Feasibility of Composite Material Construction without the Use of Molds

Factibilidad de Construcción en Materiales Compuestos sin la Utilización de Moldes

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Abstract

The evolution of materials applied to shipbuilding has meant, to a large extent, the possibility of optimized designs in shapes and weights, preponderant aspects in Naval Architecture. The present work shows in a generic way the application of Composite Materials in the construction of ships and naval artifacts and specifically the feasibility of applying a construction technique without moulds, supported by successfully developed examples.

Key words: Composites, structures, Shipbuilding, Design.

Resumen

La evolución de los materiales aplicados a la construcción naval ha significado, en gran medida, la posibilidad de diseños optimizados en formas y pesos, aspectos preponderantes en la Arquitectura Naval. El presente trabajo muestra de manera genérica la aplicación de Materiales Compuestos en la construcción de naves y artefactos navales y de manera específica la factibilidad de aplicar una técnica de construcción sin moldes, avalado por ejemplos desarrollados con éxito.

Palabras claves: Composites, estructuras, Construcción Naval, Diseño.

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Background

One of the main obstacles in deciding to use composite materials in the construction of a boat, in addition to technical considerations, is the cost involved in the process, which is usually associated with the prior construction of a matrix, a mold and finally the part required. Opting for variants in the construction systems has led to propose a method that avoids the cost involved in the manufacture of molds and which result is proven at least with an effective example. Before describing the method and showing a practical application, it is pertinent to define, in a very generic manner, some parameters involved in these processes.

What do we mean by composite materials?

We know as composite materials those that are made of two or more materials, which mechanical properties are inferior to those obtained as a whole.

Constituent Materials

We will consider as constituent materials at least the following:

- Resins, whether polyester, vinyl ester or epoxy, or their improved variants.
- Reinforcements, such as glass fibers, aromatic polyamide, carbon or hybrid fibers
- Fillers to modify resin properties
- Polyvinyl chloride cores, phenolic paper, balsa wood, cedar, etc.

Constituent Materials

We will consider at least two basic structures:

- Monolithic structures, consisting only of resins (and their fillers) and reinforcements
- Sandwich structures, to which we will add a core

Lamination Methods

Normally, the lamination method tends to be confused with the construction method, so it is necessary, at least, to point out the former, in order to clarify its applicability within the latter.

We know mainly three lamination methods:

Fig. 1. A and B Manual lamination of hull and superstructure, C Mold lamination and D Finished part (source: A and B): OMORA Project, School of Naval Engineering, Universidad Austral de Chile).

- Method of wet manual lamination, which consists of laminating the final part on an open mold. This is carried out by manual execution of the lamination using rollers, brushes or tools that allow the resin to be impregnated into the reinforcement.
- Vacuum lamination method, applied to different construction methods, allows uniform pressure on the laminate components. Today it is a widely used method that mainly consists of generating a vacuum bag containing the part to be laminated where a vacuum environment is applied that theoretically provides 1 Bar of pressure on the structure.
- Lamination by infusion. This type of lamination allows for a combination of vacuum lamination and zone-controlled lamination. It basically consists of generating a vacuum environment, similar to that described above, but not including the resin in the process, which is added by suction from the fittings arranged in certain areas of the part. The control prior to resin injection must be very meticulous and the resin must have a thixotropy that allows impregnation and advancement throughout the part in defined times.

Construction Methods

Construction methods can be approached depending on the number of parts to be developed and the level of finish to be obtained. Thus, we can define three systems, which associated with different lamination methods, will result in the finished part. It should be noted that the construction method will also depend, undoubtedly, on the costs to be assumed, hence, the final result of this work, intends to contribute with the practical introduction of a method, which we can call hybrid, favoring the final cost of the part.

- Construction by means of female mold: it consists of building a matrix, generally in wood, containing the shape of the part, for example the hull, to later generate a mold from

Fig. 2. General scheme of vacuum lamination.

