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Technology, validation and demonstration

D6.2 (WP6): CONSTRUCTION OF THE W2POWER TOWER DEMONSTRATOR

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Executive Summary

This deliverable deals about the production of the two towers for the W2POWER windmill.

It explains all the production of those large composite parts, from the design of the tools to the delivery of the parts.

It enlightens the challenges faced to integrate all the constraints due to the material, the use and the research aspects of the project.

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1. INTRODUCTION

This document is introducing the process which was used for the W2POWER composite tower building. It is focused on the parts production and the issues related.

2. DESIGN AND TOOLING

2.1. Studies

The process of building starts with the studies for the building method. The inputs are the calculations from WP4. It validates the geometry of the demonstrator and the stress associated to the building process. It also gives the scantling of the part. In this case, each tower is made of two half tower connected.

The first step is to design a mould which can produce 4 symmetrical half parts without breaking the mould for each part. This point complexify the geometry of the mould as we have a sleeve of assembly on each half mast. So each part has more than 180° of revolution. So naturally the part doesn't go away from a mould in one part.

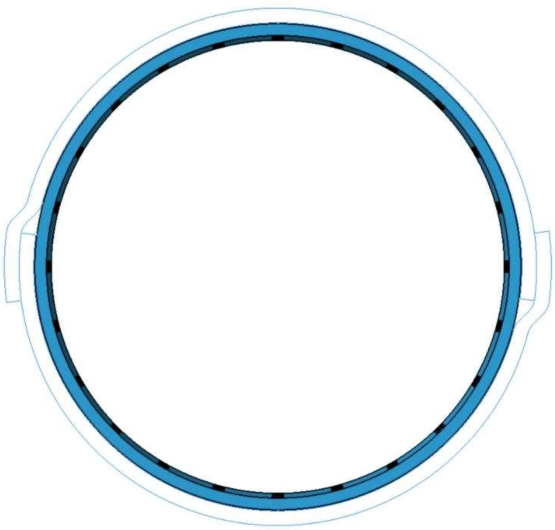

Figure 1 : design of the assembly of half masts

So the solution chosen was to add a plug in the mould. This plug should get out with the part and be reusable for the next part.

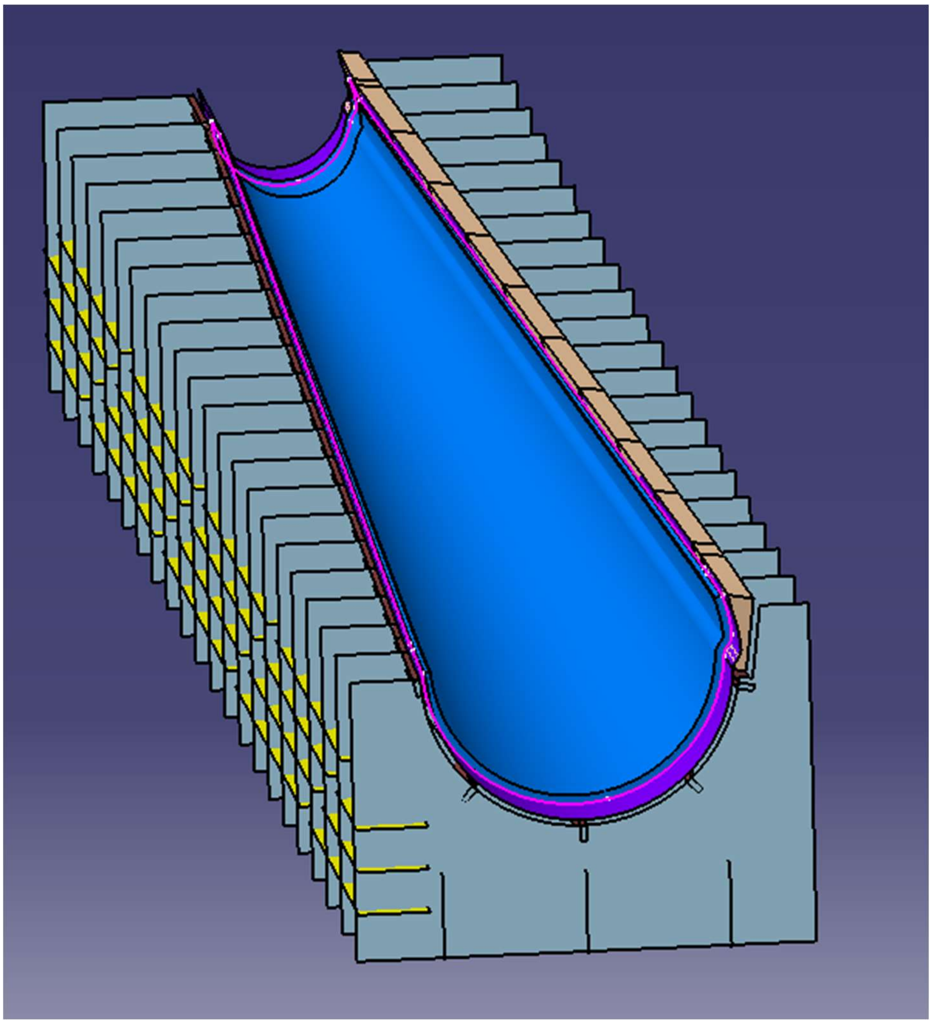

Figure 2 : half tower mould design with its plug

All the mould is designed with 3D software. The 3D files are following all the steps of the production.

