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Design and Manufacturing of the TIDETEC Turbine Housing Demonstrator in FRP

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18th April. Open Industrial Day, Madrid

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TIDETEC
Optimising two-way hydropower

A world in transition

Renewable energy challenge:

What do you do when the wind is not blowing and the sun is not shining?

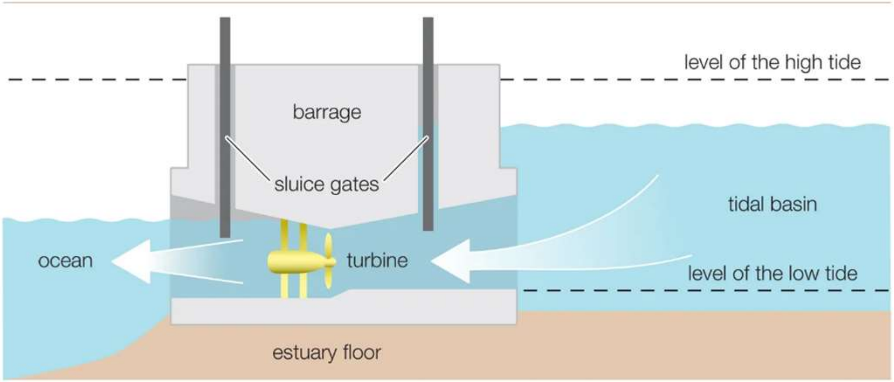
What do you do when there is excess energy and you can't get paid for the energy you generate?

Tidal range provides predictable and clean energy:

- Low cost of energy
- Provides energy storage
- Stabilizes intermittent energy sources
- Low noise and visibility
- Can provide flood protection

Planned Tidal Range projects in UK can generate 12 % of UK annual demand

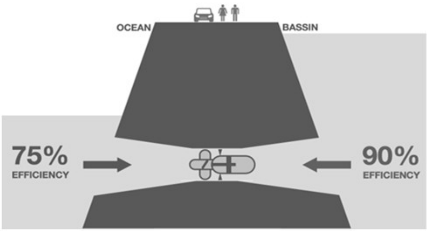
What is tidal range

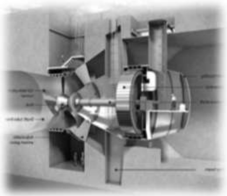


- Tidal range generates energy from the potential height difference in the tide
- Water can be held in basins, barriers, or even small ports
- Fully predictable energy
- Not affected by variable weather or external influences

Intro to Tidetec

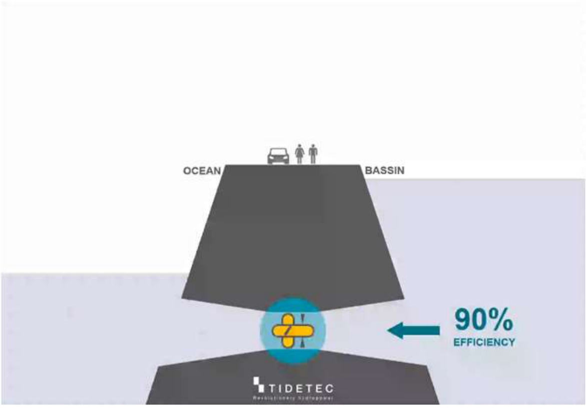
CONVENTIONAL TURBINES

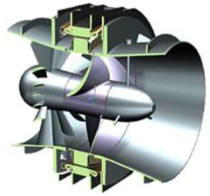




TIDETEC

- Optimal generation and pumping in both directions
  - (up to 30% increase)
- Lower CAPEX **(- 20% investment)**
- Lighter and cost effective turbine
- Lower OPEX **(- 40% cost)**





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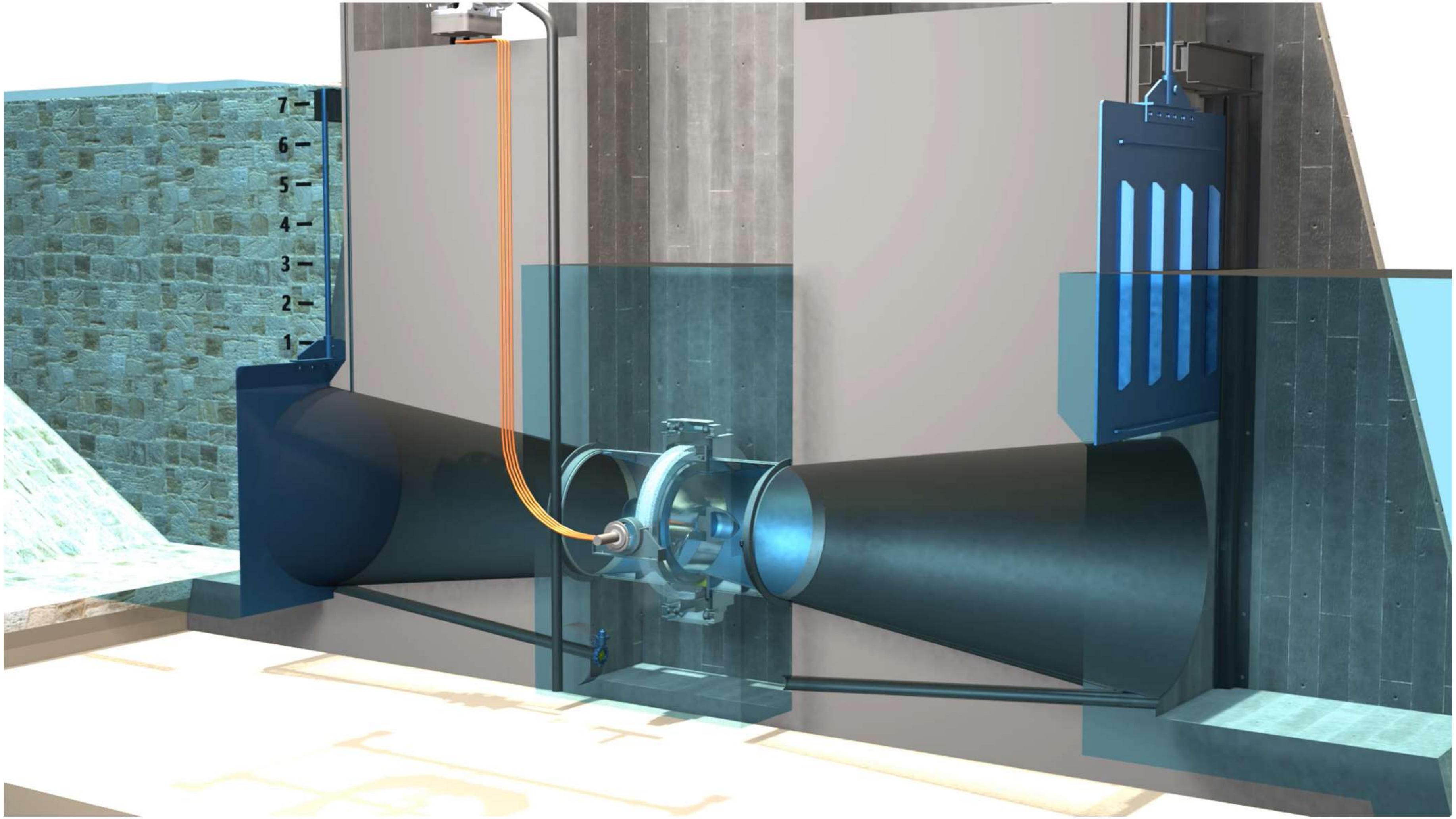
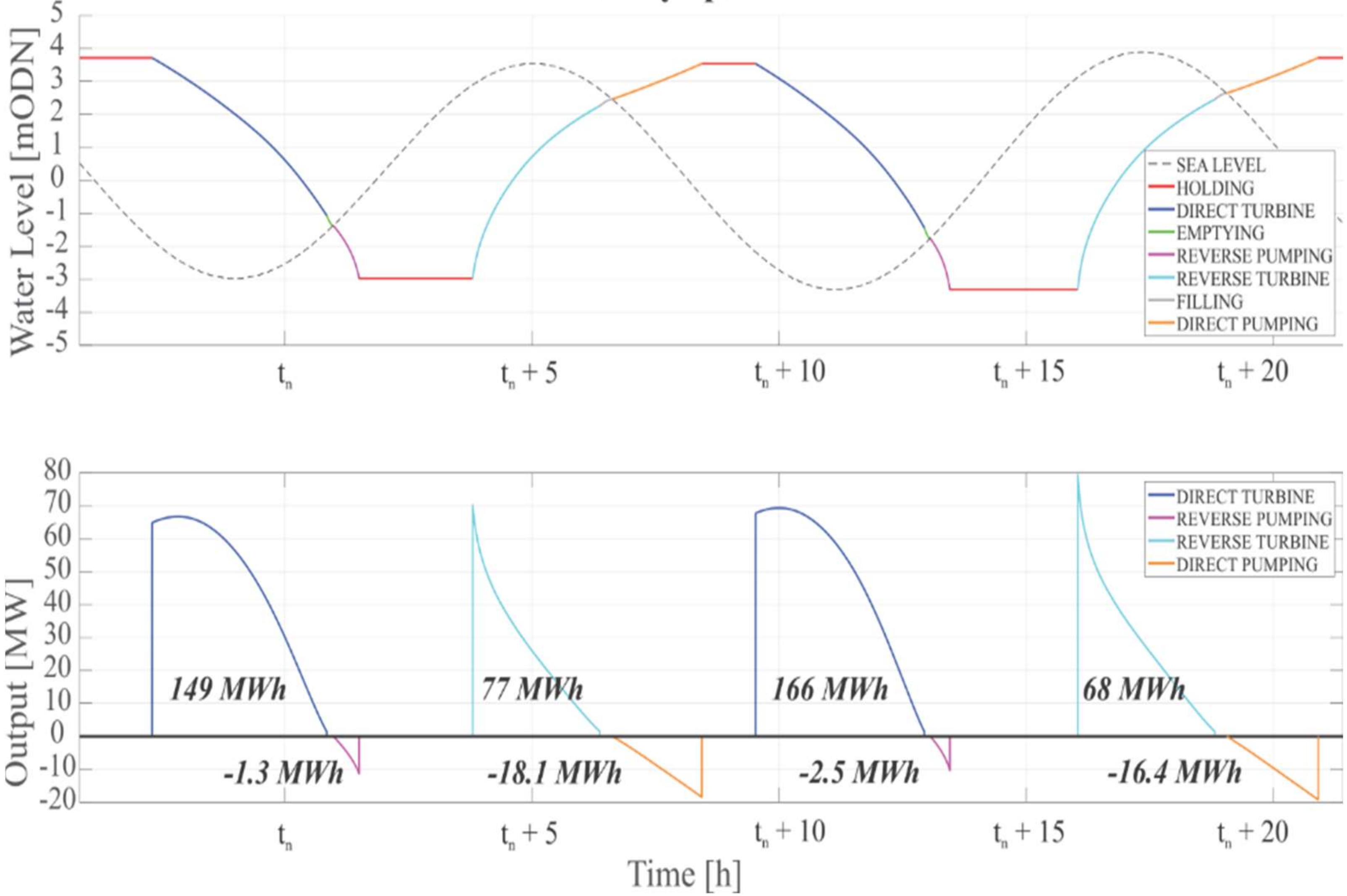
Optimising two-way hydropower

