

Final Report

A more sustainable hull form

Richard Wilson

Research team: Richard Wilson, Cristiana Chiappini, Isaac Flitta

Executive Summary

The aim of the project was to find a planing powerboat hull form capable of being pushed through the water more easily than existing hull forms and yet which still maintains, or even improves on practical performance factors such as sea keeping ability, stability, and directional stability. The speed most suited to test our hull shape is in the speed range 25 knots and under, a practical range for the general power boating public. There is some education required to have the power boating public understand the economy advantage of not carrying more power/weight than necessary.

Our overall approach was to test two different hull shapes against one another. Two hulls were designed one to be the benchmark, (hull1) its design was to reflect what is considered to be the accepted approach to modern planing hull power boats, the other hull (hull 2) is identical from the chine up but has an underwater shape, that was developed with the idea that the hull could lift and run on a flat surface at a lower speed, using less power than a deep V hull. The flat area of the hull underwater was created by designing the hull with a deep V and then removing the shape at the bottom of the V

It was considered that the cutoff point of the underwater shape to create the flat surface was important and could be adjusted in future designs to alter trim, and speed potential once the relevant data has been collected, collated, and analyzed. Hull 2 has been designed with a double keel configuration to assist directional stability and to give the hull a practical advantage over the traditional V section in that it can sit upright without the aid of a cradle.



Model 1

Model 2

A parametric study was carried out to clarify what size and weight the hulls should be. The boats designed are 8 meters long with a beam of 2.45, a popular size for a large trailer boat carrying the maximum legal beam for towing on the road. The weight of the boats studied varied from 2600 kilos for an aluminium hull to 3500 kilos for a production fiberglass hull. The weight chosen for our hull 1 was 2600 kilos which immersed the chine to achieve static stability and yet aligned with the lightest of the current designs of 8 meters available. We wanted to give the V hull the greatest opportunity to show the success of its hull

shape. The weight of hull 2, to immerse the chine a similar amount was found to be 2000 kilos; the displacement we chose for hull 2. It is recognized that the weight advantage of hull 2 is significant; however the advantage achieved was by its hull design concept, allowing for builders and designers to make full use of modern methods and materials to design and build a light, strong hull

To test hull shapes a practical approach was determined to be the most suitable to observe the performance/sea keeping ability, and record the resistance by means of a load cell.

The method adopted was to tow the hulls alongside a tow boat using an aluminium spreader across the tow vessel to extend the tow point out beyond the wake of the tow boat keeping the model towing in clear water. The equipment to do this was designed and assembled in the marine workshop at Unitec



Model 2 floating on its waterline



Model 1 floating on its waterline

To record the towing weight on the hulls software was purchased and installed in a laptop, the laptop was housed safely in the tow vessel and connected to a Data Logger, which in turn was connected to the load cell at the end of the towing arm.



Model 2 attached to aluminium spreader extending from Towing vessel during test on the Waitemata Harbour.



Data logger unit and laptop housed on the towing vessel

The models themselves ($\frac{1}{4}$ full size) have been weighted to their correct displacement model weight. The models have been towed at a range of speeds over 10 different towing days and the results recorded and averaged. The hulls were also tested in varying modes.

- By reversing the displacement weights
- by towing at the same weight
- Hull 2 with keels, hull 1 without.
- By towing with only the central forward keel on hull 2
- The hulls have been tested for directional stability by pulling sideways,
- Tested for stability by adding a weight to the B max position at Sheer height

The towing arrangement as designed was found to be well suited to purpose, there were no changes to the equipment being used, however there was a change to what had been planned, rather than tow both boats at the same time one at either end of the towing arm we elected to tow them one at a time. The reason for this was twofold; firstly it wasn't possible to reach the speed we wanted with the tow boat and power we had available towing two models together. Secondly it was clear that a considerable saving could be made by towing one hull at a time requiring only one data logger (\$ 562 00) only one load cell (\$ 431 00). It was also decided that to be able to tow one hull at a time would allow to focus only on one hull' the towing boom could then slide across to move that hull out as far as we needed to avoid the wake of the towboat. Towing the hulls individually would make no difference to the result as any small variation in conditions would be averaged out.



Towing arrangement



The location, the best place to do the towing was debated the upper harbour launching from Te Atatu boat ramp was used and we tested at Westhaven where we found the most favourable conditions, this venue is more sheltered. We found our testing from Te Atatu gave the opportunity for the long runs required however the sea conditions as soon as the wind came up weren't suitable for tow testing.



