Technical Meeting — 3 October 2018

Warren Miller, Senior Design Engineer with Composites Consulting Group (a Diab Group company), gave a presentation on the Wild Oats XI *Bow Extension Project* to a joint meeting with the IMarEST attended by 19 on 3 October in the auditorium at the Royal Prince Edward Yacht Club, Point Piper.

Introduction

Warren began his presentation with an introduction to Composites Consulting Group (CCG), which is an independent branch of the Diab Group providing businesses with the required competence in the design and manufacture of composite materials. CCG has extensive engineering and manufacturing experience from various industries giving them insight into their customers' needs. They provide structural engineering, process and mould design, manufacturing inspections and consulting, and training.

Their team of more than 30 engineers in seven countries offers 24/7 fast worldwide support. Various projects in Australia have included

- The *All Eyes on Us* sculpture, 7 m high, for the Commonwealth Games on the Gold Coast in April 2018.
- *Ocius*, the 6 m Bluebottle autonomous sailing drone from Ocius Technology (hull and deck, internal structure, mast base, etc.)
- Kenwick (Perth, WA) railway station monocoque composite canopy.

Why Modify the *Wild Oats XI* Hull?

Over the years, *Wild Oats XI* has become more powerful, with the addition of water ballast and more sail area. This means that she can be driven harder, and driving into the back of a wave slows the boat for a start, and can even become dangerous.

Three years ago side lifting foils were fitted which could be extended on the leeward side to provide righting moment. In addition, they were forward of the centre of gravity, and so provided lift for the bow.

However, they really needed the whole rig to be moved further aft, or the hull to be moved forward under the rig, to provide more buoyancy forward and so reduce pitching. This is not easy to do .....

Wild Oats XI punching into the back of a wave
(Photo courtesy Diab Group)

The Rules

The International Sailing Federation (ISAF) is the world governing body for the sport of sailing. Their Offshore Special Regulations (OSR) of 2015 in Section 3.03.3(b) states:

"A yacht of 24 m in hull length and over ….. shall have: The repair or modification designed and built in accordance with the requirements of a classification society recognised by the ISAF."

The original engineering of *Wild Oats XI* by SP Technologies was to ABS' *Guide for Building and Classing Offshore Racing Yachts*, 1994. However, the *Guide* is no longer updated or supported by ABS. It turns out that DNV GL is now the only classification society with rules applying to racing yachts, so the structural engineering of the bow extension was done in accordance with GL's *Guidelines for the Structural Design of Racing Yachts ≥ 24 m*.

This is important, because they were wanting to move the keel and mast, which could easily be done on, say, a TP52. However, the keel is not fixed on *Wild Oats XI*, but is a canting keel, and the current rules require that the vessel must be able to ground with the keel fully canted. This has not been allowed for, so the keel could not be moved.

The Plan

A team of local experts was formed to design the modifications, including Wild Oats Racing, One2three Naval Architects, McConaghy Boats, and CCG performing the structural engineering tasks.

Instead of moving the mast and keel on the original hull, they had to make decisions about what to do. The plan they came up with was to

- remove 2 m from the stern;
- remove 11.2 m from the bow; and
- replace the bow with a 13.2 m extension.

The easy part was removing the bow and stern sections, although they had to be careful where they cut, and what they cut. One goal was to lighten the vessel by removing material, one example being the removal of a large watertight bulkhead. They decided to cut the vessel forward of the daggerboard cases, and to leave the forestay attachments in the same place. The rocker profile of the hull did not change much, as the vessel is very flat from the keel aft.

