New Zealand Naval Architect

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INSIDE

Manufacturing Flexibility: Thinking Out-of-the Box with Marine Design and Processing Integration

by

Richard Bootten and Richard Downs-Honey

Custom boat builders Westerly Marine in Orange County, California, are utilising a wide range of composite fabrication technologies in the building of a unique Underwater Lifting Body high-speed powerboat for Navatek in Hawaii. The 100ft (30.5m) long vessel is supported on a volumous lifting body and a forward Pi-foil. Initially intended as a demonstration of the Navatek Underwater Lifting Body technologies in a test craft configuration, it is targeted eventually for service as a commercial ferry, see Figure 1. The project showcases not only advanced design concepts in hull form and dynamic support, but is an example of how versatile the custom boat builders are, and how no one solution fits all. Engineering of the structural laminates was carried out by High Modulus to satisfy the requirements of the American Bureau of Shipping (ABS), and accommodate the different builder's preferences in construction approach.

Figure 1: Ferry Configuration

Introduction

Navatek is a Hawaii based company pushing the bounds of conventional naval architecture with high performance vessels supported by various combinations of foils and patented and proprietary lifting bodies. These are positioned below the hull and at speed lift the vessel clear of waves, improving the sea keeping behaviour and enabling high speeds in rough conditions. There are a number of military applications in small to medium sized craft as well as commercial possibilities in fast ferries. Navatek develop concepts primarily through CFD analyses, and testing of large-scale prototypes to demonstrate the technology.

The subject of this article is the HDV® (hybrid deep vee®) 100 project, a 100ft long vessel with a flying design speed of greater than 40 knots. The configuration is a Serter anti-slamming, Deep-V

A Word from the President

Welcome to the first issue of the New Zealand Naval Architect for 2005. I trust that you all managed to enjoy some relaxing maritime activity over the Christmas period, although those of us who waited until the middle of January certainly got the best of the weather.

The annual RINA Christmas dinner was a great success. The Members Lounge at the Royal New Zealand Yacht Squadron certainly is a great setting, the food was excellent and the company superb.

The first technical talk of the year, presented by Robert Ochtman-Corfe, on design of an offshore patrol vessel certainly set the scene for an exciting year ahead. I found it fascinating to hear about the design decisions made by Robert that were driven by his personal experience and appreciation of what makes for a good vessel 'at sea'. There was a pretty intense question and answer session after the talk, which highlighted how interesting everyone had found the

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presentation. It also reinforced for me, despite my passion for technology and design, just how powerful the old 'Team New Zealand' principle of letting sailors (end users) drive the design process really is!

Thanks to all those who support the RINA activities, perhaps you'll see your picture in the gallery of recent event photographs (See page 6).

A special welcome to the participants of the Yacht Vision 05 design symposium being held in Auckland from 9-12 March. I trust that you enjoy your visit to the City of Sails, and enjoy not only the Yacht Vision conference but also the other Maritime Festival events, including the Auckland International Boat Show, the Marine Trades Challenge and the Marinas 8 Conference.

We had a good response to the request for permission to list members professional expertise in the RINA (NZ) database so that we could provide information on local expertise when requested. In all we have had 33 responses with over 67% listing boat design as their main activity. Preparation for the next High Performance Yacht Design Conference to be held at Auckland University in February 2006 continues with the first call for papers published (see page 8). The initial feedback has been encouraging and we are confident of another vibrant and technically stimulating conference.

I look forward to catching up with you at the next meeting in March or the AGM in April.

Graeme Finch

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monohull as the parent hull, with two Ama hulls approximately 60% of the main hull length. Flying support is from a pair of lifting bodies aft, connected to the main hull through vertical struts, with a cross foil between them. Articulated trim tabs along the trailing edge of the cross foil provide the control surfaces. The forward flying support is provided by an articulating Pi-foil. The hull and deck structures are being fabricated at Westerly Marine and the vertical struts and lifting bodies at a New Zealand yard. The metal components for the aft cross foil and trim tabs are being fabricated by Mayville Die and Tool in Wisconsin while the forward Pi-foil is being manufactured by MTD in the Ukraine.