Testing area.

The conclusions from the testing we have carried out are set out below.

- Boat 2 shows a horsepower reduction at the range of speeds tested from 14.49 to 15.29 EHP (Effective Horse Power).
- The keels on Boat 2 add directional stability but also result in added resistance, which increases with speed.
- Boat 2 showed better directional stability compared to Boat 1 in all conditions, light and heavy displacement, with or without keels.

The data obtained during the tests is as follows:

OVERALL DATA COMPARISON							
Towing speed	Model speed	Resistance		Comparison between boat 1 & 2	Boat weight = 2600Kg		EHP difference
		BOAT 1:	BOAT 2:		Boat weight = 2000Kg		
7 knots	14						
Average of above:		5.336	4.139	1.197	BOAT 1 - BOAT 2 AT NORMAL WEIGHT		14.49
Boat 2 without keels:			3.992	0.147	Boat 2 (with keels) - Boat 2 No keels		
Boat 1 light/ Boat 2 heavy		4.048	5.220	0.056	Boat 1 (light) - Boat 2 (NO keels)		
				0.116	Boat 1 (Heavy) - Boat 2 (Heavy & NO keels)		
				-0.091	Boat 1 (light) - BOAT 2 with keels		
8 knots	16						
Average of above:		5.726	4.733	0.993	BOAT 1 - BOAT 2 AT NORMAL WEIGHT		13.75
Boat 2 without keels:			4.527	0.206	Boat 2 (with keels) - Boat 2 No keels		
Boat 1 light/ Boat 2 heavy		4.518	5.751	-0.009	Boat 1 (light) - Boat 2 (NO keels)		
				-0.025	Boat 1 (Heavy) - Boat 2 (Heavy & NO keels)		
				-0.214	Boat 1 (light) - BOAT 2 with keels		
9 knots	18						
Average of above:		6.130	5.235	0.895	BOAT 1 - BOAT 2 AT NORMAL WEIGHT		13.95
Boat 2 without keels:			4.898	0.337	Boat 2 (with keels) - Boat 2 No keels		
Boat 1 light/ Boat 2 heavy		4.781	6.306	-0.117	Boat 1 (light) - Boat 2 (NO keels)		
				-0.176	Boat 1 (Heavy) - Boat 2 (Heavy & NO keels)		
				-0.453	Boat 1 (light) - BOAT 2 with keels		
12 knots	24						
Average of above:		6.751	6.015	0.736	BOAT 1 - BOAT 2 AT NORMAL WEIGHT		15.29
Boat 2 without keels:			5.758	0.257	Boat 2 (with keels) - Boat 2 No keels		
Boat 1 light/ Boat 2 heavy		5.84	6.954	0.085	Boat 1 (light) - Boat 2 (NO keels)		
				-0.203	Boat 1 (Heavy) - Boat 2 (Heavy & NO keels)		
				-0.172	Boat 1 (light) - BOAT 2 with keels		

Table 1. Overall resistance data comparison

Directional Stability: (data shows Boat 2 light or heavy, with or without keels HAS better Directional Stability)							
	Boat 1	Boat 2	Difference				
Day 3	6.083	6.645	0.562	Boat 2-Boat1			
Day 6	3.597	4.166	0.569	Boat 2-Boat1 Day 6 and 7 - measured at idle speed in same location			
Day 7		3.748	0.418	Boat 2 (with keels) - Boat 2 (light)without keels			
Day 9	4.657	5.338	0.681	Boat 2 (Heavy & NO keels) - Boat 1 light			

Table 2. Overall directional stability data comparison

Background

There are many power boats available to buyers in the market place today Production boats which are by far the most common at 8m length and under, are manufactured in a mould incurring an expensive outlay for tooling by the boatbuilding company. They are built in a female mould, laid up either by gun or by hand, their appeal is to the buyer who is interested in a boat of a particular size and style with a known performance, experimentation in design is not economically viable the mould is totally restrictive to shape experimentation. Modifications are small as hull design change means new tooling. Designers may be well aware of possibilities that could produce a more sustainable hull form and yet their hands are tied to a certain extent because of what the market place demands, boat building companies with established tooling produce boats that appeal to the boat buying public who don't want to be the guinea pig for a new concept unless it has proven results. There has been extensive research into yachts and multihulls as they have an established racing circuit at all levels, the power boat scene though is different, power boats do race, most powerboat hulls are a compromise design to suit people who like to cruise and fish, design concepts that have filtered through are related to boats that travel at over twice the speed of what an average powerboat is likely to do and consequently influencing hull shapes that are not efficient or relevant for boats travelling at a slower speed.