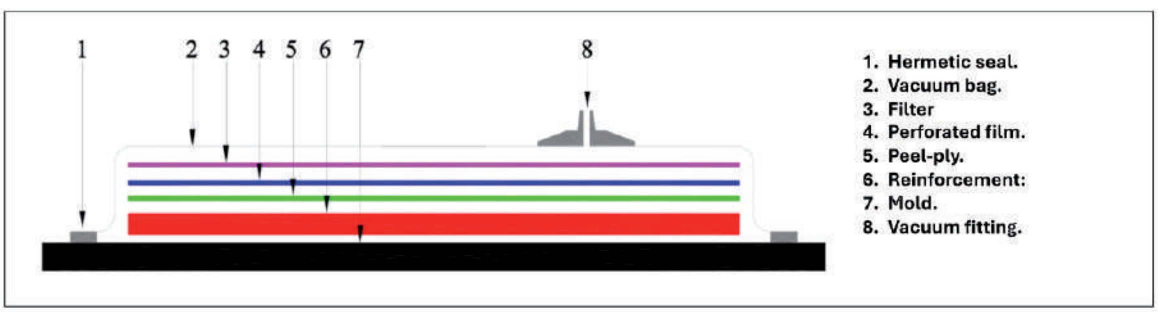
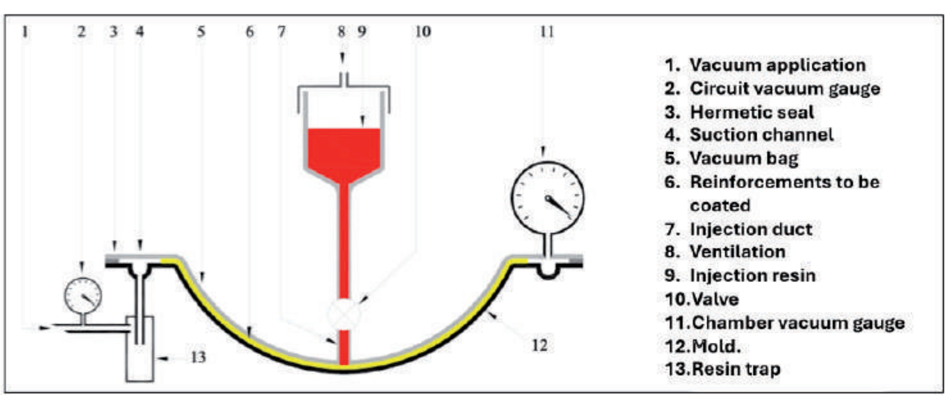


Fig. 3. General infusion lamination scheme.



that matrix, which will be used to laminate the final part. Here we can apply any of the lamination methods described above.

- One-Off Construction: When it is required to build only one part, we normally use a construction system that avoids the construction of the mold, but requires a considerable number of man-hours in surface finishing. Its cost must be evaluated according to the degree of finish desired for the final part. Special care must be taken in the dimensioning of the base support parts, since they must be considered without the thickness

Fig. 4. Construction method using female mold. - A, B and C matrix construction; D Mold laminated in the matrix, E hull demolding and F finished part. (Source: Project NCH_008 NavTec Ltda - Cotecmar).

Fig. 5. ONE-OFF construction method - A- base matrix construction, B- inner skin lamination, C- core lamination, D and E- outer skin lamination and F- finished parts.

of the structure. Although the ONE - OFF method can be considered as a "moldless" method, unlike the final method proposed, it requires a supporting "structural base" that involves the construction of a matrix, and it is not feasible to add definitive structural parts in the initial hull lamination process, and these must be included once the hull is completely laminated, including its inner and outer skins.

- Strip Plank construction: The Strip Plank construction system is applied exclusively in sandwich structures, the core being laminated first, which will be fixed to the layer. Different materials can be used for the core, including balsa wood and PVC foam. The method requires a base matrix on which the core will be placed as a first action, then the outer skin will be laminated, the hull will be rotated and the inner skin will be laminated as well. Like the ONE-OFF system, it requires a high number of man-hours in finishing.

Proposed Construction without Mold

One of the construction alternatives using a variant of the methods described above offers the possibility of substantial cost savings, avoiding the construction of a mold and ensuring the quality of the finished part.

