Partly Published in Fast Ferry International, Sept. 2001

Recent Applications of Hydrofoil-Supported-Catamarans

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Abstract

Hydrofoil assistance on a catamaran model was tried twenty years ago and an unexpected resistance improvement of 40% initiated the creation of a research project to investigate the effect. Today the research project is still active inspite of designs and model tests resulting in the construction of over 200 Hysucats. Theoretical efforts to determine the hydrodynamics of the Hysucat principle resulted in a numerical model for design analysis of planing type Hysucats which allows further design optimization. The milestones in the Hysucat Development are mentioned and the ten most recent applications (1998/2001) explained. The smallest Hysucat, a 6,5m Semi-Rigid Inflatable Hysucat, a 12m Fast Patrol Boat by Stingray Marine (Cape Town), the Panther 64 Hysucat by Prout Catamarans (UK), the 21m Kingcat (France), the 22m Ferry - Sea Princess of Cape Town, the 45m Halter Marine E-Cat (USA), the Cougar 15m Ferry, the Cougar 12m Yacht and the Alwoplast 16m Luxury Yacht with Semi-Displacement demi-hulls are described and the performance evaluation is discussed.

1. INTRODUCTION

The treacherous seas around South Africa have inspired many small craft designers to develop unconventional craft. Several power catamarans were designed and built in the last three decades as pleasure and game fishing craft as well as navy and police patrol boats. Some police craft for border control were tested in 1978 and the performance in rough water was found to be excellent but the propulsion power requirements were extremely high compared to Deep –Vee Mono-hulls. Petrol engines had to be used instead of diesel engine propulsion, which initiated urgent design improvement-thinking to reduce the resistance of power catamarans.

The idea to use hydrofoil assistance for resistance reduction was tried on one of the existing police boat test models and showed up with a 40% resistance reduction instantly. This revolutionizing result was first thought to be a test error or correlation problem and larger models were used with more carefully designed hydrofoils. The prototype prediction again gave a 40% lower resistance at top speed. The result was better than for a comparative mono-hull of similar size.

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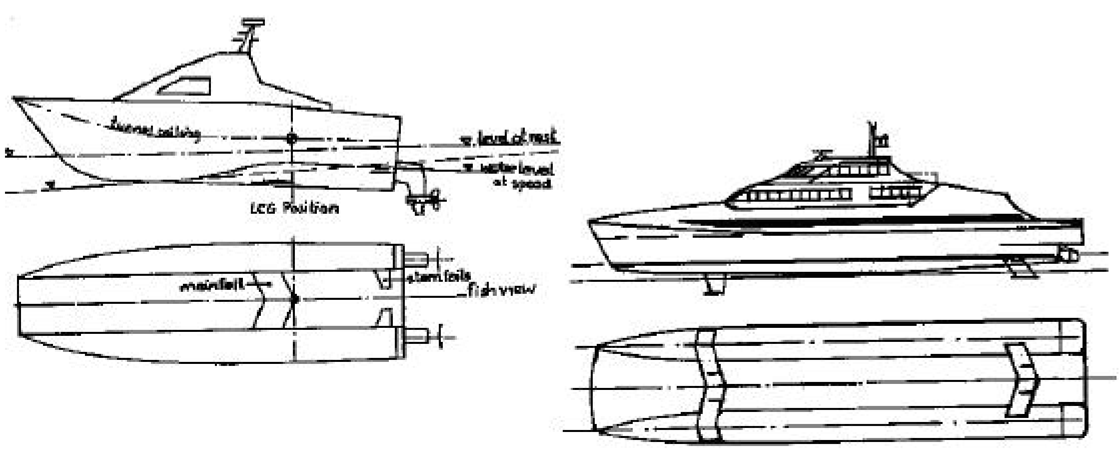
The hybrid consisting of a catamaran with fully asymmetrical demi-hulls and a single hydrofoil spanning the tunnel between the two demi-hulls was named Hydrofoil Supported Catamaran or Hysucat in short. A research project was started to investigate and optimize the Hysucat principle (it is still running after 20 years!), see Hoppe (1980-1980a). A sea going 5.3m manned model was designed and built and proved the excellent sea-keeping and low propulsion power needed for the craft. The craft was tested in various sea conditions from still water to extremely rough seas over a period of a year.