2.2. Preliminary tests

To ensure a good realization of the parts several tests were performed. The first one was to validate the feasibility of the part with a way of infusion.

The maximum scantling was put in a mold with similar section to the real one.

Figure 3 : test mould

A difficulty with carbon fabric is to know what is happening inside the part, as nothing is visible contrary to the glass fiber which is translucid. So to have more information about the resin penetration a glass layer was added on both sides.

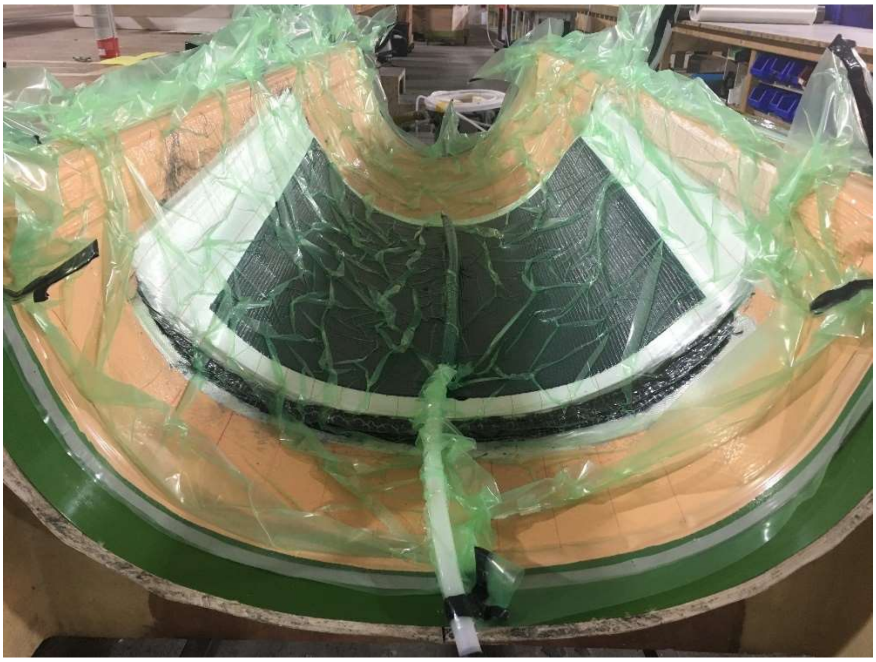

Figure 4 : Infusion test

The first part was cut in many slices to check that the resin impregnation was conform everywhere with no dry spot in the core of the part.

Figure 5 : slice cutting of the test part

Another batch of test was to validate the exact thickness of the part. One question was to know the impact of the overlapping. The width of a roll fabric is 127cm and the developed width of the mould is larger. So we have overlapping of the fabric which is increasing the total thickness of the part. The knowledge of the total thickness is primordial for the mould design. We are starting from the geometry of the metal ring, we add the gap between the metal and the composite part and then the thickness of the composite part. This gives the surface of the female mould.

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Figure 6 : edge of the test part

Figure 7 : detail of overlapping

Another test was to know the reaction of the casting resin with the assembly imagined. The resin has to stay in the gap between the parts. But this type of product is very fluid and can escape by any tiny hole.

Figure 8 : resin casting test

2.3. Mould building

Once the mould is designed in 3D by the design office, the file is forwarded to the computer numerical cutting department. The 3D file are converted and coded into files that can be read by the numerical machines. Moreover the design should be post treated to be adapted to the dimensions of the raw material. For example, the flat parts should not exceed the standard dimensions of plywood panels. For larger parts, it should be an assembly of “small ones”.

Figure 9 : panels cut by CNC

As explained previously, the mould is using several technologies. The first one is 3 axis milling, the second one is 5 axis milling.

The plug part is done with 5 axis milling machine due to the complex shape of those parts.

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Figure 10 : plug milling

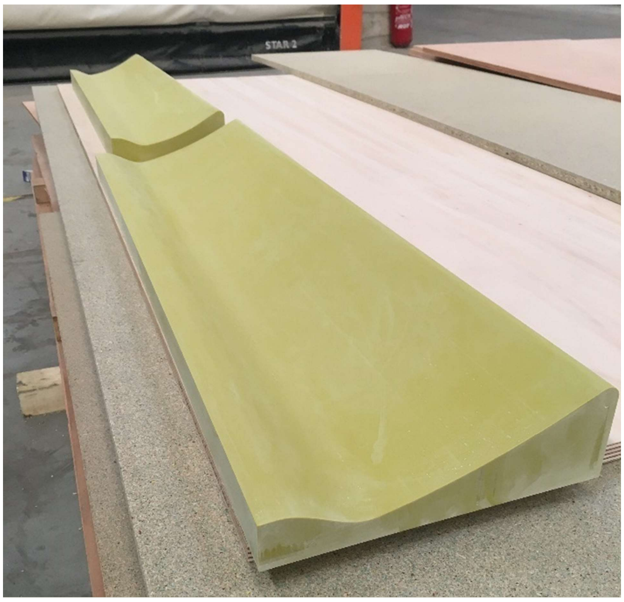

Figure 11 : section of plug finished

Once all the parts of the "puzzle" are ready, we can start the building of the mould structure.

