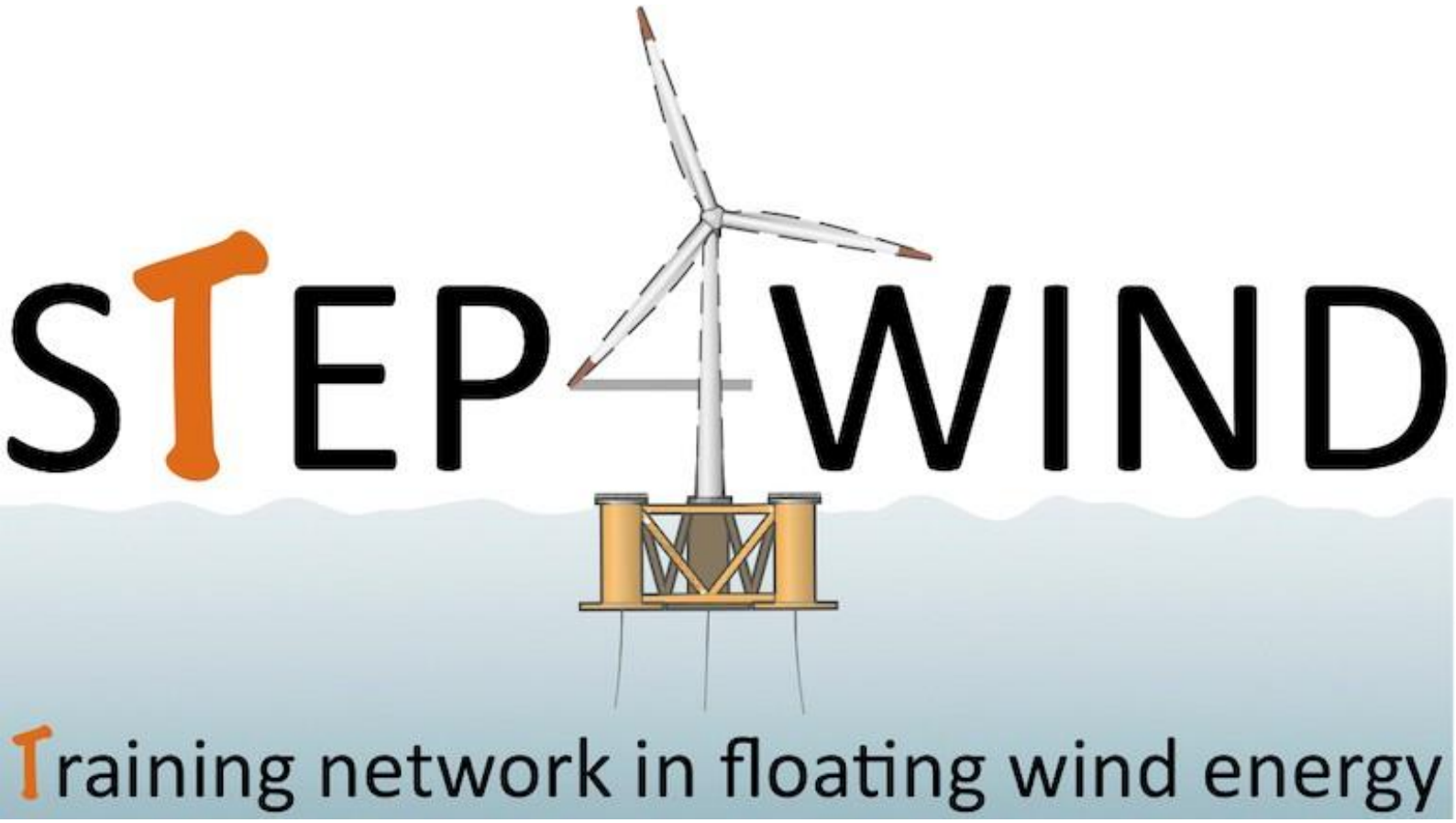
D4.3 Training materials and 3D printed models

[Version 1.0]



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Document History

Revision Nr	Description	Author	Review	Date
1	First draft	Axelle Viré (TU Delft)		14/08/2024
2	Final version	Oana Trifan (TUDelft)	Internal review	29/08/2024

Index

1. Introduction

STEP4WIND is a successfully completed project that started in the middle of the COVID-pandemic in 2020. This project is a European Industrial Doctorate programme, granted under the H2020 Marie-Curie Innovative Training Network initiative (H2020-MSCA-ITN-2019). The European Commission aims at making research careers more attractive to young people and therefore through this type of programme it offers early-stage researchers the opportunity to improve their research skills, join established research teams and enhance their career prospects. In this context, the project ran for 4.5 years and will deliver 10 PhD degrees (still in progress exceeding the project's duration), in joint supervision and training between the public and private sectors. The main objective was to address both technological and economical challenges related to the development of floating offshore wind farms.

On top of that, within STEP4WIND we aimed at establishing a joint research-training programme by an interdisciplinary and intersectoral network for providing the early-stage researchers (ESR) within the project with deep insight into cutting-edge statistical methodology. The network built up, strengthened and structured initial training of researchers at the project level based on a combination of the particular local education programmes, but mainly extending education beyond this.

The aim was to create an inspiring and productive environment on an international competitive level for the training of a new generation of highly educated researchers, who contributed and will further significantly contribute to the project's objectives.

Europe-wide exchanges meet the need for mobility in today's globalised society and the contribution of industry partners and committed stakeholders in the project offered optimal conditions for research driven by application.

The network-wide training programme defined within the project STEP4WIND - *the first of its scale exclusively focusing on floating offshore wind energy (FOWE) in Europe* – manifested its excellence and innovation in four ways:

- The partners were at the forefront of scientific and industrial research, with world-leading publications and prime investments in innovative FOWT farms and have thus incorporated the latest advances in the trainings planned so that the ESRs can benefit from practical experiences and data.

- The ESRs have had full access to the infrastructure of the partners, including in-house modelling tools, world leading experimental facilities, offshore measurement data on site, and floater/wind turbine designs, hence facilitating the knowledge transfer between academia and industry.

- The private sector has been substantially committed to the ESRs' training through long- and short-term secondments, as well as the organisation of training events. This has ensured that the training skills would match industry needs.

- The principles of open science and data were always at the core of the trainings, with the use and development of opensource models, open database, and workshops on this matter. The training materials have been disseminated broadly following the principles of open innovation. These will also be made available on the project's website.

This deliverable presents the trainings activities that have been developed by the STEP4WIND team and took place in whatever form the situation at that time allowed due to the pandemic. The document specifically focusses on giving an overview of all these trainings. These activities are part of the dissemination strategy of STEP4WIND and complement the other deliverable reports on training and dissemination activities such as D4.1, D4.4, D5.1.

2. Network-wide training events

The original training programme has been redesigned due to the COVID19 Pandemic, thus some events have been moved from physical meetings to on-line courses and the whole timing has been adapted to the new travel restrictions, because of the not known and unpredictable evolution of the pandemic. Additionally, the workshop about the WindFloat Atlantic wind farm was removed due to a change in beneficiary. Nevertheless, the content of this training has been included in one of the summer schools organised within STEP4WIND, where a new associated partner has covered the challenges and development of a floating offshore wind farm. Additionally, a site visit to the Kincardine floating wind farm in Scotland has taken place in 2023 through the collaboration of partner OREC and Flotation Energy. More information is given hereafter.

The international and inter-sectorial characteristics of the trainings defined are highlighted in the figure below.

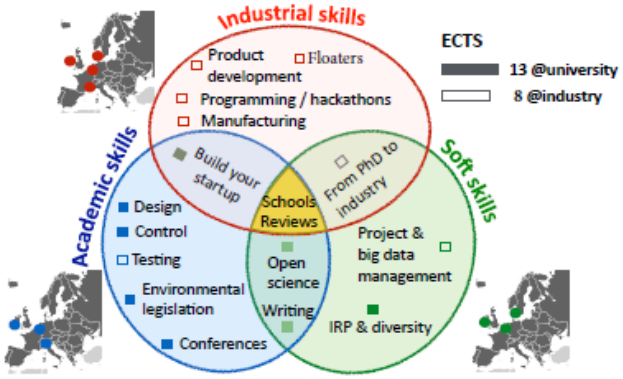


Figure 1. International and inter-sectorial training activities

Name	Short description	Lead Institution	Month from kick-off	On-line
Soft 1	Project and big data management	ORE	15	Y
Academic 1	Increase impact through open science and online teaching	TUD	16	Y
School 1	1st summer school	POLIMI	18	N
Industrial 1	1st workshop: wave tank experiments	MARIN	23	N
Academic 2	Course: Build your start-up	TUD	23	tbc
Industrial 2	Design, manufacture and testing of wind turbine blades	Eire	28	N
Soft 2	Course on scientific writing and presentation skills	UCC	28	N
School 2	2nd summer school	UCC	28	N
Industrial 3	Risk considerations for the commercialization of FOWTs	ORE	30	Y
Soft 3	Transitioning from a PhD degree to a career in industry	SIEMENS	34	N
Soft 4	4th workshop: IPR and diversity in engineering	TUD	42	N

Figure 2. Overview of the training activities after withdrawal PPP

1. Training kick-off meeting, internal research reviews, and MDAO hackathons (4 days each, led by TUD, Polimi, Siemens Gamesa). The consortium and ESRs met regularly throughout the project. These meetings enhanced networking and mutual support between the partners and ESRs. The ESRs regularly presented their research and received feedback from the supervisors, mentors, secondment hosts, and other partners. This ensured that the ESR

projects developed around a right balance of disciplines and academic-industry inputs. Additionally, multiple ESR projects interacted around the MDAO framework, so that the impact of the STEP4WIND innovations could be assessed. We see opportunities to do further in this area with additional research needed to design and optimise floating wind farms holistically.

2. Summer schools opened also to external PhD students, hence increasing the impact and networking aspects of STEP4WIND.
    a. The first summer (autumn) school: **FOWE Floating Offshore Wind Energy: Flow Physics, Modelling And Testing** (5 days, led by Polimi, 4-8 October 2021) was held in Italy, at Lake Como School and has covered matters such as: atmosphere physics and natural wind boundary layer, wind assessment and choice of wind turbine types, mechanical modelling of wind turbines using multibody approaches, aerodynamic modelling of blades, OpenFoam hands on session, hydro-dynamics modelling, wind tunnel experiments, and hydro-dynamics control. The school has been a mixture of lectures, computer hands-on, and a technical visit to the wind tunnels of Polimi. The participants have been given a research/industrial task to be solved. On the last day, the ESRs have been presented their work through group presentations.

    b. The second summer school (5 days, led by UCC- MaREI, Cork, IR, 5-9 September 2022) has been a week-long event made up of a mixture of presentations, workshops and fun team-bonding activities along with a visit to NUIG/UCC test facilities. It covered social, economic and environmental impact of offshore wind. Emphasis has been on the regional economic impact of offshore wind development activities and on the environmental impact of various end of life options for wind turbines and their support structures. The ESRs have learned how to account for these impacts at a design stage. See agenda of this Summer School in the Annex of this document.

3. The training on the **Scientific writing and presentation skills** has been covered during the UCC-MaREI summer school as well. This event has included a practical seminar on technical reporting, scientific writing, and how to use theatrical techniques when designing and delivering oral presentations. Topics such as publication ethics and publication planning have been part of the training. The ESRs have applied the techniques to a talk on their research topic.

4. **The Kincardine wind farm offshore site visit** (1 day May 2023, led by TU Delft / ORE Catapult in collaboration with Flotation Energy) in Scotland, UK. This event replaced the initially site visit planned for the Wind Float Atlantic wind farm at PPP in France, due to their withdrawal at the beginning of the project. More information of the wind farm in Aberdeen can be previewed here: https://www.youtube.com/watch?v=O6ROkGgPfIo
   A brief training session has been organised on the boat on the installation process, maintenance operations and the commercial viability of developing one of the world's largest floating offshore wind farm in the world, hence matters on the technical, commercial, and environmental ethics challenges from concept to realisation have been addressed.

5. **Risk considerations for the commercialisation of FOWTs** (initially planned as a one day standalone training, led by ORE Catapult), did not entirely took place as planned. Topics on risk analysis in the development of FOWTs has been addressed during the site visit to the Kincardine floating wind farm in Aberdeen. Despite not taking place as a regular training session, OREC has shared their methodology for risk management of FOWTs, the associated risk registers, and a methodology for technology assessment process during consortium meetings with the ESRs. Some ESRs have applied these methods to different FOWT designs. Hereunder some impressions from this site visit.

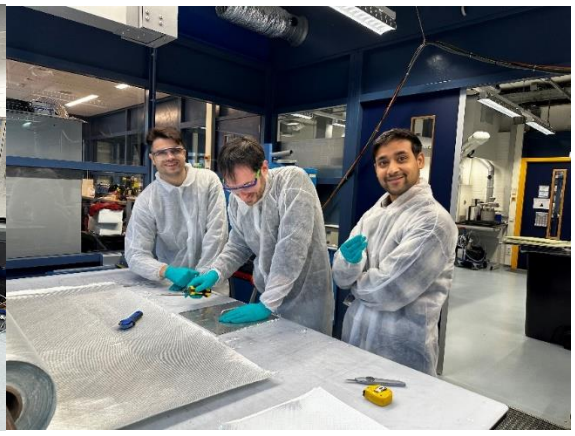
6. **Project and big data management skills** (Online, July 2021 and March 2022, 1 day training led by ORE Catapult). This course covered all aspects related to data collection, management, analysis, visualisation, and sharing. Topics were: management and interpretation of large quantities of SCADA data; open and confidential data management; practical examples of data management at ORE Catapult such as POD (Platform for Operational Data) for data collection and SPARTA (System Performance, Availability and Reliability Trend Analysis) to improve offshore wind assets. The data manager at TUD has provide additional input on project and open data management.

7. **Increase impact through open science and online teaching** (Online course, May 2021, spread over 4 weeks, led by TUD). This course focused on empowering the ESRs to become more visible and impactful researchers by learning the benefits from Open Science principles. Topics included: basic concepts of Open Science, with advantages for the researchers and science in general; how to effectively store, manage and share research data; the different forms of open access publishing; the use of social media to increase visibility and impact; and how to design online teaching materials. All the ESRs have directly applied this knowledge in their research through open-access publications, open data, open-source codes, and the STEP4WIND online game.

8. **Workshop on wave tank experiments** (2 days, 30-31 May 2022, led by MARIN). The workshop has taught the ESRs the offshore hydrodynamics applied to offshore wind turbine foundations (fixed and floating). On Day 1, lectures have covered: design considerations; model testing techniques; first- and second-order wave loads; numerical modelling of FOWTs; a case study of a semi-submersible foundation; and a practical assignment in the wave tank. Day 2 was exclusively focused on the practical work in the wave basin of MARIN. The ESRs have worked in teams of 3 to build a floating foundation from PVC tubes and foam plates. The concepts have been ranked based on their weight and the results of these tests. See hereunder some impressions.

9. **Build your startup** (3 days, led by TUD). This course focussed on “Innovation, Entrepreneurship, and Strategic Communication" and was organized by TU Delft on 15-17 November 2022, in collaboration with the company MARMAS in Germany. The course gave the ESRs a hands-on experience with building their own start-up. Topics included: hypothesis driven entrepreneurship business, model canvas, fundraising and influencing techniques communicating not only start-up ideas, but also various research related and post-doctorate opportunities.

10. **Design, manufacture and testing of wind turbine blades** (1 day, led by TU Delft instead of Eire Composites as initially planned; December 2023). The goal was to provide a strong practical understanding of the context that underpins wind blade innovation, including an infusion lecture. The ESRs have been divided into teams and asked to design a wind turbine blade taking into account how the blade will be manufactured and tested. They have used CFD/FEA software to design their blades and the results have been baselined against actual blades from industry. The event included a short overview of the processes associated with aerospace manufacturing and testing, and opportunities for cross-learning between sectors has been discussed and some back-of-the-envelope calculations. Finally, there was a demonstration of the equipment used to manufacture and test blades at the composites lab located in the aircraft hall on the TU Delft campus. Here below some impressions from this training session.

11. In the same context of this training, during the UCC Summer School in 2022 the ESRs have had a visit to the Blade manufacturing facilities of Eire Composites. This was no hands-on training.

12. **Training on IPR & Diversity in engineering** (1 day, led by TUD, December 2023). The workshop consisted of two parts and has been organised with the support of the technology transfer officer at TUD, the D&I officer at the faculty of Aerospace Engineering (TU Delft) and The Active Bystander Training Company (UK).

    Training part on IPR covered the following topics:

    - The general information about IP rights (design, copyright, trademark, patent)
    - Where to start when you have an idea and how the patent process looks like,
    - Why is patent as an IPR important? What makes it special?
    - The meaning of inventorship and ownership; under which circumstances can you qualify as inventor when you are a supervisor? Who owns ideas/inventions generated by you?
    - The explanation of the patent requirements (confidentiality, novelty, inventiveness), how to combine the confidentiality requirement with a publication,
    - The process of patent application, the PCT process (timeline),
    - What's in it for you (employees)? (our remuneration policy, possible cooperations with third parties, start-ups).

    Training part on Diversity and inclusion (with the contribution and support of Active Bystander) covered the following topics:

    - General experience of STEP4WIND PhDs from a D&I perspective
    - Awareness about bystander effect
    - What to do as an active bystander

13. **Transitioning from a PhD degree to a career in industry** (0,5 day online, December 2023, led by Siemens Gamesa). Topics included: tools for a successful transition from academia to industry (networking, industry involvement, soft-skills); HR/Management perspective on PhD applications; experience sharing from Siemens Gamesa staff holding a PhD degree.
    This session was organised by SGRE, more specifically by 8 engineers in SGRE holding a PhD in various fields (related or not to wind energy) and from various cultural backgrounds. The content was largely based on the points of

view of these engineers, sharing what they believe is an asset for industrial positions to hold a PhD, based on their personal experience. For a better preparation of this training the ESRs have sent their questions beforehand. See attached the information package on this training. The recordings are also available upon request.

14. **Session at international conferences** (1 day, led by WP leaders). Dedicated sessions have been organised at international conferences in the field, such as TORQUE2022, ISOPE, FOWT2020, WESC 2023, TORQUE2024 and other topical conferences such as EERA DeepWind and the DTU PhD Winter school. The WP leaders have helped in organising many of the sessions at these events. Additionally, the ESRs have been participating in external trainings/workshop events and in international conferences throughout their projects.

15. **Access to additional optional training materials** (TUD). In addition to the training activities outlined above, the ESRs have had various options to access the host beneficiaries' online courses, such as the TUD online course for professionals "Offshore wind farm technology: design, installation and operation" and other online courses, hence enhancing the overall training of academic, industrial and soft skills based on the ESRs' personal interests.

3. 3D models

Figure 3. Example of floating wind turbines built with families at the beach of Scheveningen (19 Sept 2021). Arrows show floating wind turbine models built by the citizens and tested at sea.

In addition to targeting relevant trainings courses and events for the ESRs, we initiated a series of outdoor outreach activities during the summer weeks (from June to September) on the beach of The Hague and on lakes in Delft. This has been taking place on a yearly basis since 2021 onwards.

This is made possible through a collaboration with OffshoreWind4Kids established with TU Delft in 2021. The PhD candidates of STEP4WIND, as well as staff at TU Delft, supported these activities by building small- scaled models of floating wind turbines and testing them at sea. Impressions of the model testing at sea is shown in this aftermovie.

Foto credits: OffshoreWind4Kids

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Home

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Programme

	Monday 4th October 2021	Tuesday 5th October 2021	Wednesday 6th October 2021	Thursday 7th October 2021	Friday 8th October 2021
8:30 – 9:00	Welcome Coffee	Welcome Coffee	Welcome Coffee	Welcome Coffee	Welcome Coffee
9:00 – 10:00	Welcome and Introduction *(Marco Belloli, Politecnico di Milano)*	Wind farm optimization *(Ilmas Bayati, PEAK wind)*	Wind Tunnel Tests *(Marco Belloli, Politecnico di Milano)*	Design of Floating Offshore Wind Turbines-Turbine OEM Perspective *(Kasper Laugesen, Siemens Gamesa)*	Lidar-Assisted control *(David Schlipf , WETI)*
10:00 – 11:00	Atmospheric phenomena for wind Energy *(Dries Allaerts, TUDelft)*	Team work activities (FLORIS) *(Paolo Schito, Politecnico di Milano)*	Wave basin Tests (Jorrit-Jan Serraris, MARIN)	Design of Floating Offshore Wind Turbines-Turbine OEM Perspective *(Kasper Laugesen, Siemens Gamesa)*	Lidar-Assisted control *(David Schlipf , WETI)*
11:00 – 12:00	Atmospheric phenomena for wind Energy (Dries Allaerts, TUDelft)	Team work activities (FLORIS) *(Paolo Schito, Politecnico di Milano)*	Discussion about tests *(Marco Belloli, Politecnico di Milano, Jorrit-Jan Serraris, MARIN)*	Free time for Team work	Final project presentations
12:00 – 13:30	Lunch	Lunch	Lunch	Lunch	Lunch
13:30 – 15:30	Wind Farm Modelling & FLORIS training *(Paolo Schito, Politecnico di Milano)*	Challenges in developing the new generation of wind turbines *(Alessandro Bianchini, Università di Firenze)*	Polimi Wind tunnel visit	Social activities	
15:30 – 16:00	Coffee break	Coffee break			
16:00 – 17:00	Wind Farm Modelling & FLORIS training *(Paolo Schito, Politecnico di Milano)*	Challenges in developing the new generation of wind turbines *(Alessandro Bianchini, Università di Firenze)*			
	Self organized dinner	Self organized dinner	Self organized dinner	Social Dinner	

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Registration

The registration fee is € 500,00 (VAT included).

It includes the accommodation in Villa del Grumello Guesthouse* (limited availability, first come first served), lunches and coffee break.

* **In October 3/4 OUT October 8/9**. Only shared accommodation is possible (distancing between beds is 2 mt). Breakfast is not included, due to COVID restriction the kitchen for self preparing breakfast is NOT available. No hairdryer or toilet articles are available. Bed linens and towels are provided.

COVID 19 PANDEMIC: Kindly remember to keep secure distance, sanitize your hands often and always wear face mask. The use of the mask is mandatory to access Villa del Grumello. For the entire security protocol, please check the following link: https://lakecomoschool.org/protocollo-covid-19/.

Please note: in order to attend the school you will need the GREEN PASS. You will have to show it everyday to the hostess in assistance.

Personal information (required)

Title

Name

Surname

Personal Address

Fiscal Code (mandatory for italian citizens and residents)

Department

Institution

Research area

Street

Postal code

Town

Country

Phone

Email

Curriculum vitae (max 2 pages) [pdf]
Scegli file Nessun file selezionato

☐ By submitting this registration form you authorise Fondazione Alessandro Volta to include your personal data on its mailing list for the distribution of information material. We will never share your personal data with any third party. According to the General Data Protection Regulation 2016/679, you may have access to these details at any time and request their modification and cancellation sending an email to: info@lakecomoschool.org

Institution

Research area

Street

Postal code

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Guesthouse IN ○ October 3 ○ October 4

Guesthouse OUT ○ October 8 ○ October 9

Male ○ Male
Female ○ Female

Payment information (required)

○ Registration fees (€ 500,00 VAT 22% included)

Payment option:

○ by credit card online ○ by bank transfer

*For credit card payment click the "pay now" button at the bottom of this page.

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Venue

The School will take place in Villa del Grumello, via per Cernobbio, 11 – Como, Italy, which is set in a park over Como lake.

How to get there

Click here for information on how to reach Como

Villa del Grumello is 20 min on foot from Como city center – you can also take a bus, lines 6 and 11 (bus stop: "Como Via Regina Piscine Villa Olmo", just after "Villa Olmo").

From the main Train Station (Como S. Giovanni), the nearest bus stop to catch line 6 and 11 is "Piazzale Rocchetto".

Click here for a map

Villa del Grumello
Fondazione Alessandro Volta
Via per Cernobbio 11, 22100 Como, ITALY

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Contact

For enquiries about the **venue** of the school, **accommodation**, and **registration** procedure, please contact **Mariagiovanna Falasconi** (mariagiovanna.falasconi@fondazionealessandrovolta.it) at Fondazione Alessandro Volta, Como.

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Organization Committee

- **Marco Belloli**
- **Sara Muggiasca**
- **Axelle Viré**

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Registration Online

Please register to the online school by October 3rd, you will receive the link (ZOOM platform)

Personal information (required)

Name

Surname

Department

Institution

Town

Country

Email

Send

Floating Offshore Wind Energy: Flow Physics, Modelling And Testing

Lake Como School of Advanced Studies, 4 - 8 October 2021

Speakers

Name	Affiliation	Short Bio	Lecture Summay
Paolo Schito	Politecnico di Milano	Paolo Schito is born in Venezia, and got his MSc in Aerospace Engineering working on sailing boat aerodynamics. He defended a PhD thesis in Mechanical Engineering on the aerodynamics of wind turbine wakes. He was involved in several projects regarding wind turbines, two successful PRACE projects and the H2020 EU funded CL-Windcon project. He is active in the actuator line numerical modelling of wind turbines and wind farms, and has experience in wind tunnel testing of wind farms.	Wind turbine clusters are called wind farms. The interaction between turbines is due to rotor wake interaction. The lecture will introduce the wind turbine wake characteristics, will speak about wake control possibilities and wind farm control strategies. The lecture will also introduce and provide a tool for the simulation of wind farm flow and wind farm control.
David Schlipf	WETI	David Schlipf received his PhD entitled "Lidar-Assisted Control Concepts for Wind Turbines" from the University of Stuttgart. After his PhD he was a research scholar at the University of Colorado Boulder and NREL, carrying out research related to lidars and floating wind turbines. Back to Stuttgart, he founded ssventio, a startup company for renewable energy control. Since 2018 he is a research professor at the Flensburg University of Applied Sciences focusing his research and teaching activities on wind turbine control.	The lecture will focus on Lidar-Assisted Control with focus on Floating Wind Turbines.
Jorrit-Jan Serrark	MARIN	As a Senior Project Manager in MARIN's Offshore Department Jorrit-Jan has been involved in many model test programs and numerical simulations for offshore structures. In the field of offshore wind Jorrit-Jan has expertise in 1) operability analysis for wind turbine installation vessels and wind turbine support vessels and 2) model testing for FOWT including hybrid/ SiL modelling techniques for wind. Jorrit-Jan graduated in 2007 from Delft University of Technology in Offshore Engineering and joined MARIN afterwards.	Hydrodynamic principles of FOWT, hydrodynamic and hybrid model testing. hydrodynamic numerical modelling, wind modelling techniques in a wave basin.
Alessandro Bianchini	Università di Firenze	Alessandro Bianchini is Assistant Professor (Tenure Track Researcher – RTD-B) at the Department of Industrial Engineering of the University of Florence (Italy). He received the degree in Energy Engineering in July 2007 and the PhD diploma in "Energy Engineering and Innovative Industrial technologies" in May 2011. At the University of Florence, he holds the courses on "Wind and marine engineering" and "Advanced systems for Renewable Energy". He is also the responsible for the module on wind turbine aerodynamics in the course of "Mechanics of floating offshore structures". Dr. Bianchini is the representative of his university in the board of the European Academy of Wind energy (EAWE), in which is presently also serving as a member of the Strategy Committee and Publication Committee and the chair of the Small Wind Turbine Committee. For the last four years, he has been also chairing the Wind Energy Committee of ASME's Turbo Expo Conference. In the field of wind energy, he has authored so far more than 100 publications in peer-reviewed journals and conferences. His main research fields are wind turbine aerodynamics, design and simulation with multi-fidelity approaches, from engineering methods to high-computing Computational Fluid Dynamics.	Challenges in developing the new generation of wind turbines
Dries Allaerts	TU Delft	Dries Allaerts is an Assistant Professor at the faculty of Aerospace Engineering at Delft University of Technology. Previously, he was a postdoctoral researcher at the National Renewable Energy Laboratory (NREL) in Boulder, Colorado (US), and at KU Leuven in Belgium. He obtained his PhD at the same university in 2016. His research interests cover the development of Computational Fluid Dynamics (CFD) techniques and their application to wind-farm flow dynamics in realistic atmospheric conditions. Particular areas of interest are Mesoscale-to-Microscale Coupling (MMC) and regional-scale flow effects caused by wind farms, such as upstream flow blockage and self-induced gravity waves.	This lecture on atmospheric phenomena for wind energy gives an introduction to the field of atmospheric science and highlights those aspects that are important for wind turbine design. The goal is to make students familiar with a number of basic concepts from atmospheric science and from boundary-layer meteorology in particular that are key to understand the wind resource and the performance of wind energy systems. Further, the lecture aims to provide a starting point and a set of useful references for further study of wind energy meteorology. Topics of interest include the range of scales of atmospheric motion, spatial and temporal variability of the wind, the atmospheric boundary layer, atmospheric stability and thermal stratification, and atmospheric turbulence.
Marco Belloli	Politecnico di Milano	Full professor in the Department of Mechanics of Politecnico di Milano. PhD in Applied Mechanics in 2004, he is teaching Mechanical Vibrations (MSc Mechanical Eng.) and Dynamic of Aerospace Systems (BSc Aerospace. Eng.). His main areas of interest are wind energy, wind engineering, fluid-structure interaction of engineering structures and sports aerodynamics. He has expertise in wind tunnel experiments, developing testing devices to simulate the hydrodynamics of floating wind turbine by means of mechanical system, numerical modelling of mechanical and civil structures and WECS control. He was the local coordinator of the MIUR financed research project PRIN 08 AEROGEN "Tower structures for large power Wind Turbines: New technologies on- and off-shore". Since 2014, Marco coordinates Polimi's research team working on the OC4 and OC5 benchmark for comparisons and validation of numerical models of Floating Offshore Wind Turbines. Since June 2015, he is the local coordinator of the LIFES50+ EU H2020 project on the qualification of a new substructure for a 10 MW floating wind turbine. Since December 2017 he is the local coordinator of the EUH2020 project "The Blue Growth Farm", for designing a scaled model of a multipurpose floating platform. He is the coordinator for Polimi of the Wind Assisted Propulsion project. In the period 2013 - 2016 he was in the Scientific Committee of «Polska» Wind Tunnel GVPM. Since September 2015, he is in the Steering Committee of ANIV, the Italian national wind engineering association. He is in the Board of the PhD in Mechanical Engineering at Politecnico di Milano.	
Kasper Laugesen	Siemens Gamesa	Master in Offshore Energy Systems (Aalborg University, Esbjerg) Technical Lead Floating Wind Turbine Development within Loads, Control and System Level Control within Technology Development IEC member of TC 88 Wind Energy Generation System Bricad, Developer	Design of Floating Offshore Wind Turbines-Turbine OEM Perspective
Rinas Bayati	Peak Wind	Education: Politecnico di Milano (MSc: 2011, PhD: 2016), Rotterdam School of Management (MBA-2021). Background: Dynamics of Mechanical Systems, Financial Engineering & Strategy Current Position: Senior Consultant at PEAK Wind / O&M Strategy, Concepts & OPEX - Floating Wind Principal. Industries: 10+ years in Offshore Renewables, Oil&Gas and Infrastructures Employers: Politecnico di Milano, MARIN, PEAK Wind	Floating Wind Farm Business Case: Operational Perspective and Key Research Lines.

