FIBREGY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

Manufacturing of W2Power and turbine housing demonstrators

Edouard WALDURA, **EXAIL**
João CARDOSO, **INEGI**

E-LASS Seminar
03/05/2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

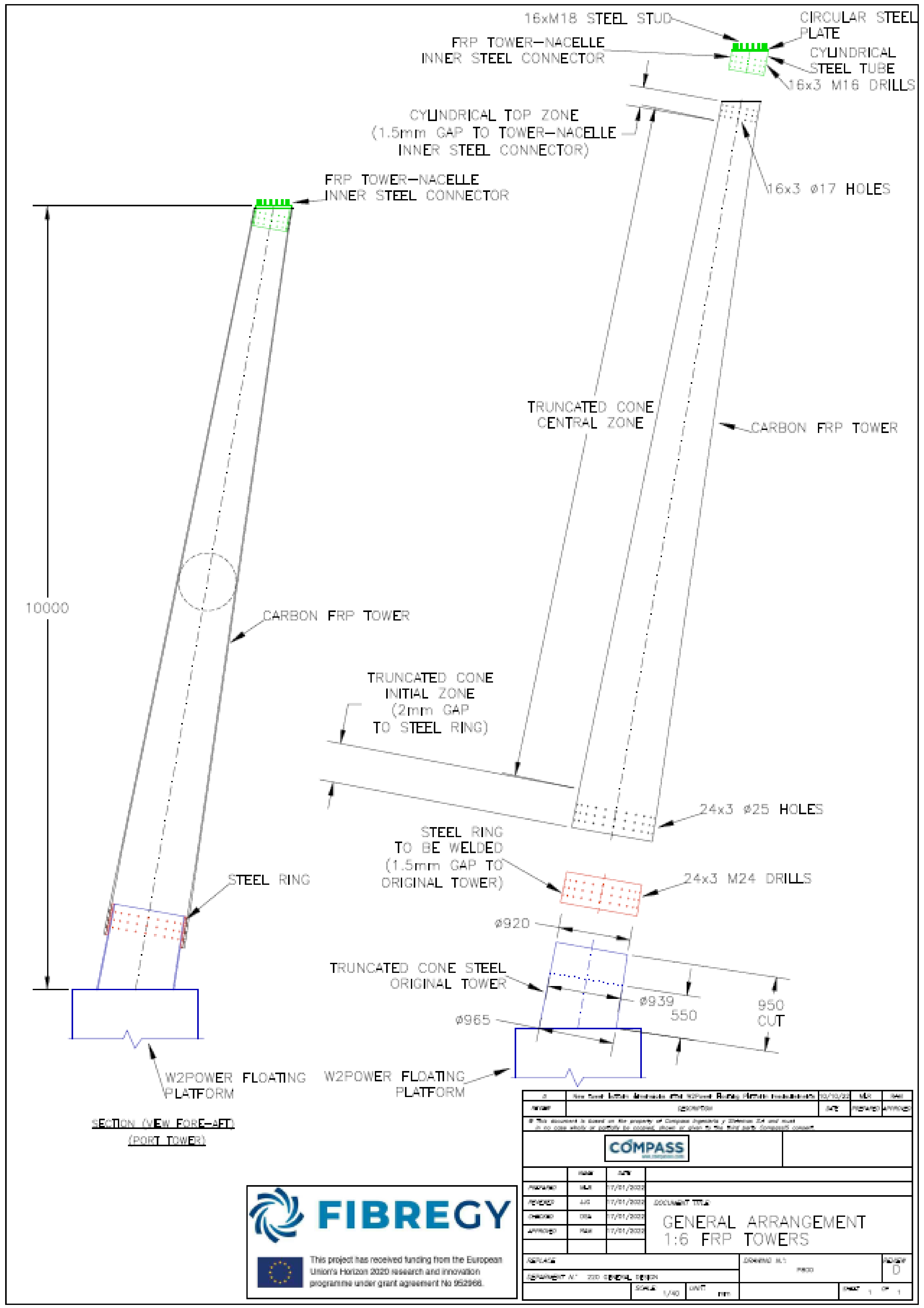
W2Power demonstrators

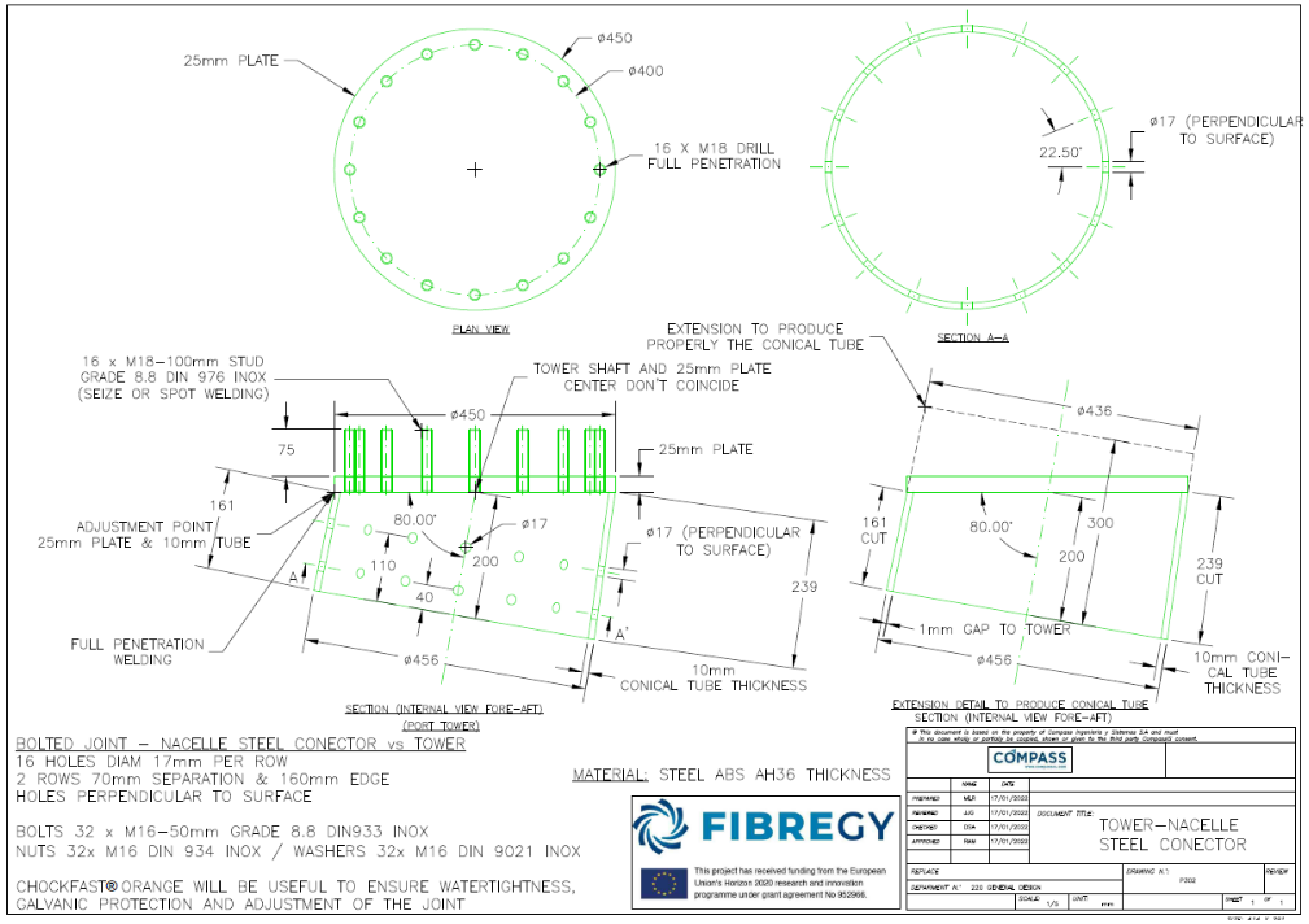
Edouard WALDURA, **EXAIL**

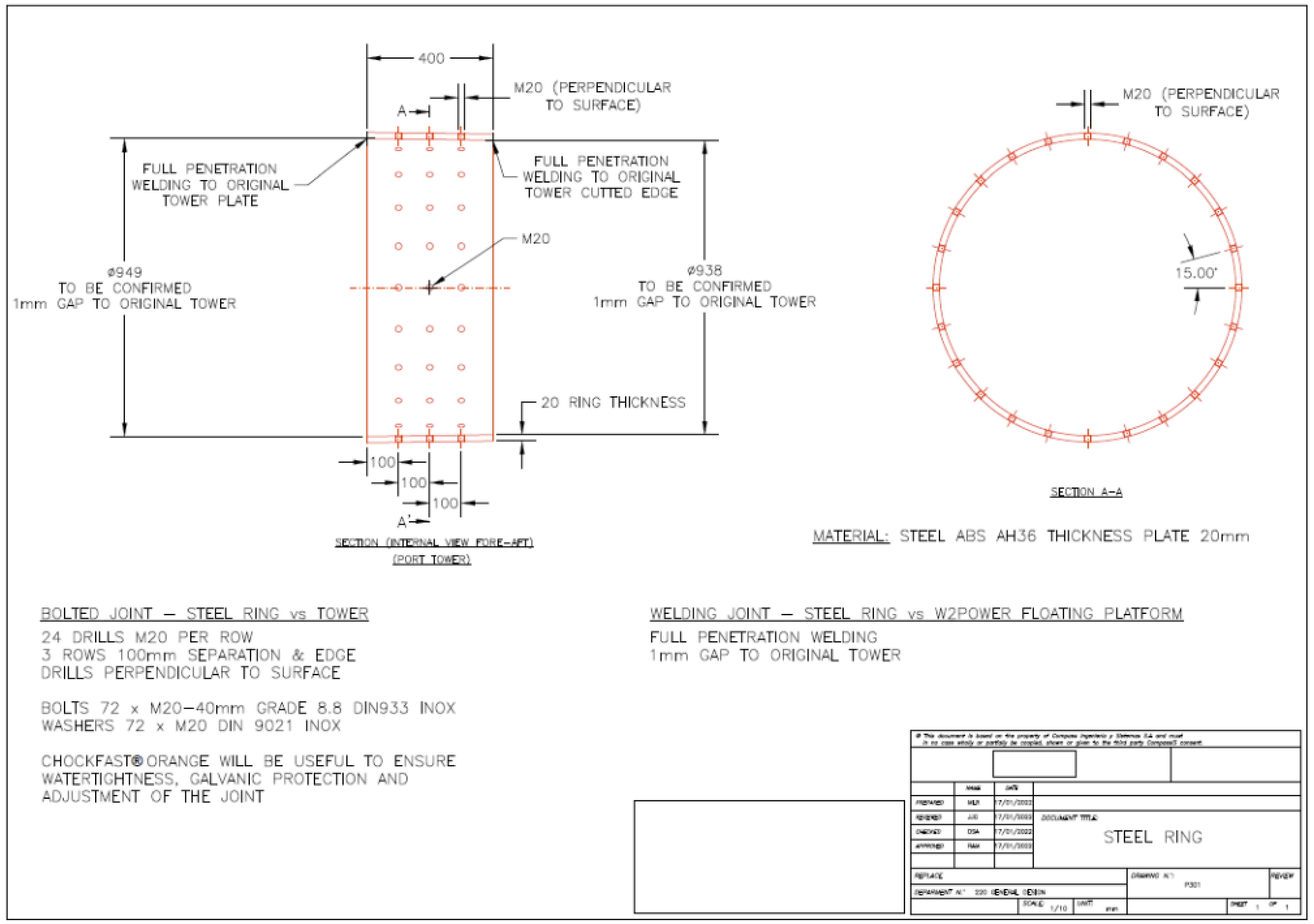
Production of 2 masts
Scale 1/6

FIBREGY

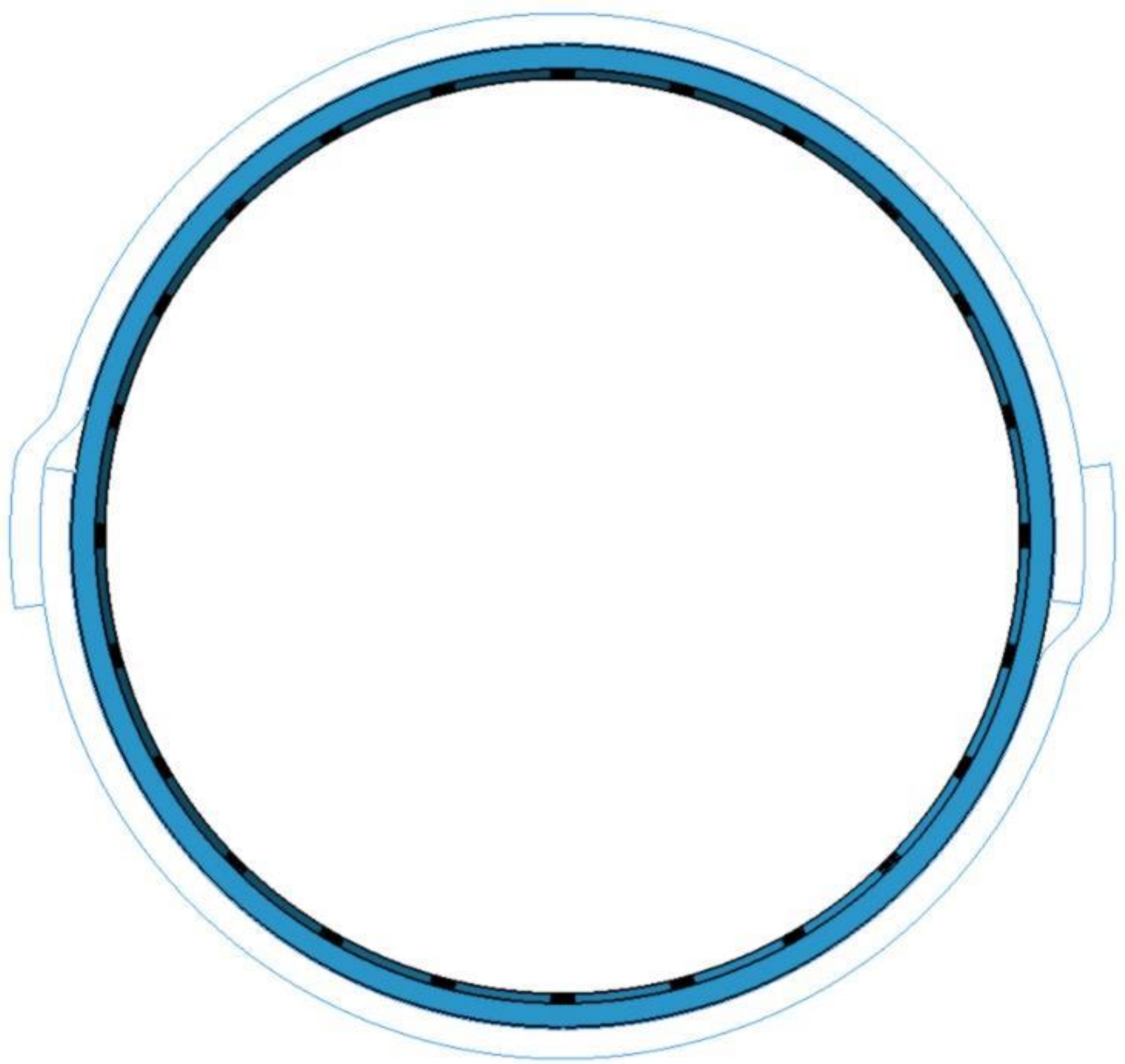
Tower design :
- 2 half tower
- Bottom metal ring connection
- Top metal ring connection

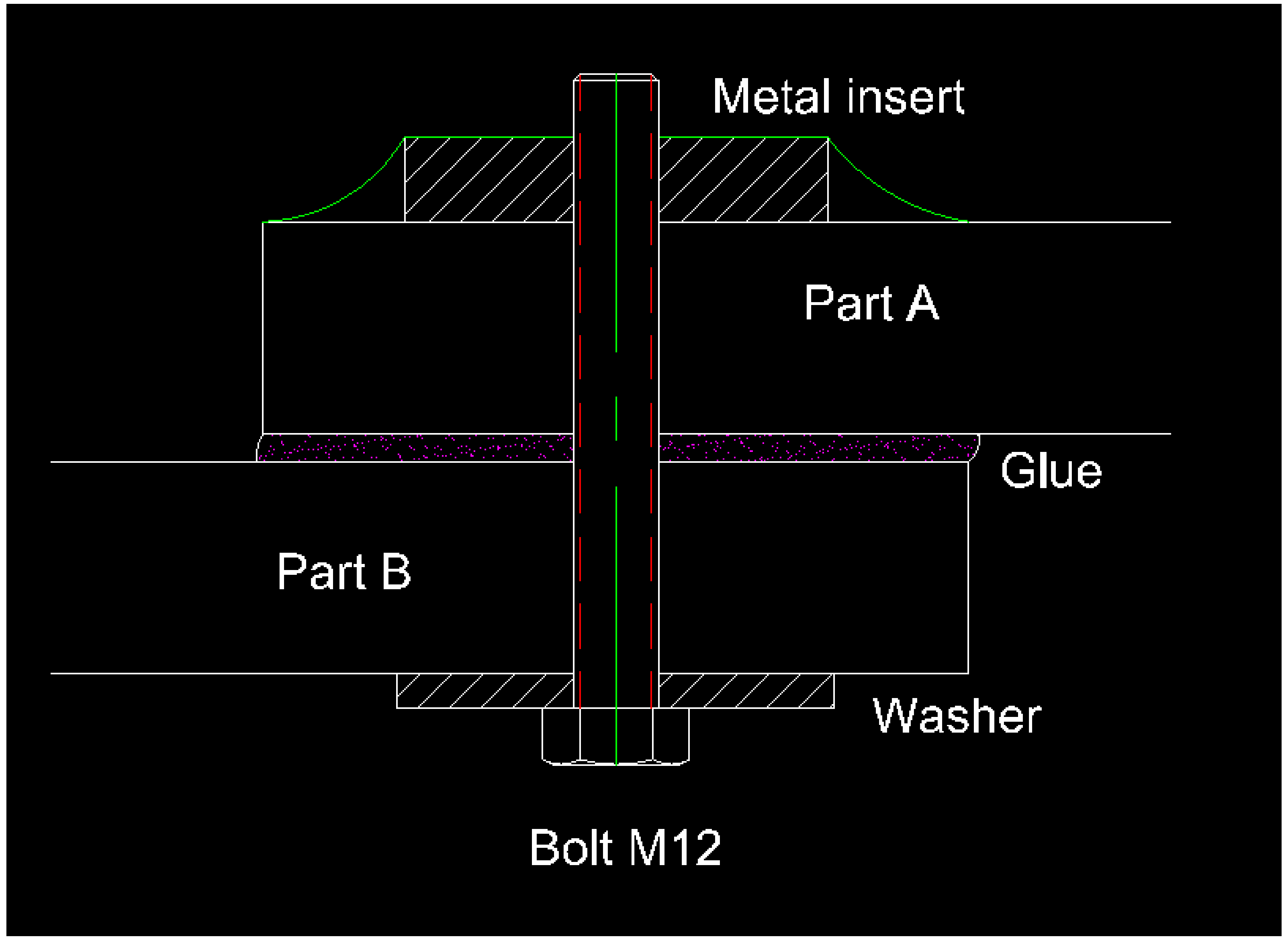




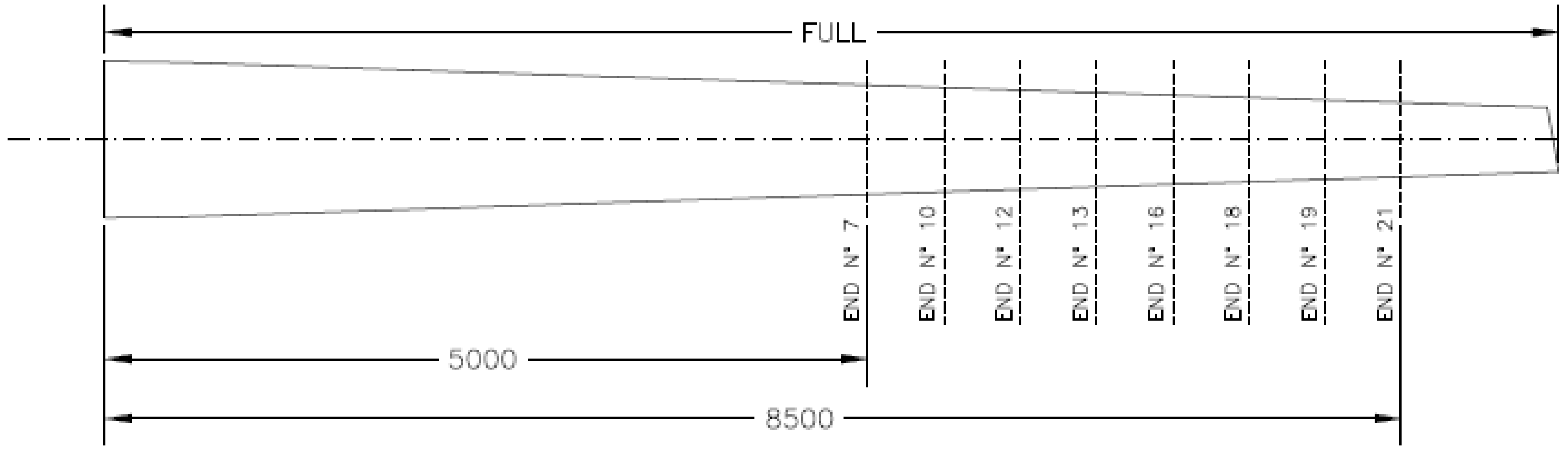


Connection design proposal
- Half part bolted
- Flange outside for ring integration





Scantling of the tower



LAYOUT FRP TOWER			TOTAL =	21.81 m²		RESIN SR INFUGREEN 810 - INFUSION PROCESS				MAIN THICKNESS	14.574			TOTAL WEIGHT	445
ORDEN	Nº	QUANTITY	MATERIAL	ANGLE FIBRE	WEIGTH DRY (g/m2)	ANGLE ROLL	RANGE (DISTANCE FROM BASE)	LONGITUDINAL OVERLAP (mm)	TRANSVERSE OVERLAP (mm)	ROLL WIDTH (mm)	THICKNESS LAYER (mm)	WEIGHT LAYER (kg/m2)	SURFACE (m2)	MATERIAL AREA (m2)	WEIGHT (kg)
OUTER	-	-	PAINT	-	-	-	FULL	-	-	-	-	-	21.8	21.8	-
	-	-	GELCOAT	-	-	-	FULL	-	-	-	-	-	21.8	21.8	-
	1	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	2	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	3	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	4	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	5	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	6	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	7	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	5000	-	-	1220	0.513	0.769	13.8	13.8	10.6
	8	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	9	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	10	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	5500	-	-	1270	0.616	0.923	14.9	14.9	13.7
	11	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	12	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	6000	-	-	1270	0.616	0.923	15.9	15.9	14.7
	13	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	6500	-	-	1220	0.513	0.769	16.9	16.9	13.0
	14	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	15	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	16	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	7000	-	-	1270	0.616	0.923	17.9	17.9	16.5
	17	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	18	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	7500	-	-	1270	0.616	0.923	18.8	18.8	17.3
	19	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	8000	-	-	1220	0.513	0.769	19.6	19.6	15.1
	20	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	21	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	8500	-	-	1220	0.513	0.769	20.4	20.4	15.7
	22	1	ZOLTEK PX35 0/90° MULTI. FABR. MD600	0°/90°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	23	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
	24	1	ZOLTEK PX35 +/-45° MULTI. FABR. MD600	±45°	608	LONGITUDINAL	FULL	-	-	1270	0.616	0.923	21.8	21.8	20.1
	25	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8
INNER	26	1	ZOLTEK PX35 50K UNI. FABR. UD500	0°	516	LONGITUDINAL	FULL	-	-	1220	0.513	0.769	21.8	21.8	16.8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

	NAME	DATE
PREPARED	MLR	17/01/2022
REVIEWED	JJG	17/01/2022
CHECKED	DSA	17/01/2022
APPROVED	RAM	17/01/2022

DOCUMENT TITLE: LAYOUT TOWER

REPLACE:

DEPARMENT Nº 220 GENERAL DESIGN

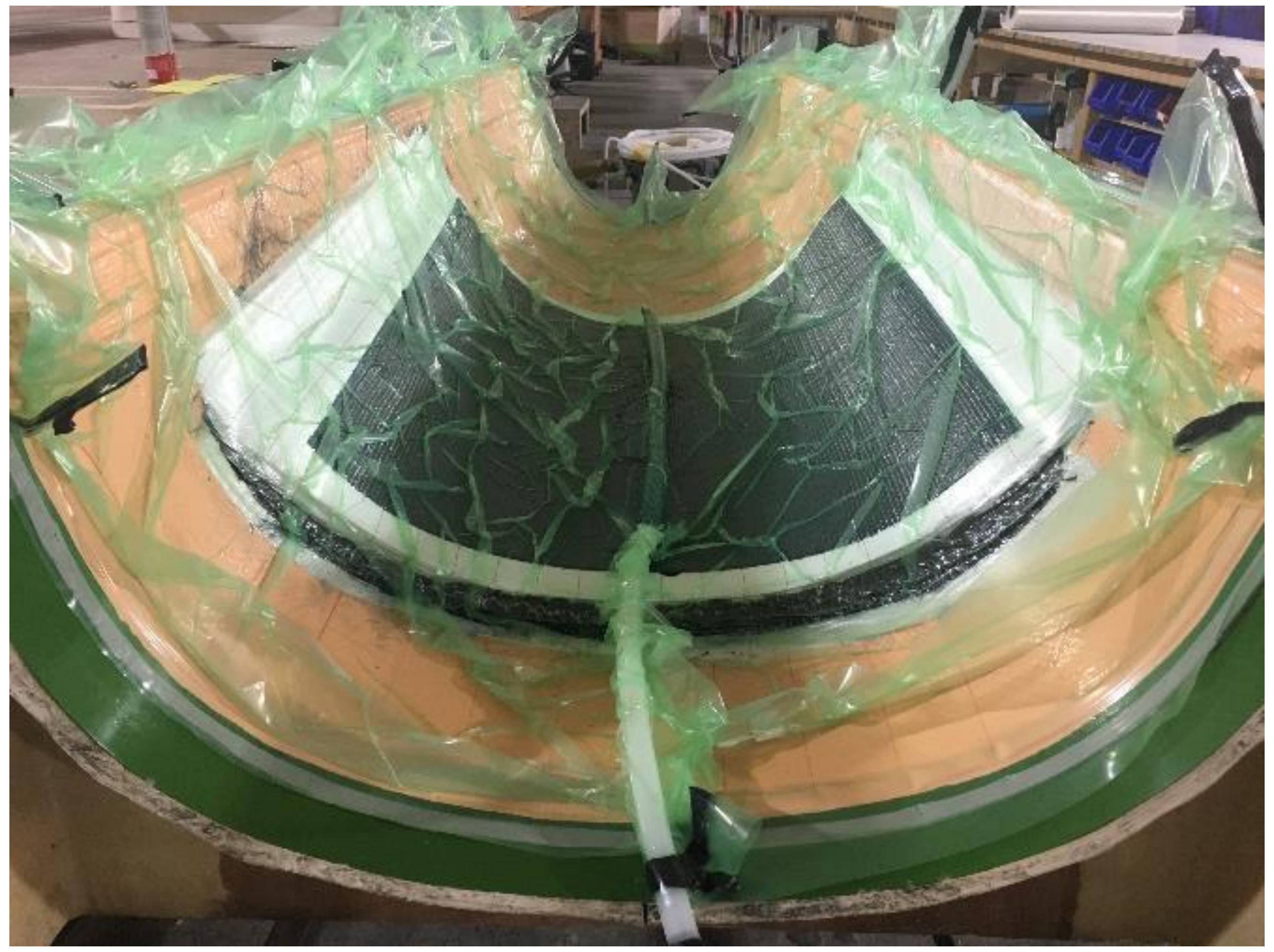
DRAWING Nº: P101

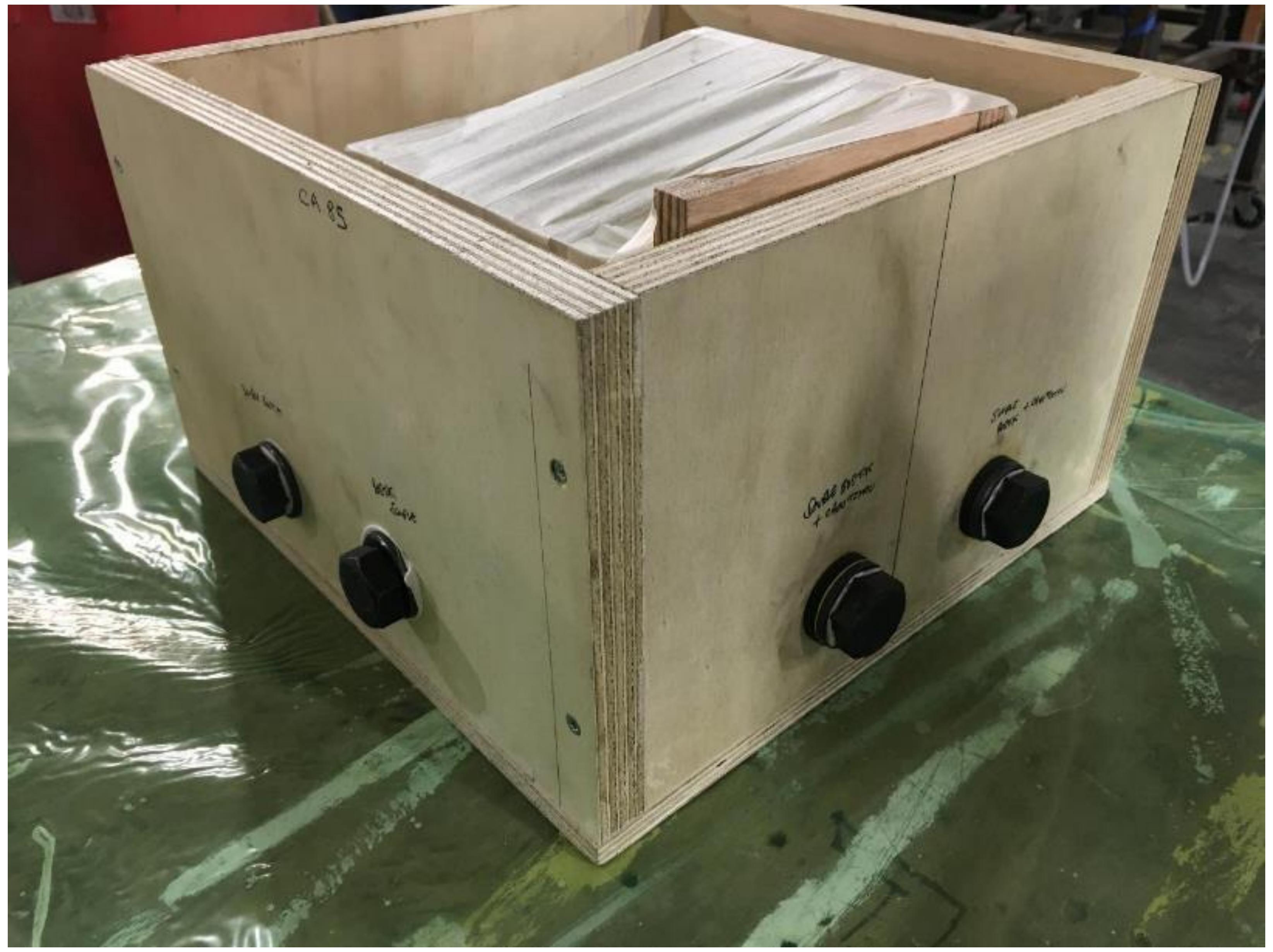
REVIEW

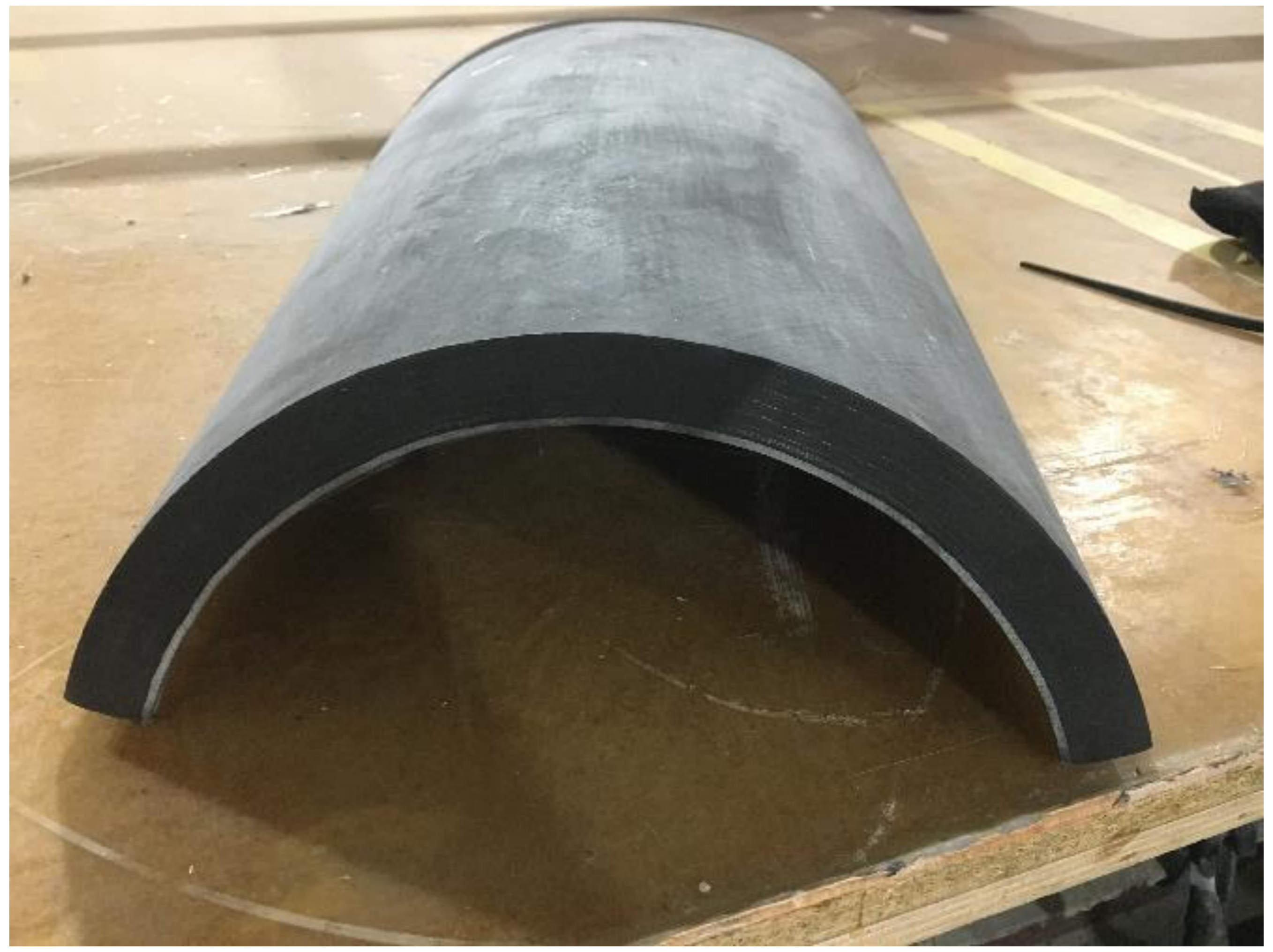
SCALE: 1/40 UNIT: mm SHEET 1 OF 1

Tests

- Validation of the feasability (infusion of big thickness)
- Validation of the overlapping
- Validation of the thickness
- Validation of the resine casting process



