COMP-ECO

PROJECT DELIVERABLE

D3.2 Report and Materials from Workshop on MANUFACTURING

LEAD BENEFICIARY:	TU DELFT
AUTHOR(S):	Otto Bergsma, Roger Groves (Delft)
CONTRIBUTOR(S):	Anna Zmiievska (TPF)
DATE OF ISSUE:	22/01/2024
DISSEMINATION LEVEL:	PU

https://www.comp-eco.eu/

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101079250

COMP-ECO

DOCUMENT HISTORY

Version and date	Changes
1.0 – 13/12/2023	Draft version, developed by Otto Bergsma (TU Delft)
1.1 – 12/01/2024	Reviewed by Roger Grooves (TU Delft)
2.0 – 15/01/2024	Reviewed and edited by Anna Zmiievska (TPF)
2.1 – 18/01/2024	Reviewed and approved by Quality and risk manager Georgios Tzortzinis (TU Dresden)
2.2 – 22/01/2024	Final version reviewed and approved by Michal Towpik (TPF)
3.0 – 24/06/2024	Added summary section by Nan Tao & Otto Bergsma (TU Delft)

DISCLAIMER

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101079250

CONTENTS

1. INTRODUCTION

1.1. ABOUT THE COMP-ECO PROJECT

The COMP-ECO project is aiming at improving the research excellence of the Polish Mazovia region-based ecosystem in the field of Fibre-Reinforced Polymer (FRP) multifunctional composites and smart structures. The ecosystem is formed by 3 organizations: Technology Partners Foundation (TPF), Air Force Institute of Technology (AFIT) and Warsaw University of Technology (WUT). These 3 Polish partners will be supported by two leading EU universities: Delft University of Technology from the Netherlands and Technische Universität Dresden from Germany.

For 3 years the COMP-ECO partners jointly implement exploratory research work to develop a technology for a permanent on-line non-destructive quality assessment of composite structures. For this purpose, 2 possible innovative sensing capabilities are being developed: (1) self-diagnostics capabilities through the introduction of electroconductive carbon nano tubes in the composite's matrix during the manufacturing process and (2) self-sensing capability through embedding PZT sensors, encapsulated in a thermoplastic fibrous material (veils), in the composite structure.

In addition to the research work, the project will organize technical workshops aimed on raising the research profile of Mazovian composite community, and management and administrative training workshops to strengthen research management capacities and administrative skills of the Polish partners' administrative staff.

The COMP-ECO activities will establish and strengthen a regional competence hub formed by TPF, AFIT and WUT, whose increased science and innovation capacities will lead to more ambitious collaboration with top EU research organisations and industry, higher participation in Horizon Europe, and a more attractive educational offer for students and young researchers.

1.2. SCOPE OF THIS DELIVERABLE

The scope of this deliverable is to provide a comprehensive overview of the organised workshop focused on the production (manufacturing) of Composite materials. The report encompasses three main areas: Workshop preparation, presentations, and outcomes.

Section 1 details the planning and organization process, including the identification of key objectives, target audience, and themes.

Section 2 focuses on the presentations delivered during the workshop. It provides an overview of the topics covered. Each presentation is summarized, highlighting key insights shared by the speakers.

Section 3 describes the actions taken to disseminate the outcome of the workshop and provide open-access training material to researchers interested in the design of multifunctional composites.

2. WORKSHOP PREPARATION

2.1 OBJECTIVES

The COMP-ECO project aspires to enhance the scientific knowledge and skills of Polish young researchers. A series of technical workshops are organised to provide an insight into the state of the art in multifunctional composites and smart structures based on a sustainable, holistic approach covering the whole product life chain, starting with the design of materials and structures, through appropriately used advanced methods of their production, testing of their properties, in-service aspects and finally reuse and recycling. The objectives of the workshops are not limited to knowledge sharing but aspire to promote open discussion with the participants in an effort to trigger brainstorming activities will enhance their problem-solving, idea generation and creativity capabilities.

2.2. COURSES TO BE COVERED

The second training workshop for research staff and students of Polish partners was held in Delft on October 26-27, 2023. The Workshop was delivered by the Professors of TU Delft's Faculty of Aerospace Engineering and covered the following courses, according to the Grant Agreement:

- **Tailoring of conventional and nonconventional laminates including aeroelastic effects**

This course provides an introduction to the physical and analytical aspects of aeroelasticity. It focuses on how composite materials can be tailored (choice of constituents, layer orientation, layer build-up, geometrical shape) to obtain structures with certain aero-elastic responses.