The materials and build processes, as well as the tooling, selected for the various components were a result of the differing scale, strength requirements, and builder's preference. In addition criteria associated with approval by the ABS and US Coastguard for service as a commercial ferry were taken into account. The design was developed using a combination of simplified formulas in keeping with the approach of the scantling rules, and finite element analysis for global deflections and detailed design of the struts and lifting bodies along with their associated internal support structures. The interface between the composite elements and the stainless steel cross foil of the lifting body was of particular interest.

Hull shell and structure

The hull is fabricated from four side shells and four bottom shell elements, each approximately 12m long; plus a transom, tunnel and two mouldings for the complex bow shape. This approach allowed ready access to each part during laminating and utilised Janicki CNC tooling. Despite the combination of timber, low density polyurethane and the higher density polyester surface, of various thicknesses the tooling stood up well to cure cycles up to 70°C, test cures of in excess of 80°C were also preformed to prove that the tooling could withstand temperature spikes and exotherm on the laminates.

A wet epoxy system from Applied Polymerics was used in conjunction with an on site impregnator. The E-glass 0/±60° triaxial reinforcements were pulled through two large diameter nip rollers and impregnated to a close tolerance with the resin before being applied to the tool, consolidated by hand and finally under vacuum before gelation. Consequently a relatively long open time (6 hours) was required in order to get the whole laminate in place before application of the vacuum bag. An elevated cure temperature of 70°C for 3 hours was required while under vacuum. A subsequent post cure of 4 hours at 70°C is also required after assembly as a number of the secondary joints were room temperature cured. Figure 2 shows

Figure 2: Hull Shell being assembled

the hull parts being assembled.

In order to meet US Coastguard requirements for a passenger ferry a flame spread rating of less than 100 in accordance with ASTM E-84 guidelines was required. The system developed by Applied Polymerics delivered a rating of 60. Coast Guard also require that the fibre content be no greater than 60% by weight, and hence care was required in the build process to insure accurate control over the resin content. The use of the wetpreg approach, with a controlled bleed stack of perforated release film and bleeders, was considered a better option than wet infusion which might have delivered much higher fibre contents.

Baltek's density controlled SuperLite end grain balsa was selected for the hull sides, with Airex R63.140 linear foam in the bottom shell. Core thickness ranged from 60mm to 40mm depending upon the region of the boat and the available supporting structure. All cores were bonded to a cured outer skin under vacuum using a wet epoxy adhesive paste

There are bands of carbon unidirectional run fore and aft along the keel to improve global stiffness along with extensive carbon patching in the hull shell in way of the struts supporting the lifting bodies. In some areas there are up to 48 layers of carbon double bias.

The internal structural arrangement was determined after consideration of a number of factors including the arrangement of the four engines located in two engine rooms. A series of primary bulkheads supported deep bottom girders aligned with the engine mounts and continuing forward. Further secondary transverse frames are located between these. In most situations the arrangement of framing would be driven by structural considerations, in this case the spacing and depth was primarily dictated by tonnage requirements upon which the vessel is classified for commercial purposes. Consideration was also given to flooding stability and hence a number of internal watertight boundaries are included in the structures. Figure 3 shows the internal structure during construction.

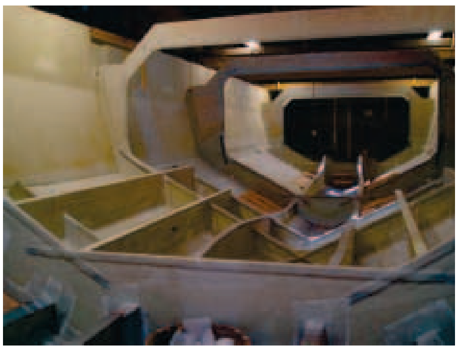

Figure 3: Partial bulkhead Installation

The flat bulkheads were laminated using both wetpreg and hand laminating techniques laid up on an aluminium table. Typically these bulkheads were double bias glass on Baltek's density controlled SuperLite end grain balsa.

Deck shell

The deck is a gentle camber, and one male tool measuring approximately 5m x 7m was used to manufacture the 23 panels that form the deck. Despite the 120°C cure temperature ABX grade plywood sheathed with 2 layers of woven E-glass cloth was found to be suitably stable. The underside of the mould was ventilated in order to assist heat transfer during cure.

The primary reinforcement in the deck was a multiaxial carbon consisting of a total of seven plies. This single ply reinforcement was economic in terms of material and labour, as well as being well suited to the structural requirements.

