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COMPTE RENDU TECHNIQUE DE LA REALISATION D'UNE ANNEXE EN LIN/PLA/LIEGE

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KAIROS

European Regional Development Fund

PARTNERS

KAIROS, ECO TECHNILIN, UBS

WORK

1) Objectives :

The purpose of this report is to present the approach taken to the design and construction of a 2.3 m long tender. Tenders are small boats used to join larger boats or to travel to places where these boats stay. Within the framework of the FLOWER project, the tender is made entirely from flat panels combining flax fibres, a 100% biosourced PLA thermoplastic resin that can be composted in industrial compost and a cork core.

The composite materials generally used in yacht building involve thermosetting resins such as epoxy, polyester or vinylester which present health risks. They are mostly irritant, neurotoxic and present CMR risks (carcinogenic, mutagenic, reprotoxic). Once associated with the fibres and shaped, thermosetting resins are polymerised. The non-reversible nature of this reaction makes their recycling expensive and energy-consuming. The majority is therefore buried (90%) and the rest is incinerated.

Thermoplastic composites offer solutions to end-of-life and toxicity issues. They are increasingly being developed in the aviation and automotive industries for medium and large-scale production. The shipbuilding sector, for its part, produces large parts in small series. For shipyards in the nautical sector, investments in transformation means are limited. The manufacture of parts with complex geometries in thermoplastic composites, requiring high pressure levels and heating, is therefore outlawed.

The work consisted in developing a technique for assembling flat panels with a simple geometry and adapted to the shipbuilding sector, offering sufficient mechanical characteristics. This process allows the production of recyclable parts using a thermoplastic matrix of the same nature as that used in the production of the panels, in this case PLA.

The process developed makes it possible to do away with the use of complex moulds, which represent a significant investment and environmental impact in construction. The development consists of putting in place the first building blocks of a technology that can be transposed to the shipbuilding sector, making it possible to respond to the sector's environmental challenges. The process allows for very rapid assembly without the drying time required for thermosetting resins.

2) Process and technical choices

Selection of the tender model

The AVEN tender model was designed in 2018 by Julien Marin, a French naval architect for Atelier Z, an association that works on the reappropriation of knowledge and techniques and the creation of spaces for social links in rural areas. The plans of L'AVEN are free of rights.

A first annex (L'AVEN 1) had been made that same year from linen/PLA/cork panels supplied by Kairos. The panels were assembled together using an epoxy thermosetting resin. Individual Kairos employees were involved in the production of L'AVEN 1.

AVEN was selected for the FLOWER project because it has the following advantages:

- Manufactured from flat panels and therefore suitable for the desired assembly technique
- Existing experience of some Kairos employees in the manufacture of L'AVEN 1
- Manufacturing cost in line with the budget of the extension requested by Kairos
- Simple size and transport allowing the AVEN to be presented at trade fairs, conferences and other events

AVEN 2 is an evolution of AVEN 1. It presents the following innovations:

- The skins of the sandwich panels are made from the card veil developed by Ecotechnilin in the work package WPT2 of the FLOWER project.
- The assembly of the panels uses a PLA thermoplastic resin

Selection of materials and process

Two types of materials were selected for the construction of L'AVEN 2: the materials for the sandwich panels and the thermoplastic resin for the assembly of the panels together.

The skins of the sandwich panels are made from 150 g/m² flax/PLA commingled carded veils produced by Ecotechnilin. The commingled card veil consists of 40% flax fibre and 60% PLA. Five plies of card web are used in the production of the skins in order to obtain the desired thickness. In order to improve the ageing resistance of the skins and in particular the bleaching of the flax fibres exposed to UV and humidity, a 500µ white PLA film is integrated on the surface. The core material used in the production of the panels is an 8 mm thick layer of agglomerated cork.

The linen/PLA/cork sandwich panels are manufactured using the thermocompression process. Essais de mise en œuvre et caractérisation mécanique .

Production of test specimens

In order to validate the strength and stiffness of the panel assembly, test specimens as shown in Figure 3. The test specimens consist of two flat panels joined together by a fillet joint in PLA.

The fillet joint is made of molten PLA thermoplastic resin and applied with a glue gun (Figure 3). Figure 3 shows the filling of the glue gun with PLA granules.

Figure 3 : éprouvette pour test d'assemblage

Figure 3 : pistolet à colle

Figure 3 : remplissage du pistolet à colle

Three sample batches of 5 specimens were made with a PLA joint and 1 sample batch of 5 specimens with an epoxy joint:

- Reference: Epoxy
- Grade 1: 100% PLA
- Grade 2: 90% PLA + 10% PBAT
- Grade 3: 70% PLA + 30% PBAT

The three grades of PLA compound have PBAT levels ranging from 0% to 30%. PBAT is a polymer that increases the elongation at break of the compound.