Step4Wind Summer School

5th – 9th September 2022

AGENDA

Monday 5th September

Hodson Bay Hotel, Athlone

Entrepreneurial Skills – Dr. Raymond Alcorn, CEO of Exceedence Ltd.

09:00 *Starting Up - Industry Landscape, Competitor Analysis, Problem/Solution, Product/Market Fit, Customer Needs, Business Model, Business Plan, Business Model Canvas*

11:00 **Coffee Break**

11.20 *Pitching – different types and audiences*

Split into teams/assign roles

13:00 **Lunch**

14:00 *Prepare Pitches*

Dragons Den Style Pitch-off with guest judges and prizes

16:30 – **Free time**

Take some time to explore the hotel grounds, nestled on the shore of Lough Ree with sweeping views across the lake and surrounding countryside. Yew Point, adjacent to the hotel, is a magnificent 140 acres peninsula of unspoiled meadowland and native woodlands surrounded by the lake, accessible to hotel residents only. The land has been untouched for centuries and the utmost care has been taken during the development of the trails to ensure all the ancient woodlands and thriving local wildlife are undisturbed. The hotel also has a leisure centre with pool and spa (booking in advance required).

20:00 **Dinner**

Tuesday 6th September

NUI Galway/Galway Wind Farm

08:00 **Bus to NUI Galway**

09:30 **Welcome to NUI Galway**

10:00 **Tour of Engineering Building and Blade Test Lab**

A short tour of the laboratory and research facilities in the Alice Perry Engineering Building will be followed by a tour of the Large Structures Testing Laboratory. Attendees will be given an overview of recent blade testing projects, demonstration of

a blade installed for testing and gain an insight into the testing capabilities of the laboratory.

11:00 **Blade Design Workshop**

Details of wind blade design and manufacturing processes will be presented, along with the use of BladeComp. BladeComp is an in-house developed wind/tidal turbine blade design and optimisation software. BladeComp comprises an advanced Finite Element (FE) analysis techniques and design optimisation strategies for efficient, robust and rapid design of turbine blades. A number of short presentations on on-going blade design and development projects at NUIG will also be presented.

13:00 **Lunch on Campus**

14:00 **Bus to Galway Wind Farm**

15:00 **Tour of Galway Wind Farm**

The 174MW Galway Wind Park, co-owned by SSE Renewables and Greencoat Renewables, in Connemara's Cloosh Valley, is Ireland's largest and best performing onshore wind farm, generating more green energy than any other wind generation site on the island. Galway Wind Park comprises 58 Siemens 3MW wind turbines, each rated to the highest international standard and specifically engineered for the prevailing wind conditions at the Connemara site to optimise generation output performance.

17:00 **Return bus to hotel**

19:00 **Dinner**

21:00 **Seán's Bar, Athlone**

live music at the oldest pub in Ireland

Wednesday 7th September

Hodson Bay Hotel, Athlone

09:45 **Boat Cruise**

Tour of Lough Ree & Hudson Bay

12:00 **Presentation Skills**

Presented by Cian Desmond, Head of Innovation, Gavin & Doherty Geosolutions Ltd.

13:00 **Lunch**

14:00 **MSP Challenge**

Hosted by Dr. Liam Carr, Head of Geography, NUIG. Human activities at sea such as offshore wind farming, shipping and fishing, easily get into each others' way. And they have a long-term impact on the marine environment. Maritime Spatial Planning (MSP) Challenge has been designed to help decision-makers, stakeholders and students understand and manage the maritime (blue) economy and marine environment. In the

interactive gameplay, country planners and stakeholders see the entire sea region and review many different data layers to make an assessment of the current status while planning for a more sustainable future. MSP Challenge is designed to engage and immerse users, making it a perfect environment for stakeholder engagement, planning through co-design, learning and education.

17:00 **Wine & Cheese Tasting**

Hosted by resident Sommelier Andres, who was voted top Sommelier in Ireland, this wine tasting experience is one not to be missed. Learn about magnificent, international wines and the best local cheeses. The Sommelier has decades of experience and knowledge, providing an entertaining and fun evening. Alternative non-alcoholic drinks available.

20:00 **Dinner**

Thursday 8th September

EireComposites, Galway

08:00 **Bus to EireComposites**

09:30 **Welcome to EireComposites**

EireComposites is an innovative design, manufacturing and testing company involved in lightweight, high performance, fibre-reinforced composite materials, with an international customer base in space, aerospace, renewable energy and industrial composites.

10:00 **Overview of EireComposites Renewable Energy projects**

ÉireComposites manufacture blades and blade components for wind turbine OEMs. It carries out extensive research and development of new materials, designs, and manufacturing methods of various renewable energy devices. ÉireComposites has also caried out extensive research and development of tidal turbine blades. As a global leader in the field it has manufactured tidal blades with lenghts of up to 8m.

12:00 **Tour of EireComposites**

13:00 **Lunch**

14:00 **Aerospace Composites**

15:00 **Composite Testing**

16:00 **Business Development**

17:00 **Return bus to hotel**

19:00 **Dinner**

Friday 9th September

MaREI Centre, UCC, Cork

9:00	**Bus to Cork**
12:30	**Lunch**
13:00	**The Development of Offshore Wind Floating Platforms**
	Presented by Jimmy Murphy, UCC
13:30	**Techno Economic Assessment of Irish Floating Wind Farms**
	Presented by Fiona Devoy McAuliffe, UCC
14:00	**O&M Optimisation for Floating Wind Farms**
	Presented by Mitra Kami Delivand, UCC
14:30	**Tour of Lir National Ocean Test Facility**
16:00	**Close**

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RENEWABLE ENERGY

STEP4WIND

Transitioning from PhD to a Career in Industry

05/12/2023

To know before we start

This is <u>not</u> a masterclass lecture

To know before we start

We want this session to be interactive and dynamic

Feel free to interrupt and share your personal opinion and experience at any time

Feel free to ask questions that deviate from the main topic, this session is an open discussion not necessarily willing to follow a straightforward path

Plan

Who are we?	9:00-9:05	5 min
Introduction: • What this session will be about • What a candidate holding a PhD can bring in a company?	9:05-9:15	10 min
Selected skills for which PhD holders have specificities that can be an asset for the industry (part 1)	9:15-10:00	45 min
Coffee break	10:00-10:10	10 min
Selected skills for which PhD holders have specificities that can be an asset for the industry (part 2)	10:10-11:10	60 min
Conclusion and Q&A	11:10-11:30	20 min

Who are we?

Who are we?

We are all

- (Internal or external) SGRE employees…
- … holding a PhD degree…
- … and currently working in the Technology department, mainly dealing with turbine or tower loads…
- … from various nationalities but working either in France or in the Netherlands

Some of us are involved in STEP4WIND as technical advisors/co-supervisors of PhD thesis

Who are we?

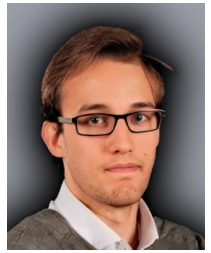
Laurent BEAUDET
Technical coordinator (wake modelling)

Paul DEGLAIRE
R&D manager France

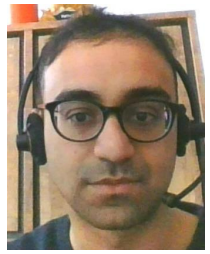
Bastien DUBOC
Technical coordinator (aeroelastic stability)

Félix HOUTIN MONGROLLE
Turbine Loads R&D Engineer
Rotor Vibrations in Idling and Standstill
Wake Advanced Modelling

Alexandros ILIOPOULOS
Advisory Engineer & Business Development Manager
SHM Systems and Services for offshore wind turbines



Etienne MULLER
Turbine loads R&D Engineer
Wake modelling (Low/High fidelity)
Wind farm control



Sachin NAVALKAR
Team Lead
Support Structure Loads [Design Centre]

Norbert WARNCKE
Technical coordinator (wind models)

Who are you?


Likhitha Ramesh Reddy
PhD student (ESR1)


Ricardo Amaral
PhD student (ESR2)


Deepali Singh
PhD student (ESR3)


Matteo Baudino Bessone
PhD student (ESR4)


Felipe Novais
PhD student (ESR5)


Alejandro del Toro
PhD student (ESR6)


Huzaifa Syed
PhD student (ESR7)


Rahul Chitteth Ramachandran
PhD student (ESR8)


Omer Khalid
PhD student (ESR9)


Omar Ibrahim
PhD student (ESR10)

- **WP1 – Design**
  - ESR1 - MULTI-SCALE NUMERICAL MODELLING OF FLOATING OFFSHORE WIND TURBINES
  - ESR2 - AERODYNAMICS OF FLOATING OFFSHORE WIND TURBINES UNDERGOING LARGE MOTIONS
  - ESR3 - REDUCED-ORDER MODELS AND MACHINE LEARNING FOR FOWT ANALYSIS AND DESIGN
  - ESR4 - MULTIDISCIPLINARY DESIGN ANALYSIS AND OPTIMISATION FRAMEWORK FOR FOWT FARMS
- **WP2 – Production and development**
  - ESR5 - HARDWARE-IN-THE-LOOP (HIL) EXPERIMENTS OF FOWTS
  - ESR6 - AUTOMATED MANUFACTURING OF CARBON FIBRE REINFORCED COMPOSITES FOR OFFSHORE WIND TURBINE BLADES
  - ESR7 - OPTIMISATION OF DYNAMIC CABLE CONFIGURATION FOR FOWTS AND FARMS
  - ESR8 - INSTALLATION AND DECOMMISSIONING OF LARGE FLOATING OFFSHORE WIND FARMS
- **WP3 – Operation and scalability**
  - ESR9 - APPLICATION OF ROBOTICS IN FLOATING WIND OPERATIONS AND MAINTENANCE (O&M)
  - ESR10 - DEVELOPMENT AND OPTIMISATION OF BLUE ECONOMY ACTIVITIES COUPLED WITH FOWT FARMS

Introduction

What this session will be about

The transition from a PhD to a career in the industry starts from

- The selection of positions
- The application to the selected positions
- The job interviews

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This session will mainly deal with technical positions

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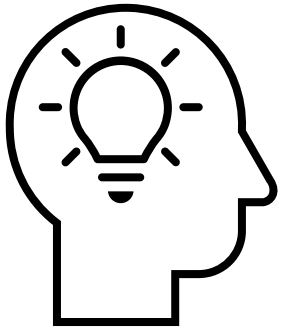
The transition from a PhD to a career in the industry starts from

- The selection of positions
- The application to the selected positions
- The job interviews

This session will mainly deal with technical positions

You must show evidence of your skills during interviews

- The current session aims at providing you details of what we see as your **valuable skills and assets** that you should be aware of and that you should be able to show evidence
- This will be achieved through a **detailed explanation of a selection of these assets**, an emphasis on the particularities of PhD holders and a bunch of **anecdotes we experienced** that showcase **how these PhD-specificities were applied in the industry** and how the lack of these skills can miss and delay the development of a career in the industry

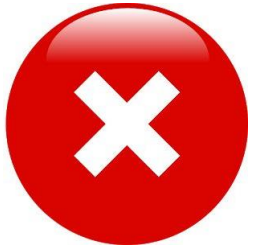


What we expect this session will bring you

- Experience sharing
- Material to run an introspective work on your own skills and experience
- Ideas of how to justify your experience during a job interview

And topics we will not address…

- Differences between a career in the industry and in the academia
- Types of positions a PhD holder can apply for
- The job market
- HR point of view, or the recruitment process
- Country-specific perceptions of the PhD
- Salary expectations



Assets of holding a PhD in the industry

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What a candidate holding a PhD can bring in a company?

- *Creative problem solving*
- *Working in stressful conditions*
- *State-of-the art*
- *Working independently*
- *Collaboration, making new collaborations, networking*
- *Novel approaches*
- *New perspectives*
- *Project management*
- *Look far ahead, long term vision*
- *Leadership*
- *Solving specific problems*

Assets of holding a PhD in the industry

What a candidate holding a PhD can bring in a company?

Her/his technical expertise

Defined as specific teachable knowledge to perform tasks and use tools

Her/his soft skills

Defined as the abilities to behave in given situations and how to interact with others

Assets of holding a PhD in the industry

What a candidate holding a PhD can bring in a company?

Her/his technical expertise

- Directly related to the position
- General, regardless the position
  - Data analysis
  - Coding/Programming
  - Project management
  - Technical writing

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Her/his soft skills

- Problem-tackling
- Transversal thinking
- Creative & critical thinking
- Communication skills
- Ability to activate a network

- Autonomy & self-motivation
- Easy-learning
- Rigor

Defined as the abilities to behave in given situations and how to interact with others

Assets of holding a PhD in the industry

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What a candidate holding a PhD can bring in a company?

Her/his technical expertise

- Directly related to the position
- General, regardless the position
  - Data analysis (1)
  - Coding/Programming
  - Project management
  - Technical writing

Defined as specific teachable knowledge to perform tasks and use tools

Her/his soft skills

- Problem-tackling (2)
- Transversal thinking (3)
- Creative & critical thinking (3)
- Communication skills (4)
- Ability to activate a network (5)
  - Autonomy & self-motivation
  - Easy-learning
  - Rigor

Defined as the abilities to behave in given situations and how to interact with others

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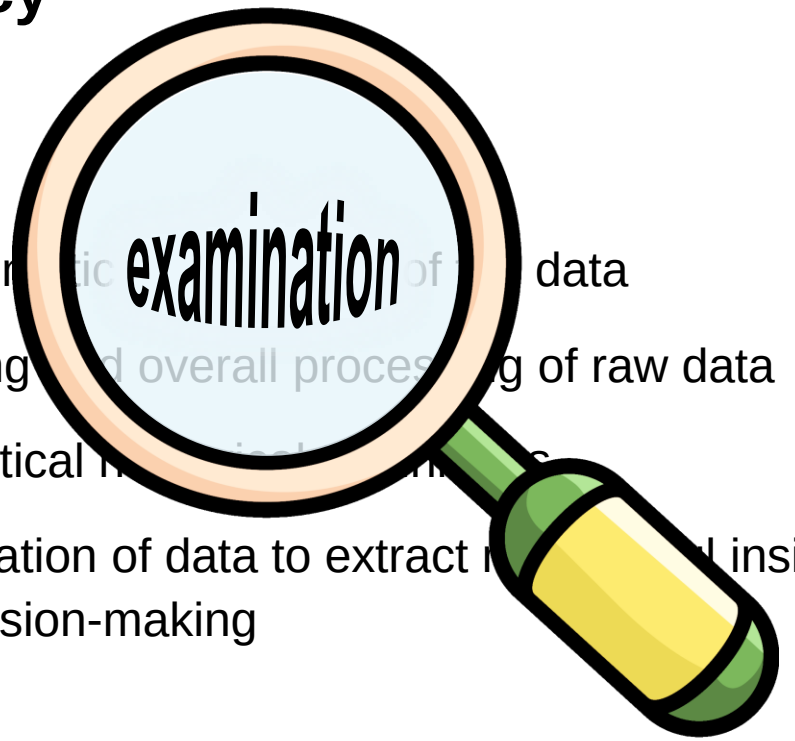
Data analysis proficiency

Data analysis proficiency
Definition

What we mean

- Data analysis includes the systematic examination of the data
- It involves the collection, cleaning and overall processing of raw data
  - It exploits data tools and statistical numerical techniques
- It is concluded with the interpretation of data to extract meaningful insights, identify patterns and inform decision-making

Data analysis proficiency
Definition



What we mean

- Data analysis includes the syste[illegible] data
- It involves the collection, cleaning [illegible] overall proces[illegible]g of raw data
  - It exploits data tools and statistical [illegible]
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Data analysis

=

✓ **Data examination**

Data analysis proficiency
Definition

What we mean

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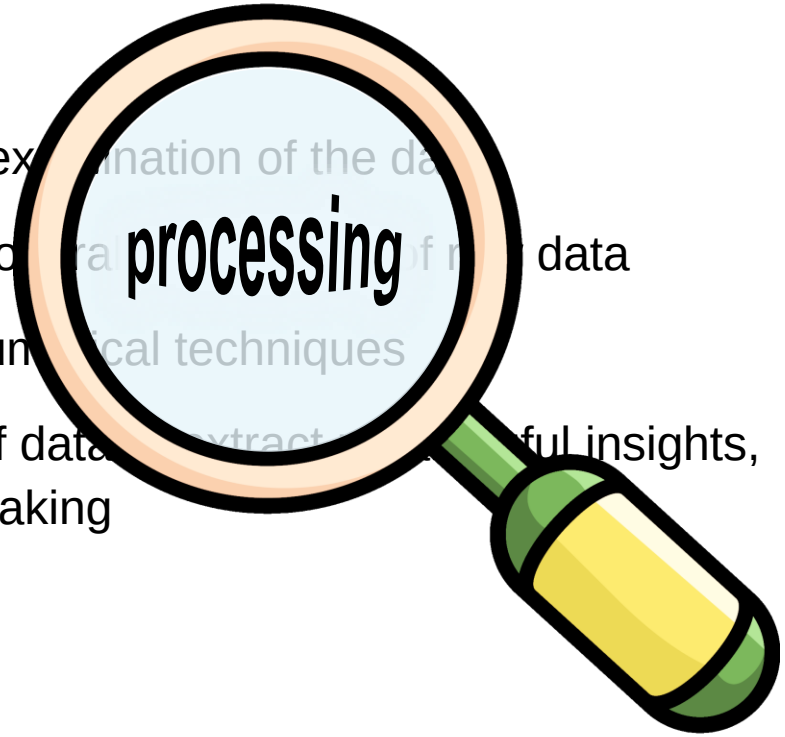

Data analysis

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✓ **Data examination**

+

✓ **Data processing**

Data analysis proficiency
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

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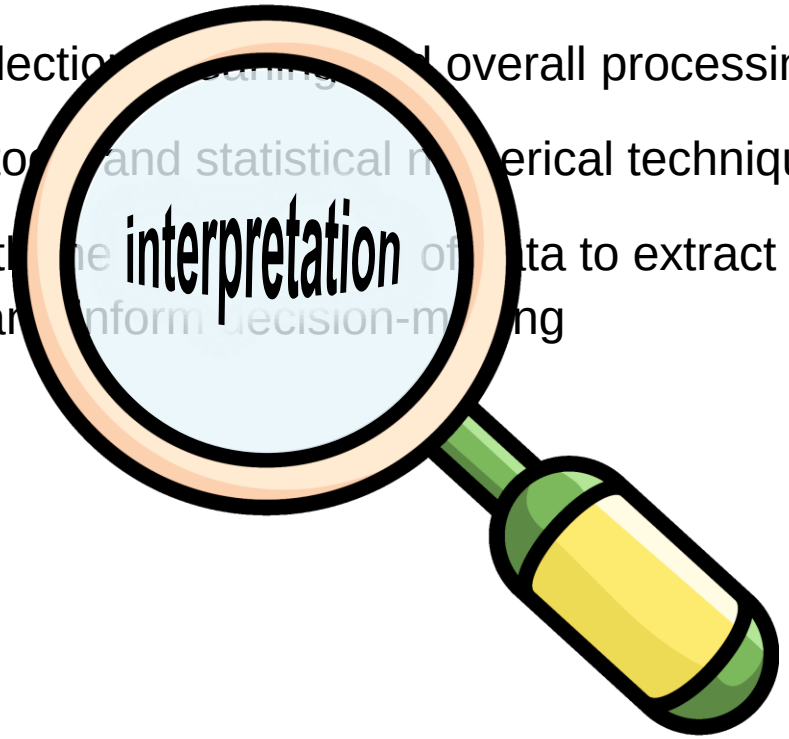

Data analysis

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✓ **Data examination**

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✓ **Data processing**

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✓ **Data interpretation**

Data analysis proficiency
Specificities of PhD holders

SIEMENS Gamesa
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Why this skill is specific to or enhanced for PhD holders?

- Data can be examined in various ways; it is expected a PhD holder to put **more emphasis and critical assessment** (question the data itself and acknowledge the critical role of data quality in deriving meaningful insights) and to perform the examination **more in depth**

Data analysis

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✓ **Data examination**

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✓ **Data processing**

+

✓ **Data interpretation**

Data analysis proficiency
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- Whatever the field, **all data have common features**: they require appropriate filtering and to extract meaningful information from it, one needs to correlate, identify patterns, visualize data, etc… A **domain-specific knowledge** is of great value to apply proven techniques, but the demonstrated experience from the PhD can bring **more sophisticated techniques and tools than the industry standards**, including techniques **from other fields**, enabling to solve **unseen problems**

Data analysis

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✓ **Data examination**

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✓ **Data processing**

+

✓ **Data interpretation**

Data analysis proficiency
Specificities of PhD holders

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- The objective of an analysis is to get information out of it, so one need to interpret data. PhD holders can stand out by **understanding the complexities and nuances** within the data

Data analysis

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✓ **Data examination**

+

✓ **Data processing**

+

✓ **Data interpretation**

Norbert WARNCKE

SIEMENS Gamesa
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Technical coordinator wind models

- **Sports:** rowing, occasionally table tennis
- **Artistic:** photography, acoustic guitar
- **Others:** cakes, pies & crumbles

1999–2001

BERUFSAKADEMIE MANNHEIM
university of cooperative education | staatliche studienakademie

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

BSc Information System Technology
- Thesis: IR Image Processing

2002–2006

Technische Universität Braunschweig

Diploma (= BSc + MSc) Theoretical Physics
- Thesis: Partitioning of Quantum Cellular Automata
- Electives: Semiconductor Physics, Fluid Mechanics/Turbulence
- lab experiments, two parabolic flight campaigns

FRÜHEINSTIEG INS PHYSIKSTUDIUM
iPS 3.0
TU KAISERSLAUTERN

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

2007–2008

SIEMENS Transportation Systems

- Programming Ks semaphores

2009–2013

TU Delft Delft University of Technology

PhD: Turbulent Particle Transport in Multiphase Flows
- PIV measurements in the wake of a rising air bubble

Postdoc 1: Heat transport in supercritical fluids (LDA in supercritical CHF_3)
Postdoc 2: Boundary Element Methods for the simulation of wind turbines (HAWT/VAWT)

AREVA

2014–2015

AREVA Adwen

Scientific Software Engineer
Boundary Element Methods for simulations of HAWTs/VAWTs
- ARDEMA3D v2
- GPU programming (CUDA), numerical optimisation
- Some R&D + MSc projects (Ahmed, Severine) on Galerkin BEMs

2016–2023

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Technical Coordinator CTA Wind (09/2019+)
- BHawC wind module
- LiDAR emulator library
- Wind Field reconstruction algorithms
- BHawC Modularisation, Env-Structure interface
- Atmospheric Physics models
- ~15 MScs & internships

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

Data analysis proficiency
Down the rabbit hole of LiDARs

Anecdote: Understanding a measurement process (Data generation)

Where do we measure?

↳At a point (the beam waist)

↳Over a volume with intensity distribution

↳With a focused TEM_{00} wave in paraxial approximation

↳TEM_{00} +higher order resonator modes of the laser, deflected by prisms, subject to atmospheric dispersion

How do we measure?

↳Effective velocity (Vlos)

↳Doppler spectrum

↳Power spectrum of sample bins

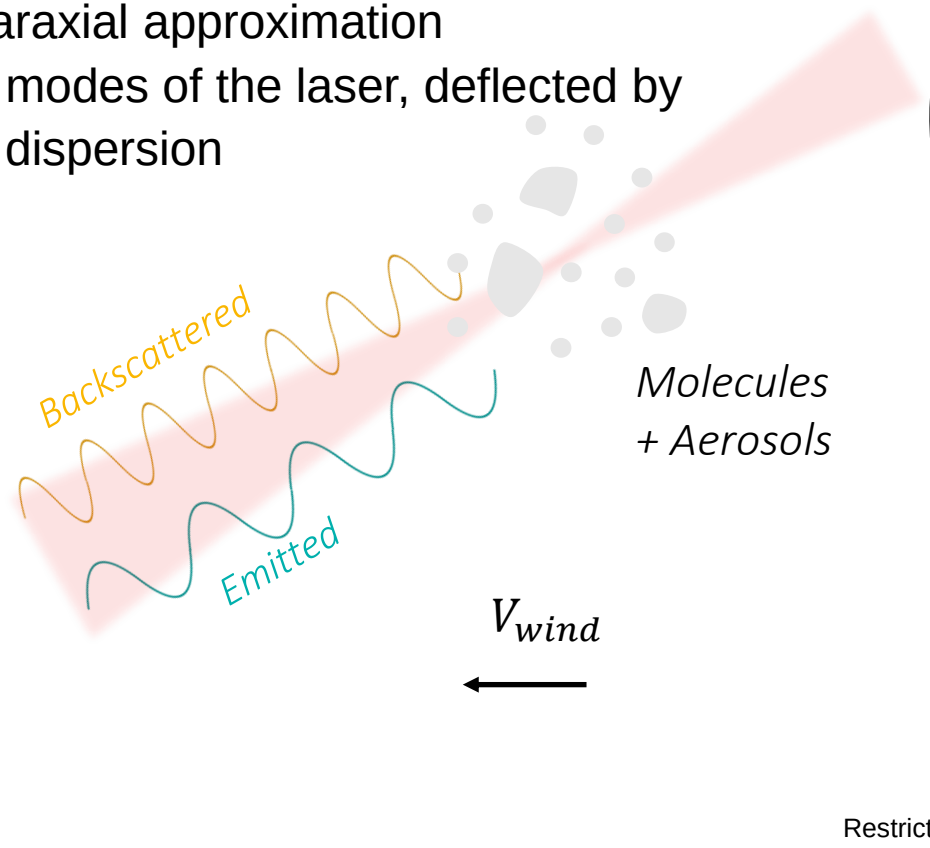
↳Intensity time series

What do we measure?

↳The wind velocity

↳The velocity of aerosols

↳The Mie back-scattered light of aerosols



Data analysis

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✓ **Data generation**

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✓ **Data examination**

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✓ **Data processing**

+

✓ **Data interpretation**

Data analysis proficiency
Down the rabbit hole of simulations

SIEMENS Gamesa
RENEWABLE ENERGY

Anecdote: Understanding a simulation process (Data generation)

What do we simulate?

↳A wind turbine and its wake

↳A velocity field with constant entropy, temperature, density

↳A PDE (e.g. the incompressible Navier-Stokes equation) with some prescribed forcing (e.g. actuator lines)

↳A large-eddy model of the NSE with a Smagorinsky eddy viscosity model inside a domain and with some initial & boundary conditions

↳ An FVM/FEM discretised version of the LES model (weak formulation) on an unstructured mesh

↳ A Newton-Raphson iteration of the nonlinear discretised operators that is subject to some convergence criterion

↳ A preconditioned Conjugate Gradient solver for the sparse and symmetric system matrix in the Poisson solver

↳ Not done yet? Nope, everything is rounded to machine precision, and accumulates numerical errors…

↳ Still not done?? GPUs do not round to IEC754 precision, “-O3 -ffast-math” eliminates Kahan summation, less accurate vector registers, variable-precision solver on tensor cores…

Data analysis

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✓ **Data generation**

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✓ **Data examination**

+

✓ **Data processing**

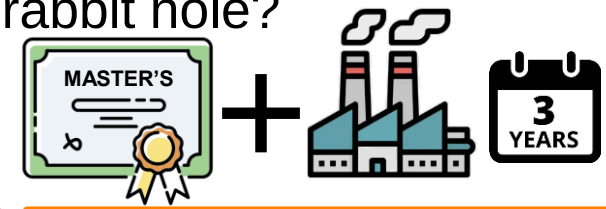
+

✓ **Data interpretation**

Data analysis proficiency

How deep can you go down the rabbit hole?

- Some theoretical knowledge about a measurement process or simulation method (e.g. from courses)
- Some practical experience with a measurement process or simulation method (e.g. acquired during MSc project)



- More experience with practical aspects of measurement (preparation, execution) and simulations (meshing, convergence studies)
- Much more experience with existing tools and automation (e.g. Ansys Fluent, some LiDARs), pre- and post-processing
- More “black-box” usage

- Some experience with practical aspects (visualization, HPC, setting up experiments)
- More in-depth knowledge about specific parts (calibration, meshing, development or implementation of methods)
- Can go further down the rabbit hole?
- Can make a black box transparent?

Alexandros ILIOPOULOS

Advisory Engineer & Business Development Manager
SHM Systems and Services for offshore wind turbines

- **Sports:** Volleyball, Cycling
- **Board games**
- **Films**

Bachelor degree
(Athens Greece)

Mechanical engineering

National Technical University of Athens

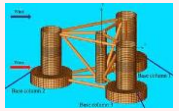
Master's degree
(Athens Greece)

- Specialization in Energy engineering
- Master thesis project : *"Load Analysis-Comparison of different conceptual designs of **offshore wind turbines** and control strategies for load reduction"*

International exchange in Mechanics of Material & Constructions

Research assistant
(Athens Greece)

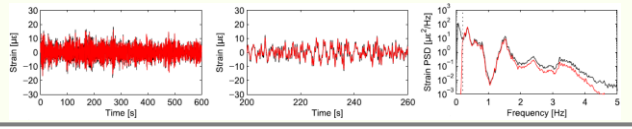
Modeling of semisubmersible floating offshore wind system for OC4 project



Ph.D.
(Brussels, Belgium)

"Virtual Sensing Techniques for Response Estimation and Fatigue Assessment of Offshore Wind Turbines"

- Development & Validation of numerical & experimental modeling techniques
- Development of robust Structural Health Monitoring techniques for OWT's through advanced data processing
- Development of remaining lifetime prediction tools



R&D offshore load engineer, then project manager & business development manager
(The Hague, The Netherlands)

- Developer of SGRE's data-driven engineering tools for assessment of Structural Health and lifetime
- Engineering project manager for offshore Validation & Monitoring projects
- Responsible for techno-commercial solutions related to turbine upgrades and end-of-life decision making
- Business development manager for offshore Validation & Monitoring service contracts

2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

Data analysis proficiency
Sensor types, sensor noise

Anecdote: Understanding measurement sensors & technicalities

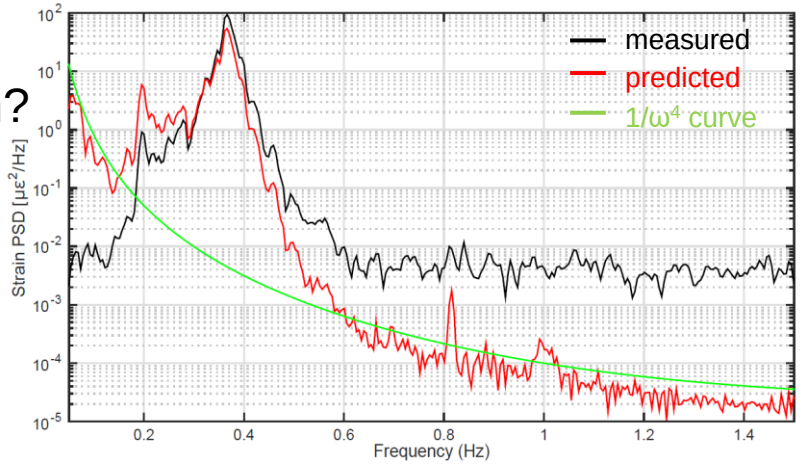
What type of sensors?

