MAKING A BOAT
RECYCLABLE PROTOTYPE

Prepared by Daniel Poirier, ing.
Composites Development Centre of Québec

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As part of a collaborative project with Innovation Maritime (IMAR), a prototype boat made of recyclable composite materials was built. The objectives of the IMAR/CDCQ project were to study the performance of recyclable materials in the design of ships. In order to create a product that meets eco-design principles, the manufacturing process of the demonstration boat was completely rethought. To allow the replacement of elements that are difficult or not recyclable (wood, core, polyurethane foam), the structure was manufactured differently. Here are the details of the manufacturing of the proposed boat according to a recyclable design.

STEP 1 : MANUFACTURING OF THE THERMOPLASTIC COMPOSITE SHELL

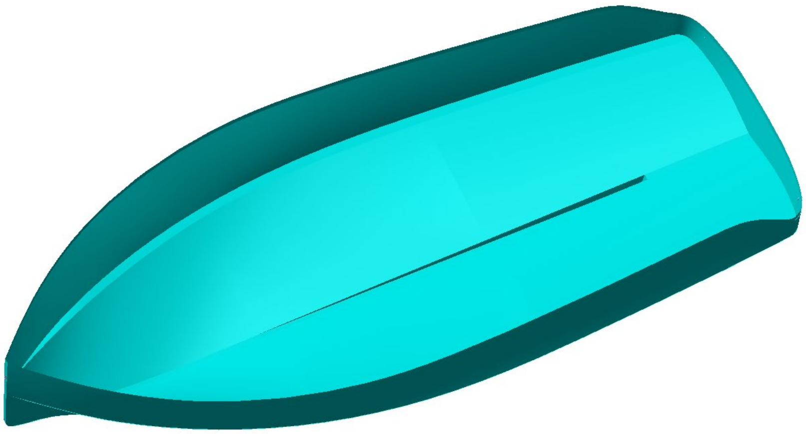


Figure 1. Moulding of the thermoplastic composite shell

The boat hull (Figure 1) was produced by infusion with fiberglass and acrylic resin in a predetermined sequence.

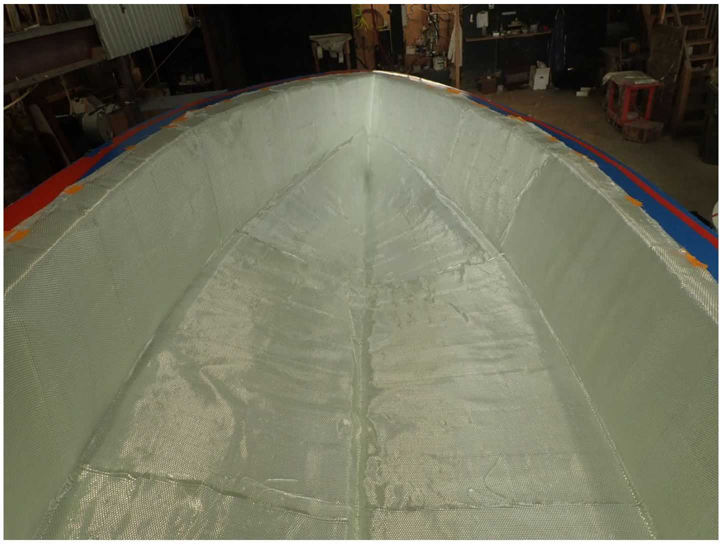
First, an NPG-isophthalic polyester gelcoat (AOC Vibrin G315AC) was applied in the mold as an aesthetic layer (Figure 2).

Next, the fiberglass reinforcements were deposited in the mold in the order shown below (Figure 3). Note that recycled composite inking inserts were added into the construction at specific locations (front and back) for future attachment.

Figure 2. Application of gelcoat in the hull mould

Mat 1.5 oz/pi² (Vectorply E-M-0015)
Mat 1.5 oz/pi² (Vectorply E-M-0015)
WR 15 oz/vg² (Georgian Bay Reinforcement Fabrics R15-A01)
Mat 3 oz/pi² (Vectorply E-M-0030)
Mat 3 oz/pi² (Vectorply E-M-0030)
WR 15 oz/vg² (Georgian Bay Reinforcement Fabrics R15-A01)
Mat 1.5 oz/pi² (Vectorply E-M-0015)
Mat 1.5 oz/pi² (Vectorply E-M-0015)
Gelcoat (AOC Vibrin G315AC)

Figure 3. Sequence of shell construction



Afterwards, the bagging materials (release film or peelply, infusion medium, tubing, sealing tape and sealing bag) were placed (Figures 4, 5 and 6) and then the laminate was vacuum infused with Arkema Elium™ 188O resin. Once the resin was cured, the part was demolded, and the periphery was cut out.