More than 40 copies were sold as ski boats and pleasure craft the following two years. Designs for 10m and 12m police patrol boats and 18m Navy patrol boats followed, some for overseas customers. The early designs were optimized in model tests but strong efforts were made to develop the theory behind the Hysucat principle, which resulted in a numerical model later based on the principle of the Savitsky (1976) formulations for planing craft and basic hydrofoil design as developed for hydrofoil craft, Lewis (1998). Equilibrium of floatation to weight and longitudinal moments is established by the computer program. With empirical data inputs from model tests and prototype trial data the numerical model was continuously updated and perfected to date. It allows accurate predictions for the standard Hysucat shape with asymmetrical demi-hulls and Deep-Vee craft characteristics and good approaches for the different hull forms. Catamaran models were first tested and optimized without foils and then retested and optimized with various foil systems.

It was found that a catamaran with a mono-foil was extremely sensitive to Longitudinal Center of Gravity (LCG) shifts and an active trim device was necessary for practical operations.
To overcome this shortcoming the Hysucat idea was extended by use of a double foil system. The main foil located slightly forward of the LCG of the craft and one trim foil or two trim strut foils near the transom as shown below in Figure 1. See Hoppe (1982,1989).



Hysucat Foil System **Hysuwac Foil System**

Figure 1: Hysucat and Hysuwac Foil Systems

Making use of the so-called hydrofoil free surface effect the Hysucat has a built-in automatic trim-stabilizing characteristic, which allows for larger LCG shifts. The design allows a stable craft with a fixed wing foil system in the full speed range. Propulsion power is down by 35% to 40% compared with similar Deep-Vee mono-hulls. See Hoppe (1991,1991a, 1992 and 1995). Many craft were built after this principle ranging in size from 4.5m to 36m.

The early hydrofoils were designed by use of NACA airfoil sections. However, it was found that the production of these foils for the larger craft was too expensive necessitating numerical controlled cutting processes. Foil shapes were therefore developed which allow cheaper production by use of rolled plate sections in welded arrangements. High tensile steel of SAF 2205 or similar had to be used for the faster Hysucats , as the foils have to be very thin to prevent cavitation. Foil loads at top speed in wave passages are extremely high and can exceed the total weight force of the craft. Extensive strength calculations including Finite Element Analysis are design requisites for the larger Hysucats.

The Hysucat hydrofoil profile sections have extended circular arc surfaces. Systematic towing tank tests were conducted with variation of the aspect ratio, angle of attack, depth of immersion and speed as little data on foil tests in extreme free surface effect are published. A second profile section shape with a concave lower surface was also tested and gave higher efficiencies in close surface approach. It is the preferred profile section for very fast Hysucats now.

Most of the catamaran demi-hulls in the Hysucat project are of the fully asymmetrical demi-hull type with a straight walled tunnel which allows for reduced hull interference and which gives the ideal flow conditions for efficient hydrofoil operation. The type of demi-hull has been proven to give the most sea friendly high-speed behavior. However, many Hysucats now on the sea, are existing catamarans for which a hydrofoil system was retrofitted afterwards. These so-called Hysucat conversions are more difficult to optimize and have somewhat lower efficiencies.

The Cape Town Company “T-Craft Marine” built a large number of 10m, 12m, 20m and 22m Hysucat conversions. The hulls have been designed by “Bob van Niekerk,” well known fast craft designer in South Africa. These craft have shown that the Hysucat principle delivers practical high speed rough water work boats. The company closed down in 1992 but some of their designs are still built with improved hull shape and foil designs, by Stingray Marine and Waterfront Charters in Cape Town.

2. RECENT HYSUCAT APPLICATIONS (1998/01)

Stingray Marine developed a 12m fast Interceptor as a Navy Patrol Boat. The fully laden craft weighs 13.5t and is propelled by twin Caterpillar diesel engines with 2 x 320kW. The propulsion is by twin Arneson surface drive systems with Teignbridge (U.K.) surface propellers. The contract speed was 35 knots, the prototype reached 42 knots fully laden in sea trials off Cape Town. Three units have been delivered in 1998 to a foreign Navy. The Interceptor has a so-called Avion Hydrofoil system designed by Prof. K.G. Hoppe at the University of Stellenbosch and contracted by Unistel Technologies, the University's technology transfer company. (See Hysucat Web page: www.unistel.com).