↳Accelerometers
- ↳MEMS
  - ↳Down to DC level but poor signal to noise ratio (SNR)
- ↳ICP
  - ↳Unable for static/DC accelerations but better SNR
- ↳Inclinometers
- ↳Strain gauges
  - ↳Resistive strain gauges
    - ↳electromechanical & load calibration?
  - ↳FBG (optical strains)
    - ↳Wave lengths?

What do we measure?

↳Turbine Dynamics with accelerometers
- ↳How many & where to place sensors?

↳Turbine loads with strain gauges



Data analysis

=

✓ **Data generation**

+

✓ **Data examination**

+

✓ **Data processing**

+

✓ **Data interpretation**

Data analysis proficiency

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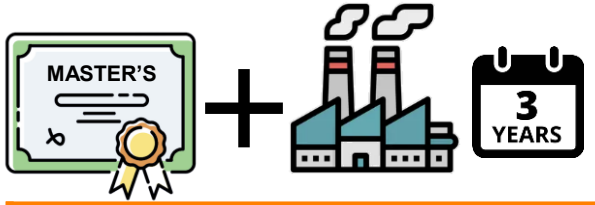
RENEWABLE ENERGY



Examination	• Working with idealized datasets with partial or negligible noise on the signals	• Can work with non-idealized datasets denoising and de-trending signals before use in wider post-processing applications	• Critically qualifies products, services, methods from 3rd parties due to advanced data analysis proficiency
Processing	• Basic knowledge of signal processing (FFT, power spectral density, etc…)	• Field-specific advanced knowledge of data analysis & signal processing (e.g. sampling, aliasing, antialiasing, etc…)	• Understands in detail the nature, the technicalities, the specifications, the applicability limits of signals measured from sophisticated sensors & develops business opportunities
Interpretation	• Will identify patterns he/she has been asked to identify	• Can identify and give a reasoning for both usual patterns and some outlying trends	• Can convert/transform the data into knowledge

Laurent BEAUDET

Technical coordinator (wake modelling)

- **Sports:** rugby, squash, bouldering…
- **Artistic:** making colorful PowerPoint slides
- **Others:** genealogy, etc…

INP ENSEEIHT
Engineering school (equivalent MSc)
- Specialization in Fluid Mechanics

+

Queen's University Belfast
International exchange in Aerospace engineering

noveol L'ÉOLIEN VISIBLEMENT INNOVANT
Industrial PhD in a start up company in PPRIME Institute (*Poitiers, France*)
- Experimental and numerical study of dynamic stall on a high solidity vertical axis wind turbine

Postdoc in EDF-R&D (*Chatou, France*)
- 1-year temporary contract
- Investigation of the effects of the stability of the atmospheric boundary layer on the wake losses

Adwen
Aerodynamic validation engineer (*Rouen, France*)
- 3-year temporary contract
- Validation of a 3D unsteady multi-body panel vortex method for horizontal and vertical axis wind turbines

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R&D load engineer, then wake modelling technical coordinator (*Rouen, France*)
- Permanent contract
- Development of wake models for wind turbines
- Leading a center of excellence on wake modelling
- Teaching "Introduction to Wind Energy" in an engineering school (INSA)

2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

Data analysis proficiency
Showcase

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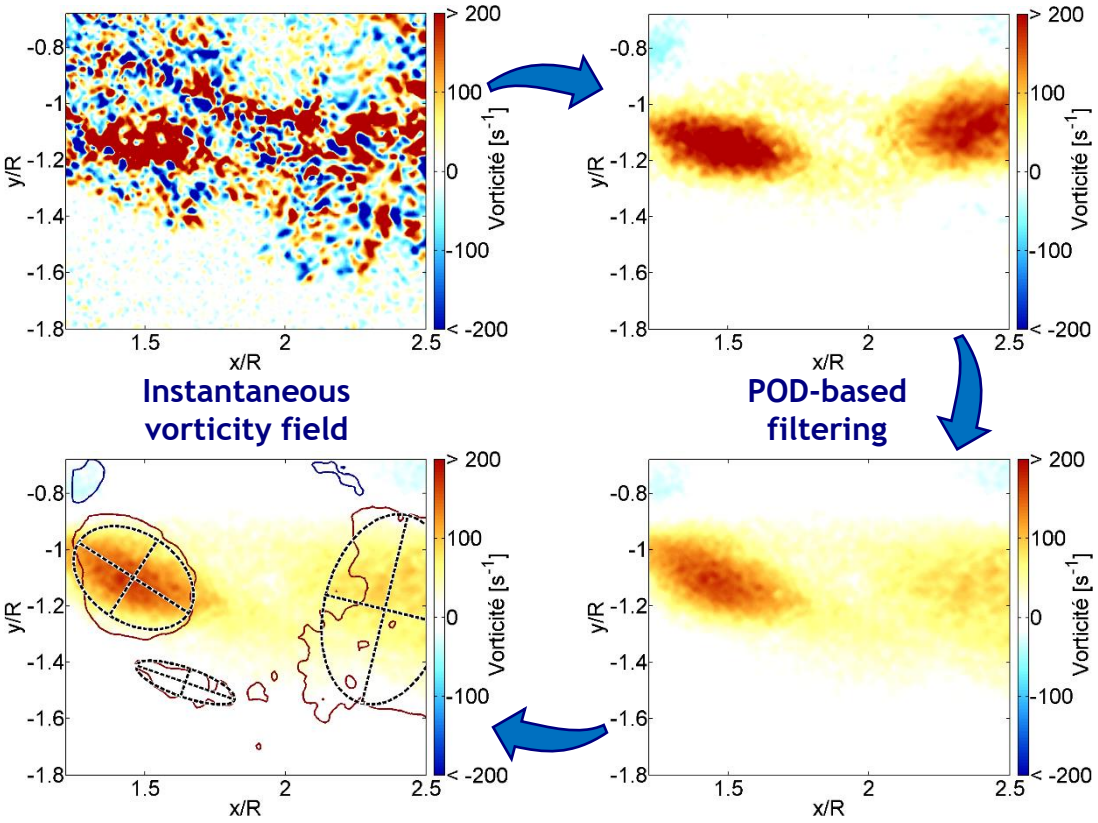
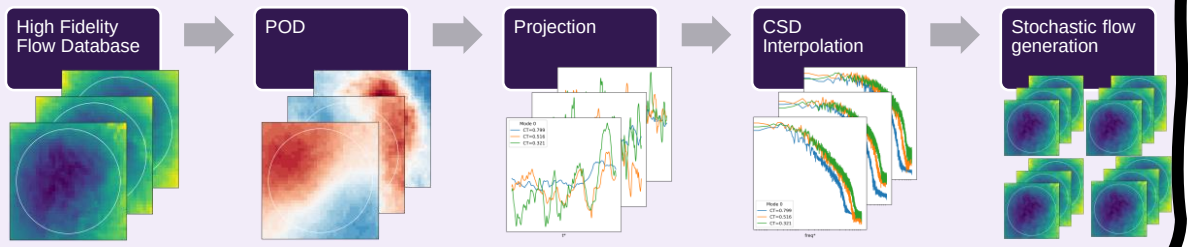
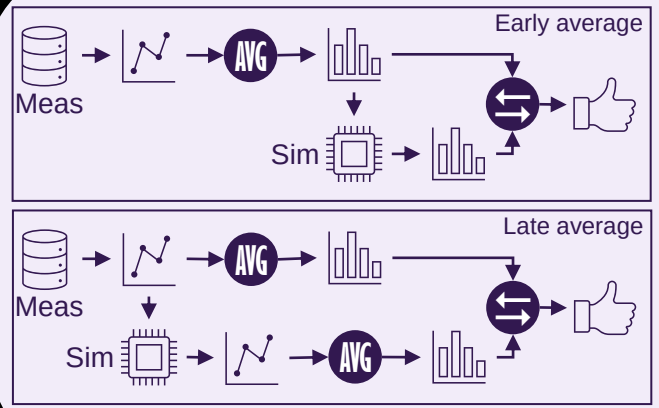
Example: (Laurent) Processing PIV



Transfer learning #1

Application of POD to wake modelling in engineering tools





Transfer learning #2

Apply the average as late as possible in the processes, because the properties of the averaged data are different from the averages of the properties of data

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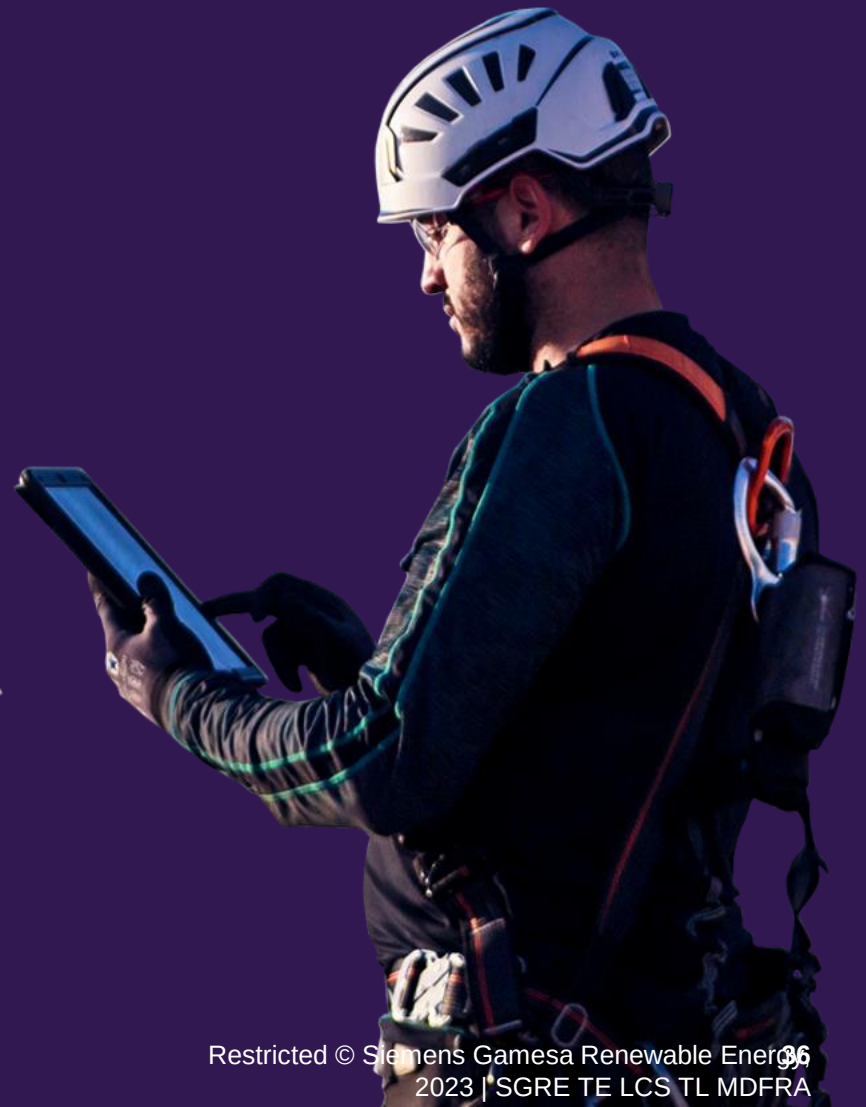
Coffee break!



Problem-tackling

Expert problem solving
Definition

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What we mean

- Problem solving consists in identifying, analysing and finding a process to reach a solution to complex problems, possibly in a set of possible solutions
- The complexity of the problems can be defined in terms of:
  - Well-defined vs. ill-defined issues
  - Single problem vs. numerous problems with high level of interlacing
  - Constant problem vs. evolving challenges
  - Small vs. large-scale problems

Expert problem solving
Definition

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  - Single prob[illegible] vs. numerous [illegible]blems with high level of interlacing
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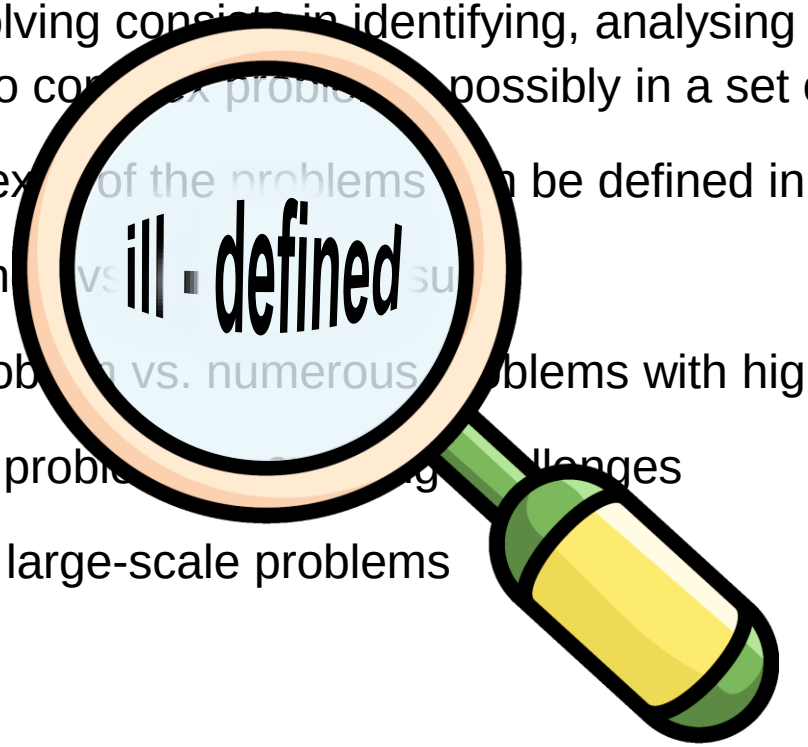

Problem complexity

=

✓ **Problem definition completeness**

Expert problem solving
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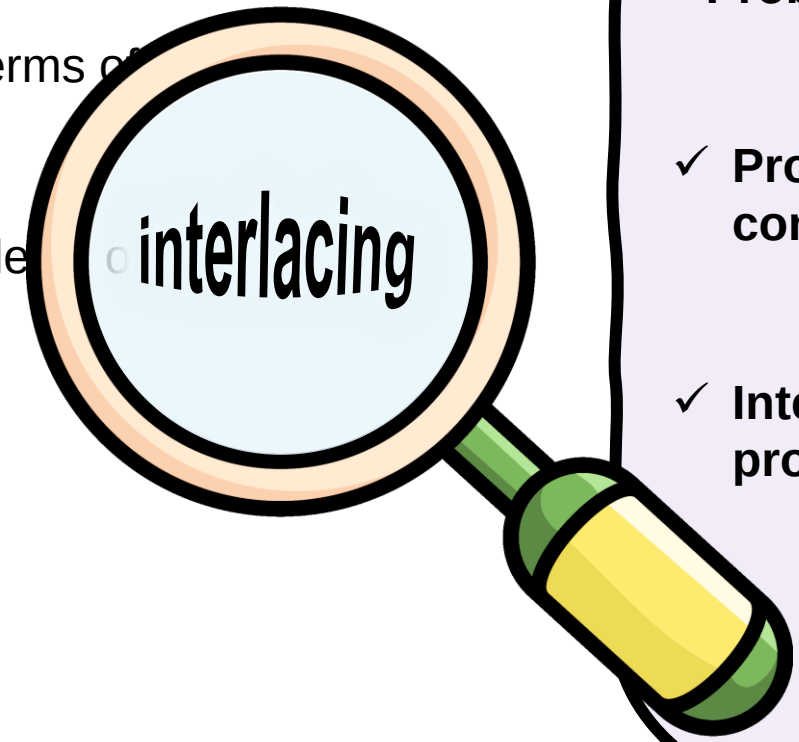

Problem complexity

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✓ **Problem definition completeness**

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✓ **Interlacing of problems**

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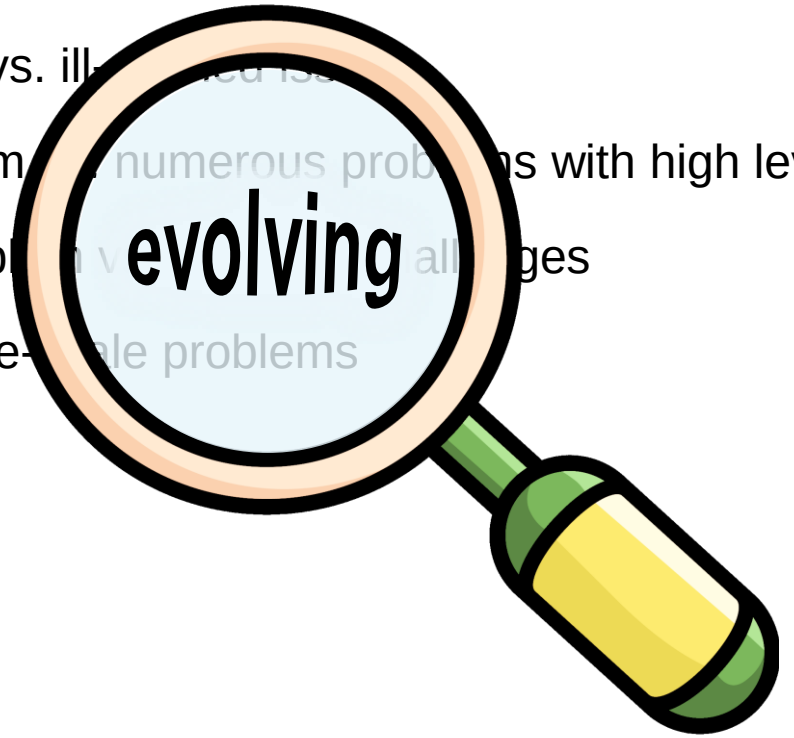

Problem complexity

=

✓ **Problem definition completeness**

+

✓ **Interlacing of problems**

+

✓ **Problem evolution**

Expert problem solving
A Dialectical Thesis

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RENEWABLE ENERGY

Why this skill is specific to or enhanced for a PhD holder?

- A PhD student tries to solve issues at the edge of the current knowledge, so it does not consist in selecting among existing solutions but rather in defining the path to a **solution to an unseen problem**. Such problems are usually ill-defined, and a PhD holder will **complete the missing parts** of the problem in order to solve it

Problem complexity

=

✓ **Problem definition completeness**

+

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- A problem is often the consequence of multiple previous ones. One needs to **dissect the problem** at a granular level that enables the understanding of the interlacing to identify the origin. The underlying factors that may not be immediately apparent, a PhD holder excels in **splitting the problem** and applying techniques to **identify links between the problems**

Problem complexity

=

✓ **Problem definition completeness**

+

✓ **Interlacing of problems**

+

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A Dialectical Thesis

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- In (academic) research, it is very common to adjust/revise problem-solving strategies based on new information or unforeseen circumstances (own observations, new publications)

Problem complexity

=

✓ **Problem definition completeness**

+

✓ **Interlacing of problems**

+

✓ **Problem evolution**

Expert problem solving
A Dialectical Antithesis

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RENEWABLE ENERGY

What type of problems are faced/solved in industry?

- Industry is a social process and as such formally independent of truth or (academic) objectivity, it creates its raison d'être by **transforming natural resources** into **products that have a social use**. Society (the consumers of the products) decide over its fate with their purchase behavior. The primary problem that industry is facing can therefore be summarized as **maintaining the process of transformation of natural goods into products under the constraints and acceptance of society**.

Problems in industry

=

× **More social than technical problems**

+

× **Narrow problem scope**

+

× **Problem solution conditional to a social need**

Expert problem solving
A Dialectical Antithesis

SIEMENS Gamesa
RENEWABLE ENERGY

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RENEWABLE ENERGY

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- Problems are not solved for their own purpose, but either for aiding the transformation process or for improving the (objective) social use/the product.
- Problem solution is conditional:
  - As simple as possible/sufficient
  - Complexity is avoided wherever possible
  - Solution is delayed until a need for a solution arises

Problems in industry

=

× **More social than technical problems**

+

× **Narrow problem scope**

+

× **Problem solution conditional to a social need**

Expert problem solving
A Dialectical Synthesis

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RENEWABLE ENERGY

How can industry and specialists in problem solving come together?

- Objectivity is on the rise again (for most people), nature tells us to **either adapt** to it **or perish** as species by eliminating the biological basis of our existence
- Existing solutions are reaching their limits in applicability to the range of problems arising, the industry is in dire needs for new solutions
- Predictability is reduced, more and more problems are faced at later product stages

Problems in industry

=

↳ **Nature dictates more and more the terms**

+

↳ **Society will adapt, but slowly**

+

↳ **Problem solution process is essential to bridging the gap**

Expert problem solving
A Dialectical Synthesis

SIEMENS Gamesa
RENEWABLE ENERGY

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- Social transformation processes (also in industry) are slow (conservatism)

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SIEMENS Gamesa
RENEWABLE ENERGY

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- Social constraints are growing in importance (social acceptance of products), and the transformation process resource → product is becoming more difficult
- Social transformation processes (also in industry) are slow (conservatism)
- Demand for problem solvers is high, but in the niches that need to be found:
  - Deep-dive into processes and methods is essential, bottom-up transformation
  - Pure high-level abstraction alone is probably not leading to new solutions ("bridging the gap" between the idea and the product)

Problems in industry

=

↳ **Nature dictates more and more the terms**

+

↳ **Society will adapt, but slowly**

+

↳ **Problem solution process is essential to bridging the gap**

Expert problem solving

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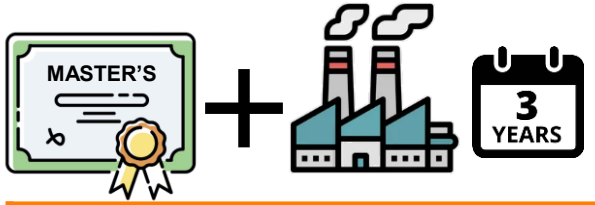
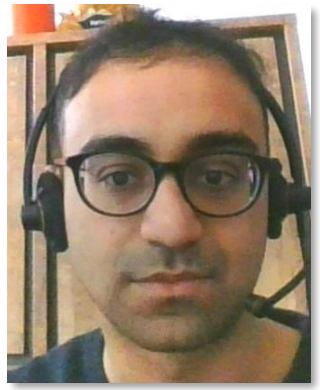
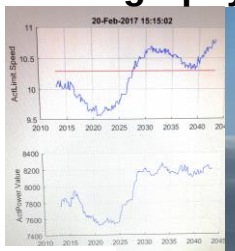
			
Problem depth	• Sticking to the domain corresponding to the education • Depth mostly in area of specialization (e.g. MSc thesis)	• Improved practical depth (constraints, workarounds, applied methods) • Development of analytical depth strongly dependent on environment	• Improved theoretical/analytical depth • Practical depth limited by PhD subject • Exposure to literature and academic exchange
Problem range	• Good generalists • No specific job experience • Mostly user of existing tools and processes	• Experienced user/worker • Covers range required by job • Likely no further exposure to other areas	• Experience limited to range of PhD project • Broader range of insights, things "heard and seen"
Social structure	• Learning/growth limited by task assignment, priority on productivity • Largely job-specific trainings, no more working towards understanding	• Integrated into the work process, regular tasks and responsibilities • Trainings largely on initiative, and likely task- or job-specific	• More likely to be assigned to a research task • Less likely to be assigned to a repetitive or automatized task

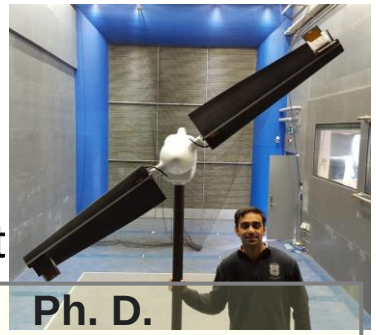


Sachin NAVALKAR

Team Lead – Support Structure Loads [Design Centre]

- **Sports:** Badminton, gymnastics, cycling
- **Cartography**





Bachelor degree
(Mumbai India)
Mechanical Engineering

Master degree
(Delft, the Netherlands)
Sustainable Energy Technology

Development Engineer

(Chennai India)	*(Århus Denmark)*	*(Hamburg Germany)*
Drive Train Dynamics	Condition Monitoring	Service Technology

Ph. D.
(Delft, the Netherlands)
"Iterative data-driven load control for flexible wind turbine rotors"
- Aeroelastic simulations
- Wind tunnel experiments
- System identification
- Repetitive Control
- Free-floating flaps + IPC

Control Engineer
(Copenhagen, Denmark)
- Lead on 8MW
- Tech Owner Control Validation
- HiL testing of turbine grid response (Fraunhofer IWES)

Offshore Engineer
(The Hague, the Netherlands)
- (Seismic) design of Ishikari OWF
- Tech Owner Control
- 15MW offshore platform rollout co-ordination

Team Lead
(Bengaluru India)

2004 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2016 | 2019 | 2022 | 2023

Iterative Learning Control: From theory to reality

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The real-world problem: The shutdown caused by a grid error is by far the most severe power and loads transient your (floating!) wind turbine will ever experience

The theoretical solution from literature: ILC is an « optimal » control strategy that will guarantee overspeed protection and loads minimisation given system constraints

Reality strikes! Where's the optimality with

- Uncertain system dynamics
- Highly non-linear systems
- No possibility for « trial and error » in the field

PhD's to the rescue!

- Evaluation in high-fidelity representative simulations
- Extraction of physical insights from theoretically optimal trajectories
- Embedment of simplified trajectories with safety guarantees in the field

*ILC for grid faults will be presented in Torque 2024: Spijkerman, Navalkar, Solberg and Mulders.

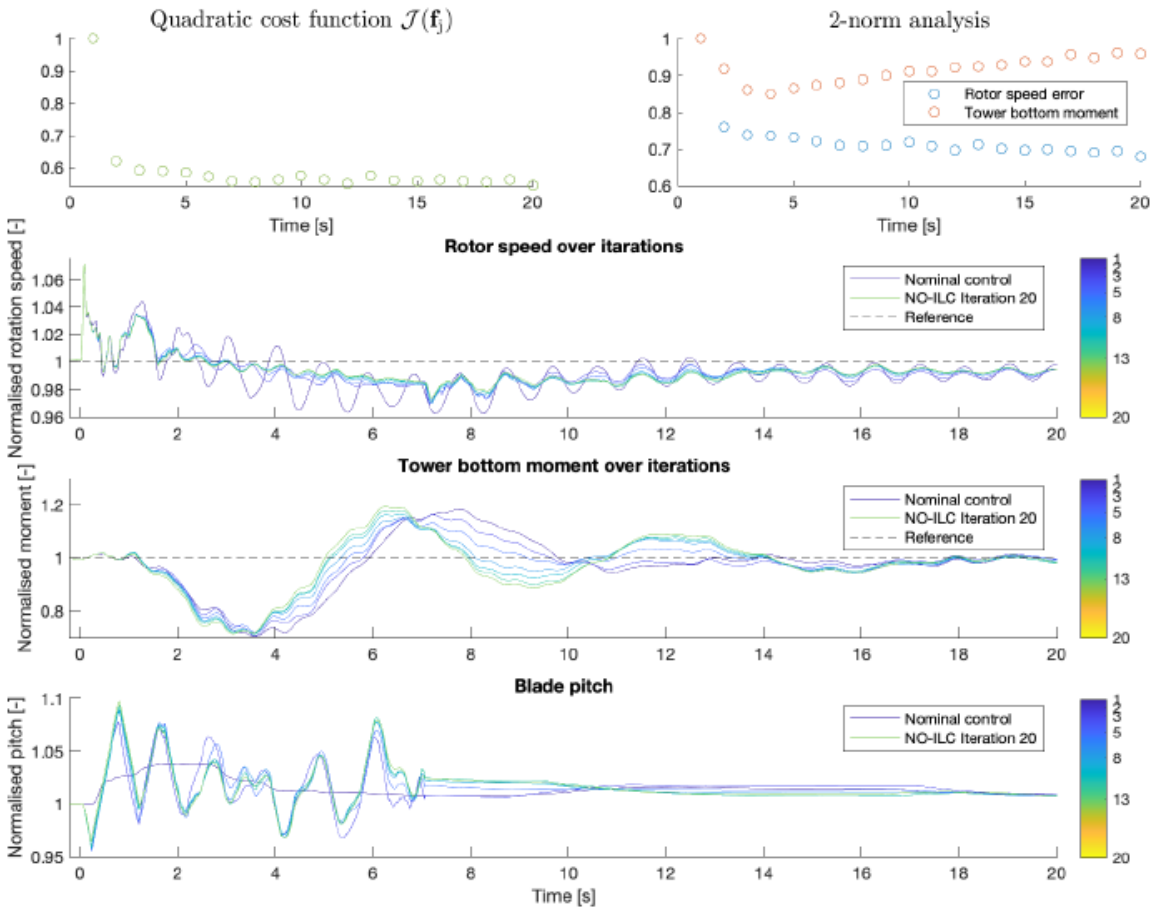
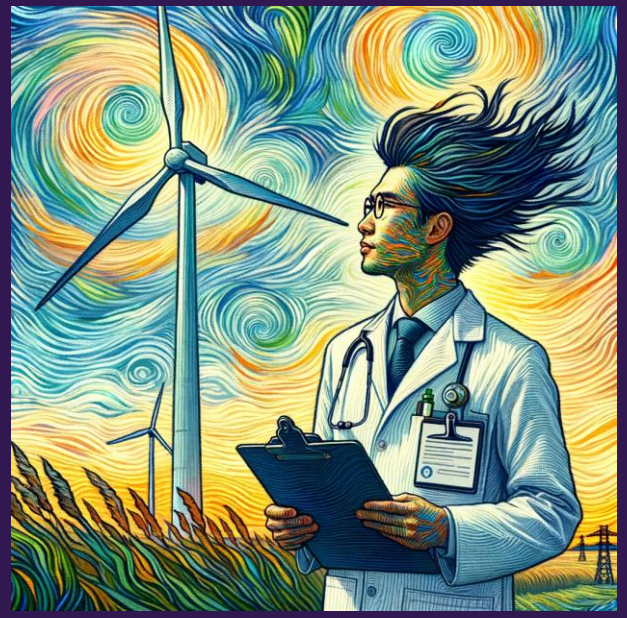
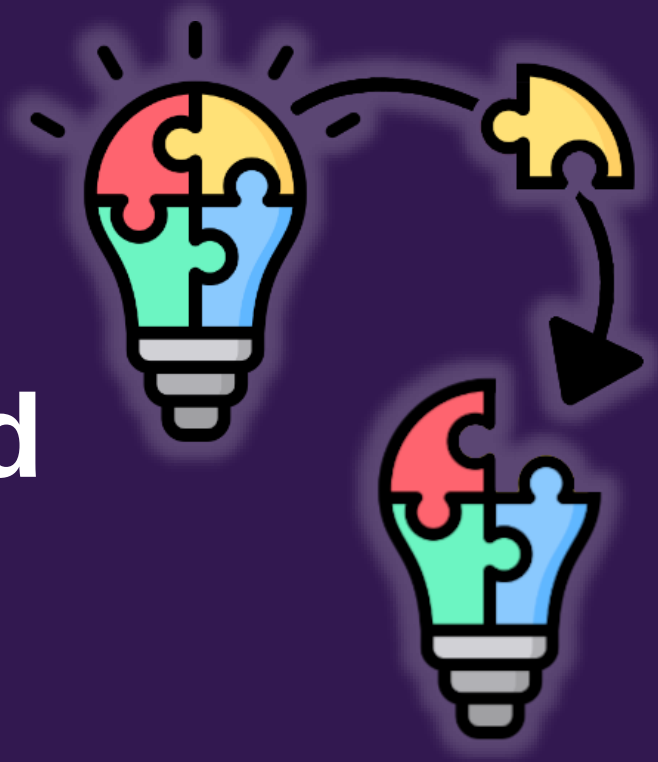


Figure 4. Comparison of norm-optimal ILC and a nominal feedback controller for a grid fault to 0.2 V/pu for 300ms on a high-fidelity simulation model. Top left shows cost function $\mathcal{J}(\mathbf{f}_j)$, top right the l^2-norm of the rotor speed and tower bottom moment.