Figure 4. Positioning of the reinforcements in the hull mold

Figure 5. Positioning of release film, medium and infusion lines

Figure 6. Bagging and infusion of the shell

STEP 2 : MANUFACTURE OF THE BRIDGE IN THERMOPLASTIC COMPOSITE

As with the hull, the boat deck was fabricated by infusion with fiberglass and acrylic resin. Structural elements (stiffeners and anchor inserts) were integrated into the casting at certain locations in the part (Figure 7). The sequence of deck constructions is shown in Figure 8.

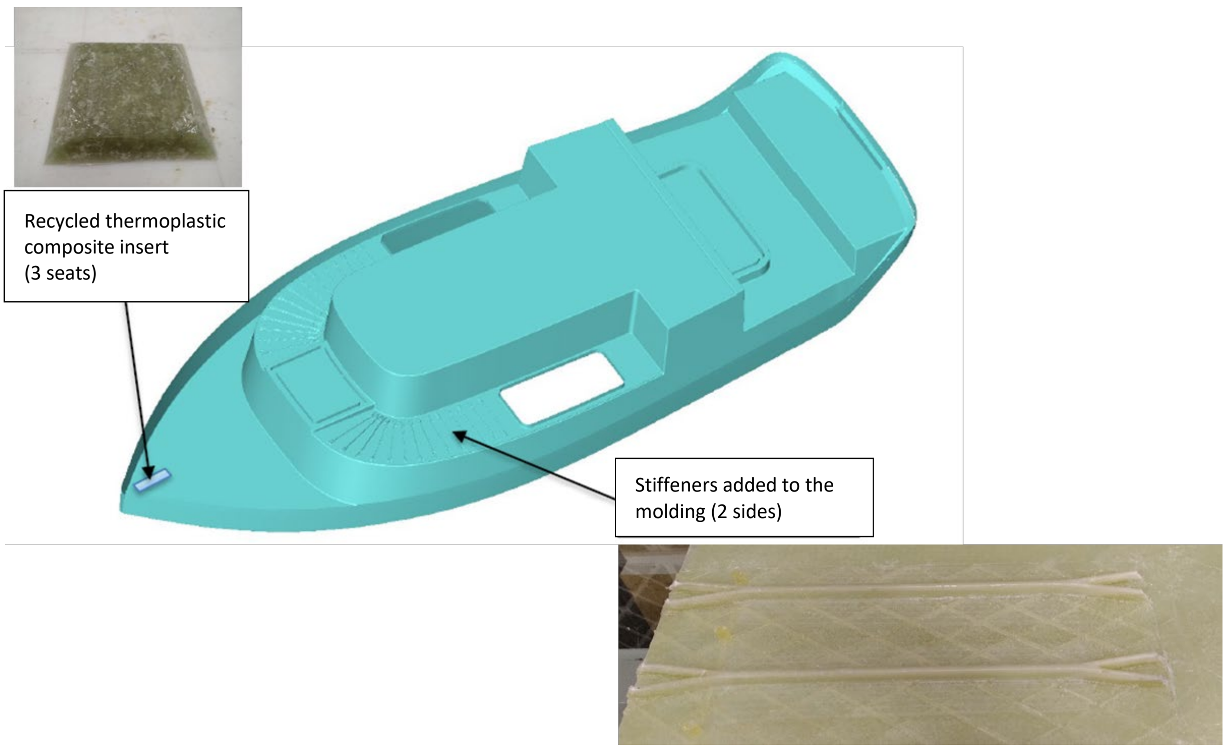


Figure 7. Moulding of the bridge in thermoplastic composite (with stiffeners)

