDT in operation
- Definition of NDT protocols for damage characterization and for COPV inspection
- Definition of AE trial plan

3.3. Summary of the WP4 objectives and results by tasks

3.3.1. WP4 Description

In WP4, periodic inspection of COPV by Non Destructive Testing (NDT) methods will be assessed. Two NDT methods will be studied as they are the most mature, already supported in standards (visual inspection) or in development (Acoustic Emission Testing). Other NDT techniques will be applied in the project as R&D expertise tools or exploratory techniques in order to characterize the characteristic parameters of the damages induced by mechanical impacts and thus allow the calibration of AE and visual inspection with respect to critical damage level.

The objectives of this WP are thus to define:
• NDT protocols to be used in WP2 and WP3 to assess composite damages (characterization of damages);
• A Pass Fail criteria for visual and Acoustic Emission Testing methods corresponding to the pass-fail criteria in terms of tolerance to damage of composite pressure vessels, identified in WP3;
• Recommendations for inspection procedures suitable with operating constraints for considered applications (the field of application of each technique will be clarified with regards to the COPVs of the project).

3.3.2. Results by task

WP4 is split into the following tasks:

- **Task T4.1 – Industrial constraints for NDT in operation (AL-M1–M3)**

The goal of this task is to give the operating conditions for the implementation of Non Destructive Testing (NDT) methods on type IV COPV. The main application of such vessel is on gas transportation by trailer (figure 2) and on refuelling stations. Two NDT methods are studied as they are the most mature already supported in standards and potentially used for periodic inspection of COPV: visual inspection of accessible areas and Acoustic Emission Testing during pressurization.

To this aims, HEXAGON and Air Liquide worked together in order to provide respectively experience in pressure vessels manufacturing and operating & maintenance.

The operating conditions to consider for the implementation of AE monitoring and visual inspection directly on site were provided. In order to not dismount vessels from the frame, the best way to achieve Acoustic Emission Testing is to use a filling bench in a filling centre or directly at the application site, allowing to pressurize at least to maximum service pressure.

Another possibility could be to perform Acoustic Emission Testing in a dedicated AE workshop (eventually in an existing retest centre) or at an accredited agency. However, this solution would lead to more perturbation in the supply chain process for an industrial gas provider. This could be a backup solution.

Figure 2: Hexagon Lincoln TITAN™ Trailer on the road.

- **Task T4.2 – Definition of characterization NDT protocols (ISA, M5 – M9)**

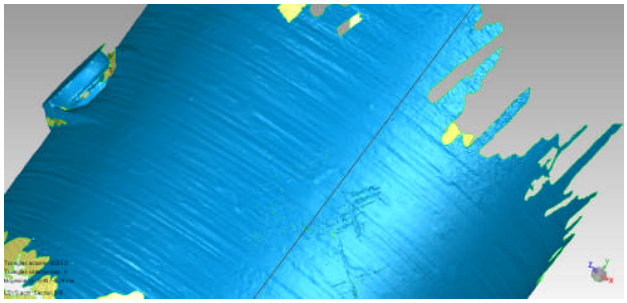
The goal of this task is to identify the best NDT techniques to characterize the defect taking into account the type, strength, location of impact.

A list of potential NDT has been established with expected performance in terms of damage characterization, threshold and data needed for simulation. NDT techniques are therefore dispatched on different partners (ISA, CEA and WRUT).

