HyPactor

Pre-normative research on resistance to mechanical impact of composite overwrapped pressure vessels

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Programme Review Days 2017
Brussels, 23-24 November

PROJECT OVERVIEW

- Call year: 2013
- Call topic: SP1-JTI-FCH.2013.5.6: Pre-normative research on resistance to mechanical impact of pressure vessels in composite materials
- Project dates: 01/04/2014-30/06/2017
- % stage of implementation 01/11/2017: 100%
- Total project budget: 4 049 293 €
- FCH JU max. contribution: 2 143 665 €
- Other financial contribution: No
- Partners: CEA; AIR LIQUIDE; HEXAGON; INSTITUT DE SOUDURE; POLITECHNIKA WROCLAWSKA (WRUT); NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET (NTNU); AYMING

PROJECT SUMMARY

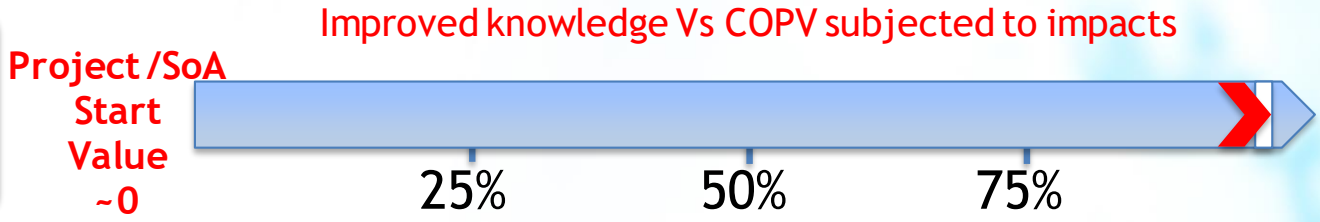
HyPACTOR

- **Objectives**
  - Provide **recommendations for Regulation Codes and Standards** (RCS) regarding the **qualification** of new designs of Composite Overwrapped Pressure Vessel (COPV) and the procedures for periodic inspection in service of **COPV subjected to impacts**
  - Create an **extensive experimental database** on characteristics of damage induced by impacts on COPV with respect to pressure levels, tank specificities and impact parameters
  - Provide scientific and technical data to assess the **effect of pressure load on COPV impact sensitivity**
  - Identify **dramatic impacts** that may lead to **immediate failure** of COPV and critical impacts that would reduce the residual strength below acceptable safety levels
  - Define impact damage that may propagate in service and decrease the safety level of COPV at **medium to long term**
- **Application and market area**
  - H2 storage and transportation

PROJECT PROGRESS/ACTIONS

Achievement to-date

% stage of implement.



Aspect addressed	Parameter (KPI)	Unit	SoA 2017	FCH JU Targets		
				Call topic	2017	2020
Improved knowledge on impacted type-IV COPV	• Identify impact conditions that may lead to immediate failure • Open access to project experimental database (more than 220 impacts)	%	90	SP1-JTI-FCH.2013.5.6		

Hypactor's output to the COPV & RCS community:
Open access to Hypactor's experimental database