WR 15 oz/vg² (Georgian Bay Reinforcement Fabrics R15-A01)
Mat 3 oz/pi² (Vectorply E-M-0030)
WR 15 oz/vg² (Georgian Bay Reinforcement Fabrics R15-A01)
Mat 1.5 oz/pi² (Vectorply E-M-0015)
Mat 1.5 oz/pi² (Vectorply E-M-0015)
Gelcoat (AOC Vibrin G315AC)

Figure 8. Sequence of bridge construction

To replace the wood cores in the bench area, stiffeners were added in the fabrication. Molding jigs (Figure 9) were used to infuse these stiffeners into the deck laminate. For the inking inserts (Figure 10), also previously made of wood, plates of thermoplastic composite materials containing recycled materials were prefabricated. These plates were then cut and integrated into the laminate.

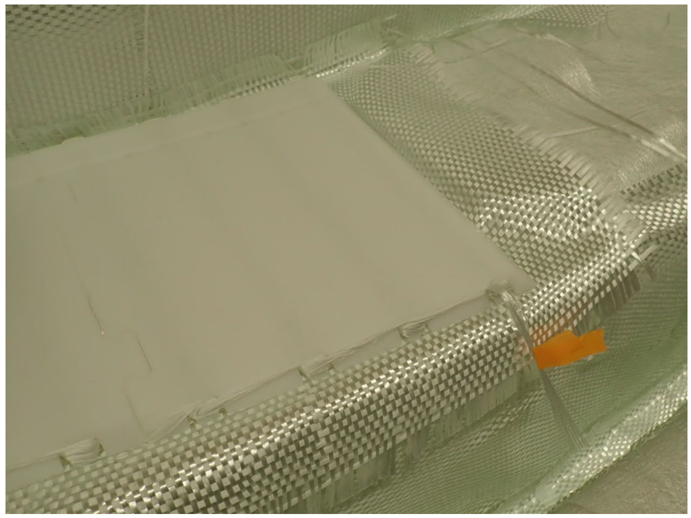


Figure 9. Integrated Stiffener Jigs

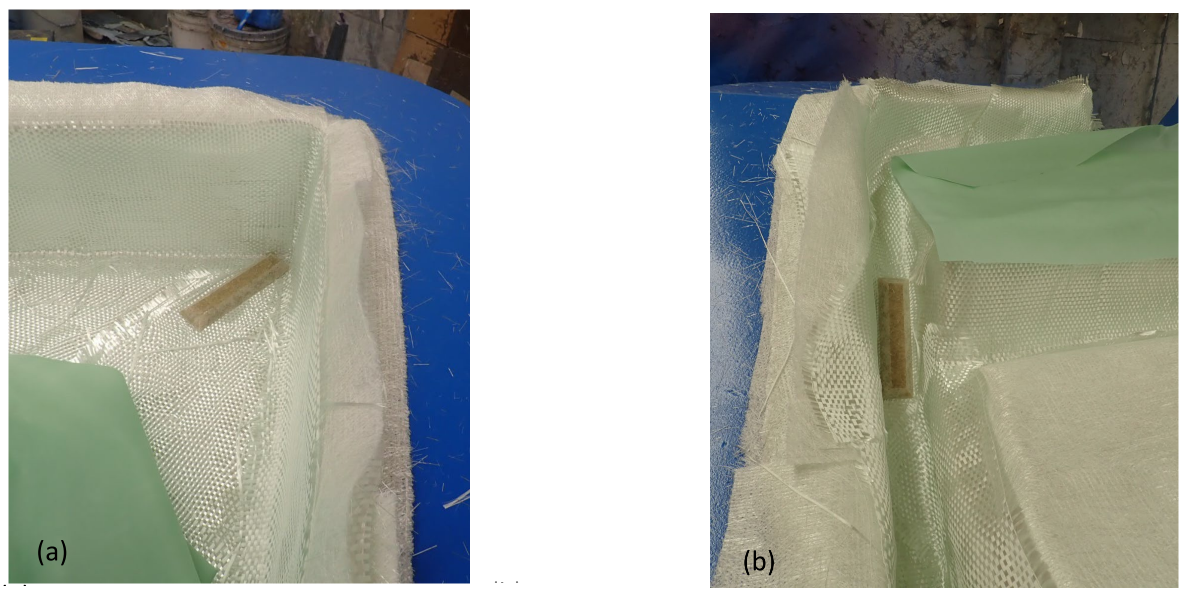


Figure 10. Recycled composite inking inserts - (a) front, (b) rear

Following the application of the gelcoat and the placement of the reinforcements and inserts in the mold, the bagging and infusion operations were performed. Afterwards, the piece was demolded and cut in preparation for assembly with the hull.