Test method

Tensile tests are performed on the specimens using a special fixture installed on a tensile testing machine (see Figure 4). The specimen is loaded in tension so that the joint tends to open.

Figure 4 : montage des éprouvettes dans la machine de traction

Results of trials

The failure modes are similar in all specimens. Fracture is initiated outside the joint area and propagates into the cork (see Figure 5: Fracture Patterns).

Figure 5 : faciès de rupture

The results of the tensile tests show that the strengths and elongations at break of PLA joints are about 60% lower than those of epoxy joints. Furthermore, the influence of PBAT on both the tensile strength and elongation of the specimens is negligible (see Figure 6).

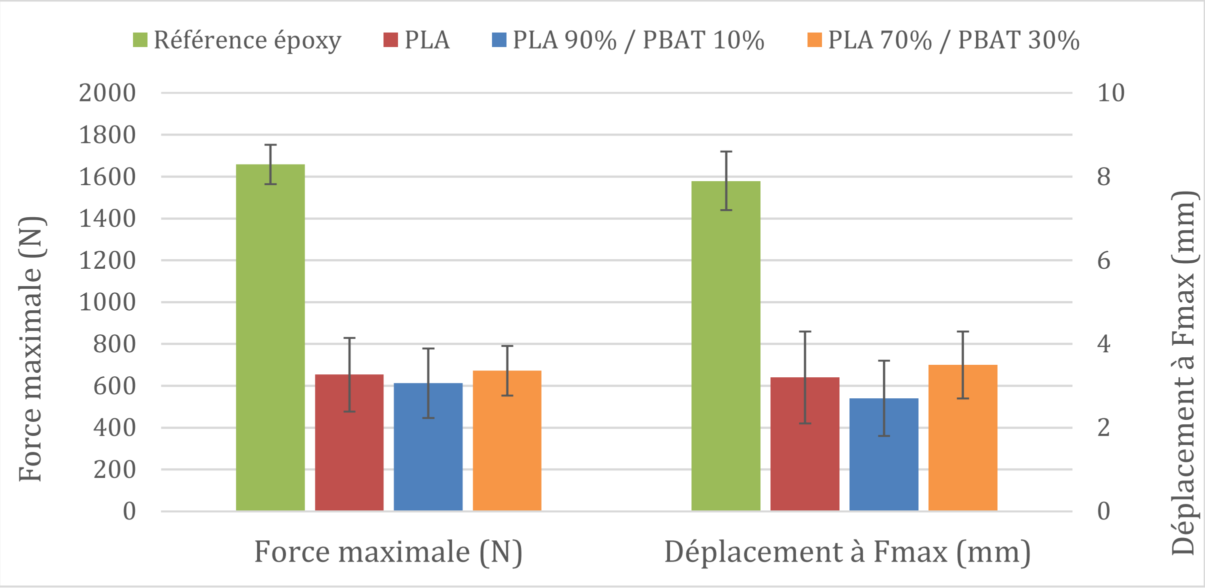

Figure 6 : résultats force et déplacement

The compound chosen for the manufacture of the annex is 100% PLA for ease of processing due to a viscosity in line with the process.

3) Manufacturing of the tender boat

Designing and production of the tooling

The 3D geometry of the tender is provided by the architect and is used as a basis for the tooling of the port and starboard hulls (see Figure 7 and Figure 8).

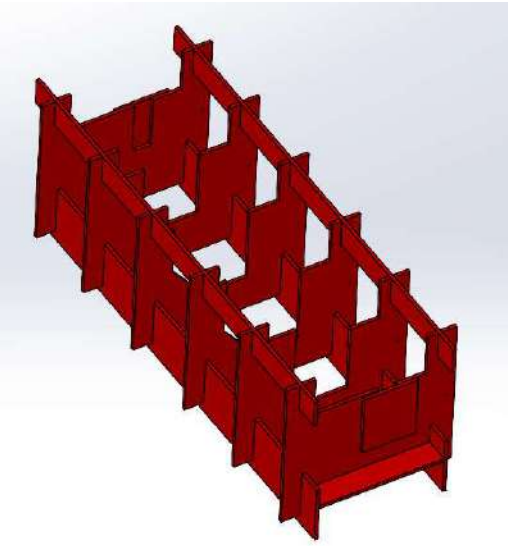

Figure 7 : outillage coque bâbord

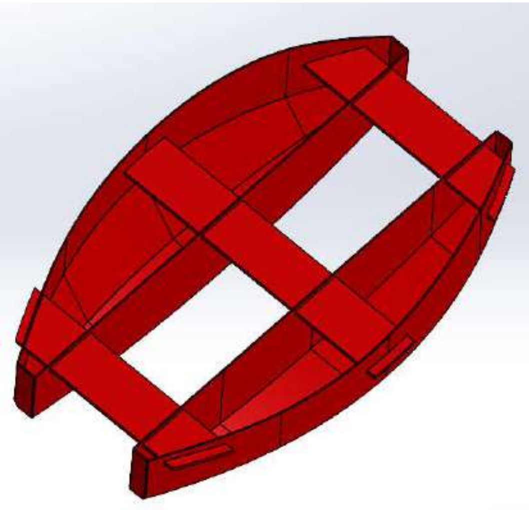

Figure 8: géométrie de l'annexe

The tools are made of chipboard and cut using a numerically controlled milling machine (see Figure 9).

