SIMPLE, EFFECTIVE PERFORMANCE RIBS: DEVELOPMENT OF PRODUCTION ORIENTATED ADVANCED COMPOSITE RIBS

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SUMMARY

Advanced composites using epoxy resin and carbon fibre reinforcements can bring a number of benefits to RIB manufacture making it possible to build lighter, stiffer structures leading to higher performance.

Whilst the use of epoxy provides benefits in the workplace, by eliminating the problems of styrene emissions during construction, use of these materials can also provide a marketing advantage or allow a premium to be added to the price of the boats.

One potential barrier to the use of these materials is their higher cost. However, through simplification of the structure and material processing activities it is possible to offset the increased unit cost of the materials by using less material and, more significantly, reduce the number of man-hours required to build the RIB.

This paper will discuss how the consideration of the total technology package of materials, structural design and processing can be used to lead to the ‘holy grail’ of boatbuilding – lighter, faster cost effective craft.

The application of this process will be demonstrated using the structural design of the new RNLI Fast Inshore Boat.

1. INTRODUCTION

Composite structures can provide significant advantages in the fabrication of marine structures, including low maintenance costs and ease with which complex shapes can be fabricated [1]. In addition, the use of advanced composites such as epoxy resin, sandwich construction and carbon reinforcements can provide significant savings in structural weight. A comparison of structural weights relative to aluminium for marine structures using increasing levels of technology is given in table 1 [2].

<table>
<thead>
<tr>
<th>Construction material</th>
<th>Overall Structural Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester CSM/WR Single skin</td>
<td>105-120</td>
</tr>
<tr>
<td>Aluminium</td>
<td>100</td>
</tr>
<tr>
<td>Glass CSM/WR Polyester/Vinylester Balsa Core</td>
<td>90-95</td>
</tr>
<tr>
<td>Glass/Aramid Multiaxials/foam core</td>
<td>78-82</td>
</tr>
<tr>
<td>Glass/Aramid outer skin/foam core/carbon inner skin</td>
<td>70-75</td>
</tr>
<tr>
<td>Carbon skins/foam and honeycomb core</td>
<td>55-65</td>
</tr>
</tbody>
</table>

Table 1: Comparison of typical structural weights of various construction technologies

The use of higher technology composite construction has historically carried a cost premium, due to the increased cost of the materials and higher processing costs. The use of pre-preg and sandwich construction has also required skilled labour in order to achieve consistent results. This has tended to restrict the use of these materials and construction methods to one off custom vessels where weight reduction is at a premium.

Production vessels have often used lower technology options such as hand laminated polyester single skin construction. Increasingly stringent environmental controls on levels of styrene in the workplace [3] are likely to restrict the use of open mould processes using polyester and vinylester resin systems.

Reducing the structural weight of a boat can provide more freedom in fit out, or give improved performance, both of which can provide a competitive advantage to a production RIB. Consideration of the total package of materials technology, structural engineering and processing methods can be used in order to provide the advantages associated with higher technology systems whilst minimising the increased cost.

2. RNLI FAST INSHORE BOAT

The design of the RNLI Fast Inshore Boat provided an ideal opportunity to prove this process could be implemented effectively. The new boat is the next generation of inshore lifeboat based on the successful Atlantic 75 design. It is approximately twenty percent larger but maintains the successful characteristics of the previous design.

SP’s brief was to develop a simple production process that produces a consistently high quality and durable FIB. Whilst weight reduction was not a design criterion, the RNLI subsequently found that reduced structural weight allowed greater flexibility in the fit out of the vessel.
The design brief was achieved by an integrated approach considering:

- Structural design
- Choice and development of materials
- Development of the construction process
- Working closely with the client

The final structure was lighter and more robust than the previous vessel, and the simplified internal structure gave much more freedom for internal layout, and will allow for easier refit in the future.

3. STRUCTURAL DESIGN

The initial structural design considered a number of concepts, from stiffened single skin to a full sandwich structure. Following consideration of the concepts a number were short-listed for prototyping.