STEP 3 : MANUFACTURE OF THE THERMOPLASTIC COMPOSITE HULL SUBSTRUCTURE

The laminates for the hull substructure were all molded in the CDCQ laboratories by infusion with fiberglass and acrylic resin. Thus, flat laminates were manufactured for the "Ω" (omega) reinforcement sections while "L" laminates were manufactured for the subfloor caissons (Figure 11). The produced parts were cut according to the designed geometries and then bent to fit the desired shape at the installation site.

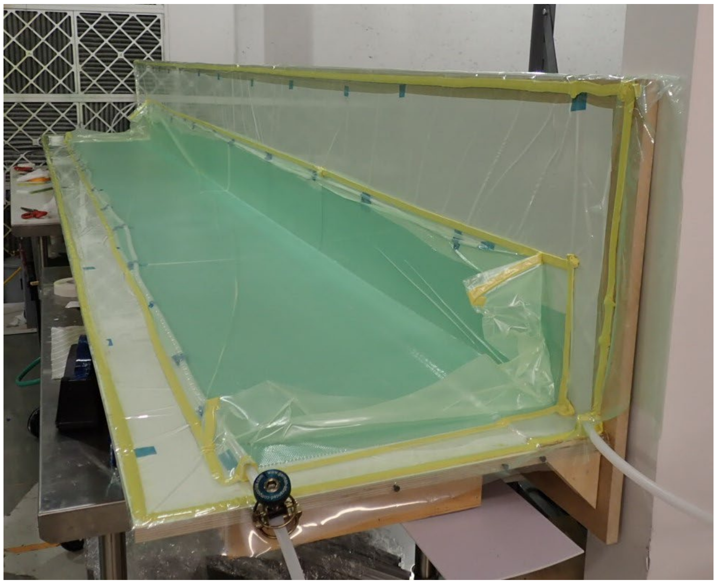
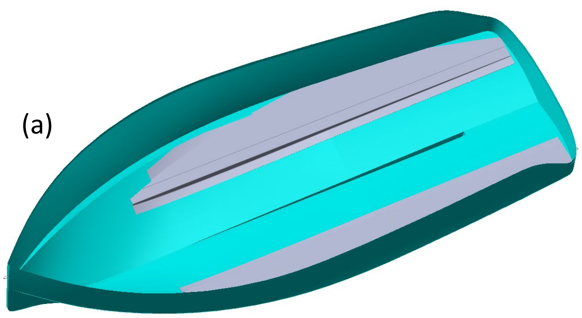


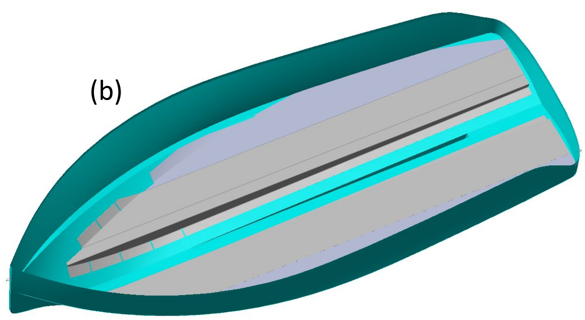
Figure 11. Moulding of the caissons

Following the manufacturing of the main parts (hull, deck, caissons and reinforcements), we realized the assembly of the boat and its substructures. The box and reinforcement parts previously produced were adjusted and assembled by gluing in the hull (Figures 12 to 15). An acrylic-based adhesive from Bostik was used for these operations. This adhesive was selected based on its recyclability with the rest of the construction.