Transversal, creative and critical thinking



Transversal, creative and critical thinking
Definition

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RENEWABLE ENERGY

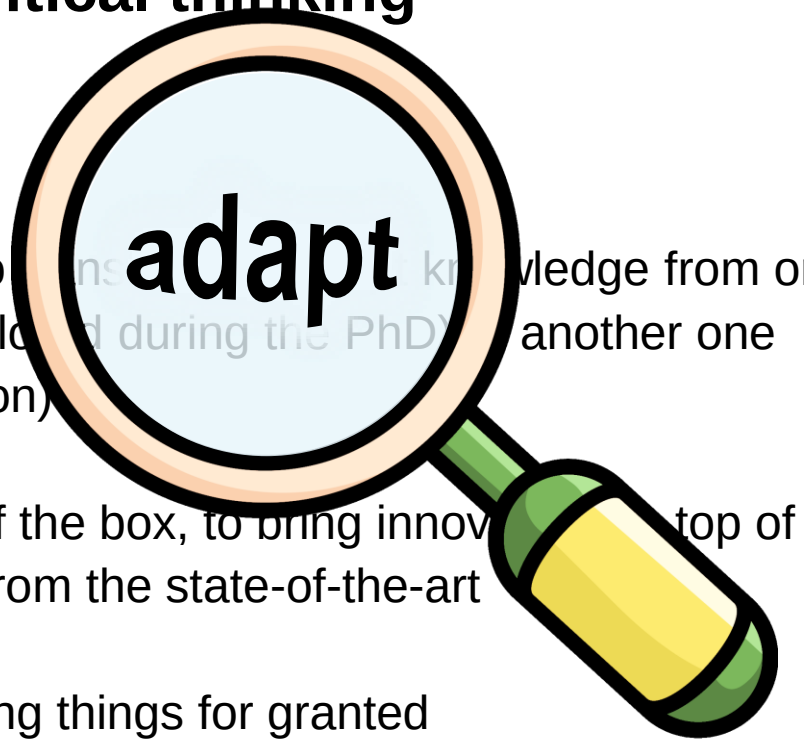
What we mean

- **Transversal thinking** is the ability to transfer and adapt knowledge from one domain (for example, something explored during the PhD) to another one (typically a topic of the current position)

- **Creativity** is the ability to think out of the box, to bring innovation on top of the usual tools used in the company or from the state-of-the-art

- **Critical thinking** consists in not taking things for granted
  - Ability to detect an unusual physical behavior
  - Not making assumptions that could lead to wrong conclusions
- **Critical thinking** is also keeping a pragmatic approach when implementing solutions
  - Does this solution already exist in the industry/academia ?
  - Is the outcome this solution worth the time it takes to implement it ?

Transversal, creative and critical thinking
Definition



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✓ **Adaptation**

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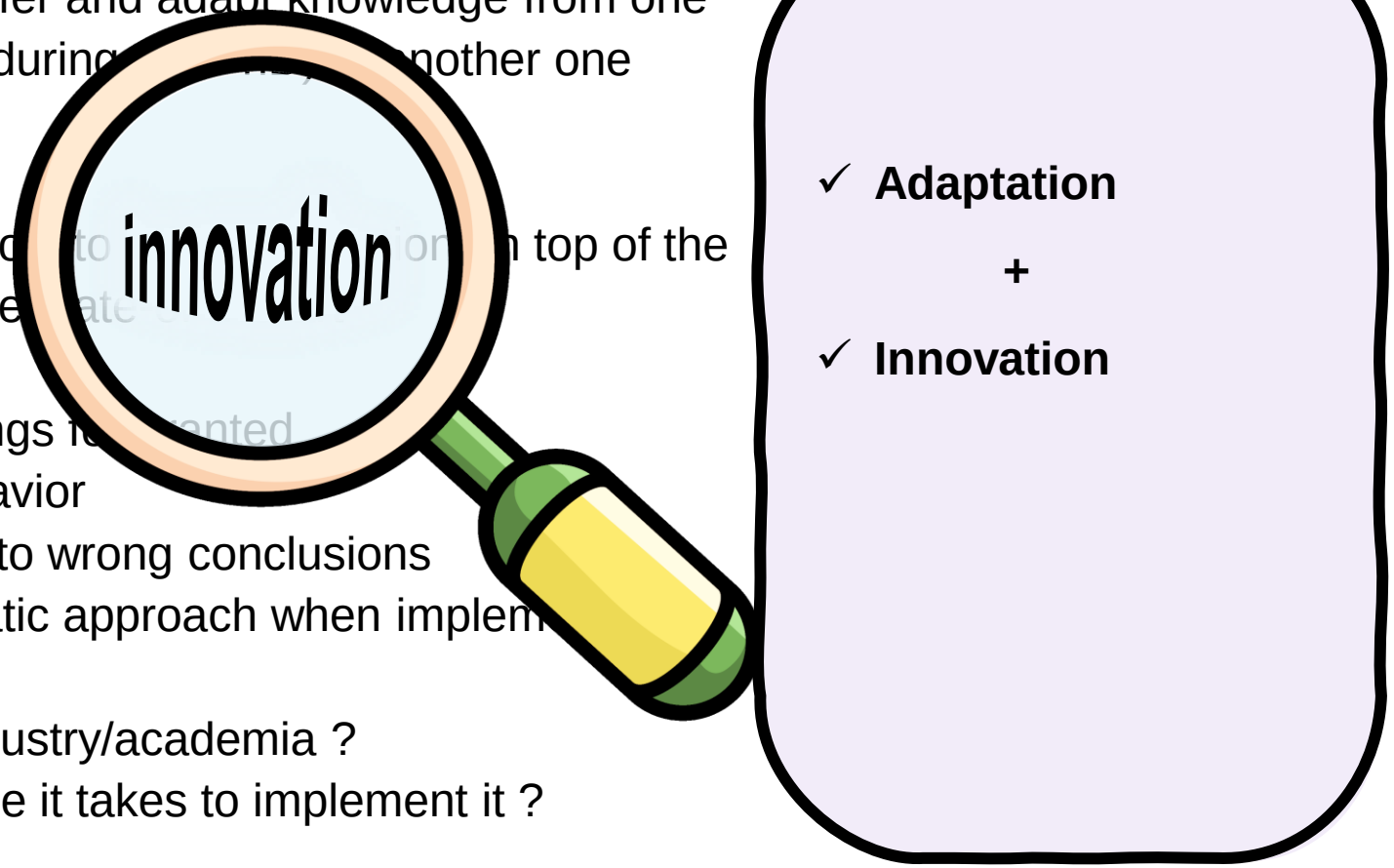

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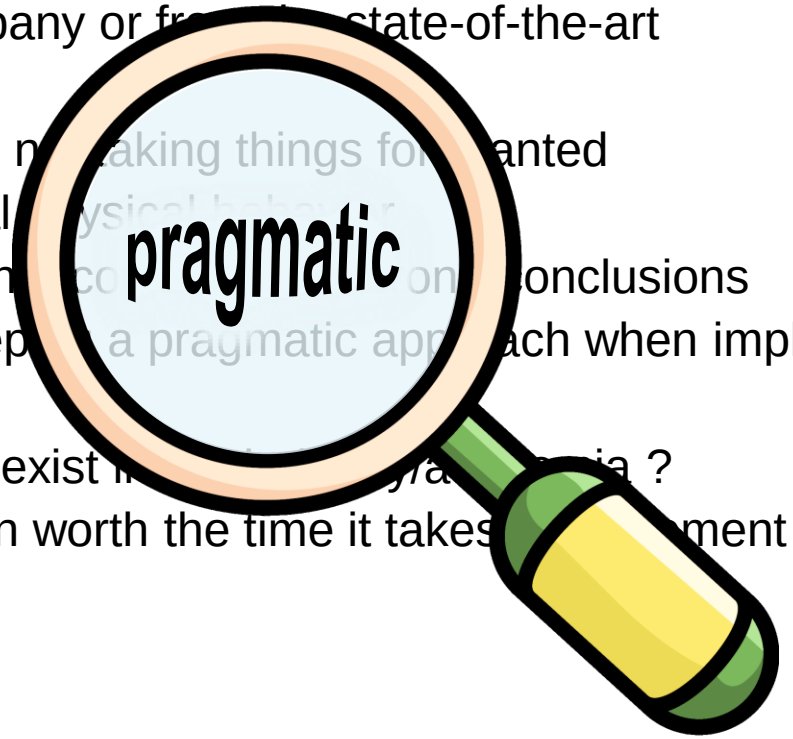

- ✓ **Adaptation**
- **+**
- ✓ **Innovation**
- **+**
- ✓ **Pragmatism**

But be thorough and pragmatic, you're a scientist

Transversal, creative and critical thinking
Specificities of PhD holders

Why is this skill enhanced for PhD holders?

- **By nature, PhD thesis topics tackle problems that don't have a solution**
- However, elements of solution or knowledge may exist in other domains to tackle this problem, where similar questions have maybe been encountered.
- It could also be that the questions encountered in those other domains are completely different, but the tools or methods that they use can be transposed to our problems.
- PhD students usually develop the habit to search for existing knowledge, possibly in transversal fields of research.

✓ **Adaptation**

+

✓ **Innovation**

+

✓ **Pragmatism**

Transversal, creative and critical thinking
Specificities of PhD holders

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- A PhD thesis also requires to create knowledge, based on existing knowledge combined with personal creativity

✓ **Adaptation**

+

✓ **Innovation**

+

✓ **Pragmatism**

Transversal, creative and critical thinking
Specificities of PhD holders

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- PhD students usually develop the habit to search for existing knowledge, possibly in transversal fields of research.
- A PhD thesis also requires to create knowledge, based on existing knowledge combined with personal creativity
- A quality probably acquired during a PhD with more difficulty: pragmatism
  - Is the new proposed model/technology/solution really necessary and will its outcome be different from already exist ?
  - Are the results that I get with this new solution expected? Does it include too strong assumptions? Is it physical?

✓ **Adaptation**

+

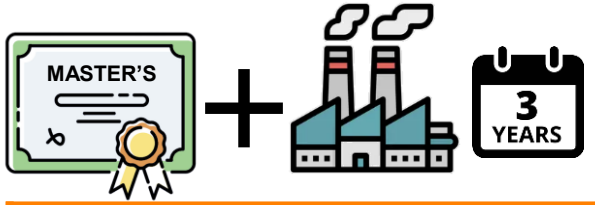
✓ **Innovation**

+

✓ **Pragmatism**

Transversal, creative and critical thinking

SIEMENS Gamesa
RENEWABLE ENERGY

			
Transversal	• Sticking to the domain corresponding to the job	• Sticking even more to the domain corresponding to the job, because of the experience ?	• Easier to adapt methods and tools from other disciplines to the domain corresponding to the job • Can bring knowledge from other domains if the PhD was in a different domain
Creative	• Mostly user of existing tools and processes	• After 3 years of experience, becomes more confident and develop creativity? But still revolving around the existing knowledge?	• Has developed creativity during the PhD • But creativity can sometimes blur a pragmatic engineering judgment (e.g. choosing the creative option even if it has no clear outcome compared to the existing option...)
Critical	• Sticking to knowledge learnt at school, more difficulties to identify special situations	• More critical when analyzing results • May not know that a solution exists already and/or may not think about doing a literature review, which may cause redundant work	• Can more easily detect unusual physical phenomena • Is used to state-of-the-art reviews, so less temptation to develop from scratch an existing solution

Bastien DUBOC

Technical coordinator aeroelastic stability

- **Sport:** bike
- **Music:** drums, bass
- **Others:** cooking

Engineering School/ Master Degree
(Rouen, France)

- Specialization in Energy and Propulsion
- Aeronautics, CFD (RANS-LES), Combustion, Turbomachinery
- Master thesis project at Safran – Implementation of a chemistry model in a CFD code for the simulation of gas generators for rocket engines

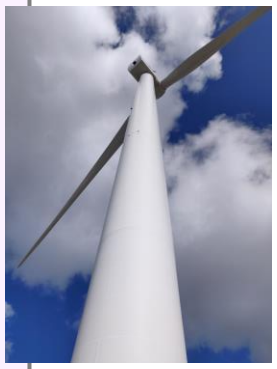
Ph.D. *(Rouen, France)*

"Hybrid Transported-Tabulated Chemistry for numerical simulation of combustion"

- Development of a new combustion model for DNS/LES codes
- Purpose: enable the introduction of detailed kinetic mechanisms of heavy fuels (kerosene, etc.) for the simulation of combustion within an acceptable computation time

Turbine Loads R&D Engineer
(Rouen, France)

- **Turbine stability in idling/standstill**
  - Support/coordination with academic partners in collaboration projects
  - Tests on turbine prototypes
- **Implementation of code coupling**
  - Support to development of coupling interfaces
  - Coupling between aero-elastic codes and CFD codes
- **Preparing and teaching lectures on wind energy at INSA**



2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

Hybrid Transported-Tabulated Chemistry
A creative idea with a lack of critical thinking – leading to skills reused in the wind industry

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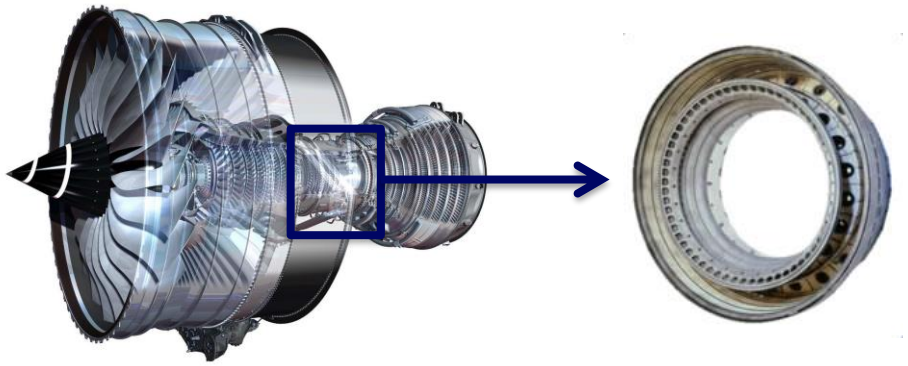


Aeronautic engine

Combustion chamber

$H + O_2 = OH + O$
$O + H_2 = OH + H$
$CO + OH = CO_2 + H$
$CO + O_2 = CO_2 + O$
$CH + O = CO + H$
$CH + CH_3 = C_2H_3 + H$
…
$CH_4 + H = CH_3 + H_2$
$CH_4 + O = CH_3 + OH$
$C_2H_2 + H = C_2H_3$
$C_2H_6 + OH = C_2H_5 + H_2O$

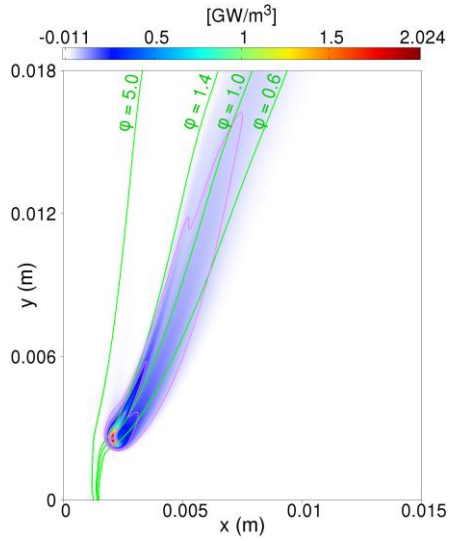
Chemical reactions/species

$$\frac{\partial \rho Y_k}{\partial t} + \frac{\partial}{\partial x_i}(\rho(u_i + V_{k,i})Y_k) = \dot{\omega}_k$$

Species transport equation in CFD
→ Costly

HTTC

Model to reduce the cost of chemistry and species transport



Simulation of "simplified" flame

- Basically a combination of existing models to keep only their advantages
  - On the paper, accurate and fast
  - Transversal & creative thinking ?
- But probably a lack a critical judgment during the model development
  - Dramatic speed gain on simplified setups, but not designed to work with the complexity of the real world...
  - Lower performance and flexibility compared to existing models when applied to real cases
- Skills in code development and numerical simulation have been reused at Siemens Gamesa

Paul DEGLAIRE

R&D manager France

- **Sports:** sailing, running
- **Others:** married, 2 kids
- **Classical piano**

MSc
École des Ponts ParisTech
- General mechanics & maths

+

University of Southampton

International exchange in Fluid mechanics

PhD
UPPSALA UNIVERSITET
DTU

Mathematical PhD on vertical axis wind turbine
Extension of theory for aero elasticity
First loads tool for VAWT turbines (even several ones based on vortex methods, coupling to elastic solver
Only in 2D

Coordinator for engineering and R&D
(Paris)
AREVA

Program operational monitoring: technical projects reviews including third parties validation
Long and mid term R&D roadmaps

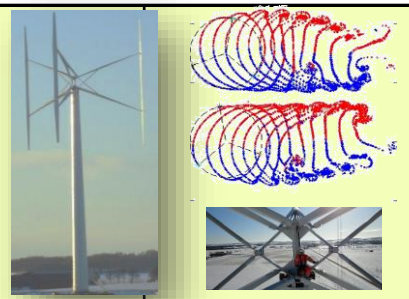
Adwen
AREVA

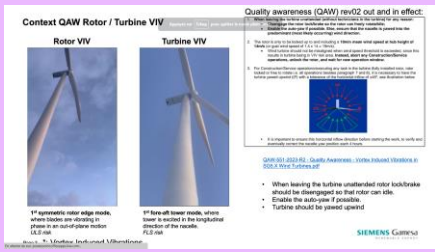
AD5-135 Wind turbine development program manager
(Bremen)
- Program execution (planning, performance, budget) Leading the cross functional team of 7 subprogram managers:

SIEMENS Gamesa RENEWABLE ENERGY

Turbine Loads Modeling FR team lead
(Paris, France)
- Management of technical experts in the field of advanced aerodynamics for loads, vortex induced vibrations, wind field reconstruction and wakes & wind farm effects.
- Leading new technology Development (R&D) project on VIV/SIV in support to New Product Development (NPD) derisking, RCA analysis

2001 | 2005 | 2008 | 2011 | 2013 | 2023





Transversal, creative and critical thinking
Showcase

- Paul: Vibrations in Alpha Ventus – what was their cause?

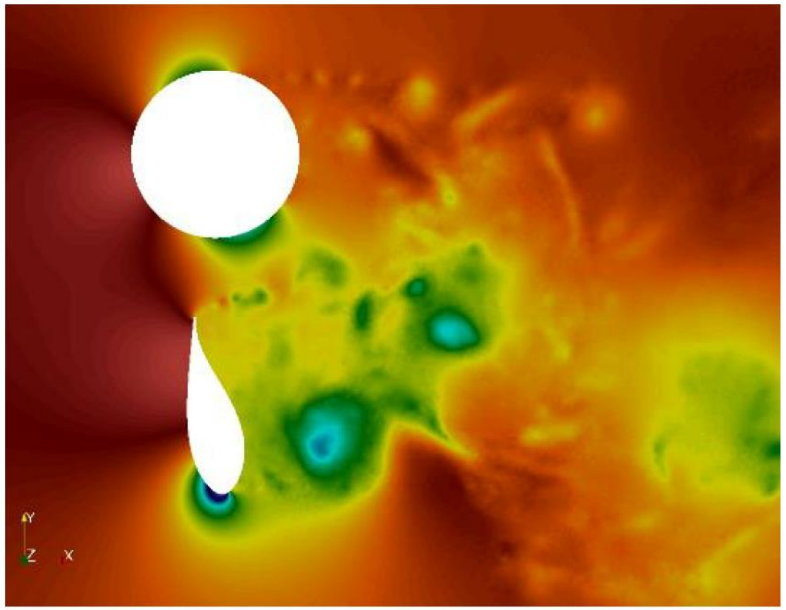
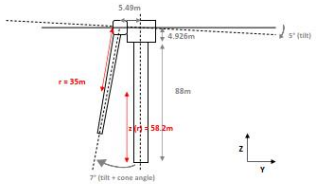
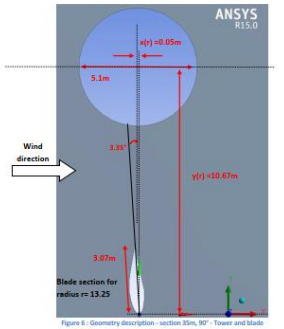


Figure 30: Instantaneous pressure field – Section 18.25m, 90°, 10m/s –Tower + Blade





Analysis of Vortex Induced Vibrations on AD-5-116 wind turbine blades – Galloping RCA	10/04/2015	Page : 11/30
F. Barnaud	Internal Ref. : TER-ADW-GTE-BW2-0003-R0	Revision : R0

	AD5-116			
	Wind Speed range	**Wind Misalignment range**	**Pitch**	**Rotor**
Mechanism 1 (swaying)	>10m/s	+90° (±30°)	90°	Standstill
	>10m/s	-90° (±30°)	90°	Standstill
Mechanism 2 (galloping)	10-15m/s	-60° (±30°)	90°	Standstill
	>15m/s	-20° to -105°	90°	Standstill
	>15m/s	+45° to +105°	90°	Standstill

Table 5. AD5-116 WTG conditions for Mechanism 1 and 2.

	AD5-135			
	Wind Speed range	**Wind Misalignment range**	**Pitch**	**Rotor**
Mechanism 1 (swaying)	>10m/s	+90° (±30°)	90°	Standstill
	>10m/s	-90° (±30)	90°	Standstill

Table 6. AD5-135 WTG conditions for Mechanism 1

Transversal, creative and critical thinking
Showcase

SIEMENS Gamesa
RENEWABLE ENERGY

- Paul: another example of transveral thinking (a bit more successful) – in links with network and expertise

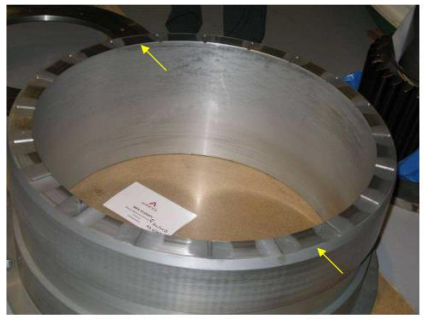


Photo 3: bearing from planet D

Photo 4: The limit is straight

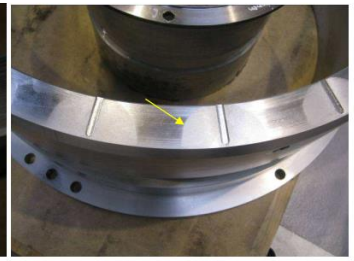
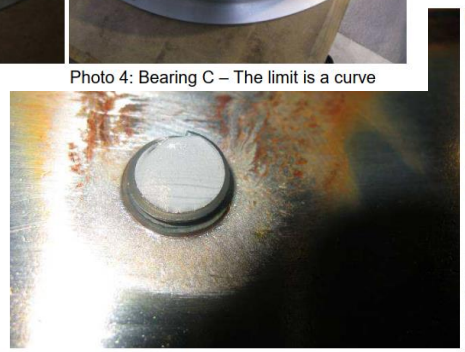


Photo 4: Bearing C – The limit is a curve



Photos 1 & 2: broken screws, part in the hub.

The other screws (planets A, B, D): the screws located on the pinion side were removed. According to AREVA Wind they are OK.

RCA04	The proposed cause for the steady increase of temperature in the bearings is an evolution of the shell dimensions that could be explained by swelling or change of metallurgical phase or stress release…
RCA06	After the evolution of dimensions (see RCA04) and thermal divergence (axial clearance decrease ➔ increase of temperature ➔ axial clearance decrease etc...), the clamping of the rings by the bush is probably the cause of the destruction of the screws and the cause of the thrust bearing problems.
RCA05	The consequences of the loss of the screw heads that fell down in the gears are most probably the damages of the 1st stage gears.
Recommendations	The Zn Al bearings are inappropriate (thermal expansion & instability) and are to be replaced by white metal bearings.
	The thrust block axial clearance must be increased.
	The thrust block (rings, screws) is not under dimensioned nevertheless improvement of the resistance is easily possible.
	The teeth coupling could be a source of problem during the next

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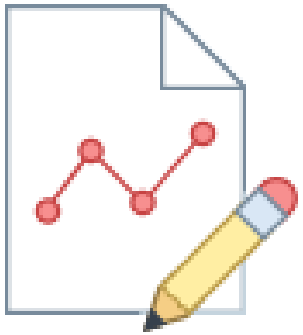
RENEWABLE ENERGY

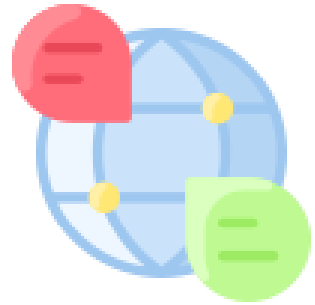
Communication skills

Effective communication skills
Definition

What we mean

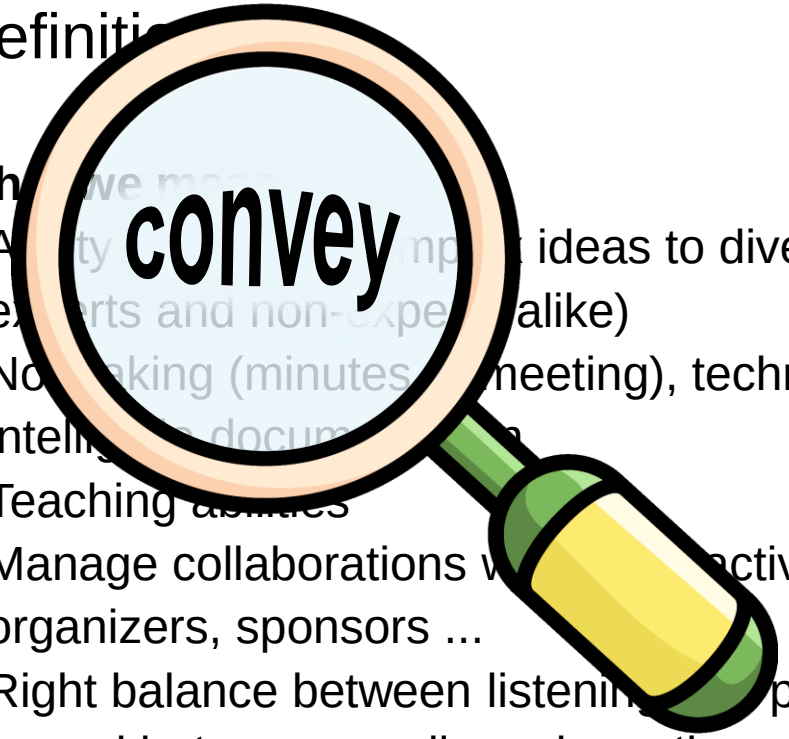
- Ability to convey complex ideas to diverse audiences (engage with experts and non-experts alike)
- Notetaking (minutes of meeting), technical report and intelligible documentation
- Teaching abilities
- Manage collaborations with other activity centers / suppliers / project organizers, sponsors ...
- Right balance between listening and proactivity ...
- … and between emails and meetings
- Intercultural communication / awareness of cultural differences
- Fund-raising / Convincing stakeholders





Effective communication skills

Definiti



Wh ve

- A ty np ideas to diverse audiences (engage with e rts and non-expe alike)
- No king (minutes meeting), technical report and intelli documen
- Teaching abilities
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- Right balance between listenin proactivity ...
- … and between emails and meetings
- Intercultural communication / awareness of cultural differences
- Fund-raising / Convincing stakeholders

SIEMENS Gamesa
RENEWABLE ENERGY

Effective communication

=

✓ **Knowledge sharing**

Effective communication skills
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

What we mean

- Ability to convey complex ideas to diverse audiences (engage with experts and non-experts alike)
- Notetaking (minutes of meeting), technical report and intelligible documentation
- Teaching, Politics
- Managing collaborations with other activity centers / suppliers / project organizers, sponsors ...
- Right balance between listening and proactivity ...
- … and [illegible] meetings
- Intercultural communication / awareness of cultural differences
- Fund-raising / Convincing [illegible]rs

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

Effective communication skills
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

What we mean

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- Notetaking (minutes of meeting), technical report and intelligible documentation
- Te[illegible]
- M[illegible] with other activity centers / suppliers / project
- [illegible] listening and proactivity ...
- [illegible] and meetings
- In[illegible]cation / awareness of cultural differences
- Fund[illegible]takeholders

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

Effective communication skills
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

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- … and between emails nd
- Intercultural communic or of tural differences
- Fund-raising / Convinc stakeholders

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

+

✓ **Appropriate**

Effective communication skills
Specificities of PhD holders

SIEMENS Gamesa
RENEWABLE ENERGY

Why this skill is specific to or enhanced for a PhD holder?

- Participation to several international conferences / workshops
  - Concise but intelligible presentations of technical results
  - Initial contact with researchers / fellows from the same field
- PhD students are sometimes asked to give lectures or to supervise practical sessions to supplement their project fundings
- Habit to write extensive technical reports, journal papers / thesis

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

+

✓ **Appropriate**

Effective communication skills
Specificities of PhD holders

SIEMENS Gamesa
RENEWABLE ENERGY

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- PhD projects can include a lot of stakeholders both from industry and academia, and all of them need to be informed of recent progress on a regular basis (weekly/monthly/yearly …). The content of such communications is adapted to get target feedbacks.