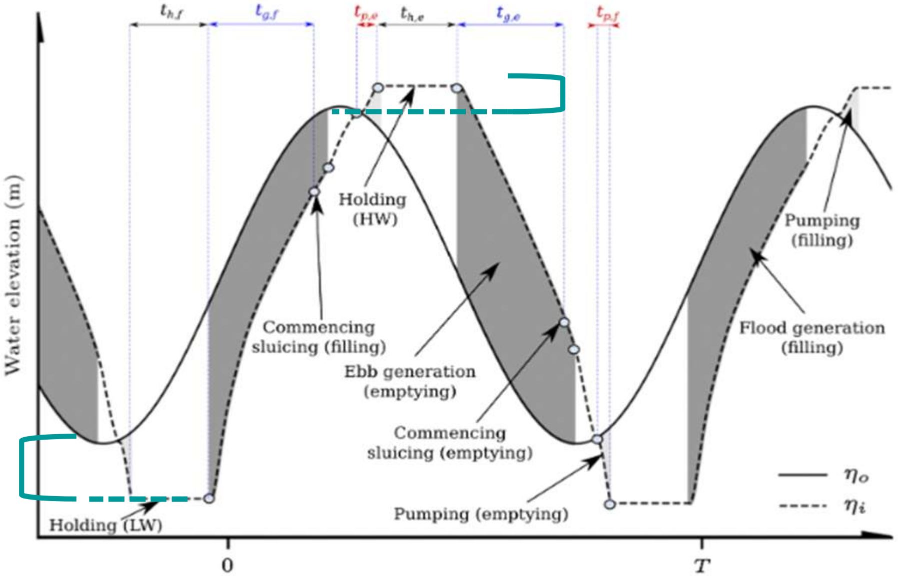
Production Cycle - Generic Method



Two-way operational mode



SmartLagoon- adaptive pumping

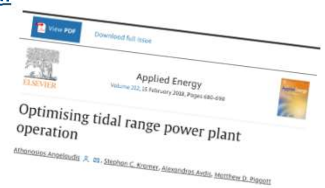


With Tidetec’s turbine optimized for both generating and pumping, the SmartLagoon concept can achieve its highest potential

Achieve higher potential in tidal lagoons

Through extra pumping at the highest and lowest water levels, **SmartLagoons can create 20-40%** [1] improved energy output compared to conventional two-way operation.

[1] Source: Angeloudis et. al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Applied Energy
Optimising tidal range power plant operation

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TIDETEC
Optimising two-way hydropower

The solution is flexible and applicable for several markets and use-cases

ENERGY PRODUCTION

Integrated in lagoons, tidal basins, and flood barriers

Retrofitted in existing infrastructure such as drydocks

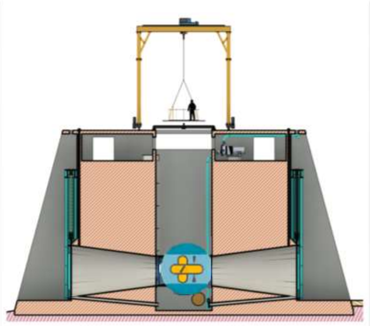
ENERGY STORAGE

Pumping for energy storage in low-tide locations

Booster pump for pumped-storage hydroelectricity

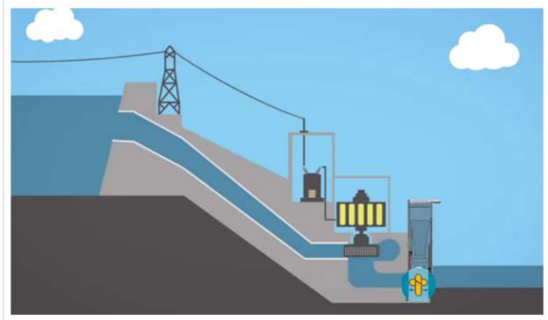
Utilize energy stored in onshore fish farming plants

Tidetec Applications

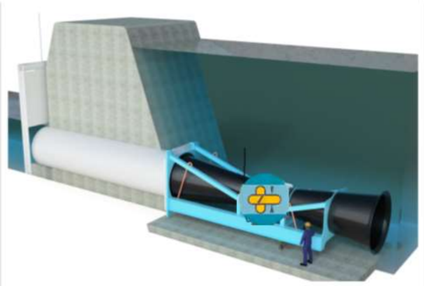


Integrated solutions:
Lagoons, Barriers, Tidal basins, flood defence

Integrated solutions:
Energy generation from wastewater in onshore aquafarming



Pumped storage «booster» solutions:
Conversion of hydropower to pumped hydro



«Tidal-in-a-box» solutions:
Integrated in existing infrastructure dry-docks, port basins