(a)



(b)



(c)

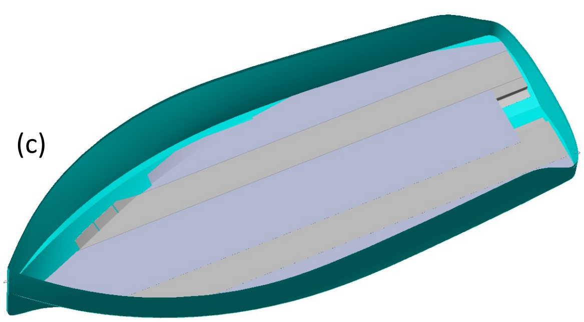


Figure 12. Assembly of the boxes
(a) 1st serie,
(b) 2nd serie,
(c) central box

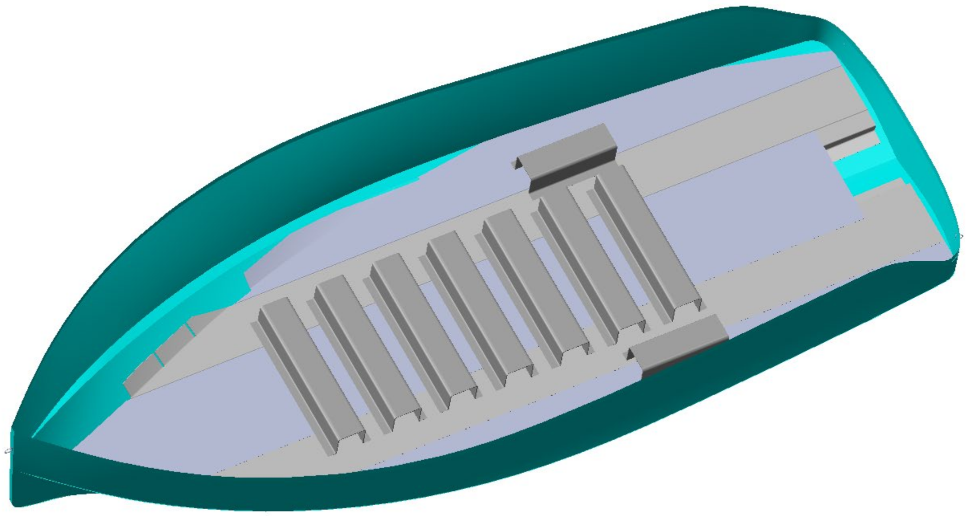


Figure 13. Assembly of "Ω" reinforcements

The engine rear deck substructure was also constructed from a fiberglass and acrylic resin laminate. The infusion-molded laminate was cut, folded and glued to the hull. Then, the space between this piece and the hull was filled with a mixture of acrylic resin and recycled glass/acrylic composite fillers. This deck configuration was chosen to replace the wood used in the original construction. The new deck configuration is fully compatible with the other materials of the boat and therefore recyclable. In addition, its construction provides the required compressive strength for engine mounting.

