Foil Assisted Ship Development

By Prof. Dr.-Ing. K.G.W. Hoppe

MD Foil Assisted Ship Technologies cc

1) Historical Background
2) Optimisation of the Hysucat
3) The BMI-Hysucat Sea Model
4) Evaulation of Hysucraft
5) The Hysuwac Development
6) Milestones in Hysucraft Development Significant Examples

Foil Assisted Ship Developments

By Prof. Dr.-Ing. K.G.W. Hoppe

1) HISTORICAL BACKGROUND

After the Simon's Town Agreement expired (June 1975) the UK Naval Base was transferred to the South African Navy and the Mechanical Engineering Department of the University of Stellenbosch / Cape Province was extended to also teach Marine Engineering including basic Naval Architecture and typical test facilities to support R + D projects of the Maritime Industry and Navy were built up.

A towing tank (95m * 4,65m * 2,75m), a Cavitation Tank (0,6m * 0,6m test section) and a free-surface Water Circulating tank were built.

A 12m Navy Dive Boat design by "Bob van Niekerk" who was also Lecturer at the time at the Department, was model tested to investigate why the craft did not reach the design speed of 40 knots and why it blew several of the 350 HP Petrol engines. A further request for improved sea keeping in the rough waters of the Cape of Good Hope had well been satisfied. Propulsion was by Sterndrives. "Bob" had a great name in offshore racing boat designs.

The model tests were conducted 1978 in the Free Surface Water Circulating Tank but all measures to reduce the resistance failed. My proposal of a supportive hydrofoil spanning the tunnel were not accepted by the Navy at the time.

Instead the Navy reduced speed and had smaller Diesel engines installed.

After the tests had been finalized I followed up on my idea of the Dolomede with a supportive hydrofoil which gave an astonishing resistance improvement of 34%, see the evidence in the BMI "Technical Report on Model Tests on IMT Catamaran Dolomede", by BMI of the University of Stellenbosch, Fig 1a.

The Dolomede in initial sea trials is shown on Fig. 1b together with the model shape and the hydrofoil on Fig. 1c of this report. The model test result (Fig. 1d) were properly correlated and showed that the prototype had similar improvements. With weight shifts inside the model we even got 40% improvement.

My curiosity had been triggered and I registered my Research Project called "Hysucat Development" at the University of Stellenbosch 1979.

Hysucat stands for HYDROFOIL SUPPORTIVE CATAMARAN and was chosen to clearly differentiate to the well-known Hydrofoil Craft which carry full craft weight when foil borne.

Later the University registered Hysucat as their tradename. In my Sabatical leave I again met Prof. Dr. Ing. S. Schuster, Professor at the T.U. -Berlin and Director of the "Vesuchsaustalt fuer Wassbau und Schiffbau, Berlin (Berling-Towing Tank) and who had been my PhD Promoter.

He had considerable expertise in Hydrofoil design due to his involvement with the German Navy Hydrofoil Patrol Boat development during World War II and which had been captured by the Russian Army and brought to Petersburg where they started the well known Russian-River-Hydrofoil development and also due to his involvement in the Supramar Hydrofoil (Switzerland) which I witnessed partly and later had a project to develop contra-rotating propellers.

I showed my test results to the expert but his comment was "The aspect ratio of the foil in the catamaran application is too small to achieve good results". My remarks that 40% resistance, power and consumption improvement are not that bad were replied to as "The model is too small!

So, he did not believe any test results but I firmly believed in these predictions as I had also tested Deep-V-Planing hulls under similar conditions and had got very good predictions in the planing speed range.

At this stage I could not argue with him. Today I could explain the interference effects between planing hull and the hydrofoil increased the effective aspect ratio considerably, near doubling it. That is the main contributor to the excellent resistance and performance of the Hysucat.

2) OPTIMISATION OF THE HYSUCAT

My idea was how to optimize the Hsyucat but that was not an easy project as the theory behind the Hysucat had to be developed and not sufficient hydrofoil data were available.

The first step was then to develop our own Hysucat hull. Deep-V-Planing hulls of the Levi type were the only well performing hulls in rough water with good stability but needed large propulsion power. The foils were to reduce the power beyond mono-hull power.

A catamaran with fully asymmetrical demi-hulls was chosen as it offers the least disturbed flow through the catamaran tunnel and which gives best hydrofoil performance.

3) *The BMI Hysucat Sea Model*

The typical hull is shown in Fig. 5 which was the manned model of a 12m Hysucat. Smaller models were tested in the circulating tank and 1,2m models in the towing tank. Again all models predicted a 40% resistance reduction at high planing speeds. The Bureau for Mechanical Engineering (BMI) at the University of Stellenbosch had propogated Hysucat but could not find any interested party to develop such craft. It was then decided to build a sea-going prototype, called the BMI-Hysucat which is shown in Fig. 5, launched June 1982, displaying the foil system and sea behavior. It performed perfectly and showed up with an unbelievable fuel consumption rate. It also gained us the Design Institute / Shell Design Award 1983, first time to be given to a University, see Fig. 6.

The 5,6m Hysucat displaced 1,25 t to 1,4 t full load and reached 25 knots with twin 35hp Johnson Outboards which had only 28hp on the propeller shafts. Later it got twin Suzuki 80hp for 32 knots top speed and it performed astonishingly well especially in rough water and was tested in rough seas around the South African Coast over more than a year, collecting most important trial data.

At the same time about the above Dolomede -Dive Boat, which had a half size manned model called Blickboat was equipped with a foil at the “Institute for Maritime Technology” / Simon’s Town (IMT) and sea tested. This formed a Navy-Student thesis project.