http://www.hypactor.eu/

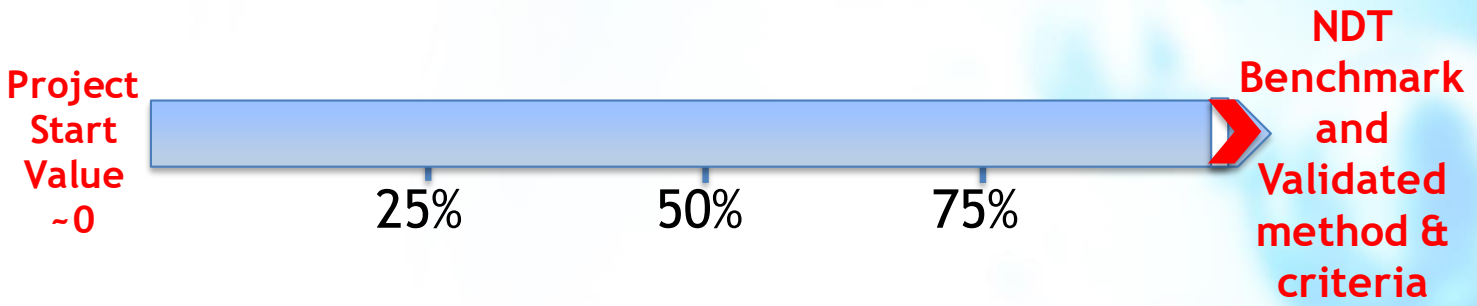
Future steps: *impacts on domes*

Extensive db 223x34
Nb of impacts : 223
Nb of bursts : 37
Nb of cycles : ~248 300
Nb of records: 55MAE+ 87AE
tanks : PS=25; 70 and 95MPa
Volume= 36; 255; 513L

PROJECT PROGRESS/ACTIONS

Achievement to-date

% stage of implement.

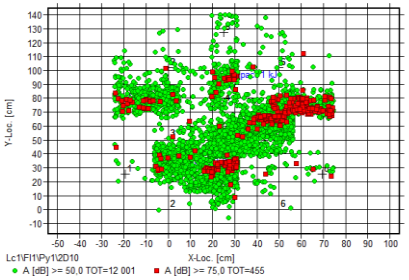


Aspect addressed	Parameter (KPI)	Unit	SoA 2017	FCH JU Targets		
				Call topic	2017	2020
Inspection procedure	• Non-destructive method developed (AES) • Real time and post-processing criteria validated for inspection whatever the cycling period	%	100	SP1-JTI-FCH.2013.5.6		

Future steps:

New project to enlarge vessel panel and contribute to extend the validity area to other suppliers/materials.

Use AE in the field for COPV inspection

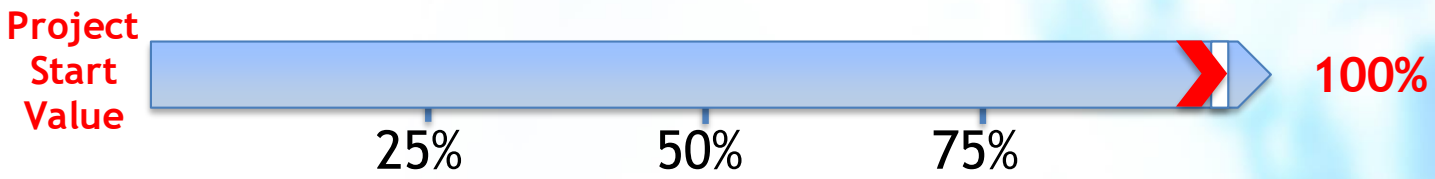


PROJECT PROGRESS/ACTIONS

HyPACTOR

Achievement to-date

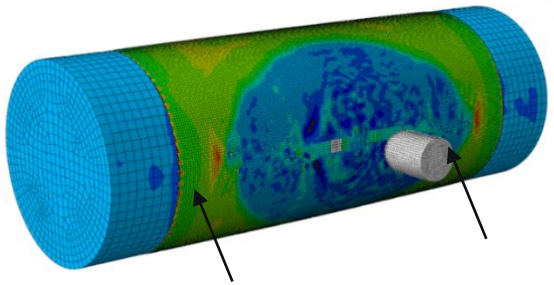
% stage of implement.