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

+

✓ **Appropriate**

Effective communication skills
Specificities of PhD holders

SIEMENS Gamesa
RENEWABLE ENERGY

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- Even though an open-door policy may be opted for by some supervisors, PhD holders usually learnt to respect stakeholders availability

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

+

✓ **Appropriate**

Effective communication skills
Specificities of PhD holders

SIEMENS Gamesa
RENEWABLE ENERGY

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- PhD projects can include a lot of stakeholders both from industry and academia, and all of them need to be informed of recent progress on a regular basis (weekly/monthly/yearly …). The content of such communications is adapted to get target feedbacks.
- Even though an open-door policy may be opted for by some supervisors, PhD holders usually learnt to respect stakeholders availability
- PhD students are often travelling abroad to get their degree, and may sometimes be expected to apply to scholarships on their own
- Articles submitted to journal or conferences usually undergo a strict peer review process, leading the students to learn how to respond constructively and respectfully to comments / criticisms

Effective communication

=

✓ **Knowledge sharing**

+

✓ **Inclusive**

+

✓ **Balanced**

+

✓ **Appropriate**

Etienne MULLER

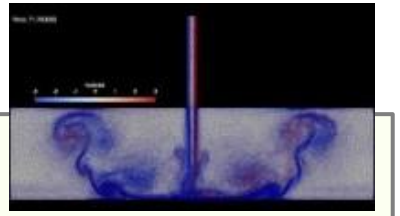
Turbine Loads R&D Engineer
Wake modelling (Low/High fidelity)
Wind farm control

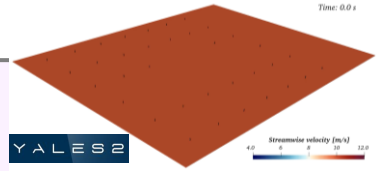
- **Sports:** Running, Badminton, Basketball
- **Reading:** Fiction, Mangas
- **Others:** Coding, video games

Arts et Métiers Sciences et Technologies

POLYTECHNIQUE MONTRÉAL

CORIA UMR 6614 + SIEMENS Gamesa RENEWABLE ENERGY





Engineering School

(Angers, France)

- General training
- Stronger focus on industrial and mechanical engineering
- First introduction to CFD
- First contacts with the industrial world

MASc

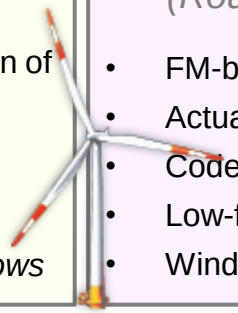
(Montreal, Canada)

- Specialization in fluid mechanics and CFD
- FEM-based CFD
- (U)RANS simulations

Ph.D.

(Montreal, Canada)

- FEM-based CFD / (U)RANS
- Adaptative numerical methods for optimization of the CPU costs
  - *Adaptative time-integration* ($\Delta t, p$)
  - *Automatic local mesh adaptation*
- Local solution transfer *(Galerkin projection)*
- *Applications: Heat transfer, FSI, separated flows*



Post-Doc

(Rouen, France)

- FM-based CFD, LES, HPC
- Actuator line method
- Code coupling (YALES2-BHawC)
- Low-fidelity wake modelling
- Wind farm control – wake steering

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

Effective communication skills
Showcase

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RENEWABLE ENERGY

Fund-raising ➔ Application for a Doctoral training Scholarship

Québec Fonds de recherche du Québec

News Events Contact Portal access FR

Scholarships and grants | Partnerships | Research showcases | Responsible research | About

FRQNT 2024-2025 - Doctoral Training Scholarships

FONDS DE RECHERCHE DU QUÉBEC
NATURE AND TECHNOLOGIES

Competition year :	Deadline (application) :	Amount :
2024-2025	October 3rd, 2023 at 16:00 (EST)	25 000$
	Announcement of results : April 2024	Duration : Maximum 12 semesters

EVALUATION CRITERIA – DOCTORAL TRAINING	WEIGHTING
Academic record and background	**45 points**
• Transcripts;	
• Honours (awards, distinctions, scholarships);	
• Achievements (scientific, professional, social, etc.) and relevant experience (related to the project or background)	
• Capacity for engagement and leadership (in and out of academia);	
• Ability to facilitate dialogue between science and society.	
Research project (55 points)	**55 points**
• Originality of the project and contribution to the advancement of knowledge;	
• Clarity and coherence of the research problem;	
• Relevance of the methodology;	
• Feasibility of the project and realism of the time frame.	
TOTAL	**100 points**

Some of the required attachments

- Description of the research project (**2 pages**)
- Bibliography (**1 page**)
- List of relevant achievements (**4 pages**)

Effective communication skills
Showcase

SIEMENS Gamesa
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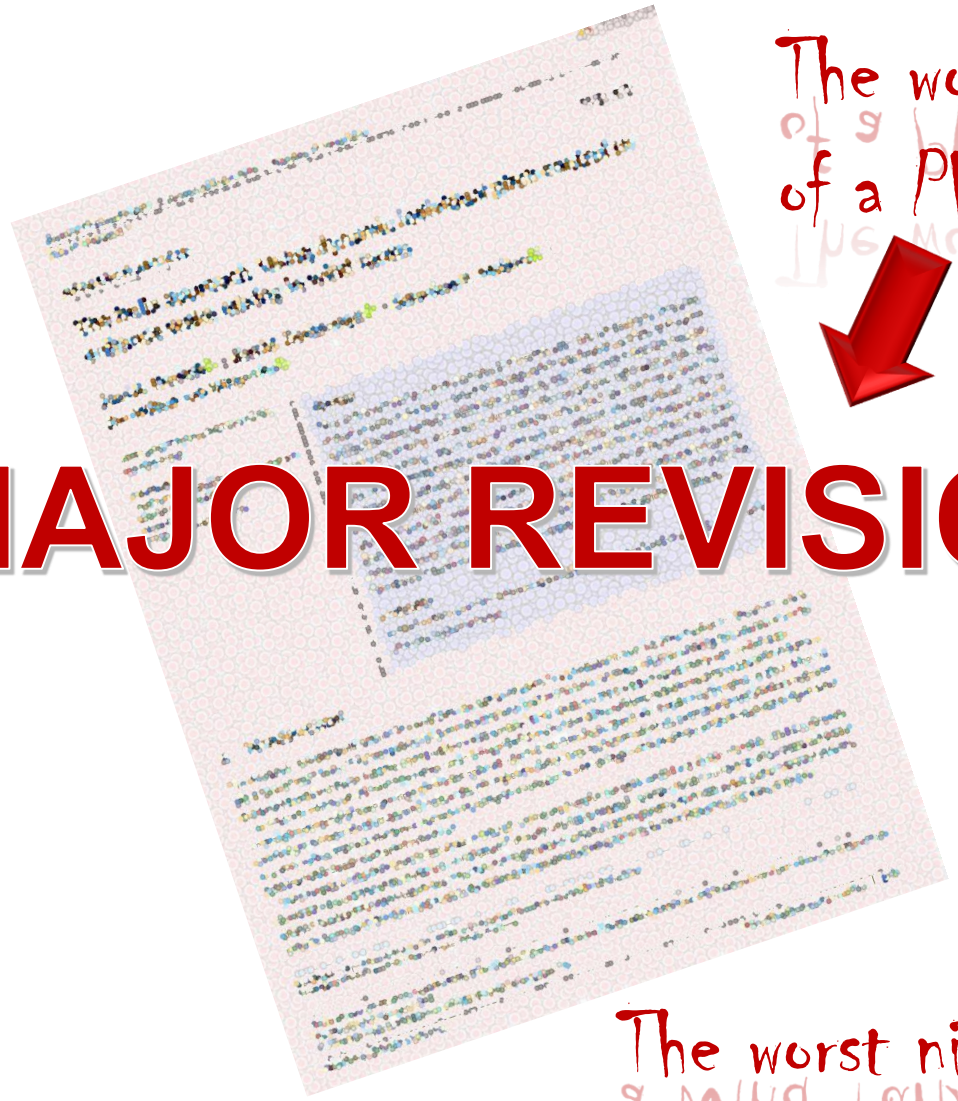
The worst nightmare of a PhD candidate



MAJOR REVISION

CONDITIONALLY CERTIFIED

The worst nightmare of a Wind Turbine OEM

Effective communication skills
Showcase

SIEMENS Gamesa
RENEWABLE ENERGY

Differences in interpretation of highly technical topics

Ability to defend your technical perspective while respectfully refuting opposing claims

Confidence, tenacity and creativity in achieving publication

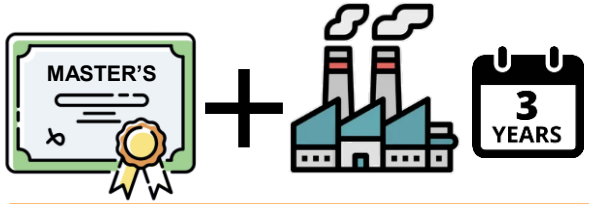
Differences in interpretation of highly technical topics

Ability to defend your technical perspective while respectfully refuting opposing claims

Confidence, tenacity and creativity in achieving certification

Effective communication skills

- Mostly listening in technical meetings
- Most of the time waiting for inputs / requests before starting or trying something new.
- Provide summarized documentation
- May ask too many questions



- Can be proactive in technical meetings depending on the project background
- Used to reach out to colleagues to get specific pieces of information / knowledge
- Used to internal presentations
- May have attended one or two conference(s)
- May oversee some parts of a detailed documentation
- May be used to international projects / intercultural exchanges depending on the company size.

- Mostly proactive but know when to listen
- Used both to internal and external presentations
- Attended at least one conference
- Enjoy detailed documentation, even though writing it is often less prioritized.
- Usually know how to well organize a report
- Used to multicultural environments
- Used to navigate in cross partners collaborations

Ability to activate a network

Richness of your network
Definition

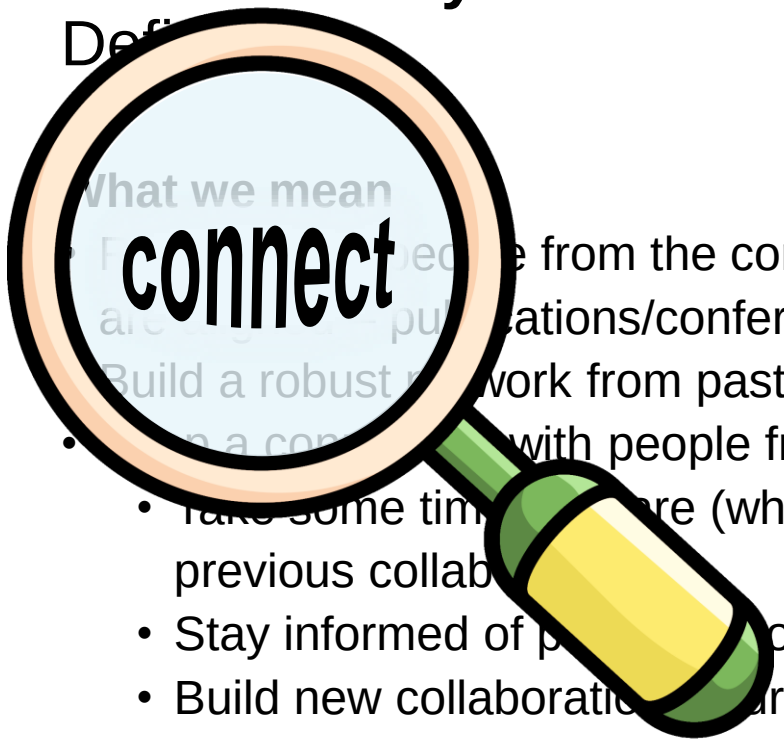
SIEMENS Gamesa
RENEWABLE ENERGY

What we mean

- Reach out to people from the community (academia/industry) if your goals are aligned – publications/conference/other
- Build a robust network from past project
- Keep a connection with people from past-project
  - Take some time to share (what you can) with actors of previous collaborations
  - Stay informed of past collaborators work
  - Build new collaboration if current goals are aligned
- Leveraging networks for collaboration and opportunities
- Research is sometime a small world

Richness of your network

Defi



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  - Stay informed of p orators work
  - Build new collaborati rrent goals are aligned
- Leveraging networks for collaboration and opportunities
- Research is sometime a small world

Sustainable Network

=

✓ **Connect**

Richness of your network
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

What we me

- Reach o people from t community (academia/industry) if your goals are alig – pub ati s/co erence/other
- Build a us m t project
- Keep a nection with peo from past-project
  - Take s e time to sha what you can) with actors of previous
  - Stay informed of past colla work
  - Build new collaboration if cu are aligned
- Leveraging networks for collaborat pportunities
- Research is sometime a small world

Sustainable Network

=

✓ **Connect**

+

✓ **Maintain relations**

Richness of your network
Definition

SIEMENS Gamesa
RENEWABLE ENERGY

What we mean

- Reach out to people from the community (academia/industry) if your goals are aligned – publications/conference/other
- Build a robust network from past project
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Sustainable Network

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✓ **Share**

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SIEMENS Gamesa
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- Leverage your collaboration and opportunities
- Research is sometime a small world

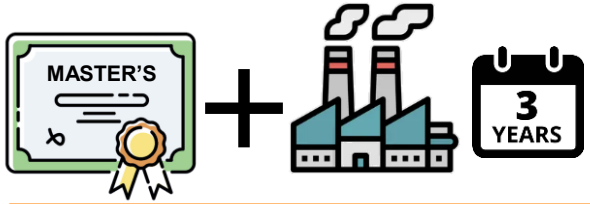
Sustainable Network

=

- ✓ **Connect**
- **+**
- ✓ **Maintain relations**
- **+**
- ✓ **Share**
- **+**
- ✓ **New collaborations**

Richness of your network

- Builds professional connections



- Builds professional and academic network if agenda & responsibilities allow

- Leverages networks for collaboration, research, and industry impact, showcasing a strategic approach to networking
- Builds consortia from professional and academic connections to participate in EU funding calls
- Forms Joint-industry project agreements with fellow PhD graduates

Félix HOUTIN MONGROLLE

Turbine Loads R&D Engineer
Rotor Vibrations in Idling and Standstill
Wake Advanced Modelling

- **Sports:** Sailing, Kite surfing, Badminton
- **Other:** Wood craft, cooking

Bachelor degree

(Rennes France)

Fundamental Physics

Engineering School/ Master Degree

(Rouen France)

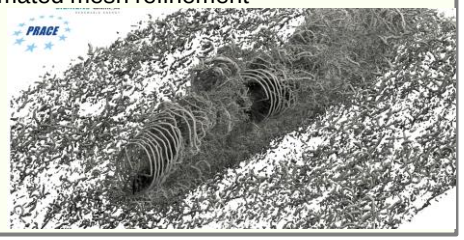
- Specialization in Energy and Propulsion
- Aeronautics, CFD (RANS-LES), Combustion, Turbomachinery
- Master thesis project at Safran Aircraft Engines: *"Numerical study of primary atomization for a liquid fuel spray"*

Ph.D.

(Rouen, France)

"Investigation of yawed offshore wind turbines interactions through aero-servo-elastic Large Eddy Simulations"

- Actuator line method, LES, fluid structure interaction, coupling code (Yales2-BHawC), Massively parallel computing, Aero-servo-elasticity, Streamtube analysis, automated mesh refinement
- WIMPY (Prace 21)
- Neptune 1
- Partnership with SGRE



Turbine Loads R&D Engineer

(Den Haag, The Netherlands)

- Rotor Vibrations in Idling and Standstill
  - Blade resolved simulation, ALE mesh displacement
  - URANS, DES/SBES turbulence modeling
  - Methodology development
  - Root-Cause-Analysis projects
- Wake Advanced Modelling:
  - Pursuing PhD work: Coupling BHawC-Yales2 applications
  - Automated simulation procedure

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023

Richness of your network
Showcase

WAKE-OP project (2019/07 – 2022/10)

Develop new high-fidelity tools for the characterization of wind-turbine wakes, so as to further optimize existing and future offshore wind farms

YALES2

Aerodynamic solver
Solve the Navier-Stokes equations (NSEs) for incompressible flows

Actuator line method (ALM)
Compute the aerodynamic loads acting on the blades
Translate them into additional body forces in the NSEs

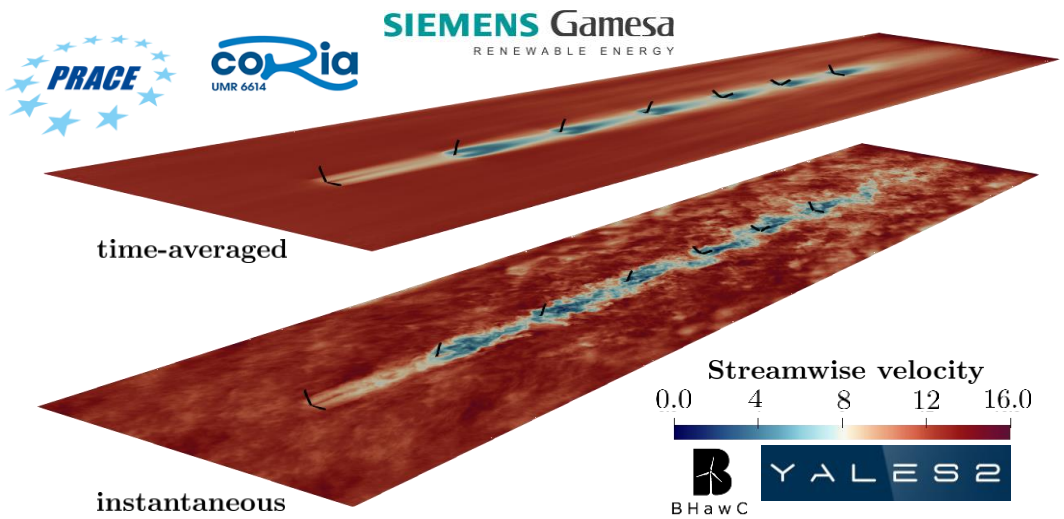
Aerodynamic loads

Blades position

BHawC

Servo component
Control operating parameters (rotation speed for instance) using an emulation of the real controller

Non linear elastic solver
Solve the blades deflection and torsion resulting from the aerodynamic loads
Advance the blades



Richness of your network
Showcase

SIEMENS Gamesa
RENEWABLE ENERGY

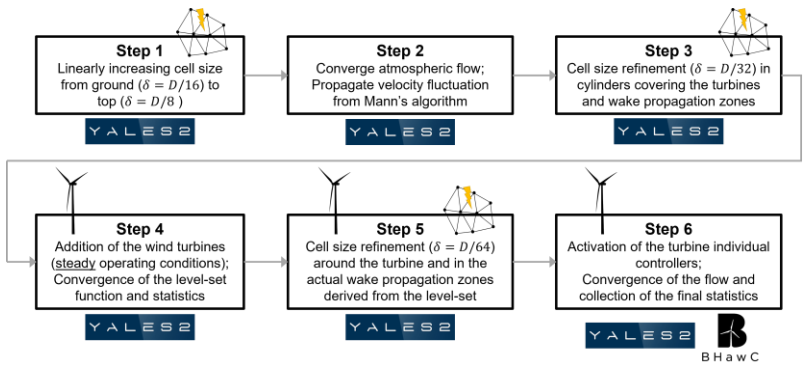
W2ITASEC project (2023/05 – 2023/12)

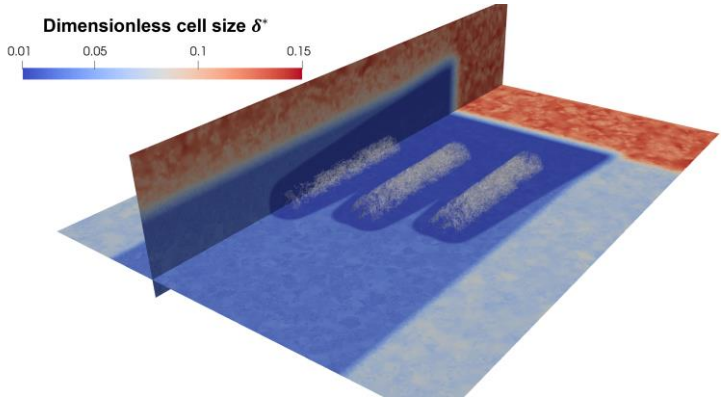
- **Grant of 22M CPUhs** on the French cluster **Joliot Curie / Irene (Partition AMD Rome)**
- Following the submission of a research project proposal for the **Grand Challenge access call**

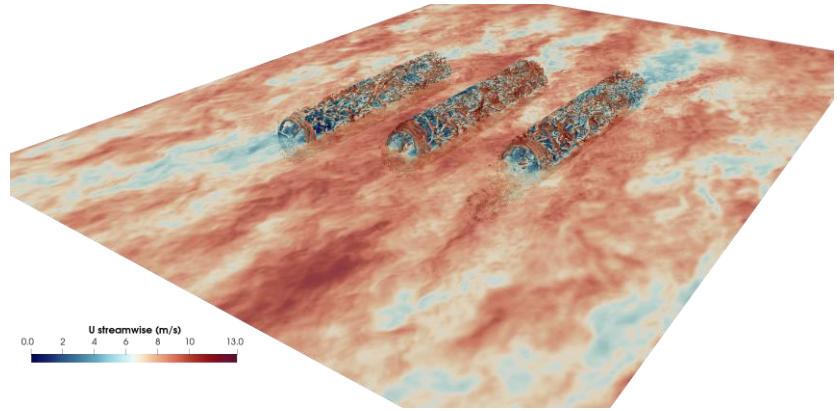
- **Research topics**
  - Blockage effects
  - Wakes superposition
  - Simulation of neutral atmospheric flow
  - Wind farm flows

Being part of the YALES2 / CORIA community was essential in many ways:

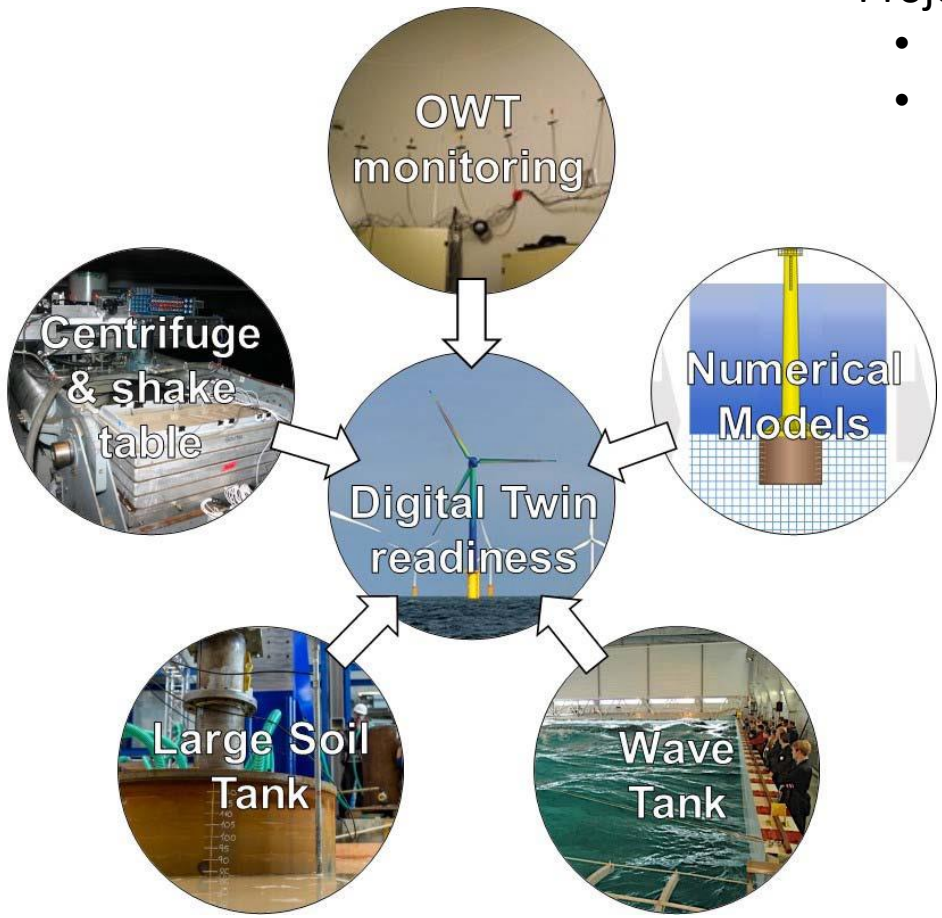
- Learning about this access call
- Preparation of the proposal
- Getting an extension of the project initial duration







Richness of your network
Showcase



WINDiLIFE project

- Research & Innovation Action – Proposal submitted under the H2020 framework
- Project made it to Stage 2 but was not granted. However:
  - Network was enriched and facilitated JiP
  - Strengthened partnerships & collaborations outside the EU call

Strong team of 11 partners

NGI · SIEMENS Gamesa · VATTENFALL · DHI · Fraunhofer · SINTEF · TU Delft · DTU Technical University of Denmark · equinor · ISIG 5 · NCREE

We made it to Stage 2!

Call LC-SC3-RES-1-2019-2020

- No. of submitted proposals: **130**
- No. of proposals passing Stage 1: **23**
- Applied Threshold **9.5/10** (!) – indicating very high quality of the proposals
- Total budget requested for over-threshold proposals: about **M€97**
- The available budget is **M€20**, so 1 in 5 of those passing Stage 1 will pass Stage 2

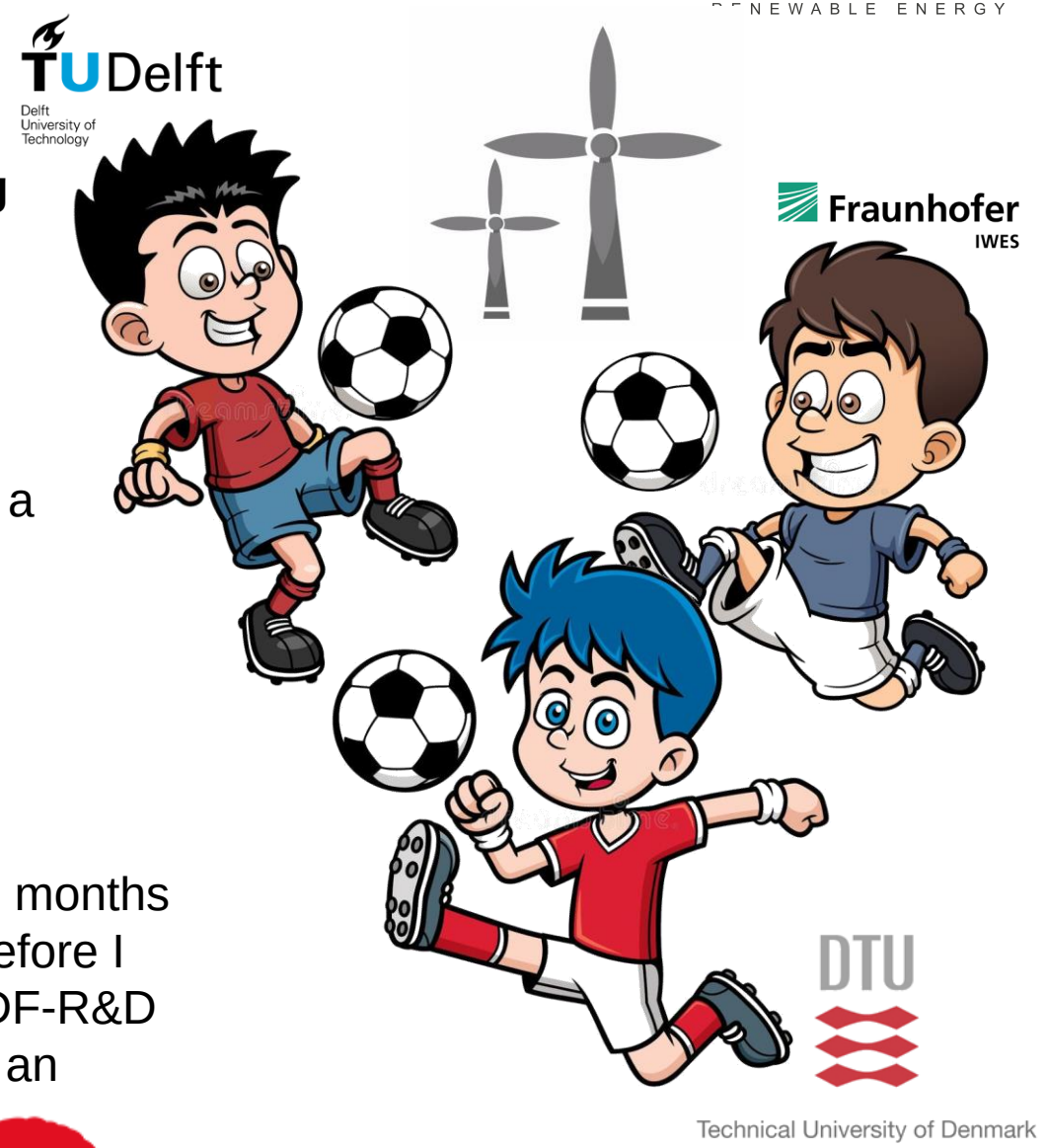
- **Very encouraging to make it through to Stage 2, but still high competition!**

Richness of your network
Showcase

Not having network can also cause difficulties in knowing the opportunities, and being selected for the positions

- I did my PhD in a lab specialized in Hydrodynamics and Environmental Flows, not in wind energy. Thus, I did not participate to many wind energy conferences; I did not have a clear understanding of who were the key players in the wind energy field, and I did not have the opportunity to build a strong network…

- It took me more than 8 months and many rejections before I found a post-doc at EDF-R&D thanks to a job offer in an association, not to my network…



ABG Association Bernard Gregory

Conclusion

Conclusion

SIEMENS Gamesa
RENEWABLE ENERGY

Key takeaways

- **Your experience in the PhD is valuable** and must be valued when applying for positions in the industry
  - Valuable when discussing **with technical recruiter**, not always in HR rounds (except of maturity)
  - Right balance between technical competences and maturity
- PhD holders bring an added layer of **depth, complexity, and adaptability** to the industry compared to MSc graduates
- PhD holders may lack domain-specific knowledge and know-how, but they can compensate with **creativity and an alternative way of thinking**

- **Advise: if you are not a pioneer (no judgment there), choose an organization already containing PhDs or be ready to use your convincing skills;-), be ready to take slams in any case (keep the direction – sometime at low noise)**

Q&A

SIEMENS Gamesa
RENEWABLE ENERGY

STEP WIND
Training network in floating wind energy

Thanks!

Infusion

Julie Teuwen
Faculty of Aerospace Engineering, Delft University of Technology

TU Delft

What will you do today?

- Do an infusion
- Lay-up and vacuum bagging
- Processing of resin
- Infusion of resin

Lay-up and vacuum bagging

- Metal mould
- The surface is cleaned with **isopropanol** to get rid of dirt such as aluminium oxide. This is done by pouring isopropanol on a paper towel and cleaning the plate three times.
- Afterwards, It was also cleaned with **acetone** only one time, which is a more aggressive liquid to get rid of obstinate particles.
- The next phase is marking the areas with **paper tape** where the vacuum bag/tacky tape will come. The purpose of this is actually protect the area against liquids, which will be used next.

Lay-up and vacuum bagging

- The plate will be covered in **three layers of release agent, Marbocote 227CEE**. It is applied alternately in the horizontal and vertical direction, whenever you swap from one direction to the other direction you will have to wait five minutes to let it dry. The release agent is used to easily remove the product from the aluminium plate otherwise it will stick to it, because resins are used to make the composite plates.

- After applying the release agent, **paper tape can be removed** to **place tacky tape** on the same areas where the paper tape was. The tacky tape can stick to aluminium plate since there is no release agent on the paper taped area. The tacky tape makes an air tight seal with the vacuum bag, which will be used at a later stage of the vacuum infusion process.