Figure 9 : outillages assemblés

Assembly of the panels

The panels are positioned in the tooling by bending them to the final geometry. The joints between the panels are made with the glue gun presented above (see Figure 10).

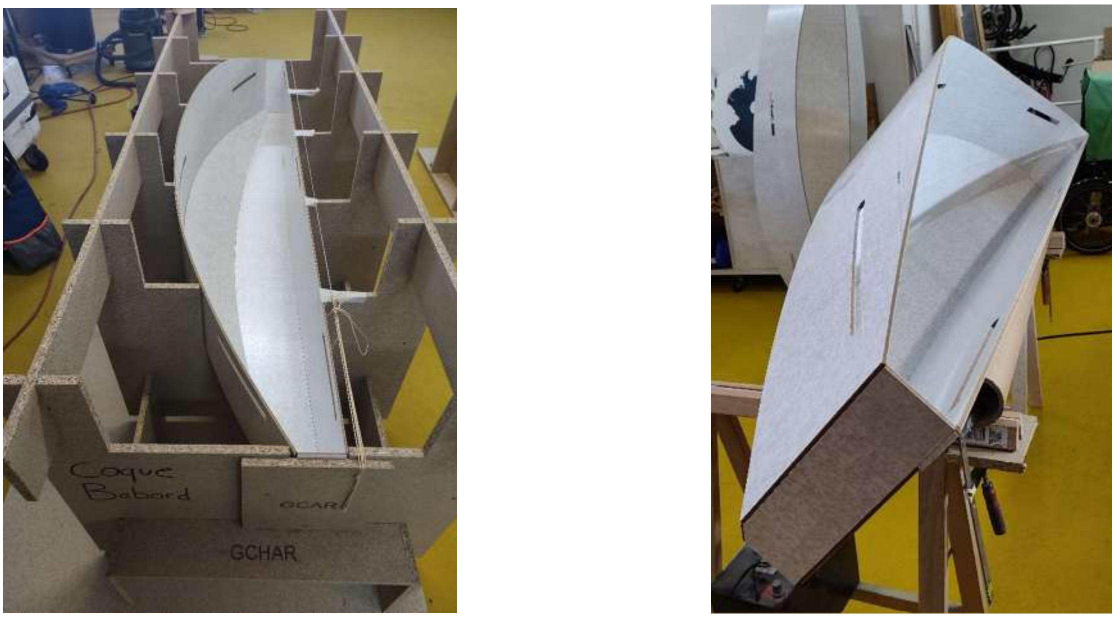

Figure 10 : panneaux assemblés

The hulls of the tender are joined together with removable plywood benches (see Figure 11).

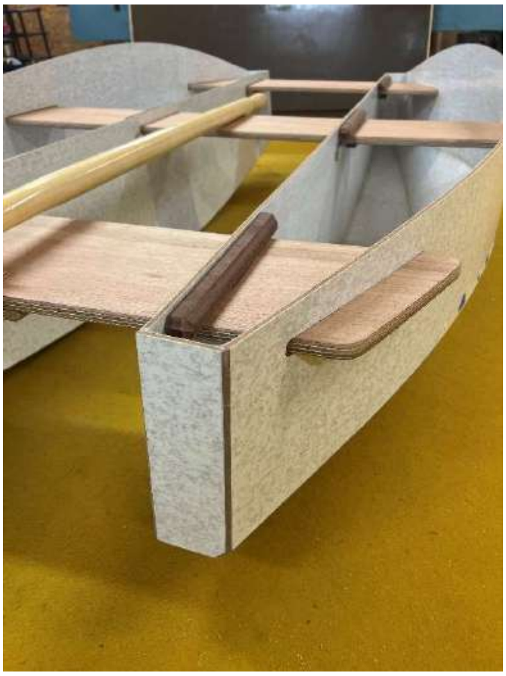

Figure 11: annexe assemblée

4) Trials at sea

The sea trials validated the mechanical strength of the joints and the watertightness of the joints between the panels (see Figure 12).

Figure 12 : essais en mer

CONCLUSION

This report presents a summary of the work that has been carried out on the manufacture of the AVEN 2 Annex. It presents the results of the tests carried out which enabled the manufacturing process to be developed. Although the strength offered by the PLA joint is lower than the reference epoxy joint, the sea trials show that this feasibility trial is relevant. The process will need to be further developed to suit the manufacture of larger boats. The next step will be to integrate long fibres with a thermoplastic matrix to make the joints.