The following Hysucat application in 1998, which was completed with successful trials in England, is the conversion of the well-known **Panther 64** by Prout Catamarans Ltd in the U.K.. The Panther 64 is a luxury yacht of nearly 20m with 35t displacement. It has fully asymmetrical demi-hulls similar to deep Vee planing hulls for good rough water performance. The straight tunnel between the hulls with nearly vertical sidewalls offers very favourable flow conditions for a hydrofoil system. The overall beam is 6.7m with a tunnel width of 2.85m allowing a main foil with reasonable aspect ratio to be fitted.
The Panther 64 is propelled by twin 850kW MTU diesel engines driving two Parker waterjets built by Vosper Thornycraft, so called Vos-jets. The waterjets allow trim adjustments of the craft at speed by means of adjustable exit nozzles, which makes these jets especially useful in a Hysucat application.

Figure 2: The Prout Panther 64

The avion type Hysucat foil system used, was developed by Prof. K.G. Hoppe at the University of Stellenbosch and contracted through Unistel Technologies, the Universities Technology Transfer company. The foil system was optimized by use of the numerical model, which had been validated in many previous applications, by use of physical models and prototype sea-trial back feed data.

It was therefore not necessary to perform tank testing on the Panther hull although it is usually strongly recommended. The main foil was built of high tensile stainless steel by Maitland Metal Fabricators, Cape Town. The stern foils were cast in aluminium bronze and accurately machined and ground to a high quality surface finish. The foils were shipped to the UK where they were installed on the Panther 64 after initial sea trials without the foils. This way the improvement due to the foil system could be determined accurately.

It was a welcome procedure for the designer who had encountered strong disbelief in his 40% performance improvement prediction. Without foils, the Panther 64 reached 29 to 30 knots (occasionally) with a displacement of 32.5t in the initial sea trials over the measured mile on the Thames estuary. A week later with foils fitted the Panther 64 showed up with a top speed of 44 knots over the same mile and weight but including the foils (33.5t). Fully tanked and equipped it ran 42 knots with 35t.

The average improvement in top speed, therefore, was in excess of 40%. No other changes had been made to the craft. Certain further speed improvements are still feasible when the underwater fittings such as water intakes and exits and echo sounder installation are adapted to the new top speed and are further streamlined. The general hull finish can be further improved by use of smooth anti-fouling paints.

In a previous publication in FAST FERRY International, see Hoppe (1991), a performance comparison method of ships was developed which resulted in the so called power ratio

$$e_p = p_b / ? \text{ [t]} * 9.8 * V \text{ [knot]} * 0{,}5144$$

which gives a dimensionally clean physical performance comparison. It was found that the $e_p = 1 / ?_T$ with $?_T$ being the well known transport efficiency.

The smaller the e_p value of a craft build-up with the top performance data the more efficient is the craft. Usually the e_p increases for ships operating at larger Froude Displacement Numbers

$$Fn_D = V / ? \overline{g * ?^{0.333}}.$$

The diagram Figure 4 of Hoppe (1991) gives many different craft e_p values aside of tendency curves over Froude number. It can be used for direct comparisons of a design proposal with successful craft.

The power ratio e_p of the Prout Panther without foils is $e_p = 0{,}346$ at $Fn_D = 2{,}76$.

With the foil system installed is e_p = 0,229 at FnD = 3,82, which means an improvement of 33,8% in performance and a 26,8% speed improvement.

A tandem Hysucat hydrofoil system was developed for the 22m Ferry **"Sea Princess"** for Waterfront Charters in Cape Town, RSA. The hulls were designed by "Bob van Niekerk" for the former company T-Craft. Model tests were conducted in the towing tank at the University of Stellenbosch with various foil systems. The tandem foil system gave the best result at the top speed of 34 knots and in the middle speed range around 25 knots which is mainly used for sightseeing operations and allows most economical cruising.

The craft weighs fully laden (120 Passengers) nearly 60t and reached a top speed of 32 knots. However, the propellers only absorbed 80% of the MTU Diesel engines of 1000kW in the initial seatrials and the power ratio is e_p = 0,19 at the Froude Number FnD = 2,50 and a slenderness ratio L/?$^{0.33}$ = 5,27, (? being the volumetric displacement) making the Sea Princess a very efficient hull.

The photograph of Figure 3. shows the Sea Princess during sightseeing trips around the Cape Peninsula off Cape Town harbour.

Figure 3: The Sea Princess

A hydrodynamic stabilizer system was developed for the 21m Yacht **“Kingcat”** built by Kingcat SA Shipyard in France on the basis of the Hysucat principle. The Kingcat has symmetrical planing demi-hulls of the wave piercing type with moderate deep-V and extremely fine bows for reduced pitching in rough water. The hydrofoil system consists of a mainfoil slightly forward the LCG position and a full beam sternfoil with attack angle control spanning the tunnel width near the transom.