Lay-up and vacuum bagging

- Two **glass fabrics** (300 mm in width and 300 mm in length) laid with the layup [45/-45/-45/45]. **Airtech non-coated peel ply** is used on top of the glass fabric to texture the back side of the composite. It is to make sure it is in contact with the bleeder.
- In this way, it can be ensured that there is vacuum applied on the composite. Furthermore, a perforated **Release film from Airtech Wrightlon 3900 blue** is added on top with a dimension of 300 by 300 mm to guarantee easy removal of the vacuum bag elements and also for resin flow to the composite.

Lay-up and vacuum bagging

- To distribute the resin over the composite equally a flow mesh is added on top of the perforated release film, **Airtech greenflow 75**. It is 280 mm in the width and 210 mm in the length. It is smaller than the composite in order to force the resin to flow through the composite and not directly flow to the **bleeder (Airweave N10),** which is placed between the composite and the outlet tube to absorb excessive resin. The required dimension of the flow mesh can change for different resins and fibre reinforcement, if it is too short, then it will take more time to flow through the reinforcement and there could be a chance that not all the fibre are wetted with resin.

Lay-up and vacuum bagging

- The infusion mesh is wrapped around and fastened with staples to the **infusion line**, which is connected to the **inlet tube**. The resin will flow from the inlet tube to the infusion line. The infusion line makes it possible for the resin to flow to the infusion mesh. The resin can now flow with the same speed over the width.
- The **inlet and outlet tube (Rehau Rauclar-E)** face each other on the opposite side.
- **Tacky tape** is rolled around the inlet and outlet tube and stuck to the tacky tape which was already on the aluminium plate. Another strip of tacky tape with a length of 200 mm is laid over the inlet and outlet tube to hold it in position.

Lay-up and vacuum bagging

- **A piece of bleeder** is also placed in the outlet tube to make sure that the outlet tube is not closed during vacuum and also to reduce the resin flow to the outlet tube.
- One of the final steps before putting the **vacuum bag** is to **tape everything that is sharp with Kapton tape** to prevent any leakage in the vacuum bag. The end of the infusion line is cut with scissors and might contain sharps edges so that must be taped. The edge of the infusion mesh can also be taped, but it is done partly during the manufacturing process to save time. In addition, the staples in the infusion mesh are also taped. Furthermore, other parts such as the peel ply, perforated release film, infusion mesh and infusion line is also taped to hold it in position. The reason for this is when putting the vacuum foil on the infusion area, the other parts might move and it will be difficult to reposition these parts, since the vacuum foil is stuck to the tacky tape.

Lay-up and vacuum bagging

- The **vacuum bag** used here is the **Airtech WL7400**. It is cut in the size 400 by 400 mm, which overlaps the infusion area to be sure that is more than enough. **Pleats** of tacky tape can be used to reduce the amount of wrinkles in the vacuum bag.
- The final step of the vacuum bagging process is to perform a **leakage test**. The **inlet hose** is **clamped** so that air cannot enter and escape the inside of the vacuum bag. The outlet tube is connected to a **vacuum pump**. The pressure inside the vacuum bag is reduced to 50 hPa, then the pump is turned off. If the pressure increases with 1 hPa every 10 seconds or longer it should be alright. However, this is the case if there is a small leakage on the outlet tube side. If the leakage is somewhere in the inlet tube side, then the air bubbles could travel through the composite, which can lower the quality of one or more samples. In the case that leakage is spotted in the form of a gap between the vacuum bag and tacky tape, it can be sealed by pressing the vacuum bag firmly to the tacky tape or adding more tacky tape to this area.

Processing of resin

- Since the vacuum bagging is done the **resin can be mixed** for the infusion process. A weighing balance is used. The resin for the composite is a two component epoxy: base agent (Araldite LY1564) and accelerator (Aradur 3487). They are put in a **white bucket** and mixed in the ratio 100 gr Araldite with 34 gr Aradur. It is stirred for five minutes to mix the two components good. After this, **scotch brite** is put in the resin and hold in place with a **wooden stick that is clamped to the bucket**. It is used for the **degassing process** to reduce the number of air bubbles in the resin. The resin is degassed for 15 minutes in a special vacuum chamber. The time for stirring and degassing is kept up with a timer.

Processing of resin

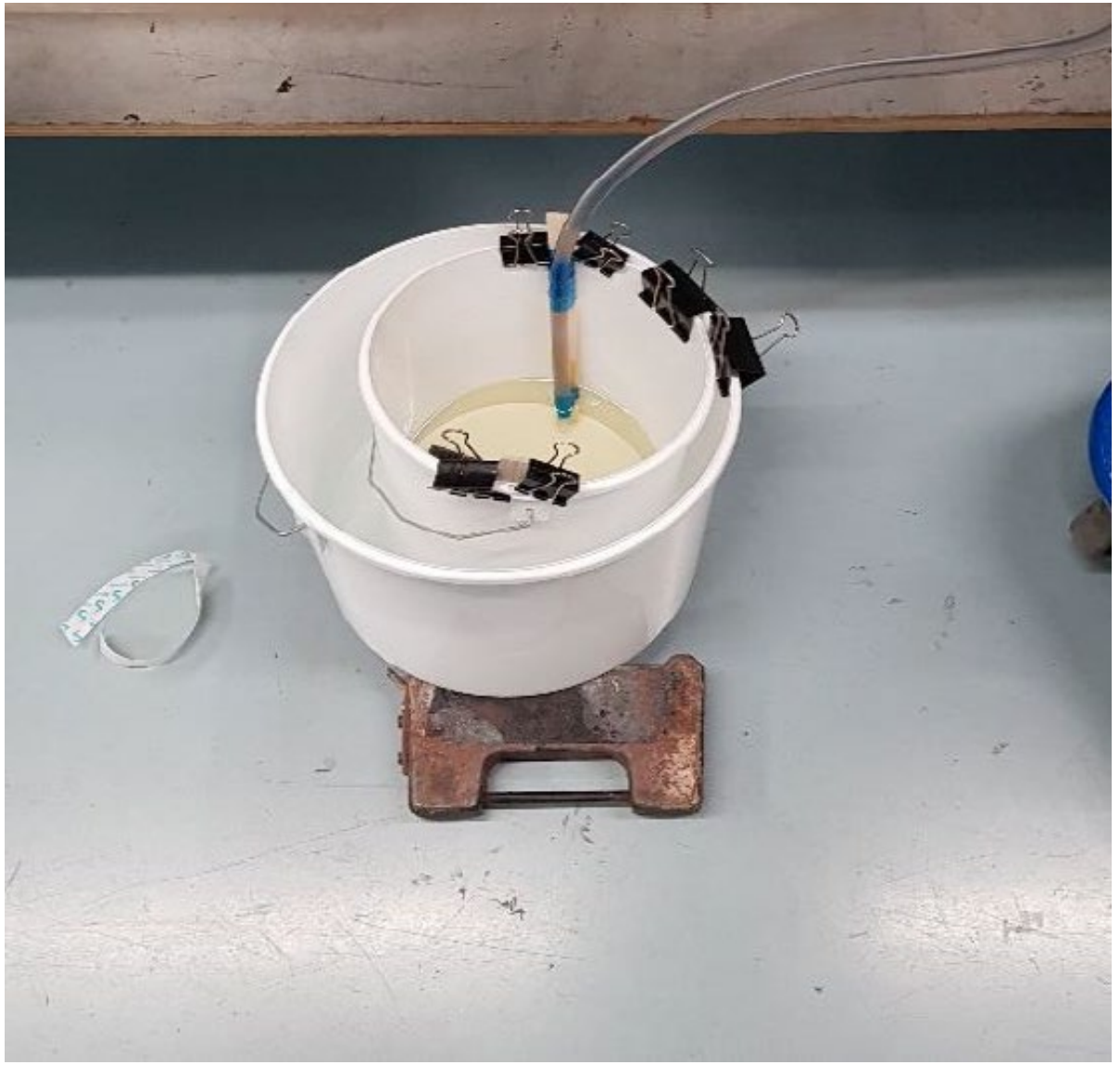
Vacuum infusion

- The white bucket with the degassed resin is then placed **in a larger bucket with water**. The purpose of this is to cool down the bucket with resin, because after mixing the resin components, an exothermic reaction happens, which can generate heat.
- Next, the **tip of the inlet tube is cut at an angle** so when the tube is put in the bucket with resin, the tube doesn't get stuck with the bucket during vacuum infusion. The **tube is taped around a wooden stick** to make it more rigid. The stick is then clamped to the resin bucket to fix the tube in place. Before the inlet tube is placed in the bucket of resin, the **inlet tube is clamped**.

Vacuum infusion

- Additionally, the resin bucket is also stuck to the water bucket with a clamp to fix it in place. A weight is put under the edge of the water bucket making the **resin bucket lean on an angle**. The reason for this is to accumulate more resin to the spot where the tube is placed in the resin bucket. More resin can be taken from the resin bucket during vacuum infusion now.

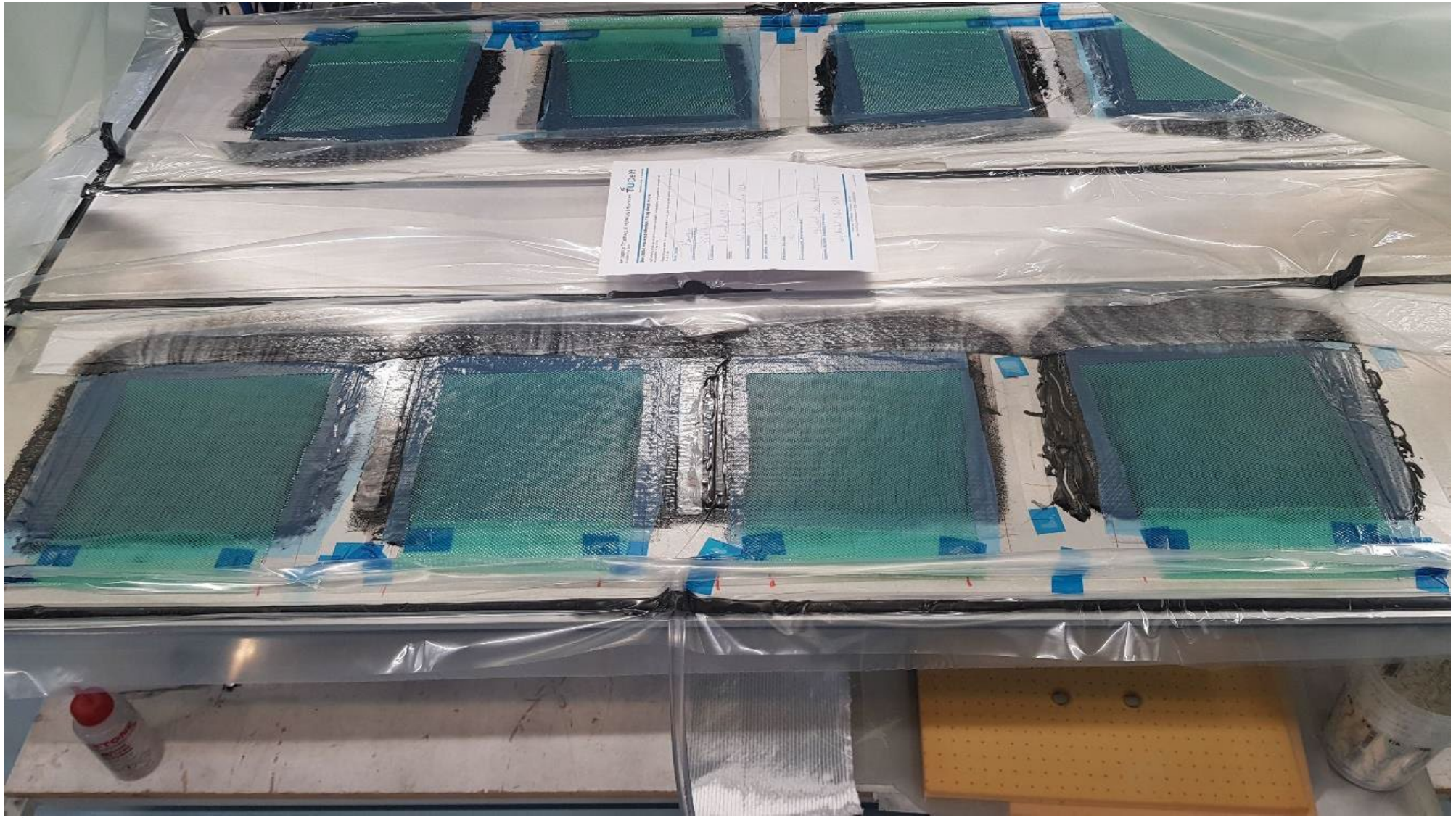
Vacuum infusion



Vacuum infusion

- The outlet tube was already connected to a vacuum pump for a leakage test. The next step is setting the **pressure to 70 hPa on the pump**. The final step to let the resin flow through the laminate is unclamping the inlet tube. The resin starts to flow through the composite and it takes about 20 minutes to reach the end of the composite plate. A pressure of 70 hPa is **maintained for 2 hours after this, the pressure is changed to 500 hPa** to create a laminate with a balanced resin-fibre content. After 15 minutes from the moment that the pressure was changed, **the inlet tube is clamped again.** This is done to have an equal pressure over the laminate and thus creating a laminate with an equal thickness. **The composite samples are cured at room temperature (22^0 C) for seven days**.

Vacuum infusion



Blade manufacturing & structural analysis

Julie Teuwen (&Dimitrios Zarouchas)
Faculty of Aerospace Engineering, Delft University of Technology

TU Delft

What will you do today?

- Do an infusion
- Understand more about blade design, manufacturing and testing

Content

- Introduction
- Design requirements?
- Materials in blades: old… – now – new!
- Different structural lay-out of blades
- How is it made?
- Processing steps & design
- Structural design and analysis
- Building block approach

Introduction

Composite Materials – Composite Structures - Composites

Composite is a material made from two or more constituent materials with significantly different properties, when combined, produce a material with characteristics different from the individual components

Polymer based composite materials

Fibre Reinforced Polymers

Applications

Composites in Wind Turbines

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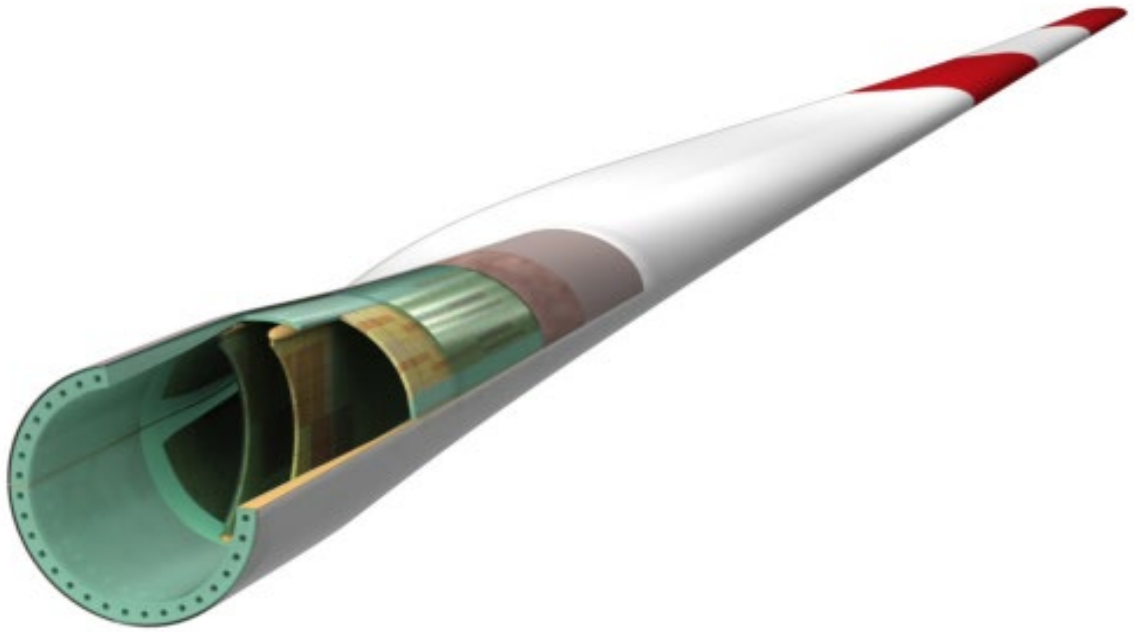
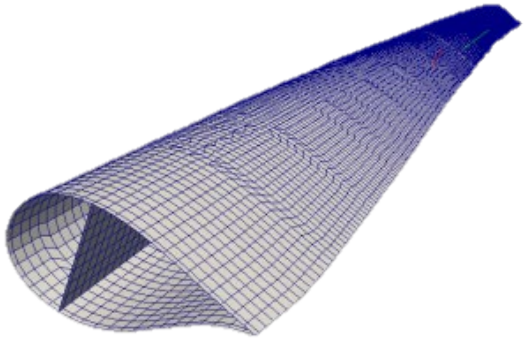
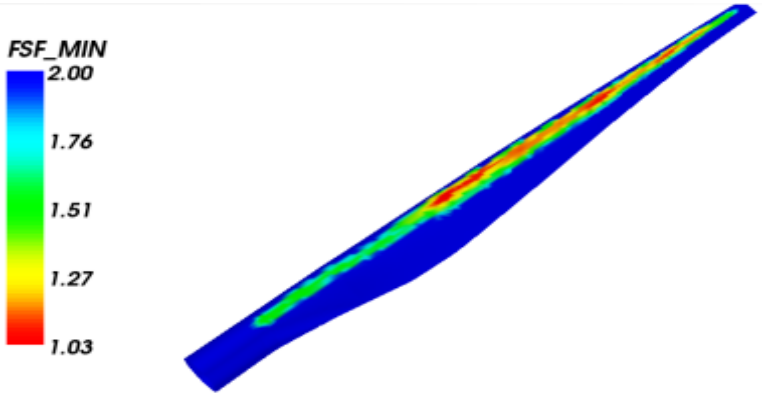
Wind Turbine Blades







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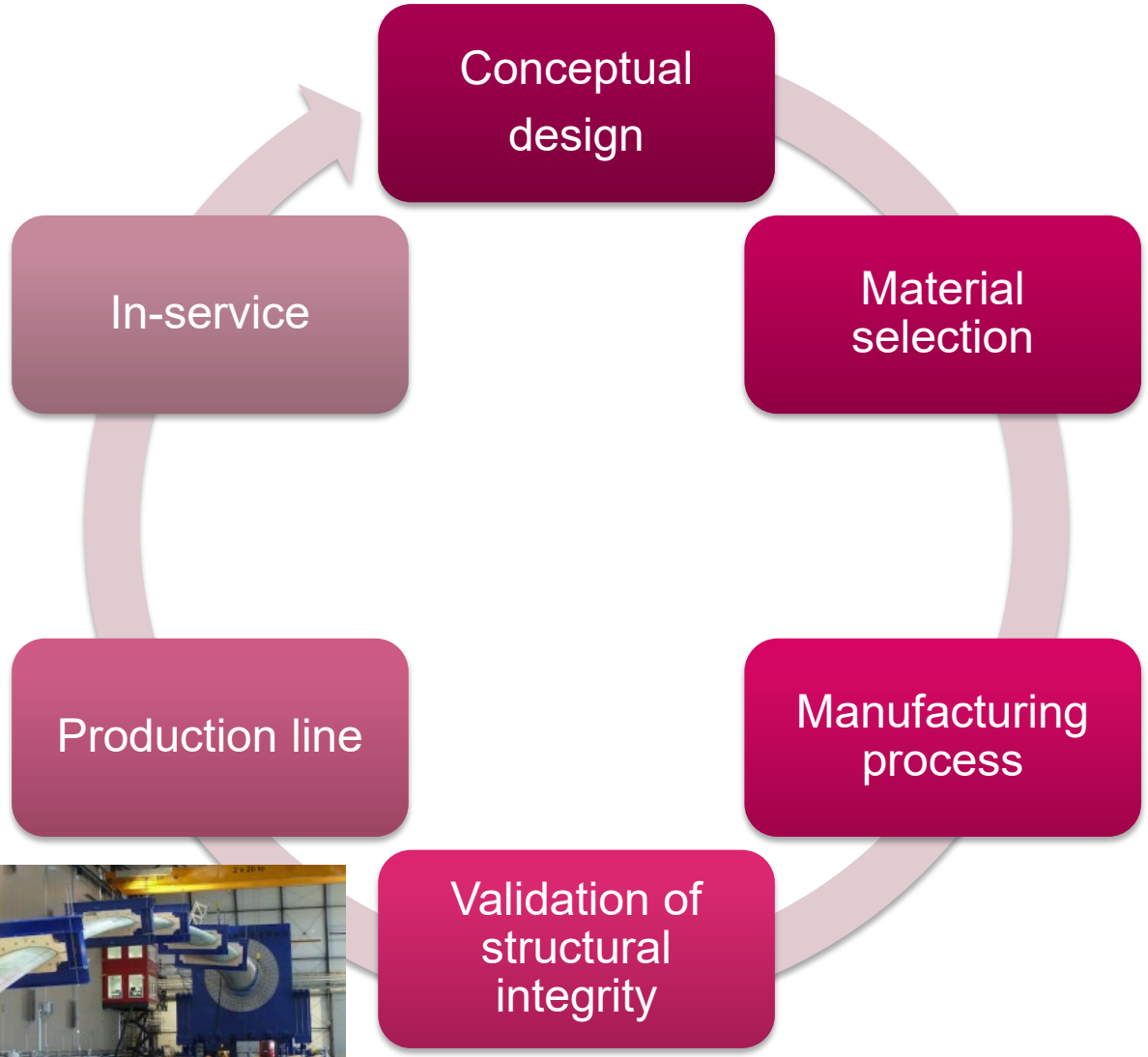
Design of Wind Turbine Blades

Holistic approach



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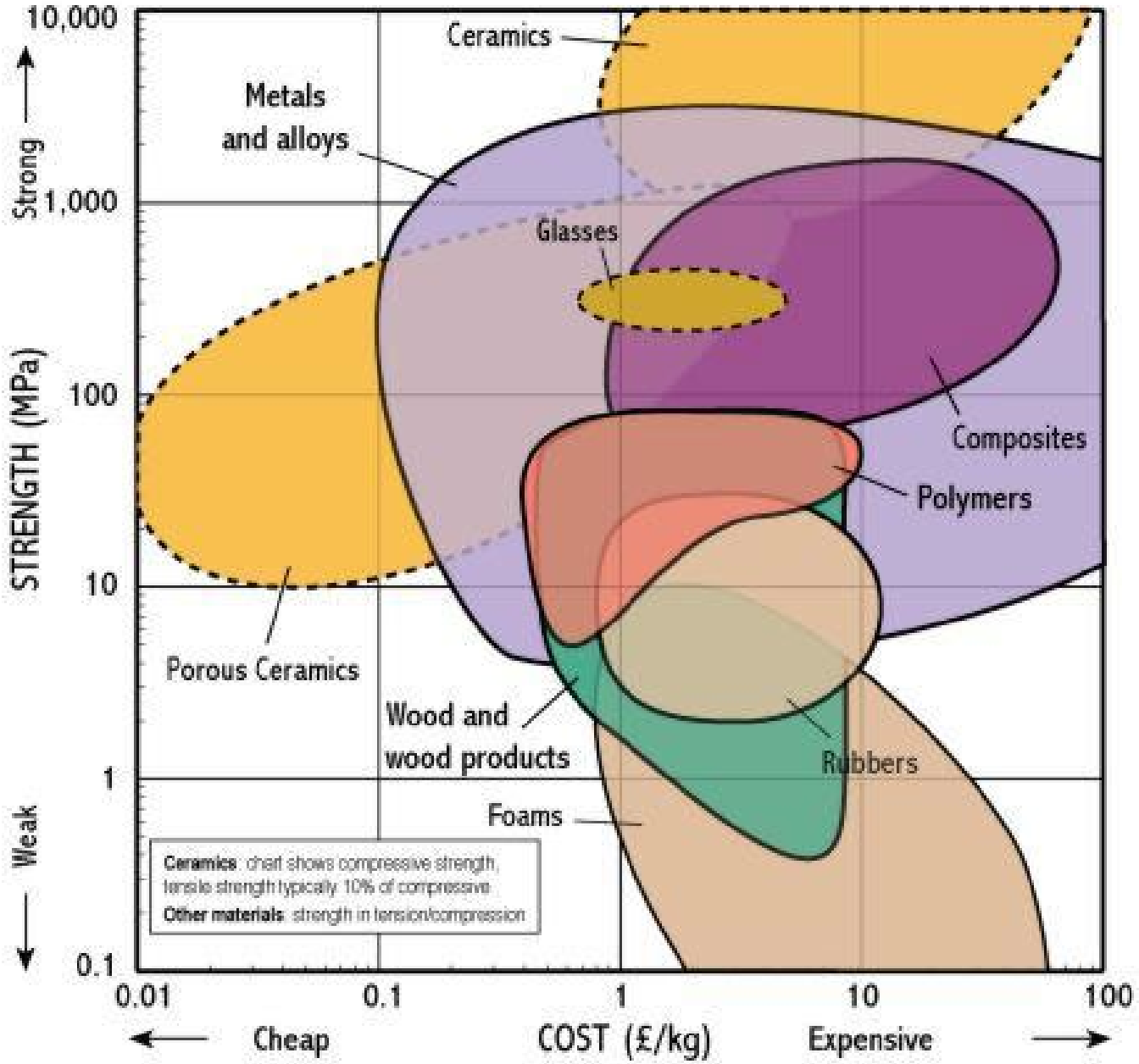
Design requirements?

Materials

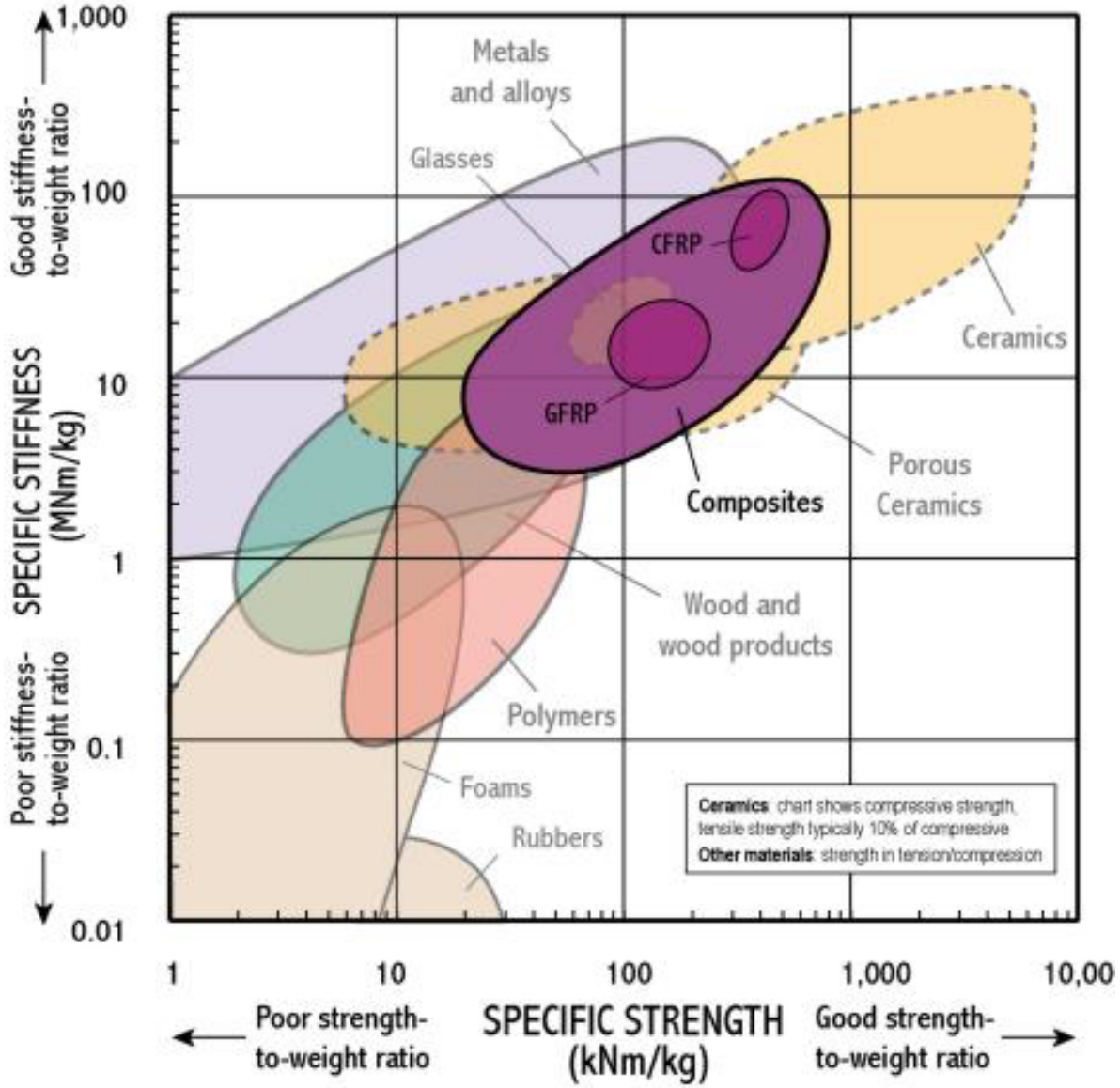
Requirements

- Specific mechanical properties (static and fatigue)
- Low cost
- Processing properties
- Quality
- Environment, Health and Safety
- Availability

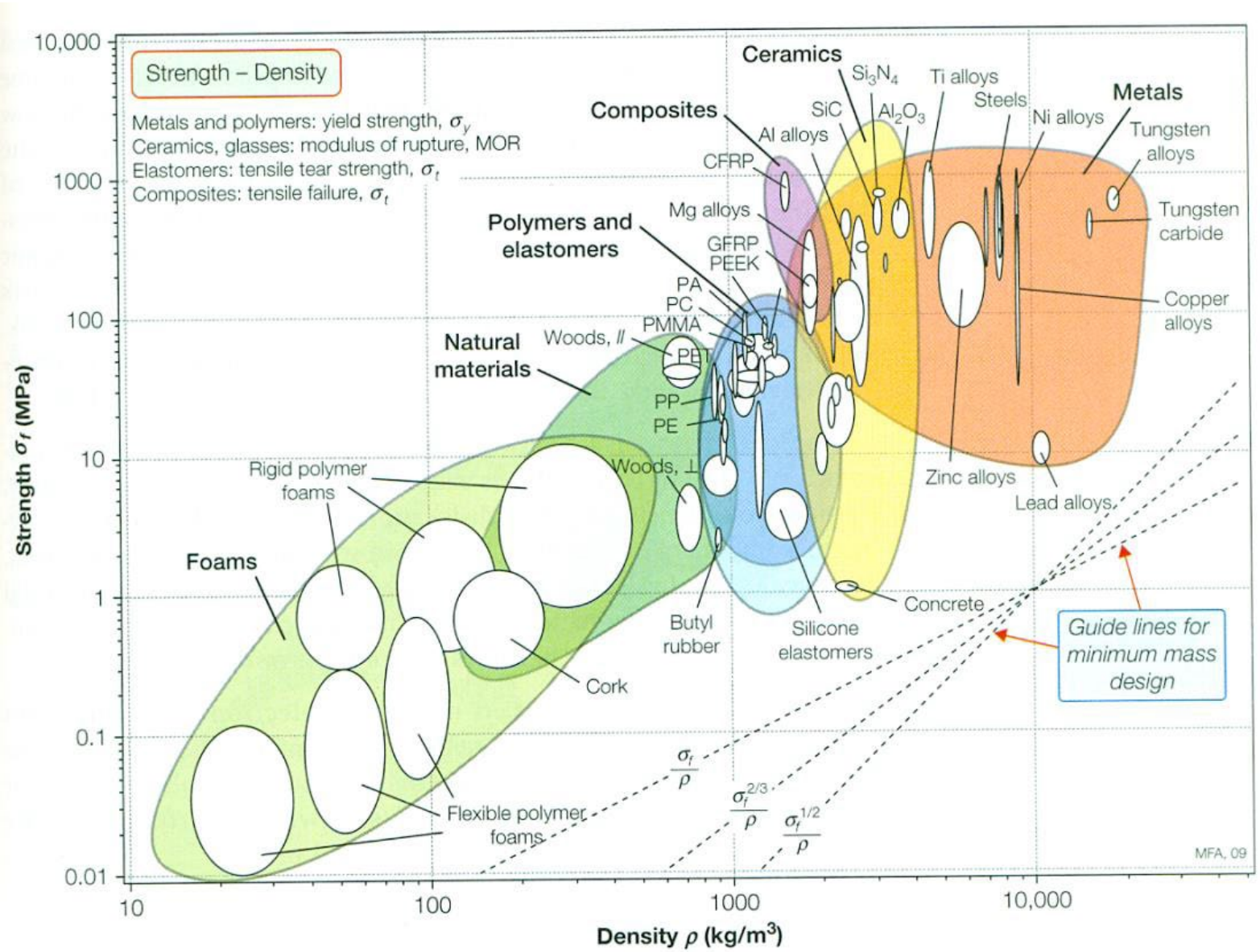
Cost driven?


