Challenging!

More impressive perhaps than her recent transatlantic record was the fact that the new *Mari-Cha* crossed and recrossed the Atlantic – at some speed – with little or no technical difficulty straight out of the box. JMV Shipyard built *Mari-Cha IV* under the watchful eye of skipper Jef d'Etiveaud, who tasked SP Technologies with getting the composite engineering right… first time. Design engineer Fred Louarn reports

Measuring 44.3m overall, with a total sail area of 1,100m² upwind and 1,500m² downwind, *Mari-Cha IV* is similar in size to her illustrious predecessor, *Mari-Cha III*. However, this impressive yacht displaces only 60 tonnes in sailing configuration, making *Mari-Cha IV* almost 50 per cent lighter than her predecessor.

Unique design features, such as her canting keel and two almost identical rigs that require separate teams of grinders and trimmers, have attracted a lot of industry interest, while so far at least owner Robert Miller and project manager Jef d'Etiveaud's brief to produce the fastest racing monohull yet seen appears to have been fulfilled.

SP was commissioned to engineer *Mari-Cha IV*'s ambitious composite structure and we worked closely as part of the project team, maintaining constant communication with the designers and JMV Shipyard throughout a two-year construction process that involved no fewer than 50 skilled boatbuilders on a full-time basis. In total the time spent by our engineers on this project already amounts to some 4,500 man-hours; and more radical devel-

Big and flat, though not quite as large as the 'deck of an aircraft carrier' as reported by an excited journalist from the London *Times*... One heck of a hardware order nonetheless

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Perfectly in proportion if just a little out of the usual scale. The little 'runabout' pictured in the background (*opposite right*) as *Mari-Cha IV* emerged from the shed at JMV Shipyard last July is Emma Richards' Owen-Clarke designed Open 60 *Pindar*. Fitting the vast canting keel required the use of double-stacked containers on which to rest the new boat's cradles to achieve sufficient ground clearance. Some idea of the task of resolving the longitudinal bending demands of this giant but shallow girder can be gauged from the profile shot below – although the engineering challenge was made 'slightly' easier by the requirement for the boat to have a downwind bias

opments are planned for the future...

Mari-Cha IV is designed for maximum speed, placing the emphasis on offwind performance, so the quest for weight saving has been paramount throughout the project. The flat hull is optimised to operate in semi-displacement and full planing modes where weight creates drag in an almost linear relationship. The level of optimisation required in terms of engineering has been achieved through extensive use of analysis tools such as state-of-the-art Finite Element Analysis (FEA) software, MSC Nastran and Patran.

Mari-Cha IV is an ocean-going vessel and will face some harsh conditions, but the focus on weight saving does not mean that safety and reliability were overlooked in any way. High elongation carbon fibres have been used as the primary reinforcement material throughout the vessel, providing sufficient fracture toughness and the required strength. Kevlar has also been applied in areas of the hull shell, further improving toughness and forming an additional barrier against penetration. The resulting hull shell structure is a combination of single skin laminates in the bottom forward (slamming) region, and Nomex sandwich elsewhere. No foam cores were used on this project. In total some 20,000m^2 of prepreg carbon were used in the construction.

The secondary internal structure is a combination of longitudinal beams in the sandwich area and transverse frames in the monolithic region. The transverse internal structure allows the 0^o fibres to have the required local panel strength, to contribute to global hull girder strength and stiffness.

As well as having to resolve local hydrodynamic loads, the hull shell is also subjected to global rig and hydrodynamic forces. *Mari-Cha IV* features a schooner rig, effectively splitting the total sail area between main and mizzen rigs. Compared to a sloop, this arrangement has the advantage of spreading global bending forces.

Although designed maximum mainsheet load peaks out at just over 13 tonnes, with several hundred tonnes of load through localised areas of concentration such as the mast step and chainplates, reinforcement of the hull girder is primarily driven by stiffness rather than strength requirements. Increased stiffness also results in higher accelerations and care is needed to prevent the structure from resonating when vibrations are excited. Intermediate modulus carbon has been used selectively to fulfil stiffness and energy absorption requirements while limiting the weight penalty.

With regard to the local point loads, such as deck hardware attachments, *Mari-Cha IV* represented an extreme design case and this was a major challenge for SP's engineers. These loads vary continuously over time in terms of magnitude and possible direction. They enter the structure at localised attachment points and must spread to transfer forces evenly to the whole vessel.

To deal with the effect of these concentrated loads SP developed a particular in-house philosophy, or approach, that has been applied to this (currently) extreme project. The technique used involves building up factors from a maximum steady-state load to a peak dynamic load, then a limit case, and finally an ultimate one – the point of structural failure. With *Mari-Cha IV*'s enormous 20-tonne canting keel, which can be swung to +/-40 degrees, or the two rigs towering 40m above the deck,

structural design loads equivalent to several hundred tonnes are common. Not surprisingly, these 'points' of maximum load are where structural weight is most concentrated in the boat and where the outstanding properties of modern carbon fibres, combined with an efficient structural system, can be used to their full potential.

With 21 winches to be found on *Mari-Cha IV*'s deck, we faced a 'challenging' deck plan. With static working loads on rig line control systems varying from two to ten tonnes, crew safety became an absolute priority, followed by careful weight consideration on each and every fitting. Composite strap fittings form one of the most efficient structural systems, making the best use of the specific tensile strength of carbon fibres, and these have been used to reinforce the rig attachments and, wherever possible, to support deck fittings. Many specific adaptations were also made to fitting attachments to ensure satisfactory dispersal and resolution of the very high transverse deck loads.

This project, extreme as it may be, is a great illustration of the areas of consideration that good structural engineering should encompass, ranging from performance to seamanship and safety. Working near the limits of current technology, every architectural decision has structural implications and vice versa.

Mari-Cha IV was launched in August 2003 from Cherbourg, and shortly afterwards successfully completed her sea trials with a fast delivery to New York in preparation for the West to East transatlantic attempt. The 2,925-nautical mile passage started from Ambrose Lighthouse, New York on 2 October and finished at Lizard Point off southwest England. *Mari-Cha IV* shattered the current record held by Bernard Stamm's *Armour-Lux*, of 8d 20h 55m 35s, and completed the voyage in a staggeringly swift 6d 17h 52m 39s.

Mari-Cha IV had already made sailing history during the crossing when she smashed the 24-hour record, sailing 525.5 nautical miles in 24 hours, beating the previous record of 484 nautical miles set by John Kostecki on *illbruck*, coincidentally becoming the first monohull to sail over 500 miles in a day. So far so good.

Fred Louarn and Giovanni Belgrano, SP Technologies ❐