Instructive

World champion designer and skipper Graham Bantock guides Dobbs Davis through the nuances of International One Metre development

There are no box rule classes in sailing that boast more diversity in design than the International One Metre (IOM) class. Since the IOM was introduced in the late 1980s dozens of designs have been tried and tested throughout large and highly competitive fleets in Europe and Australasia, with no one variety evolving to dominate. Why has a unique solution not been found to these intriguing radio-controlled yachts? The answer lies in the quasi-tolerant nature of the box rule, the diversity of regatta venues and the relentless pace of development in hull and appendage shapes, albeit within fairly strict rule parameters.

The IOM's genesis in 1988 started with the goal of creating a class that would be simpler, smaller and cheaper than the Marblehead and other larger boats, with several key features:

- Three one-design rigs, each with tightly controlled sail sizes and profile.
- A sound method for determining draft restriction with a minimum and maximum value.
- Alloy or wood spars only.
- Glass or wood hulls only.
- Two channels of radio control (RC) only.
- A maximum weight for the ballast plus fin and minimum for the complete yacht.

'The class was for people who wanted a yacht that would be restricted to many of the same basic parameters as others in the fleet,' explains Graham Bantock. 'Unlike some of our other classes, this fleet was not to be a battleground for highly skilled builders with better technical solutions.' No one would know this better than Bantock, whose shop has produced amazingly detailed technical solutions to every component part of RC yachts for nearly two decades.

But as the IOM grew and developed in the early 1990s clever attempts to poke at the limits of the rule were repeatedly stymied by the class hierarchy, whose rulings generally fell in favour of keeping to the basic principles. This became particularly important as the fleet increased past 1,000 boats in 1994, when significant changes would risk rendering many boats obsolete. Nonetheless, trickle-down innovation from the less restricted Marblehead found its way into the IOMs, including, but not limited to, hull shapes and appendage types.

Bantock's ongoing analysis has generated many interesting trends in wetted surface, righting arm, and stability, and waterline length. Since it is regattas and not tanks or CFD simulations that are the true proving grounds for IOM design, Bantock's own timeline serves as a useful synopsis of design evolution.

Early days: the mid-1990s and the rise of Down Under designs

The 1994 New Zealand championship attracted 32 entries with eight boats from Australia, the best being Gary Cameron who finished in 10th sailing his wide new skiff-style TS2 design. The New Zealand boats comprised a mix of UK, French and local designs, principally by John Spencer, Geoff Smale and Martin Firebrace.

Spencer was a designer of lightweight, large and usually hard-chine yachts, the most famous being *Ragtime* which won the Transpac twice (and featured in the previous issue of *Seahorse*). He had taken to designing RC yachts for fun and was technical committee secretary for the IOM class. Smale is a past winner of the Prince of Wales Cup for International 14s and won a gold medal in the Flying Dutchman at the 1964 Olympics.

By the time of the Australian IOM championships in January 1995 the Australian sailors using the TS2s were much better practised. The boats, built to a high standard by Craig Smith, dominated in the breezy conditions thanks to massive stability from their 290mm beam. Even so, there was enough lighter air for Bantock to scrape an overall win with his narrower 1994 world champion design *Red Wine*.

Although famous for breeze, the concrete-edged Fleetwood Lake used for the 1996 Europeans, the next major championship, can also see light air and so the top UK sailors elected to use relatively conventional designs. Come the event and the conditions ranged from a near gale to light and variable, and Martin Roberts won with the 188mm-wide Widget design by Chris Dicks – after a long tussle with Dicks' own beamier *Metric Magic*. In third place an even narrower design (at 160mm beam), Tonic, designed by Alex Austin, made its debut in the hands of Peter Stollery. But common to all these 'conventional' hulls was midship tumblehome (with maximum beam carried down near the waterline) rather than the flare common to almost all modern IOM designs.

In the build-up to the world championship in 1997 the TS2 had dominated racing in Australia and begun to perform similarly in New Zealand. Kiwi designers realised the threat the skiff type posed and dramatically modified their own designs in response.

For the 1997 championships Geoff Smale used the Firebrace-designed 2 Dogs with a maximum beam of 210mm, carefully optimised for the expected windy conditions; 2 Dogs featured a larger rudder, a fin shaped like an inverted spade with the top third about three times the chord of the bottom, and the bottom of the transom sitting some 6mm underwater at rest (this feature, common to powerboat hulls, has only relatively recently begun to appear in bigger keelboat classes such as the Volvo 70 and Imoca 60).