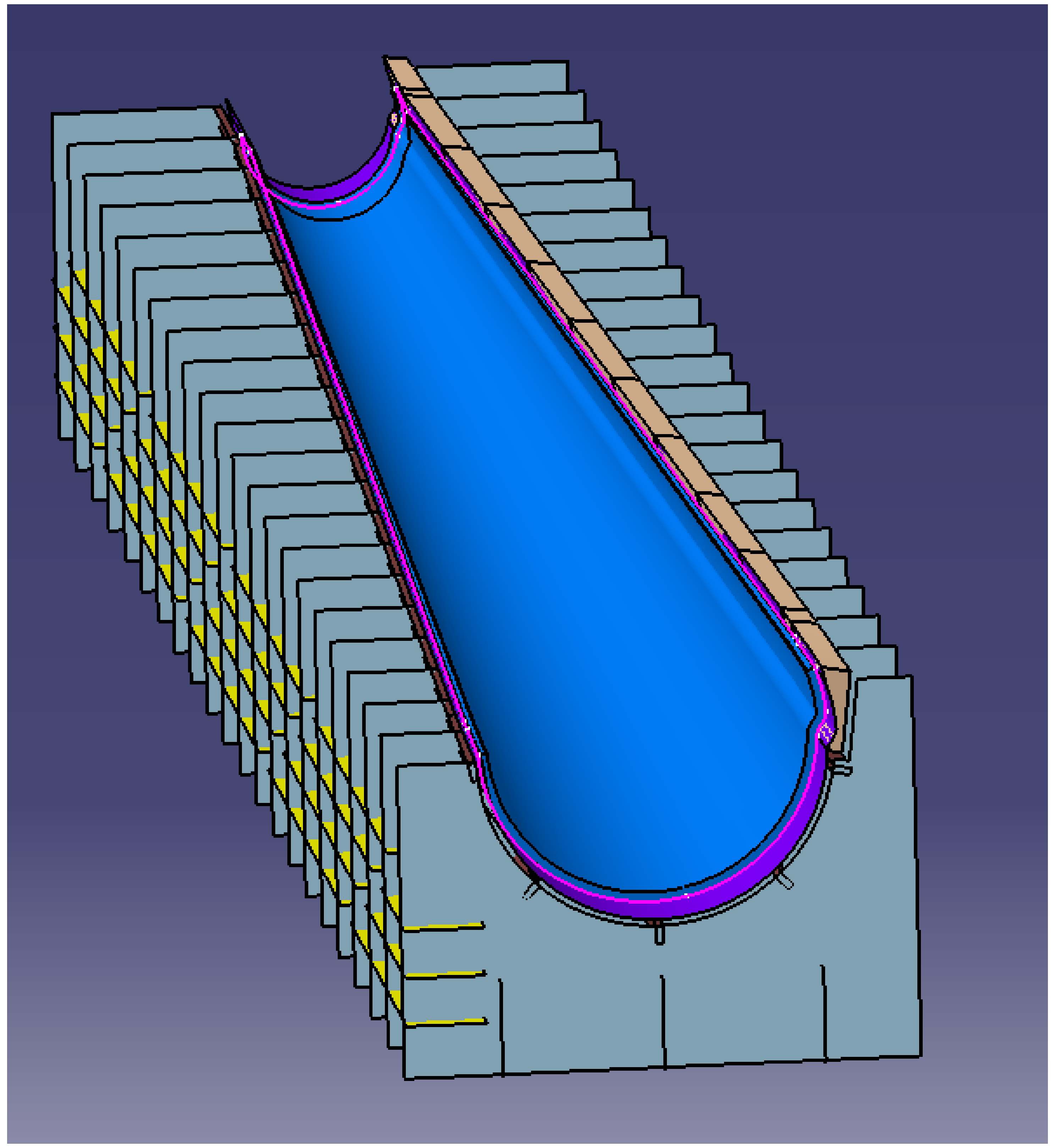


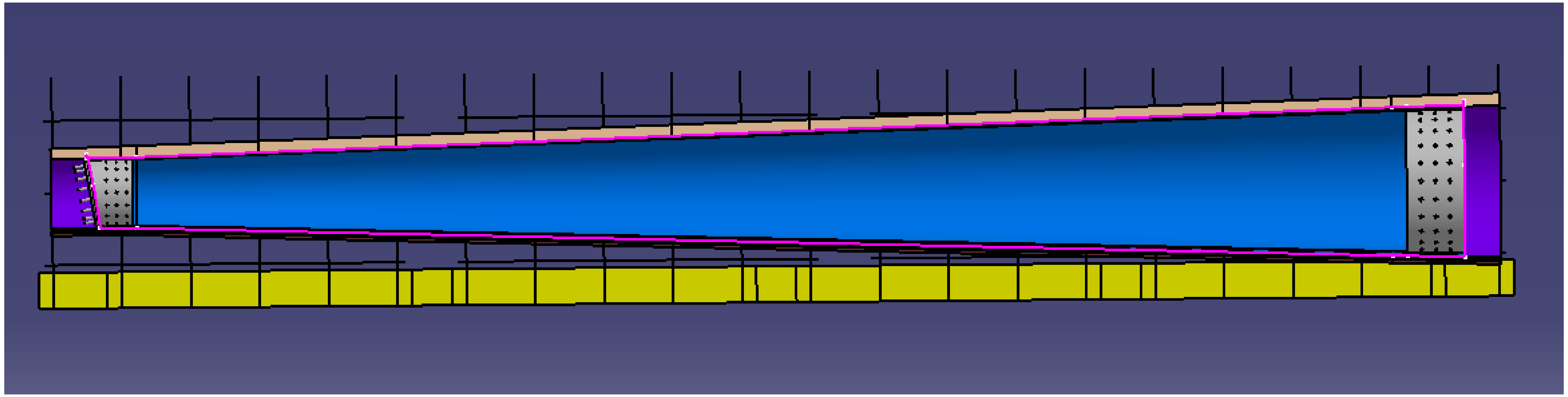


Mould production

Design :

- Pre design of the connection area
- Design of the mould
- Definition of the building process

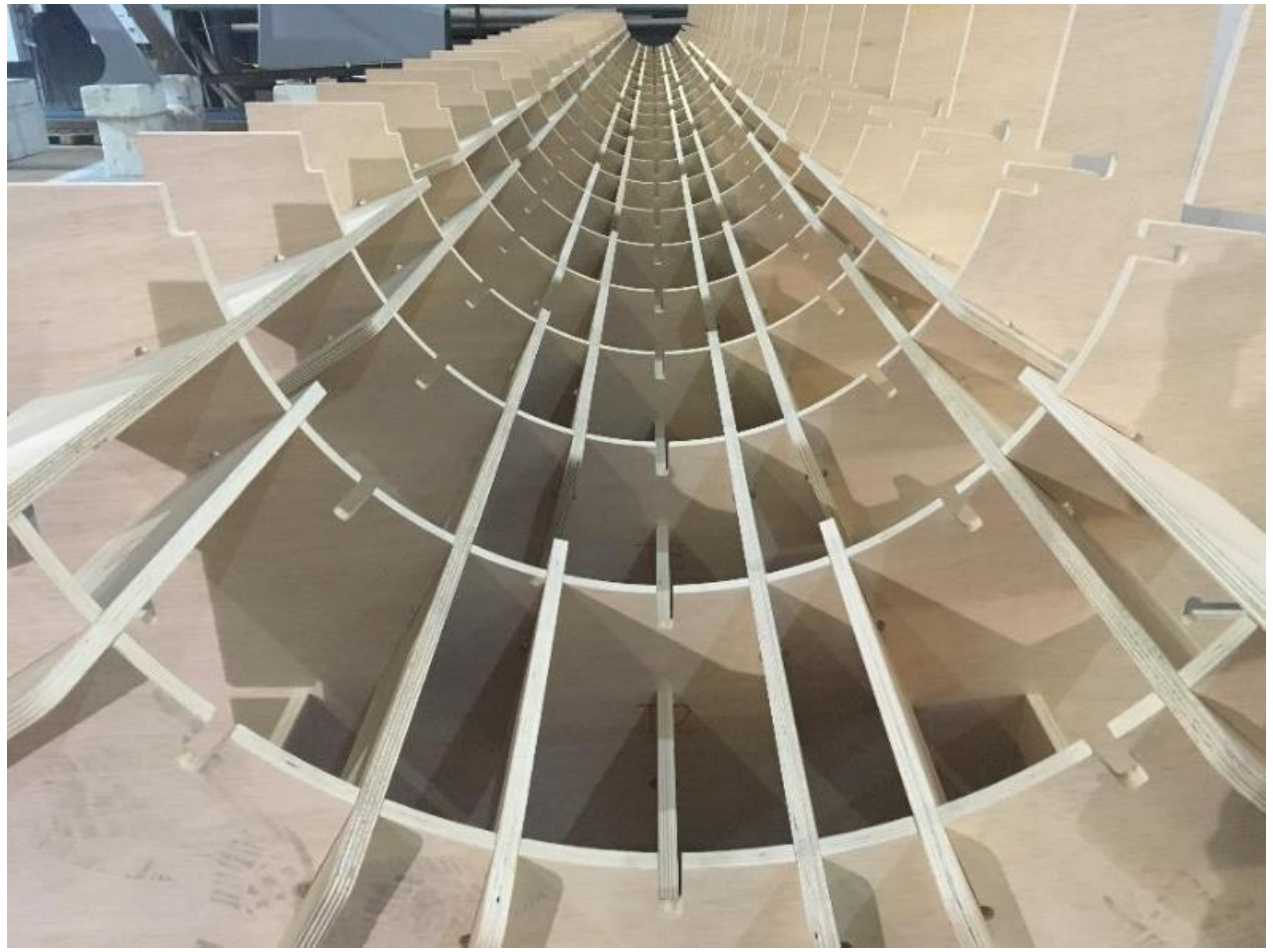




FIBREGY

Mould production

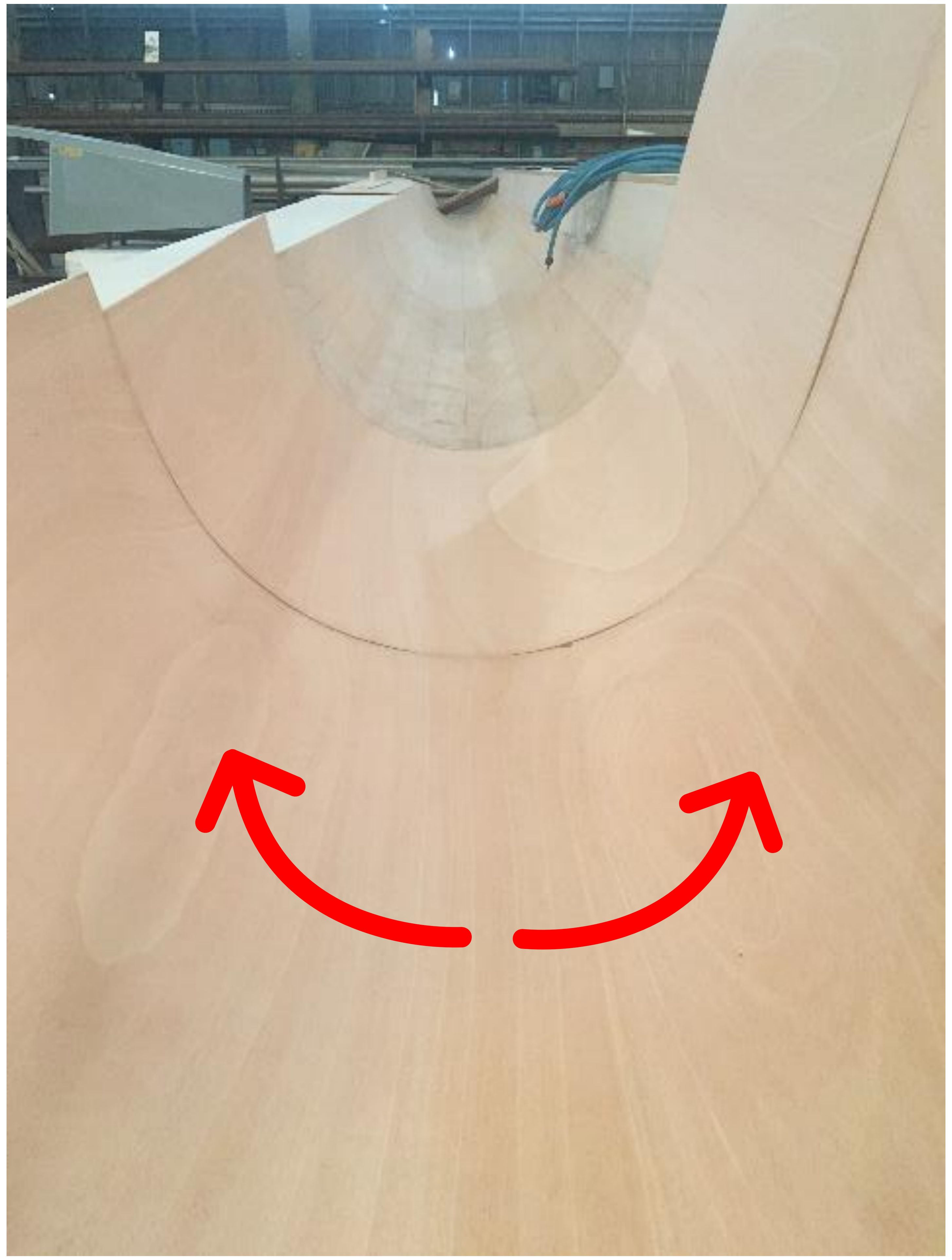
Mould cutting and milling :
- 5 axis plugs milling
- 3 axis structure cutting



FIBREGY

Mould production

Surface preparation :
- Mould surface with special flex ply wood
- Lamination of the surface



Mould production

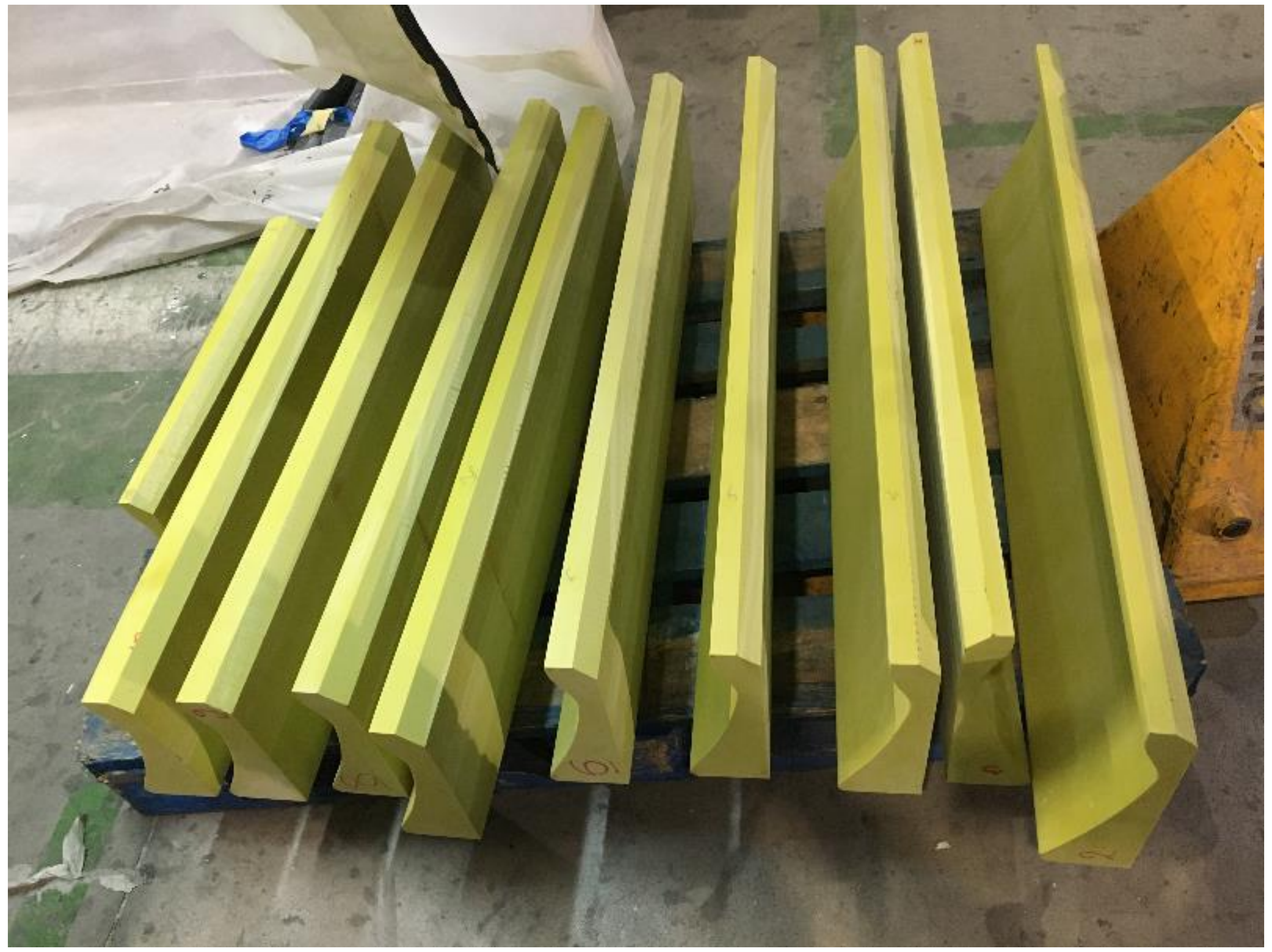
Mould finishing :

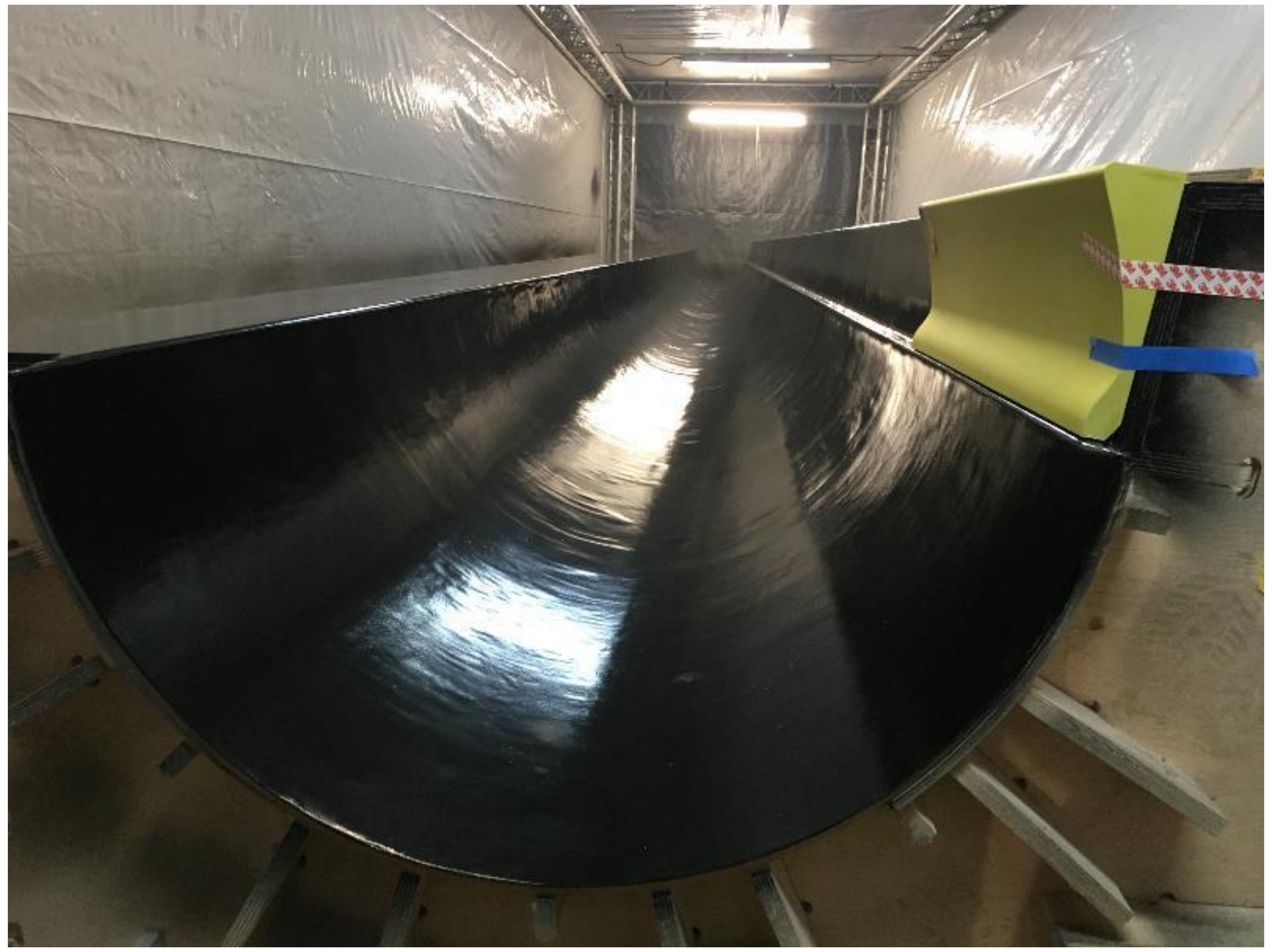
- Fairing for the local defects
- Primer application
- Paint application
- Vaccum test

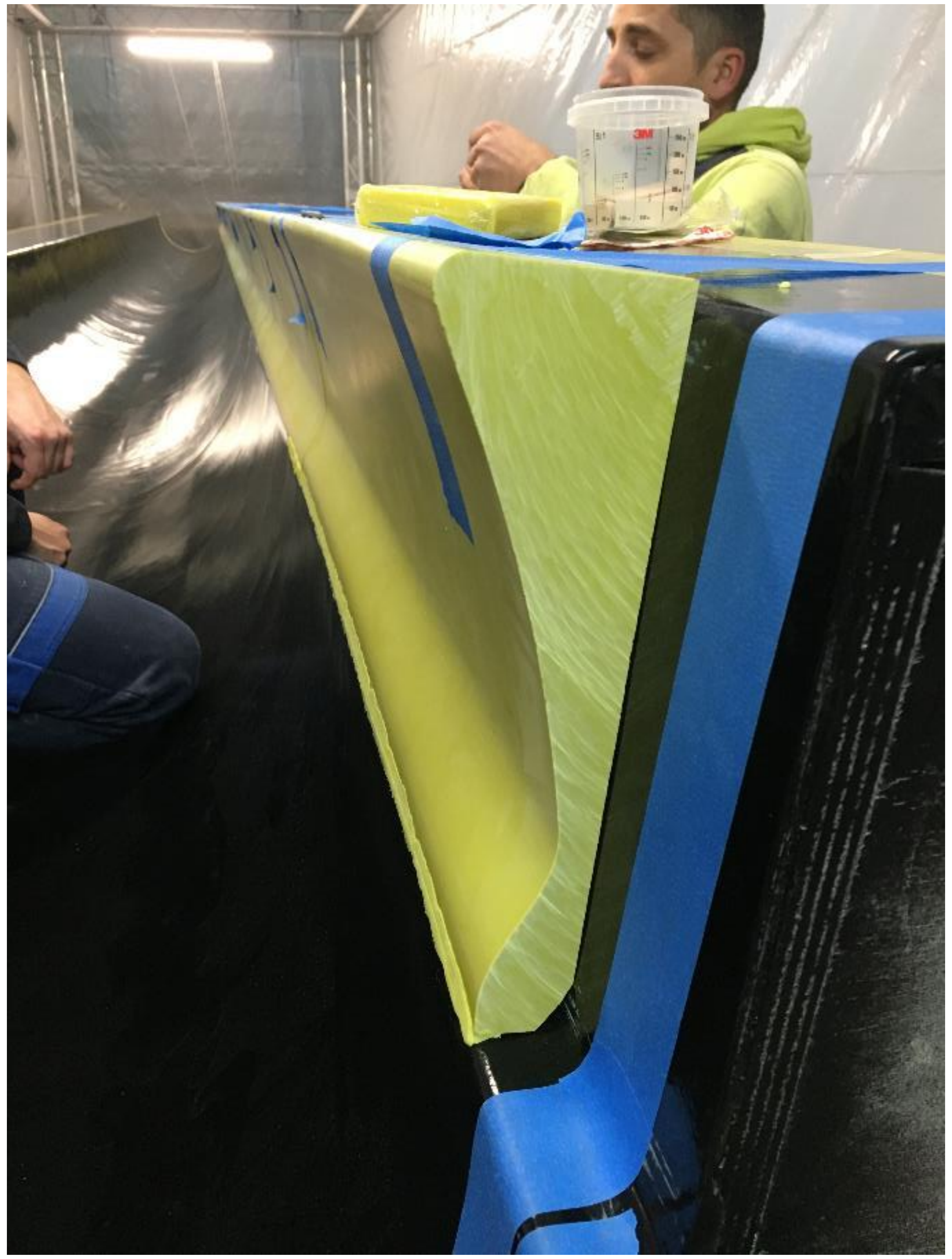
FIBREGY

Mould production

Plugs integration in the mould
- Should support all the layers
- Should get out with the part
- To be trim to keep a nice shape

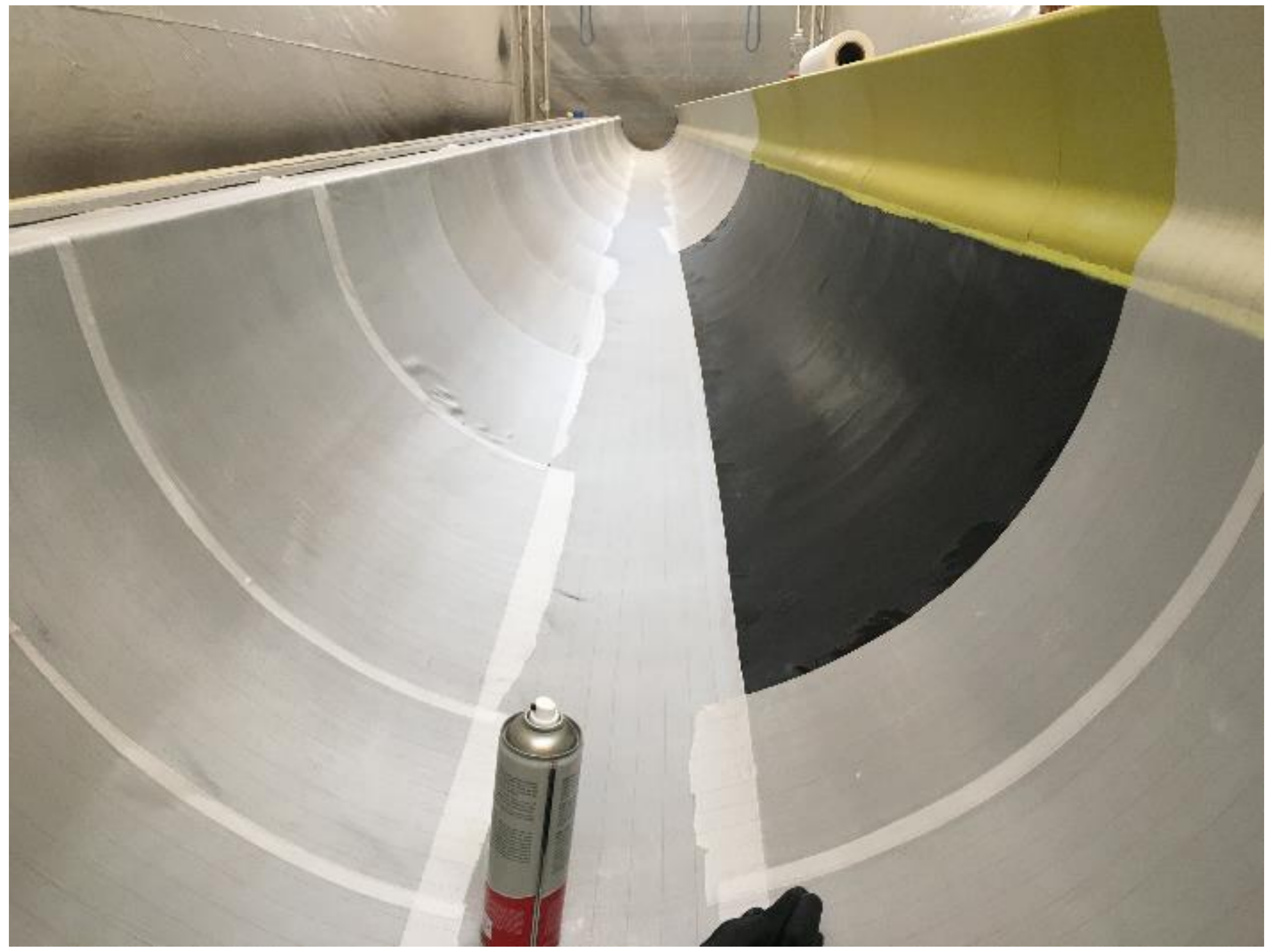


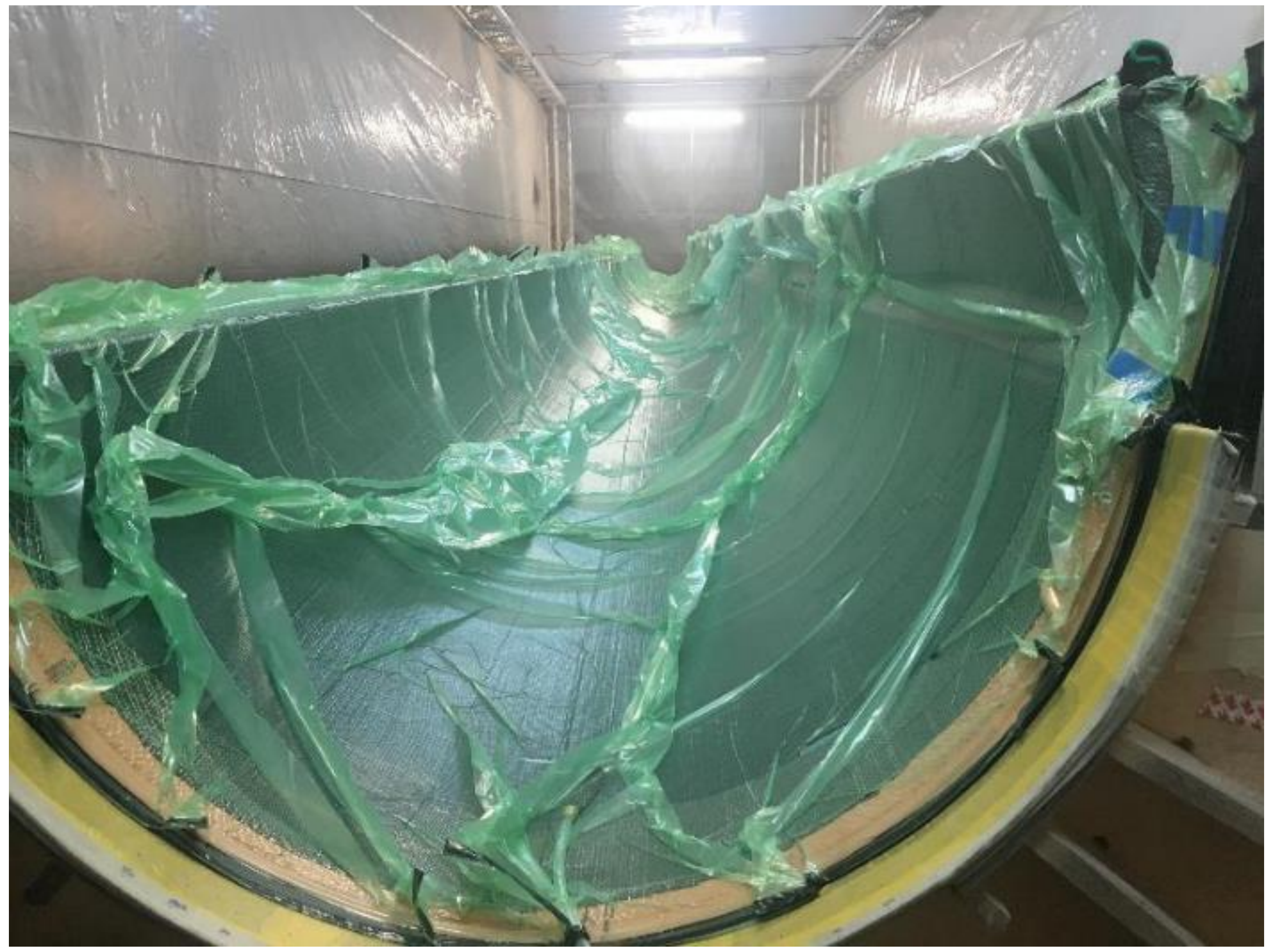


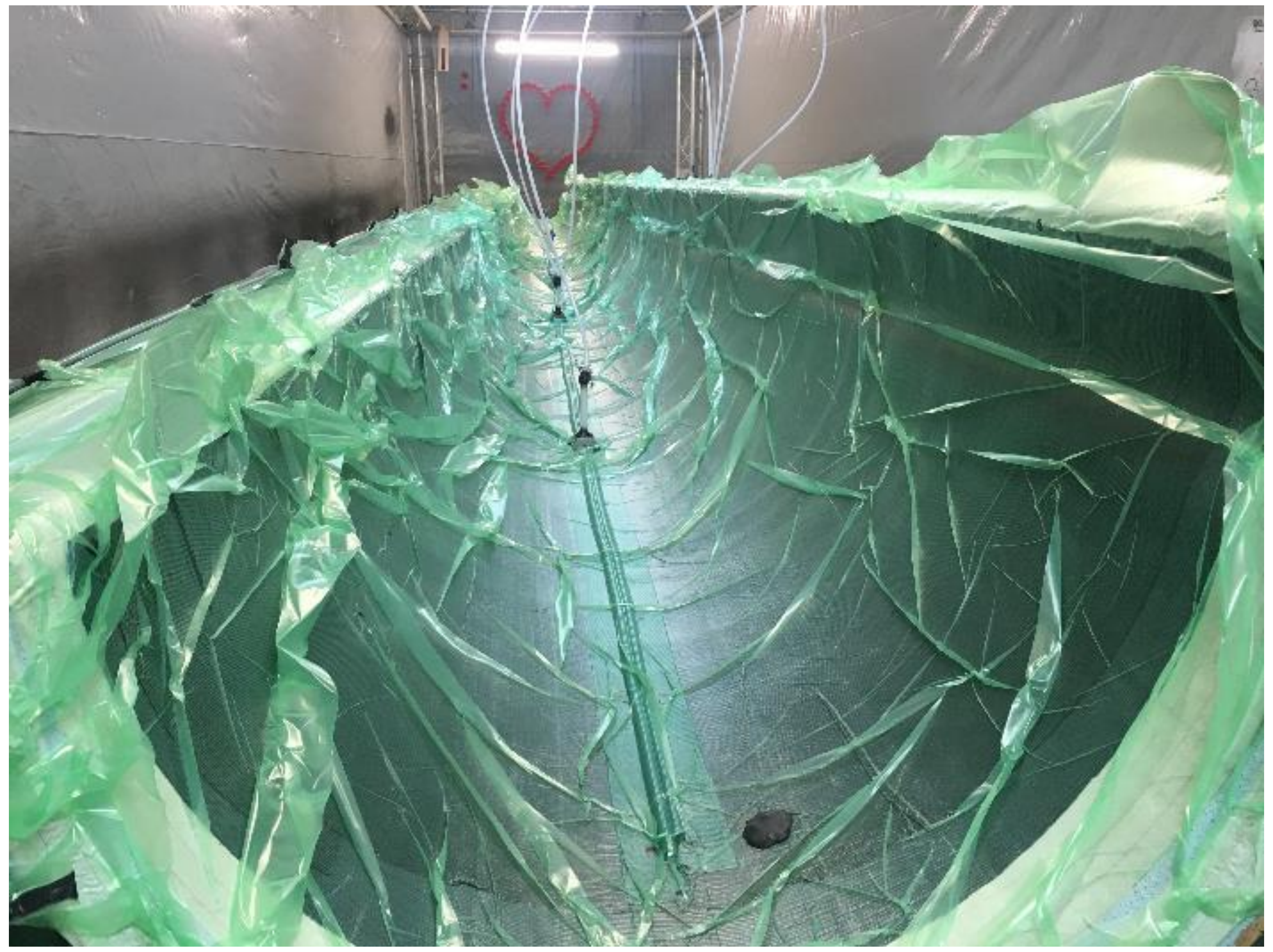


Half mast production

Lay up
- Management of the overlapping
- Fabric with vaccum every night
- Infusion







