MARTINA ORSINI

Knife, gunfight

When a leading skiff designer who is equally renowned as an America's Cup innovator and structural engineer turns his attention to the Moth class the result is never going to be anything less than fascinating

In the aftermath of the 2017 America's Cup, as I was packing up our things to move back to Seattle after two years in Bermuda, longtime Moth sailor and SoftBank Team Japan performance coach Scott Babbage came over to discuss a new Moth project he had in mind.

At that stage Moth evolution had been continuous but incremental and Scott saw an opportunity to take forward some of the latest configuration improvements in the boats and incorporate them in a brand new no-compromise design that also took advantage of some of the things that we had learnt from our recent experiences in the Cup. Taking an excursion back into the world of high-performance skiffs after spending the previous three years almost exclusively working on foiling AC catamarans sounded like a nice way to wind down from the Cup!

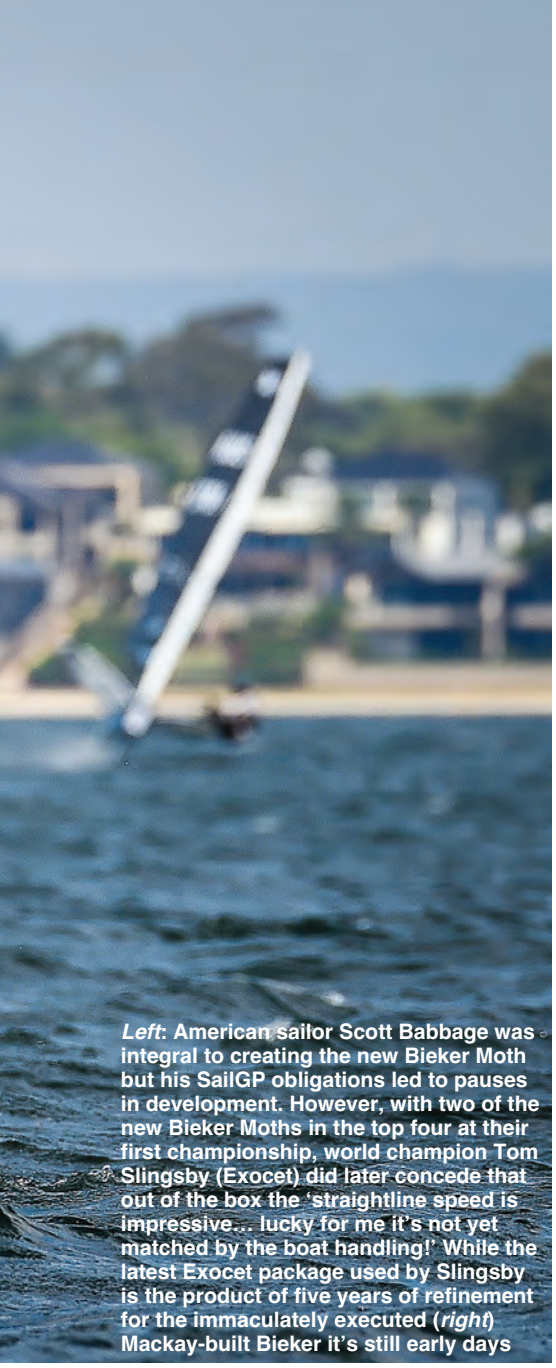
I had designed bits and pieces for Moths over the years – initially with innovative American Moth sailor Bora Gulari. That said, this was the first time I'd been given the chance to design a complete package.