Base Proposal

The proposal is mainly based on using a layer built with the hull shapes, which dimensions must consider the discount of the complete thickness, to later laminate, independently from the layer, developed parts that will be mounted and assembled to constitute the final structure. Although the method is mainly applied to sandwich structures, it has been used for monolithic structures, using a system very similar to steel erection and construction. The substantial difference with the Strip Plank method is that the laminates are made, almost entirely, before being installed on the layer, by means of developed and flat-laminated parts.

Step by step description

The following figures detail a "step-by-step" application of the method, in this case, in the construction of an 8-meter RIB. Although the method allows for the addition of previously developed and laminated parts, areas that are more difficult, either because of their curvature or their position, should be assembled with parts laminated only in the inner (or outer) skin as appropriate.

Fig. 6. Construction method using female mold. - A, B and C matrix construction; D Mold laminated in the matrix, E hull demolding and F finished part. (Source: Project NCH_008 NavTec Ltda - Cotecmar).

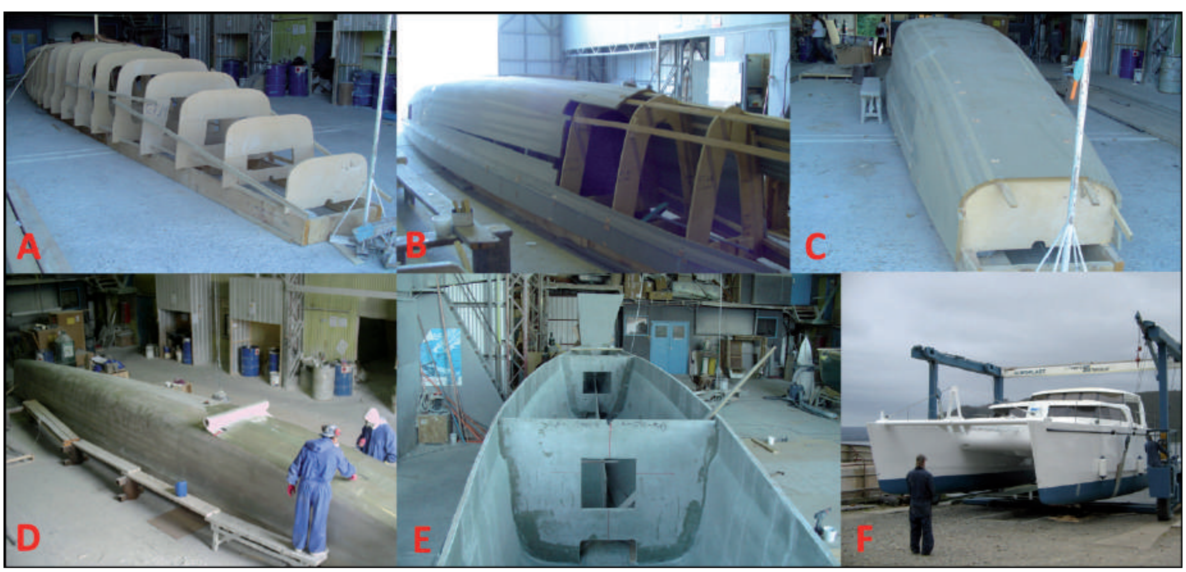
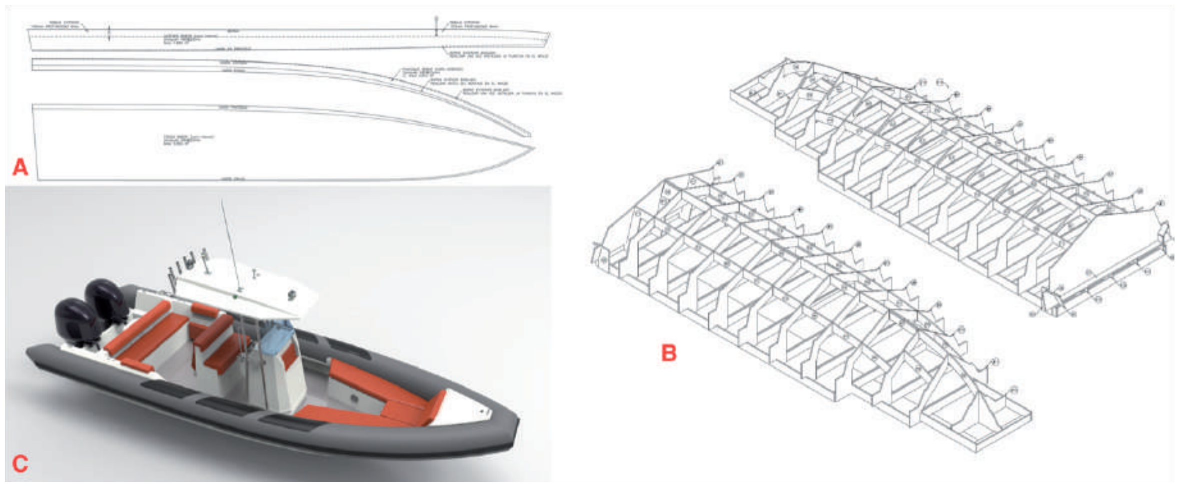
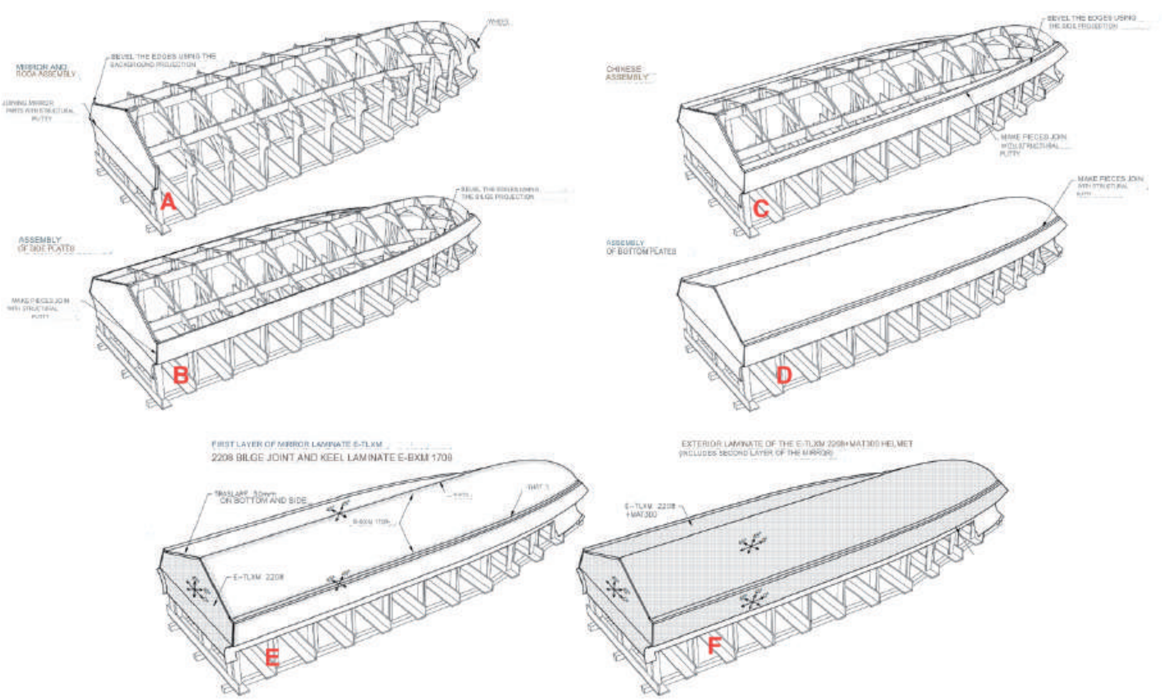


Fig. 7. A - development of hull parts and flat lamination, B - design and assembly sequence of layer and C - digital mock-up of the project (source: Project NT_522 - NavTec Ltda. / M&M Colombia).



Source: Project NT_522 - NavTec Ltda. / M&M Colombia.

Fig. 8. Hull assembly sequence.



Example of application

The application example is a support vessel for the salmon industry to transport personnel to and from the salmon farming centers in southern Chile.

The ship was designed to be built in composite materials and sandwich structure, propelled by water jet. The structural calculation was carried out using international standards, in this case, ISO 12-215 and Bureau Veritas, in addition to the calculation of specific zones using the finite element method.

Fig. 9. General longitudinal profile.