Half mast production

- Extra lenght cutting
- Integration of the metal inserts
- Building of the drilling trolley

FIBREGY

Mast geometry setting

FIBREGY

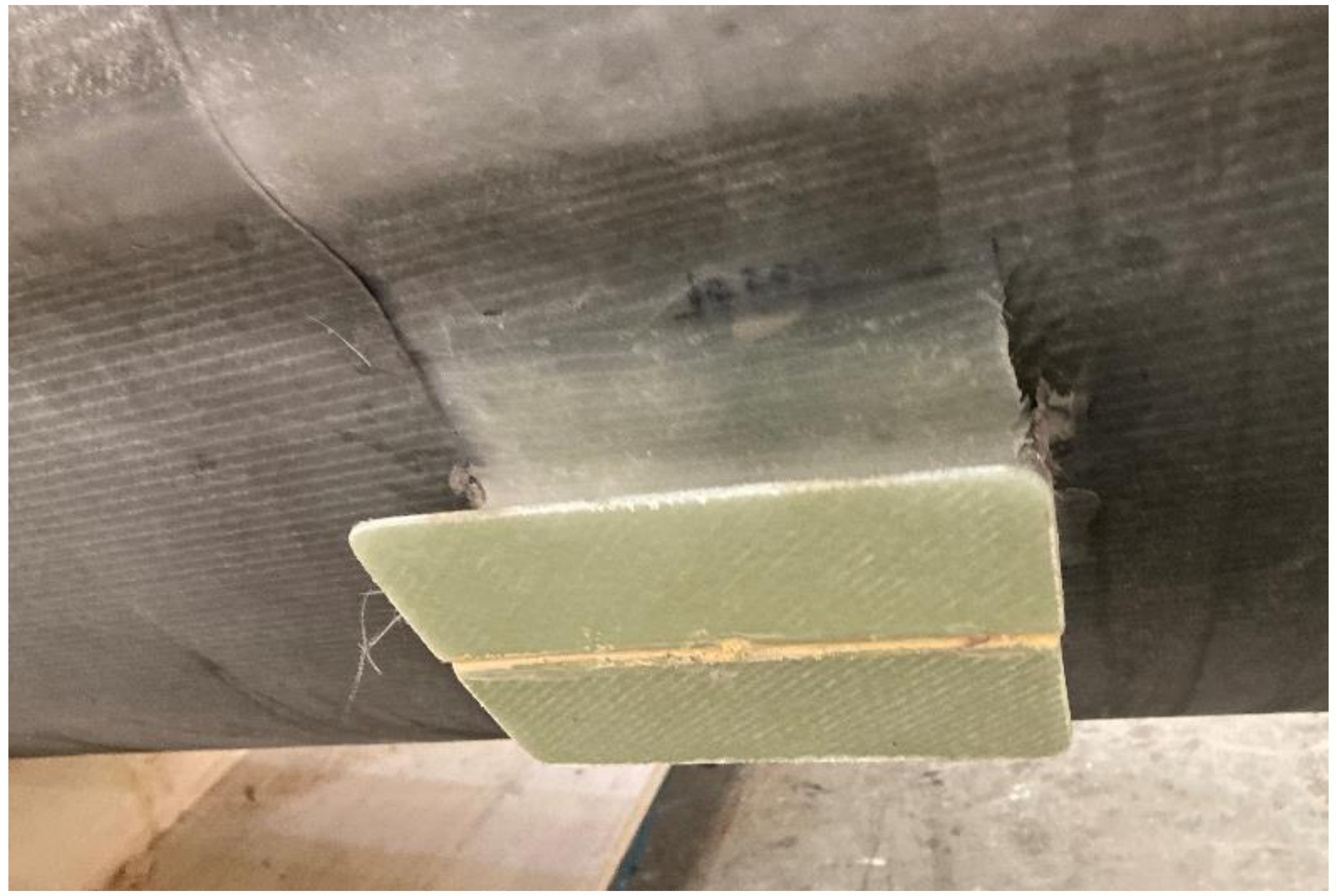
Assembly of the mast

- Drilling
- Threading
- Integration of plates
- Bolting to the torque

FIBREGY

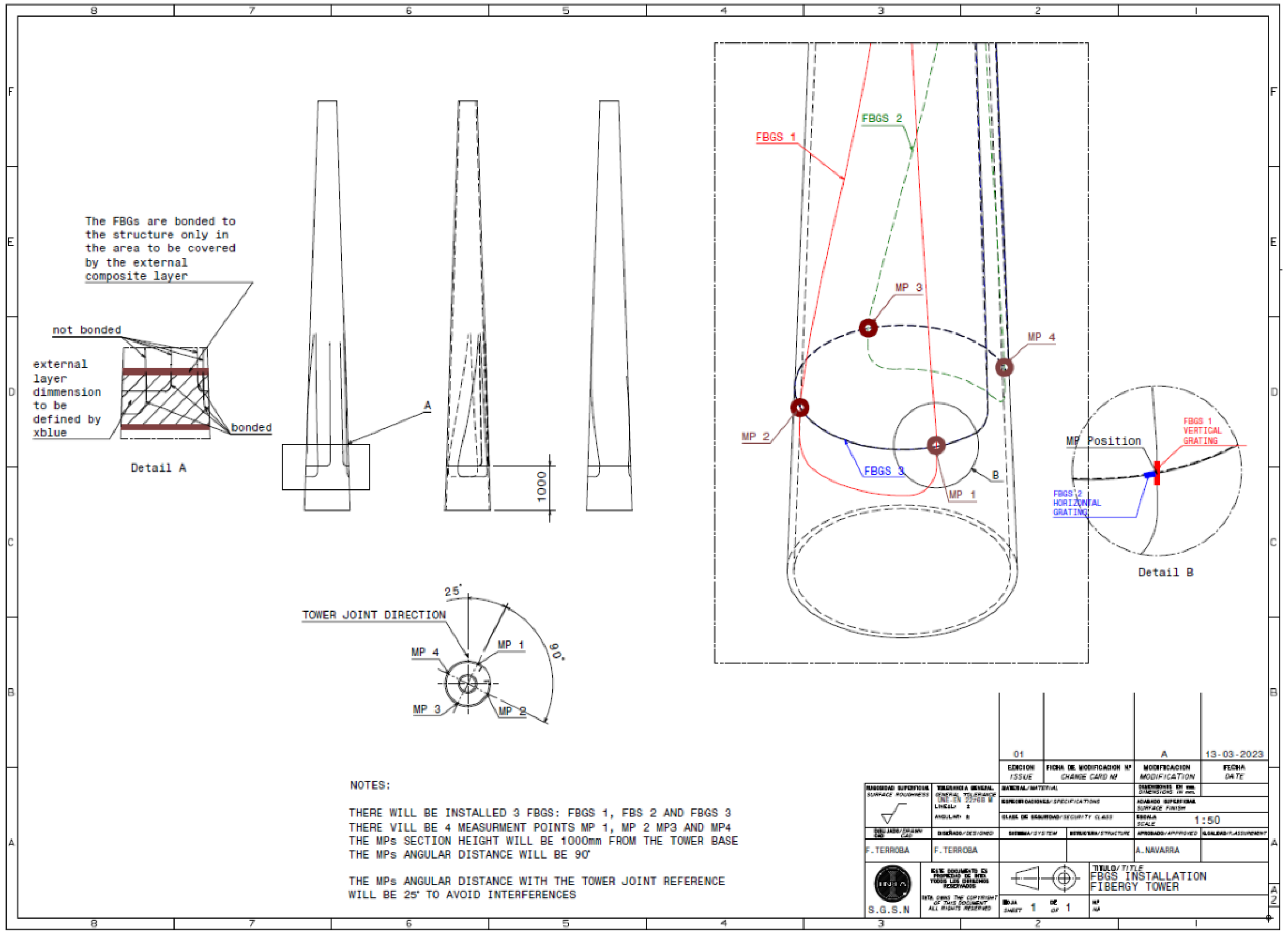
Integration of mast's supports

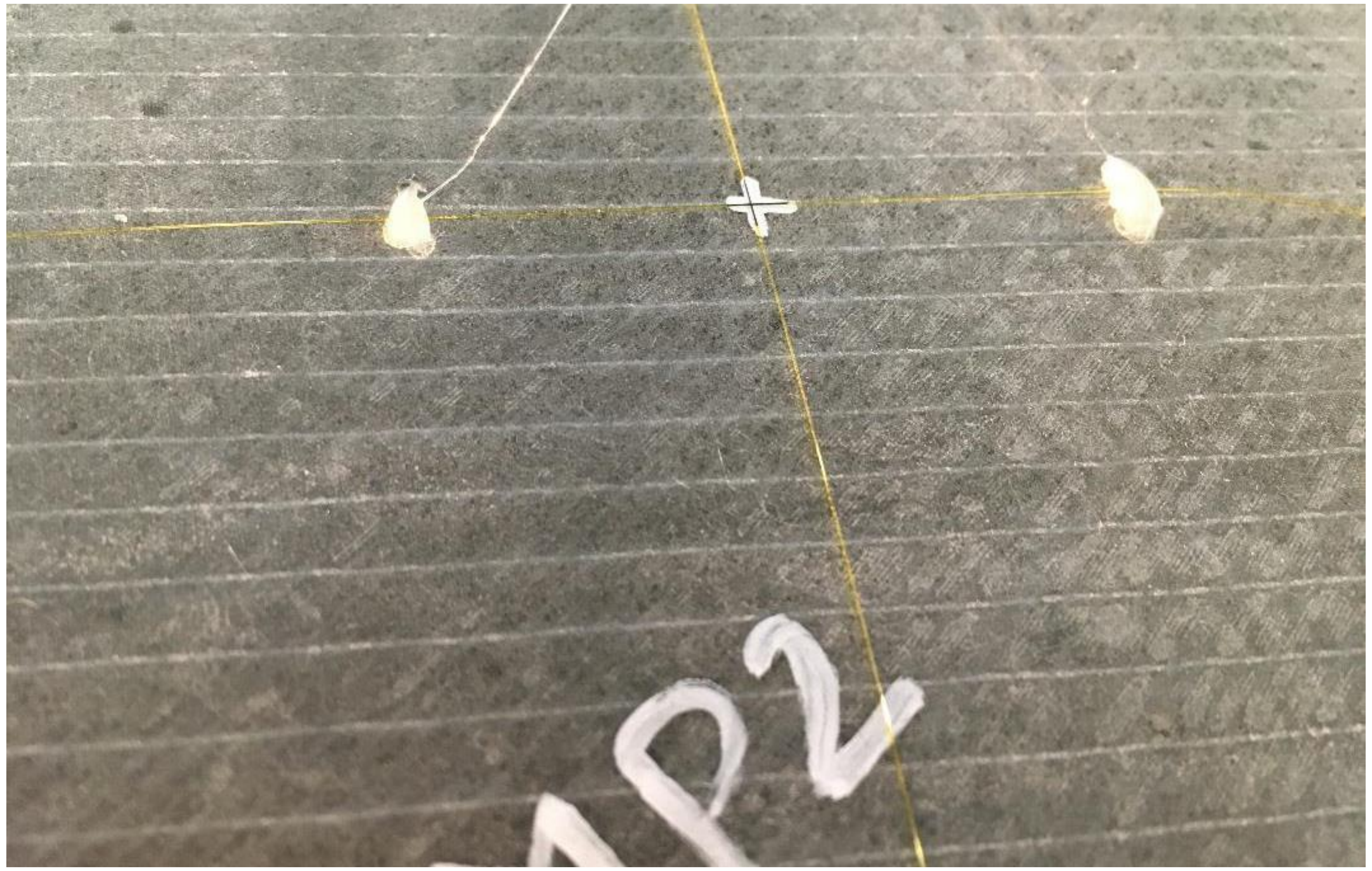
- Electric boxes
- Cable tray
- Cameras



FIBREGY

Integration of optic fibre





Tower finishing

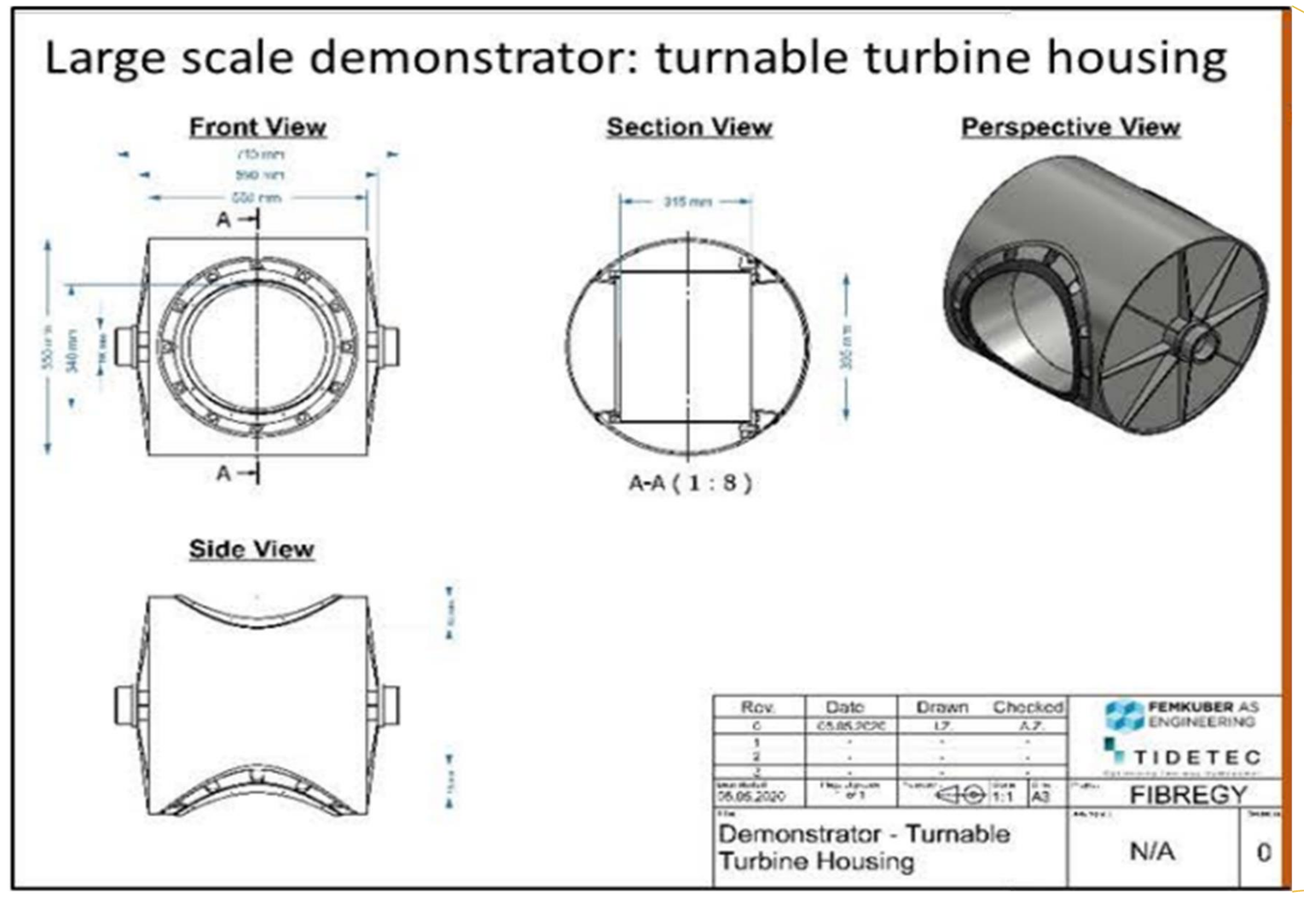
- Fairing
- Primer application
- Painting
- Sticker

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

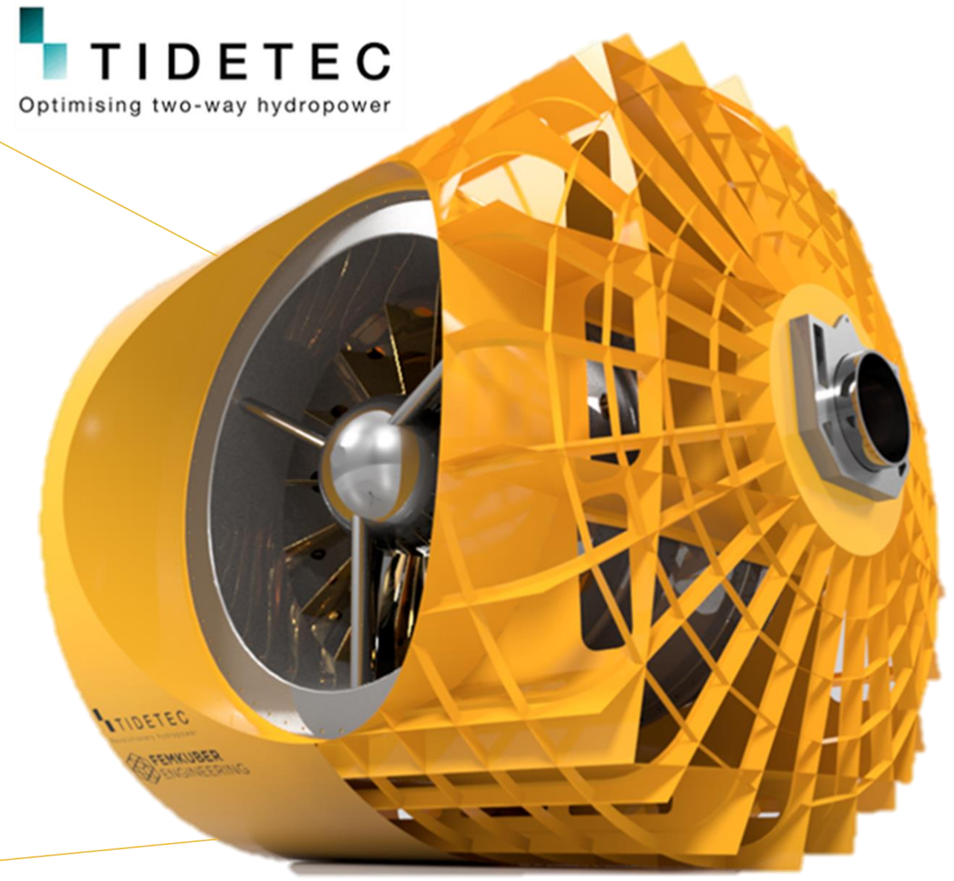
Turbine housing demonstrator

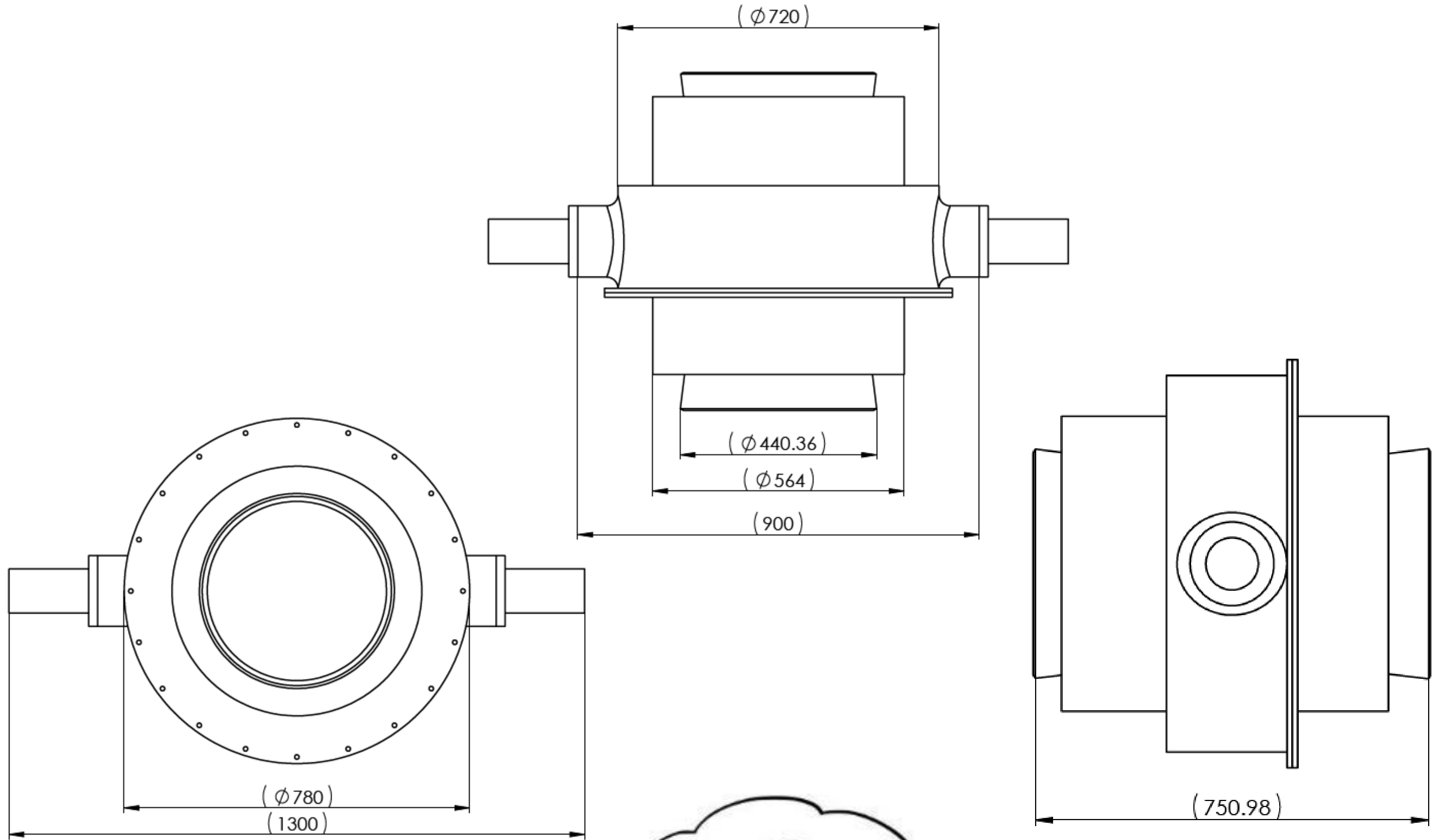
João CARDOSO, **INEGI**

Context

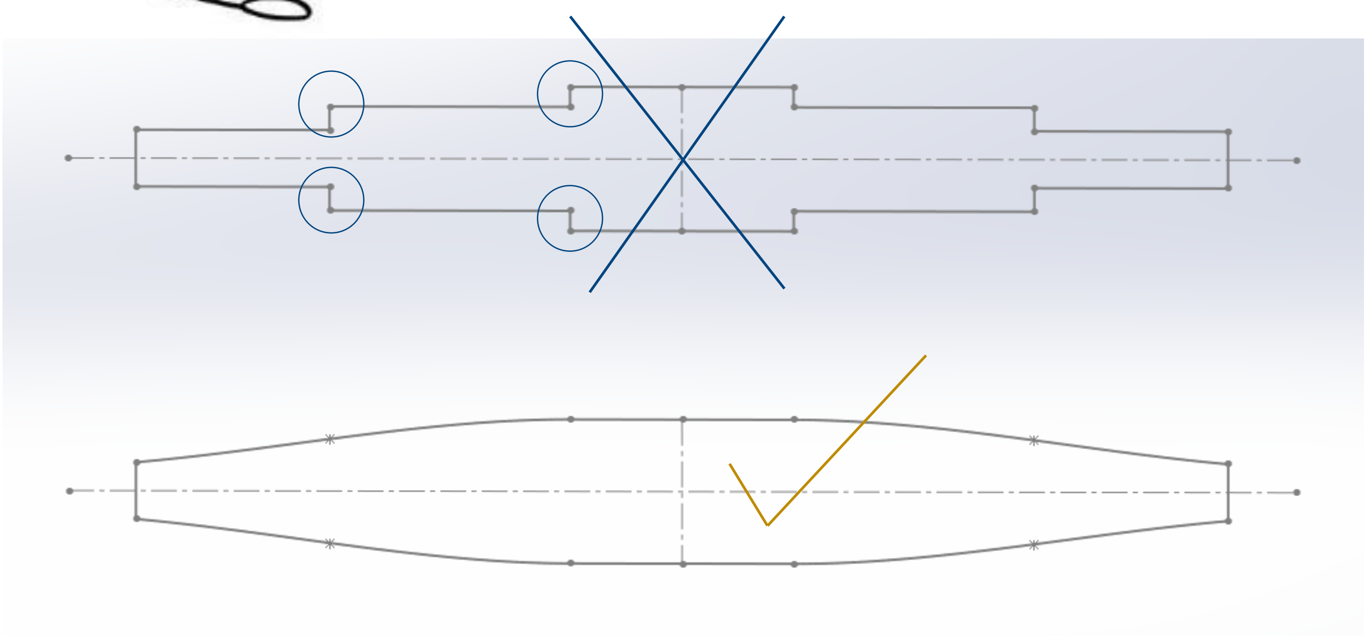


TIDETEC's tidal turbine





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)

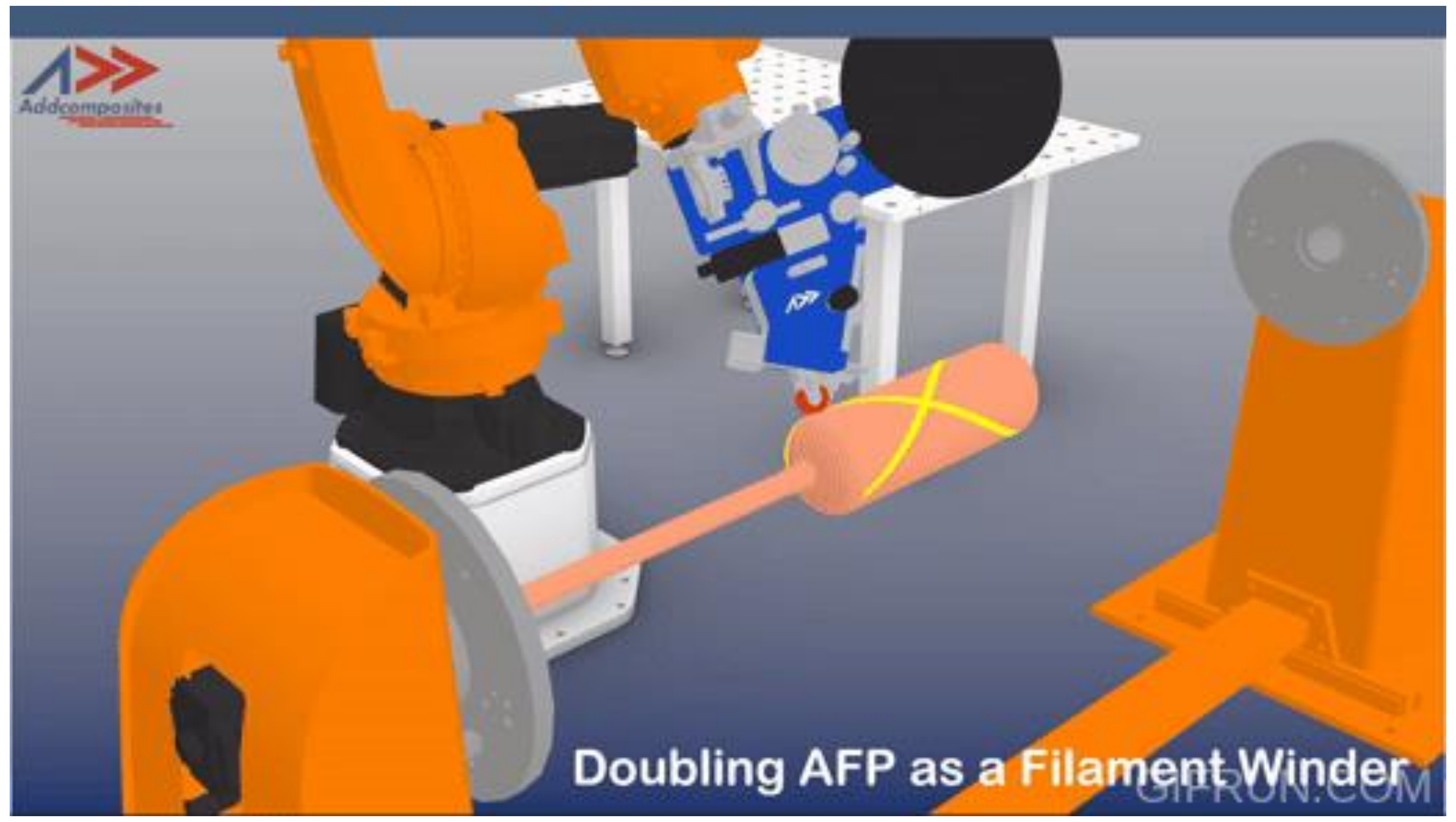
Manufacturing Process: **Towpreg Winding/AFP**

Disadvantages:

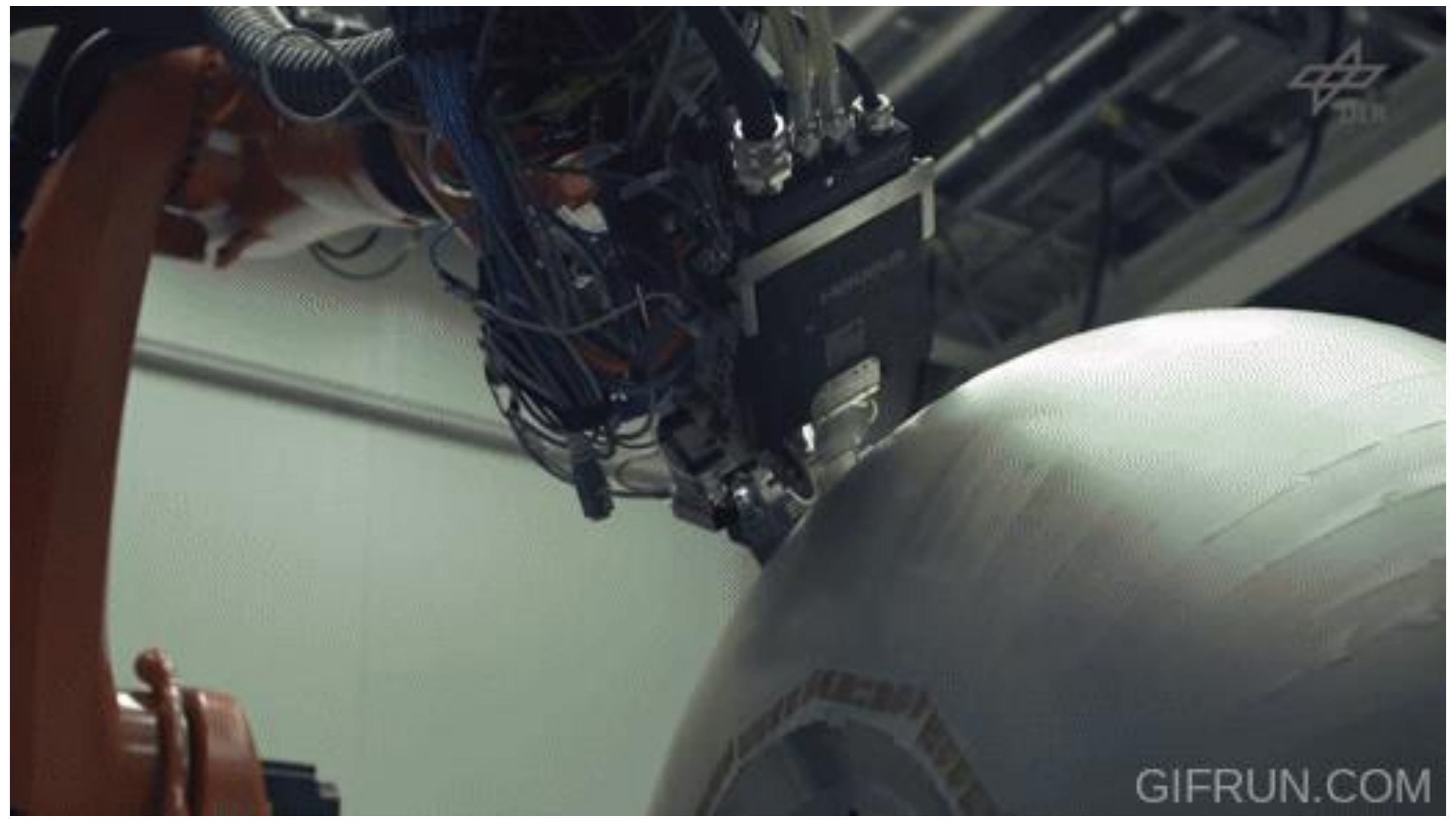
- Controllable and repeatable process;
- Lower material waste;
- Precision placement of tape;
- Ideal for making cylindrical and/or hemispheric components;
- Increased material throughput;
- Improved composite structure quality;
- Quicker manufacturing time.