Wild Oats XI with the 11.2 m bow section cut away
(Photo courtesy Diab Group)

Major Considerations

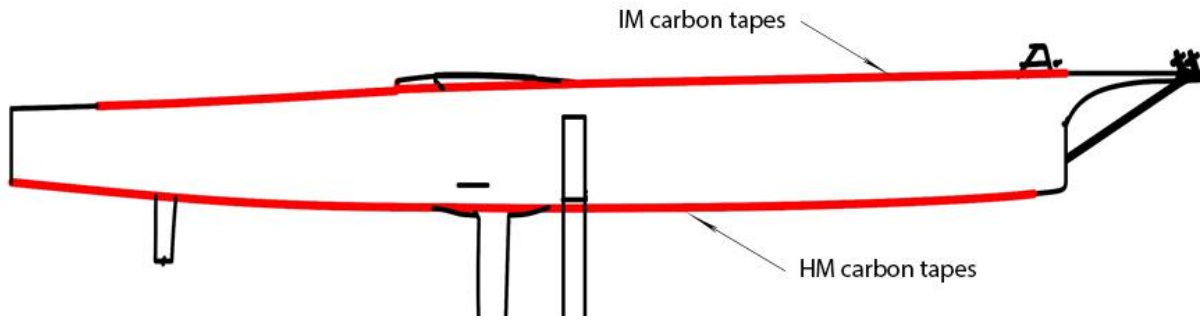
Hull Curvature

It was difficult to keep the sheer line of the vessel, and this was a major factor in deciding on the location of the bow cut.

Global Stiffness

Analysis showed that, with the forestay, backstay and mast loads, they had to allow for a total bending moment on the hull of 3600 kN-m! That meant that, for global strength and stiffness, they had to have Intermediate Modulus carbon tapes on the deck, and High Modulus carbon tapes on the hull bottom.

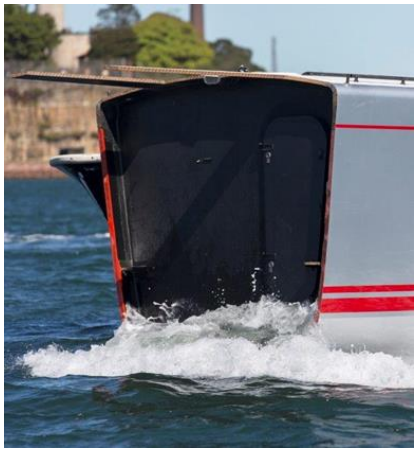
Carbon Type	**Young's modulus**	**Ultimate strains**	
	GPa	%	%
High-strength carbon fibres	130	1.1	–0.82
Intermediate modulus fibres	163	1.0	–0.71
High modulus fibres	208	0.75	–0.45



Carbon tapes on deck and hull for global strength and stiffness

(Image courtesy Diab Group)

The old deck was therefore cut away from the deck "planks" of carbon tapes, and the planks reinstated on the new deck.



Hull under tow showing deck planks
(Photo courtesy Diab Group)

Joining

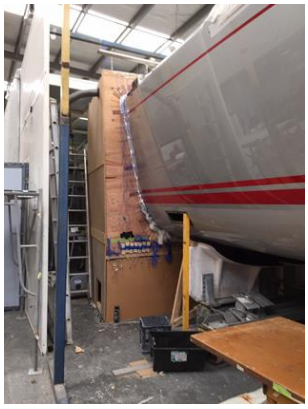
There were a number of considerations in joining the bow extension onto the main hull:

- Cutout geometry: they had to avoid the daggerboard inboard webs and tapes.
- They had to join as far aft on the topsides as possible to fair into the existing topsides.
- Longer laps for global tapes means that it was advantageous to step forward on the hull bottom.
- Due to lack of availability of wet-laid HM fibre they used the equivalent strength of IM fibres for both hull and deck global tape joins.

The bow extension was joined to the main hull at the deck level with five plies inside and five plies outside the sandwich laminate construction.

The bow extension was joined to the main hull sides and bottom with five plies inside and eight plies outside the sandwich laminate construction.

Hull ready for joining
(Photo courtesy Diab Group)



Hull join being vacuum bagged

(Photo courtesy Diab Group)

McConaghy Boats did all the work, and they were amazing. They had done previous cut-and-join work, and so were familiar with the type of work required. A specialist, Peter Britt from Forster, was brought in to oversee the join of the new bow to the hull. The join fit perfectly.