As predicted, the 1997 worlds were dominated by strong winds and, in superb conditions for the skiffs, the close competition between Smale and Smith made for excellent spectator sport. Both would use big No1 rigs when the rest of the fleet played it safe with No2s, while Smale usually stretched out a good lead by the leeward mark before Smith took it back upwind! Another TS2 kept Roberts down in fourth place and only two of the top 12 boats were old-school canoe designs.

The late 1990s: back to Europe and the rise of the long bulb

The TS2s' clear dominance of the 1997 worlds created an immediate demand for the skiff type. However, the rather poor design copies produced in the UK had disappointing performance and, rather than try to continue to emulate the TS2, most UK designers' response was to reduce beam to the 230-260mm region. This gave the boats more stability than previous European designs with better light airs and broad downwind speed than the TS2.

Designs of this type produced in the aftermath of the 1997 worlds included Firebraces's 3 Dogs, Ian Vickers' V3, Bantock's Ikon and Byerley's Mirage and Rage. Features common to these new

The generally light air 2008 Europeans in Croatia were dominated by less extreme designs. *Foreground left to right*, Karaoke, modified Topiko and Disco designs. *Second row*: Extreme, Taktic, Topiko. *Left*: the heavily flared German Test-5s fared less well at 56th and 61st overall

designs were a lowered mast position and a raised or heavily cambered foredeck which permit each rig to be carried further up-range, thanks to the lower heeling arm and the ability to shed water when the bow is depressed on a run.

Since 1994 the TS2 had used a bulb with a length:diameter ratio close to 7. In contrast, almost all other contemporary designs featured a comparable ratio closer to 5. Bantock soon started to investigate this area in more detail: 'I went back to basics and took a long look at the data in Hoerner's *Fluid Dynamic Drag* for low-speed drag of bodies of revolution.

'After fitting logical curves to the experimental data his calculations clearly showed a steadily decreasing drag for ballast bulbs as the length:diameter ratio increased. Obviously this also increases stability – a real win/win situation.

'The only restriction appears to be practical problems of long, thin ballast strength and the increased moment of inertia in yaw and pitch. In practice the moment of inertia issue is not as critical as on a comparable bigger boat, such as a V5 ACC design, as One Metre models already have incredibly high inertia in pitch due to the deep draught and tall rig. So the effect of the longer ballast on this still unquantified effect is minimal.'

During 1998 Bantock began to use ballasts with L/D ratios around 10 and this has since become the norm. That refinement, in combination with the Ikon hull design, developed with help from a VPP, proved successful enough to win the 1998 European and 1999 world championships, both in a wide range of conditions.

The new millennium: towards a sweet spot

By winning the 2000 Europeans in France and the worlds the following year in Croatia, Martin Roberts' new Gadget by Chris Dicks began to turn the tide, regaining the high ground for narrower designs. The Gadget featured 10mm more beam than a Widget and less tumblehome, giving it slightly more stability for windward performance. However, but for an unfortunate incident in the last race, the Europeans may as easily have gone to Guillermo Beltri sailing an Ikon. Bantock placed third with the new Italiko at 215mm beam.

Like Ikon the Italiko features a heavily flared hull and is aimed at best performance in No1 rig conditions. In fact, so fast was this design in the Adriatic drifters that it timed out most of the A-fleet at both major events in the lightest airs.

As we moved further into the new decade focus switched briefly from hull shape to sail handling. Going into 2003 few would have predicted Trevor Binks as a world champion but, prior to the 2003 worlds in Canada, he and his brother Ken had been busy testing Barry Chisam's 215mm-wide Isis against the TS2 and found it really strong, especially downwind. But as well as finding themselves a nice hull set-up, the brothers had also been ▷

pioneering the latest Hitec 5745 servo system for sail control and discovered significant advantage in being able to gybe, sheet on or sheet out in an instant. Binks went on to dominate that year's worlds with good speed and immaculate, crisp boat handling.

The 2004 UK championship was sailed in very light airs and Michael Scharmer provided brief discontinuity in the development curve with a strong performance sailing his amazing 135mm wide, wooden sparred design, eventually placing sixth. However, Bantock successfully defended the status quo, retaining his title with his Italiko (now also using Hitec servos)

But Scharmer had demonstrated that the argument for wider hulls was far from over.