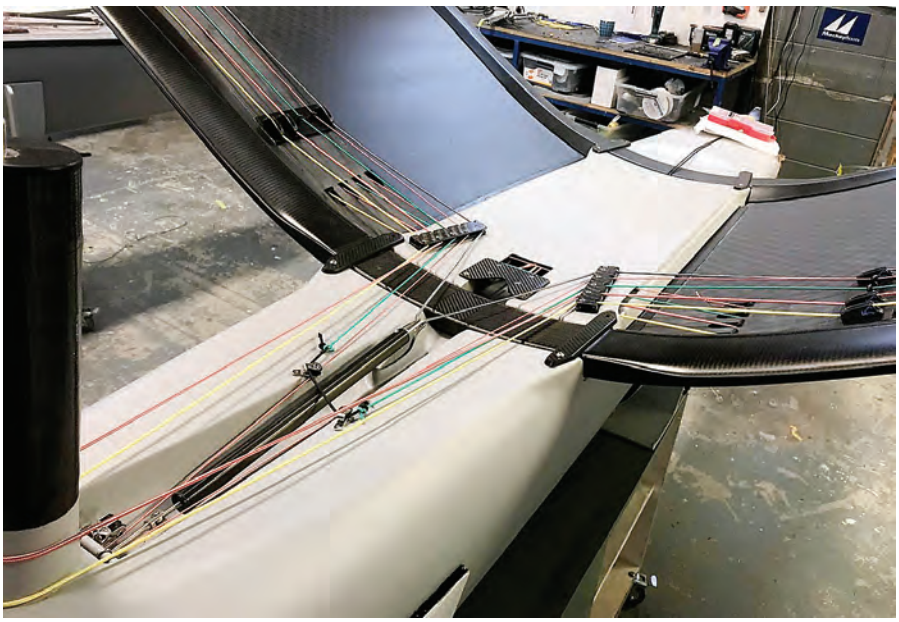
Our principal goal for the new boat was evolutionary rather than revolutionary: primarily to improve the aerodynamic efficiency of the package and to increase the righting moment by increasing the length of the foil struts as well as increasing the height of the hiking wings relative to the hull. In addition to this, I wanted to apply rigorous structural engineering methods to the boat to make it as dependable and stiff as possible for its weight.

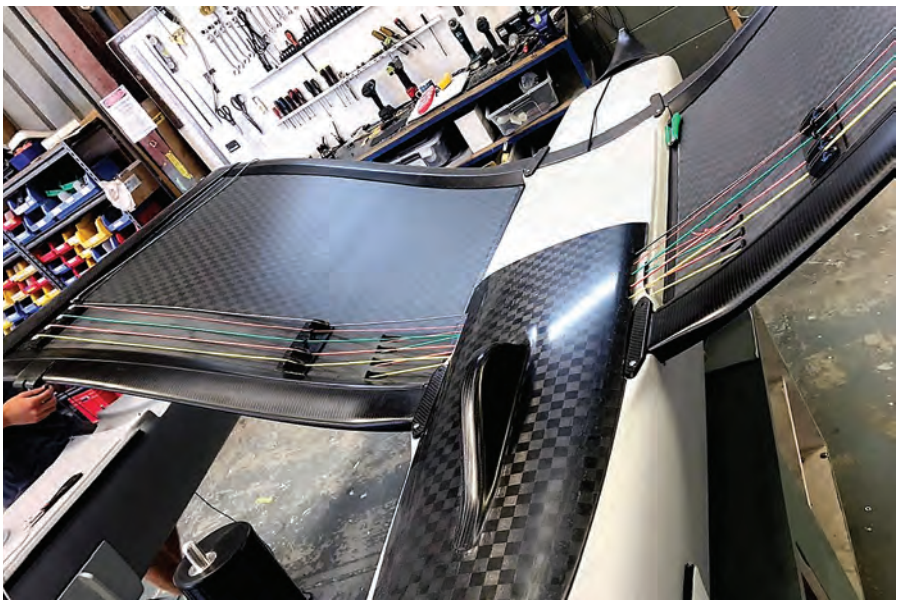
Scott and I pulled together a team that included SoftBank Team Japan boatbuilder James Gell and Oracle Team USA design engineer Riley Dean to assist us in turning the boat into a real product. Throughout the next 12 months the core team was boosted by additional specialist FEA expertise from Thomas Hahn and Leopold Fricke from the composite design and analysis firm Ixent, foil section analysis from Hal Youngren and CFD analysis from Nico Rousselon to help us to develop the design.

Pulling together a diverse, geographically separated team for what was essentially a passion project was always going to be a challenge, but the enthusiasm and interest from the team members, along with persistent prodding by Scott himself, pushed the project along nicely. Boat #1 launched at the end of July 2018 in New Zealand, some 16 months before its debut at the 2019 Moth Worlds in Perth.