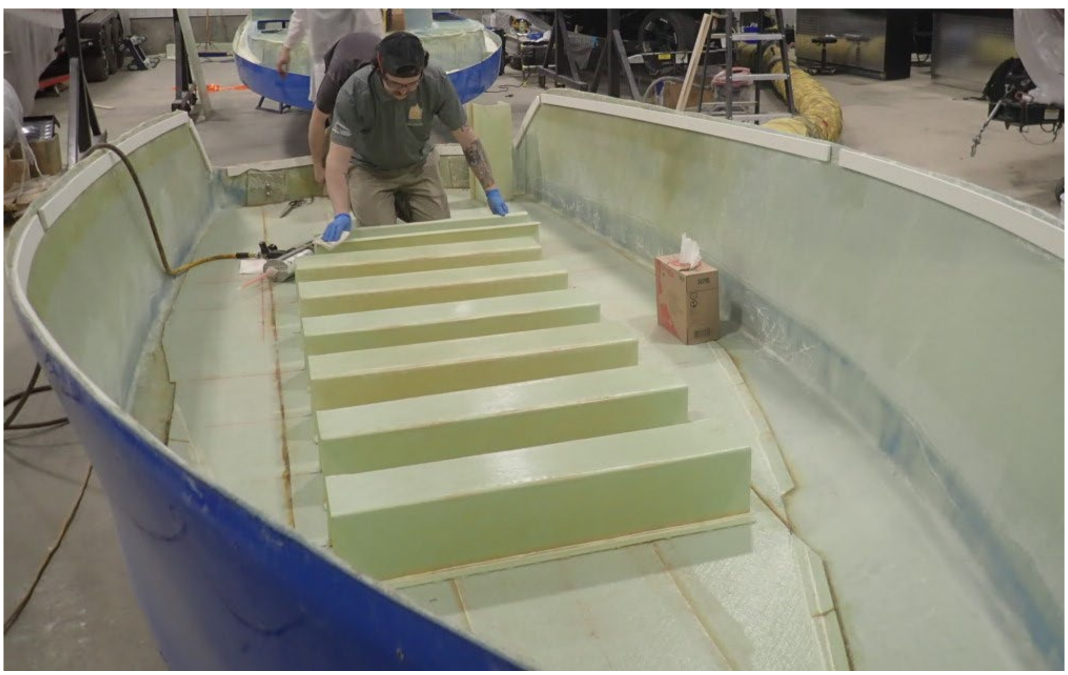


Figure14. Assemblage de la sous-structure de la coque

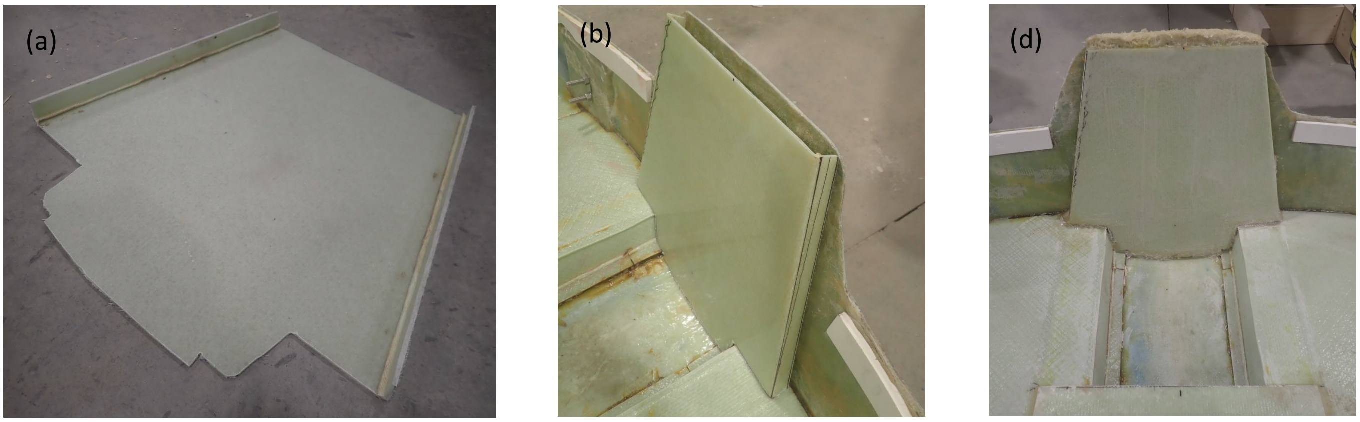


Figure 15. Manufacture of the engine deck
(a) cutting and bending of the infused laminate,
(b) gluing on the hull,
(c) filling with resin and recycled fillers

STEP 4 : FABRICATION OF THE BRIDGE SUBSTRUCTURE IN THERMOPLASTIC COMPOSITE

The elements for the bridge substructure (Figure 16) were also molded in the CDCQ laboratories by infusion with fiberglass and acrylic resin. Thermoformed omega stiffeners were fabricated while a fir tree shaped laminate was created for the front sub-deck.