The design was made to have a self blocking geometry of the structure. Each part is participating to the general stability of the mould.

Figure 12 : mould structure

Then the mould structure is covered with several layers of soft ply wood. The orientation of the wood fibre is very important to ensure a smooth surface. The wood surface is laminated to give more strength to the mould and allow a production of several parts is the same mould.

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The finish step is made of fairing to erase the local defects, primer and paint to have an air tight mould. In the case of parts made by infusion with epoxy resin it is mandatory to have an air tight mould.

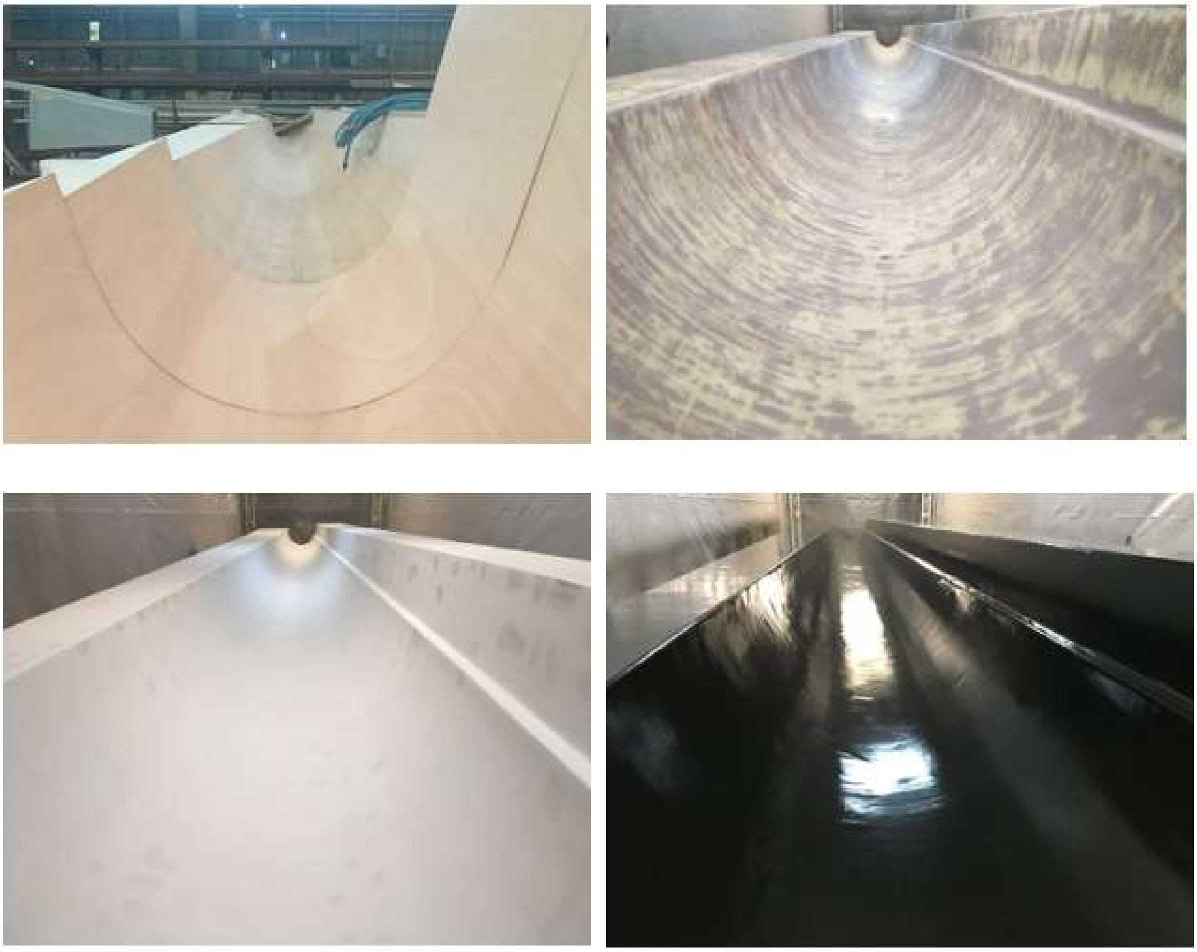

Figure 13 : finishing steps

Once the vacuum test is validated, the mould can be waxed. The waxing system depends of several parameter like the temperature, the type of resin, the type of process...

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The plugs are coming in a recess made in the mould. Their utility is to allow the production of a part with a geometry which couldn't get out of the mould without breaking it. They should come with the part when unmoulding. The plug's integration is challenging as they should be strong enough for the lay up and they should slide perfectly when unmoulding the part.