Disadvantages:

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

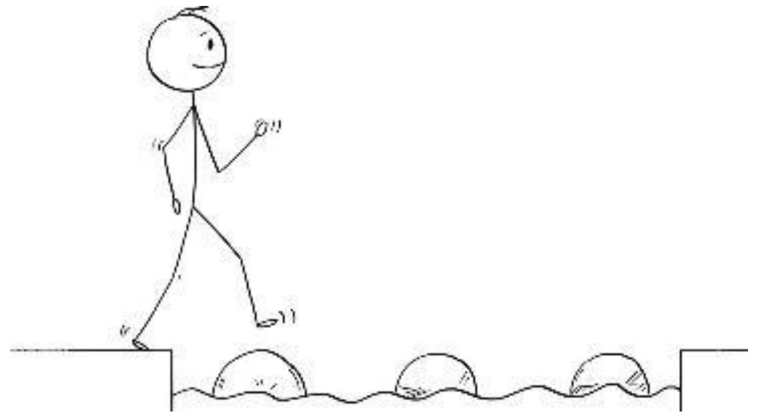


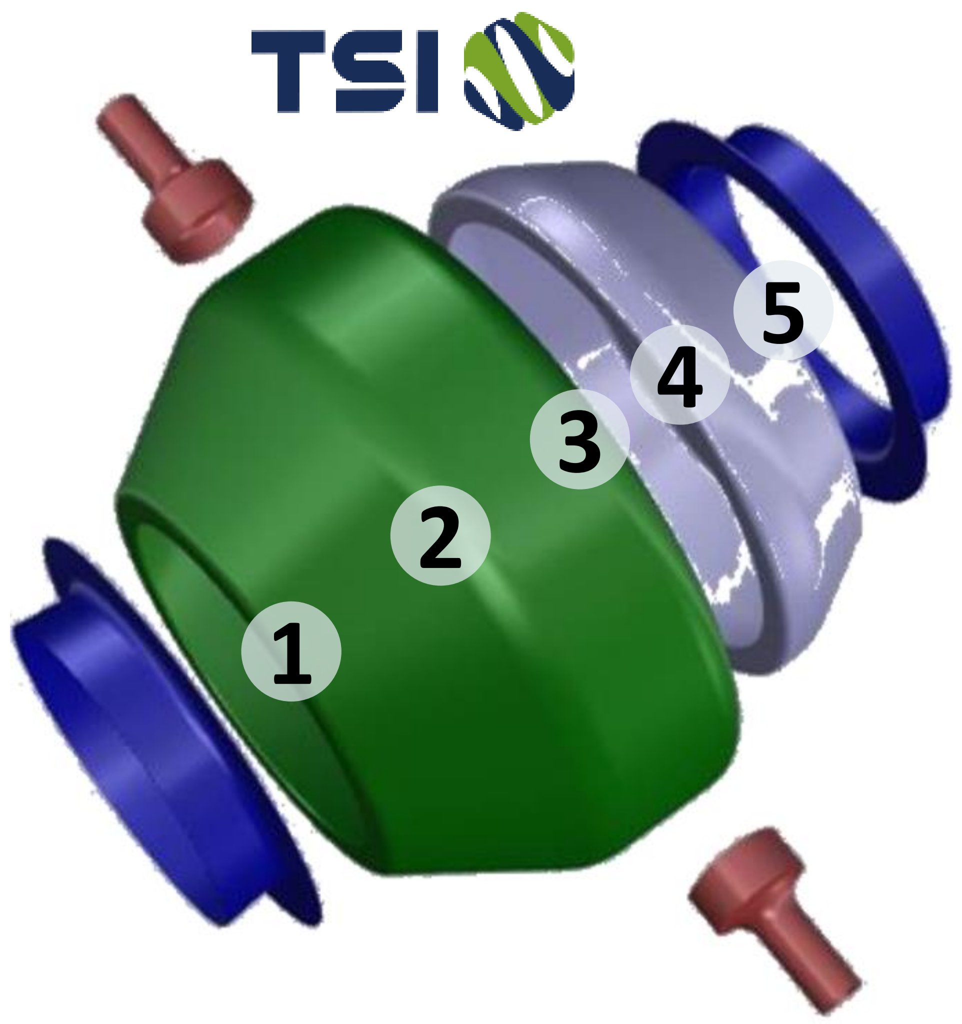
Source: Addcomposites



Source: Project PROCOMP

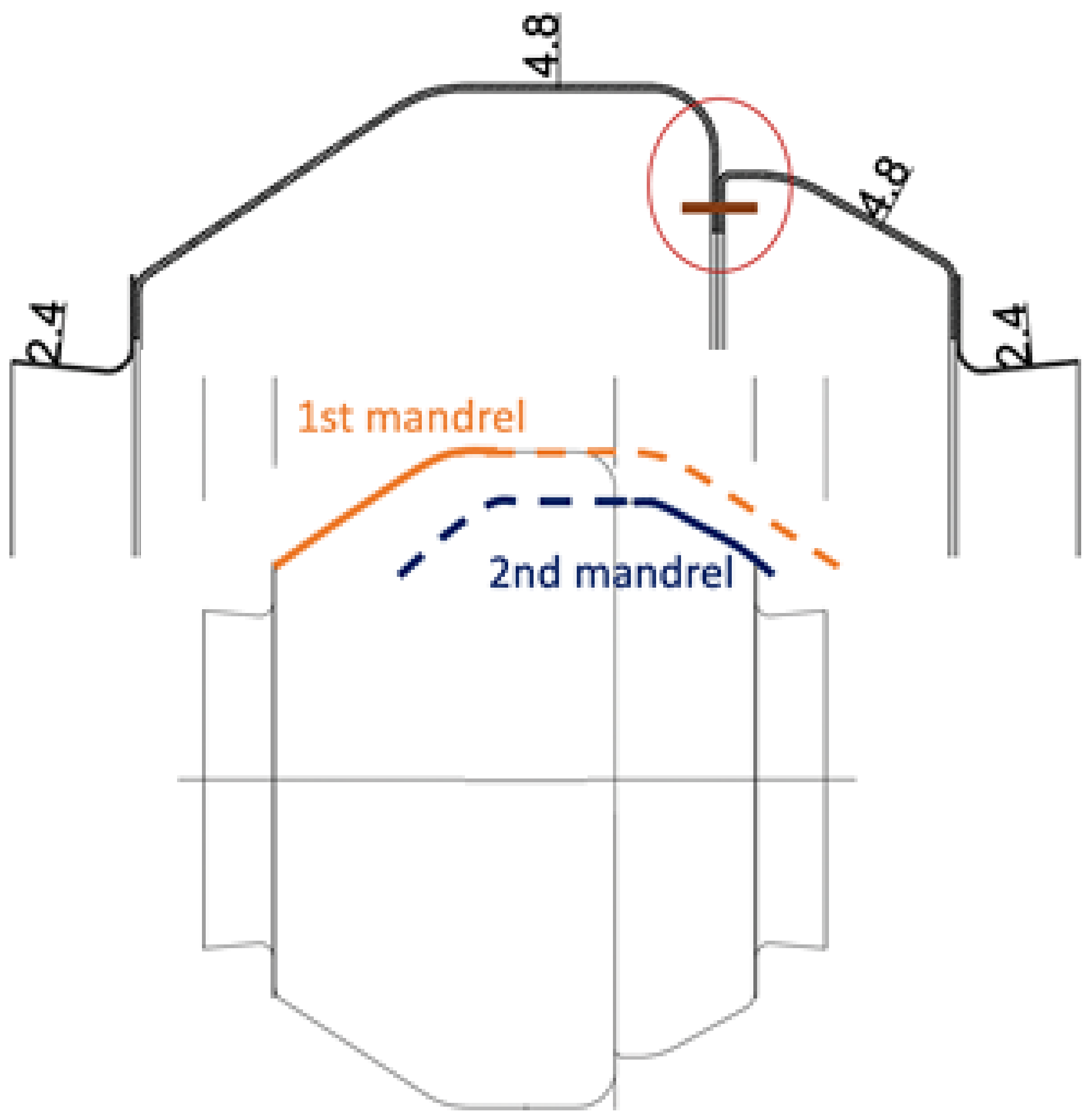
Design for Manufacturing (DfM)

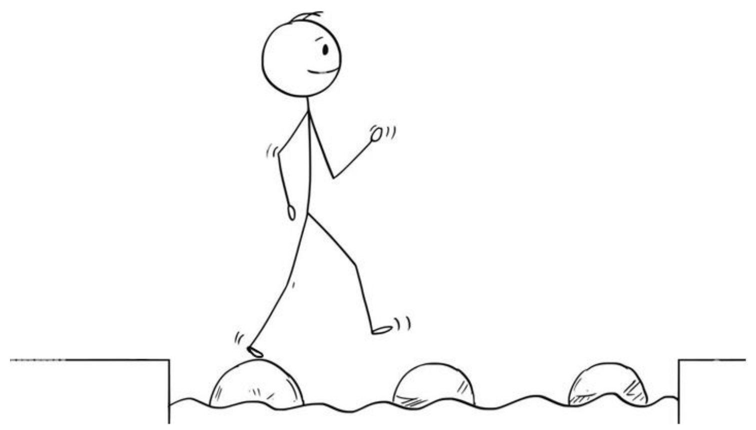


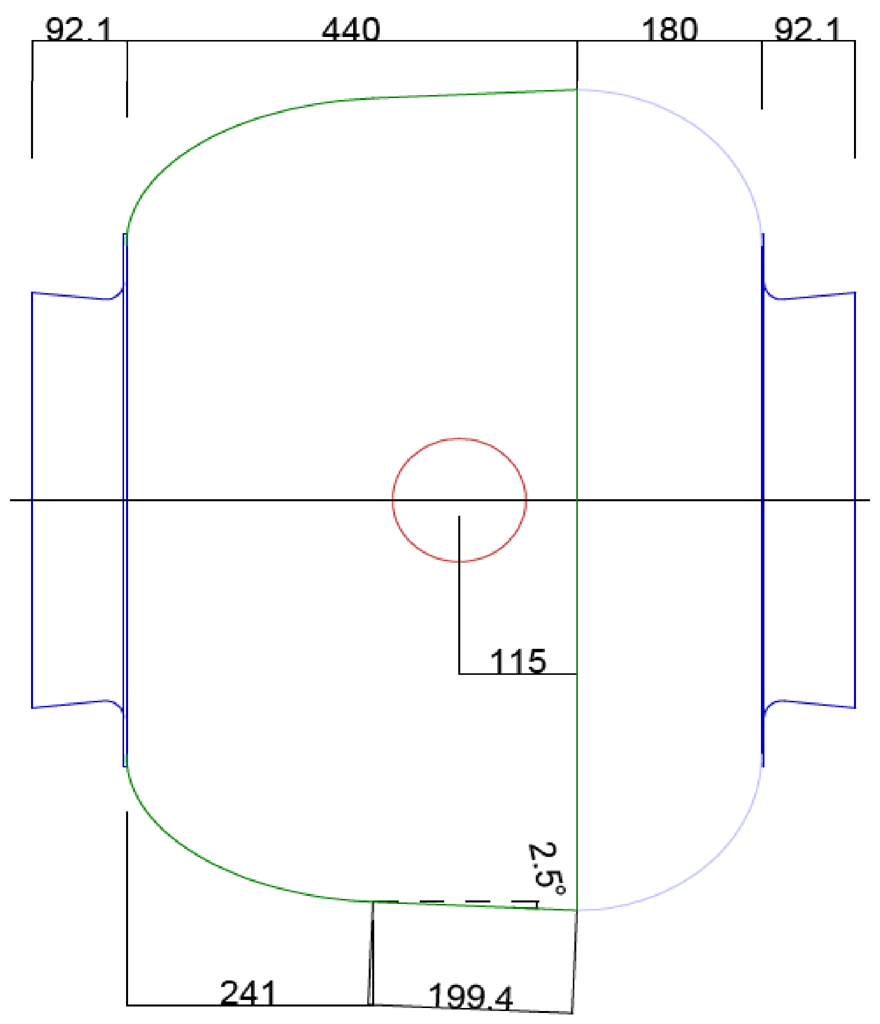


Cons:

- Sharp angles 1 through 5;
- Assembly with nut and bolts between 3 and 4 is impossible to reach;
- Joining 3 and 4 with adhesive defeats the purpose of turbine accessibility for maintenance;
- Requires use of 2 mandrels.







Pros:

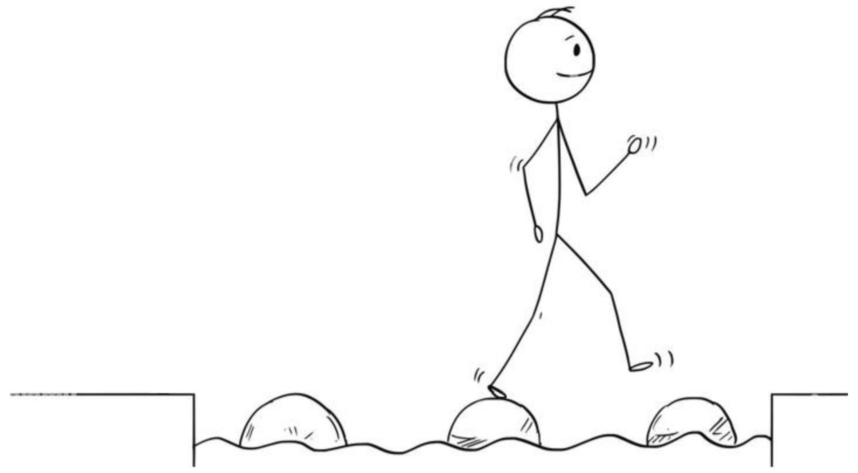
- Smoother angles;
- Only requires one steel mandrel;
- Has demoulding angle which facilitates manufacturing.

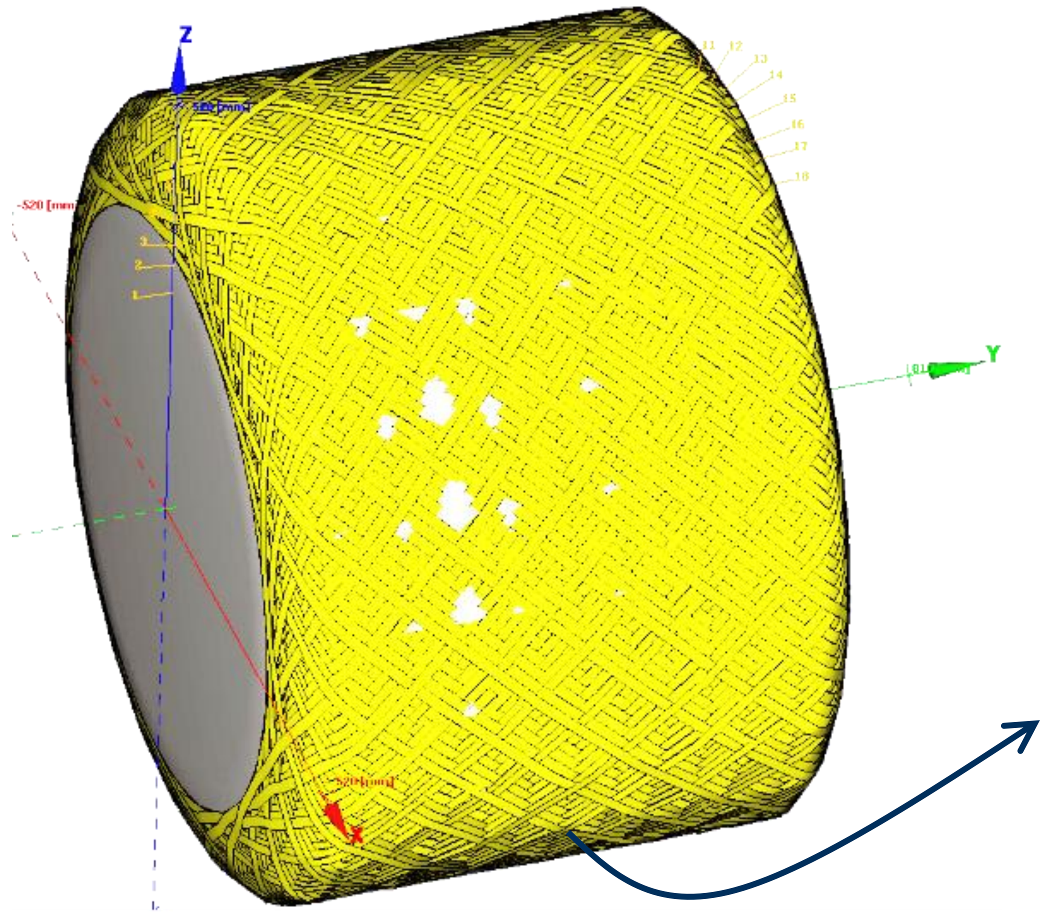
Cons:

- Studs are not necessary;
- Domes' geometry undefined for manufacturability.

Design for Manufacturing (DfM)

Low pressure Dish Head





No demoulding angle;
Twisted fibres.

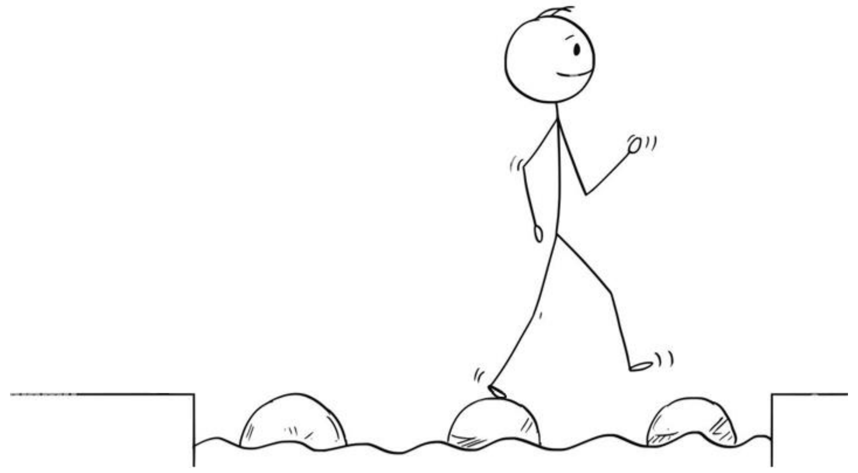
Pros:

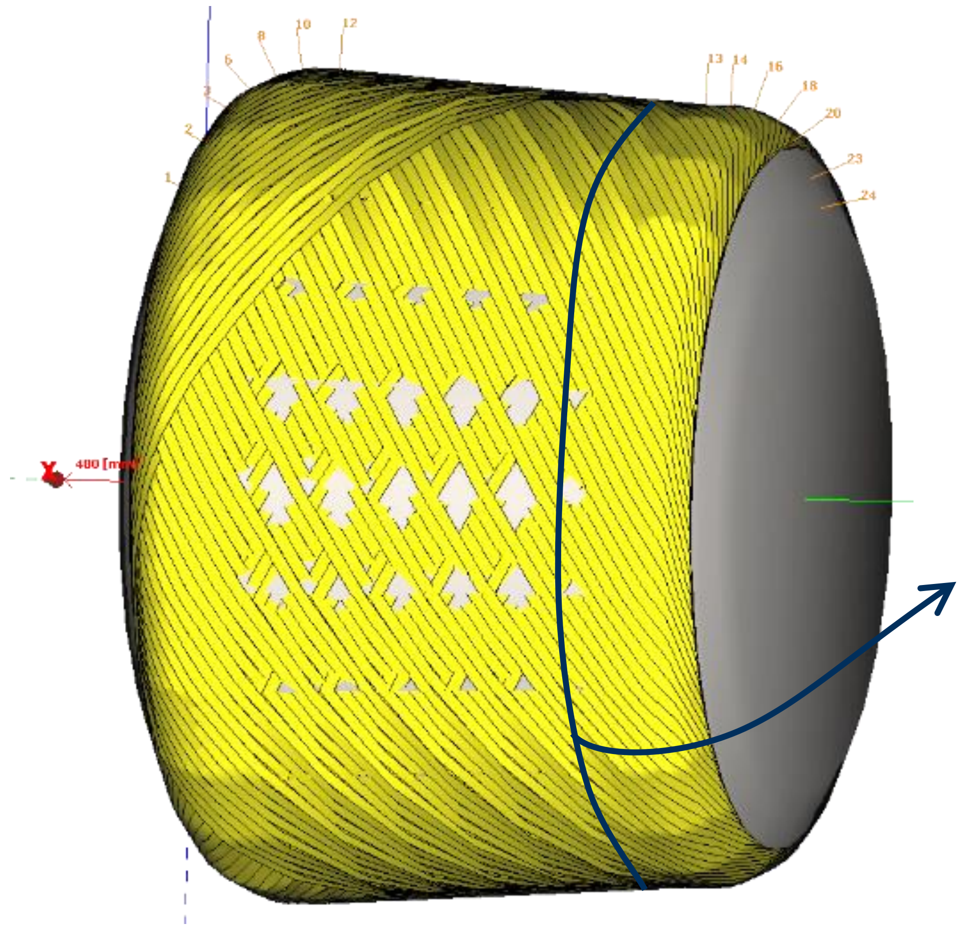
- **Cheaper and easier to manufacture the mandrel.**

Cons:

- **Not windable in the software if considering demoulding angle;**
- **High likelihood of twisted and/or breakage of tows.**

Torispherical Dish Head Type Klopper (w/ flange) - DIN28011





Composite is sagging and not filling the mandrel;
It wasn't possible to find a good pattern and winding angle to close the tops.

Pros:

- **Easier to manufacture mandrel.**

Cons:

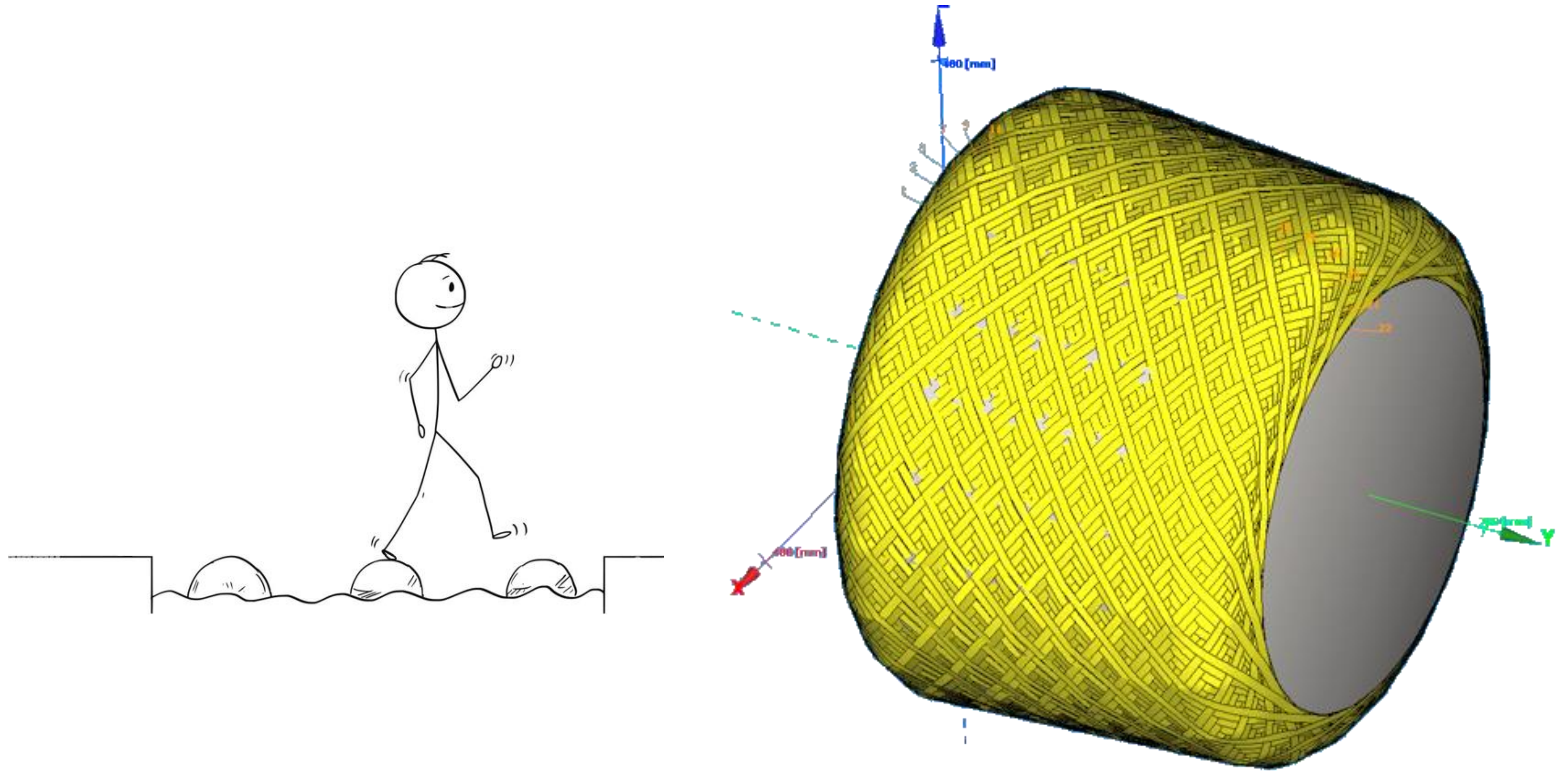
- **Not feasible in winding software.**

Angle: 3,82° → too high

Height: 91 and 104 mm

Design for Manufacturing (DfM)

Torispherical Dish Head Type Klopper (w/o flange) - DIN28011



Pros:

- **Windable but with limitations.**

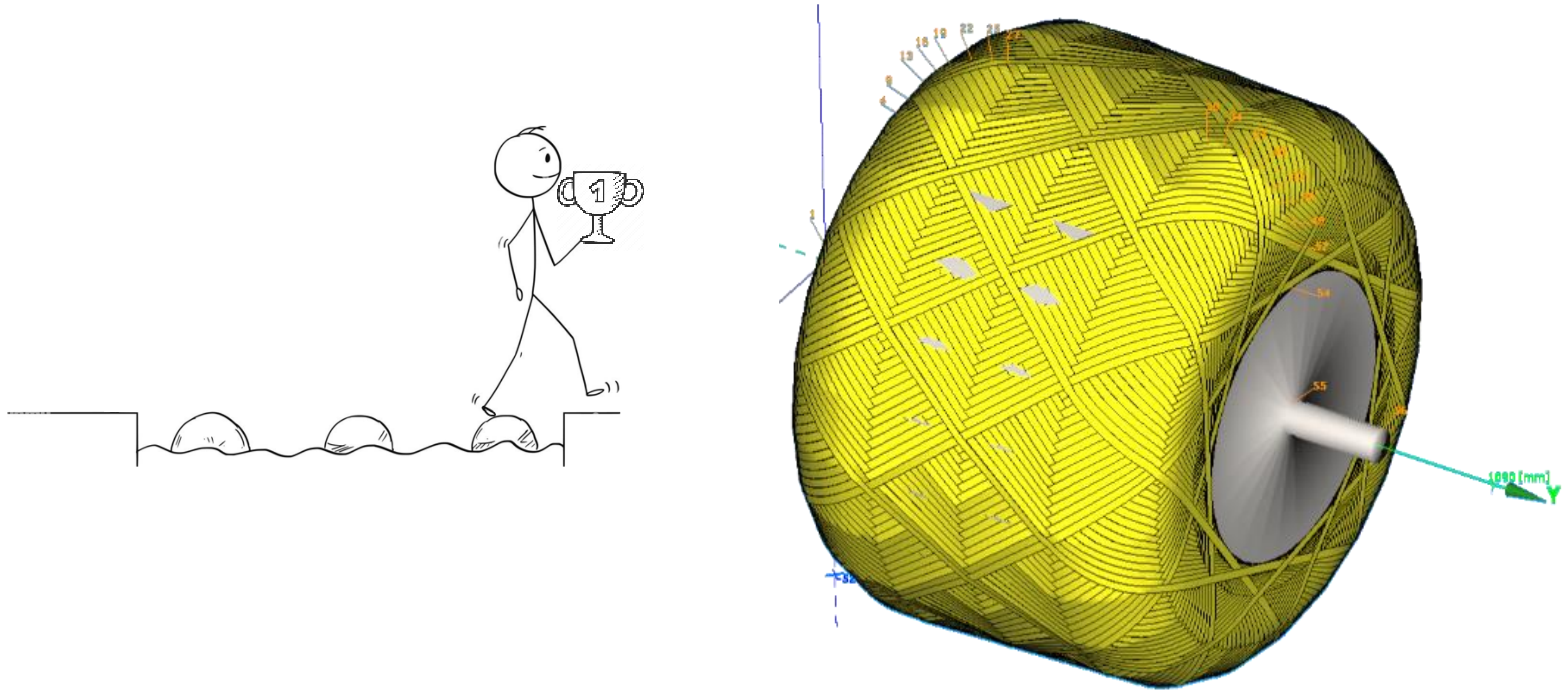
Cons:

- **Harder to manufacture mandrel because of peripheral weld near the radius.**

Angle: 3,37°

Height: 91 and 104 mm

Spherical Dish Head - Custom



Pros:

- **Smoother angles (closer to TSI design shape);**
- **No twisting of fibres;**
- **Good demoulding angle.**

Cons:

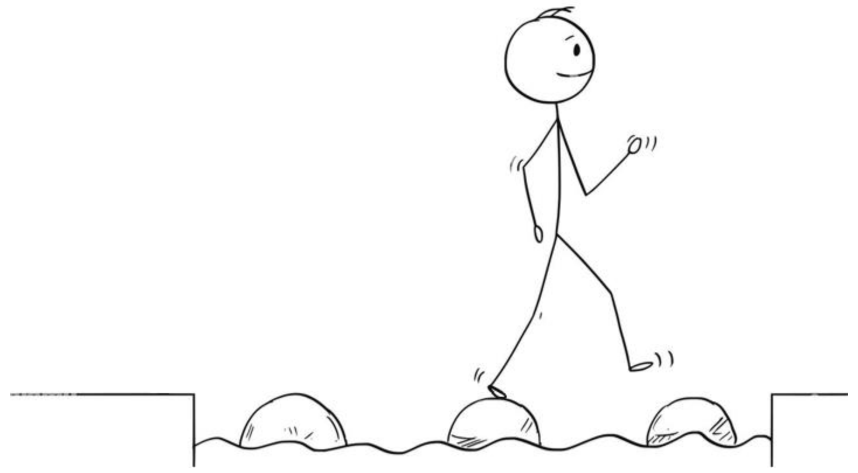
- **More expensive manufacture.**

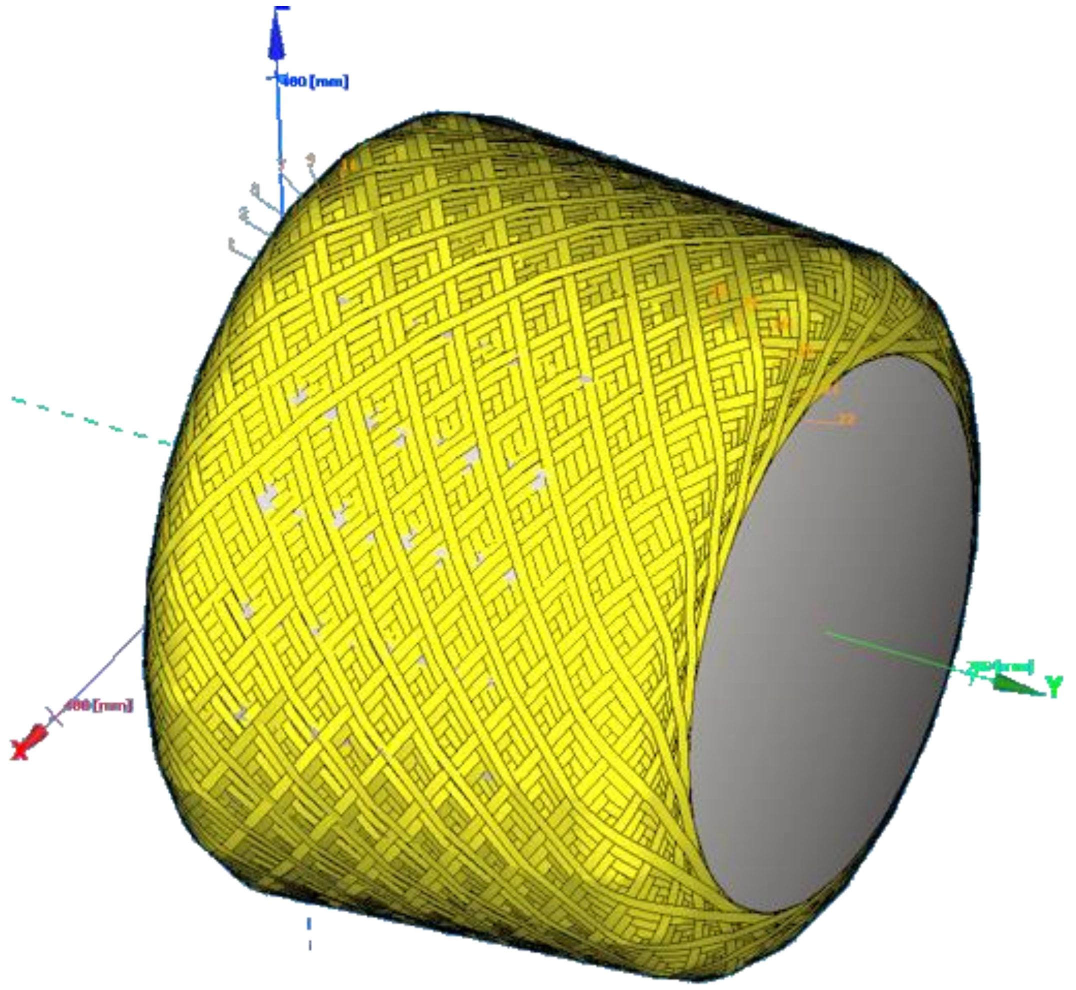
Angle: 1,55°

Height: 129 and 169 mm

Design for Manufacturing (DfM)