Pumped storage «drydock» solutions:
Low head marine pumped hydro

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Optimising two-way hydropower

Next steps

	2023	2024	2025	2026	2027	…

Small commercial scale 1-100 GWh

Tidal-in-a-box

- Exploit existing infrastructure
- **Pre FEED consultancy**
- **Project delivery**

- Energy as a service
- Storage as a service
- Recurring revenue
- Off-grid increases margin
- **Market size: >€100m**
  - At least 40 docks in UK

Full Scale Demonstrator 100 – 500 GWH

Tidal lagoon/Tidal barrier

- Position to become preferred technology

- Supplier/consortium partner
- **Market size: €30bn**

Large, Full Scale 500 GWh-5TWh

Large Infrastructure projects

- Licensing or solution provider with EPC partner

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Tidal energy opportunity vs offshore and onshore wind energy

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Example: Comparison between a tidal lagoon, an offshore, and an onshore wind farm

	Floating Offshore Wind	Fixed Bottom Offshore Wind	Tidal Range Structure
Capacity of unit turbine[MW] :	6.1	8.0	16.0
CapEx [£/kW] :	3,942	2,775	4,609
OpEx [£/kW/yr] :	97	82	46
Number of turbines [-] :	15	12	8
AEP [GWh] :	305	319	300
Capacity Factor [-] :	38 %	48 %	25 %
Total Capex, 25 yrs period [£] :	£361m	£266 m	
Total Capex, 100 yrs period [£] :	£1 .4b	£1.07b	£590m
Total OpEx, 25 yrs period [£] :	£222m	£197m	
Total OpEx, 100 yrs period [£] :	£887 m	£787m	£590m
Total Decom. costs, 25 yrs period [£] :	£17m	£18m	
Total Decom. costs, 100 yrs period [£] :	£68m	£72m	
Strike price [£/MWh]:	88	57	100
Revenue, 25 yrs period [£] :	**£670m**	**£455m**	**£750m**
Revenue, 100 yrs period [£] :	£2.7bn	£1 .8bn	£3 bn
	Environmental Footprint - Greenhouse gas (GHG) emissions		
GHG emissions [g CO_2 - eq./kWhe] :	15	14	23
GHG emissions, 25 yrs period [Mt CO_2]:	4568	4473	-
GHG emissions, 100 yrs period [Mt CO_2] :	18,271	17,891	6,900
Comparison with TRS [-] :	165 %	159 %	-

Conclusion:
Despite the over conservative estimates for tidal energy, the revenue will still be higher in the long-term

Assumptions:

1. Strike price of £100/MWh
2. Capacity factors: 25% for tidal range
3. GHG emissions
4. Steel prices for wind turbines based on publicly available info for 2019. The prices are about 15% higher now

TRS: tidal range structure

Demo project Norway/UK

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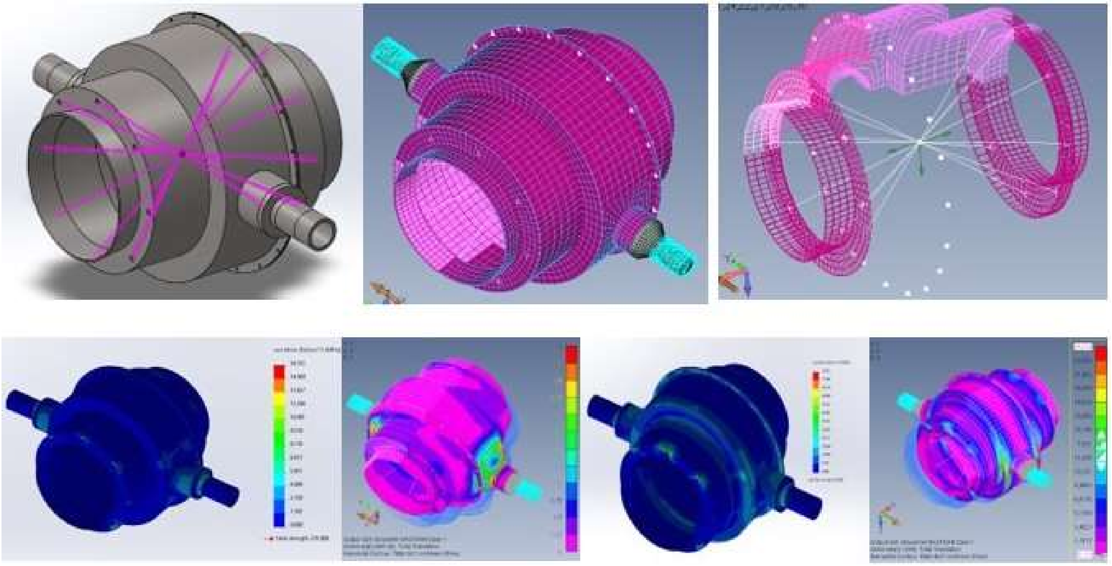
Considerations for the redesign of turnable turret

Achieve higher potential in tidal lagoons

- Must be able to rotate 180°
- Connection points to install model turbine
- Inner limitations due to the turbine
    - Decision made to not include the arms that form the turning mechanism in order to prevent extreme complexities in fabication

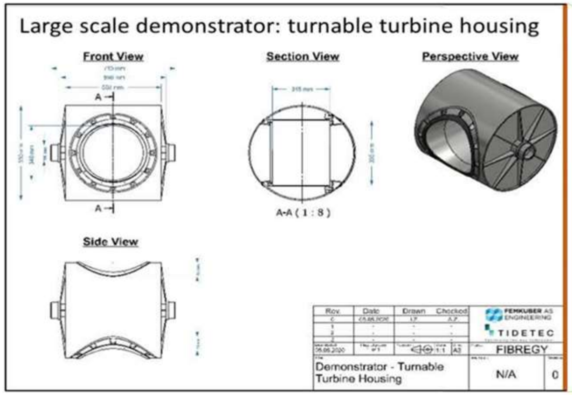
Considerations for the redesign of turnable turret



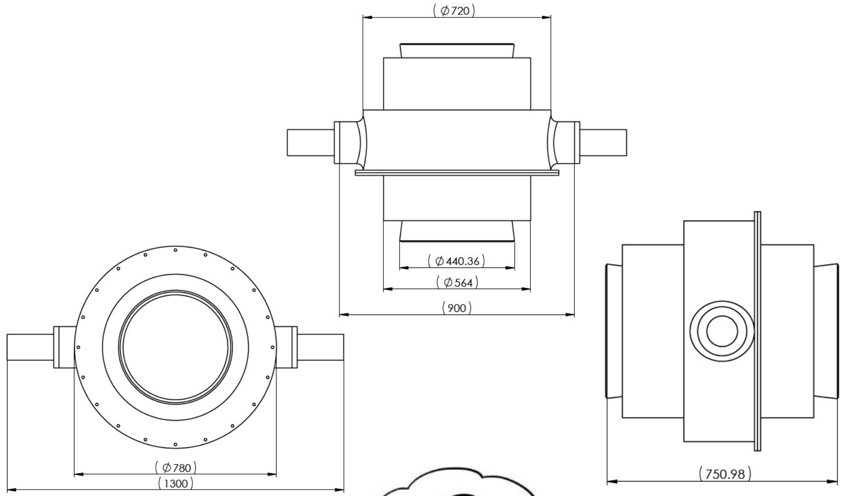
- Finite element analysis performed first on the steel design as a baseline
  - Static and modal analysis of three load scenarios
- Follow up FEA analysis with composite materials to inform the redesign process

- Next steps: what design will allow for manufacturing of the turret in composites while fulfilling design requirements?