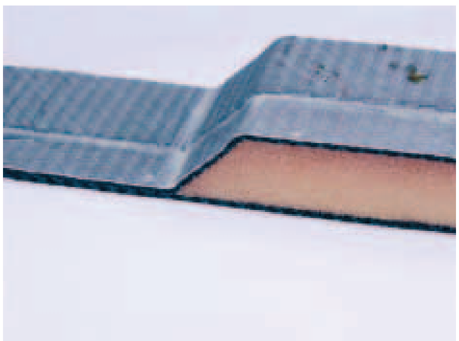

Figure 4: Deck Panel Edge Detail

However the heavier weight and tight nature of the fabric did pose issues with regard to processing. After some trials on smaller samples it was decided to develop a resin film infusion process as this insured even distribution of the resin, controlled resin content (to meet Coastguard requirements) and with an elevated temperature a low enough viscosity to impregnate the fabric with assistance from the vacuum.

Airex C71.75 proved to be easily processed in this situation and was used for all the deck panels. The resin film used was the Newport Adhesives and Composites NB117 system to meet the fire retardant requirements. Figure 4 shows the finished product.

Aft Foil Assembly (BWB)

The BWB, blended wing body, forms the aft lifting element of the vessel and employs a wide range of construction techniques from autoclave-cured prepregs to wet laminating. The assembly consists of two vertical support struts, two submerged lifting bodies and a cross foil with control surfaces. Both the struts and lifting bodies are constructed in composites, with the cross foil in stainless steel. A total of 16 CNC machined plugs and moulds were used during construction, along with a number of hand made moulds. The design also allowed the parts to be disassembled for shipping, later modification or maintenance that lead to a large bolted joint between the strut, pods and cross foil. The lifting body construction also incorporates bolt on metal leading and trailing edge. The basic arrangement is shown in Figure 5.

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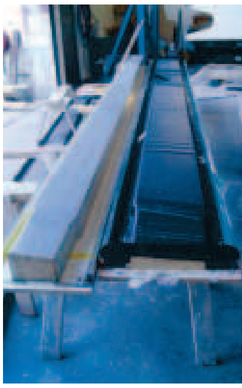
Figure 5: Exploded Basic Assembly



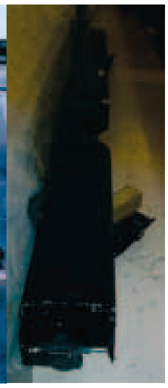


Figure 6: Plug and SPRINT tooling

Figure 7: Finished Part

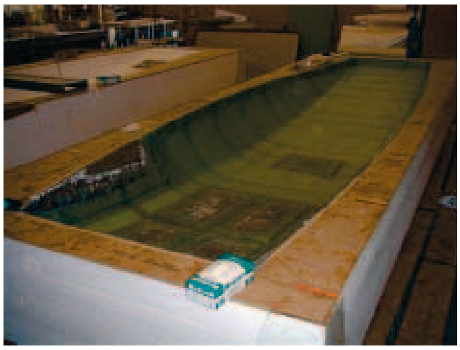


Figure 9: Completed Outside Skin

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Struts

The structure in the struts takes the form of a series of box section beam elements, approximately 230mm x 300mm. These transition down the length of the strut from rectangular inside the hull to a foil section between hull and lifting body. The box beams used Newport Adhesives and Composites collimated unidirectional prepreg tape, in a combination of intermediate modulus and standard modulus carbon fibre. Each box beam was moulded inside female tooling moulded off CNC machined plugs. The female tooling was laminated using a SPRINT carbon woven cloth system, see Figure 6. The moulds were made in two parts, with the prepreg laminated inside each half; the halves were then assembled together with an overlap join on the webs. A vacuum bag was laid through the moulds and sealed around the outside with the requirement for a full vacuum. Final curing is completed under Autoclave conditions. Figure 7 shows one of the finished parts, note the kink in the web where the beam section is modified to pass around the main hull support pin.

The struts also have a number of metal parts and systems that needed to be incorporated into the design. Aside from the main attachment pin to the hull, the strut design had to accommodate mechanisms for control surface adjustment as well as restraint and adjustment of the angle of attack.

Final assembly of the struts was in a moulded shell; the mould is shown in Figure 8. The shell was a basic laminate of E-glass and Kevlar/E-Glass hybrid stitched fabrics, with areas of reinforcement laminated in place. The shells also incorporated a solid foam leading edge with additional laminates of Kevlar/E-glass hybrid to provide some impact resistance. Figure 9 shows the completed outside skin.