- **Smart structures – health monitoring and self-sensing capabilities of composites**

This is a course on developing the critical thinking needed to perform measurements in an NDI Laboratory. It includes an introduction to the most common sensors for experimental mechanics, non-destructive testing and structural health monitoring, evaluation of the performance of these sensors, selection of sensors for different applications and signal processing and control algorithms.

- **AI Development and Applications for Manufacturing**

This course provides an overview of artificial intelligence (AI) and its current use in manufacturing. In addition to a general overview of what AI is, the workshop will illustrate specific use cases on how AI can improve the manufacturing process using applications such as object classification, optimization, prediction, object detection, and combinations of applications to solve more complex problems. The workshop will show some of the current struggles with implementing AI in a real-world environment, and will share the best practice methods for resolving issues, testing, and bringing AI solutions into production.

2.3. WORKSHOP AGENDA

To cover the above topics, the following two-day programme (Table 1) was proposed by Delft, which was responsible for the organisation, and approved by the other partners during the regular consortium meeting in September 2023. In detail, the workshop consisted of 6 slots, each lasting 45 minutes to 1 hour, and included both lectures and activities.

TABLE 1: WORKSHOP PROGRAMME

	Thursday 26th October	Friday 27th October
9:00	Welcome	Start of day 2
09:15	Tailoring of conventional and non-conventional laminates including aeroelastic effects by Roeland de Breuker	AI Development and Applications for Manufacturing by Nathan Eskue
10:00	Break	
10:30	Tailoring of conventional and non-conventional laminates including aeroelastic effects - continued	AI Development and Applications for Manufacturing - continued
12:30	Lunch	

13:30	Smart Structures – health monitoring and self-sensing capabilities of composites by Roger Groves	Visit and Demo SamXL
14:30	qqBreak	
15:00	Smart Structures – health monitoring and self-sensing capabilities of composites - continued	Progress meeting COMP-ECO
17:00	Recap of the day	Recap of the day

2.4 TARGET AUDIENCE

The workshop was organised in the framework of WP3, which aims to provide state-of-the-art training to young researchers from the Polish consortium partners. To meet the requirements, both the presentations and the activities were adapted to the level of knowledge and potential of the graduate and PhD students from different backgrounds. It is worth noting that the vast majority of WUT and TPF participants have a strong background in materials science, while AFIT members have a broader range of studies and consist mainly of mechanical and aerospace engineers.

3. WORKSHOP MATERIAL

3.1 PRESENTATIONS

Within section a brief description of each activity taken place on the framework of the workshop is given.

- **Tailoring of conventional and nonconventional laminates including aeroelastic effects**

The first part of the workshop was on the application of the use of composites for aeroelasticity. This a multidisciplinary approach. This part of the workshop is did not have an interactive lab session as most validation is done in wind tunnel laboratories. However, data from real experiments is shown.

The interaction between structures and aerodynamics is clarified, as that is essential to aeroelasticity. A focus is given to when the interaction is called significant. Starting with some history on aircraft it was e.g. shown why bi-planes were preferred in the beginning of the fight era.

Building the wing is based on the shape at 1-g. For this to be found non-linear effects need to be taken into account. This seems trivial, but it is not. Next to this, flight performance of aircraft linked to weight and flight envelope is taken into account.

Flexop, a European project where a demonstrator was developed, with tailored wings was discussed. This aircraft was actually flown. Due to the limits in freedom in design, the result comparing unbalanced to balanced layup was not that spectacular, but still very significant. (e.g. 10% less moments at the wing root).

The actual testing was done with fibre optics measurements, finding loads and the wing shape during loading for this very slender wing. From the developments in this field it becomes clear that lowering the weight by tuning the build-up of the wing will only become possible when sufficient monitoring can be done.

The slides from this lecture are available via this link: Aeroelastic tailoring, Roeland De Breuker

- **Smart structures – health monitoring and self-sensing capabilities of composites**

The second part of the workshop was on health monitoring and self-sensing capabilities. There were two focus areas:

- Fibre optic sensing for smart structures and
- Guided wave ultrasonic sensing for smart structures.

These two areas were clarified via an interactive lecture, followed by lab demonstrations in the two areas of interest.

The fibre optic sensing part started by clarifying the principles of light wave measurement techniques, followed by more in depth explanation of the bragg grating method. A list of available commercial interrogators was given to supply links for potential usage. Applications were shown and discussed, so the field of application became clear. Two PhD research ware addressed, one on SmartX Morphing Wing and the other on Curing of thermoset polymers having a focus on space applications.