With extensive mechanisation and computer control of all essential functions of the ship it weighs about 72t and therefore has a very low slenderness ratio $L/?^{0.33}$ = 5,13 (heavily loaded hull !).

It was found in the Kingcat model tests at the University of Stellenbosch, RSA, that the tandem foil system gives considerably improved resistance in the medium speed range compared to the Hysucat foil system with two rear struts, especially if the rear foil attack angle can be adjusted for optimised resistance at the hump resistance speed. The helmsman has total control over the trim angle at speed and can choose the best trim for the top speed. The four MAN D2842 Diesel engines of 4 x 880kW driving 4 Lips waterjets L J 43DL give the Kingcat a topspeed of 46 knots and fully laden 44 knots.

It was a design condition that the frontfoil was not to be connected to the hulls below the waterline and the lift at speed is transmitted by two vertical struts fixed to the tunnel ceiling. The rearfoil is fixed on two shaft struts carried by the flange. The shaft struts do not penetrate the hulls and even in a collision damage the watertight integrity of the ship is not affected. Figure 4. shows the Kingcat in the initial trial runs off Sable D’Olonne on the French Atlantic coast.

Figure 4: The Kingcat

The power ratio e_p of the Kingcat made up with the trial data is e_p = 0,21, calculated with full power absorption at a Froude Displacement Number of Fn_D = 3,52 which can be entered in the Graph of Figure 4, of the report Hoppe (1991).
It shows that the Kingcat Hysucat has a 34% improved total hydrodynamic efficiency against a Deep-V-monohull. However, this result could be better as it was observed during sea trials that the full engine power of the MAN engines was not absorbed and an 18% power reserve remained.

Increasing requests for foil assistance for the larger high speed ferries initiated a research and development project about four years ago. **Several semi-displacement catamaran** hulls were developed at the Mechanical Engineering Department of the University of Stellenbosch and tested in several model test series with various foil systems.

At first it looked as if these large catamarans could not be improved with a standard hydrofoil system and only at very high Froude numbers improvements were recorded. The standard high speed semi-displacement catamaran operates most efficient at a Froude number of 2,1 to 2,3 and below the corresponding speeds the foil system gives no improvement and sometimes even a resistance increase. For higher Froude numbers considerable improvements were possible, but the ships in operation usually had not sufficient power reserves to reach the necessary high speeds for Froude numbers above 2,1 or 2,3.

It was necessary to develop a foil system which could already improve at the lower speeds and especially at the hump-resistance speed. The model of a 72m car ferry was tested with 8 different foil systems and an improvement over most of the speed range, including Froude numbers of 2,1 was only possible with a tandem foil assist system consisting of a high aspect ratio forward foil, positioned relatively far forward of the LCG position and a full-tunnel-width rear foil connecting both demi-hulls near to the transoms, see Fig. 1. The foil system was arranged to minimize the foil interference between forward and rear foil and the interference between each foil and the demi-hulls.

The hybrid with this foil system was named Hydrofoil-Assisted-Watercraft (Hysuwac) as it is applicable in principle also to fast mono-hulls and tri-marans. The subsequent model tests showed that resistance improvements on semi-displacement catamarans in the higher speed range of over 40% are possible without severe penalties in the lower speed range. The seakeeping quality and rough water performance are also improved with a considerable damping effect at speed. The model tests also indicated that the wake wash of these foil supported models was observed to be considerably lower than on the models without foils and on those models which had a standard Hysucat foil system.

With the experience gained in the Hysuwac development project a foil system was developed for the Halter Marine **E-Cat** which is a 45m high speed semi-diplacement catamaran developed for low wash operation. The E-Cat has very fine bows and a high slenderness degree ($L/?^{?}$ = 7,5) with a beam-draught ratio of nearly unity. The wide tunnel between the demi-hulls gives an ideal situation for a high aspect ratio foil system allowing a forward foil spanning nearly 11m.

After initial calculations a design including a model test was proposed. Halter Marine responded with stating that they had already a model. The question about the model's size was answered with "45m overall length" and meant the 45m E-Cat demonstrator in New Orleans, USA.