Aspect addressed	Parameter (KPI)	Unit	SoA 2017	FCH JU Targets		
				Call topic	2017	2020
Numerical modelling	A first 3D FE model for quantitative prediction of mechanical behaviour of impacted composite pressure vessels including fatigue	%	100	SP1-JTI-FCH.2013.5.6		

Future steps:

- *The model has only been applied to a few experimental cases*
- *The modeling principle will be published, but validation/confidence needs to be built*
- *Future experimental studies will provide targeted experimental results for comparison, e.g. NO - MoZees project started 2017.*
- *Adequate damage characteristics required to feed the model*



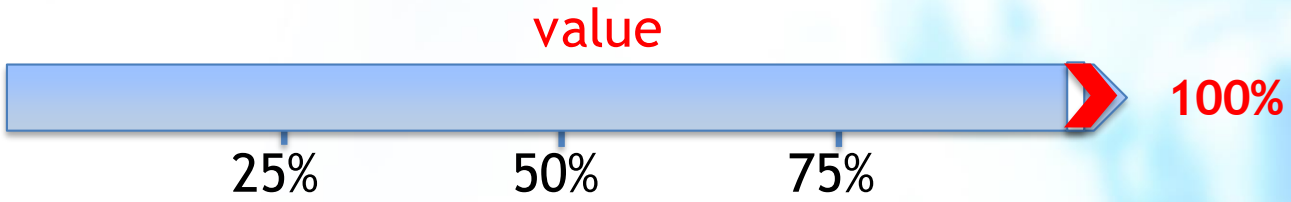
Failure in progress

PROJECT PROGRESS/ACTIONS

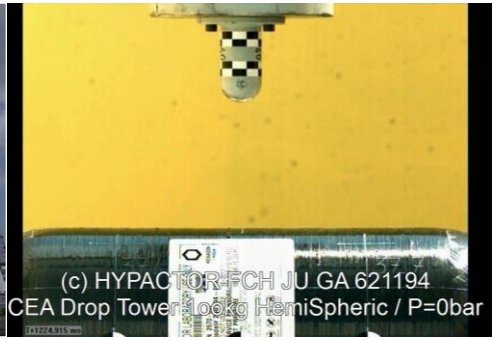
Achievement to-date

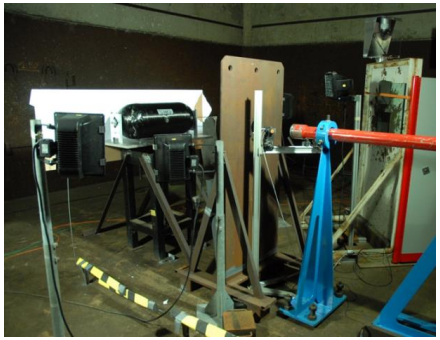
% stage of implement.

Current standard derived from low pressure metallic cylinders



Aspect addressed	Parameter (KPI)	Unit	SoA 2017	FCH JU Targets		
				Call topic	2017	2020
RCS	Provide recommendations on testing configuration	-	Benchmark drop tower and pneumatic canon on empty and pressurized COPV Testing configuration and methodology recommended	-	-	-



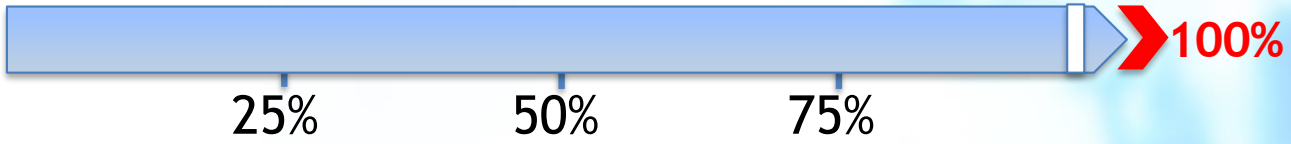


PROJECT PROGRESS/ACTIONS

Achievement to-date

% stage of implement.