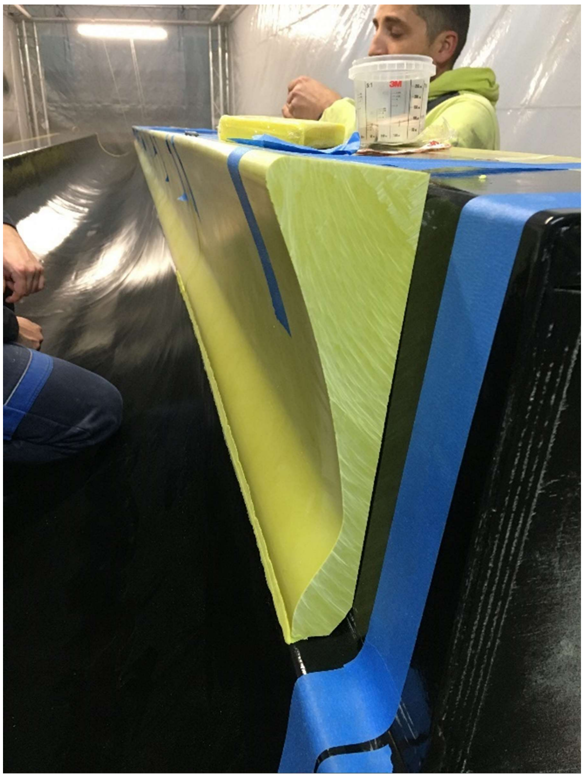

Figure 14 : plug's integration

3. TOWER PRODUCTION :

The goal is to produce 4 half towers made of composite. By the end of the process is will give the 2 new masts of the W2POWER plateform.

The first step is to lay the peel ply in the mould.

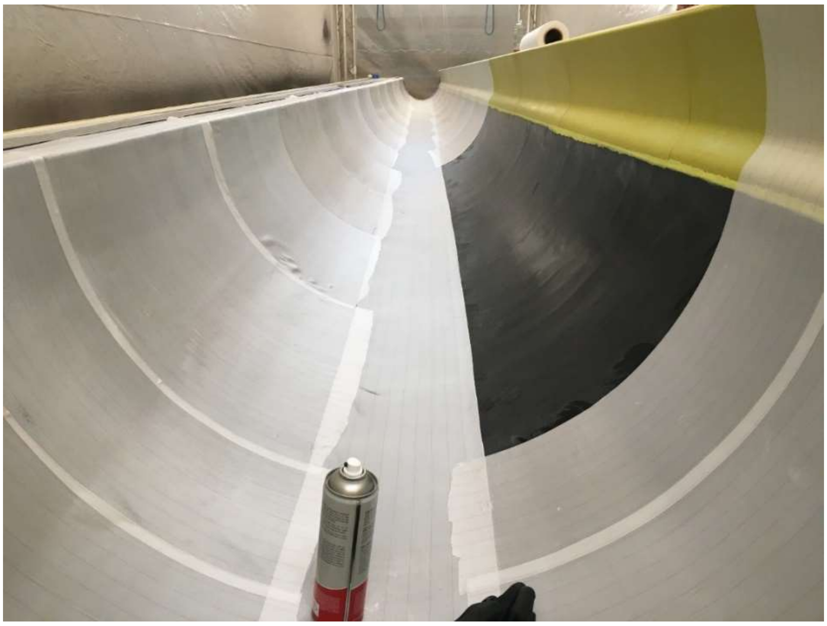

Figure 15 : peel ply on the mould

The width of the mould is larger than the composite roll's (127cm). So overlapping are mandatory for each ply.

According to the tests the positioning of the overlapping is very important to avoid making extra thickness area. So the lay up is done with a special care to the angle position of the overlapping for each ply in order to make a nice repartition of the extra thickness.

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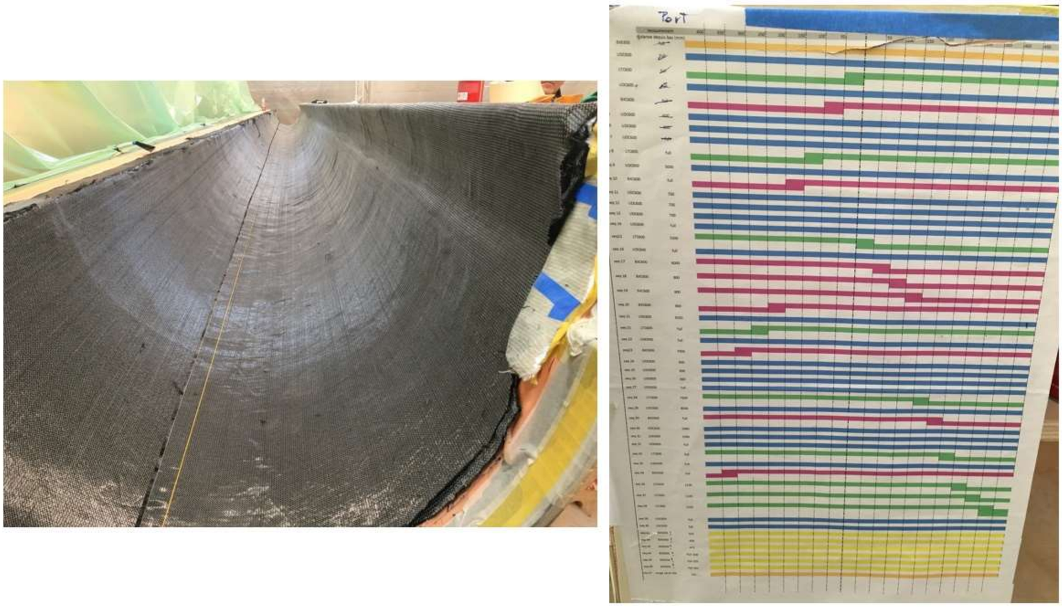