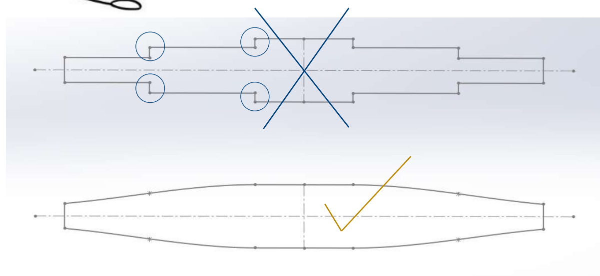
CONTEXT



TIDETEC's tidal turbine



How can it be manufactured using FRP materials?



Objective: Design and Manufacturing of a Turnable Turbine Housing demonstrator in FRP materials with the purpose to verify the technical and economic feasibility of using FRP materials in the TIDETEC's tidal turbine housing.

DESIGN FOR MANUFACTURING (DFM)

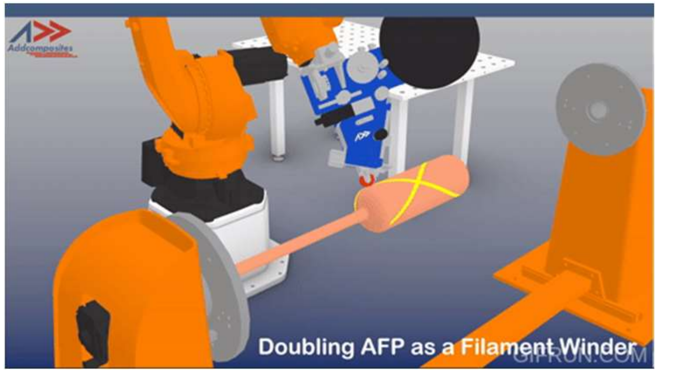
Manufacturing Process: AFP

Advantages:

- Controllable and repeatable process;
- Lower material waste;
- Precision placement of tape;
- Ideal for making cylindrical and/or hemispheric components;
- Increased material throughput;
- Improved composite structure quality;
- Quicker manufacturing time.

Disadvantages:

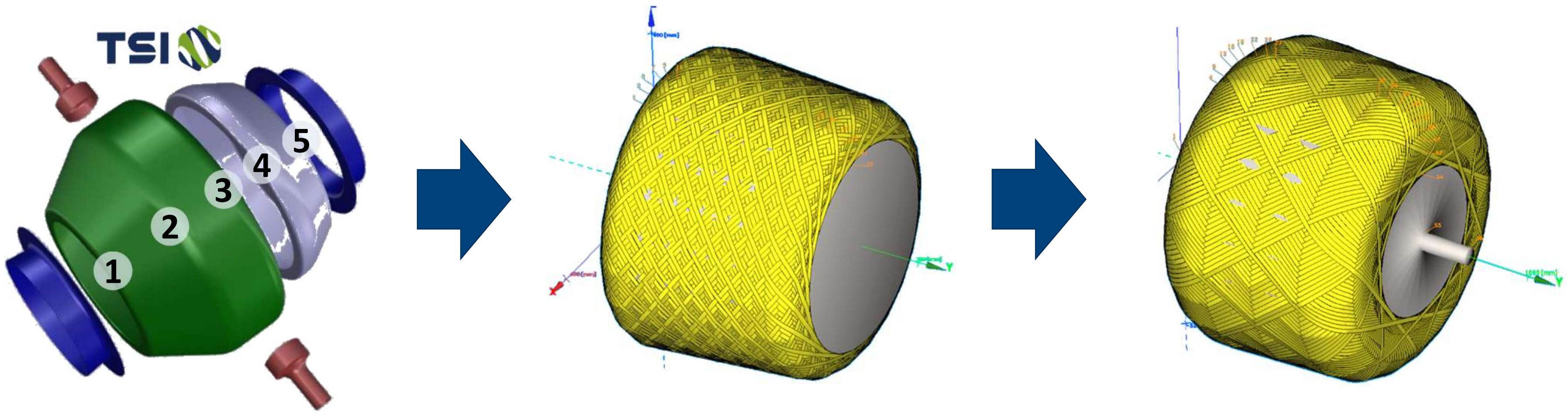
- High material cost;
- Requires cold storage in freezer and difficult handling;
- May require oven or autoclave cure.

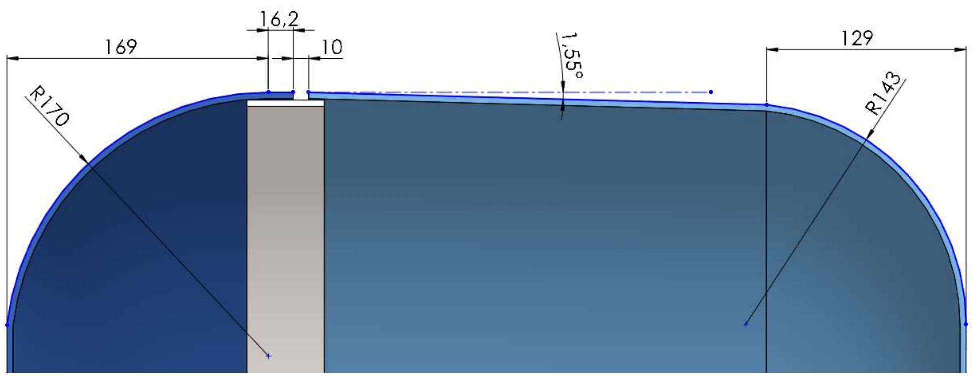


Source: Addcomposites

Source: Project PROCOMP

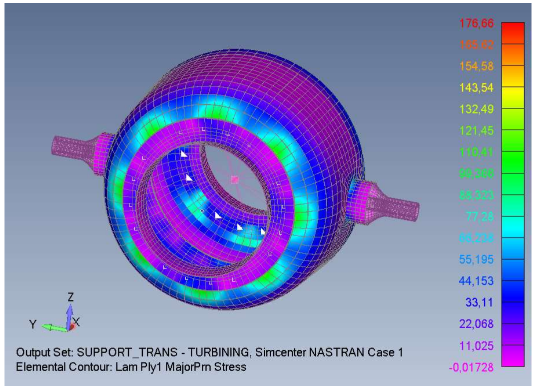
DESIGN FOR MANUFACTURING (DFM)

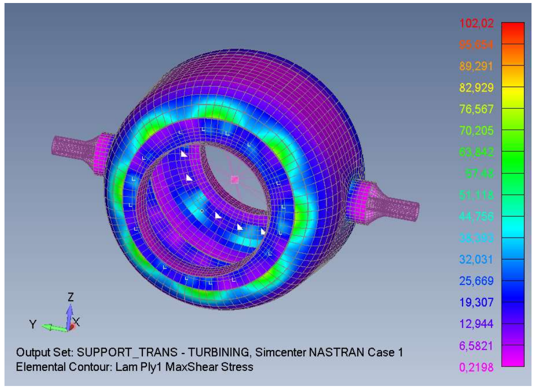


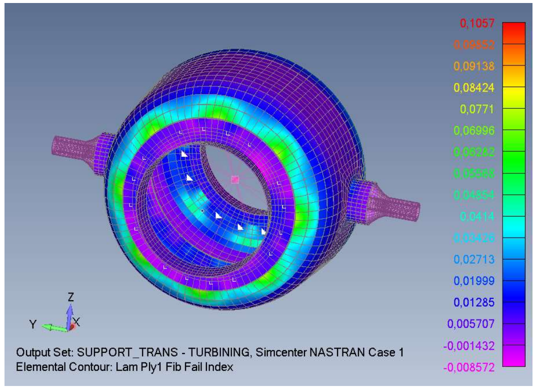


NUMERICAL ANALYSIS & VALIDATION

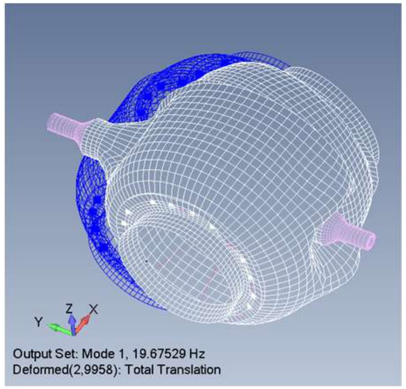
Results obtained in the static analysis:

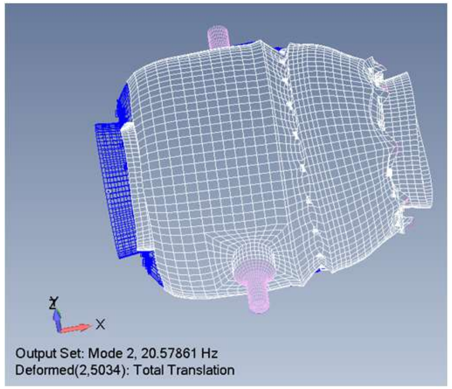


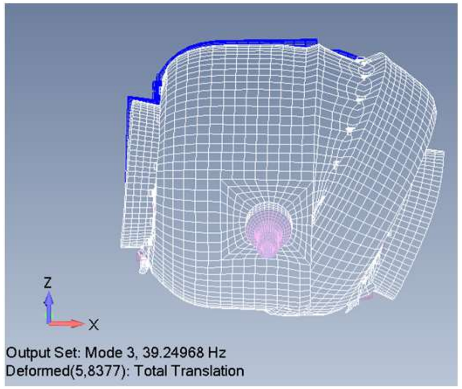




Results obtained in the modal analysis:

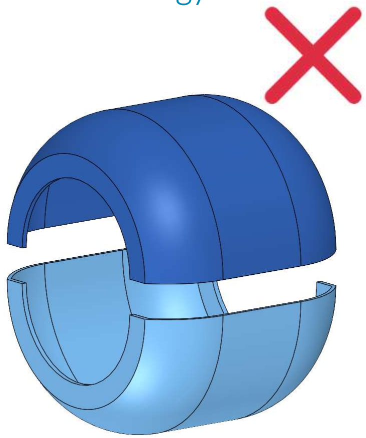






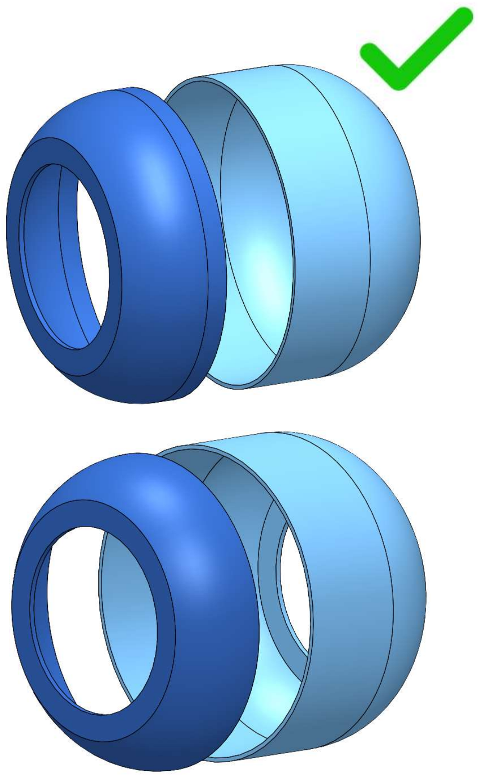
MODULAR BUILDING STRATEGY

Strategy A

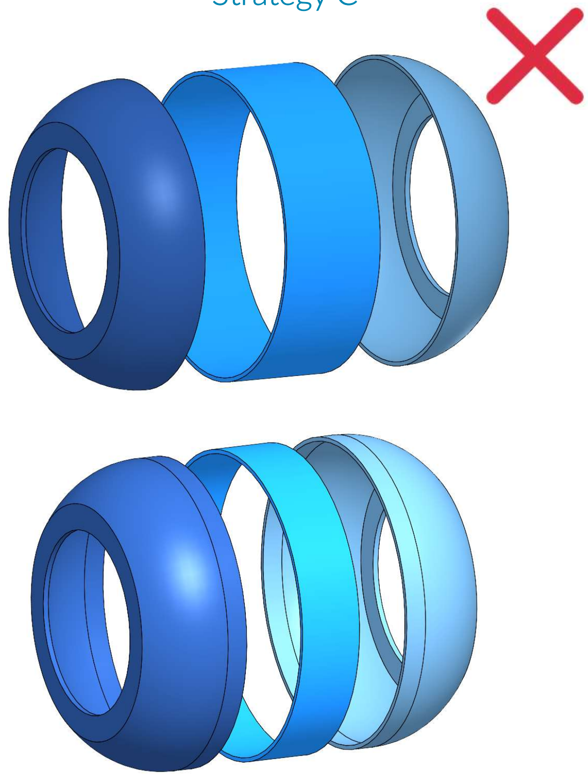


More difficult maintenance procedure and connections/assembly

Strategy B

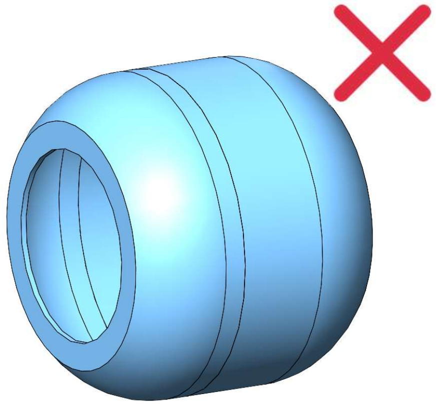


Strategy C



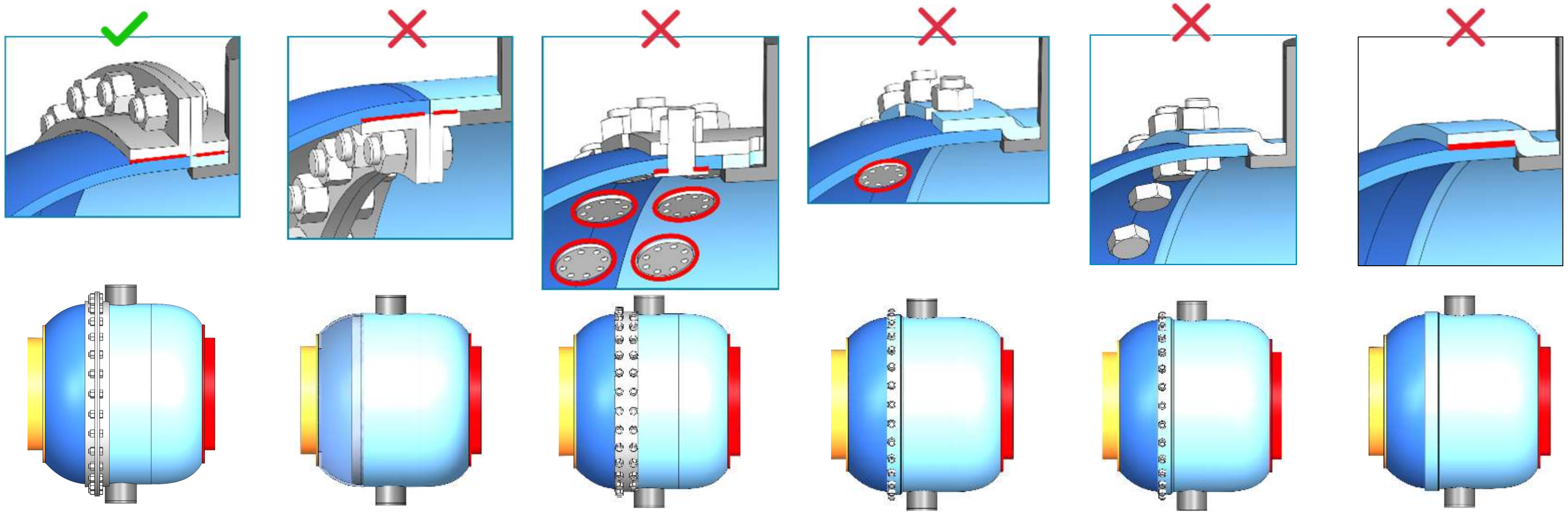
Unnecessary access points and extra steps in manufacturing and connections/assembly