The challenge was taken up and a design without model tests was produced and the foil system was built by the Halter Marine Shipyard in New Orleans. Seatrials were run in September and October 1999 and proved the predicted enormous resistance reduction with the E-Cat at 175t load displacement reaching 42 to 44 knots top speed and 46 knots at a lighter load. Propulsion is by twin Caterpillar Diesel engines 3516B of 2 x 1910kW and twin MJP / Bird-Johnson 650 waterjets, see Halter Marine (2000).

The E-Cat power ratio with these trial results give a power ratio for the craft without foils of

e_p = 0,140 at Fn_D = 2,16 $?_T$ = 7,14

and with a Hysuwac foil system installed

e_p = 0,103 at Fn_D = 2,92 $?_T$ = 9,71.

This presents the lowest power ratio or highest transport efficiency of any comparable ferry type hull found in literature and used for the Hysucat data base. It also indicates that massive improvement on fast ferries with Semi-Displacement hulls are feasible.

Wake tests conducted by Mr. Stumbo of Washington State Ferries (WSF) confirmed the low wash of the foil assisted E-Cat observed in earlier model tests on similar hulls, see Stumbo S. (2000).

Mr. Stumbo stated that the E-Cat had the lowest wash of all the ferries tested in his program, but that the water depth in the lake was relatively low and that shallow water effects could not be eliminated completely and that a CFD-study will have to clear the situation and the influence of the water depth. Most other wake tests were conducted in deeper water. Usually the wave wake wash is amplified in shallow water.

The photograph in Figure 5 shows the foil assisted E-Cat at speed in the seatrials. The hulls are now running much higher out of the water and therefore it will be necessary to extend the Tigres picture along the side hulls well below the waterline.

Figure 5: The E-Cat with foils at 42 knots

Figure 6. shows the E-Cat mainfoil at a speed of 44 knots during the trial runs. A somewhat new flow phenomenon was observed which can not be classified as cavitation but rather as low pressure ventilation, see the “white water flow” over the foil which moved forward with increasing speeds. At lighter loads the E-Cat achieved up to 46 knots and the ventilation effect appeared even stronger, however, no cavitation erosion or performance reduction were observed even through the speed was far above the design speed of 40knots and the foil-tip profile thickness – chord – ratio too high for cavitation free operation.

It is believed that the foil in close surface effect mode is not prone to cavitation as expected. This means that much higher speeds will be possible when operating the foils in close surface effect mode. Further research is necessary to clarify this new phenomenon.