The lifting bodies are a non-symmetrical complex 3D shape made from E-glass and Kevlar/E-Glass hybrid reinforcements with an AIREX linear foam core in "wetpreg" epoxy. The moulds were constructed from polystyrene, machined in a number of block parts and assembled to form four separate top and bottom shell moulds. With a requirement for very close tolerances during the build, the Polystyrene moulds proved to be very temperature stable. The lifting bodies also had a requirement for access to the control surface mechanisms as well as access aft into the void spaces for bilge pumps etc. This meant the inclusion of numerous complex hatches moulded into the shells during construction. Figure 10 shows one of the completed pod shells. The internal structures are also E-glass.

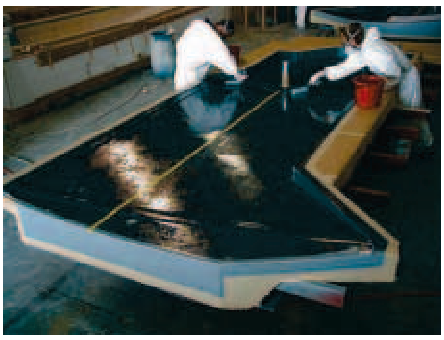

Figure 8: Strut Shell Mould

The resin system employed was Adhesive Technologies ADR246/ADH160 epoxy, postcured at 50-60°C.

Final assembly involves fitting the transverse and longitudinal internal structures into the shells, along with the cassette to house the cross foil and socket for the struts before the shells are bonded together and externally taped.

Summary

This project illustrates the wide choices offered when building with composites, both in the range of materials and processes. So often a solution will be developed which fails to take advantage of the possibilities. In this situation we have three types of foam core, plus

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balsa, combined with a variety of styles (unidirectional, woven cloth, 0/±60° triaxials) of E-glass, Kevlar, and carbon reinforcements. Wet epoxy systems were used from two suppliers, along with higher temperature cure prepreg and film materials. Tooling ranged from simple plywood formers through to CNC machined low-density foam elements and carbon prepreg items suitable for autoclave curing. Processes covered everything from vacuum consolidated hand and on-site impregnated wet systems, resin film infusion and autoclave consolidated uni-tape construction. One of the key elements in allowing this complex but tailored solution was the flexibility of the builders who were willing to develop appropriate processes to solve the immediate problem, in a short time frame.

Richard Downs-Honey is Managing Director of High Modulus.
Richard Bootten is a structural engineer for High Modulus, who specialise in marine composite structures and materials.

"Galileo" - Open 60

by
Angelo Lavranos

The "Galileo" has been designed as an all rounder to compete in upwind races such as the Transatlantic Onestar & Twostar as well as downwind races like the Transat Jacques Vabre. Vpp/ parametric optimisation was carried out to achieve a better boat, from close fetching to broad reaching at all "powered up" wind speeds. The IMOCA stability requirements for this class are now very much the driving factor in the design. These effectively limit the overall beam so that maximising the water plane inertia and lateral buoyancy shift with heel become more important. The design of "Galileo" has carried this issue further than any other boat to date including the yachts Sill and Bonduelle. These vessels incorporated a topside knuckle as a method of increasing beam on the waterline (Interestingly the first VOR 70 - ABN Amro is also following this line). In achieving the design solution, helm balance and other control issues made daggerboard, rig and rudder positioning critical. Initial on water indications are very positive, the boat handles well and is achieving speed predictions. Her best upwind VMG ranges from 8 knots in 12 knots true wind to 9.3 knots in 25 knots of wind. When reaching with the main and code #2 a speed of 23 knots in 25 knots (@ 140 deg) has been achieved. Average speeds of 20 knots in optimum conditions are possible. The boat speed exceeds the wind speed on one or more points of sailing up to 15 knots true wind speed. "Galileo" is proving to be an extremely powerful boat that will give the "class of '04" a hard time.

The design of Galileo has been a New Zealand venture. Angelo Lavranos is principal designer and naval architect, Susan Edinger of High Modulus Ltd did the analysis of the carbon nomex structure, Chris Mitchell the rig engineering, Tim Sadler engineered the swing keel fin and hydraulic systems and Doyle Sails (NZ) supplied the sails. The yacht is equipped with Harken deck fittings, has a fixed Hall Spars rig and Future Fibre rigging.