Strategy D

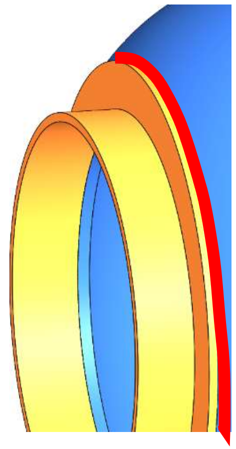


Doesn’t enable maintenance or fitting in the turbine. Cutting the housing defeats the purpose of destroyable mould

CONNECTIONS



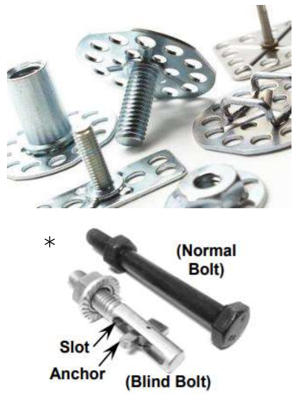
Adhesive Joint between Main body & Side Fairing // AFT Cover & Side Fairing2



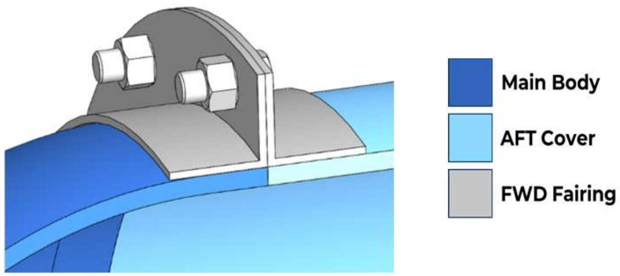
- Main Body
- AFT Cover
- FWD Fairing
- AFT Fairing

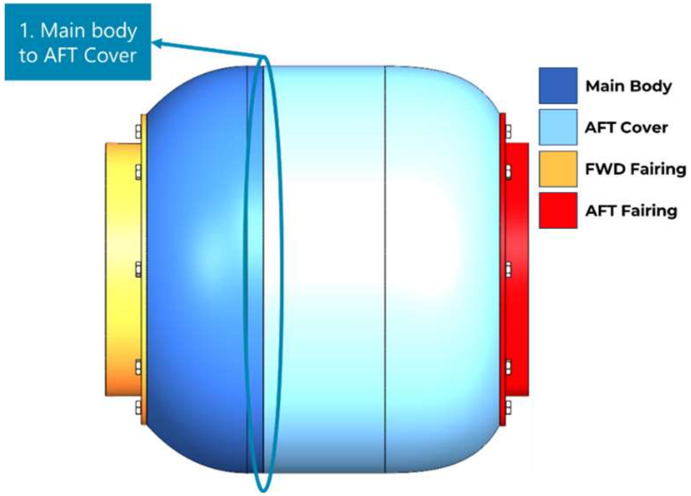
Process Chain

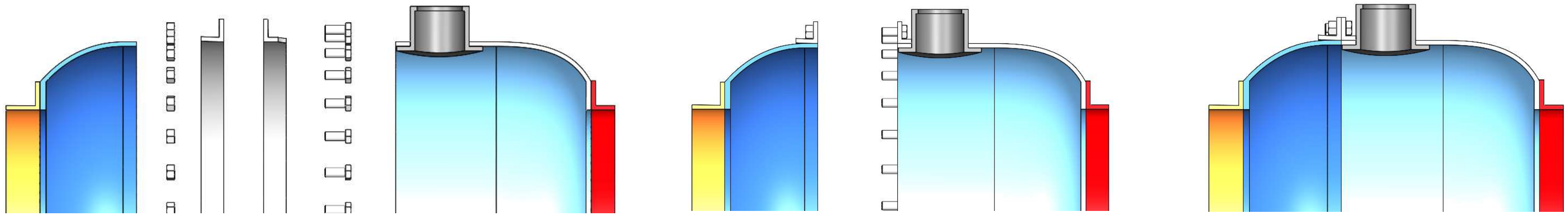
1. Cylinder and flange manufacturing
2. Polishing and surface preparation for bonding
3. Bonding Main Body to flange1 Bonding AFT Cover to flange2
4. Assembly to cylinder



ASSEMBLY PLAN



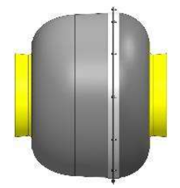


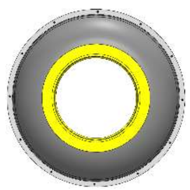


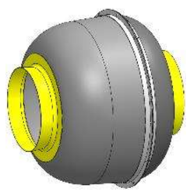
1. Main Body and AFT Cover, flanges, fairings and studs manufacturing
2. Edge triming and surface preparation prior to bonding
3. Bonding: AFT cover to studs; AFT Cover/Main body to respective flange
4. Assembly to housing