Torispherical Dish Head Type Klopper (w/o flange) - DIN28011





Pros:

- **Windable but with limitations.**

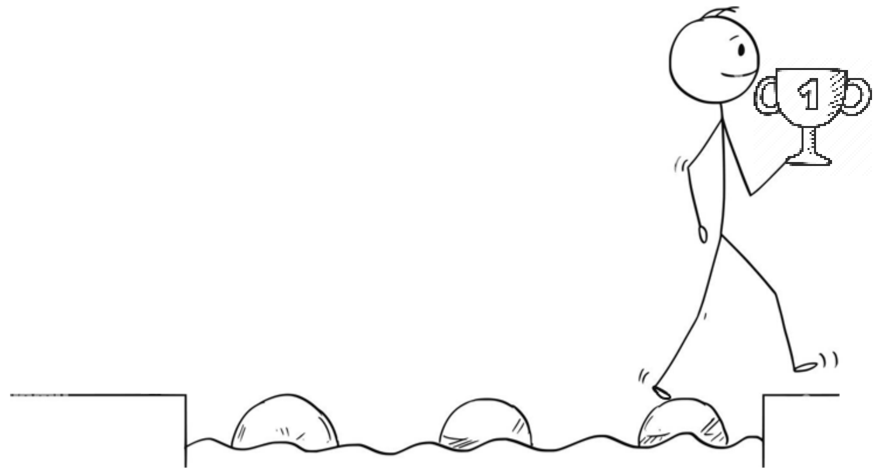
Cons:

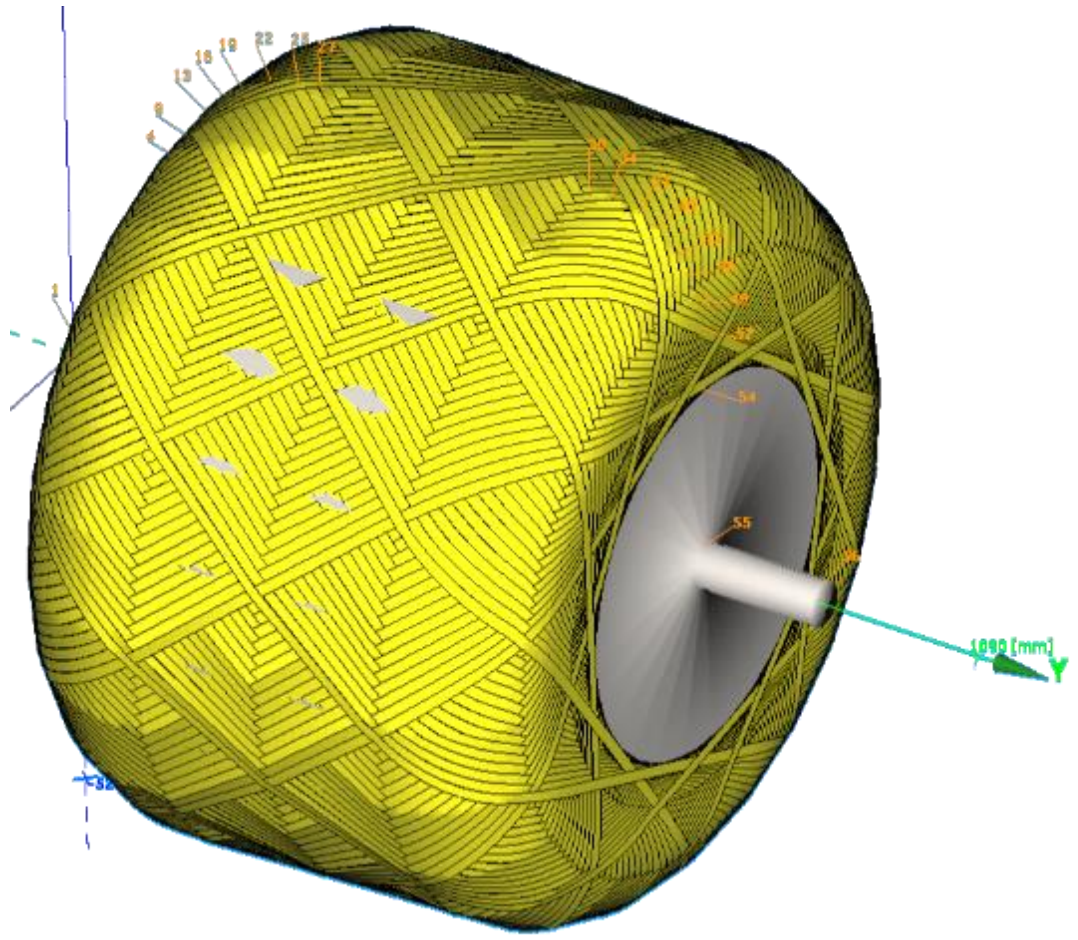
- **Harder to manufacture mandrel because of peripheral weld near the radius.**

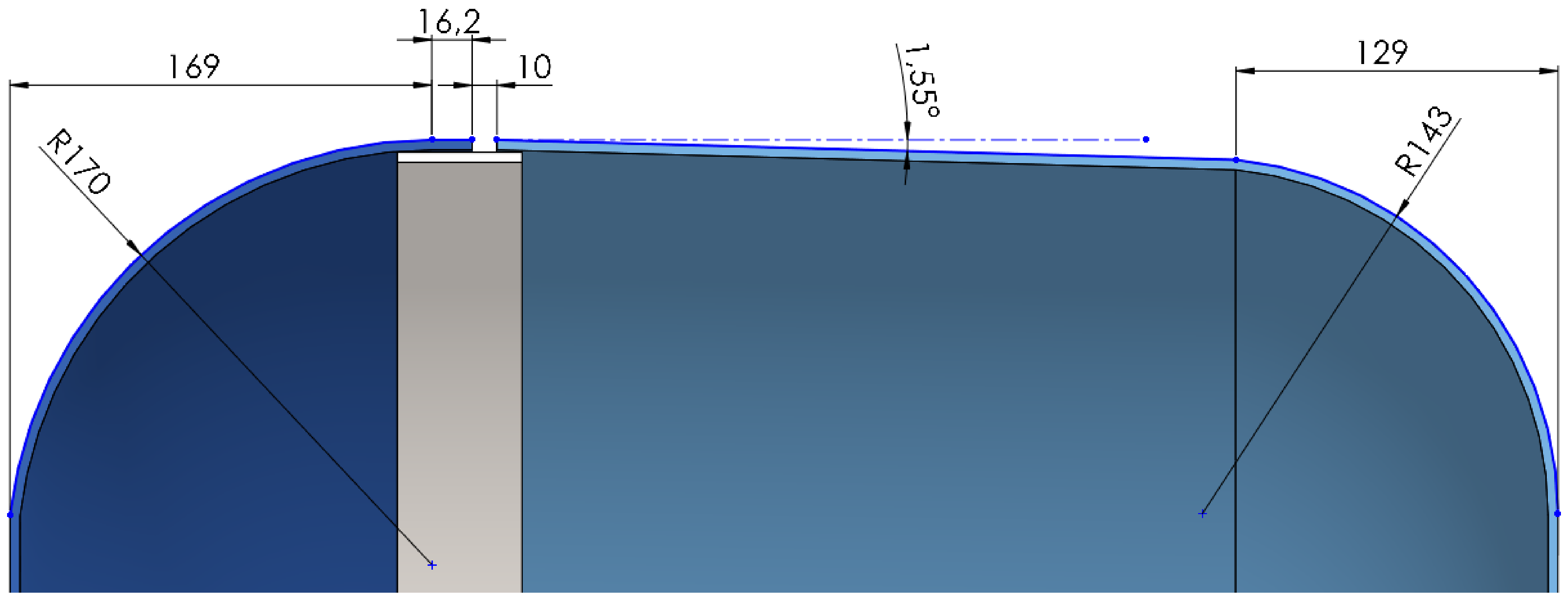
Angle: 3,37°

Height: 91 and 104 mm

Spherical Dish Head - Custom



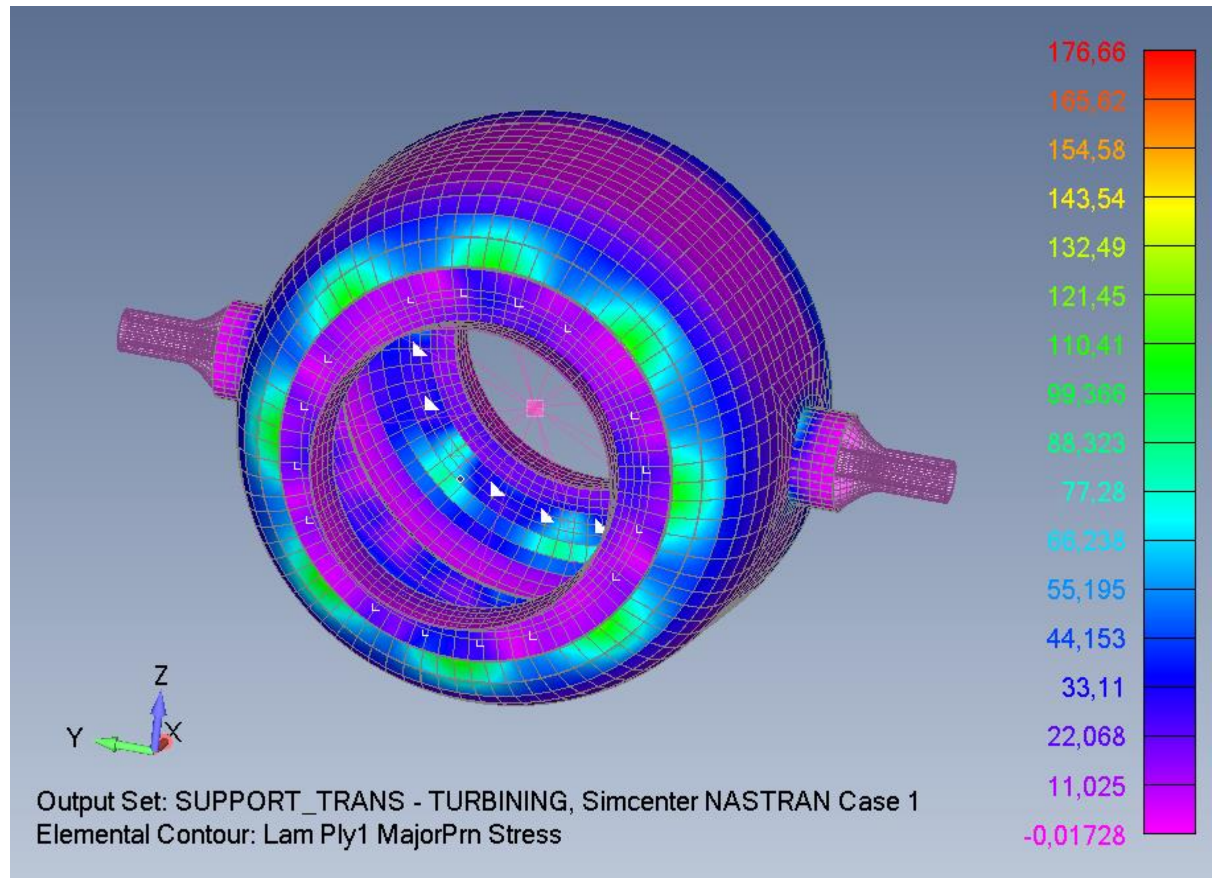


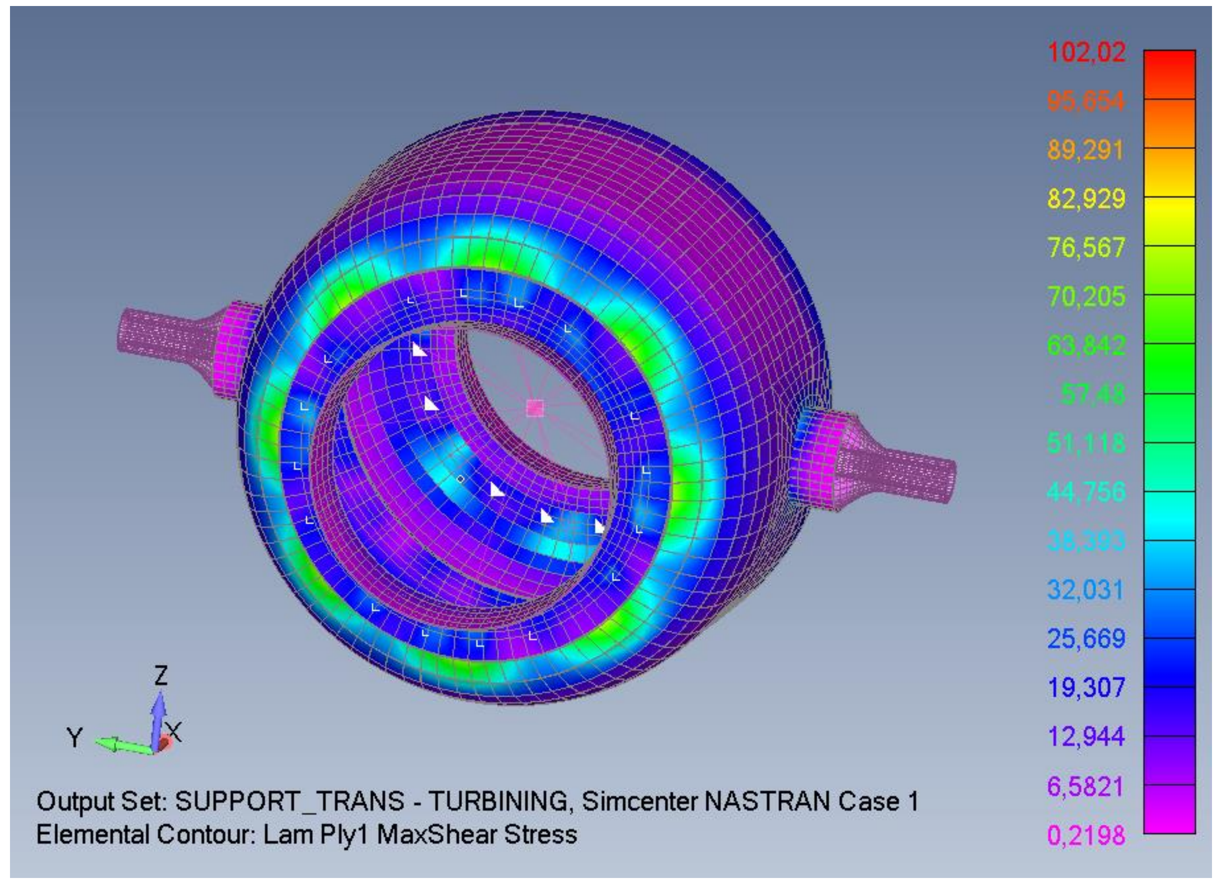


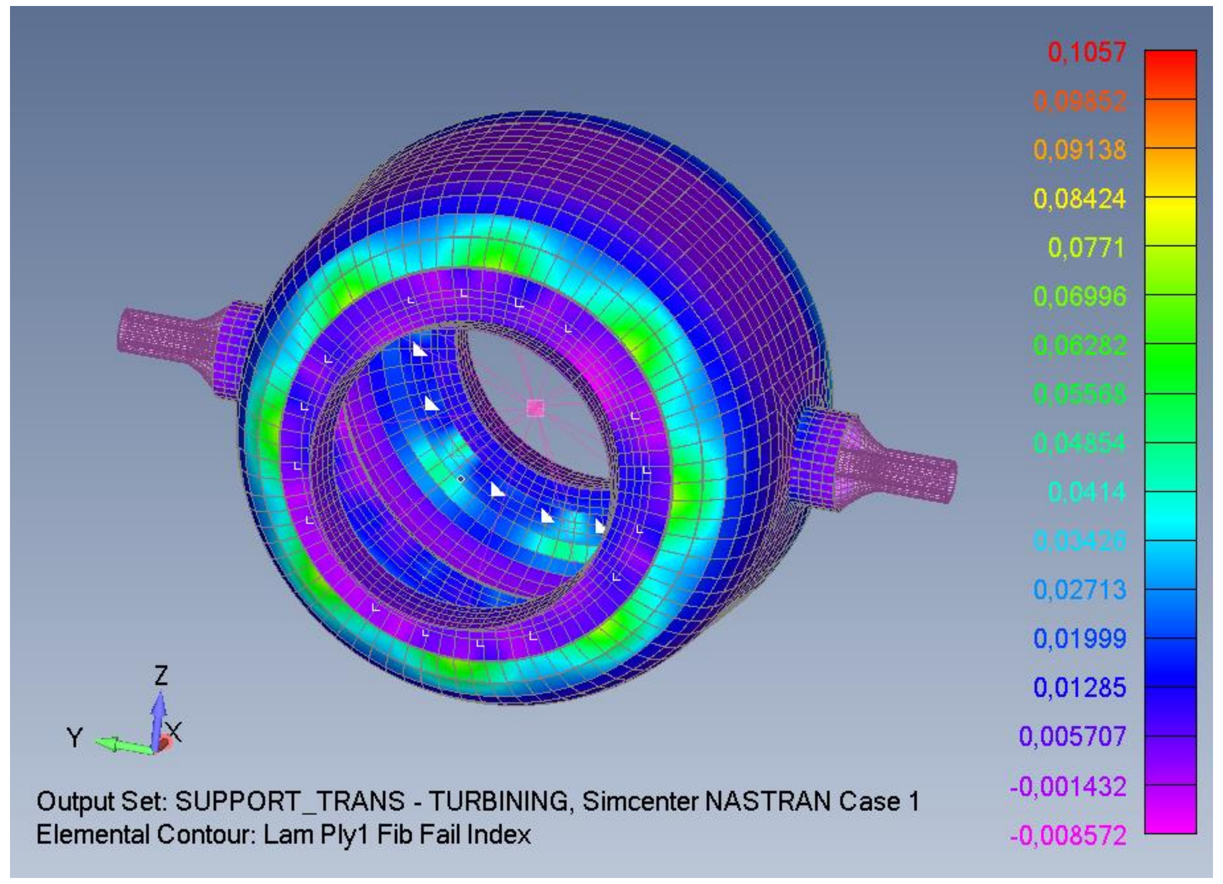
Numerical Analysis & Validation

TSI

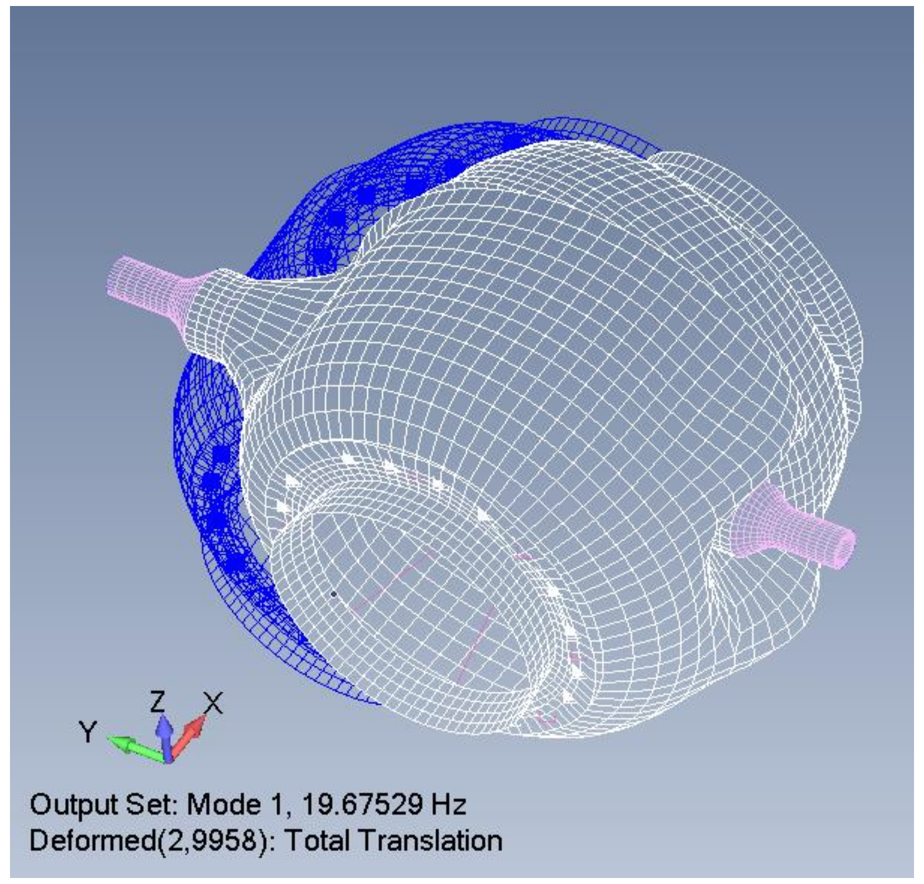
Results obtained in the static analysis:

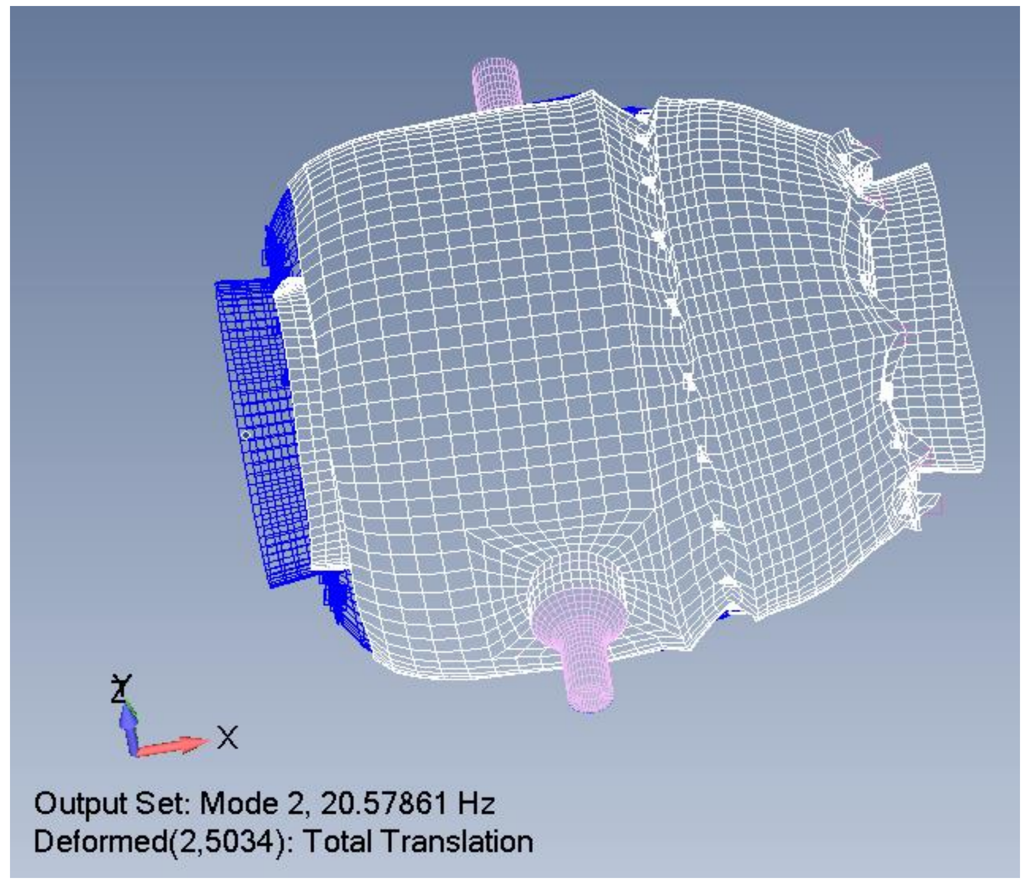


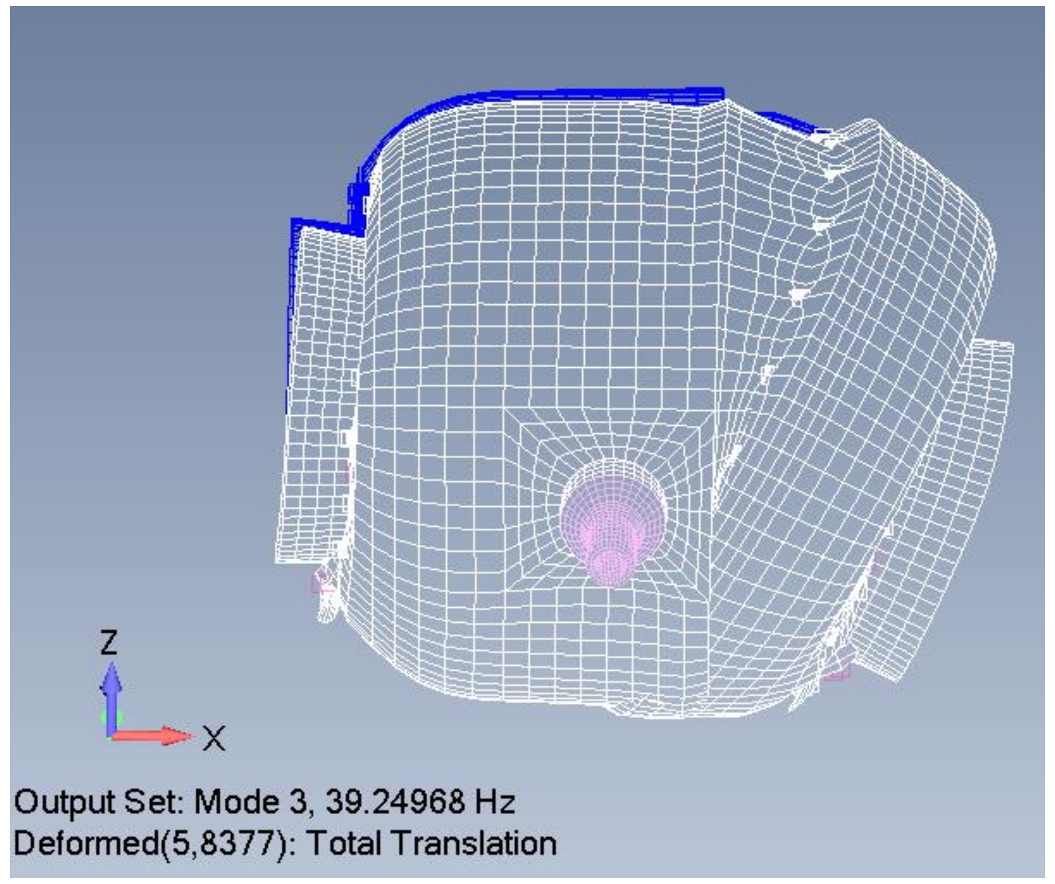




Results obtained in the modal analysis:

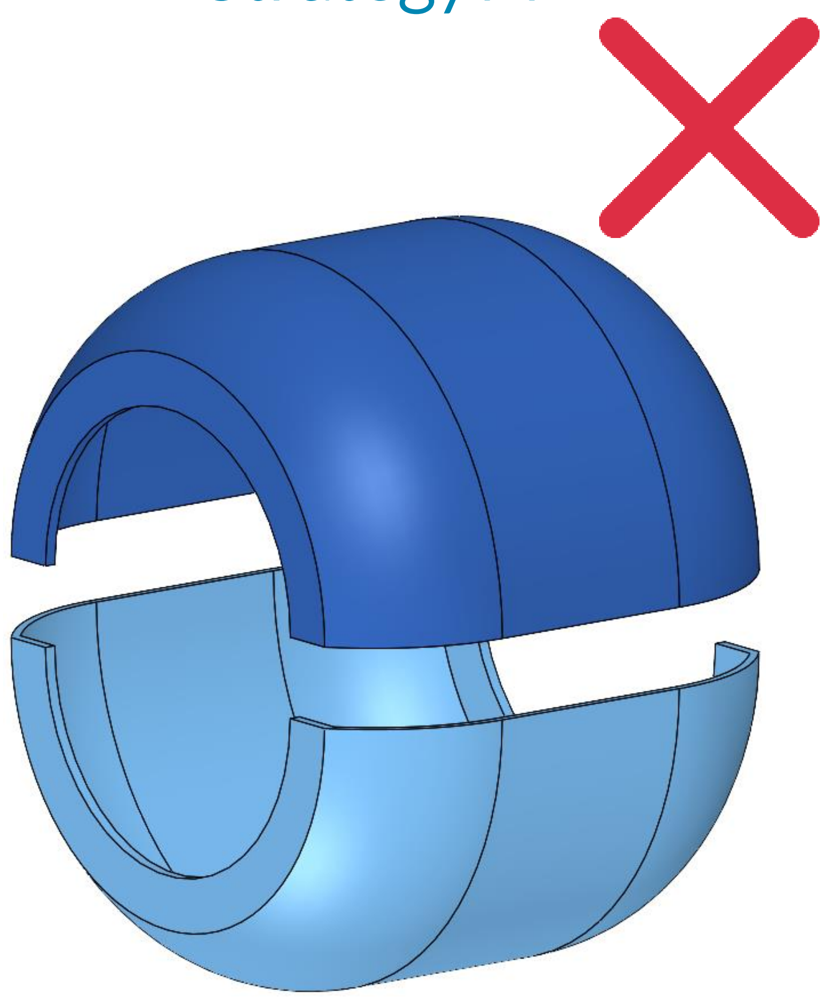






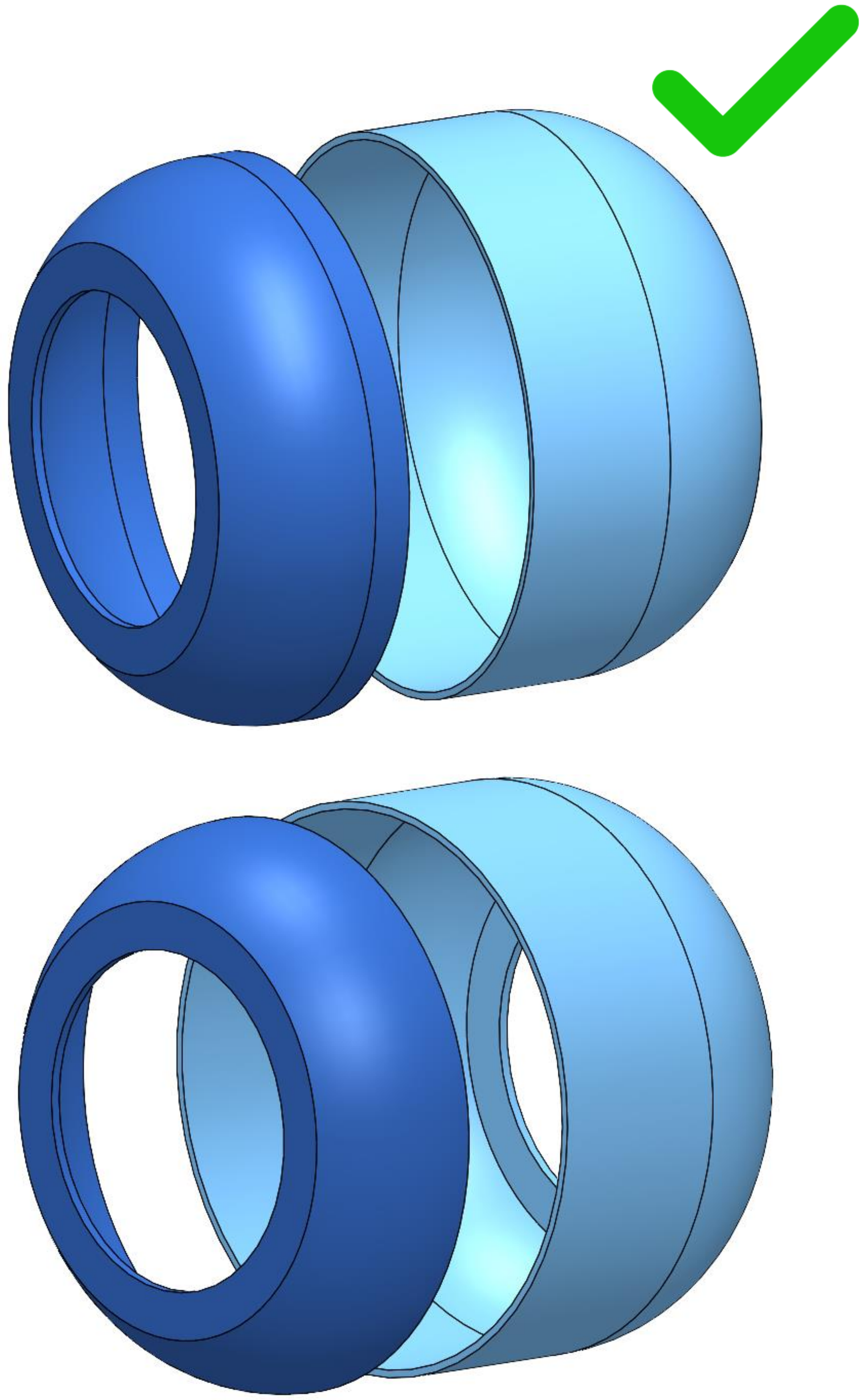
Modular Building Strategy

Strategy A

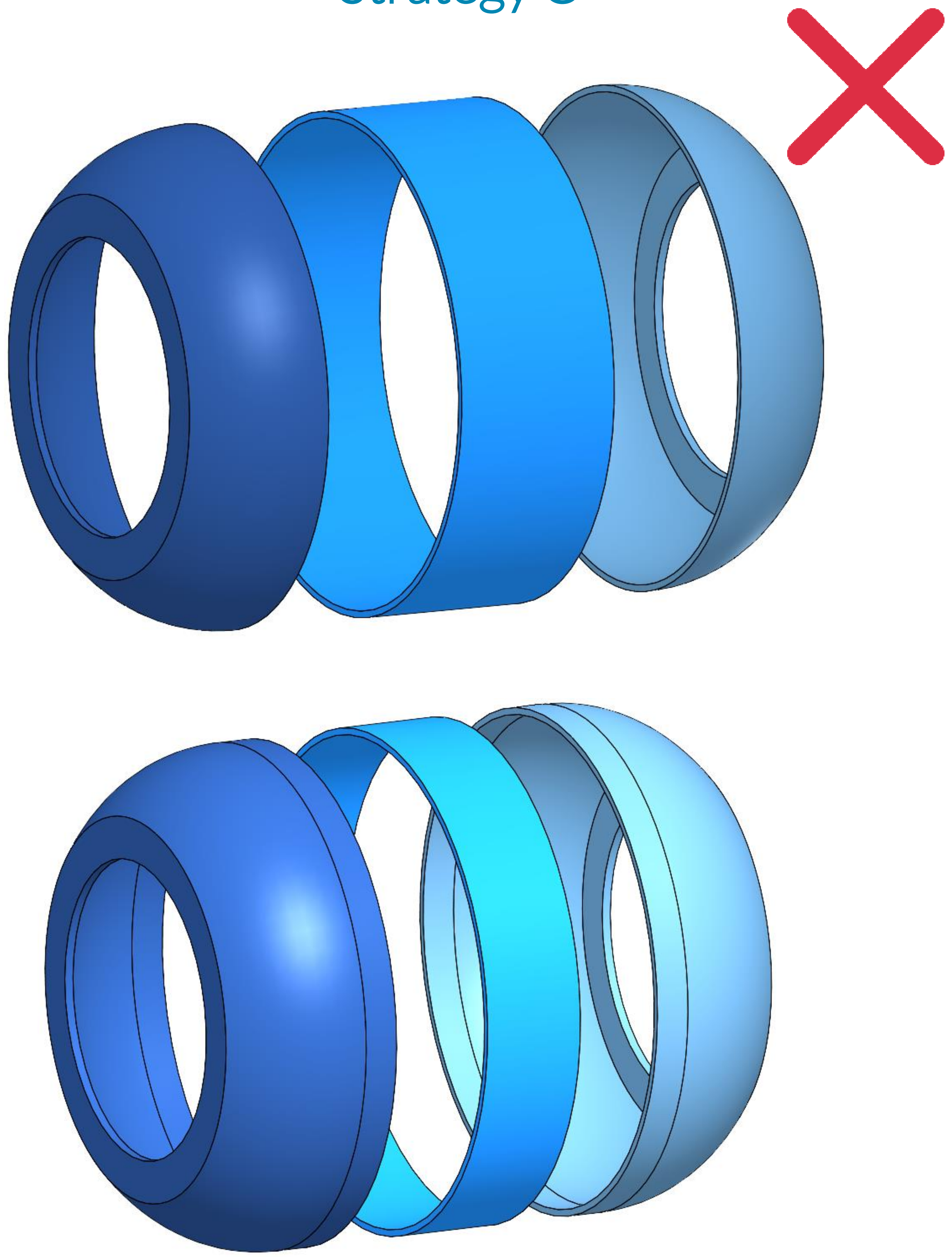


More difficult maintenance procedure and connections/assembly

Strategy B

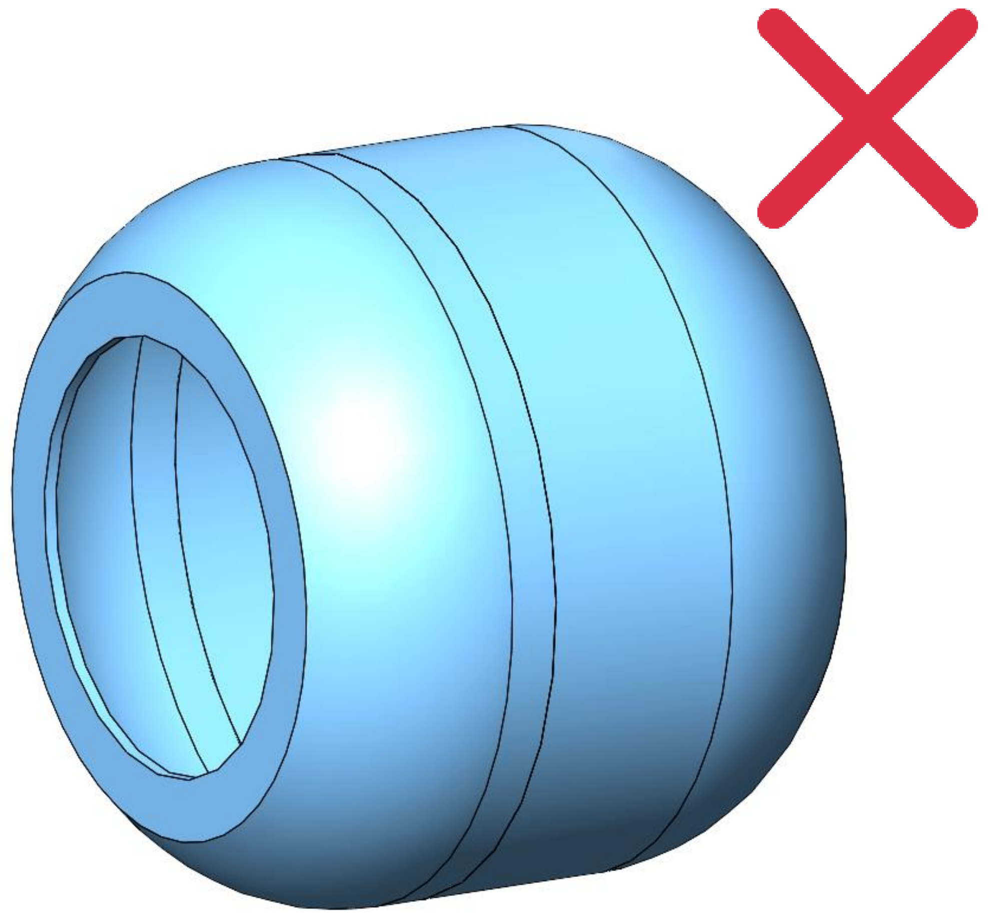


Strategy C



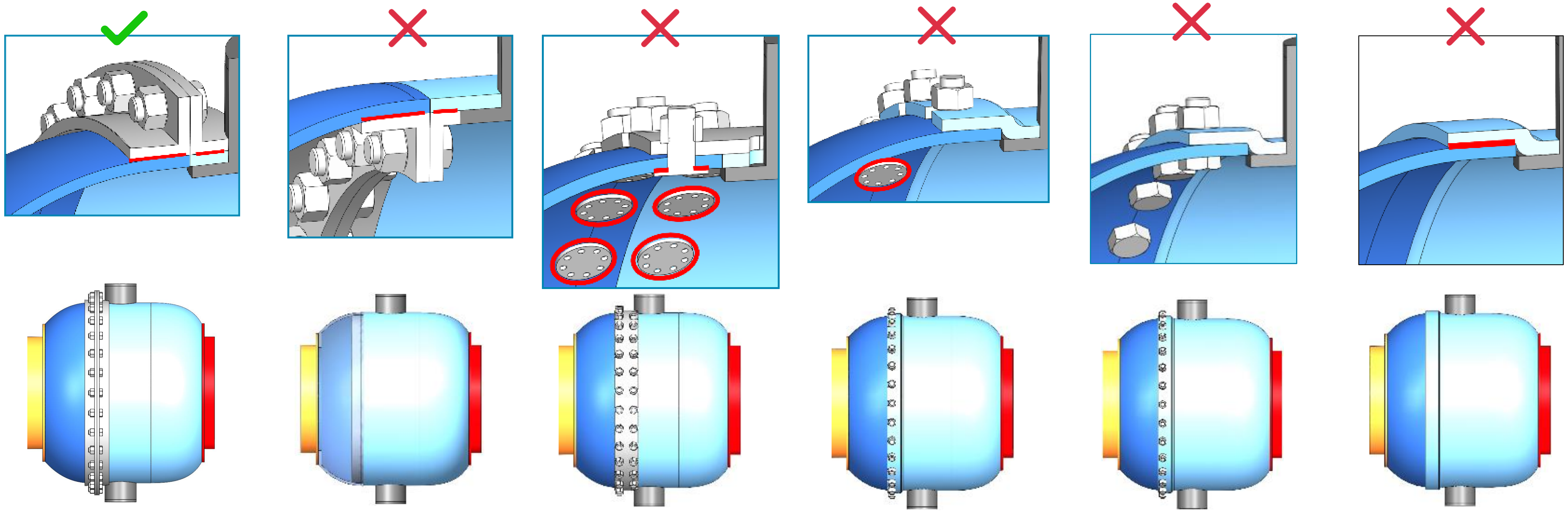
Unnecessary access points and extra steps in manufacturing and connections/assembly

Strategy D



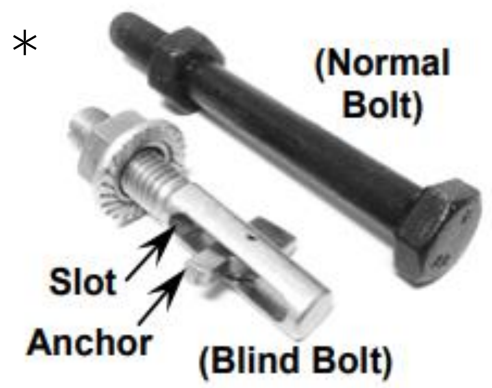
Doesn't enable maintenance or fitting in the turbine. Cutting the housing defeats the purpose of destroyable mould

Connections

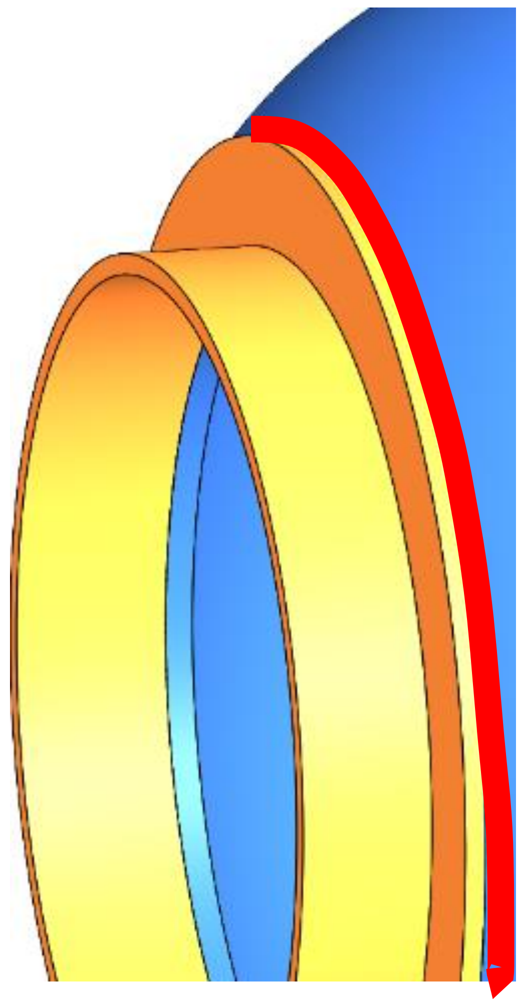


Process Chain

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

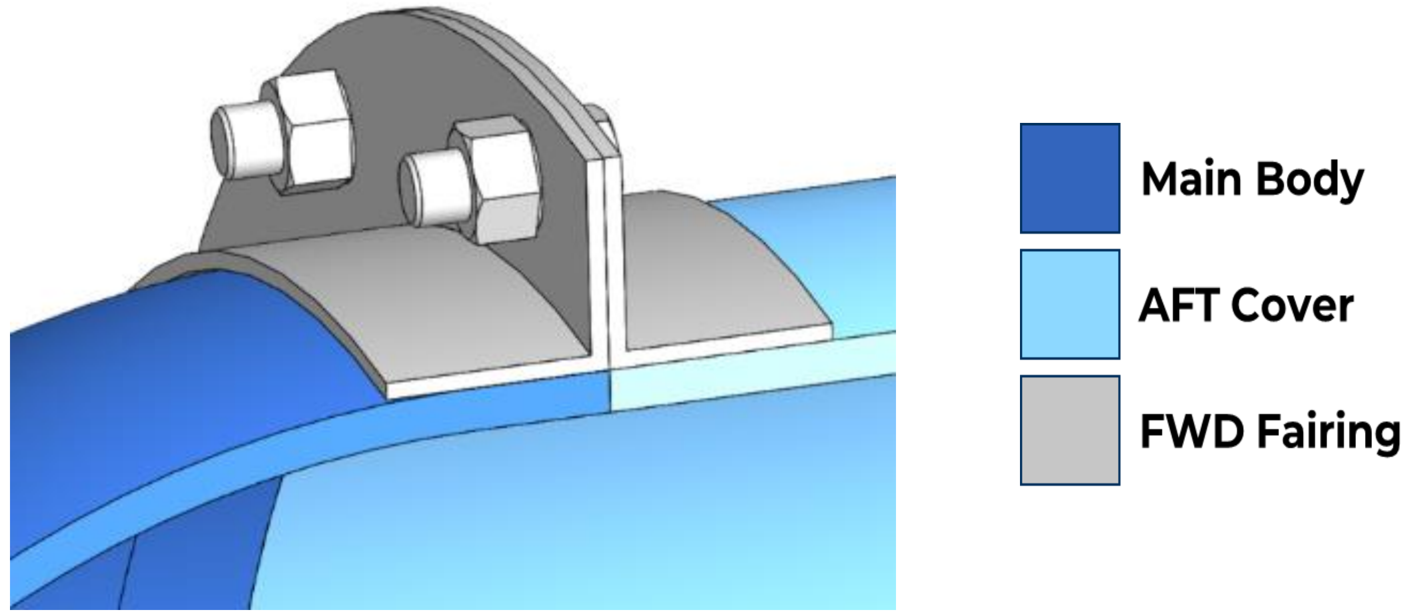


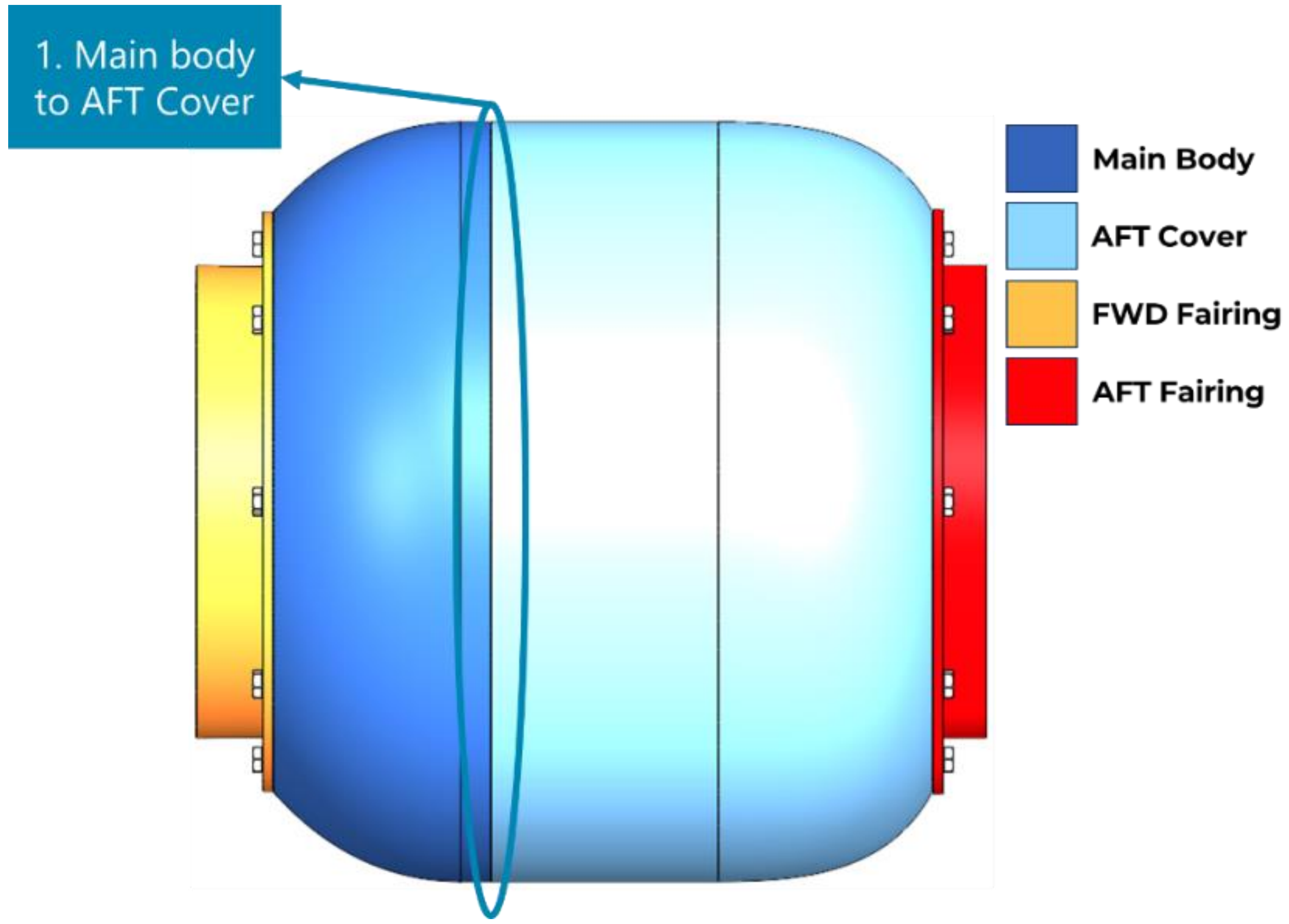
Adhesive Joint between Main body & Side Fairing // AFT Cover & Side Fairing2

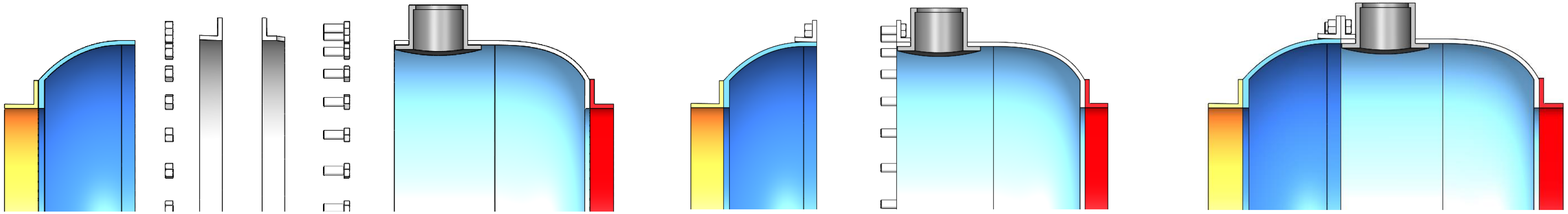


- **Main Body**
- **AFT Cover**
- **FWD Fairing**
- **AFT Fairing**

Assembly Plan





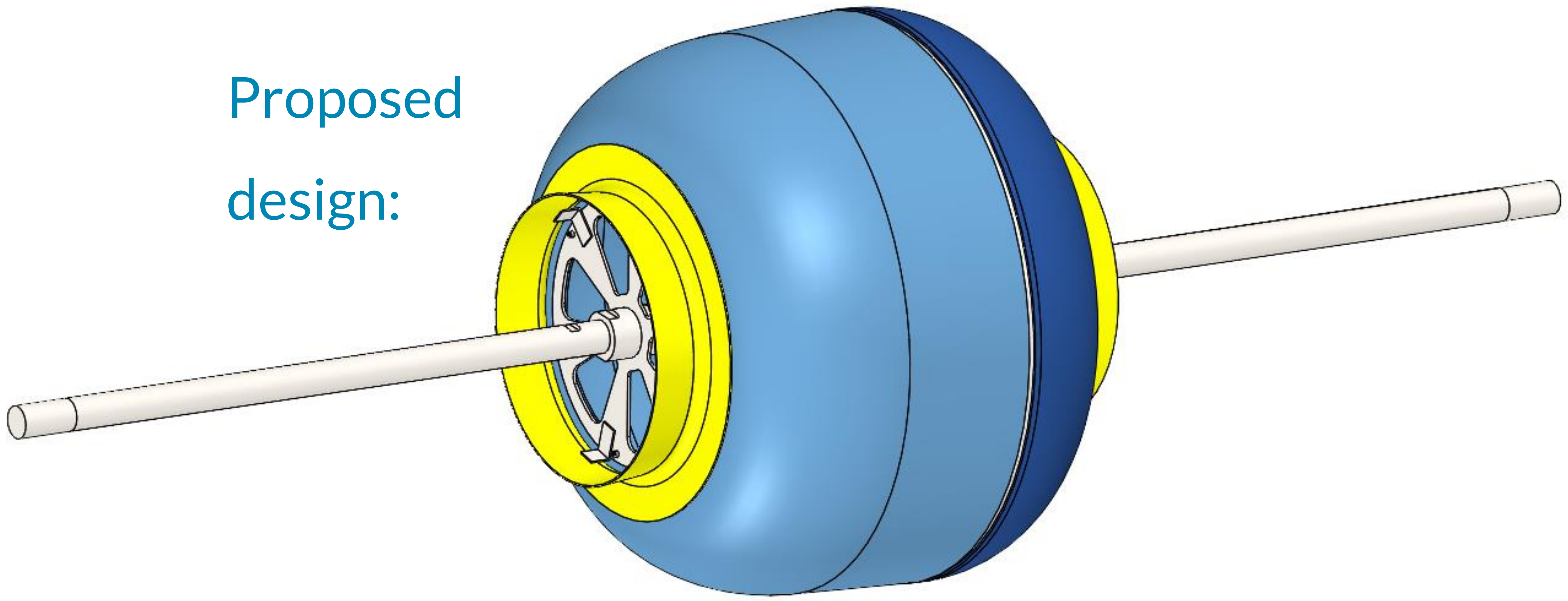


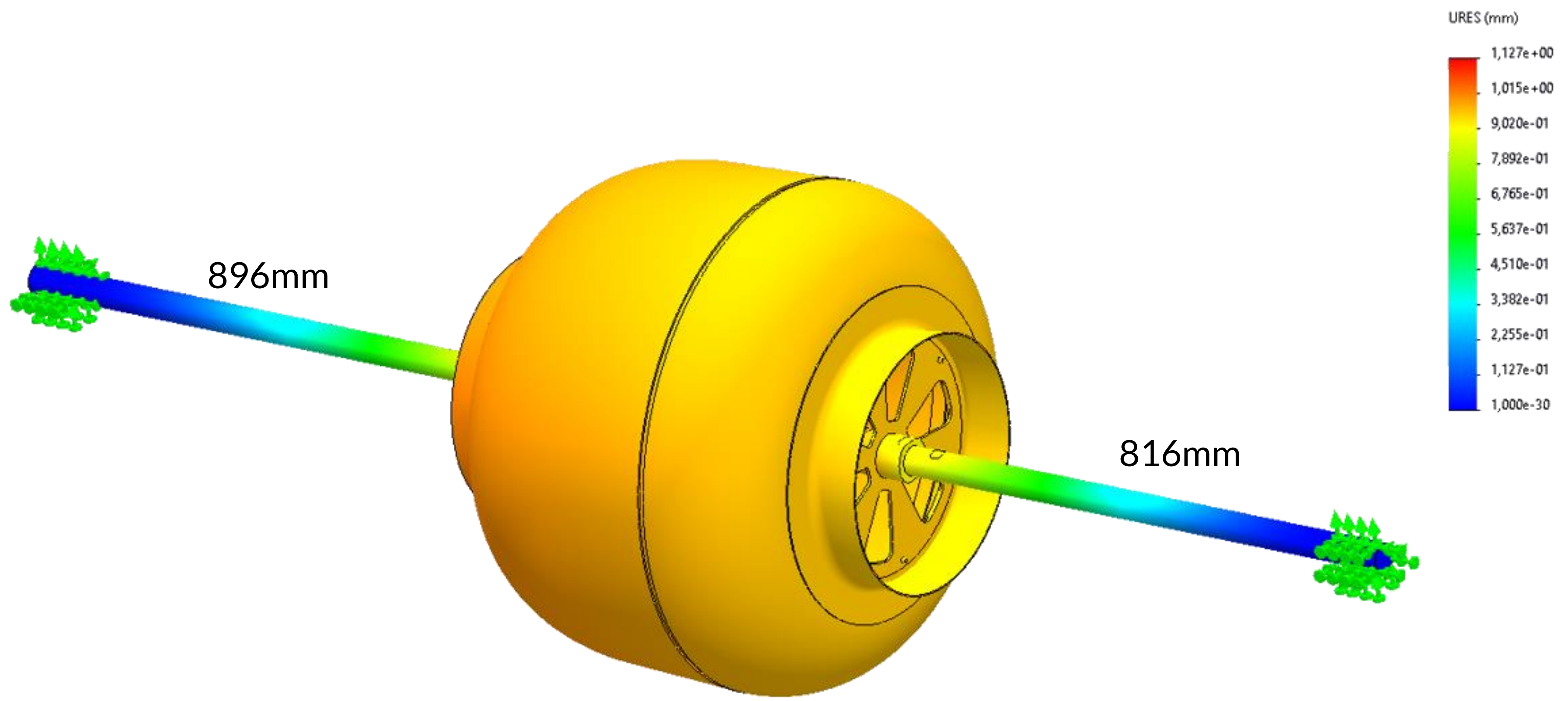
1. Main Body and AFT Cover, flanges, fairings and studs manufacturing
2. Edge triming and surface preparation prior to bonding
3. Bonding: AFT cover to studs; AFT Cover/Main body to respective flange
4. Assembly to housing

Main Body & AFT Cover
↓
Towpreg Winding

Mandrel Design: Shaft Diameter vs Deflection

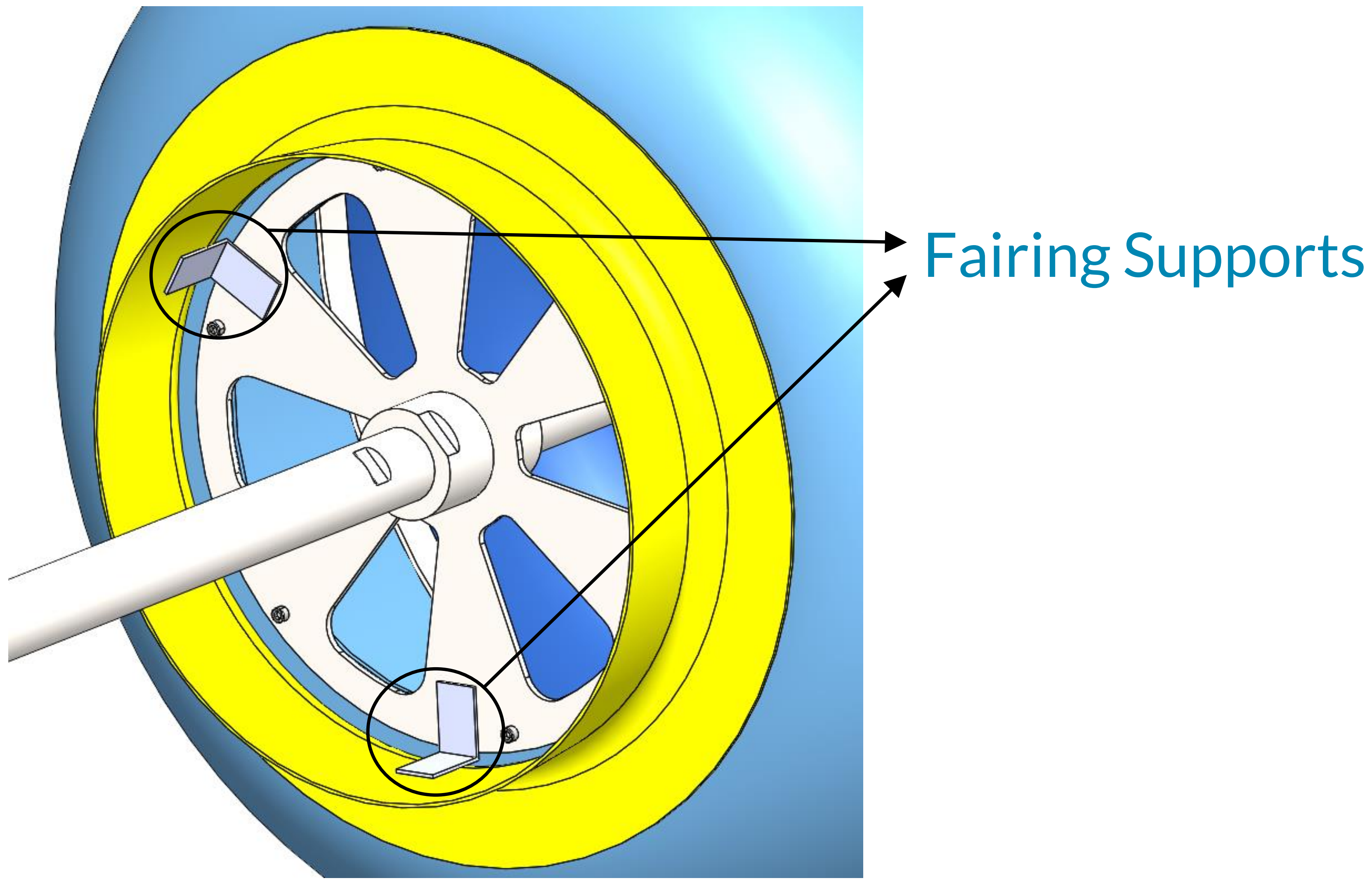
Proposed design:





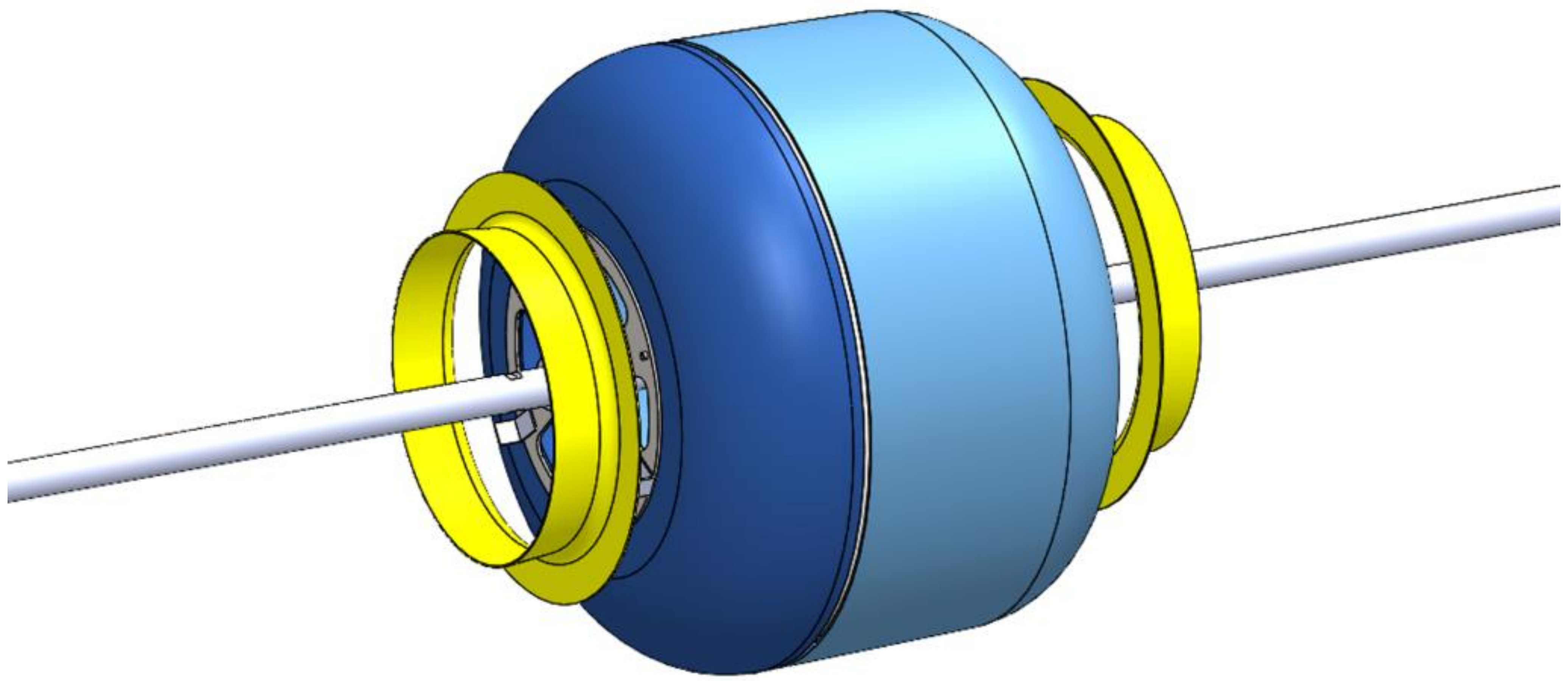
ϕ Shaft [mm]	Maximum deflection of shaft [mm]		Weight of shaft tips[kg]
	Self Weight	Self Weight+ Tension of 10 fibres (80N*10 or 342,616Nm)	
45	1,642	3,488	25,8
50	1,127	2,346	31,5
55	0,809	1,651	37,9