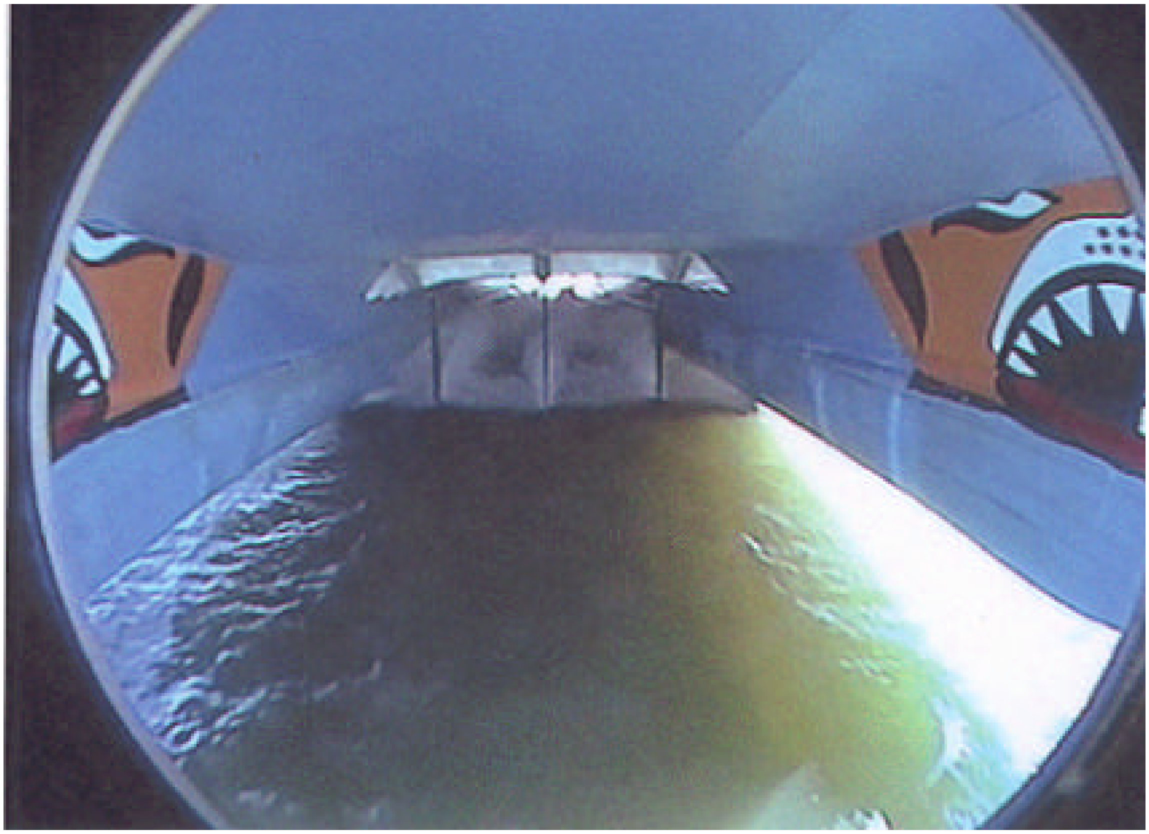


Figure 6: The E-Cat foil at speed

At the beginning of the year 2000 a Hysucat hydrofoil system was developed for the 14.6m high speed catamaran **“Wildcat” (Cougar 15)** built by **Cougar Catamarans**, Australia. This open deck ferry for 54 passengers and 2 crew members is used for tourist transport and so called joy-rides in waves off the shores of Bermuda Island.

The catamaran has a beam of 5,2m and a maximum operational full load displacement of 22 t. A new aspect in this hull concerning the foil design is the semetrical demi-hull shape with a high deadrise angle of over 40° and nearly prismatic shape of most of the length of the hull. It meant that a three-dimensional mainfoil had to be designed which had to be fitted to the planing bottom somewhere between the keel and the chine.

Otherwise a standard Hysucat foil system with the mainfoil slightly forward of the LCG position and two rearfoil struts near the transom was adapted. The “Wildcat” is powered by twin Caterpillar 340GE Diesel engines rated at 588 kW and seafury SF30 surface drives.

The initial trial runs were first completed with the “Wildcat” without foils and achieved a topspeed of 40 knots at a displacement o 20,7 t. Due to high propeller pitch the engine rpm’s were 500rpm down.

This corresponds to a power ratio e_p of

e_p = 0.282 at Fn_D = 3,97

which indicates a good performance for a standard catamaran.

A few days later with the Hysucat foil system installed and with the maximum total load of 22 t, simulated with sandbags, the “Wildcat” reached 49 knots with the engine rpm’s still down by 365 rpm. The propellers apparently had still a too high pitch or diameter and the predicted speed of 52 knots could still become reality with further fine tuning.

The Cougar-Hysucat 15 under these conditions gives a power ratio of

e_p = 0,216 at Fn_D = 4,81

which means an efficiency improvement of 23,4%. Once the propulsion system is optimally adapted to the new speed conditions further improvements have to be expected.

The “Wildcat” ran the Bermuda Challenge race in July 2000 but had to withdraw 60 miles out of Bermuda due to one engine failure. Up to this point it had broken the standing record easily. The photograph in Fig. 7 shows the “Wildcat” with foils at about 44 knots during the trial runs.

Figure 7: “Wildcat”

Another foil system was developed in parallel for the **Cougar Catamaran 13,2m** with a relatively lower propulsion power for the weight concerned of twin 320 kW Diesel engines with Seafury SF26 surface drives. The Cougar 13 has a waterline length of 10,700m and an overall length of 13,2m and a beam of 4,20m. The design weight was estimated to be 12,5 t. The demi-hulls are also of the symmetrical type with high deadrise and prismatic shape over most of the hull length .

However, the final maximum weight in the trial runs ended up with 16 t which reduced the prospects of achieving the predicted topspeed of 42 knots.

In the initial trials in June 2001 the Cougar Hysucat 13,2m reached a topspeed of 38 knots with 16 t displacement and 40 knots at a lighter load (about 2 tons less).

This craft has a Hysucat tandem foil system (full tunnel-width-rearfoil) which reaches higher efficiencies in the midspeed range. The rearfoil was designed to be easily re-adjustable in attack angle by a shift of one bolt. The power ratio e_p under these conditions with considerably increased displacement weight is

e_p = 0,209 at a Froude Number of Fn_D = 3,940

which is close to the predicted result. The propulsive coefficient P.C. = Pe / Pb results in a P.C. = $?_t$ / e_p = 0,115 / 0,209 = 0,55 wherein $?_t$ is taken from design calculation data, which seems low for a surface propeller system.

