COMP-ECO

PROJECT DELIVERABLE

D3.1 Report and Materials from Workshop on Design

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

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DISCLAIMER

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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 design of Multifunctional Composite and Smart Structures. 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 will be 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 three technical workshops will be 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 first of the three workshops, focusing on the Design of Multifunctional Composites and Smart Structures took place June 26-27, 2023 in Warsaw at the WUT premises. According to the Grant Agreement the workshop covered the following courses:

- **Function integrative lightweight structures**

An introduction to plane and spatial kinematics, analytical models for rigid body mechanism – flexible structures and design hints for motion generation with compliant structures

- **Integrating of functional elements**

The focus was on Multifunctional Structures and the acquisition of knowledge and skills for the description and calculation of active structures. The course will provide knowledge on different active materials and the calculation as well as the “real” application of multifunctional structures.

- **Design of lightweight structures**

The course introduced the calculation and design of complex lightweight structures made of isotropic and anisotropic materials. In addition to thermoplastic and thermoset matrix systems, metals and ceramics will also considered as matrix materials.

- **Design aspects of Composite structures**

The workshop provided insight in what is needed and what should be avoided during design of lightweight structures, including composites. Design rules, repair, fabrics, sandwiches, and other special topics are addressed to strengthen knowledge on these lightweight structures.

2.3. WORKSHOP AGENDA

To cover the above topics, the following two-day programme (Table 1) was proposed by Dresden, which was responsible for the organisation, and approved by the other partners during the regular consortium meeting in May 2023. In detail, the workshop consisted of 10 slots, each lasting 45 minutes to 1 hour, and included both lectures and activities.

Prof. Bergsma from Delft gave the lecture "Composite Materials" and the activities "Tasks and Calculations in Design" on the first day, while the rest of tasks were taken over by Dr. Albert Langkamp, Dr. Georgios Tzortzinis and Mr. Jan Wittig from Dresden.

TABLE 1: WORKSHOP PROGRAMME

	Monday 26/06/2023	Tuesday 27/06/2023
9:00 - 9:10	Introduction – Motivation	System and functions
10:00 - 10:45	Lightweight engineering I	Function Integration I
10:45 - 11:15	Break	
11:15 - 12:00	Lightweight engineering II	Function Integration II
12:00 - 13:00	Lunch	
13:00 - 13:45	Composite Materials	Tasks on Application
13:45 - 14:15	Break	
14:15 - 15:00	Tasks and calculations on Design	Elevator pitch
15:00 - 16:00	Recap of the day	Open discussion

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.

- **Introduction-Motivation**

The workshop started with a round table introduction where all participating members briefly outlined their scientific background and research interests (when applicable). This was followed by interactive icebreaking activities, where participants were asked to state with up to three words their understanding of the workshop topics and the advantages and disadvantages of the relevant technologies. Finally, Dr Langkamp gave an introductory talk about the workshop, in which he

also emphasised the need for a holistic approach to evaluating a research idea in terms of impact and potential commercialisation.

Relevant slides are labeled as “Presentation_1 Introduction”

- **Lightweight engineering I & II**

Both were prepared to cover the topics of the course “**Design of lightweight structures**” described in Section 2.

The **first lecture** aimed to deepen the participants' fundamental understanding of lightweight engineering. The following aspects were explicitly discussed:

Lightweight engineering categories: A description of the main pillars addressed by practicing lightweight engineering, namely: Economy, Efficiency, Function and Environmental Neutrality.

Principles of lightweight engineering: The principles of lightweight engineering, which form the basis for the development and sustainable design of lightweight products, were presented in detail and explained through real life applications. Namely: The use of lightweight materials, the multi-material hybrid design, the formed lightweight design, the conditional lightweight design, and the conceptual lightweight design.

Fields of action in lightweight engineering: Technology, materials and methods are addressed in the context of Neutral Lightweight Design, where the entire product life is assessed in terms of its environmental impact.

The **second lecture** in lightweight engineering focuses on Isotropic/anisotropic materials and manufacturing technologies. In particular the following aspects are covered:

Polymers and fibres: A detailed analysis of the typical polymer groups (thermoplastics, elastomers and thermosets) and fibre types (glass, carbon, aramid) employed in reinforced polymer composites.

Fibre Reinforced Polymer (FRP): Micro and meso scale presentation of FRPs, introduction to the rule of mixtures, presentation of analytical material lows for anisotropic materials, and finally the related fracture modes.

Manufacturing technologies for Fibre Reinforced Polymers: In the form of an open discussion, the participants were able to gain a good insight into the most common textile manufacturing technologies and compare the performance of each technology based on the resulting morphology.

Relevant slides for the first and second lectures are labeled as “Presentation_2 Lightweight Engineering I”, and “Presentation_2 Lightweight Engineering II”, respectively.

- **Composite Materials**

The fourth lecture of the workshop focuses on the basics of design and calculations for composite materials, and covers the topic of the course "**Design aspects of Composite structures**" presented in Section 2. The following aspects were covered:

Composite materials composition: The most common types of matrix materials are listed, and their characteristics and features are explained.