Current standard derived from low pressure metallic cylinders



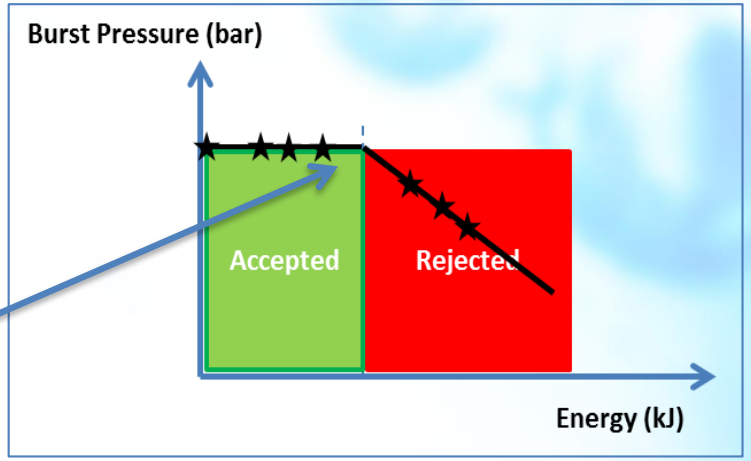
Aspect addressed	Parameter (KPI)	Unit	SoA 2017	FCH JU Targets		
				Call topic	2017	2020
RCS	Provide recommendations on periodic inspection and qualification	-	Benchmark drop tower and pneumatic canon on empty and pressurized COPV Immediate failure level identified Testing configuration recommended Methodology for qualification and inspection Add. Work (not planned) on MAE (in order to provide technical feedback to FR/EU committees with respect to US ISO DIS 19016)	-	-	-

PROJECT PROGRESS/ACTIONS

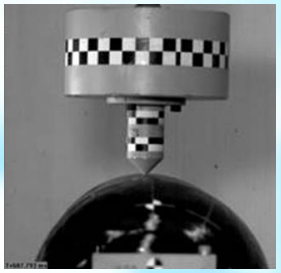
Recommendations on Periodic Inspection:

Hypactor recommends:
- determining the threshold impact each cylinder design can absorb, without reduction of burst capacity (inflexion point),
- When no better indication is available, Hypactor proposes a formula to make a first estimate of the threshold.
- Hypactor also recommends an impact test program to be included in qualification testing program and to complement the operating instruction manual with these pictures of impact damage (to be used as reference for inspection)

Burst pressure reduction curve with respect to impact energy can be used to assess COPV performance



$E_{incident} = (P_{burst} * R_i) \cdot 30.10^{-6} / 0.65 \cdot$ (units = S.I.)



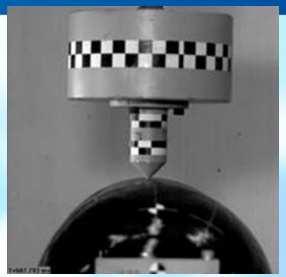
Recommendations on Qualification testing:

1- Cylinder manufacturer should specify an impact energy in relevance with the real resistance of their COPV (or estimated with the formula) and in accordance with cylinder application

2- Demonstrate by burst testing that the impacted cylinder can still demonstrate minimum burst capacity and no performance reduction compared to healthy cylinders batch results

3- Further testing with higher impact energy might be beneficial for evaluation of impacted cylinder in service (on voluntarily basis- not part of the initial type approval test program- but will help refining the threshold and provide visual pictures for inspection calibration).

PROJECT PROGRESS/ACTIONS



Recommendations on Periodic inspection:

- Visual examination
  - A visual aspect showing loose fibres should lead to vessel rejection, whatever the elliptic damaged surface
  - Some pictures of damage after impact may be plotted under the curve, with respect to impact energy level. Visual aspects larger than critical damage (reduction of burst pressure) should be rejected

- Acoustic Emission
  - Use of AE is more adapted to periodic inspection than to inspection at time of filling
  - Calibration of AE criteria should be performed for each vessel design, and connected to the burst pressure reduction curve, as well as visual inspection calibration