In the design the topspeed of the catamaran without foils was estimated to be 32,7 knots with a displacement of

? = 12,5 t, which means a power ratio

e_p = 0,311 at Fn_D = 3,529

which is a good expected result for a catamaran after tendency curves.

The foil system improved the power ratio or the transport efficiency by 32,8%. Speed was increased by 15% with a weight increase of 28%.

In the trial runs the full engine rpm's were not reached but were down 400rpm. With proper tuning of the propulsion system to prevailing hull and foil conditions considerable improvements are still feasible. However, the boat was delivered this way. Slight porpoising tendencies could be corrected by a slightly higher sternfoil angle (increase +1 degree!).

In summary it can be stated that both Cougar Catamarans were considerably improved by the foil systems with higher topspeeds and improved fuel efficiency. There is no other way than by a foil system to achieve such significant improvements.

Towards the end of the year 2000 a feasibility study by FASTcc for a foil design for the **16m catamaran "Molly"** with symmetrical Semi-Displacement demi-hulls was conducted for the shipyard **ALWOPLAST Ltda** in Valdivia in Chile. The ship, called "Molly" had been built after the design of Brett Crowther, Australia and achieved a top speed of 22 knots with a full load displacement of 22 t and two Yanmar 8CX-ETE Diesel engines developing 313 kW each.

The hydrodynamics of a Hysucat and a Hysuwac foil system were calculated by use of Prof K.G. Hoppe's Hysucat computer model and gave the resistance and thrust curves shown in Figure 8. Together with the Hamilton waterjet characteristic of the HJ 321 Jet. It indicates that the Hysuwac foil system is more efficient in the speed range 15 to 35 knots than the Hysucat foil system, with about 16% improvement at 25 knots. After these calculations the catamaran without foils should reach a top speed of nearly 26 knots. This was also the Crowther prediction.

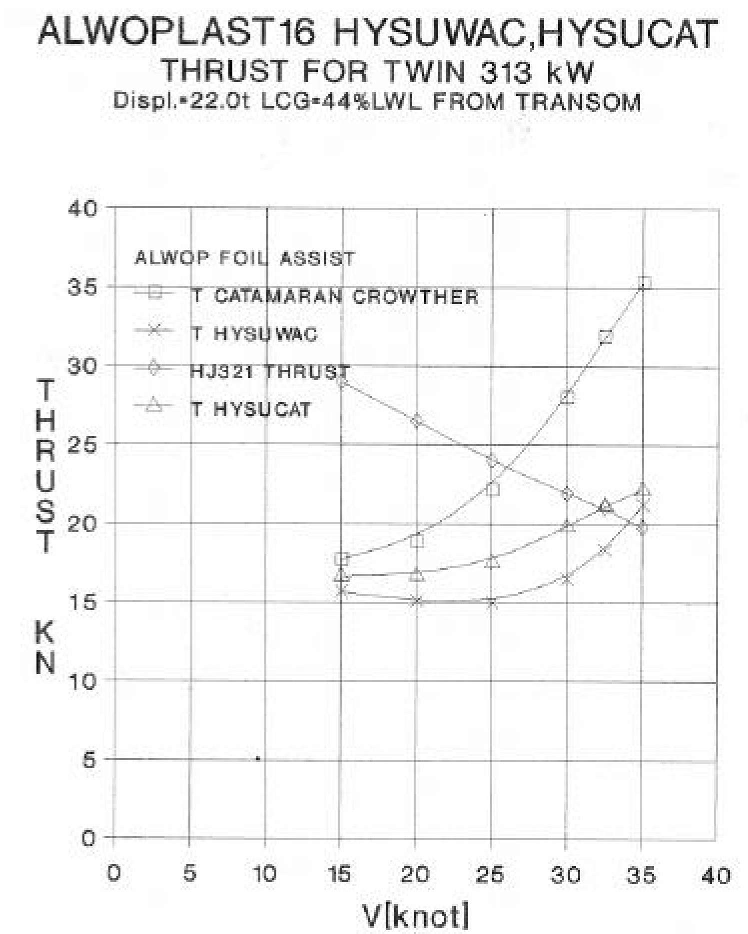


Fig.9 MOLLY WITH TWIN JETS HJ321

However, the trials in Chile only gave a top speed of 22 knots. The deficiency was partly traced down to come from additional drag of four large transom skegs for directional stability.