Sandwich structure reduces the number of internal components and also allows greatest flexibility for internal fit out of the vessel. This results in a significant saving in the labour costs for assembly of the structure as well as a significant weight saving in the internal structure. A transverse frame arrangement suits RNLI's required fit out, and full height longitudinals are used to support the hull and deck.

The first two prototype boats were built using glass outer skins and carbon inner skins for the hull and deck. The internal structure consisted of four transverse frames with two longitudinals each side of the boat. Subsequent boats used carbon reinforcement throughout the boat, which allowed the internal structure to be reduced to one longitudinal per side.

A structural GA of the carbon option is shown in figure 1. This change to all carbon structure and modification to the bonding of the internals reduced the structural weight of the vessel (complete structure with deck bonded on) from 500kg to 390kg.

This reduced structural weight allows more freedom in the fit out of the vessel and provides more freedom to ballast in order to obtain the optimum centre of gravity and radius of gyration to improve handling of the vessel in rough conditions. Increased unit cost of the carbon fabrics used in the skins is offset by the reduced quantity of the structural materials and the reduced labour required as a result of fewer structural components.

4. MATERIALS

A significant objective considered during the structural design was to minimise the number of materials, which helps to reduce wastage and simplifies ordering. It is important to use a processing technology that enables a robust, repeatable construction process, as this reduces the variation in the laminate properties. Increased confidence in the construction process enables improved design properties to be considered for the design of the laminates.

It is also a significant advantage to be able to produce cored laminates in a one shot process. This reduces the time required to laminate these components and enable the advantages of sandwich construction to be achieved without significant increase in the labour costs

SP’s SPRINT® processing technology [4] offers a robust and reliable process, which combines excellent laminate quality with the potential for reduced processing time. The materials consist of a layer of fibre reinforcement either side of a precatalysed resin film. The fibres remain dry and unimpregnated by the resin until the curing process.

![Figure 1: Structural GA](image-url)
This provides improved handling and health and safety compared to traditional pre-pregs. The high breathability produces excellent laminate quality with very low (less than 1%) void content from vacuum bag processing, and eliminates the need to debulk at regular intervals.

Resin rich variants with additional resin for core bonding are available which are suitable for one shot laminating of sandwich components.

5. PRODUCTION TECHNIQUES

During the manufacture of the first prototype boats, SP has developed the production techniques to significantly reduce the labour hours required to build the boats. The boats are delivered for fit out with internals fitted and the deck bonded on, and the first boats required around 1000 hours to get to this stage. This has been reduced to 300 hours by a combination of improved production techniques and feedback from prototyping to modify the structural details. Some of the modifications made to the processing are discussed below.

5.1 KITTING

Cutting and fitting core has traditionally been a very time consuming part of building vessels. This process was taking around 8 man-days in total for the deck and hull. The core is now supplied pre-cut from Corecell in kit form, which incorporates dog-bones to hold the core in place. These kits can be placed directly into the mould as shown in figure 2.

Cutting the reinforcement fabrics also previously took about 25 man-days for the vessel, and cutting the fabrics also represented a possible source of error. SP’s experience with virtual templating and kitting of materials for automotive projects [5] suggested that this could provide significant savings in build time.

In this case templates were generated from lay-ups in one of the prototype boats. These were then converted to electronic format, forming a kit booklet as demonstrated in figure 3. This enabled the kitted parts to be fed into nesting software, which drives an automated cutting machine. The pre-cut kit of fabric is supplied to the prototyping facility in a series of cardboard boxes, numbered in the correct order for lay-up of the hull, deck and internals as described in the build manual.

The use of kitted fabrics and core have enabled the lay-up of the hull after tack off of the gel coat to be achieved in two days, and lay-up of the deck in one day.

**Figure 2: Kitted hull core placed on outer skin in mould**

**Figure 3: Example of ply book**
5.2 MOULDED FLANGES

The first prototype vessels had internal frames and longitudinals constructed in a similar manner to one-off vessels. Webs and frames were built over size and then trimmed to the hull shape. Bonding of the internals was achieved using structural adhesive fillets and biaxial tapes. This was taking in the region of 30 man-days to complete.