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES

- **Interactions with national and international-level projects and initiatives**
  - 4 meetings, 2 workshops and 3 regulatory ISO TC58 (SC4/WG15, SC3, SC3/WG32 and SC3/WG35) between February 2014 and June 2017. During those meetings, Hypactor was presented, feeding the experts with its outcomes and updates on impact energy.
  - Consortium participated to an ISO meeting on Modal Acoustic Emission (MAE) standard (TC58/SC4/WG15 DIS 16016).
  - Workshop with the French ANR project "TOLEDO" in 2014 on Damage tolerance of COPVs and discussion on test series and recommendations
  - The MAE database built in Hypactor is unique in Europe, as it was the first evaluation of this method on periodic inspection of type IV COPV. Results and comments were communicated to the WG15 through the project workshops (a webinar in November 2016, a workshop and webinar in June 2017) and also to AFNOR; a second presentation is planned for the next ISO meeting in November 2017 in the USA

DISSEMINATION ACTIVITIES

Public deliverables

- D2.1: Review of international impact related incidents on pressure composite tanks
- D2.3: Impact test matrix
- D5.5: Report on the recommendation for standardisation for periodic inspection
- D5.7: Report on the recommendation for standardisation for qualification testing

Conferences/Workshops

- 2 organised by the project
- 17 in which the project has participated (but not organised)

Social media

2 webinars available on YT: https://www.youtube.com/channel/UCtm3bCwTuUIy1JzMjZgIhrw

Publications: 3

- "Acoustic Emission of Composites Structures: Story, Success, and Challenges", Physic Procedia, F. Dahmene & al. (ISA), 2015
- The sensitivity of the burst performance of impact damaged pressure vessels to material strength properties, IOP Publishing, K. Lasn & al (NTNU), 2016
- Artificial impact damage for estimating the short-term residual burst pressure of COPVs, (submitted) Proceedings of ICCM-21, K. Lasn & al (NTNU+all partners), 2017

Patents: 0

Thank You!

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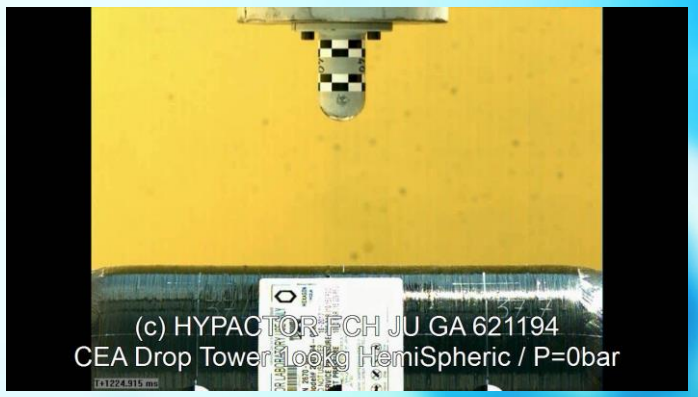

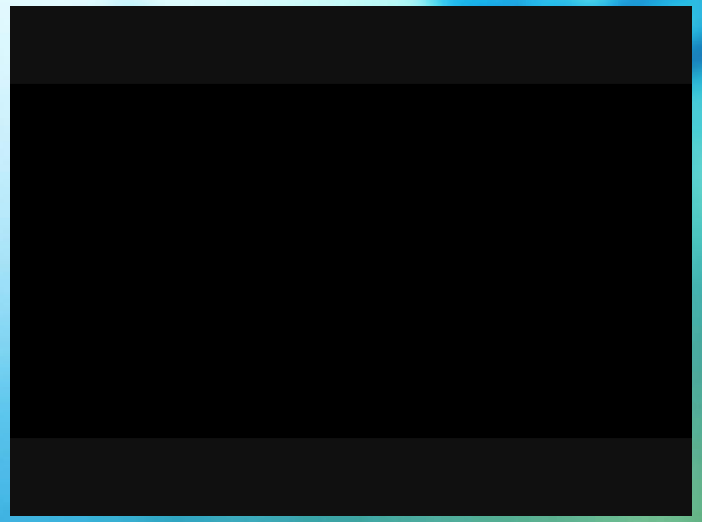

NEW – Hydraulic cycling [-40;+85C]
tanks up to 300L @1050bar
capability ΔV=46L @1050bar