The owners decided to choose the Hysucat foil system in spite of the higher resistance vis-à-vis the Hysuwac foil system because of shallow water conditions which did not allow the front foil of the Hysuwac to penetrate about 400mm below the keel line.

With some correction on the skegs a top speed of 32,5 knots for the Hysucat was predicted and a contract of Unistel Technologies (Pty) Ltd, the Stellenbosch University's Technology Transfer Company accepted for the Design and Technology package. The design was subcontracted to FASTcc and the foil system built by Hydrofoil Manufacturers (Pty) Ltd in Gordon's Bay who subcontracted to Hydrospeed (Pty) Ltd of Cape Town.

The foils were installed in February 2001 and the following initial trials gave top speed readings of 32 to 34 knots in relatively calm water after the report by Mr. Wopper of Alwoplast. In rough sea conditions ("confused sea") the 18 knots at 2700rpm for the catamaran became 22 knots at 2500rpm for the Hysucat.

The faster ship showed some bow steering in strong winds and steering with too large jet rudder settings became necessary which indicated that the skegs were still too large and counteracted the jet steering effect.

Alwoplast is replacing the skegs at the moment with two steerable spate rudder-skegs in order to steer the ship in future at speed by rudder and not by waterjets as the use of excessive waterjet nozzle steering leads to a thrust loss which can exceed 20% and which reduces the top speed immediately and which leads to increased fuel consumption. Improved performance is expected soon.

So far it can be said hat the Hysucat foil system has improved the ship considerably. The power ratio (transport efficiency!) e_p without foil was determined on the base of the original trial results and was

No foils: $e_p = 0{,}257$ at a Froude Number $Fn_D = 2{,}16$

With foils: $e_p = 0{,}166$ at a Froude Number Fn_D 3,34

which indicates an improvement of 35,4% in performance. In the situation for which the Hysucat top speed was only 32 knots the improvement is still 31,5%.

So far, the "Molly" is the first Semi-Displacement catamaran with a Hysucat foil system. The foil system is complicated by the hull shape with round bilge to which the foil flanges have to be carefully adapted. The rearfoil is adjustable in attack angle by use of an oil-hydraulic actuator driven by the inboard high oil pressure supply of the waterjet system.

It is reported that the trim can be fast and easily adjusted to the helmsman's wishes and the running attitude of the boat be adapted to the prevailing sea conditions in the best way. The photograph in Fig. 9 shows the Molly with foils at about 30 knots during the initial trials.

Figure 9 : Molly with foils during the initial trial runs

3. CONCLUSION

The hybrid of a catamaran hull in combination with lifting hydrofoils improves the hull efficiency considerably and this has now been proven in many applications. The lift carrying capability of hydrofoils when designed for optimum condition is so much better than the one of the standard fast ship hulls that still further improvements seem feasible.

However, not only the resistance improvement alone is important but all other performance parameters of a craft as the dynamic trim, course-holding, transverse and longitudinal stability at all speeds, broaching and porposing behaviour, seakeeping etc. must not be negatively off-set by the addition of a foil system. This makes the design of a Hysucat a formidable and sophisticated task which very few designers are able to tackle without extensive use of model- or prototype testing.

The progress in the Hysucat development is therefore very slow. The use of supporting hydrofoils for catamarans was first thought to be of advantage for the smaller craft only and 20m long craft were thought to present the optimum. However, on request larger craft were investigated and new foil systems developed which were optimal for the new conditions and also considerable improvements were achieved. The largest foil system designed to date and under construction is for a 72m car ferry weighing 630t.

The gaul in this project of a Diesel driven ferry is a speed increase from todays 48 to 50 knot to nearly 60 knots with foil-support. The advantages of foil assistance do not end here and the application to the fast and larger gas turbine powered ferries might prove even more fruitful with reduced resistance and propulsion power per weight unit, reduced consumption and emmision.

Such new designs are not easily reached by simple conversions of existing ferries to foil-assisted catamarans but have to be designed from the beginning on as an intergrated entiety including the propulsion system. The author has the strong belief that considerable design improvements will follow in the near future. So far all Hysucat and Hysuwac foil systems have been designed by Foil-Assisted-Ship-Technologies c.c. (FASTcc). For further information please visit the Webpage of FASTcc, www.FASTcc.co.za

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