10,000
1,000
100
10
1
0.1
Strong
Weak
STRENGTH (MPa)
Ceramics
Metals
and alloys
Glasses
Composites
Polymers
Porous Ceramics
Wood and
wood products
Rubbers
Foams
Ceramics: chart shows compressive strength, tensile strength typically 10% of compressive
Other materials: strength in tension/compression
0.01
0.1
1
10
100
Cheap
COST (£/kg)
Expensive

Mechanical properties driven?



Weight driven?



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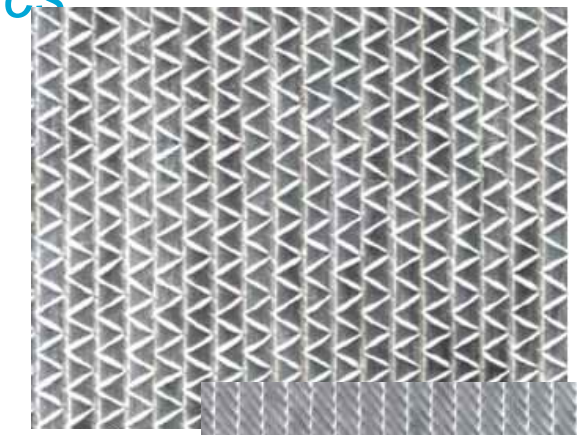
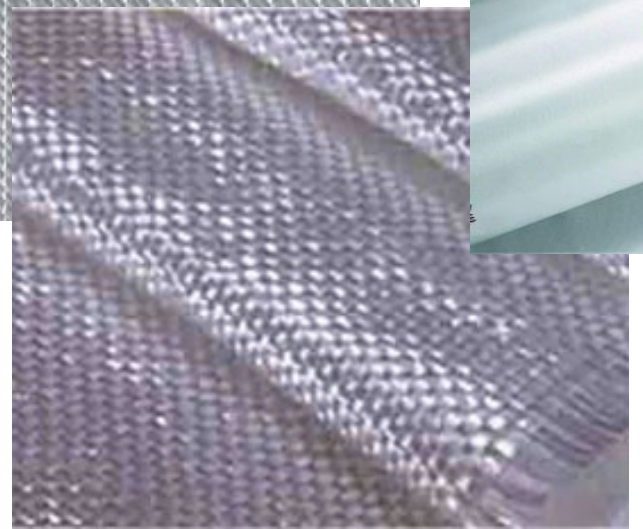
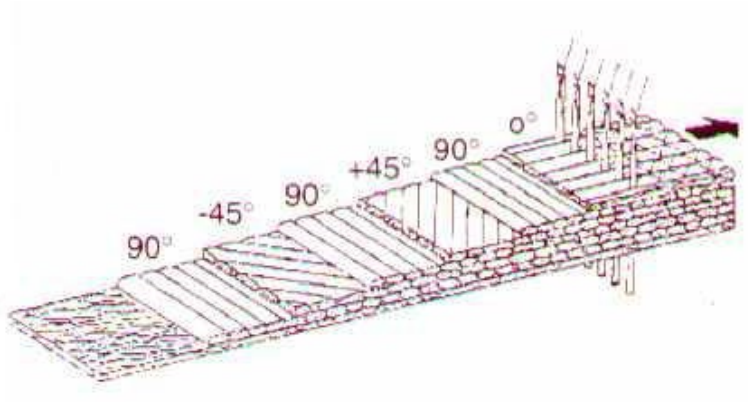
Materials

Fibres

Reinforcement fabrics







Trends reinforcements

Old

Glass: E-glass (mainly)

Now

Glass:
- E-glass: improved compatibility glass-resin
- H-glass: higher properties
- Pultruded glass

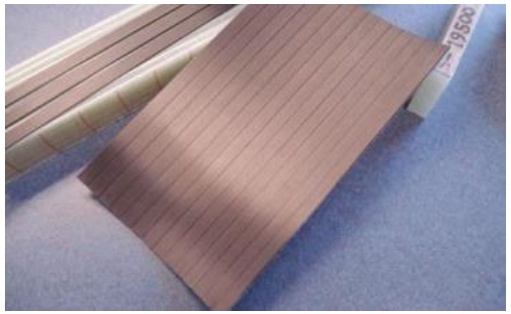
Carbon:
- Pultruded carbon
- Reducing cost
- Low temperature cure prepreg

Hybrid glass/carbon spar caps

More properties for glass
Less cost for carbon
Quality

Future?

Tape-laying of glass prepregs
Hybrids

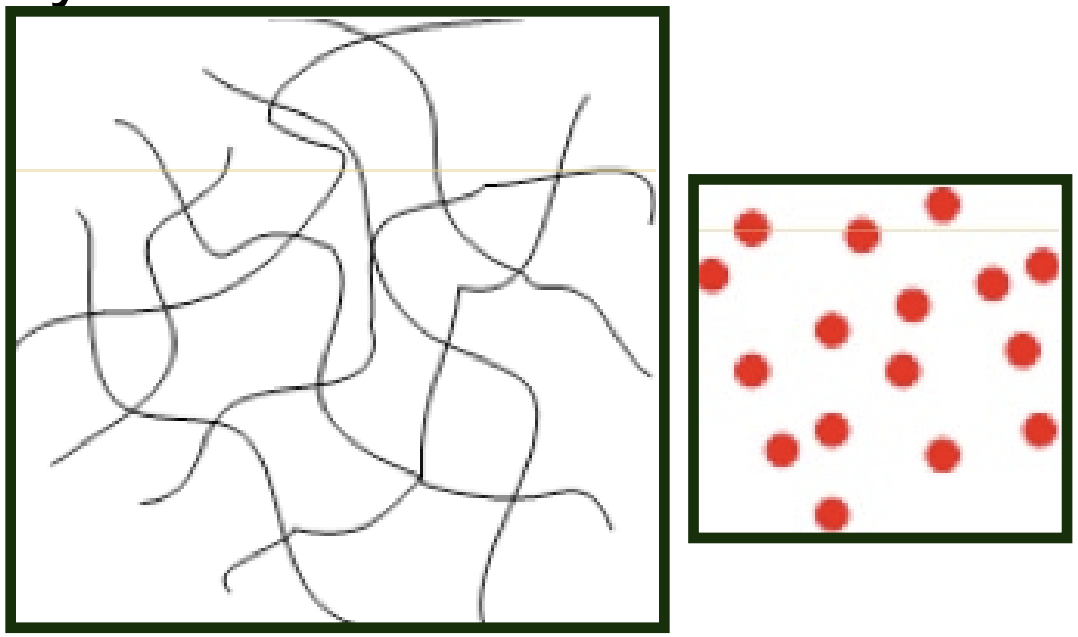


More quality
More properties
Less cost
Glass/resin integration

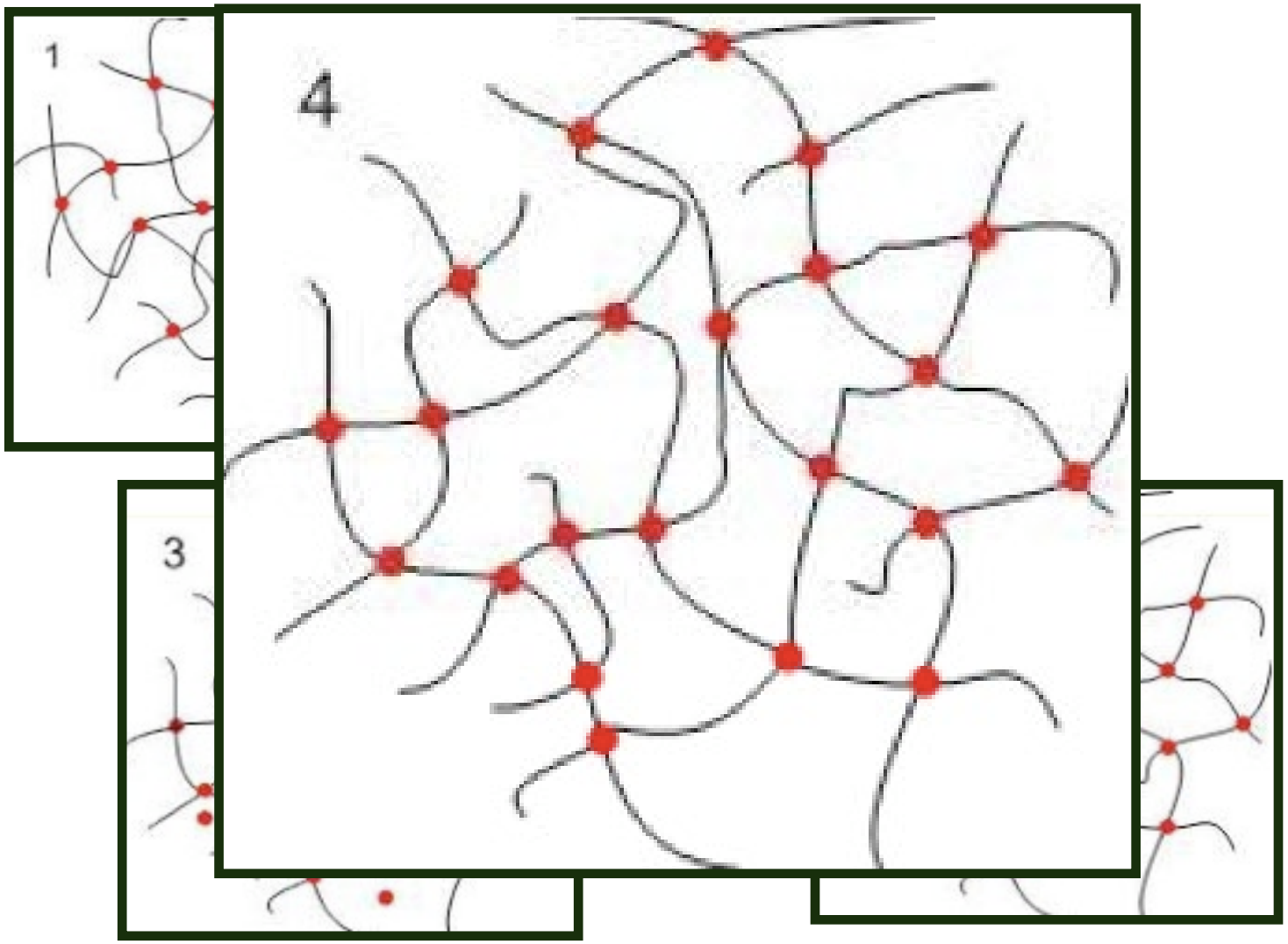
Materials

Resin

- Polyester
- Epoxy



What can be the result after curing?



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Trends resins

Old

UPR
EP

Faster processing
Higher mechanical properties

Now

EP:
- Faster, easier, lower temperature processing

UPR:
- Higher mechanical properties
- Faster cycle times

Faster processing
Higher mechanical properties

Future?

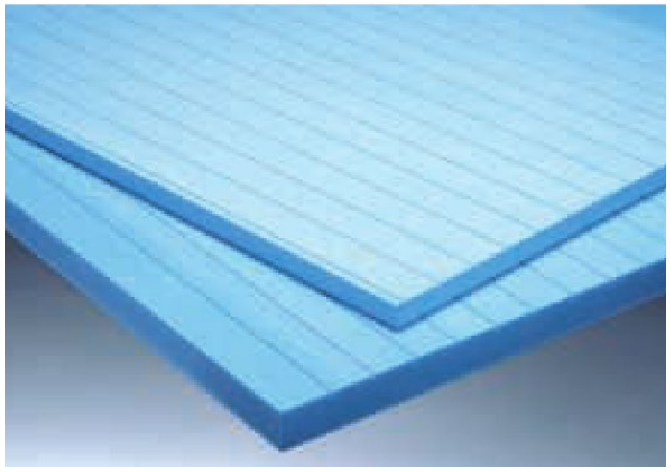
- Thermoplastic resins: weld, form, recycle
- Low viscosity resins

PU, pDCPD, EP: fast processing
- Polyurethanes: fatigue

Materials

Core material

- Foam:
  - PVC
  - PET
  - SAN
  - XPS
- Wood:
  - Balsa



Materials

Adhesive

- Epoxy (EP based blades)
- Vinylester (UPR based blades)

Materials

Coating

- Putty
- Pore filler
- Top coat
- Leading Edge Protection:
  - Erosion

Design concepts

Structural design concepts

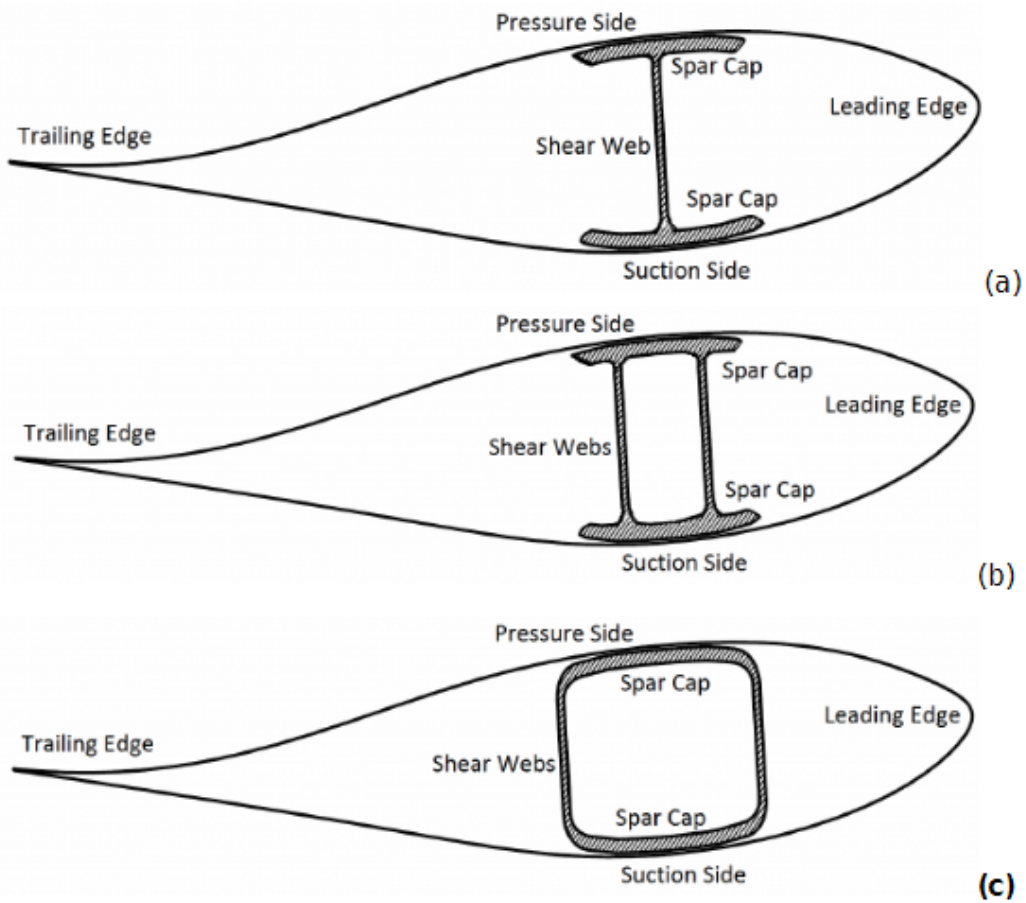
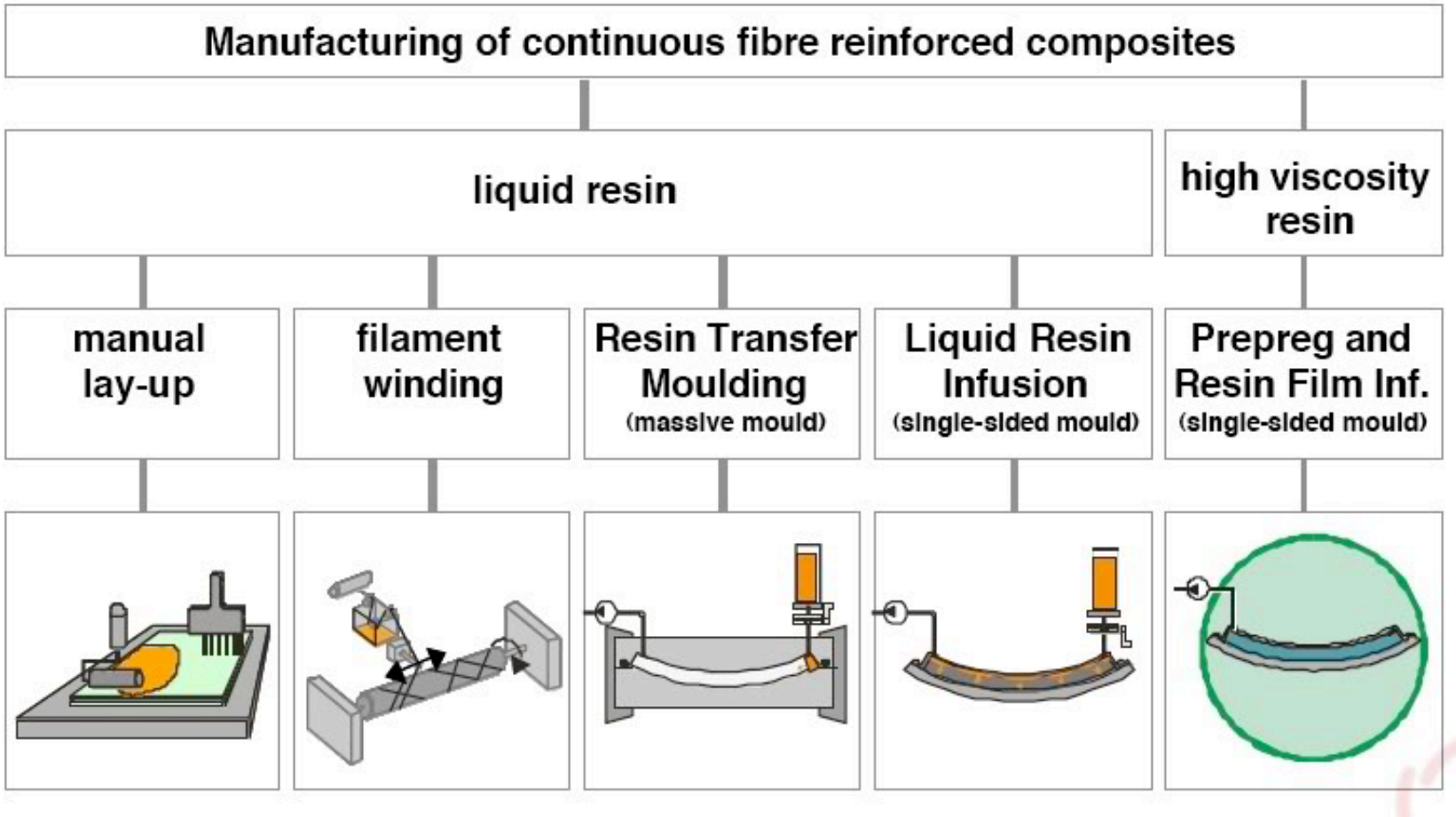


Figure 1 Cross sections of different wind turbine blade constructions: a) with one-shear web, b) with two-shear webs and c) box-like beam

How is it made?

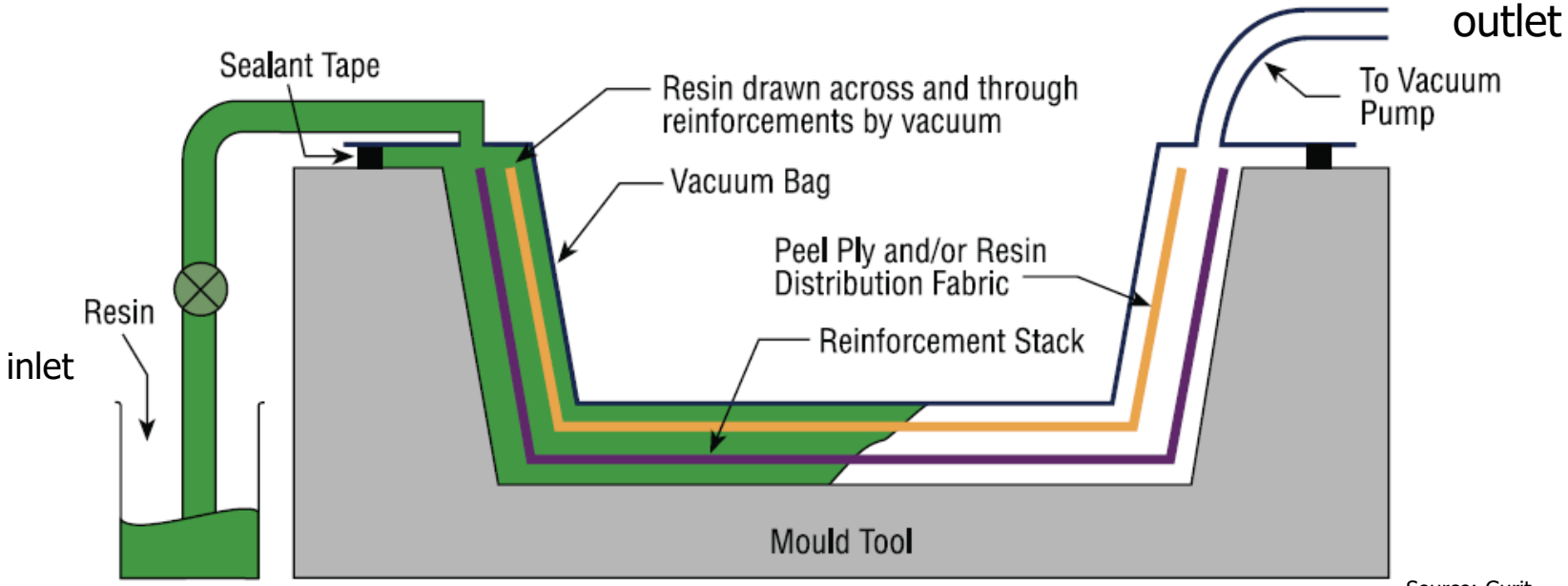
Manufacturing process



Manufacturing processes WTB

	<1,5MW	3MW	>3MW
Process	Hand lay-up Prepreg	Prepreg RTM VI	VI
Reinforcing material	Glass	Glass	Carbon/Glass
Resin	EP, UPR	EP, UPR	EP, UPR

Vacuum infusion



Source: Gurit

- P_{inlet} = 1 bar, P_{outlet} < 1bar
- 1-side tool only, disposable vacuum bag on other side:
  - Moulded finish 1 side only
  - Low tooling costs
  - Large components
- Relatively low viscosity resins needed

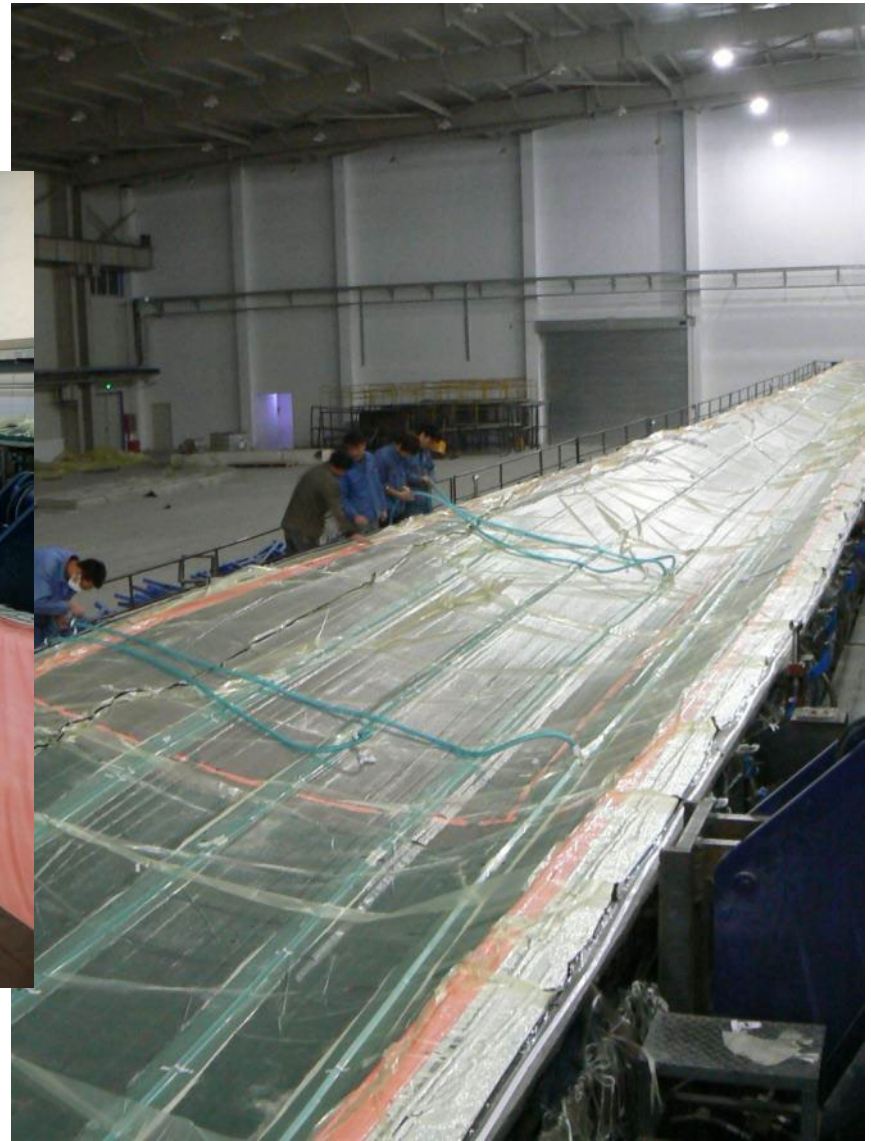
Processing steps

Shell lay-up

Prefab placement

More shell lay-up

Vacuum bagging



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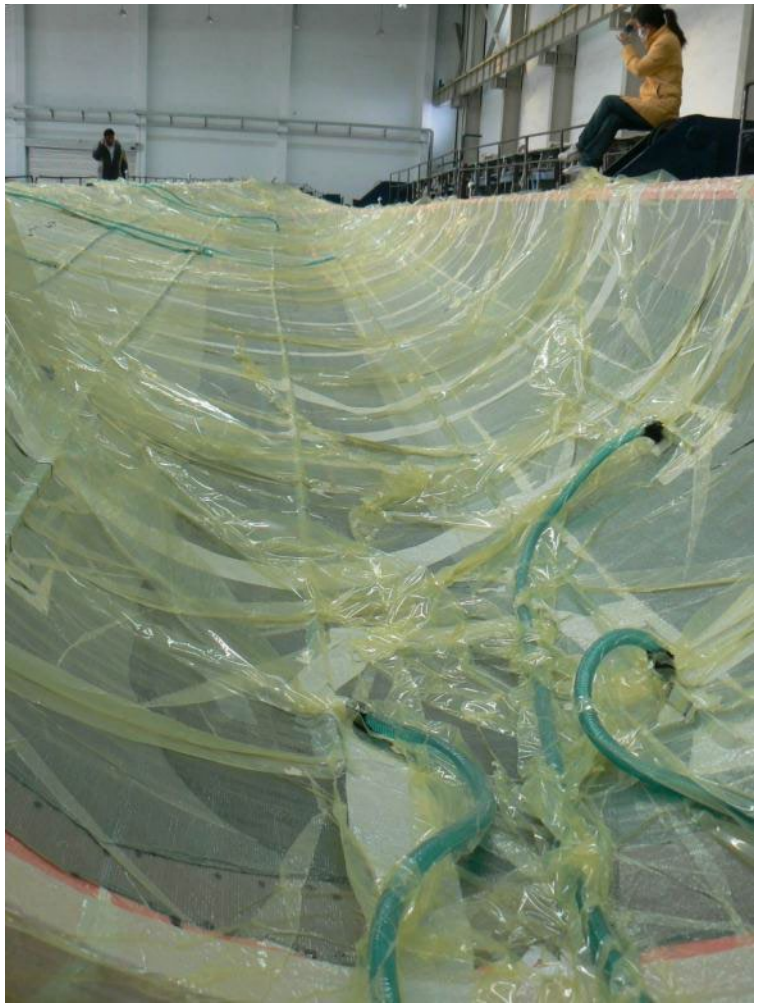
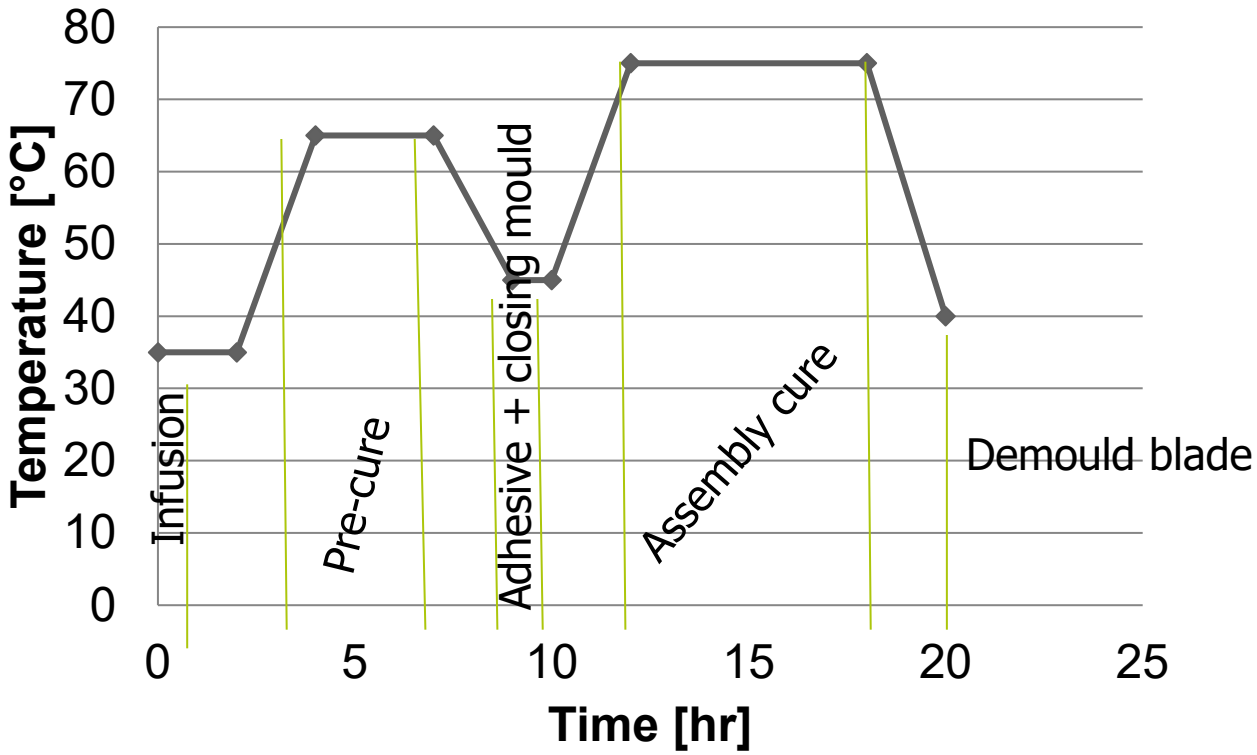
Infusion

5 min



14 min

Cure cycles


Temperature [°C]
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Time [hr]
Infusion
Pre-cure
Adhesive + closing mould
Assembly cure
Demould blade

Assembly

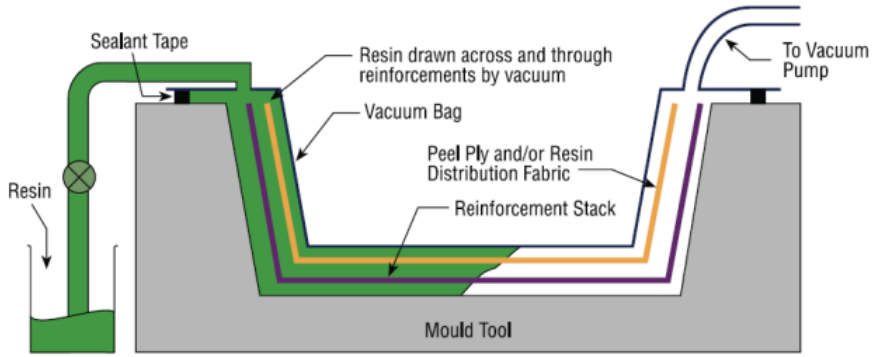
TU Delft

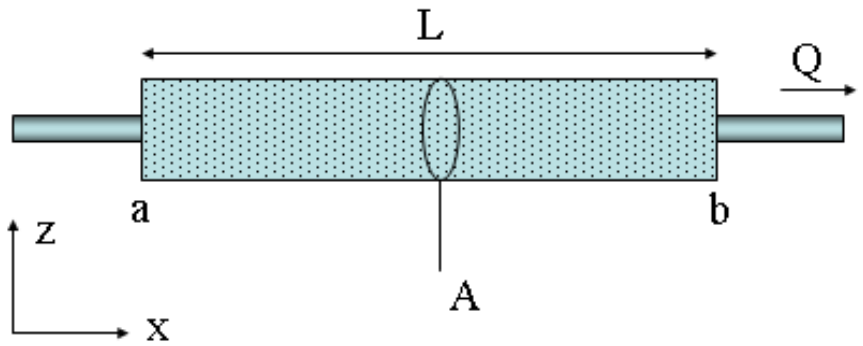
Finishing

How to design the process?