Slimming down again: replacing the TS2

Following Scharmer's performance in the UK, and perhaps accepting that a shift back towards a narrower, or rather less wide, hull was essential, Australian Craig Smith was now replacing the long-serving TS2 skiff.

Smith's early developments did not prove entirely successful but by the time of the worlds in Mooloolaba in 2005 his new Obsession was thoroughly tested and ready for battle. At 230mm beam it sat just above most other previous designs in terms of stability but featured a waterline beam and wetted surface area close enough to the best light-airs boats to be in contention all the time. Craig won the 2005 event by a handful of points from Bantock's Topiko and ahead of Jeff Byerley's 240mm-wide design Cockatoo sailed by Paul Jones.

Last year's world championship in France proved a truly competitive event, with the outcome decided between the three top helms only in the last race. A week of widely varying conditions, from light air to Mistral, showed no particular overall pointers for design except that extreme boats are to be avoided! The event was narrowly won by Australian skiff sailor Brad Gibson using a Widget, ahead of Guillermo Beltri on a borrowed Topiko. Craig Smith used his Obsession to place third, followed by a Widget, a Tonic, and by three more Topikos, one sailed by French sailor Guillaume Florent – who subsequently won a bronze medal in the Finns in Quingdao.

Over last winter the Topiko was further developed to address one perceived weakness. Its bow is very clean right up to the deck, allowing easy penetration of waves and better airflow onto the headsail upwind. Downwind in steady conditions, with or without waves, the boat is very fast too, but in the gusty conditions more prevalent on smaller ponds the Topiko is prone to bow burying. To address this the bow was given more flare and a transitional chine was added along the aft 20 per cent of the hull.

The 2008 European championship in Dubrovnik was dominated by light and fickle airs, lots of current and sloppy waves.

Designs featuring in graphs and illustrations but not detailed in main text: *Oscar* is a Peter Wiles design that has shown great downwind speed. *Kite* and *Trinity* are two earlier Bantock designs which are still in current production in the USA by Mike Hughes. *Vektor* and *Zig Zag* are two more recent Graham Bantock designs and are optimised for reaching and windward/leeward courses respectively

However, the best sailors were not unduly troubled by the challenging conditions. Guillermo Beltri showed excellent speed to head the top four, which was an even mix of Pikantos and Topikos.

The most obvious area of IOM development in 2008 was above the waterline, with a much wider than usual variety of sailmakers and sail designs in the top half of the latest world championship fleet.

The current paradigm

Moving into 2009, the 'safe' design space lies within the 190-240mm range of maximum beam with a waterline beam of 170mm to 190mm – characteristic of a well-flared hull form.

However, this is not the only successful hull form, with slab-sided and even tumblehomed midsections still capable of top performance. The 2006 UK nationals had been won by Dave Potter sailing the Lintel design of David Creed, a tumblehomed, high-prismatic hull with a developing chine from midships to the transom which went particularly well in No2 and No3 rig conditions and big waves. A maximum beam of 210mm just above the waterline gives the Lintel high stability but also high wetted surface area.

Michael Scharmer continues to develop his ultra-narrow hull forms and earned a good win in the 2006 German championship. It seems that the downwind performance of his earlier boats has improved with attention to the detail of the hull design, while the rig's performance is being improved by small increases in maximum beam, enough to reduce mast compression to a manageable level.

In conclusion, the best performance in the IOM fleet is no longer determined by the simple ratio of stability per unit of hull wetted area alone. Other factors, such as a hull form suitable for low wave drag at high speed, the quality of appendages, rig performance, balance and so on, are now important enough for the obvious features to be less of a determinant than in the past.