Type of failures: A detailed explanation of failure modes for composite materials, and the respective dominant consistent.

Design principles: Selection of design values, definition of limit strains, and the interaction between application, process and materials.

Additional teaching material is provided by Prof. Bergsma in the form of videos (Q matrix, Interlaminar effects and ABD matrix), which can be accessible here: https://www.comp-eco.eu/design-of-composite-structures

- **Tasks and calculations on Design**

During this calculations oriented interactive session, an introduction to classical laminate theory was given. The participants, with the use of demonstrators, acquired explored the delamination phenomenon, as well as the macroscopic mechanical properties of unidirectional FRPs.

The relevant slides from this task are combined with the ones from the "Composite Materials" session and are labeled as "Presentation 4 Composite Materials and Calculations Tasks"

- **Function Integration I & II**

These courses were prepared to cover the "**Function integrative lightweight structures**" and "**Integrating of functional elements**" courses described in Section 2.

The **first lecture** focuses on the following topics:

Introduction and motivation: A detailed description of the general demands that motivate function integration in the framework of modern industrial and societal demands. Function integration can be identified in material, component as well as structure level.

Functionalities and methods: Functionalities with increasing complexity (structural, sensory, signal, actuation and complex) are demonstrated using ongoing and completed research projects from the Institute of Lightweight Engineering and Polymer Technology. The importance of identifying the main function that a component/structure should fulfil and gradually increasing the functional density was emphasised. The step-by-step design process for a lightweight component is also demonstrated.

The **second lecture** covered the followed aspects:

Evaluation of function integration: After the advantages of function integration, which were explicitly described in the previous presentation, the focus is placed on the associated challenges.

Function integrative design process: Integrative development processes are presented with the use of a demonstrator from the aviation industry. In detail, the design of a self-diagnostic composite fan blade with an integrated sensor-actuator-network, control and communication modules is described.

Design for neutrality: Recycling is considered as a complex, non-mechanical function during the design phase. We investigate the impact of substituting pristine with recycled fibers on the main structural function of a component by applying step by step the function-oriented spiral development approach.

Introduction to compliant mechanisms: Brief introduction to compliant mechanisms and their classification into hybrid and monolithic mechanisms. An example of the design and fabrication of an active compliant mechanism is also included.

Material from the two presentations is labeled as "Presentation_5 Function Integration I", and "Presentation_6 Function Integration II", respectively.

- **Tasks on Application**

Renewable energy sources have become increasingly important as the world has become more aware of the need to reduce greenhouse gas emissions. Wind energy, as a renewable energy resource, can be used to generate electricity and has been growing in popularity over the last decade. However, wind turbines located in cold regions are frequently subjected to icing problems, reducing or even pausing their operation.

The attendees used experimental data and machine leaning scrips through a step by step methodology for the prediction of ice accumulation on small scale blades. The methodology was based on the ice effect on the frequency response of wind turbine blades. The frequency response spectra of blades under varying icing conditions is calculated by capturing the acceleration on the tip blades, introduced by integrated actuators.

This work will be submitted for publication. Only a few introductory slides will be provided until the status of IP rights with the journal becomes clear. All the relevant scripts might be also uploaded.

Relevant slides are labeled as "Presentation_7 Tasks on Application".

Elevator Pitch

The two day workshop concluded with a two-three minutes speech from each participant, which included a short summary of the main points of interests, main conclusions, as well as potential application on own research topic.

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 young scientists participated in the Workshop, 19 on site and 9 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/design-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.