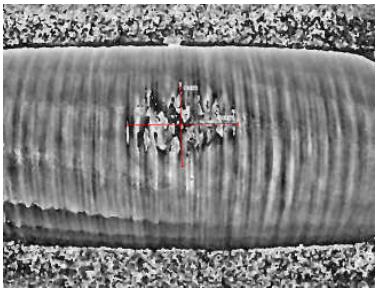
The first impacted cylinders have been inspected at CEA with X-Ray technique and videoendoscopy, and at ISA with the following techniques:

- Ultrasonic
- Laser 3D scanning
- Thermography
- Deflectometry
- Shearography

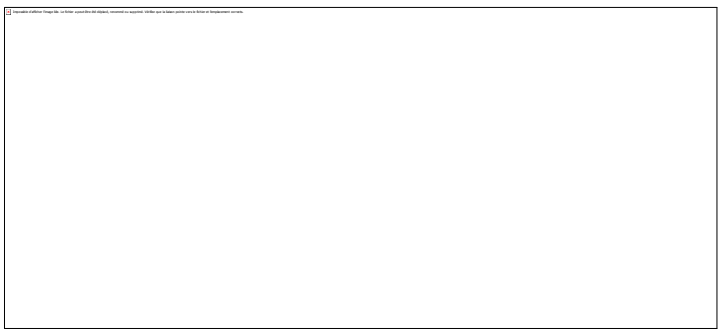
Some results are illustrated in the figure below.



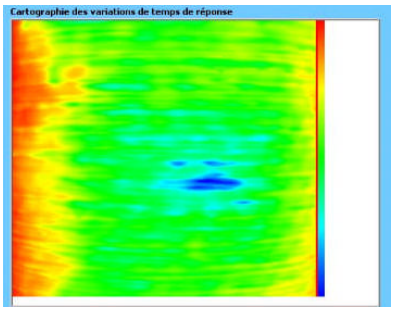
Laser 3D



Shearography



Ultrasonc C-scan



Thermography

Figure 3: Some NDT results.

In order to limit discrepancies, NDT procedures were written by ISA. These procedures include calibration, setting-up and reporting format for each NDT. The relevant NDT was then selected in accordance with all partners, and applied for damage characterisation on all vessel experienced.

- **Task T4.3 – Collection of AE data (ISA, M5 –M30)**

The goal of this task is to collect all Acoustic Emission data coming from the tests on COPV conducted in WP2 & WP3. To do that, an AE trial plan has been built by all partners and an AE procedure was defined.

The procedure aims to reduce acquisition parameters dispersion, and reliably compare data recorded via different systems (multi-channel system, preamplifier, sensors, products of Vallen and Mistras) of the project partners. This procedure describes AE implementation for COPV hydraulic test. All the verification before and after the pressure test are then detailed:

- Personnel qualification
- AE Instrumentation & Acquisition parameters
- Preliminary tests (before loading)
- Pressurizing test
- Operations after test
- Security

Front view **Bottom view**

Figure 4: An example of sensors location on 36L Hexagon COPV. (Burst chamber CEA)

In order to define acquisition parameters (threshold, DDT, RAT, PDT, HDT, HLT), a calibration test was performed on 36L (figure 4) using ISA and CEA instrumentation and then using CEA and WRUT instrumentation. Results of calibration test using pencil lead breaks (PLB) are similar in terms of amplitude, number of hits and waveform. An example of PLB calibration is showed in figure 5.