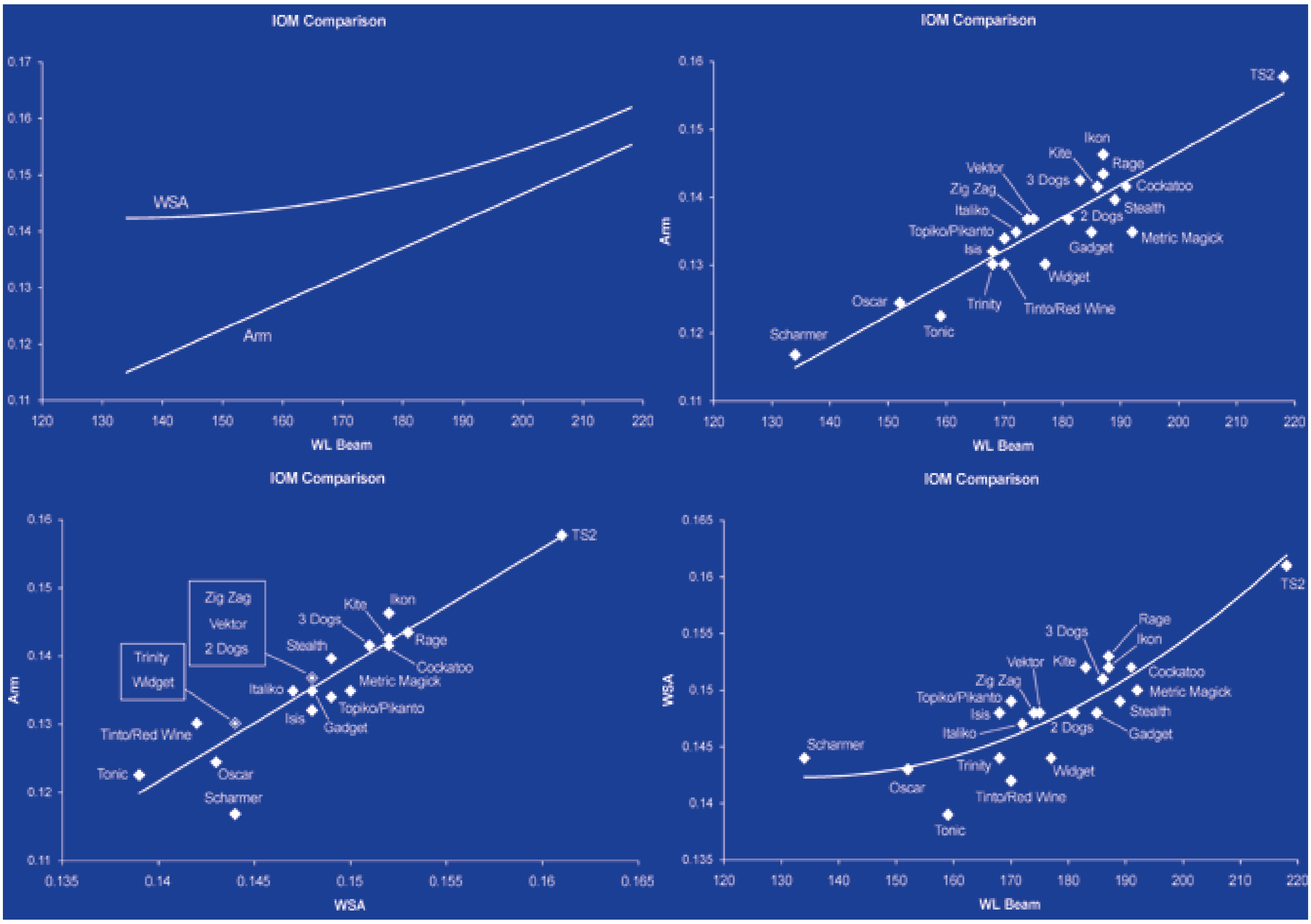
Designing foils for low Reynolds numbers

– David Hollom

The problems of designing foil sections for model racing yachts, which operate at very low Reynolds numbers (Re), are very different from the problems of designing foil sections for full-sized boats that operate at high Re, though the same physical laws apply to both. (If the reader is unfamiliar with some or all of the technical terms such as Re transition and separation bubble they are referred to the series of articles 'Go with the Flow', *Seahorse* issues 288, 289, 290 and 292).

Re measures the relationship between viscous and inertia forces in a fluid. At low Re viscous forces, which tend to hold the molecules together, are relatively more important than inertia forces and laminar flow over large chord lengths is relatively easier to achieve than at high Re when the inertia forces, which tend to throw the molecules asunder and thus destroy laminar flow, predominate. (A laminar boundary layer can be important because its drag is considerably less than that for a turbulent boundary layer).