Figure 16 : lay up of the half tower

Due to the large thickness of the parts, every night the part is kept under vaccum to have a good compacting of the fabric.

Figure 17 : Compacting of the fabric

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Once all the layer were in the mould, all the flow media were laid.

The infusion had to be performed in an environment with a good management of the temperature. The big thickness of the part is making the control of all parameters vital. If any of them is turning wrong the infusion can fail. In such a case all the material goes to the garbage.

Figure 18 : infusion

After the polymerization of the resin, the parts are post cured to ensure the best properties of the composite. Once this step is done, the parts are removed from the mould and the edges cut according to the final dimensions.

Figure 19 : half mast unmoulded

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Due to the internal dimensions of the mast, the assembly solution chosen is to bolt both parts. It is not possible the have operators working inside for long lamination process.

A stripe of steel is laminated on each half part in order to be drilled and thread during the assembly without internal intervention.

Figure 20 : lamination of the steel insert

Some extra layers of glass fabric were added in the rings areas to have a possibility for grinding in case of geometry problem. The aim is not to grind the carbon fabric.

Another function of this layer is to be an insulator as glass is a non-conductive material.

Figure 21 : Two half parts ready for assembly

The assembly of the two halves is to be done according to the following schema.

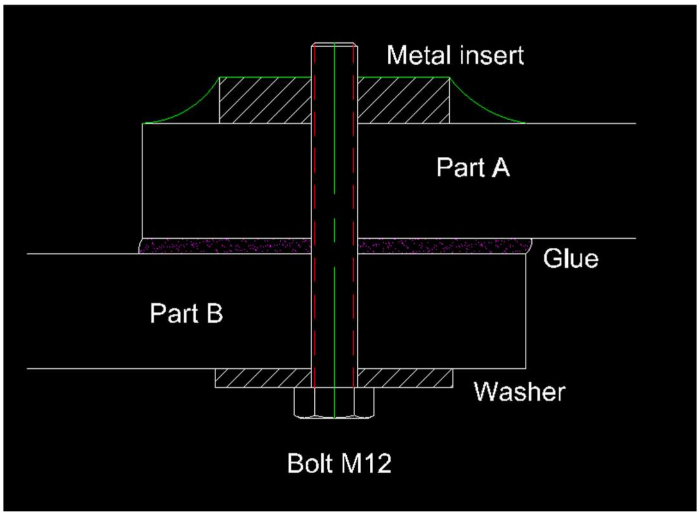

Figure 22 : assembly schema

The geometry setting is a serious concern. The top ring is assembled in iXblue facilities, but the bottom ring is going to be removed for the final assembly in Canaria Island.

A gap of 2mm is asked for the bottom part to ensure the movement of the ring during the mounting operation. The rings are supposed to be circular, but in reality, due to the thickness of the steel, the rings are more or less circulars.

So the assembly should take into consideration the following constraints :

- possibility to remove and re-assembly the bottom ring,
- drill the junction bolts for the two halves in the middle of the inserts,
- make the assembly and the resin casting for the top ring possible.

A specific trolley was designed to perform the hundreds of holes for the assembly procedure. The berth system is design to maintain the top part of the mast on a horizontal line to fit the drilling system on the trolley.

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Figure 23 : drilling trolley

The drilling operation is quite a long step, as there are more than 300 holes to drill and thread.

Figure 24 : drilling operation

The bolts are put for an temporary period to allow the turning of the mast.

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Figure 25 : Temporary bolting

During the pre tightening an area between the two parts was not correctly fitted with glue. The stiff of the part is so important that with a very low torque we encountered a delamination in the area. We had to perform an non destructive ultrasonic survey to evaluate the damage and set up a repairing process.

Figure 26 : results of ultrasonic NDT

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The repair process was to grind from the surface to the delamination and to rebuild the scantling by vaccum hand layup. All the scarf and overlapping were respected.

Figure 27 : grinding of the area

Figure 28 : Repair under vaccum

Once the assembly of the two half masts done, the assembly of the extremities could happen.

Some special tools were made to use the thread of the bottom ring as a guide, but without any risk of damaging them. From this step the position of the ring regarding the tower cannot be changed.