Mass Savings

A secondary aim of the project was to save as much mass as possible.

Interestingly, the ABS 1994 *Rules* required a minimum skin thickness. whereas DNV GL do not. This means, for example, that *Comanche* has laminate skins which are about half the thickness of *Wild Oats XI*'s originals. As a result, the bow extension has lower skin thicknesses than the original, and the nomex honeycomb was replaced with aramid honeycomb, allowing for further mass savings.

The original estimated bow with structure was 5954 kg. The original topside mass was 8.4 kg/m², and the modified mass is 7.4 kg/m². The original bottom mass was 17.62 kg/m², and the modified mass is 10.96 kg/m².

In addition, there was removal of old supporting structure and implementation of simpler structure.

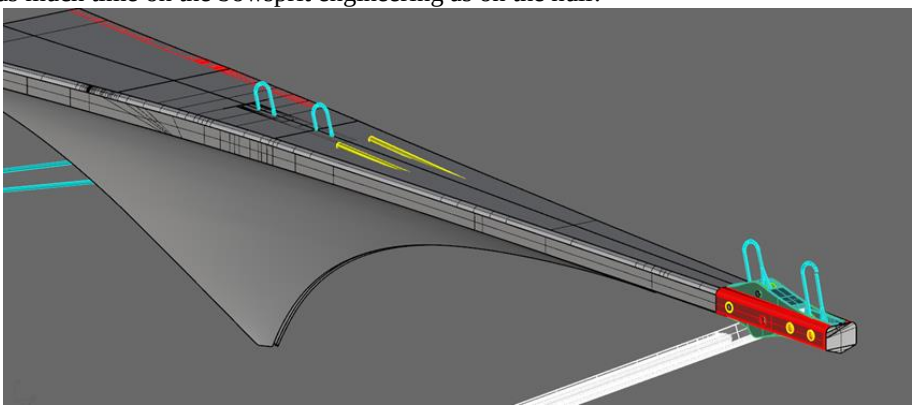
All of this gave rise to a total saving of 725 kg (including the modified bowsprit), or 12% of the hull mass.

Side Benefits

A side benefit of the bow extension project is the longer bowsprit. When the bow extension project was first planned, they thought that they would get away with a shorter (1.5 m) bowsprit. However, when the sailmakers became involved, they ended up with a longer (4.0 m) bowsprit than original! The benefit comes when handling headsails.

Older vessels (like *Loyal*) have hank-on headsails and, in heavy weather at night, it can take hours to change headsails. The new bowsprit on *Wild Oats XI* allowed the use of top-down furling headsails, which are easier to manage between sail locker and deck as a roll, and one can be hooked on before the other comes off, so that the vessel is never without a headsail.

However, the tip of the new bowsprit was a real structural challenge, including a solid carbon bobstay. They spent almost as much time on the bowsprit engineering as on the hull!



Wild Oats XI new bowsprit
(Image courtesy Diab Group)

Results

The hull modifications have changed the yacht's performance, and the crew is now much happier with how she handles.

Downwind, *Wild Oats XI* can make a better VMG [*velocity made good; i.e towards a given waypoint* — Ed.] by sailing 15° lower but at a slightly lower speed than, say, *Comanche.* One reason for this is that she has a lower wetted surface area and so less frictional resistance.

Conclusion

The bow extension project for *Wild Oats XI* has involved removing 2 m from the stern and 11.2 m from eth bow of the vessel, and replacing the bow with a 13.2 m extension. The structural analysis was complex, and involved many decisions. The work was carried out by McConaghy Boats who did a wonderful job. The result has been the desired improvement in performance, which has kept the vessel competitive with contemporary modern designs, and the crew are very happy with what has been achieved.

The vote of thanks was proposed, and the certificate and "thank you" bottle of wine presented, by Jason Steward.

Warren Miller (R) accepting the “thank you” bottle of wine and certificate from Jason Steward
(Photo John Jeremy)