Darcy's law

- Flow of a liquid through a porous medium



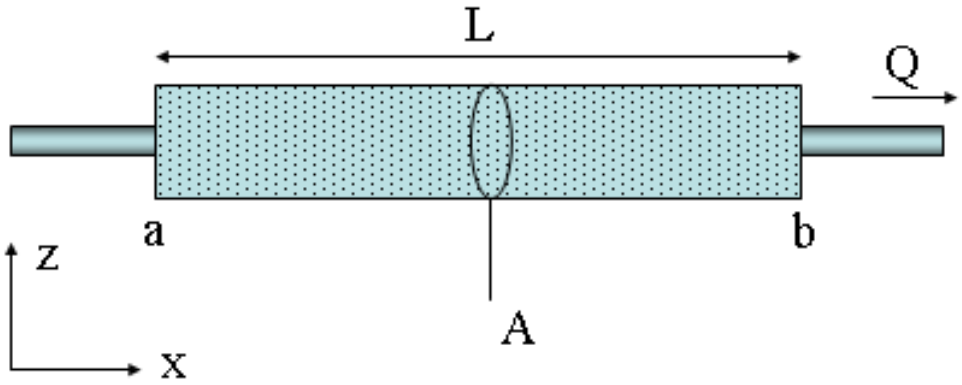


Darcy’s law

- With Darcy’s law:
  - Calculate **infusion time** for given materials and infusion set-up
  - Identify important **process parameters**
  - Draw **infusion strategies** which minimise infusion time
  - Analyse **effect of materials** on infusion time

Darcy's law

$$\frac{Q}{A} = \frac{k\Delta p}{\eta L}$$



- Q: Volumetric flow rate [m^3/s]
- A: Unit area [m^2]
- k: Preform permeability [m^2]
- Δp: Pressure gradient [Pa]
- η: Viscosity of the resin [Pa.s]
- L: Flow length [m]

Resin

Viscosity

Material	Viscosity [mPa.s]
Water	1
Blood	10
Kerosene	10
Corn oil	50-100
Maple syrup	150-200
Glycerine	250-500
Ketchup	2.000-3.000
Peanut butter	150.000-250.000

Infusion resin

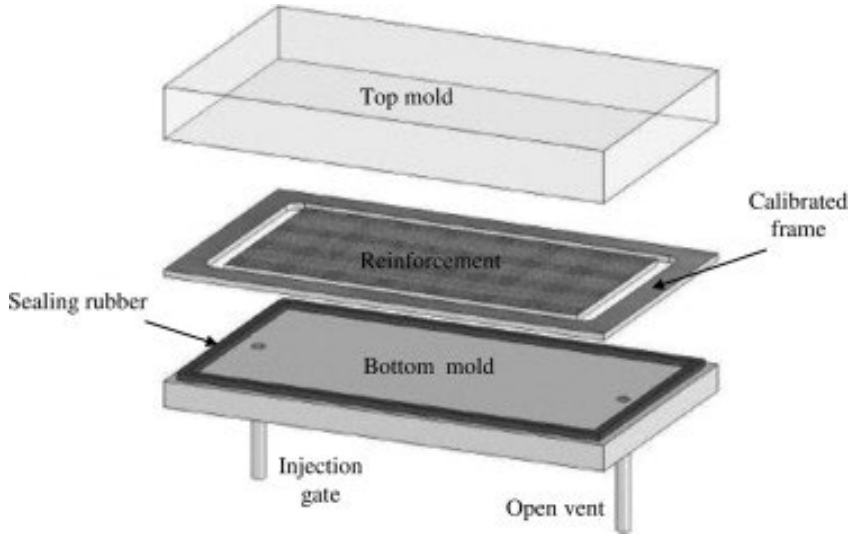
Up to 1.000mPa.s for infusion
Typical epoxy infusion grade resin viscosity: 50-300mPa.s

Source: Fundamentals of Composites Manufacturing. Materials, Methods, and applications, A.B.Strong, p.429

Permeability

Measurements

- Based on Darcy's law
- Constant resin viscosity (silicon oil, motor oil)
- Rigid mould halves
- Transparent top mould

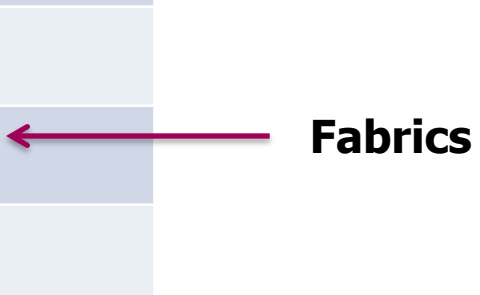


Source: Experimental Determination of the permeability of engineering textiles: Benchmark II, N. Vernet et al, Composites Part A: Applied Science and Manufacturing, Volume 61, June 2014, Pages

Permeability

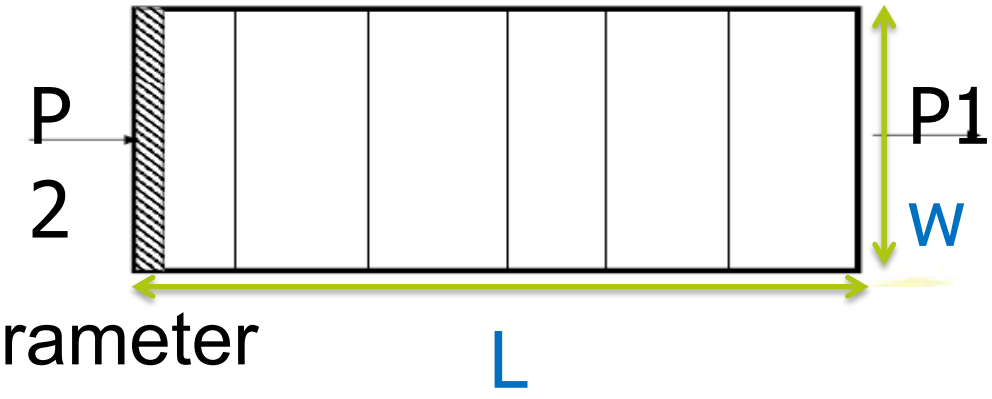
Typical values

Soil	K [m^2]
Well sorted gravel	$1x10^{-8}$ - $1x10^{-7}$
Well sorted sand	$1x10^{-9}$ - $1x10^{-11}$
Peat	$1x10^{-11}$ - $1x10^{-12}$
Very fine sand	$1x10^{-12}$ - $1x10^{-15}$
Sandstone	$1x10^{-14}$ - $1x10^{-15}$
Layered clay	$1x10^{-13}$ - $1x10^{-15}$
Fresh limestone	$1x10^{-16}$ - $1x10^{-17}$
Fresh granite	$1x10^{-18}$ - $1x10^{-19}$

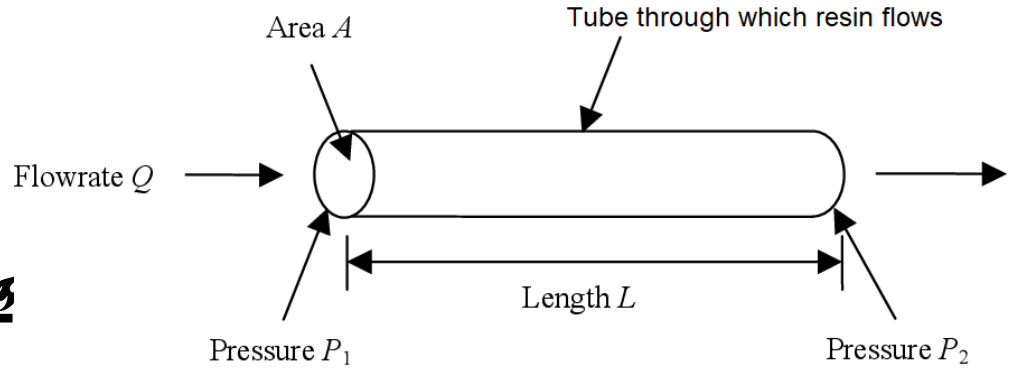


Infusion time

- Find the **expression for the infusion time** based on Darcy's law for a flat, rectangular panel with dimensions:
  - Width w
  - Length L
  - Thickness t



- Identify the most important process parameter



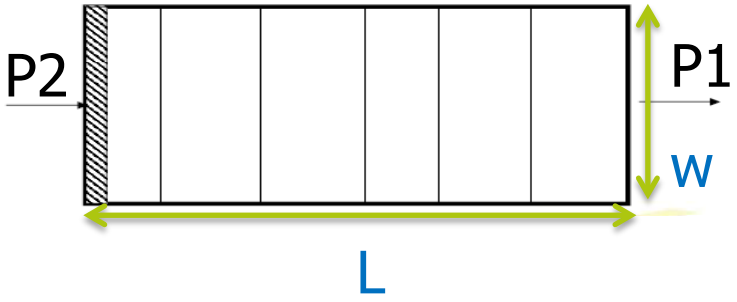
- Q: Volumetric flow rate [m^3/s]
- A: Unit cross-sectional area [m^2]
- k: Preform permeability [m^2]
- Δp: Pressure gradient [Pa]
- η: Viscosity of the resin [Pa.s]
- L: Flow length [m]

$$\frac{Q}{A} = \frac{k\Delta p}{\eta L}$$

Process parameters in LCM

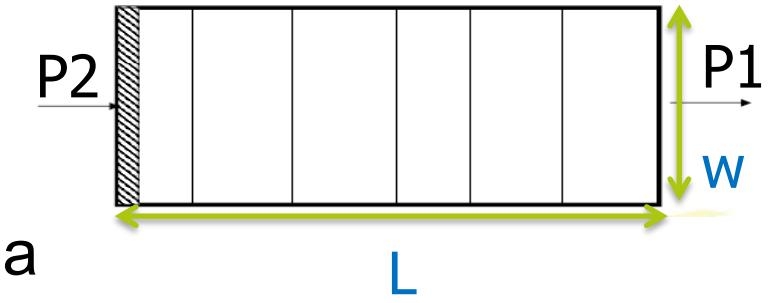
Darcy's law

- Infusion time t $= \frac{L^2 \times \eta}{\Delta p \times k}$



Infusion of a 1m x 0,5m x10mm panel

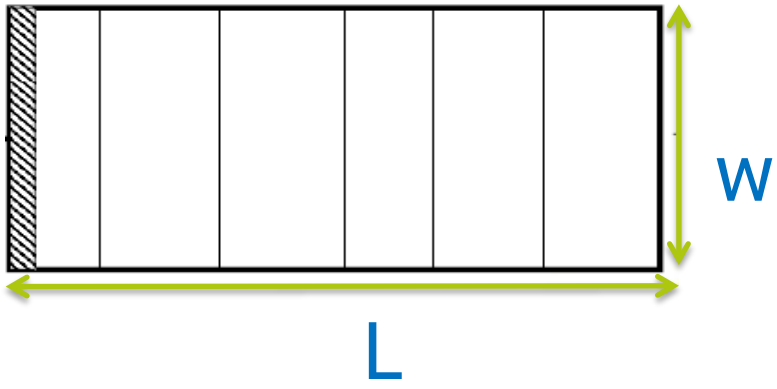
- Typical material parameters:
  - Fabric permeability = $1.10^{-9}m^2$
  - Resin viscosity = 0.25Pa.s
  - Pressure gradient = P2-P1 = 750mbar=75kPa
  - Flow length L= 1m
  - Thickness of fibre stack = 10mm
  - Width of fibre stack w= 0.5m
  - Darcy's law applicable
- Infusion time of panel: 55 min



Darcy's law

$$t = \frac{L^2 \times \eta}{\Delta p \times k}$$

- Suppose the resin gel time is 30 min, how can you make sure that the part is fully infused?



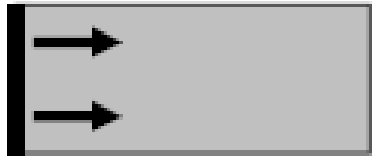
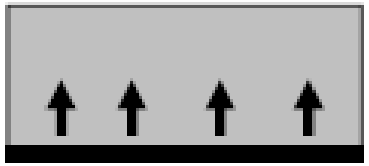
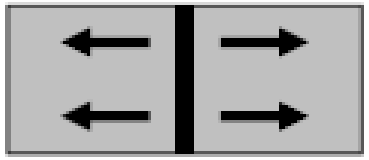
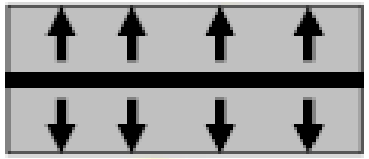
Given:

- Fabric permeability = $1.10^{-9}m^2$
- Resin viscosity = 0.25Pas
- Pressure gradient = 750mbar
- Length of product = 1m
- Thickness of fibre stack = 10mm
- Width of fibre stack = 0.5m
- Darcy's law applicable

Darcy's law

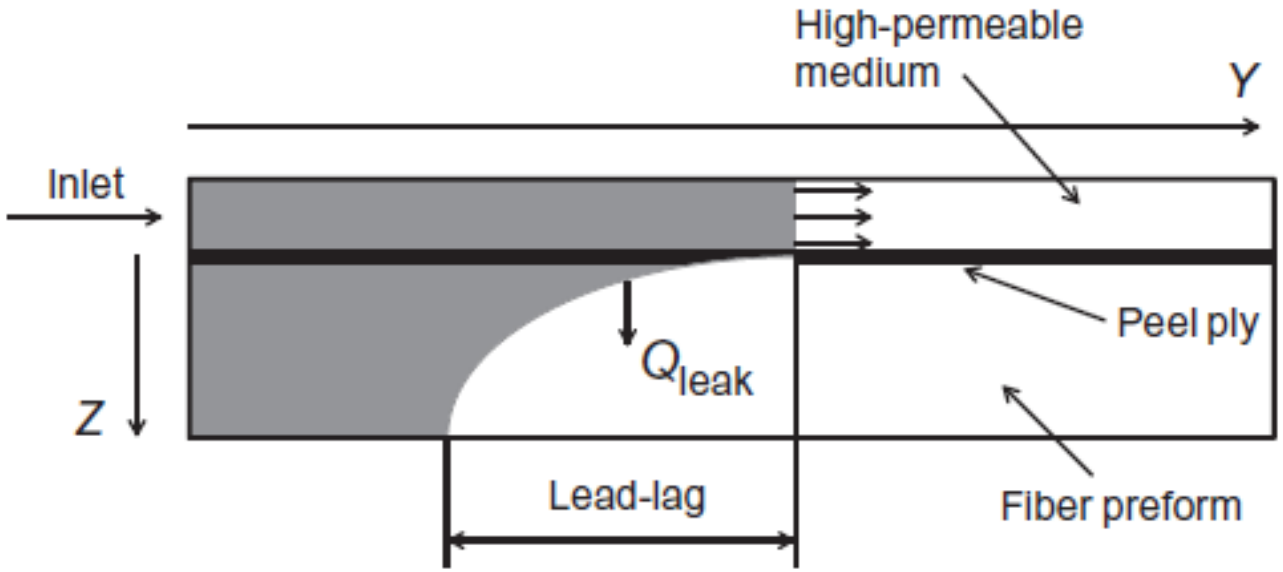
Infusion strategies

- Infusion time t $t = \frac{L^2 \times \eta}{\Delta p \times k}$

Fill time	Infusion strategy
» 60 min	
» 15 min	
» 15 min	
» 3.75 min	

Flow media

- Accelerates infusion speed
- Creates lag of infusion from the bag surface to the tool surface



Source: Advances in composite manufacturing and Process Design, P. Boisse, p358

Design

Structural Design & Analysis

- Stiffness & Strength
  - Stiff enough to avoid large tip deflections and strong enough to withstand the loads
- Light
  - Reduce the gravitational forces
- Durability/reliability/functionality
  - The design lifetime should be at least 20 years according to GL and IEC-61400 standards

Static and fatigue tests on a single test blade

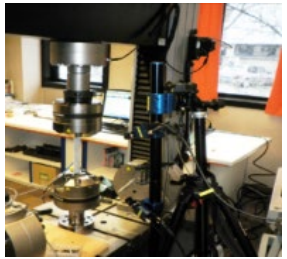
- The structural approval of the blade becomes challenging as its dimensions increase

Safety factors → Weight

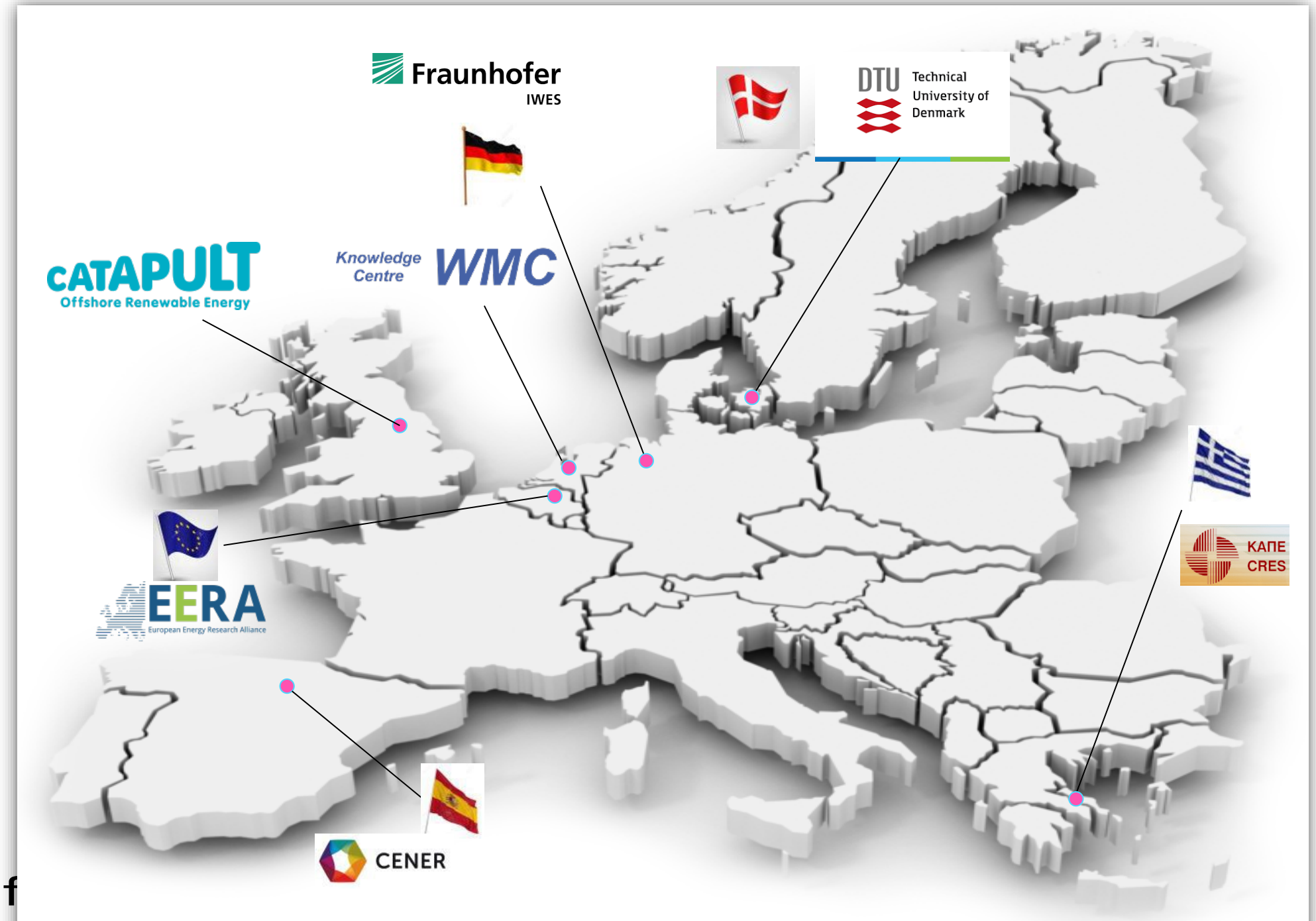
- Failure modes occurring in the blades, cannot be detected by coupon testing

Design is based on testing coupons






TU Delft


Fraunhofer
IWES
DTU
Technical
University of
Denmark
CATAPULT
Offshore Renewable Energy
Knowledge
Centre
WMC
EERA
European Energy Research Alliance
ΚΑΠΕ
CRES
CENER

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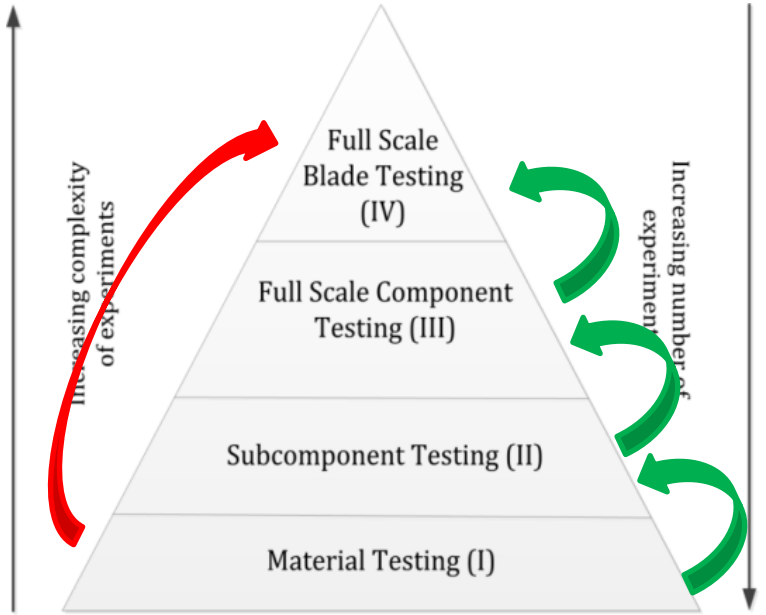
Full scale testing

Building Block Approach



DNV, 'Design and manufacture of wind turbine blades, offshore and onshore wind turbines', October 2010

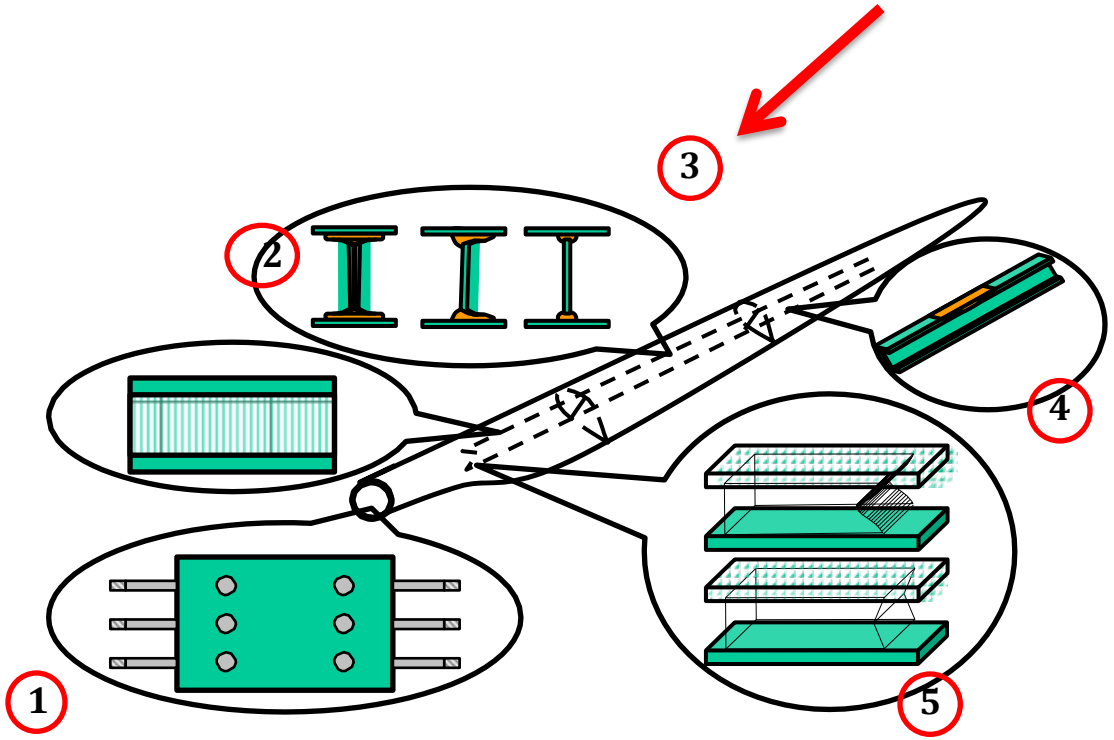
Safety factors → Weight

Safety factors → Weight

The building block approach is an iterative analysis and testing procedure which is conducted at increasing levels of structural complexity

What is a subcomponent?

Subcomponent is a structure which represents a structural detail of a blade



Nijssen et. al. EWEC 2008, Brussels

1. Blade root connection
2. Sandwich panels of leading & trailing edge
3. Adhesive connection between spar caps & shear web
4. Spar Caps
5. Ending of the shear web

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Blade failures

- Blade failures (Data collected in the field)
  - Lightning & foreign object impacts (36%)
  - Tip hits the tower (13%)
  - Adhesive bonding failures (20%)
  - Voids in skin & core (18%)
  - Improper cure (13%)

- Blade failures (Data collected during lab tests)
  - Laminate defects such as voids, dry spots, waviness (40%)
  - Adhesive bonding failures (40%)
  - Design problems in the sandwich panel and ply drops (10%)
  - Root failures (10%)

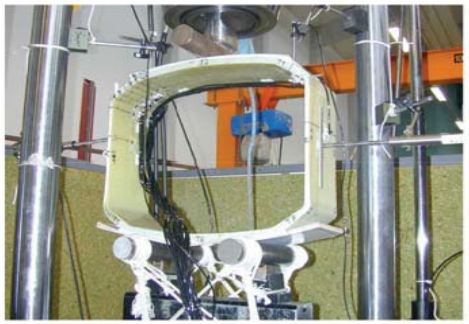
Why use a subcomponent?

1. Investigate the structural performance in terms of damage mechanisms & failure modes under realistic stress and strain fields

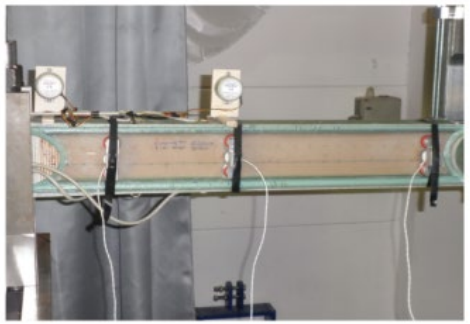
2. Validate the numerical material models

3. Optimize the use of SHM techniques for monitoring the blade

4. Investigate the influence of different design concepts



Compression of box-beam, Risoe Denmark



Asymmetric 3pb Henkel I-beam, IWES Germany

Symmetric 3pb UpWind I-beam, WMC Netherlands

That’s all for today!