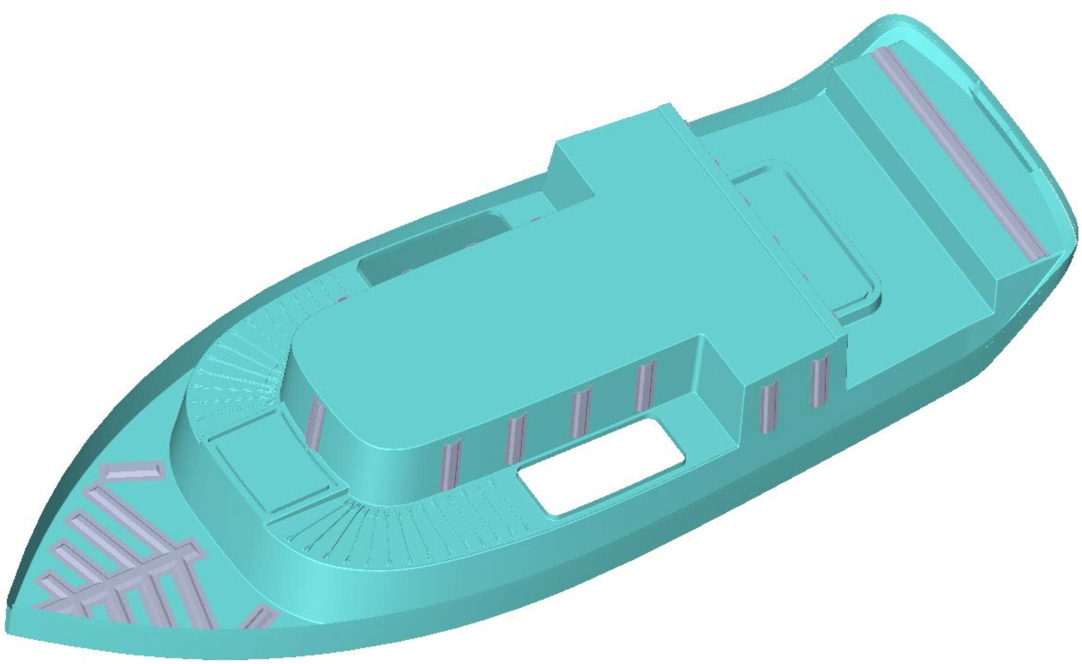


Figure 16. Substructure of the bridge

The fir tree shaped front sub-deck stiffener was made with a preform produced flat using a robotic cell (Figure 17). We validated this manufacturing method because it minimizes material loss during manufacturing. This fiberglass preform was then infused with Elium™ resin on a prototype mold with the desired geometry (Figure 18). This part along with the omega stiffeners were bonded to the inner surface of the bridge during assembly (Figures 19 and 20).

Figure 17. Robotic pre-forming of the front sub-deck reinforcement

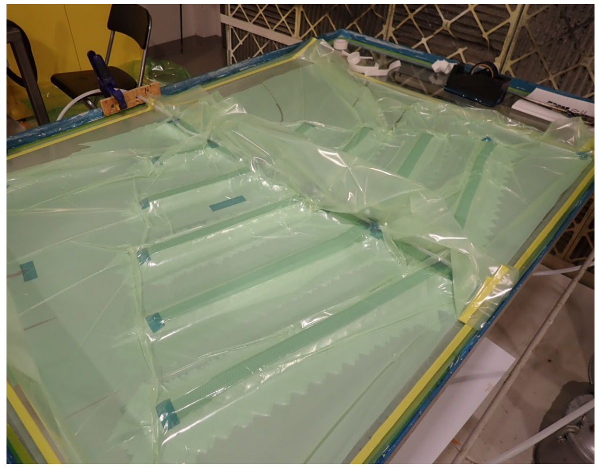


Figure 18. Infusion of the front sub-deck reinforcement

Figure 19. Gluing of the front sub-deck reinforcement

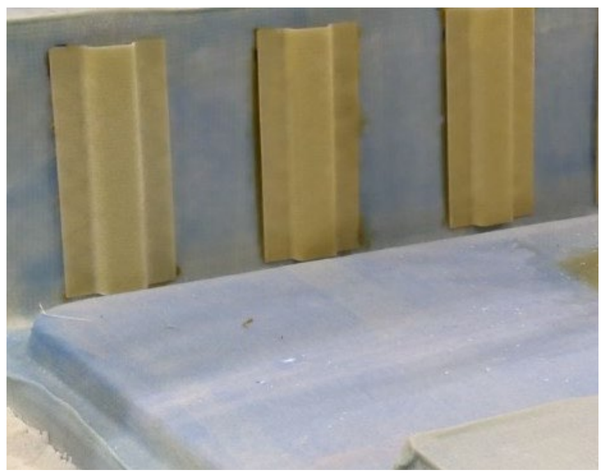


Figure 20. Collage de raidisseurs en omega sur le contour des bancs

STEP 5 : ASSEMBLY AND FINISHING OF THE BOAT

To obtain the desired flotation characteristics of the boat, an acrylic foam was added in the hull and in the deck. This low-density foam was specifically formulated and developed for the project for the recyclability aspect. Typically, the foam used in the manufacture of boats for flotation is a polyurethane. For the hull, the foam was integrated under the caissons while for the deck, the front and side parts were foamed (Figures 21 and 22).