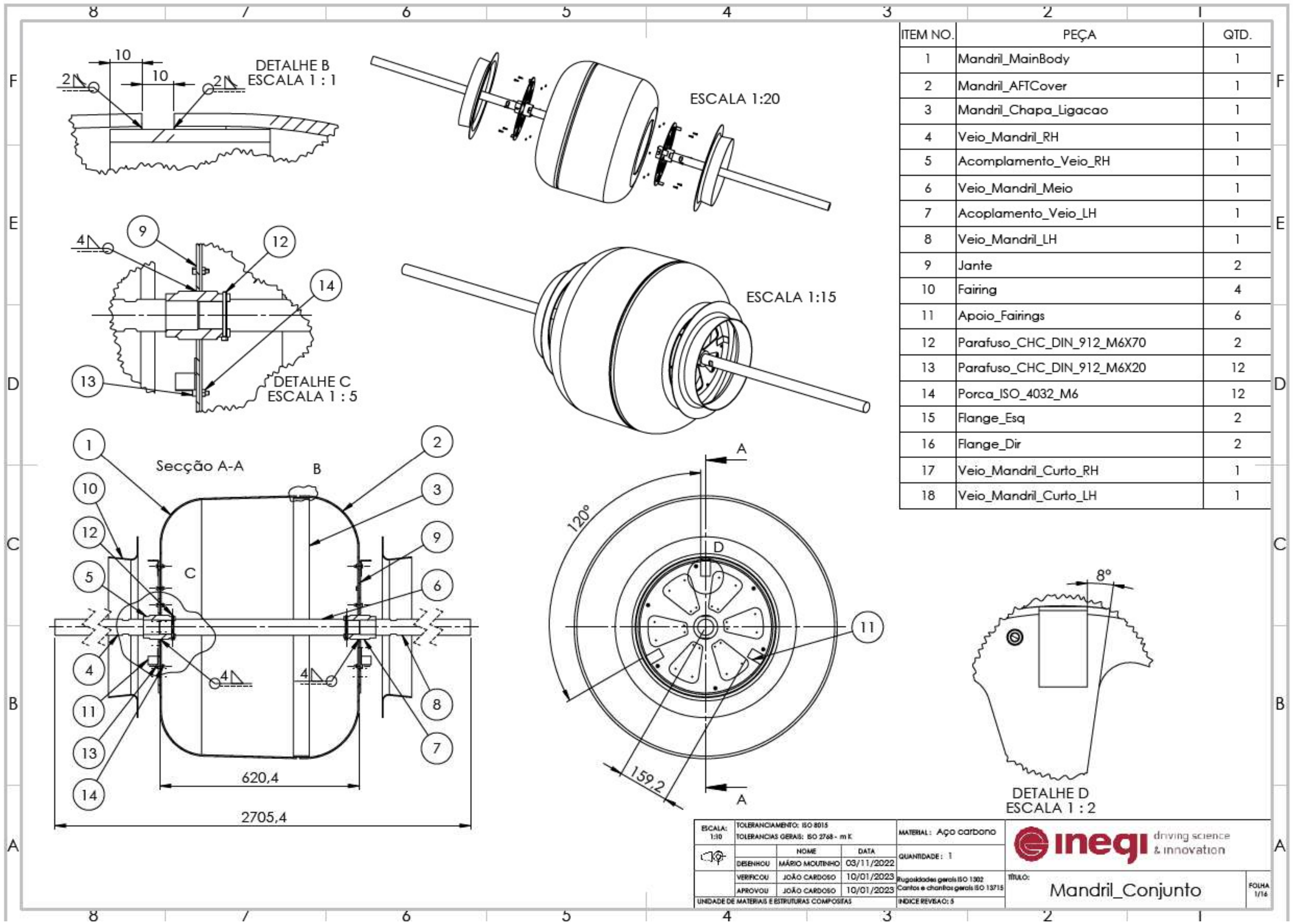
Main Body & AFT Cover
↓
Towpreg Winding

MANDREL DESIGN: ASSEMBLY DRAWING



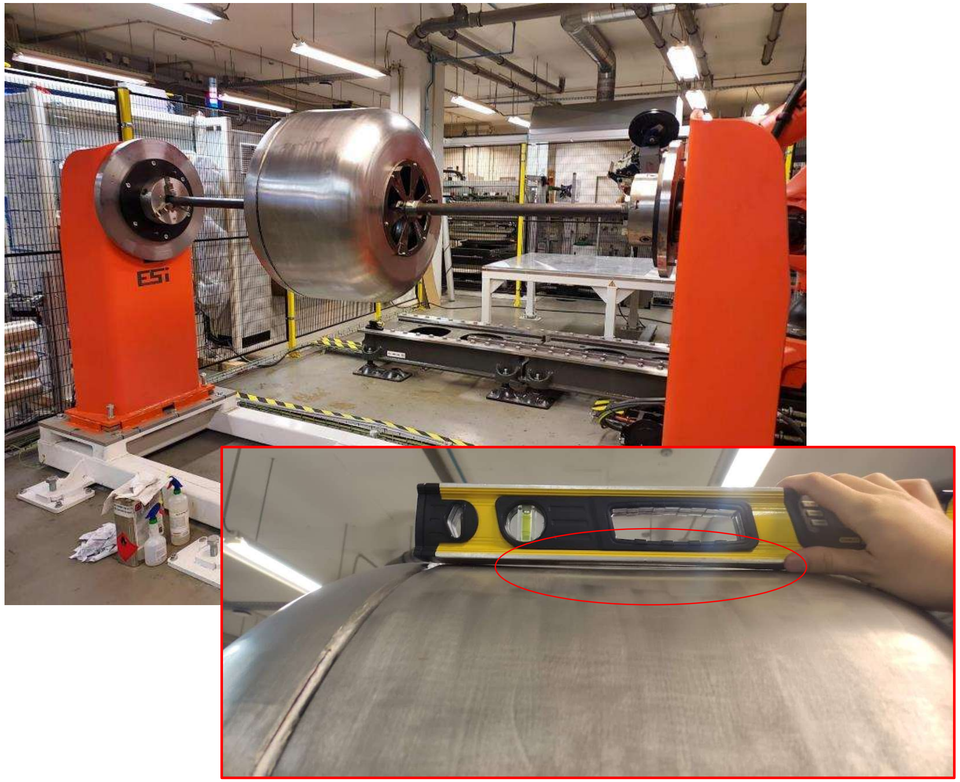






ITEM NO.	PEÇA	QTD.
1	Mandril_MainBody	1
2	Mandril_AFTCover	1
3	Mandril_Chapa_Ligacao	1
4	Veio_Mandril_RH	1
5	Acomplamento_Veio_RH	1
6	Veio_Mandril_Meio	1
7	Acoplamento_Veio_LH	1
8	Veio_Mandril_LH	1
9	Jante	2
10	Fairing	4
11	Apoio_Fairings	6
12	Parafuso_CHC_DIN_912_M6X70	2
13	Parafuso_CHC_DIN_912_M6X20	12
14	Porca_ISO_4032_M6	12
15	Flange_Esq	2
16	Flange_Dir	2
17	Veio_Mandril_Curto_RH	1
18	Veio_Mandril_Curto_LH	1

FINISHED MANDREL

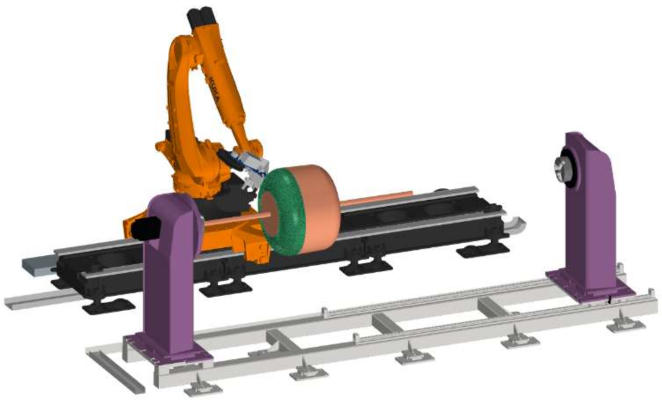


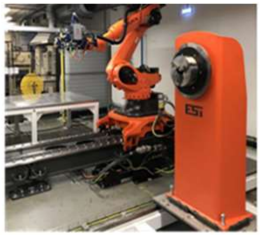
Negative draft angle due to sinking/warping

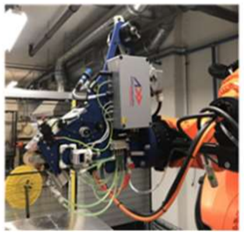
Good draft angle after correction

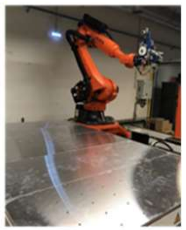
MANUFACTURING PREPARATION

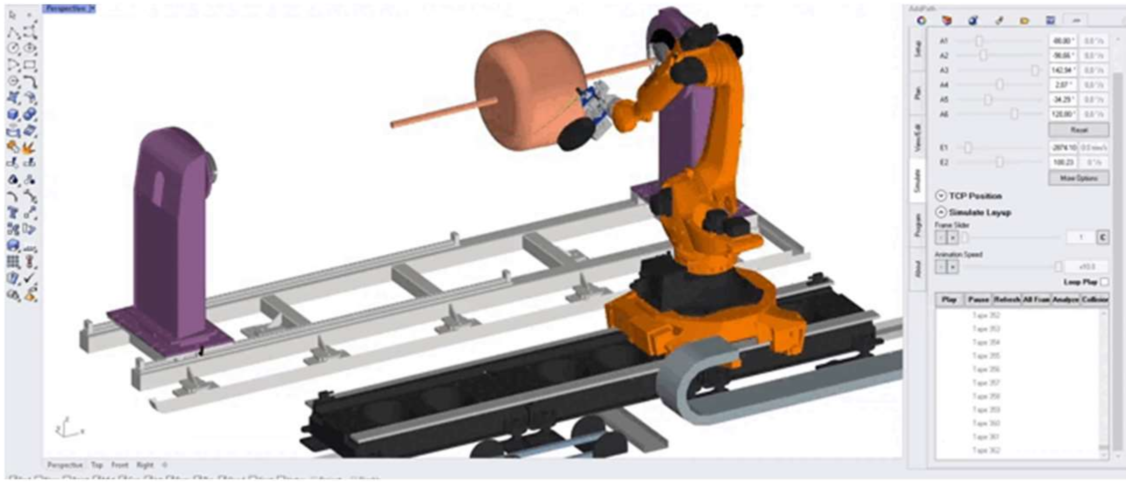
Process Simulation (AddPath)