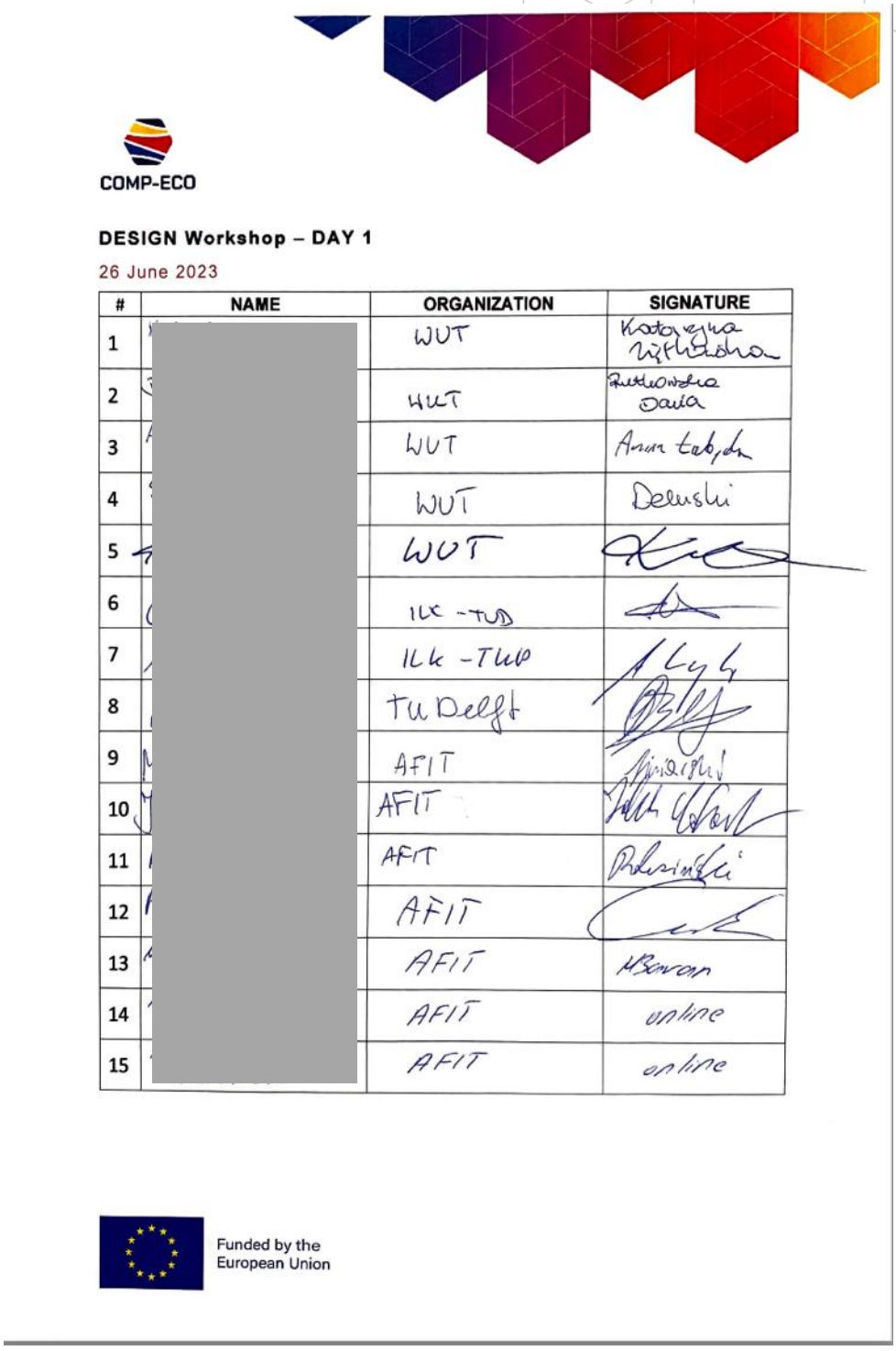
5. SUMMARY

The two-day workshop on the design of Multifunctional Composite and Smart Structures was meticulously organized to provide state-of-the-art training to young scientists, primarily from backgrounds in mechanical engineering and material science. It featured interactive sessions that encouraged the exchange of information and knowledge between participants and speakers.

The lectures encompassed a wide range of topics, covering aspects from the design to the data evaluation gathered form smart structures. Initially, participants were engaged in tasks that challenged their understanding of classical laminate theory and provided insights into design challenges through demonstrative examples. In the area of function integration, the audience gained a comprehensive understanding of both the advantages and the associated difficulties. Additionally, participants had the opportunity to access and work with machine learning algorithms for post-processing real data from multifunctional blades.

Finally, during the open discussion and wrap-up sessions, speakers addressed questions and offered their insights into the current research topics relevant to the young scientists in attendance.

APPENDIX 1 – LIST OF PARTICIPANTS



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DESIGN Workshop – DAY 1

26 June 2023

#	NAME	ORGANIZATION	SIGNATURE
1	[redacted]	WUT	
2		WUT	
3		WUT	
4		WUT	
5		WUT	
6		ILK -TUD	
7		ILK -TUD	
8		TU Delft	
9		AFIT	
10		AFIT	
11		AFIT	
12		AFIT	
13		AFIT	
14		AFIT	online
15		AFIT	online

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DESIGN Workshop – DAY 1

26 June 2023

#	NAME	ORGANIZATION	SIGNATURE
16		AFIT	online
17		AFIT	online
18		AFIT	online
19		AFIT	Nowakowski
20			
21		AFIT	
22		AFIT	
23		AFIT	
24		AFIT	ONLINE
25		AFIT	
26		TPF	
27		WUT	Mabek
28		WUT	ONLINE
29		WUT	ONLINE
30			

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DESIGN Workshop – DAY 2

27 June 2023

#	NAME	ORGANIZATION	SIGNATURE
1	[redacted]	WUT	
2		WUT	
3		WUT	
4		WUT	
5		WUT	
6		WUT	
7		WUT	
8		WUT	
9		WUT	
10		WUT	
11		AFIT	
12		AFIT	
13		AFIT	
14		AFIT	
15		AFIT	online

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DESIGN Workshop – DAY 2

27 June 2023

#	NAME	ORGANIZATION	SIGNATURE
16		AFIT	online
17		AFIT	online
18		AFIT	
19		AFIT	
20		TUD	
21		TUD - ILM	
22		TU Delft	
23		~~AFIT~~	~~Online~~
24		~~AFIT~~	~~Online~~
25		TECPAR	
26			
27			
28			
29			
30			

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