The process is gradual but the crossover Re where inertia forces begin to dominate is around 1,000,000. Below this Re laminar flow is almost automatically achieved (flow on a flat plate is laminar to an Re of about 1,000,000), but as Re rises above 1,000,000 laminar flow becomes increasingly more difficult to maintain and shaping of the foil, to maintain an accelerating flow, is necessary to maintain laminar flow up until the desired chord-wise position of transition to turbulent flow. Accelerating flow is important in maintaining laminar flow because increasing velocity means lower pressure so that accelerating the flow means that the point of



WETTED SURFACE AREA
The wetted surface area (sqm) is of the canoe body alone with no appendages. A canoe body displacement of 3.62kg is compatible with a (rule minimum) displacement of 4.01kg fully rigged. Generally hulls with high prismatic coefficient (the fullness of the ends relative to the maximum section) have larger wetted surface area for a given beam and displacement. They will also have larger stability for a given waterline beam. For a given wetted surface area the largest stability is usually achieved with lower prismatic coefficient and a slightly larger beam. The minimum wetted surface area that an IOM hull could have is around 0.137sqm for a 990mm waterline and 160mm waterline beam. However, hull forms approaching this figure have poor stability and wave-making characteristics and are unlikely to offer good performance in winds above 1m/sec. Lower wetted surface can be achieved with a shorter waterline length (*Red Wine* and *Tonic* feature sub-rule maximum waterline length) but, for a given wetted surface, longer hulls have less skin friction drag and lower wave drag.
The diagram of wetted surface area vs waterline beam illustrates the relationship with a dip to a practical minimum of about 0.142sqm at around 160mm waterline beam and a rise each side.

RIGHTING ARM
The lever distance in metres about which the displacement acts to right the boat when heeled at 40°; measured for flat water, with No1 rig, with a standard vertical weight distribution. Generally narrower and deeper hulls will do slightly better, and wider and shallower boats a bit worse, than the graphs indicate when hull weight and internal ballast placement are considered (Hydromax performed the hydrostatics' calculations permitting free trim).
Righting arm vs waterline beam shows a fairly linear relationship. The minimum righting arm at 115mm is obtained with a hull of 135mm waterline beam with no form stability. From there a 50mm increase in waterline beams brings a 25mm rise in righting arm. More stability will always promote performance on any leg where heel exceeds 20° unless the method used to obtain extra stability brings too much drag. The 35% extra stability of the *TS2* compared with the *Scharming* makes the 13% increase in wetted surface look attractive. In flat water the *TS2* may well have an edge to windward. However the narrower hull may penetrate waves with less added drag and exhibit a less disturbed motion so that the improved ratio of drive to drag gives an overall result better than the wider hull, particularly when rig movement is taken into account.

minimum pressure lies downstream (at the point of maximum velocity) and the molecules are being pulled to this point which tends to stabilise them and is thus a favourable pressure gradient.

At low Re the problems are different. Laminar flow is now easy to achieve and the problem becomes one of control. If the flow is laminar, up to the point of maximum velocity (minimum pressure), transition to turbulent flow will be via a laminar separation bubble.

A laminar boundary layer is typified by orderly layers of molecules, each sliding smoothly against its neighbour. The molecules next to the surface of the foil are stationary and each layer, moving outwards, moves ever faster until the outermost layer is moving at the same speed as the local fluid velocity at that position. After the flow has reached the point of maximum velocity it will, obviously, begin to slow so that it can, as it approaches the tail, reach free-stream velocity, which it eventually must.

As the flow slows the molecules nearest the surface, which were never moving very quickly and are now fighting a suction force that is now upstream, eventually halt, forcing the outer layers of the flow off the foil. The resulting void in the flow is then filled with a bubble of recirculating fluid, a laminar separation bubble.

At high Re the bubble is small and its effect on the foil's performance is important but relatively small and the design emphasis is on maintaining long runs of laminar flow with wide low-drag buckets. At low Re, however, the bubble can be very large, compared to the chord length of the foil, and it then has a very large effect on the performance of the foil. At the low Re typical of model yacht foils the main thrust of design is, therefore, to control this bubble to advantage.

High-performance dinghy foils offer an even greater challenge as they operate at a spread of Res that straddles the magic 1,000,000, so that a successful foil has to be good in both design regimes. But that's another story.

Since 1992 Graham has exclusively used four of our sections, designed specifically for Re numbers typical of model yachts, and we have been lucky enough to achieve an improvement in performance with each one. However, progress never stops and further improvements are in the pipeline… ❑