The ultrasonic wave propagation did also start with an explanation of the principles. Detection of damage within a structure was discussed and the possibilities of the electromagnetic wave spectrum was linked to that. The different waves types (longitudinal, shear, surface love, surface Rayleigh & lamb waves) were shown and linked to their usage. The principle of phased array ultrasonic beams was addressed and from that the differences between A, B and C scans. The last part was on guided waves ultrasonics, showing and comparing the results on non defect plates to defected plates.

The processing of these resulting signals was done via AI methods providing the link to the third session of this workshop.

The lab demonstrations were held in the Aero NDT lab, and the participants could talk with the researchers of TU Delft and discuss their personal interests, while witnessing the demonstration of the previously discussed focus areas.

The last part of the first day was a round-up meeting in the lecture room to give more opportunity to discuss topics of interest with the staff members.

The slides from this lecture are available via this link: "Roger Groves - Smart structures ".

- **AI Development and Applications for Manufacturing**

The part on AI started with story telling "But I wore the juice", all about a person thinking to become invisible using lemon juice on his skin. Interactively this story was linked to AI development. In the next part the participants were asked to describe the definition of a cat by looking at 10 pictures and present their thoughts. This exercise was continued up to the level of how AI will process such pictures.

Training of AI and preventing false positives turn out not to be too straight forward. The example of the fish made this clear. Asking an AI to draw a fish, showed a fish with human hands supporting the fish.

By examples the fundamentals of AI were clarified, as well as the different types of AI.

Deep learning – Machine Learning and Artificial intelligence their relation was also clarified.

Via risk of failure it is shown that trustworthiness is key for AI systems. This was linked to inspection of parts for NDI assessment of these parts. The question whether 95-98% right decisions is acceptable for spacecraft was posted and discussed.

A slide with resources to learn more was supplied for the people with more interest in this topic.

The second part of the AI part of the workshop explained multiple details, again delivered via interactive questions, quizzes.

Machines learning both supervised as unsupervised was clarified. Reinforcement Learning (RL) was explained using five volunteers playing a game in from of the other participants. Extrapolating this learning principle to e.g. a computer game, showed that AI used a bug in the programming, so it got to huge amounts of points without advancing in the game.

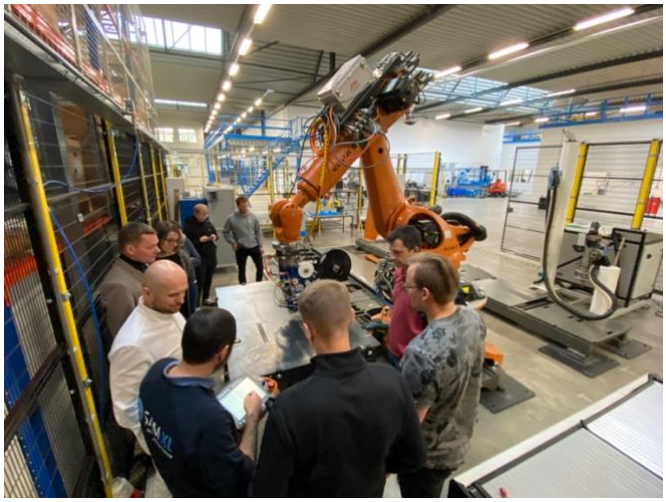
Using the example of other games showed that AI can be disturbingly creative in combination with reinforcement learning. Bringing AI to the real world was covered as well via five different projects. I showed that reinforcement learning can simulate/optimize hight variable processes.

The slides from this lecture are available via these links: "High Level Introduction to AI" and "Machine Learning and Reinforcement Learning"

- **Visit to the NDI lab and the SAMXL (Smart Advanced Manufacturing XL) facilities of the faculty.**

The visit to the NDI lab was done in 2 groups to allow them to interact with the young researches at Delft and investigate which of the techniques could be suitable for them, but also giving feedback to issues occurring in the research in Delft.

The visit to the tape placement robot at SAMXL showed that validation of thoughts is always needed. As the devil is always in the detail, small discrepancies (variation in tape width, tape thickness, tape stickiness) can have detrimental impact on expected results. In this case this did not occur as the demonstration of placement of reinforcement partially over an other, preciously placed tape, did not lead to problems.



3.2 PARTICIPANTS LIST

To facilitate the participation of members among the partners the workshop had the form of a hybrid event with both physical and remote attendance. In total 28 scientists participated in the Workshop Day 1 (11 on site and 17 online) and 18 scientists – in the Workshop Day 2 (10 on site and 8 online). The anonymized list of participants is in the Appendix 1.