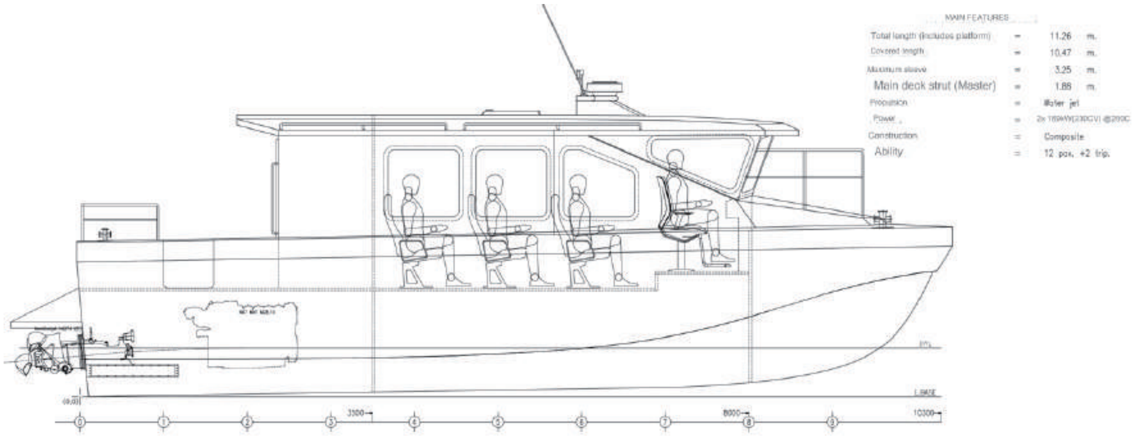


Fig. 10. Digital mock-up.

Fig. 11. Layer sections.

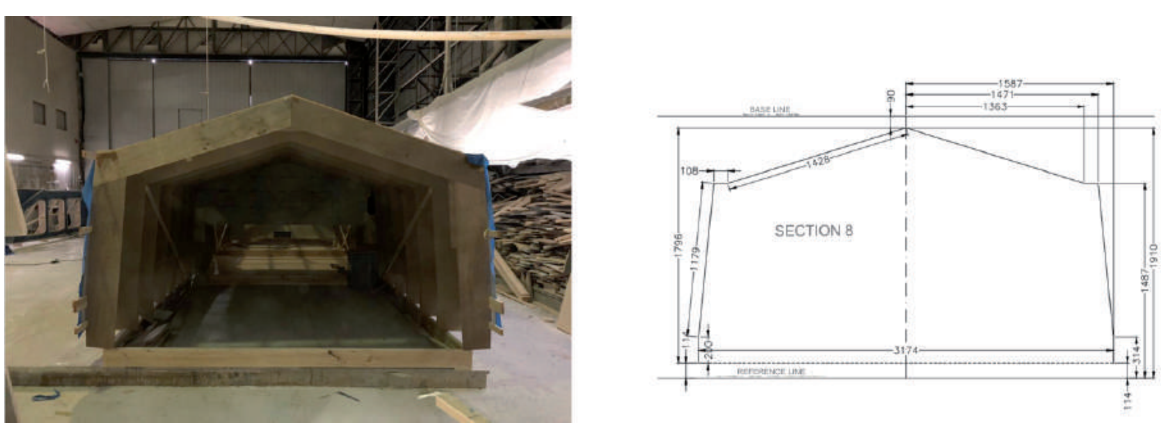


Fig. 12. Development of hull parts and laminate table.