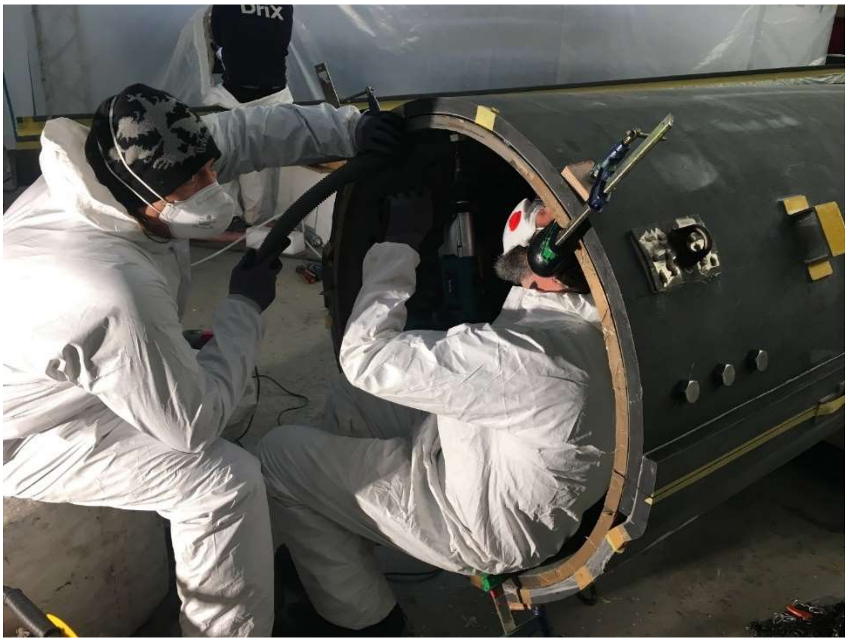

Figure 29 : drilling for bottom ring assembly

We had to keep the gap maintaining tools during the drilling process to ensure a good possibility of movement for the final assembly.

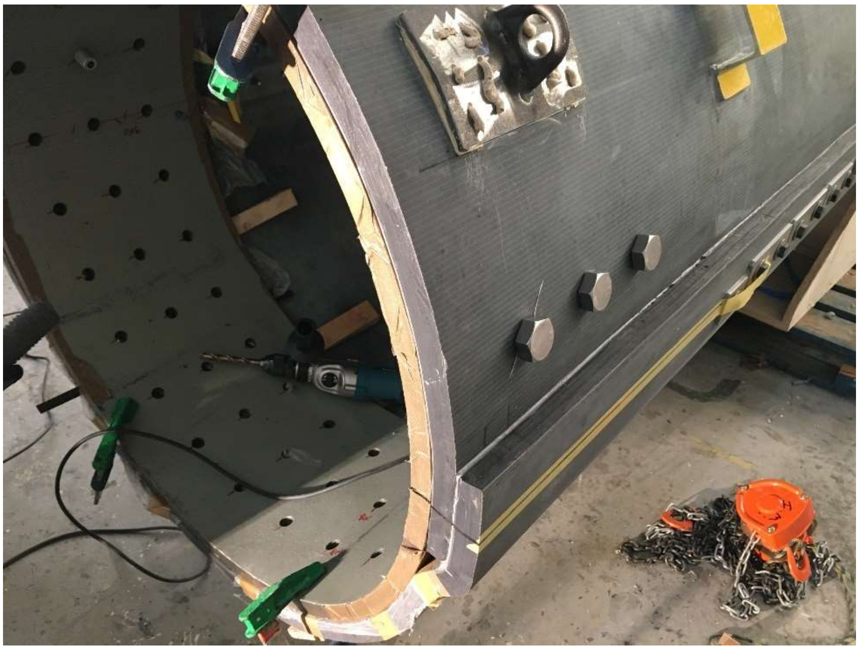

Figure 30 : details of gap maintaining tool during drilling

Once in the right position, a resin casting should fill the gap between the composite part and the metallic ring.

Figure 31 : resin casting for top ring

Once the gap filled, the bolting process is carried on. Like for the other one, repartition plates are use. The torque can be applied on the bolt with no risk of damaging the composite.

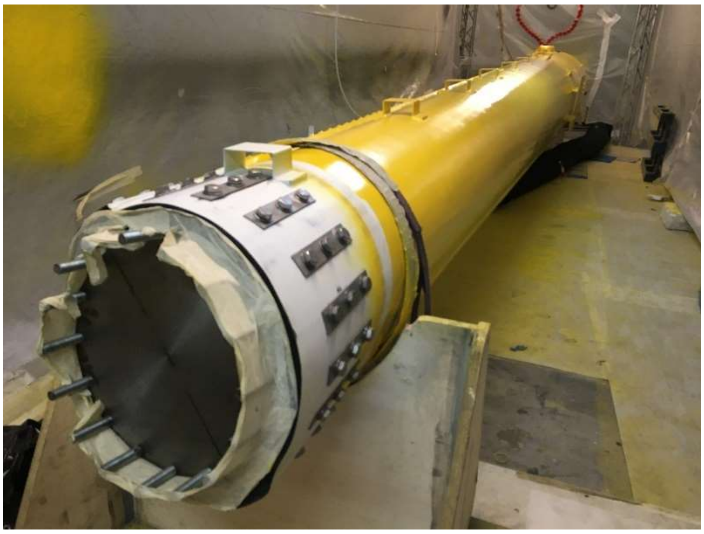

Figure 32 : Top ring bolted

3.1. Supports integration :

The tower has several equipment fitted on. Two electrical boxes, two camera supports and a cable tray to have the connection from the nacelle to the platform.