Min. tension each fibre	10	N
Max. tension each fibre	80	N

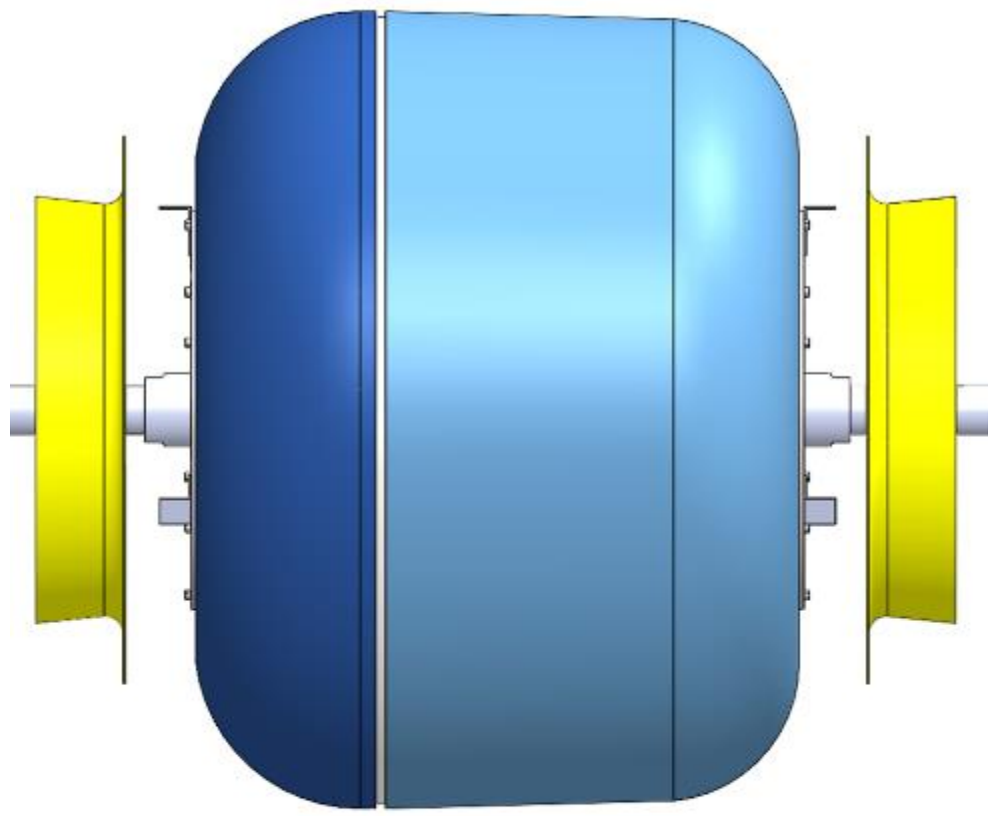


Mandrel Design

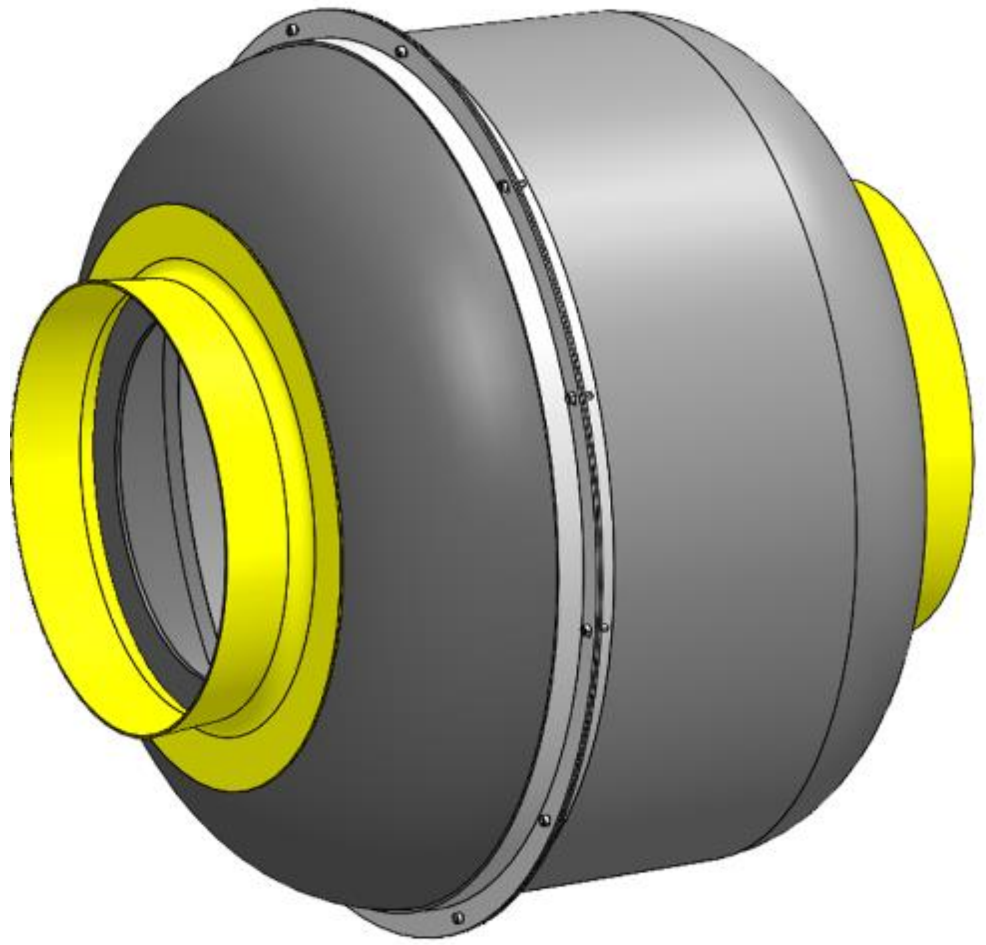
Mandrel



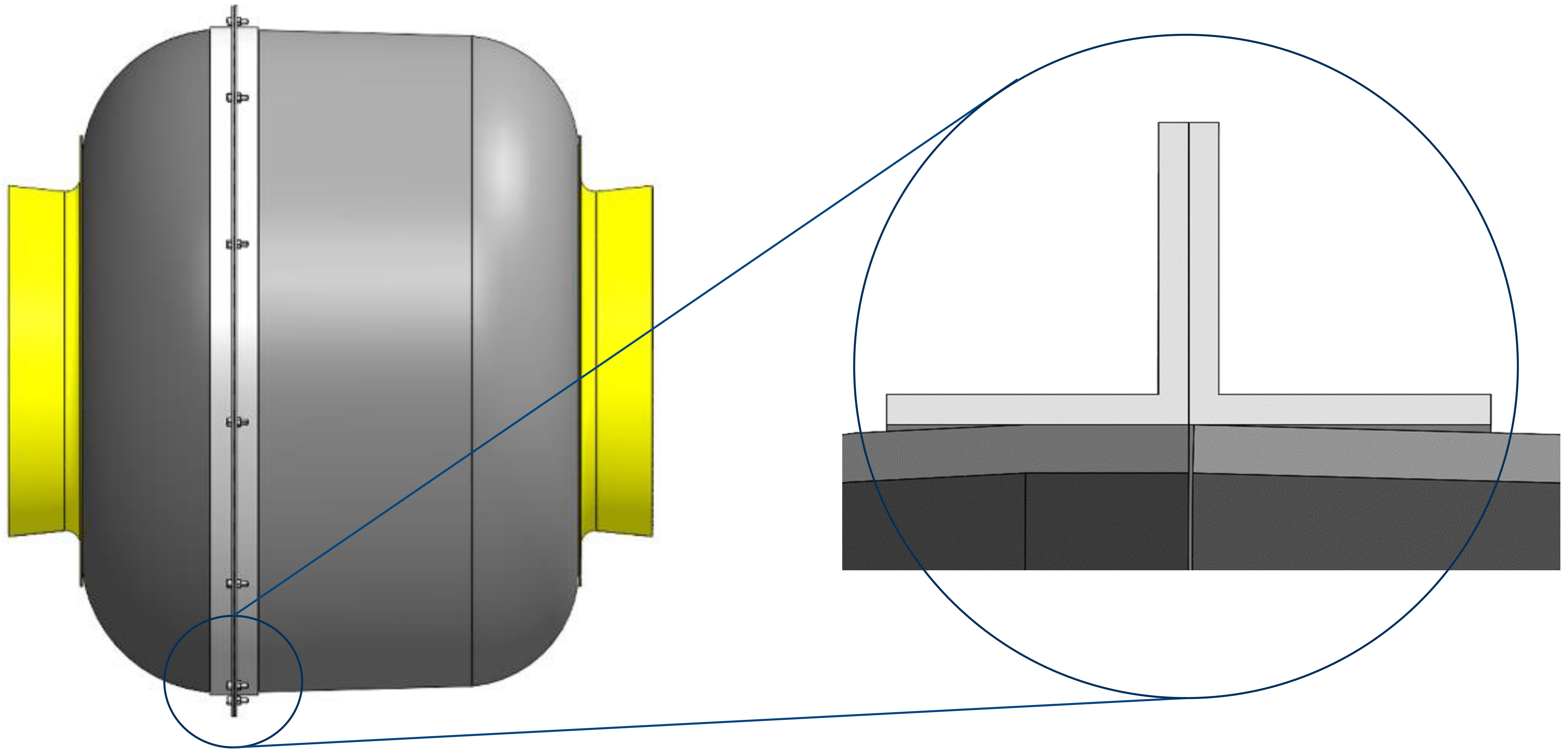
Side View



Resulting Composite

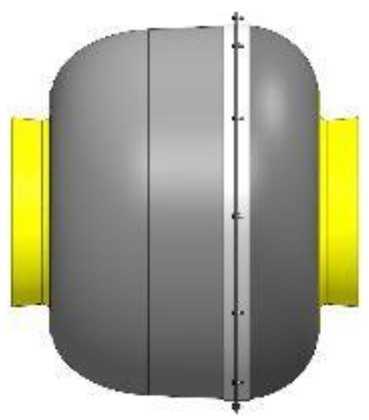


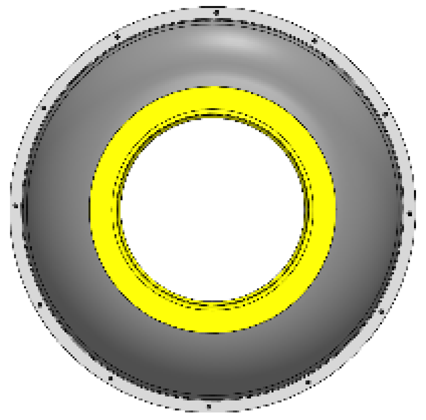
Side View

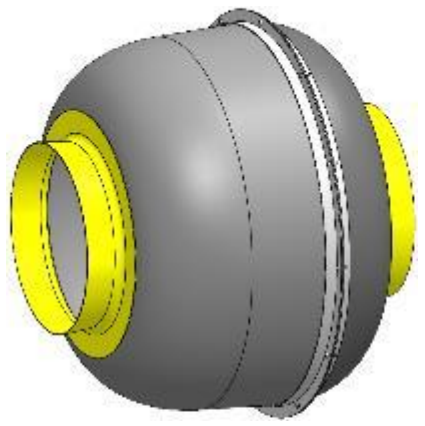


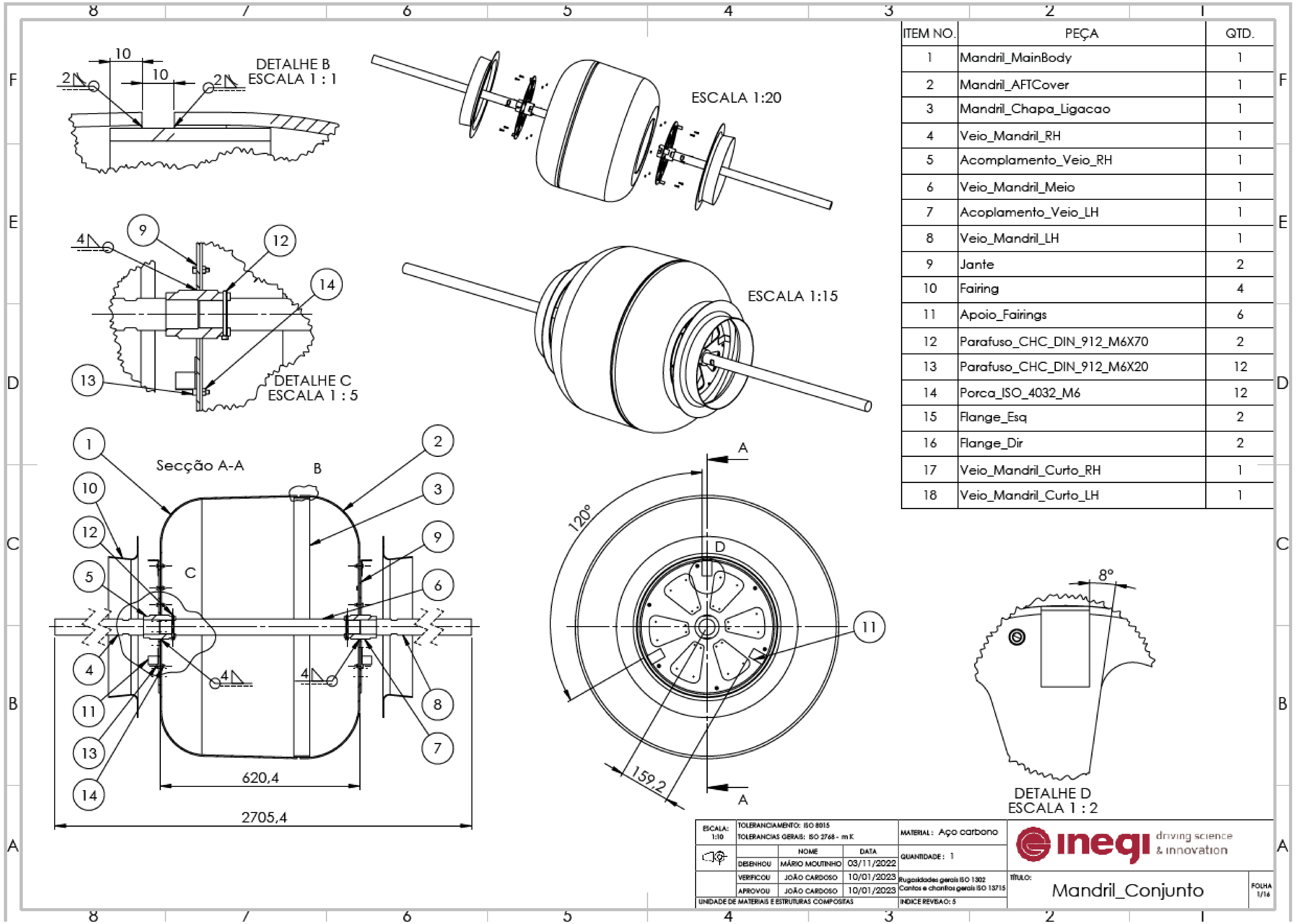
AFT Cover
FWD Cover
Fairing
Composite AFT Cover
Composite FWD Cover
Flanges

Mandrel Design: Assembly Drawing





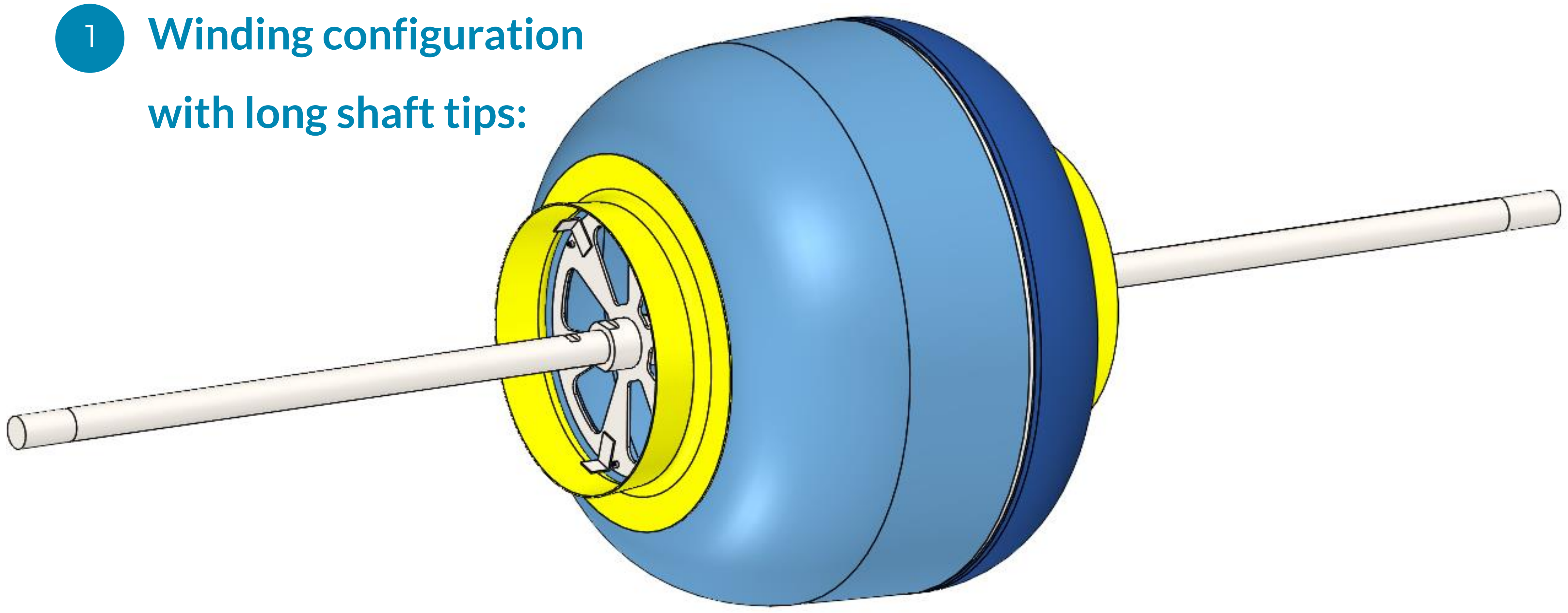




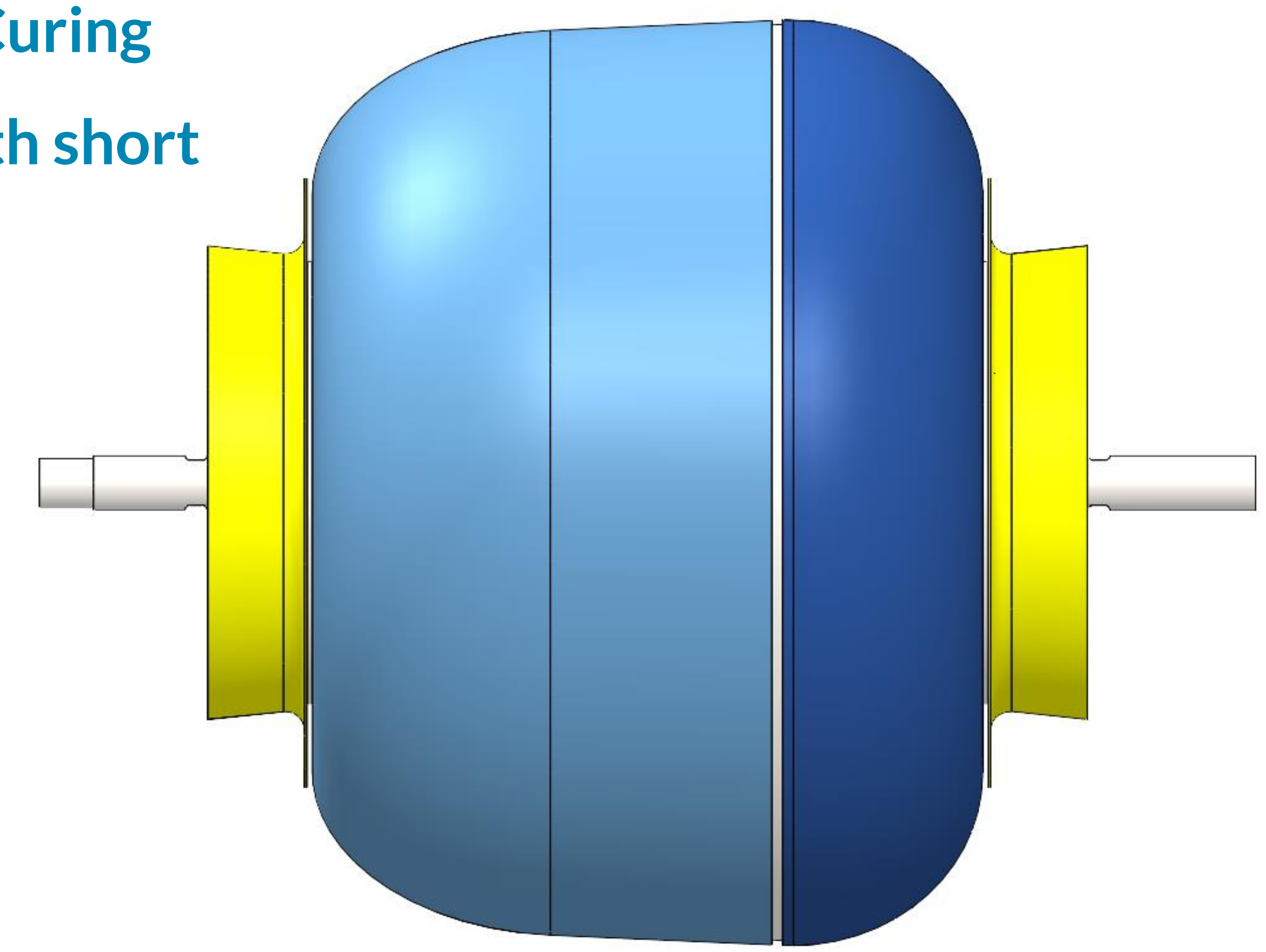
ITEM NO.	PEÇA	QTD.
1	Mandril_MainBody	1
2	Mandril_AFTCover	1
3	Mandril_Chapa_Ligacao	1
4	Veio_Mandril_RH	1
5	Acomplamento_Veio_RH	1
6	Veio_Mandril_Meio	1
7	Acoplamento_Veio_LH	1
8	Veio_Mandril_LH	1
9	Jante	2
10	Fairing	4
11	Apoio_Fairings	6
12	Parafuso_CHC_DIN_912_M6X70	2
13	Parafuso_CHC_DIN_912_M6X20	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

Different Configurations

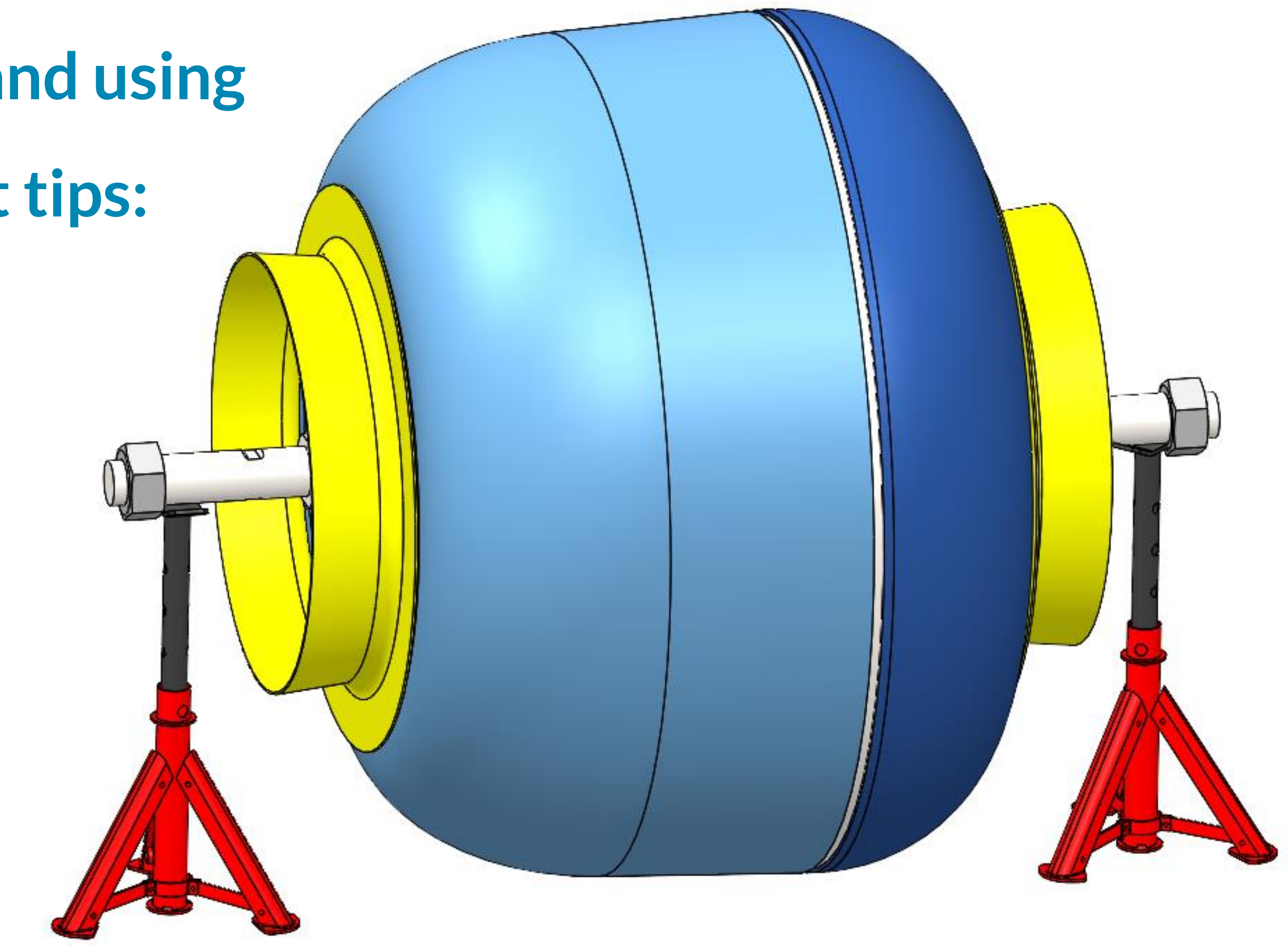
1 Winding configuration with long shaft tips:



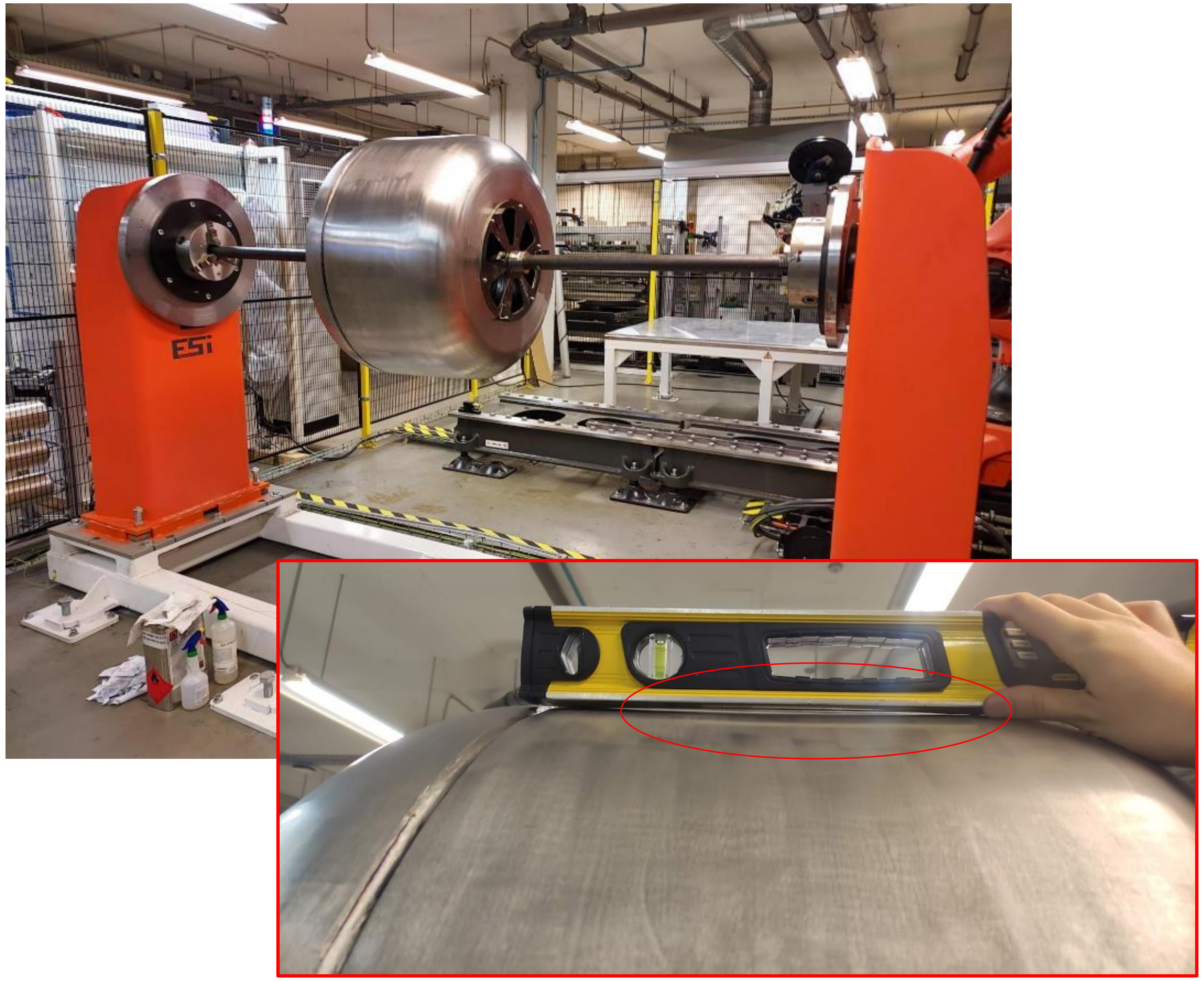
3 Transportation/Curing configuration with short shaft tips:



2 Horizontal Stand using the short shaft tips:



Finished Mandrel

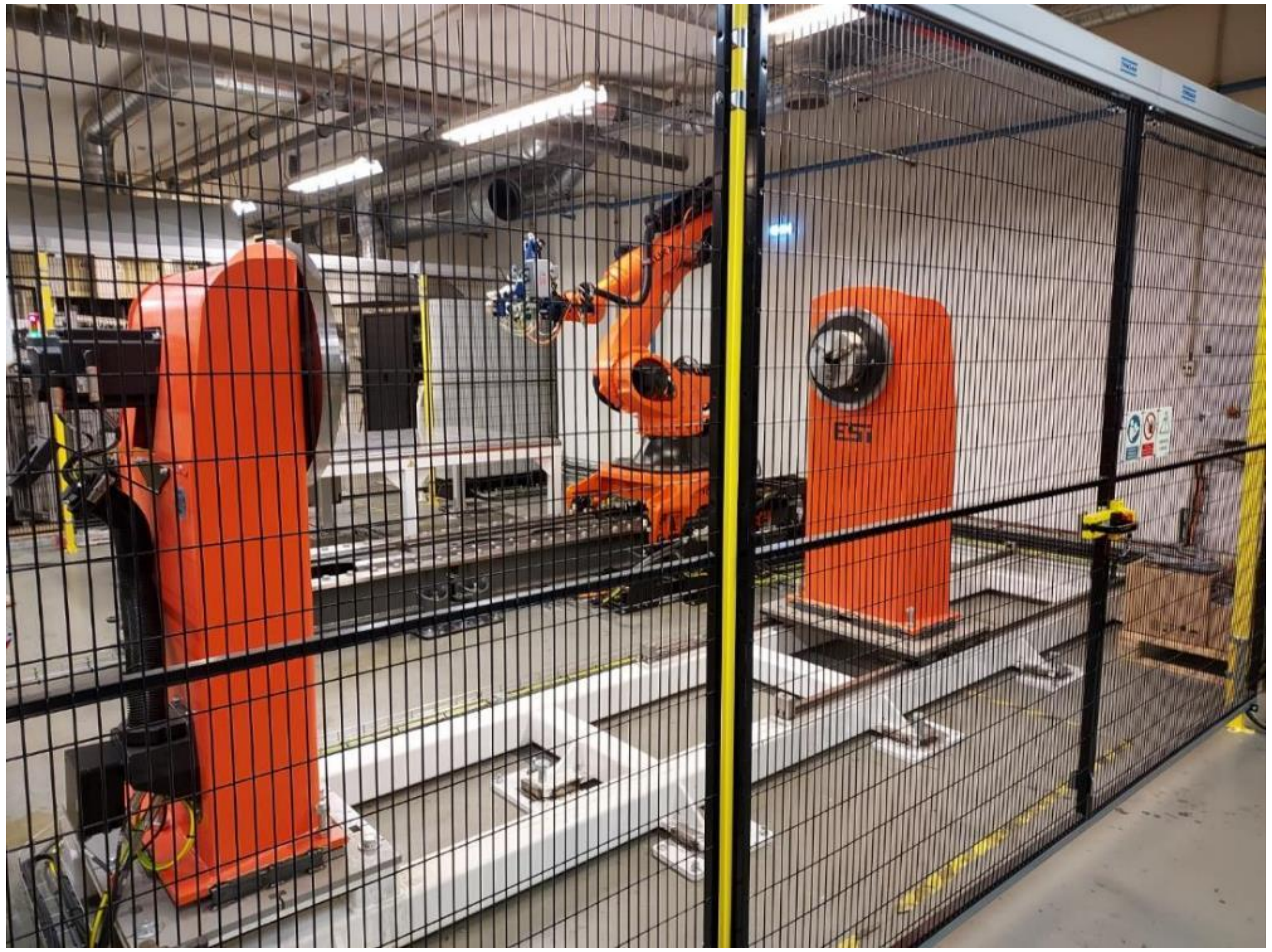


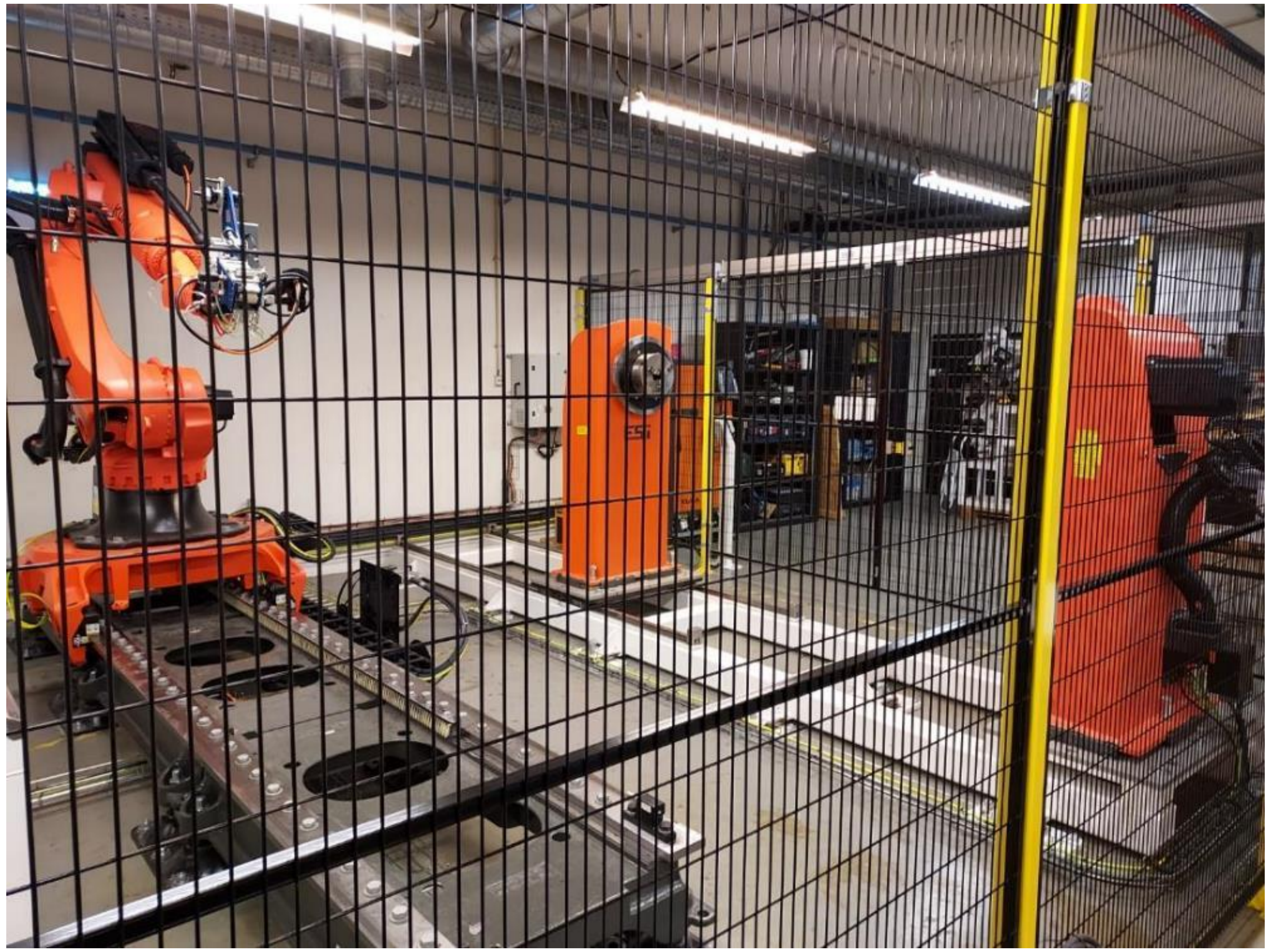
Negative draft angle due to sinking/warping

Good draft angle after correction

Manufacturing Preparation

Configuration and Assembly of Robot Setup



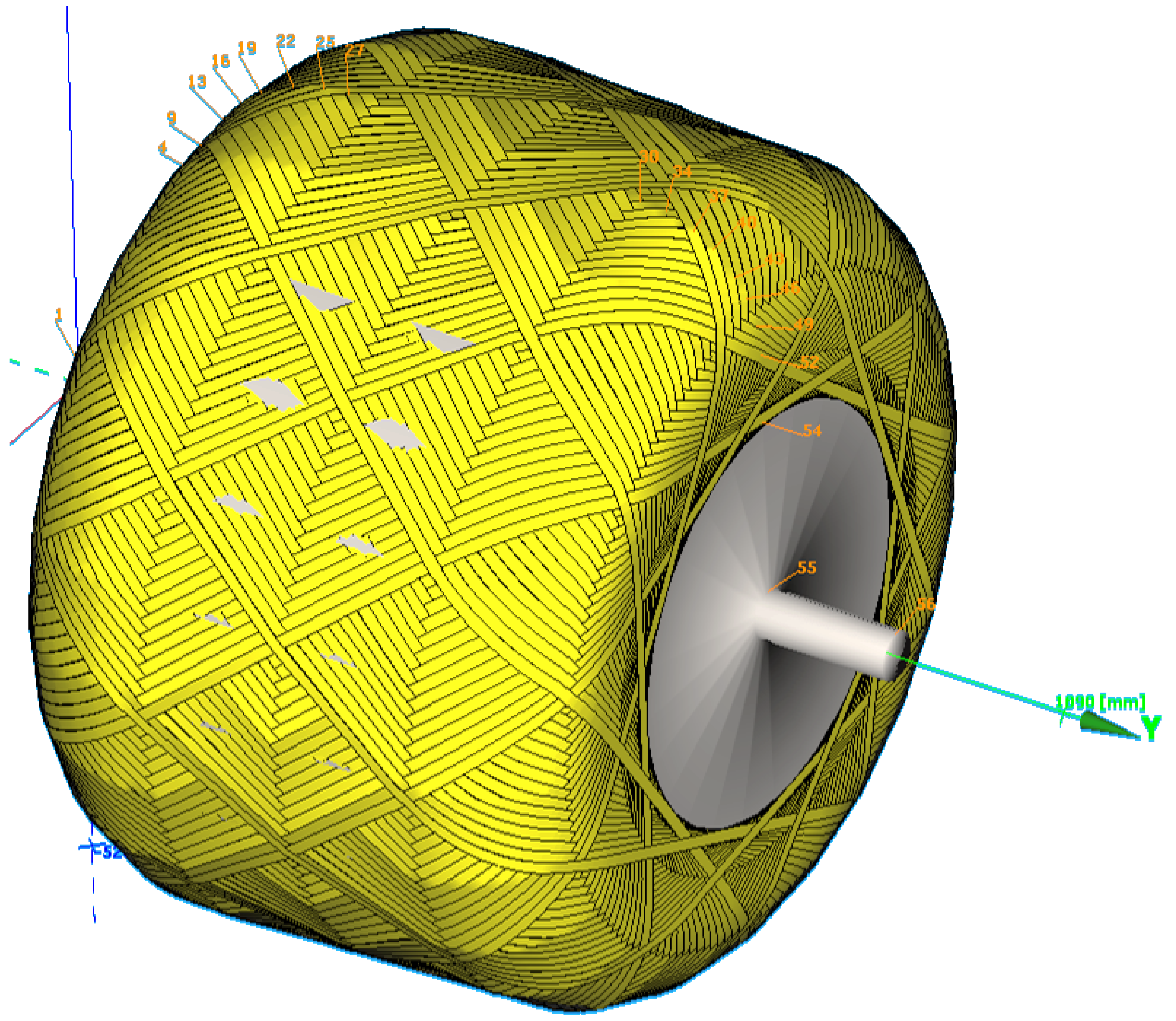


KUKA KR – 120 R2700 – Linear Axis KUKA KL 40000

Manufacturing Preparation

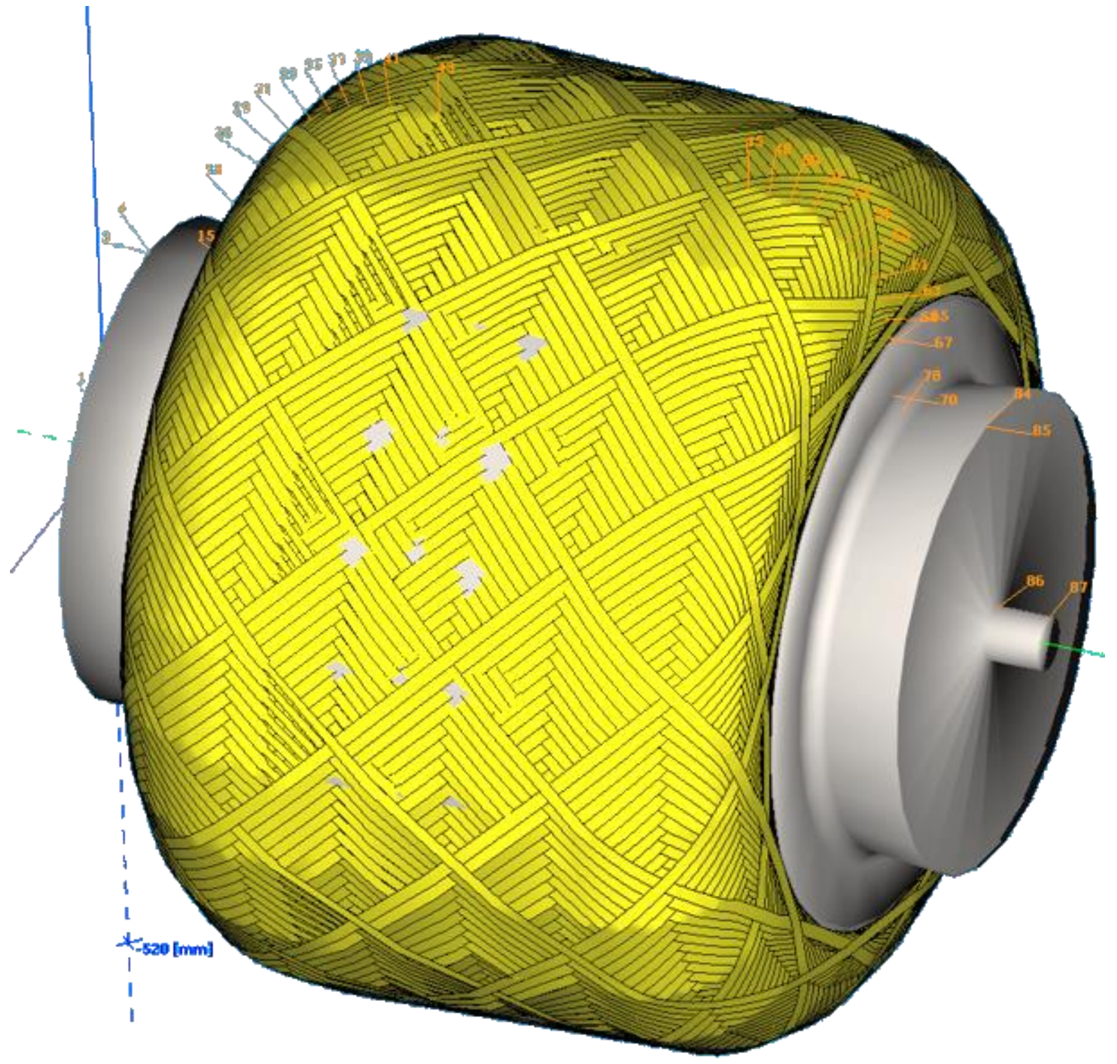
1º

First layers without the fairings



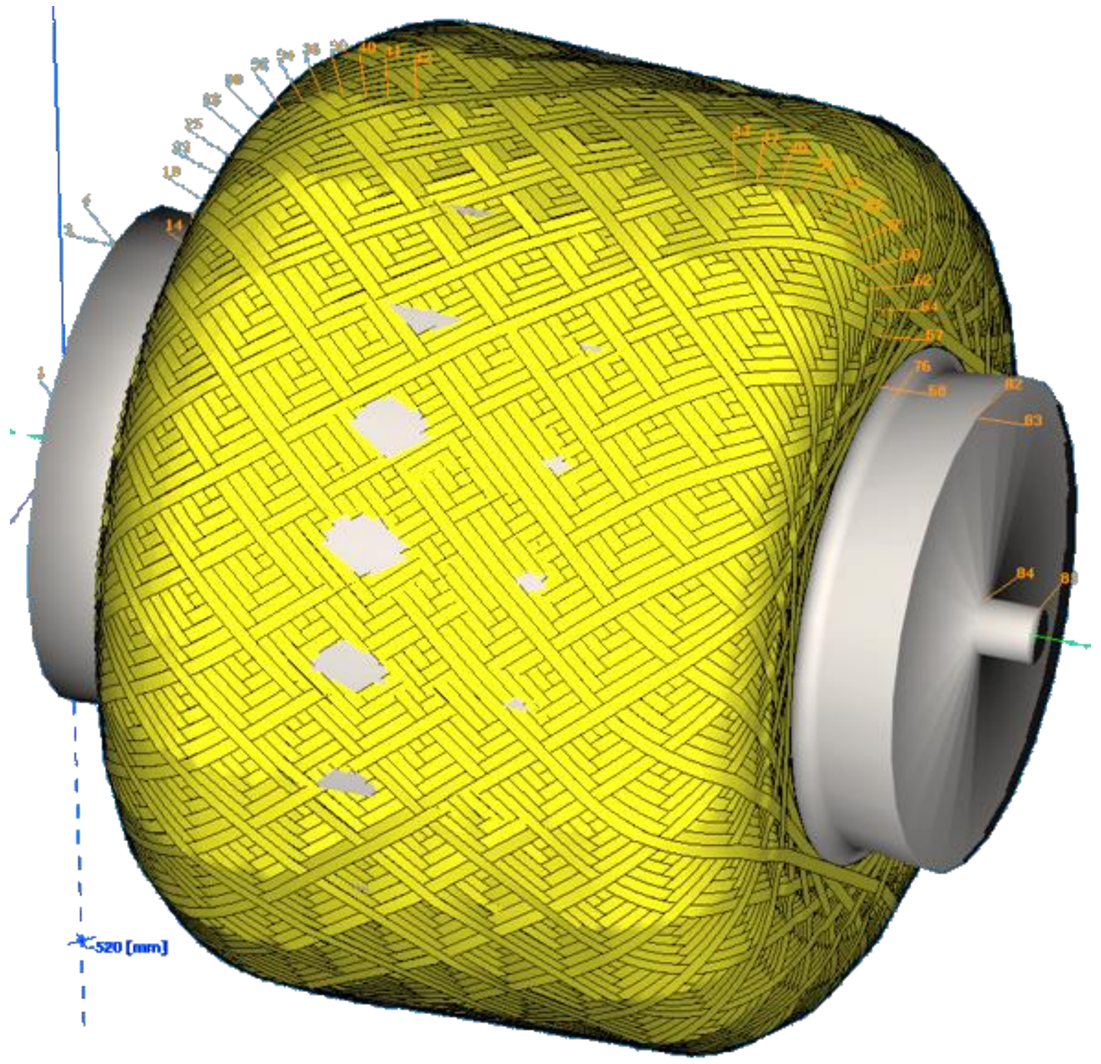
2º

Middle layers up to the top of the fairings



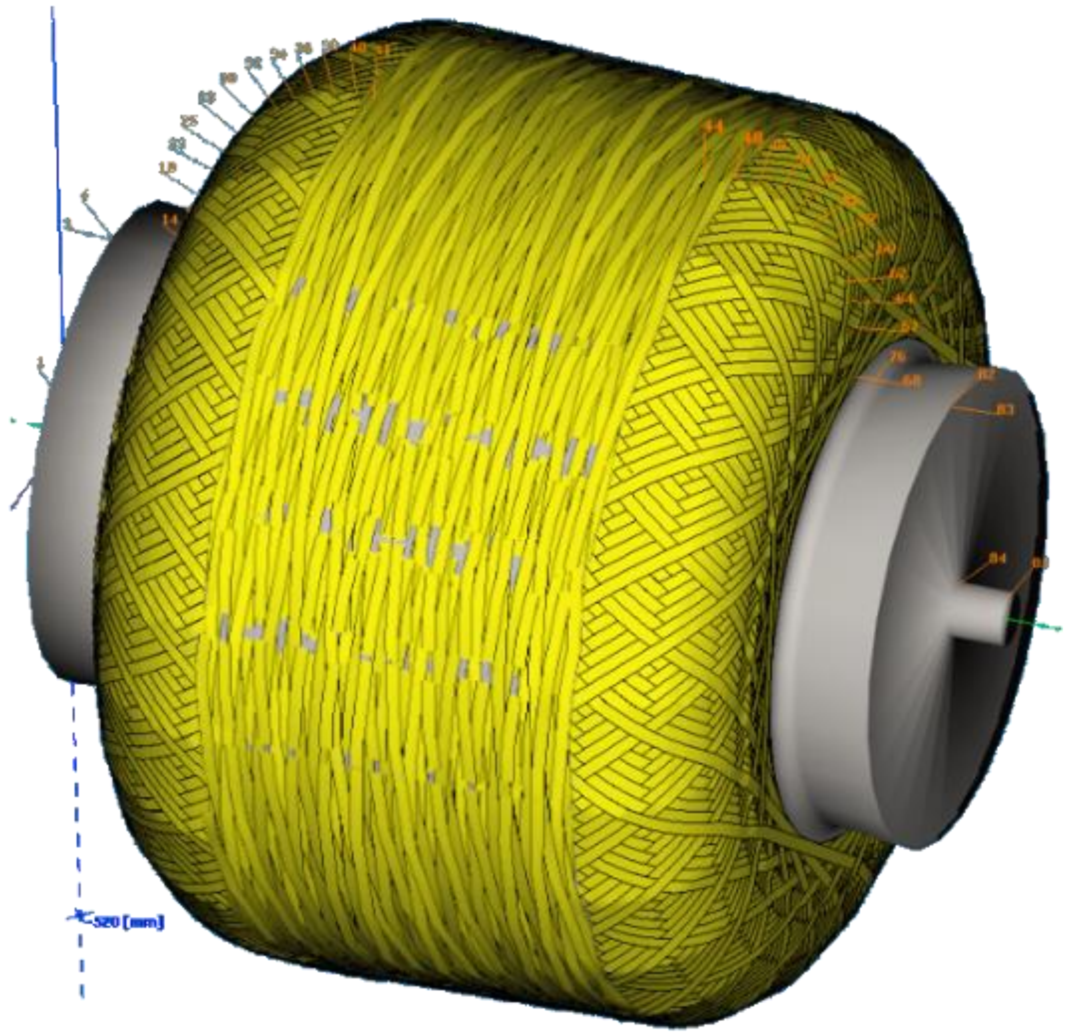
3º

Final layers closing the fairings



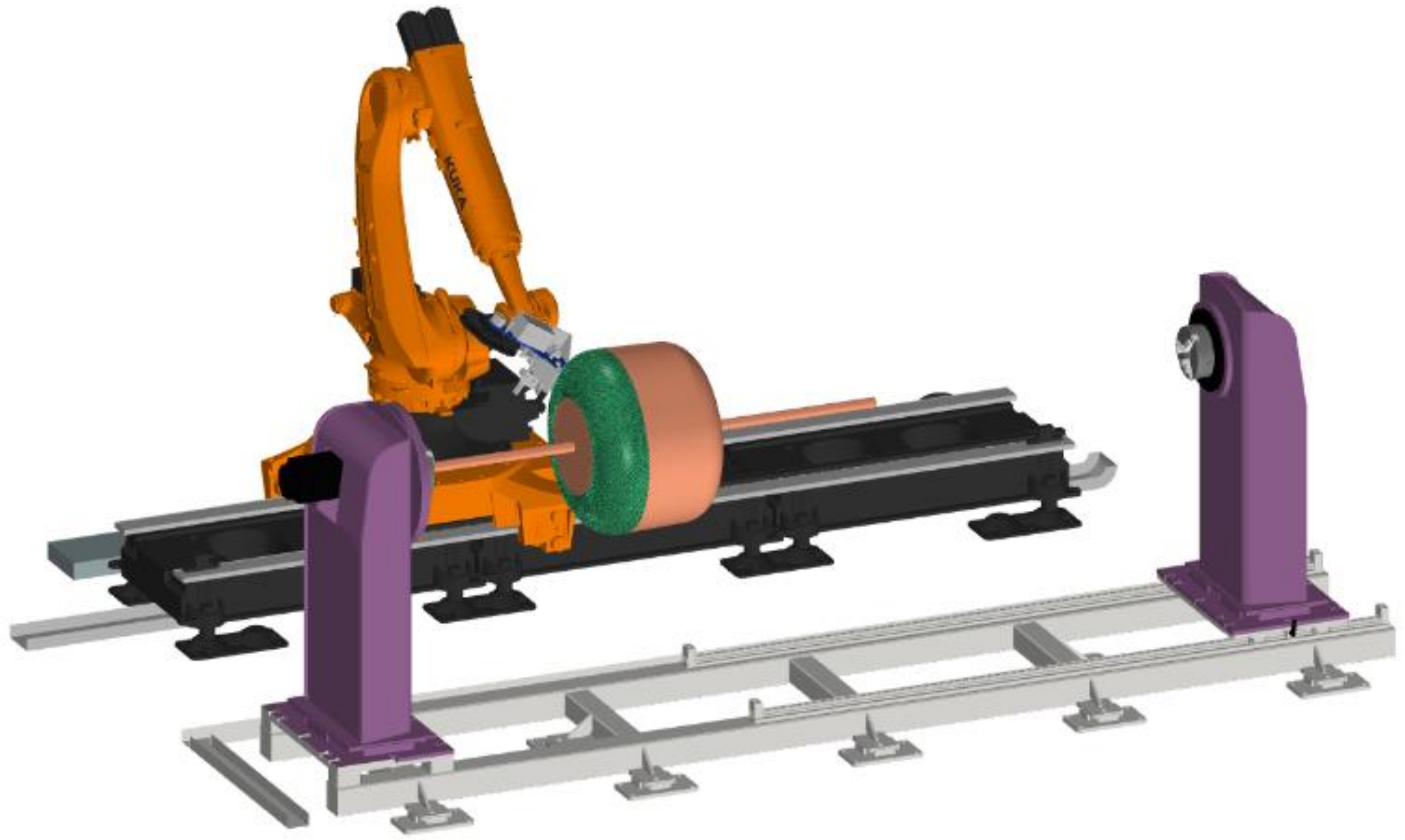
4º (Optional)

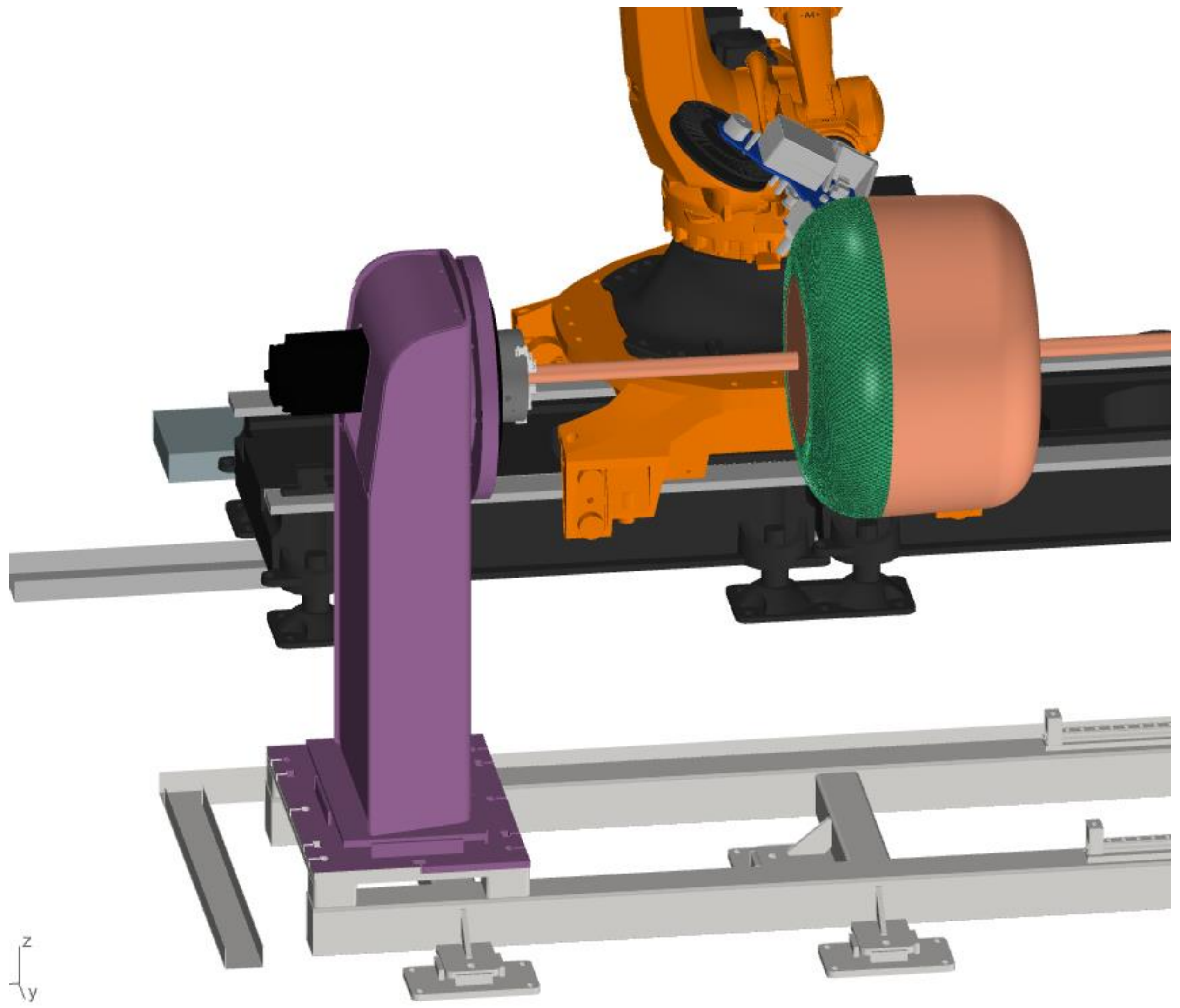
Hoop winding reinforcement

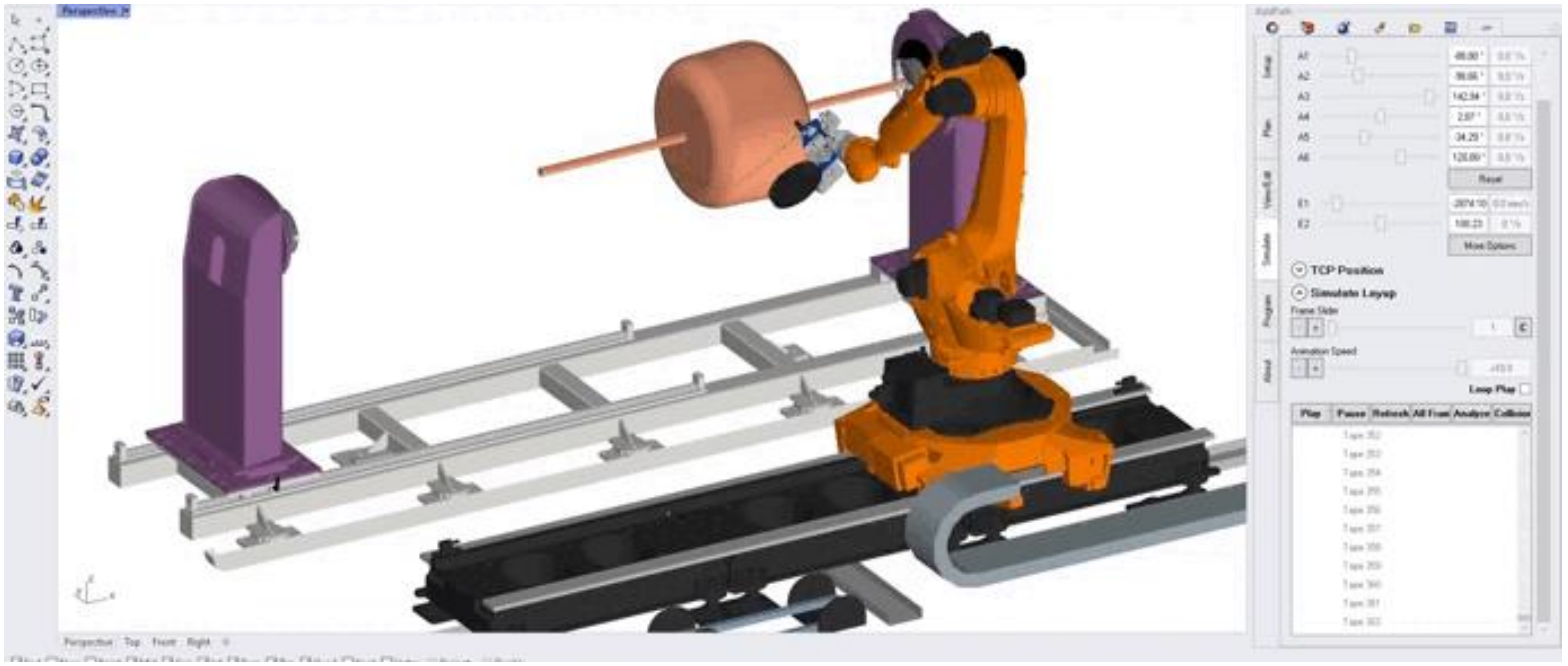


Manufacturing Preparation

Process Simulation ([AddPath])







Manufacturing Trials

Ongoing: First trials

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

Re-spooling from bobbin onto cassete
No available material already on cassete

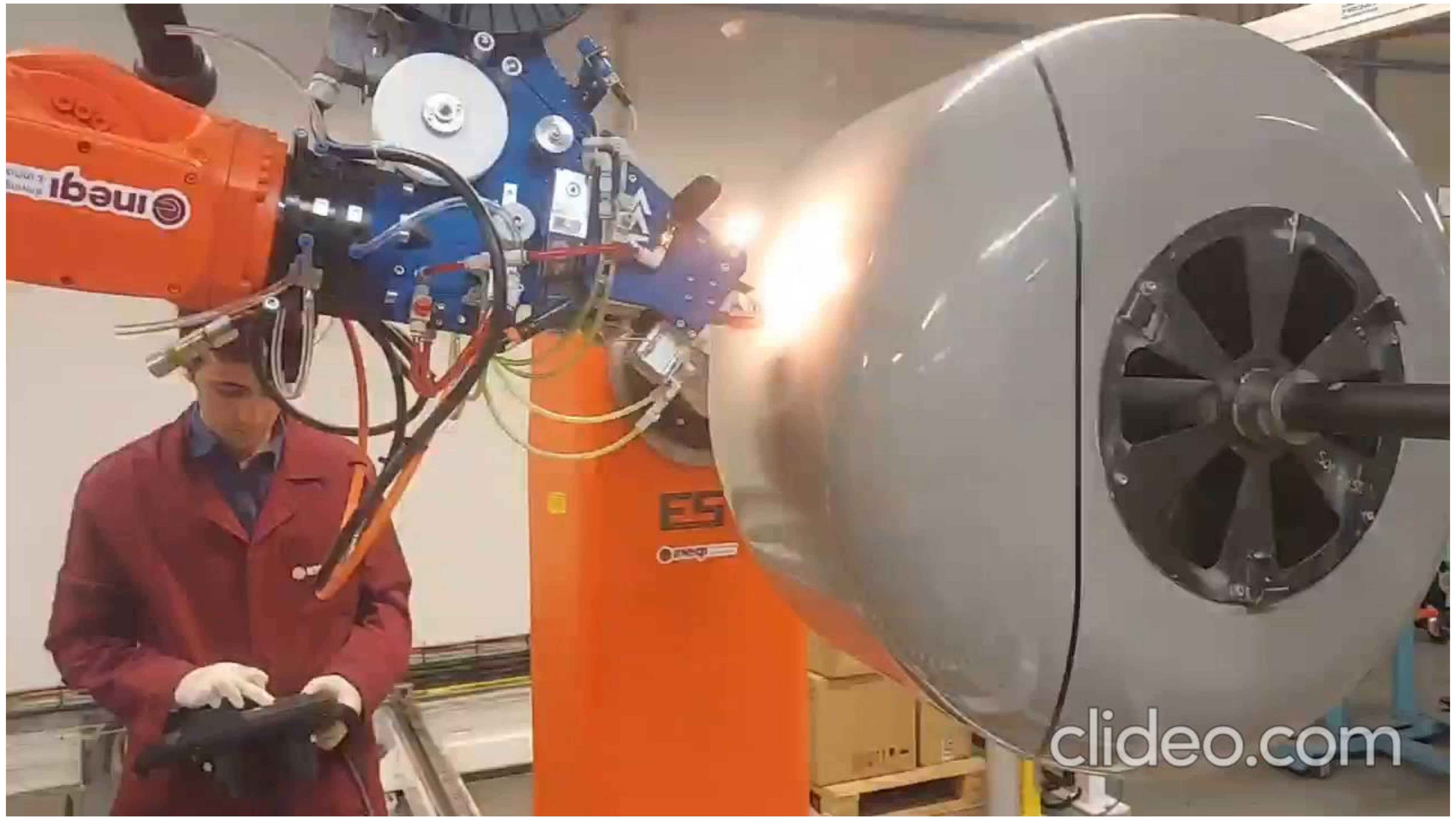
Placement of the first tows

Manufacturing Trials

Ongoing: First trials

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

Re-spooling from bobbin onto cassete
No available material already on cassete



Placement of the first tows (4x speed)

Next Steps

- Manufacturing of the turbine demonstrator
- Non destructive testing of the demonstrator

Next Steps

- Guidance notes for the production of large FRP OWTP


FIBREGY
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

Development, engineering, production and life cycle management of improved FIBRE-based material solutions for the structure and functional components of large offshore wind enerGY and tidal power platforms

D5.4 (WP5): Guidance notes for the production of large FPR OWTP

Responsible Partner: INEGI
Contributor(s): INEGI, TUCO, IXBLUE, BV

Current Progress

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

THANK YOU