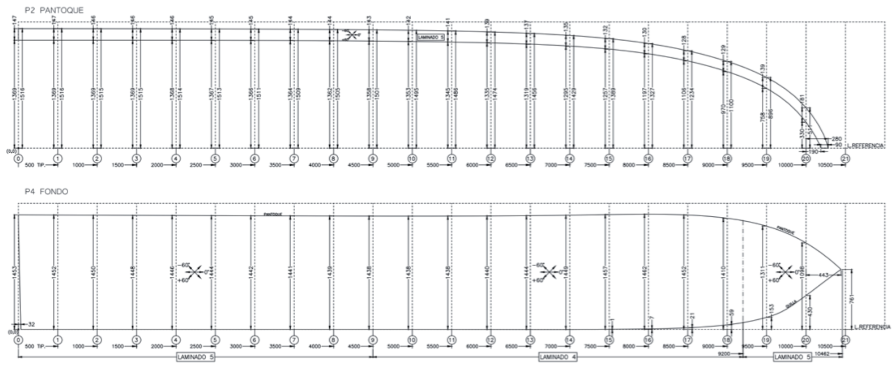
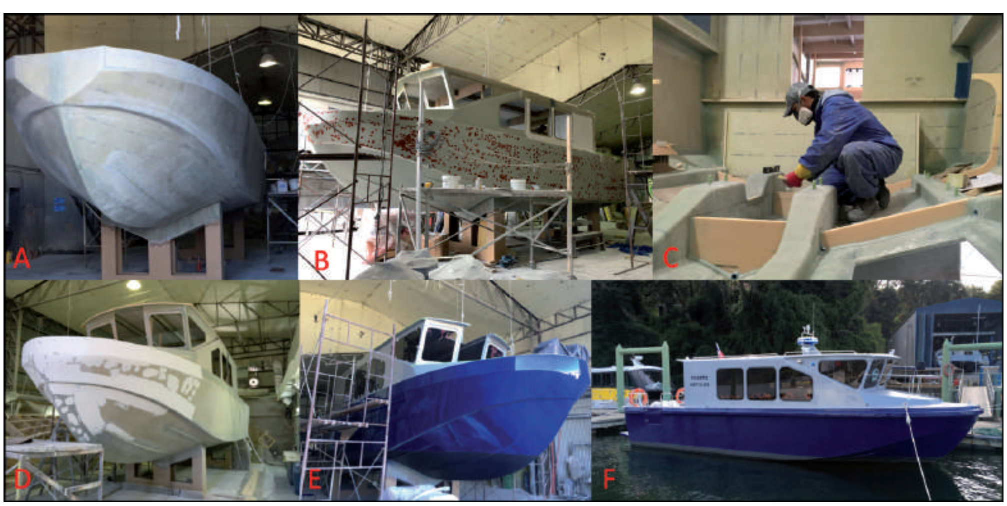


Fig. 13. Sequence of laminates: A - construction of base matrix, B and C - plat parts lamination, D - lamination of superstructure roof, E and F - lamination of hull.

Fig. 14. Finishing: A -hull turn, B -finishing and caulking, C -engine room structure lamination, D -surface finishing, E -hull painting, and F -finished vessel.



General Cost Considerations

Although the technical aspects are relevant, the economic aspect is even more so. Tables 1 and 2 show, in general terms, the materials used and a list of approximate production costs of the boat, with and without molds.

Table 1. General table of structural materials.

Fabric	Architecture	Qty. (m^2)
MAT 300	Mat	356.40
EBX 1700	45º,-45º double bias	71.41
TLX 2700	0º, 45º,-45º Warp Triaxial	182.58
TLX 3600	0º, 45º,-45º Warp Triaxial	78.98
H60 @20mm	pvc foam	42.48
H60 @25mm	pvc foam	23.13
H80 @30mm	pvc foam	79.55
H100 @30mm	pvc foam	16.51

Table 2. General cost estimate.

Item	US$
Structures	35000.-
Equipment / propulsion	108000.-
Miscellaneous and others	160000.-
Total cost	303000.-
Cost Mold for series	105000.-
Base matrix cost	15000.-

The cost of the mold usually amounts to 4 or 5 times the cost of the structure, varying according to the labor costs of each shipyard.

The cost differential associated with the application (or not) of the method can only be correlated in the case that in both situations only one vessel is built, which normally does not happen when they are serial vessels, in which case, the mold is prorated at least in the first 5 vessels.

As a Conclusion

The use of composite materials in the marine industry has been encouraged by the wide range of possibilities, not only in applications in high competition boats, but also in the military and civil industry. The costs associated with these materials, while often higher than traditional materials such as steel, aluminum and wood, have been reduced by implementing construction methods that allow savings in some part of the production chain. The method shown here demonstrates the above, avoiding the construction of a mold and/or fine-finish matrix base, which in terms of cost, can reach a value much higher than that of the hull construction.

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