The use of high performance SP340LV adhesive allowed the structure to be bonded in without over taping the joints. In later boats, this was taken advantage of by laminated the internal structure in moulds, which enabled the incorporation of flanges for bonding to the hull and adjacent structure. Previously SP340LV had to be mixed either by expensive mixing machines or by hand, which was time consuming and resulted in air entrapment that compromises the performance of the adhesive bond. The adhesive has now been made available in cartridge form enabling mixing through the use of helical nozzles. The combination of the improved dispensing of the adhesive and flanged mouldings has resulted in a reduction of the time taken to fit the internal structure to around 6 man-days.

5.3 SPRAY RAILS

A typical damage tolerant design of a spray rail for sandwich construction is shown in figure 4. This can be very time consuming to laminate, as it requires cutting of several plies of laminate and well as fitting of a foam core piece. In pre-preg construction this detail would also require curing separately from the hull in order to ensure good consolidation of the spray rail laminate.

During the building of these RIBs the prototyping team and materials development team worked together to develop a mono-component adhesive which would achieve the cured properties required for the spray rails whilst having suitable handling characteristics to enable the spray rail to be applied in one go from a cartridge.

This has enabled the four spray rails on the RIB to be prepared and ready for overlamination with the hull outer skin in round 3-4 person-hours.

5. FEEDBACK FROM PRODUCTION

A further advantage of the integrated approach of this project was the ability to feedback experience from manufacture of the prototype RIBs to the structural design. This enabled modifications to the structural design details to be investigated in order to reduce build time without compromising structural integrity.

One example of this was the influence of the modified production methods on the design of the transom to deck joint. The original design is shown schematically in figure 5, and the construction sequence was as follows:

- Lay-up transom
- Cut transom to shape
- Lay-up closing laminate
- Bond on deck
- Trim deck
- Over laminate
- Fill and fair the transom

This was a time consuming procedure, and also resulted in significant finishing costs to fill and fair the transom.

Once the core and fabrics were kitted, leading to a more accurate deck and transom, it was possible to modify the construction sequence to produce a more efficient process. Additional laminate was included in the deck.
flange, and, combined with the greater accuracy of the kitted construction, this enabled the modified joint shown in figure 6.

![Figure 6: Modified transom detail](image)

In this case the kitted core of the transom ensures the correct shape of the transom, and the skin laminates can be laminated around the ends of the core. The deck with additional laminate in the flange is then bonded on and does not require over taping.

The modified construction sequence reduces the labour required to create the joint as:
- No trimming of the deck or transom required
- No wet laminate taping required
- No additional finishing of transom required

6. FURTHER OPTIONS

Although significant improvements have been made on the build time during the prototyping run there are several areas that offer opportunities for further gains.

- Use of laser alignment system to aid faster and more accurate alignment of fabric kit pieces
- Improve jigs used for fitting of internal structure
- Use of more accurate CNC cut moulds for hull deck and internals to improve fit of components and kits
- Use of intensifiers in place of large vacuum bag
- Use of improved adhesive dispensing equipment
- Improving facilities on mould for demoulding of components

7. CONCLUSIONS

Advanced composites can bring a number of benefits to RIB manufacture with a lighter, stiffer structure. Reduced structural weight can offer more freedom for fit out, or increased performance.

The higher unit cost of the materials used can be mitigated by consideration of the total package of structural engineering, materials and processing technology to reduce the amount of materials and labour required to build the vessel.

For the design of the RNLI FIB, SP aimed to prove that it was possible to produce a vessel with advanced composites using a fast, efficient production process to assist in the creation of a superior quality and light, durable craft.

This was achieved with a prototype RIB some 20% larger than the previous inshore lifeboat with a 25% reduction in structural weight, which we believe would be capable of production at a comparable cost to the previous vessel.

8. REFERENCES


8. AUTHORS’ BIOGRAPHIES

**Mark Hobbs** holds the current position of lead engineer at SP. He is responsible for supervising a team of structural engineers specialising in composites.