The Iambus2 Footy Design – David Wilkinson

Water Line Length and Bow Design

A “Heavy displacement” type of design was therefore selected. Since almost unlimited Sail Area could be used this meant the boat would spend a lot of time at around hull speed, defined by a Froude Number V/(Lwl x g)^0.5 = 0.4 or at a speed Vh = 0.4 (Lwl x g)^0.5 = 0.69 m/s for Lwl = 0.305m. Clearly the Lwl needs to be at or near the maximum allowed by the rules and the measuring box limits this to no more than one Foot or 0.305m.
However there is still a choice to be made on the shape of the stem. With unlimited sail area the boat speed limit on the run is set by diving. The cause of this is easy to understand. The drag from the hull is close to water level and the drags from the fin, lead and rudder are below water level. The drag forces are backward. The drive from the sail rig is well above water level, at about a third of the rig height plus the freeboard, and this is forward and equal to the drag when at equilibrium boat speed. These two main forces cause a pitch-down moment due to their vertical displacement that has to be balanced by fluid flow forces from the hull.
When the boat is not moving the integrated pressure forces on the hull give an upward force equal to the total weight and zero forward or sideways forces. There are no skin friction forces. When the boat is moving through the water several things happen. There is skin friction on the hull, fin, lead and rudder with some pressure forces due to turbulent separation that give the viscous drag.
The water has to flow relatively faster round the hull, than if the hull had no volume, so its pressure reduces by Bernoulli’s equation. This means that if the hull was in its static position the integrated pressures would give a vertical force that was less than the boat’s weight. To restore equilibrium the boat has to sink slightly to generate higher pressures to balance its weight. For an IOM this “sinkage” is about 6 mm. For a Footy the sinkage is probably a bit less but still significant compared to the size of the boat. This means that all those designs, including this one, drawn with the waterline just at the bottom of the stem and transom may be correct statically but not when on the move. The boat will sink down and the transom be partly submerged.
As the boat moves through one waterline length it has to shove its displacement in water out of the way and let it recombine behind it. As the boat is at a free water-air interface this produces waves which travel off to infinity taking energy with them and this energy has to be paid for at the rate of wave drag times boat speed. The wave drag is caused by a bow wave at the front and a rather smaller stern wave at the back. With a fairly flat run of the hull to the transom the stern wave may appear behind the boat and the flow at the submerged transom going relatively faster and producing suction drag. The bow wave produces higher pressures near the front of the boat and hence extra drag. The integrated pressures produce the backwards directed wave drag. There is an additional effect due to the higher pressures at the front and lower pressures at the back acting on the hull. These produce a pitch-up moment which is enough most of the time to balance the pitch-down moment from the sail drive and boat drag. This is why boats go along in a more or less horizontal attitude most of the time rather than being permanently pitched down. It is only when the hull is driven well above hull speed that the two moments fail to balance and the hull dives. It then slows down due to the extra drag and is using mainly static buoyancy to get into equilibrium.

The two main ways of increasing the righting moment in pitch by bow design are to use a raked stem and/or a flared bow shape. Obviously a higher stem freeboard also helps.

Most full size racing yachts have a vertical stem but tend to be very wet as waves come aboard easily. Full size cruisers generally have a raked stem which gives a drier boat and more resistance to pitch. Almost no full size yachts use flared bows which are confined to motorboats and battleships but pitching moments are relatively less important at full size than at model size. That is the way the scaling laws go so flared bows are a successful feature of many model yacht designs although others are still competitive without them.
The initial choice with Iambus2 was to use a slightly raked stem, by 5mm in 70mm freeboard. A late addition was a primitive form of flare that was probably beneficial. A raked stem is much easier to design and build than a flared bow. There is a slight reduction in waterline length from 305mm to 300 which is worth (300/305)^0.5-1 = -0.8% in hull speed which is easily made up for in other ways.