At launch interest and expectations for







***Left*: American sailor Scott Babbage was integral to creating the new Bieker Moth but his SailGP obligations led to pauses in development. However, with two of the new Bieker Moths in the top four at their first championship, world champion Tom Slingsby (Exocet) did later concede that out of the box the 'straightline speed is impressive… lucky for me it's not yet matched by the boat handling!' While the latest Exocet package used by Slingsby is the product of five years of refinement for the immaculately executed (*right*) Mackay-built Bieker it's still early days**

the boat were high. Over 50 deposits were placed within the first fortnight, with the challenge for James being how to both refine and problem solve the initial boat… and then produce several years' worth of forward orders at the same time. While the prototype survived its initial launch in Tauranga and sea trialling in Sydney, needless to say there were plenty of bugs to be ironed out and a lot of refinement left to do before the boat was fully race ready.

The boat itself was not without its challenges. High-angled, small-area wings and long foils made it difficult for even experienced sailors to adapt to the change in handling characteristics. In fact, this difficulty made it hard at times to evaluate performance relative to other Moths.

With Scott working in New Zealand with SailGP for the last few months of 2018, progress on the water slowed and the performance of the new boat remained unclear. The potential was there, but so were the doubts. Intense interest is a double-edged sword for a developing concept in a world where news gets around fast.

Most of the work to get the boat up to speed involved refining the control system linkages and getting the foil angles of attack dialled in. In addition, the initial front foil concept didn't meet performance expectations and so the team sought to eliminate some of the variables by adapting existing main foils to the longer Bieker Moth struts. Meanwhile, Scott worked with CST Composites and Rob Greenhalgh from North Sails to develop a deck-sweeping rig and sail that took full advantage of the clean new platform layout.

In August 2019 the whole concept started to hit its stride. Modifications to rig geometry, and the addition of some aerodynamic fairings, tipped the boat over the edge. In the Sydney training group, which included Tom Slingsby and Rob Greenhalgh, Scott went from fighting hard to having wheels. Over the next few months a mini America's Cup of evolution occurred, with the group leap-frogging ahead each week with changes. By the worlds in December the boats were regularly seeing upwind boat speeds some 4kt faster than only a few years earlier.

Our new Moths are now being built by Mackay Boats in New Zealand, which has the facilities and manpower to keep up with orders. James Gell manages the Moth build team at the Mackay shop so there has not been a loss of continuity in the construction detailing of the boats. And we are continuing to improve the platform, most recently by transitioning from woven pre-pregs to ultra-lightweight spread tow pre-pregs in the hull, a new AP main foil design which is adapted to the recent increases in boat speed and a new, more aerodynamic rudder pod.

After that it looks as if there is room to further improve the aerodynamics of the rigs, especially now that the boat speeds upwind have broken into the 20s. Moths are interesting boats and a lot of fun!

Racing

The 2019 Worlds in Perth was the first international event for the Bieker Moth. All of the boats built over the previous 18 months by LSF Composites and then Mackay Boats were competing, with boatbuilder James Gell attending in support.

In Perth's strong wind conditions the ▷

JOSHUA MCCORMACK

Fig 1


Fig 2

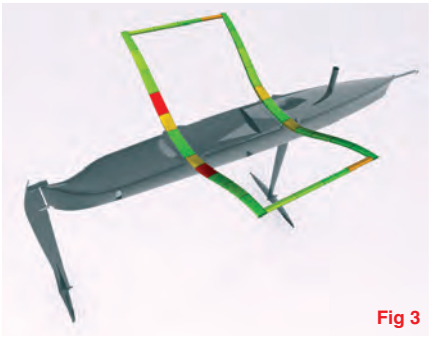


Fig 3


Fig 4


Fig 5

Figure 1: using a (top-end weight) sailor of 100kg all the major load cases were then considered in the optimisation process. Figure 2: rack sizing before optimisation (blue) and after optimisation (orange). Figure 3: property optimisation. Result of unidirectional laminate thickness (mm). Figure 4: final check – stress distribution is demonstrated across the rack using an envelope of the worst overall load cases. Figure 5: final check of stress distribution on hull – envelope of the worst load cases

low aero drag of the Bieker gave them a crucial upwind speed advantage. Out of the blocks the boats would quickly and reliably establish themselves in the leading group, which then paid dividends on a consistent racecourse. Despite their strong wind drag advantage the Bieker also won the lightest race of the final series on the last day, showing the platform hadn't painted itself into a performance corner.