The type of hull shape that has evolved over the years is a hull shape that relies on a steep angle of dead-rise to cushion the ride typically 20 deg and up to 24 deg at the transom. The effect of the dead-rise is described by Sorensen (2008) "All that dead-rise tends to rob speed because with more dead-rise less lift is developed"(p.55).

Sorenson (2008) also states that flat bottom hulls are "able to carry a lot of weight, easiest to push through the water, and the most stable at small angles of heel" (p53).

What has been attempted is to create a design able to take advantage of a steep dead-rise forward, and yet plane on a flat surface aft. Previously this has been done to a lesser extent on the warped hull concept; where underwater shape actually twists from relatively flat aft to deep V forward proving to be a hull shape which is propulsion efficient, with a superb ride. (Sorensen, 2008)

Sorensen (2008) points out that adding weight and dead-rise reduces speed, and finally Marshall (2002) discusses high speed deep V hulls and notes that they don't make good fishing platforms as they tend to roll heavily.

Form stability is increased on the same length hull when the water line plane area is increased, in other words if a deep V hull does not immerse the chine its water line plane will be less and the boat will be less stable. (Marshall, 2002)

The factors noted were what formed the basis for design. The hull should be able to be built light and still immerse the chine (stability), the hull has a deep V forward, in excess of 25 deg (smoothness of ride) and finally to present a flat bottom for the hull to ride on should produce Dynamic lift more efficiently (economy)

An area of concern in the past with flat bottom hulls is their inability to hold direction, they have no directional guide, this is assisted by increase in chine immersion, what was chosen to add to the design despite performance loss due to resistance and friction were twin keels aft, and one keel forward. This innovation worked very well on our models and gave more positive directional stability in all conditions than the conventional design (see results in Table 2 above). Another advantage of the twin keels is the ability to support the boat without the aid of a cradle, an advantage for shallow water cruising, transporting, and hauling out on a hardstand. Hull modes were changed, the twin keels removed (hull 2), which allowed us to establish what their cost to performance was. The central keel on hull 2 was never removed, the hulls directional stability would always require that keel as against the conventional V design which does not have a keel but relies on weight, projected area, and its shape to hold direction.

Aims and Objectives

The aim is to test innovative planing hull shapes against what is the accepted v hull form normally associated with open water design.

The research will investigate whether: (objectives)

- A boat presenting a flat planing surface will generate more dynamic lift and be propelled through the water more easily with improved stability compared to a boat with a deep v hull form.
- A new hull design that exhibits a flat planing bottom surface can still present V hull sections to the waves, producing the most efficient and sustainable hull form that requires less propulsion power, therefore less fuel to run it
- Meaningful research data on boat hull form will be gathered at a location on the Waitemata Harbour as opposed to the more traditional tank testing method

The aim of our research project remained the same as we had intended, however some of the objectives were unable to be established for the following reasons

- *A boat presenting a flat planing surface will generate more dynamic lift and be propelled through the water more easily with improved stability compared to a boat with a deep v hull form.*

Dynamic lift could not be measured by towing weight on the load cell and to establish whether more dynamic lift was generated by the flat bottom could only be assumed through performance. There was also some doubt as to the stability of the flat hull form while both hull's were moving, this was assessed through observation and although the appearance seemed to substantiate that the hull did have a more stable ride it was not a measurable performance factor, we are unable to claim these objectives as facts. The movement of the tow boat even though it was relatively slight made videoing difficult therefore adding to the problem of measuring hull stability while underway

Testing confirmed that a boat presenting a flat surface to the water is propelled through the water more easily (see Table 1 for data).

- A new hull design that exhibits a flat planing bottom surface can still present V hull sections to the waves, producing the most efficient and sustainable hull form that requires less propulsion power, therefore less fuel to run it

This objective has been achieved; it is proven that the hull operates with less resistance and the forward sections of the hull cut the waves, operating just as the conventional design (hull1) does. The hull does ride on its flat section aft, does require less propulsion and therefore less fuel to run the engine. This is proven by our towing data

- Meaningful research data on boat hull form will be gathered at a location on the Waitemata Harbour as opposed to the more traditional tank testing method

This objective was achieved.

Methodology

The global aim of the project is to develop validated research by means of towing two hull models and collecting the relevant data.