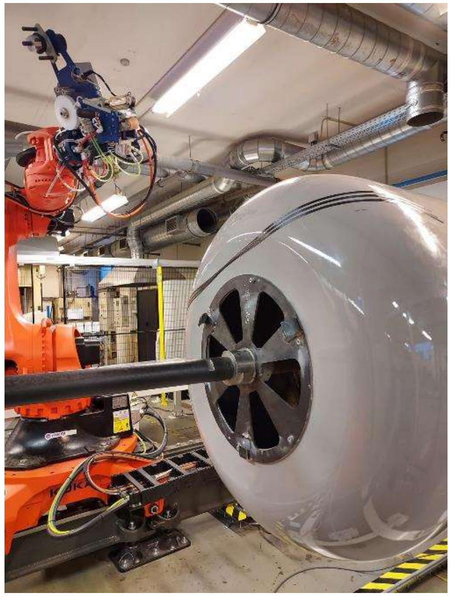






MANUFACTURING TRIALS

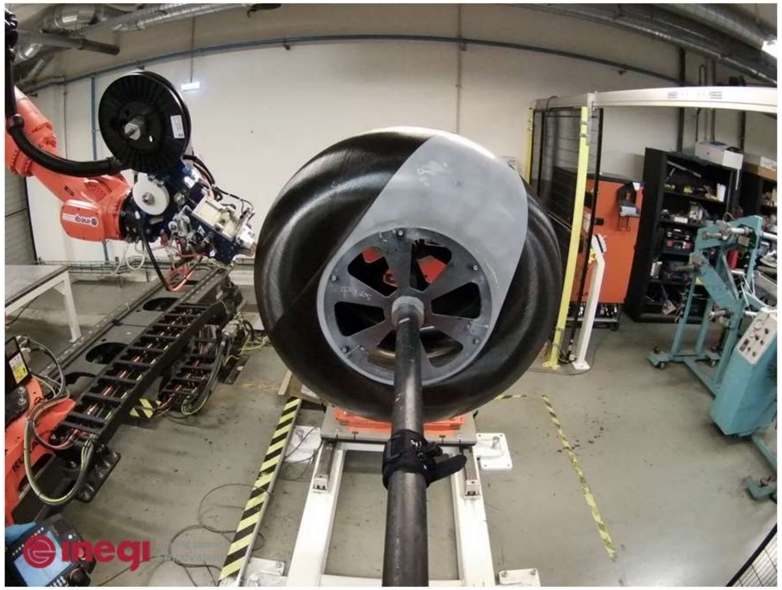
Toray MR014-2 Towpreg Resin
324gsm
Epoxy 34% resin by weight
Thickness 0,32mm and Width 6,35mm



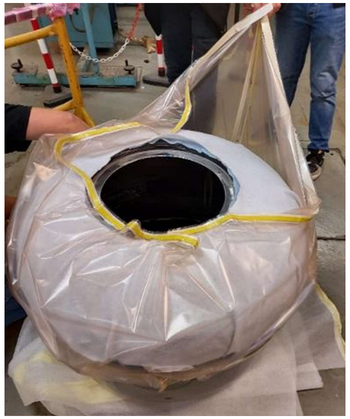
Placement of the first tows for parameter tuning

Manufacturing

MANUFACTURING



Vacuum bagging



Removal from oven

Demoulding

Demoulded part

Trimming and sanding

Bonding

TESTING AND VALIDATION

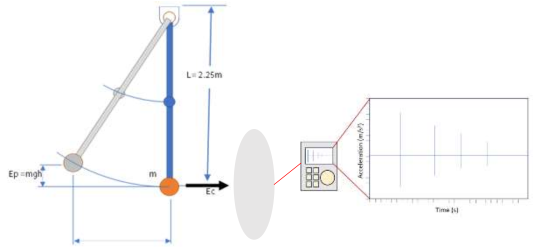
In collaboration with TSI

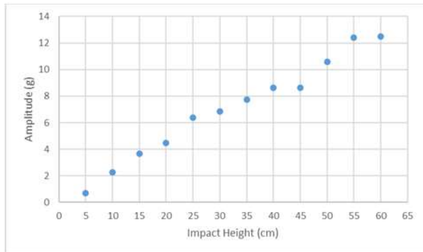
Vibration Assessment

Modal parameters, including natural frequencies (table below), damping, and mode shapes of the housing

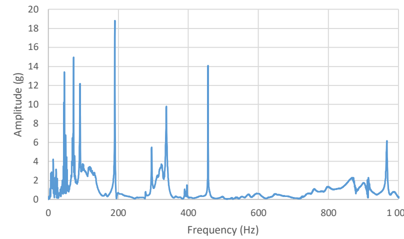
Mode	Test 1 (Hz)	Test 2 (Hz)	Test 3 (Hz)	Test 4 (Hz)	Test 5 (Hz)	Test 6 (Hz)	Test 7 (Hz)	Test 8 (Hz)	Average (Hz)	SD (Hz)
1	403.1	403.1	403.1	403.1	403.1	403.1	403.1	403.1	403.1	0.00
2	496.8	500.0	503.1	503.1	503.1	496.8	500.0	500.0	500.3	2.44
3	525.0	531.2	521.8	525.0	525.0	528.1	528.1	531.2	526.9	3.10
4	896.8	900.0	900.0	896.8	896.8	900.0	896.8	896.8	898.0	1.51
5	1028.1	1028.1	1031.2	1031.2	1018.7	1025.0	1025.0	1031.2	1027.3	4.06

Impact Assessment





Acceleration Amplitude as a function of the Impact Height for the different ball impacts



Fast Fourier Spectrum of the Tidal Turret

RESULTS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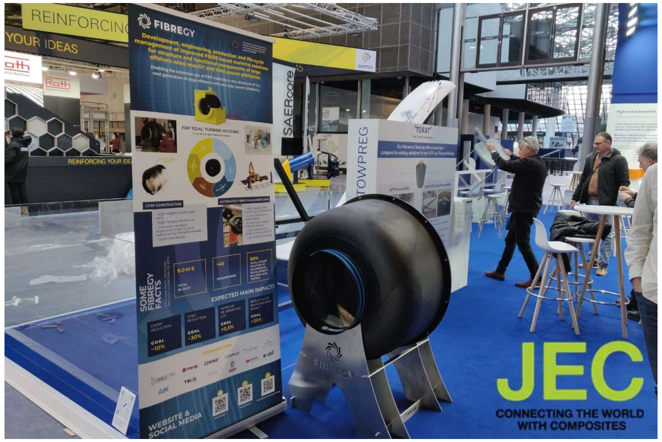
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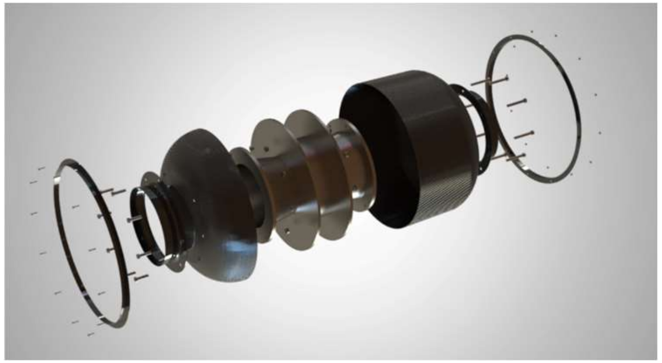
CONNECTING THE WORLD
WITH COMPOSITES



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THANK YOU

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