Several supports were used to do a process test with the dry paint coating.

Figure 33 : cable tray support with dry coating

The supports were bonded or laminated, depending of the weight supported.

Those supports allow an easy interface with the equipment. They can be drilled and bolted without having composite knowledges.

Figure 34 : electrical box support laminated

3.2. Optic fiber sensors integration :

The towers have several type of sensors.

Some of them are optic fiber with BRAGG networks. Three fibers are embeded in the composite of the tower.

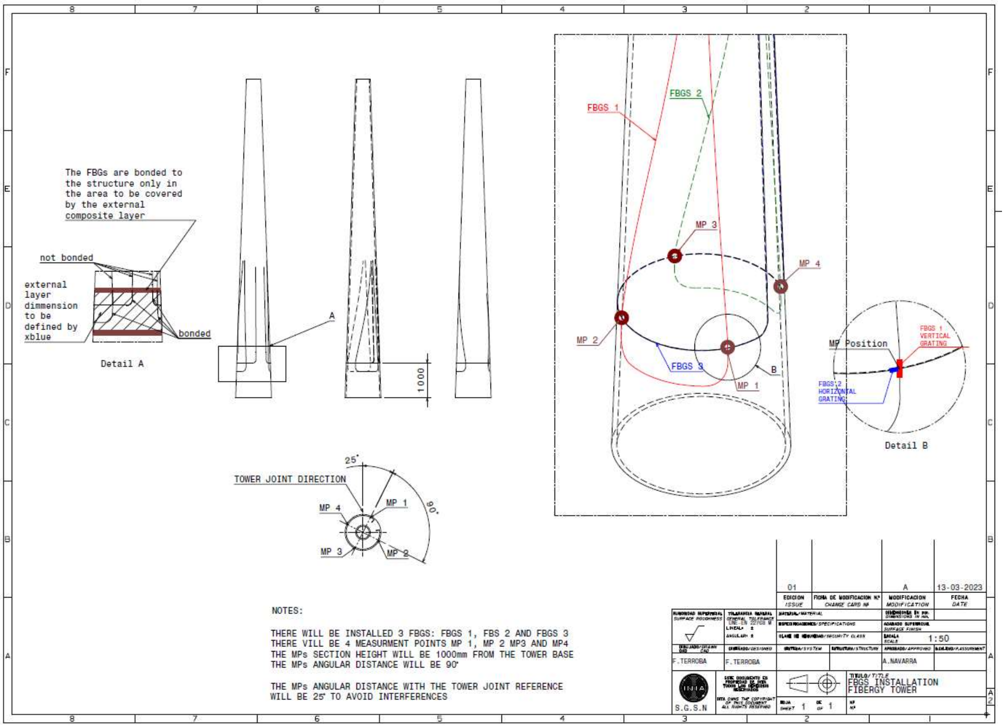

Figure 35 : optic fibre positioning drawing

The positionning is accurate in order to compare the real datas to the digital twin.

One line is horizontal and the two other one should cross on a vertical axis.