Angelo was commissioned on the strength of his past record in the Open 60 class (two Transatlantic Twostar wins and records, three BOC leg wins and records, and Round Britain win and record, plus two OSTAR 2nd places). His two previous Open 60's designs were Voortrekker II ('82 -'86) and Allied Bank ('90/1). He has also had IOR & IMS successes. The boat was built in Brazil, and the client is aiming at the Calais Round Britain and Fastnet in May and July 2005. The owner, Walter Antunes, project managed and funded the construction himself.

The boat carries water ballast in six tanks (three per side). These can usually be filled and emptied in 2-3 minutes. These tanks in addition to the swing keel ensure that trim and

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stability may be optimised in various conditions. The swing keel can be cranked to leeward in very light airs and the forward tanks filled when wetted surface is reduced dramatically. As the wind speed increases the keel is swung up to more than 30 degrees to weather. The added water adds righting moment not only due to lateral moment, but also due to increased sinkage. The aft tanks are used for hard reaching conditions to keep the bow from "stuffing" at high speed. The asymmetric twin daggerboards provide lateral resistance as needed. The twin rudders are so positioned to provide control at all normal heel angles.

Principal Characteristics

LOA	18.28 meters
Beam	5.54 meters
Draught	4.50 meters
Displacement	8800 kgs
Mainsail	170 m^2
Code 0	190 m^2
Code 2	370 m^2

Photo Gallery

Here are a few photos of recent members meetings. Can you spot your face in the crowd?

December 2004:

Christmas dinner at the Royal Yacht Squadron.

November 2004: Tour of Auckland University's Centre for Advanced Composite Materials.

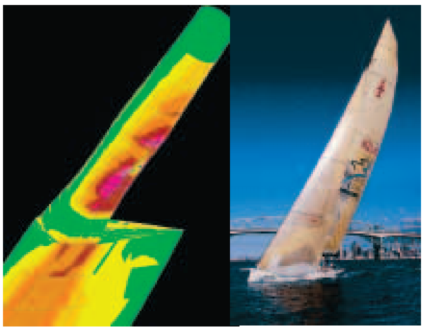
February 2005: Offshore Patrol Boat Presentation by Lt. Cdr Robert Ochtman-Corfe, RNZN Hull and Structural Engineering Officer.

Smart Marine Structures

Update from Industrial Research by Graeme Finch

Industrial Research Limited is internationally recognised for its research into dynamic loading of marine vessels and composite structures. Although it no longer receives any government funding for marine related research a number of interesting projects have been completed over the last year ranging from dynamic load measurements on sailing yachts through to forensic failure analysis of marine composite structures.

A project to investigate structural loads induced in the rudder of an Americas Cup yacht was undertaken on NZL40. This involved not only establishing a realistic finite element model of the carbon fibre structure but also strain gauging the rudder blade and stock, calibrating the measurement system and conducting on-the-water sailing measurements.



The dynamic loads experienced by a 50 ft racing yacht were monitored using a system of 7 accelerometers over an extended period as part of a programme to quantify typical hull accelerations levels. A customised low power measurement system recorded the yachts sailing parameters as well as significant transient loading events. Based on experience gained from this activity a fully portable motion measurement system has been developed that will be used by the Auckland Maritime Police Unit to evaluate the seakeeping response of candidate vessels to replace their present police launch Deodor II.

Measuring the dynamic response of a sandwich composite panel exposed to high speed slamming events were undertaken in our unique 'slam test' facility. This is part of our long term collaboration with the Royal Institute of Technology in Stockholm. The work in conjunction with theoretical modelling studies in Sweden, will provide better knowledge of the structural loads imposed by this widely recognised but poorly understood phenomena.

NZ Division Library

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To see a list of the collection via the internet access the site **www.irl.cri.nz/infoservice** and search the library catalogues.

Technical Meetings

More information on the following events will be provided in Update.

MARCH 8th: Vaudrey Miller Shipyard visit

APRIL: RINA NZ Division AGM ***(Date to be confirmed)***

Don't forget to look up our RINA web site (www.rina.org.nz) It is where you'll find

- NASNZ Standard Terms of Trade and Standard Design Contract, available for free download.
- Past issues of the NZ Naval Architect

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