4. DELIVERABLES AND DISSEMINATION

To effectively disseminate the workshop's outcomes and facilitate access for engineers, scientists, and researchers an open-access repository is established on the COMP-ECO webpage: https://www.comp-eco.eu/open-repository .

This repository will serve as a comprehensive platform for sharing state-of-the-art knowledge, not only among the participating partners but also with researchers around the world. The presentations and supplementary video materials from the workshop on Design are published in the Repository via this link: https://www.comp-eco.eu/production-of-composite-structures

These valuable resources are readily available and easily accessible to a diverse audience seeking to enhance their understanding in the field. By uploading this content to the repository, we aim to foster knowledge exchange and contribute to the advancement of the scientific community on a global scale.

5. SUMMARY

This section summarises the materials and knowledge generated during the workshop and also summarises achievements from the workshop.

This workshop was organized at the Faculty of Aerospace Engineering, TU Delft on 26th & 27th October 2023. It was second of the series of technical workshops covering the whole product life chain through appropriately used advanced methods of their production. 28 scientists participated in the Workshop Day 1 (11 on site and 17 online) and 18 scientists in the Workshop Day 2 (10 on site and 8 online). This workshop consisted of four parts. During each of them participants acquired specific knowledge, namely:

1). Presentation and Discussion on tailoring of laminates including aeroelastic effects by Dr. Roeland de Breuker. The participants learned the physical and analytical aspects of aeroelasticity.

2). Presentation and Laboratory session on health monitoring and self sensing capabilities of composites by Dr. Roger Groves. The participants acquired knowledge on developing the critical thinking needed to perform measurements in an NDI Laboratory.

3). Interactive lecture session on artificial intelligence (AI) development by Nathan Eskue. This provided an overview of AI and its current use in manufacturing for the participants. The participants were engaged in critical exercises to formulate AI problems.

4). Laboratory Tour and Roundup Discussion led by Dr. Otto Bergsma. This included lab tour on different NDT/SHM techniques (covered lamb waves and fibre optics) and discussions of all topics within the workshop. The participants engaged with fellow TU Delft PhDs and postdocs on their research topics.

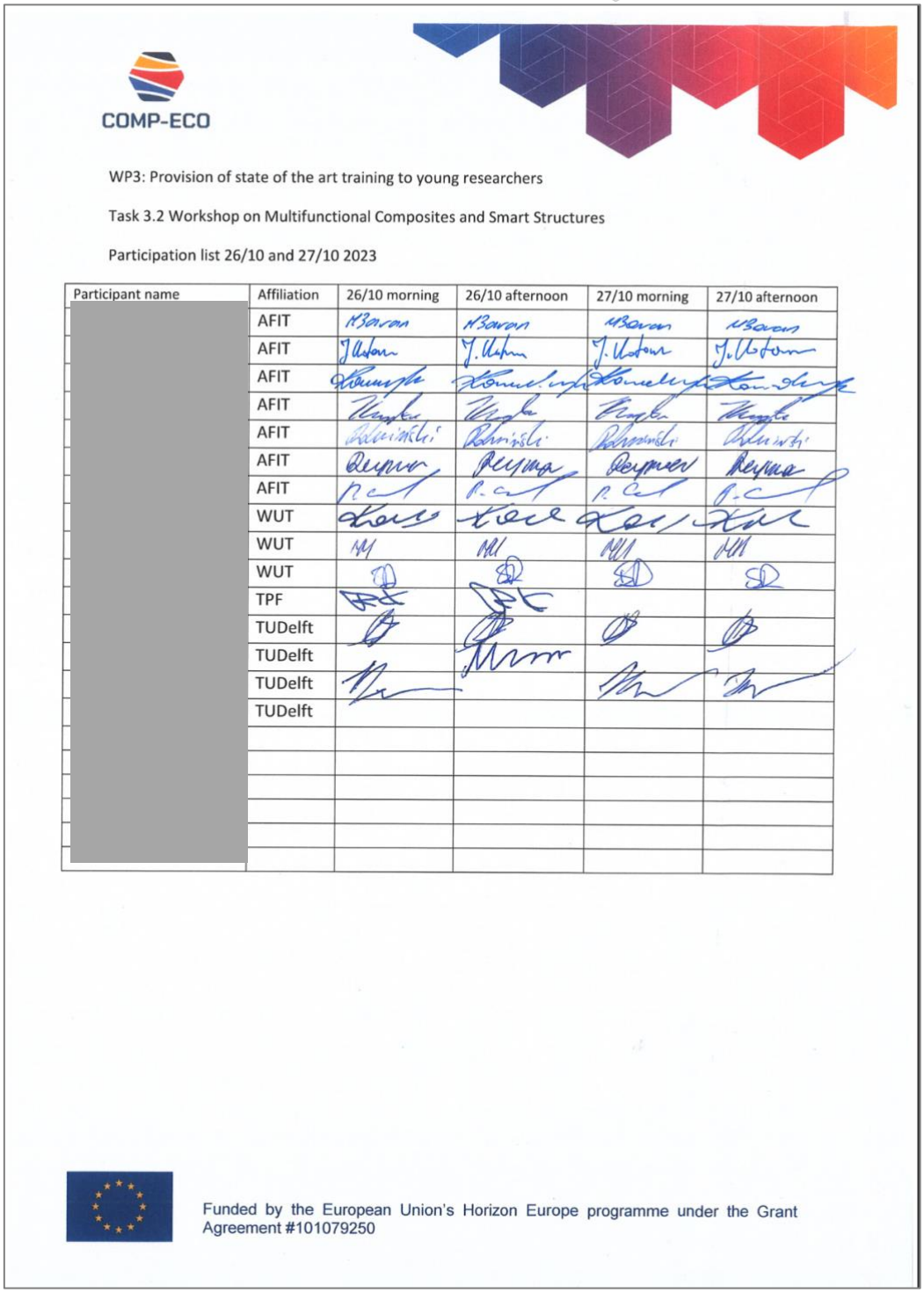
The workshop was streamed and recorded via Teams to make it available for participants not present in Delft and allow review of material at a later stage (available at the open repository of the project).