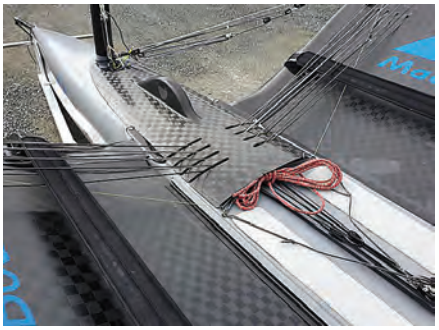
In hindsight the results for the boat were remarkable given their relative newcomer status among strong, established rivals. While Tom Slingsby dominated the Worlds in his Exocet, Scott Babbage was able to equal his score in the Nationals and placed fourth in the Worlds. Kyle Langford finished second overall, with Matthew Chew in eighth. Six Biekers in the top 15 – more than any other design.
Paul Bieker, Seattle

Structural design and optimisation

Nowadays the use of numerical simulation in the development of yacht structures is very advanced as can be seen in the multiple articles on various yacht projects in this journal. Unfortunately, however, simulation is often only used late in the process, to check the final configuration for strength and stiffness. What we have done during development of the Bieker Moth is push these simulation methods to the next step of numerical optimisation.

Despite the widespread availability of this technology it is seldom used to its maximum benefits. Yet the motivation to use optimisation is compelling and, in mechanical applications that we are focusing on here, weight saving and/or stiffness increases can be achieved without sacrificing the safety of the structure. And today there are more types of optimisation available, depending on the development stage, design freedom and objectives.

With Paul's almost emotional connection to structural design it was obvious that we had to transfer these methods from the America's Cup into the Moth project. Once the decision was made to take this path we took step after step from the conceptual design to the final detailing, using suitable and different optimisation types in every stage.



Exquisite use of the finest high modulus materials by Mackay Boats led by SoftBank's AC50 builder James Gell has delivered an end product that would look equally at home in a major design museum as on – and above – the water. An unusual amount of design and engineering brainpower to go into producing an 11-foot foiling dinghy but someone still needs to turn all of that thinking into a boat

Setting up the problem

One of the advantages of numerical optimisation is the simultaneous consideration of multiple load cases including varying loads and boundary conditions. In Figure 1 (*opposite*) the main load cases considered in the optimisation process are shown. One can easily imagine that a designer is capable of focusing on one load case and getting reasonable solutions for strength and stiffness, but simultaneously focusing on all load cases is an impossible task. Here the computer is a great help!

First step: sizing

The first optimisation task we tackled was the geometric sizing of the rack: what is the optimum aspect ratio of the rack beams and how are these distributed to achieve maximum stiffness without breaking? As the objective is minimum weight the optimiser was also allowed to modify rack beam height. In Figure 2 we see the configuration before and after the optimisation. It then needed Paul's expertise – and therefore still some human inspiration – to interpret these results and combine this with other design requirements of the Moth (ergonomics, aerodynamic drag, fitting positions and so on).

Detailing: laminate scantlings

Next step in the optimisation process is the property or thickness optimisation. Here laminate thicknesses, layer orientation and material types are optimised again under the objective of minimum weight. The optimisation delivers, for example, a distribution of the unidirectional fibres in a preselected high modulus material (it also reveals the lay-up for the other directions). Figure 3 shows such a distribution across the rack.

Final step: validation

The optimisation process shown here (for the rack structure) is only a typical extract of what we have undertaken on the rest of the boat. Hull, rudder, main foil and so on all underwent a similar procedure with the objectives individually set in each case (weight, deflection etc).

As on other projects the final step is checking the structural response of the Moth with every detail incorporated in it. Figures 4 and 5 show the stress envelope on the current rack and hull over all load cases – a very evenly distributed stress distribution points to a very efficient structure.

The methodologies described here are readily available – all that is required are designers willing to incorporate them into the design process.

Leopold Fricke and Thomas Hahn, Ixent, Munich ❑

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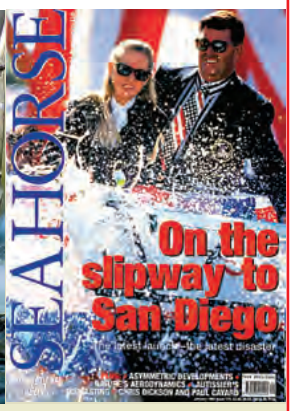

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