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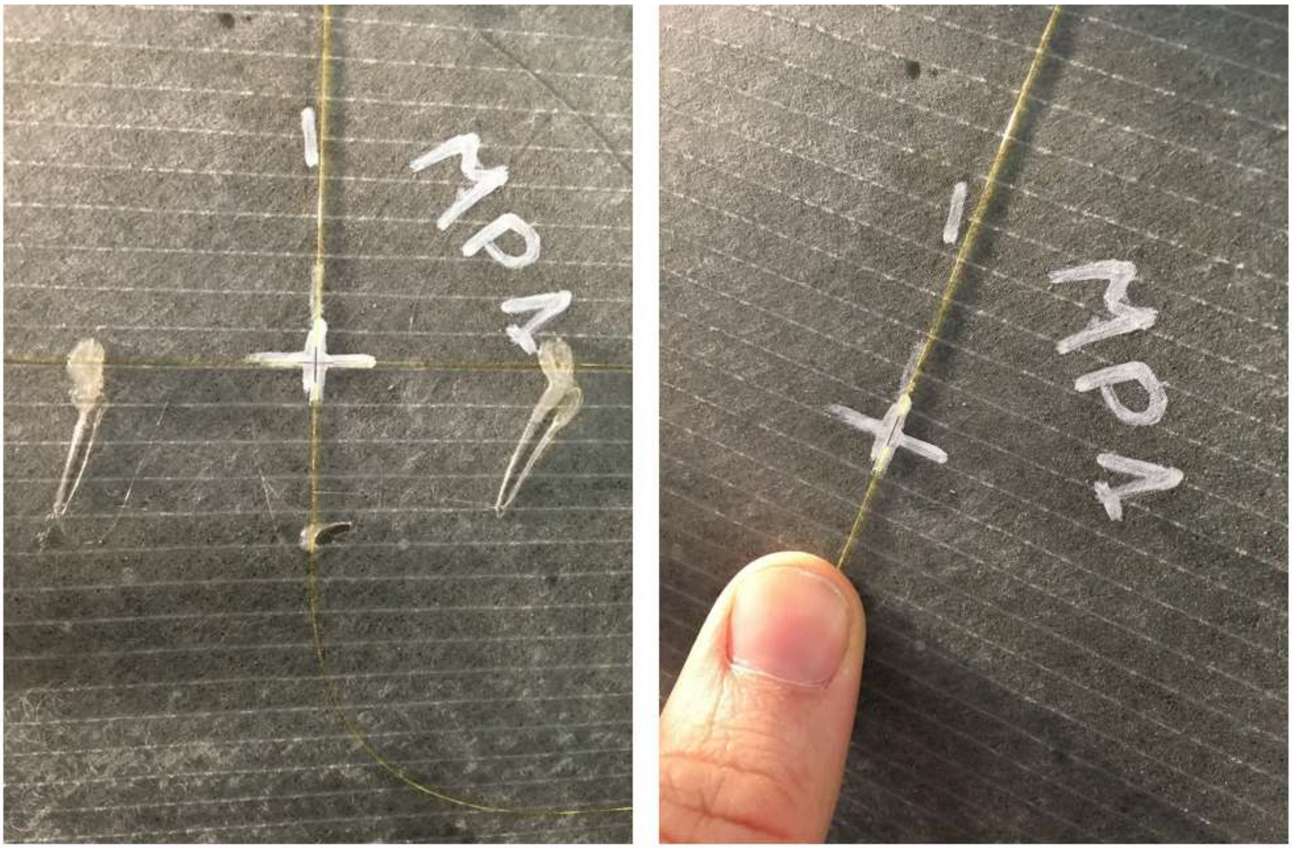

Figure 36 : crossing point for 2 optic fibres and size of the fibre regarding a finger

The black area on the fiber is the BRAGG mirors engraved in the optical fibre. Theses small areas should be on the defined points.

One dificulty is to work with the bare fiber. The embeded fibre area has no protection, so the fiber is very fragile and complicated to see during manipulation.

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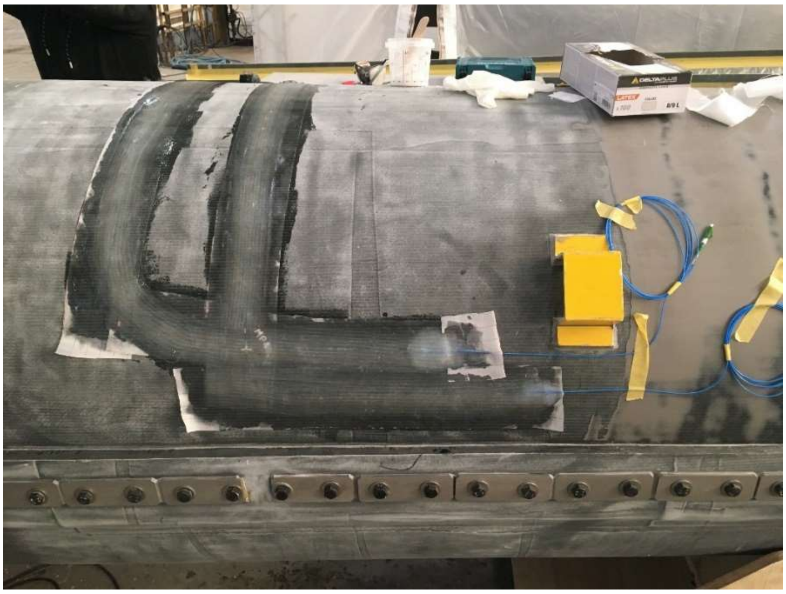

Figure 37 : optic fibre laminated to the tower

There is an extra length (with protection in blue) ended by the connector. This connector will be plugged to the interrogator to have the data for the structural health monitoring of the structure.

3.3. Finishing

The tower got a finishing system. The steps were a fairing of the surface to eliminate the small defects, a primer and a topcoat respecting the color reference.

Figure 38 : mast with fairing

Figure 39 : mast in primer

Figure 40 : Mast with topcaot

The last step is to apply the stickers with the logos and the EU official texts.

The mast was ready for shipping from France to Canaria Island.

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Figure 41 : mast ready for shipping

The process for the second mast is exactly the same. It was more smooth as we have faced and learnt from the problems on the first mast.

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3.4. Delivery

The first mast was delivered in the local shipyard in Canaria Island. Some technical meeting occurred to define to process for the towers' swap.

Figure 42 : composite mast and steel demonstrator

4. Conclusion

The building of the two masts was a technical challenge with many constraints from many fields. The aim was to integrate all of them and produce the parts according. Many problems occurred during the process, but all of them were solved and the production went to the end.