To achieve this aim there were 4 key objectives:

- (1) To design and build one model (scale 1:4) with a conventional V bottom hull shape (model #1)
- (2) To build the towing equipment and install it in the towing vessel (including installation of electronic data collection equipment)
- (3) To build a flat planing hull (model #2). The hull to have the same main design characteristics as the V bottom hull model apart from its underwater shape
- (4) The flat planing hull (model #2) was tested against the conventional V bottom hull (model #1) and data collected.

The hulls were built using a cold molded style of double diagonal planking forward where the shape of the hull formed a rounded surface and joined to sheet plywood aft where planking surfaces are relatively straight.

The shape was laid over permanent frames and the deck and transom formed from sheet plywood, all plywood thickness's total 4mm

The towing equipment consists of an aluminum pole (towing boom) set athwart ships across the deck area of the tow boat held in place firmly by U Bolts with wing nuts to allow for easy adjustment, this means the TB can be adjusted across the hull to extend the model boat being towed beyond the wake of the tow boat.

On the end of the TB is a vertical strut (VS) lowering the tow point so the model tows from a bridle at deck height with a horizontal pull. Where the bridle is attached to the VS is located the load cell which is connected to the digital indicator, housed in a dry location under the deck of the tow boat, and connected to a laptop which has data logging software installed. The program allowed the read out of towing loads at whatever intervals we wanted, 2 seconds intervals were chosen which gave us a good amount of data over a run of 2 minute.

The boats were tested for directional stability by connecting to the bow and stern with a bridle and attaching the centre of the bridle to the load cell. With the bridle at the correct length the pull point at the CLR pulled the boats sideways evenly. Travelling at 2 knots we recorded the resistance and used this as a figure to show directional stability

Resistance to angle of heel with the models stationary was tested at rest by adding a weight to the B max position at sheer height and the angle of heel recorded by using an inclinometer

Another method that could have been used to test was to get resistance figures from one of the design software programmes such as Mac-surf or Auto Ship, to do this wouldn't have allowed

1. - Meaningful research data on boat hull form will be gathered at a location on the Waitemata Harbour as opposed to the more traditional tank testing method
2. To observe and video the testing to assess performance and sea keeping ability

Outcomes/findings

Research showed that a hull that presents a flat surface to the water therefore traveling at the same speed as the conventional deep V hull but using less power

Research also showed that a flat bottom hull can ride on its flat surface and still present a V section to the waves.

It was proven in research that meaningful data is gathered by towing on the harbour

The research was not able to substantiate whether or not the flat hull (2) is more stable travelling at speed, visual analysis suggests this to be the case

Conclusions

We can conclude that the design produced (model 2) has an advantage over the conventional style V bottom

1. Because it is able to be pushed through the water more easily (hull form).
2. Model 2 displacement is less therefore the hulls weight is less to immerse the chine for stability (a lighter hull is more easily driven through the water)
3. Hull 2 is able to be supported on its own bottom in an upright position out of the water
4. Hull 2 although lighter in displacement has the same righting moment to 11 deg angle of heel as the conventional V bottom design
5. Hull 2 resists sideways pull to a greater extent than the conventional V bottom design, leading one to presume that directional stability will be improved

Implications

Our research has identified a concept of hull design which could benefit the end user both pleasure and commercial by the fuel saving that has been proven to be possible, because the hull is more easily driven it requires less power, which in turn means that less fuel is used. Because the hull is lighter than the deep V design the structure to withstand loads while the boat is in use is also lighter, meaning less material cost. There is a link between displacement (weight) and cost, the heavier the boat the more it costs although this factor depends on the construction method and the material chosen/required

Advantages of the hull being able to free stand (twin keels) are

- Pleasure craft and commercial users can beach at any time to avoid sea conditions, to go ashore, to do maintenance,
- Both pleasure and commercial users are able to transport the hull by trailer more easily
- There is a cost saving for all users, they don't require a cradle to support the hull to perform maintenance

Publications and dissemination

Our research "a more sustainable hull form" was presented at the 2010 Unitec research symposium,

The preparation is underway to present a paper at the International conference on marine design which is being held at the Coventry University, Great Britain, 14-15 September 2011. The opportunity was not identified when we applied for research funding but it is our preference to attend this conference

Papers are being prepared for journal publication; journals have not been identified at this time

References

Marshall, R. (2002). *All about Powerboats*: McGraw-Hill.

Sorensen, E. W. (2008). *Sorensen's Guide to Powerboats*: McGraw-Hill.