Figure 21. Floatation foam in the front part of the deck.

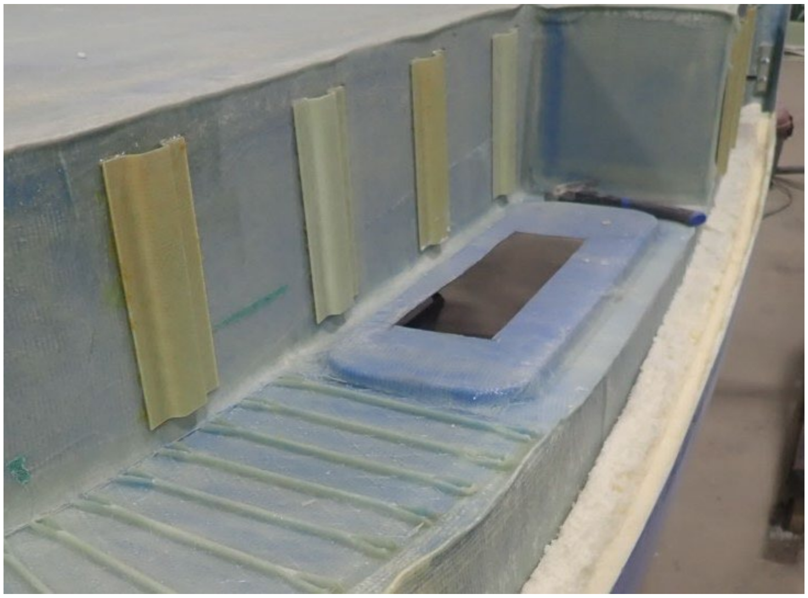


Figure 22. Floatation foam on the sides of the deck

Once all the manufacturing operations were completed, the two main parts were joined together by adjusting the contours of the parts as needed. An undercut was installed at the intersection of the two parts using stainless steel screws to mask the joint between these parts and ensure the assembly of the hull and deck. The openings in the thwarts were completed and the finish of the boat was reworked to repair certain imperfections and ensure an aesthetic piece. Finally, the moulding and some accessories were installed.

Figure 23. Assembling the boat

Figure 24. Finition du bateau (avec accessoires)

Once the CDCQ completed the composite material portion of the recyclable boat demonstrator, the prototype boat was transported to IMAR for the trim of the latter with the other essential components (steering, motorization, etc.). The installation of the console and the finishing of the cockpit were done by IMAR. The choice of materials and ease of disassembly were taken into account for easy future dismantling. The table was also produced from recycled composite materials. An electric motorization was installed and then tests on water were carried out (Figure 25).

Figure 25. Recyclable boat

CDCQ
Centre de développement des composites du Québec

cegep de Saint-Jérôme
SAINT-JÉRÔME
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MONT-LAURIER

CONCLUSION

The project has made it possible to

- ✓ Compare the performance of alternative recyclable materials to traditional materials for replacement in ship design.
- ✓ Demonstrate the viability of these materials by designing, building and monitoring the evolution of a functional prototype.
- ✓ Demonstrate the recyclability potential of continuous fiber thermoplastic composites for use in the marine sector.

Additional information

Presentation of the recycled boat
Arkema video

Recovery of grounded boats made of fiberglass (Colloque RICQ-CDCQ 2019)
https://www.cdcq.qc.ca/wp-content/uploads/2019/11/04-Valorisation-des-bateaux-%C3%A9chou%C3%A9s-en-fibres-de-verre-Daniel-Poirier-CDCQ.pdf

Recyclable composite materials for the nautical sector (Bulletin du CDCQ – Février 2021)
https://www.cdcq.qc.ca/wp-content/uploads/2021/02/Materiaux-composites-recyclables-pour-le-secteur-nautique.pdf

Demonstration of the revalorization of long fiber thermoplastic composites (Bulletin du CDCQ – Juin 2021)
https://www.cdcq.qc.ca/wp-content/uploads/2021/05/Valorisation-composites-thermoplastiques-a-fibres-longues_18mai2021.pdf