This workshop not only fostered knowledge sharing but also aspired to promote open discussion with the participants in an effort to trigger brainstorming activities that will enhance their problem-solving, idea generation and creativity capabilities.

Achievement: Extension of their research network from face-to-face discussion with TU Delft colleagues. Ability to decide when AI can be applied in their research field.

APPENDIX 1 – LIST OF PARTICIPANTS

Physical participation



COMP-ECO

WP3: Provision of state of the art training to young researchers

Task 3.2 Workshop on Multifunctional Composites and Smart Structures

Participation list 26/10 and 27/10 2023

Participant name	Affiliation	26/10 morning	26/10 afternoon	27/10 morning	27/10 afternoon
[redacted]	AFIT				
	AFIT				
	AFIT				
	AFIT				
	AFIT				
	AFIT				
	AFIT				
	WUT				
	WUT				
	WUT				
	TPF				
	TUDelft				
	TUDelft				
	TUDelft				
	TUDelft				

Funded by the European Union's Horizon Europe programme under the Grant Agreement #101079250

Online participation

Day 1

Attendance Report – Day 1

Attendance Count • Number of attendees who were present	18

Participant Name	Connection Times
[redacted]	11:18 AM - 1:31 PM
	8:58 AM - 9:02 AM 9:21 AM - 9:40 AM 1:35 PM - 1:37 PM
	1:36 PM – 3:33 PM
	10:40 AM - 11:16 AM 12:14 PM – 12:20 PM 3:07 PM - 3:19 PM
	9:15 AM - 10:51 AM 10:53 AM - 12:38 PM
	9:00 AM - 2:46 PM
	11:00 PM - 11:12 AM 11:33 AM - 11:48 PM 12:45 PM - 12:56 PM 2:45 PM - 3:03 PM 3:29 PM - 3:33 PM
	9:26 AM - 10:51 AM 12:06 PM – 12:07 PM
	8:56 AM - 11:58 AM 11:58 AM - 12:14 PM
	9:53 AM - 11:57 AM 11:57 AM - 12:57 PM 2:27 PM - 3:12 PM
	9:07 AM - 2:44 PM 2:44 PM - 3:33 PM
	11:58 AM - 11:59 AM
	12:02 PM – 12:05 PM
	9:09 AM - 9:39 AM
	11:58 AM - 11:59 AM
	8:58 AM - 11:18 AM
	8:52 AM - 11:52 AM 11:53 AM - 3:33 PM
	12:20 PM - 3:33 PM

Day 2

Attendance Report – Day 2

Attendance Count • Number of attendees who were present	

Participant Name	Connection Times
[redacted]	9:24 AM - 12:27 PM
[redacted]	9:05 AM - 9:19 AM 9:30 AM - 10:35 AM
[redacted]	10:37 AM - 11:00 AM
[redacted]	8:59 AM - 9:05 AM 9:05 AM -12:24 PM
[redacted]	8:40 AM - 12:20 PM
[redacted]	9:02 AM -1:37 PM
[redacted]	2:39 PM – 2:47 PM
[redacted]	9:09 AM - 10:07 AM 10:26 AM - 1:29 PM