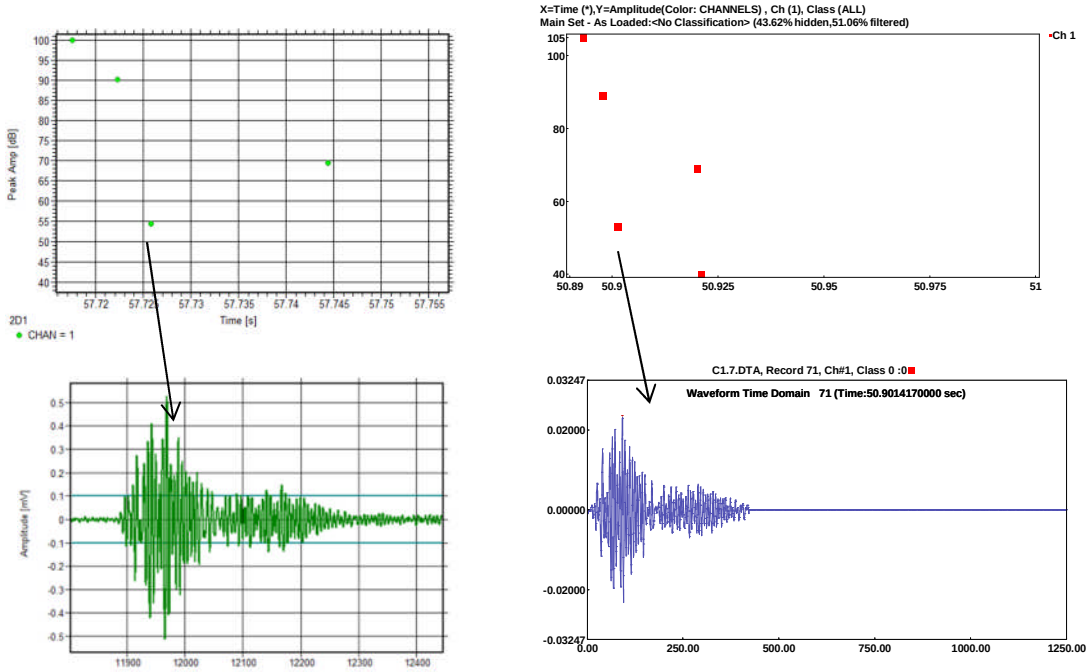


Figure 5: Calibration of the two systems (vallen left and Mistras right) with pencil lead breaks.

Results of pressure test using Vallen AMSY5 (ISA) and MISTRAS PCI2 (CEA) systems are also similar (figure 6).

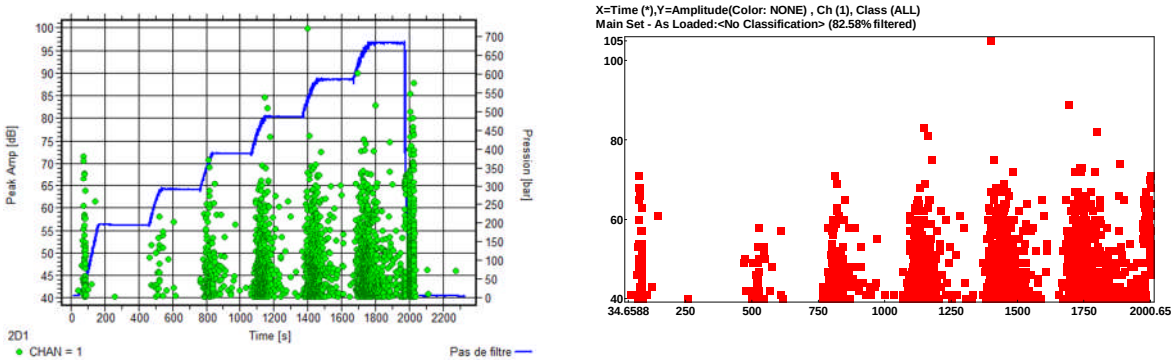


Figure 6: AE activity during hydraulic pressure test of COPV (vallen left and Mistras right).

- **Task T4.4 Development & Validation of pass-fail criteria by NDT (visual inspection & AE) (ISA, M10–M36)**

The goal of this task is to define pass-fail criteria to be used in periodic inspection of COPV by combination of visual examination and AE test.

This task is not yet started.

3.4. Expected final results and their potential impact and use

The key expected impacts of HYPACTOR results are:

- The development of an extensive experimental database on mechanical behaviour of composite vessels submitted to impacts;
- An improved understanding of short & long terms residual performance of impacted COPV;
- Identification of relevant impact conditions that are likely to induce cylinder failure;
- The development of a model for quantitative prediction of mechanical behaviour of impacted composite vessels;
- The assessment of Non Destructive Testing with respect to inspection of COPV.

3.5. Address of public website

www.hypactor.eu

3.6. Conclusion

This deliverable summarizes the work achieved in the WP4 entitled “Inspections methods” during the first period of the project (M1-M18). The revision of this deliverable will be performed in M30 (Sept 2016).