It performed well on the rough seas but took up a large trim at hump speed (about 11 knots) and to get it faster into the full planing speed range, one person aboard had to move forward to the bows (to shift the LCG position forward!). Once over the hump speed the Blickboat picked up speed fast and performed much better than without the foils. It had a very soft run in strong waves. To prevent the required LCG shift we designed a rearfoil near to the transom which automatically kept the trim and resistance low at hump speed. This was then incorporated into all Hysucats and is shown in Fig. 3.

Most early Hysucats were optimized in towing tank model tests. However, these are extremely expensive and time consuming. For better optimization of the hybrid Hysucat the theory of the foils and hulls and their interactions had to be developed. Theoretical foil and hull data were not easily available (S.A. boycott!). A foil and hull database had to be established to allow comparison between theoretical and practical approaches.

Table I and Table II gives an idea of what the “Hysucat Development” required to allow proper optimization of any Hysucraft.

This involved many tests on the elements involved in the hybrid Hysucraft. Tests on foils and hulls and the combination were tested in the towing tank. Some of these tests series involved final M+Students thesis work and it took several years to get the data for proper optimizations together.

Table I: *Needed for Hysucat Development and Optimization*

F o i l   D a t a :

↓ Towing Tank Tests

(Drag and lift) See Fig. 2

↓

Profile section

(K – Profiles)

↓

Lift-Drag Ratios

in Surface Mode

↓

Reynolds numbers →

for laminar and turbulent

boundary layer flow

↓

Foil strength Calculations →

Beam theory

↓

Influence of Support Struts

↓

Cavitation flow, foil use limited

↓

Theory of Correlation for low Reynolds numbers, laminar

boundary layers

↓

↘ Theoretical foil data:

Early air craft theory

↓

Aerodynamic approach

Aircraft profiles, large literature!

↓

Wind tunnel tests, large database but no surface

effect and no cavitation limits.

↓

Software, Subrontine foil:

Theoretical lift and drag calculations for foil wings,

dependent on foil geometry, effective aspect ratio, attack angle,

depth of submergence (Froude Depth Number!)

max thickness ratio.

↓

Evaluation of ship-near flow conditions.

↓

Incorporation in Hysucat Mathematical Program

Software for prototype to model correlation combined with full data.

Table II

H u l l   d a t a:

Series tests of planing hull hull and Deep-V-planing craft collected.

↓

A so-called Split-Deep-V-planing hull catamaran investigated and model test conducted.

↓

Quality of flow-through tunnel tested, Asymmetrical demi-hulls give best flow conditions.

↔ Mathematical Hysucat Fortran Program

Theoretical hull data:

↓

So-called Savitzki Equations for planing hulls investigated,

↓

correction for hump resistance, Results applied to Hysucat hulls and compared to model test results.

↓

Software developed for Hysucat hull calculations,

↓

Combined with foil software (Sub routine programs)

↓

Mathematical Hysucat Fortran Program

↓

Mathematical Hyscraft program extended to include Hysuwac foil Systems.

↓

Today version 53, which gives all hydrodynamic detail results and performance data.

4) *EVAULATION OF HYSUCRAFT*

A method to properly compare the performances of different ship types with the hybrid Hysucraft was developed but ended up with a dimensionless parameter called the Power Ratio ep,

$$\text{ep} = \frac{\text{Pb [kW]}}{\Delta[\text{t}]*\text{g}\left[\frac{\text{m}}{\text{s}^2}\right]*\text{V}[\frac{\text{m}}{\text{s}}]} = \frac{\varepsilon}{\text{O.P.C}}$$

with ε being the Resistance displacement ratio and O.P.C. = $P_{effective}$ / $Pb_{\ Diesels}$, which is actually the inverse of the well-known Tranport Efficiency η_T.

Typical diagrams of comparison were built up as ep over the Froude Displacement Number

$$\mathbf{F}\text{nD} = \text{V}/\sqrt{\text{g} * \nabla \exp 0{,}333}$$

With g = acceleration of earth, ∇ = volumetric displacement. A typical diagram with tendency curves for various ship types is given in Fig. 9.

5) THE HYSUWAC DEVELOPMENT

The Australian Ship Designer AMD (for Advanced Multihull Development Pty Ltd) ordered model tests on their 36m high speed aluminium ferry and also for a 72m Car ferry, equipped with a Hysucat foil system. These ships were of Semi-Displacement type.
The model tests gave only moderate improvements of about 15% to 20% resistance reductions. Observations let to the conclusions that these hulls create the flow around the midship section with accelerated velocities and negative pressure areas on the lower hull. That creates a situation where the interference factor foil to hull becomes negative and the resistance increases considerably.

A new foil system had to be developed and the computer program adapted to prevent the negative interferences.
The new foil system was called Hysuwac standing for “Hydrofoil Supported Watercraft”. Patents were entered in 1998 and taken over by the University. It is still active until 2018. The

foils were placed near the bows of the catamaran and near the transom, well away of the negative hull pressure field, see Fig.8.
The following model tests with Hysuwac foils gave for both hull types over 40% resistance reduction.

The 72m Car ferry was contracted in by Buquebus/Argentina and the foil partly built when the company ran into financial trouble and stopped paying progress payments. The project was abandoned.
Around the same time Halter Marine in Louisiana/US wanted a foil for their Ferry E-Cat. When I asked if they had a model of the hull they answered "Yes!". When I did ask, how long it was, they answered 45m. So, no towing tests! Design by Mathematical Model.

A Hysuwac foil system was designed and then built by Halter Marine. The ship had not got the full super-structure, but it's weight was simulated by steel plates on deck when the trials were run. With foils the E-Cat reached 42 knots full load and 46 knots at lighter load conditions, up from 31 knots full load without foils. It had the best ep ratio of any boat tested so far. Fig. 8a shows the E-Cat with foils at launch exposing the Hysuwac foil system and the mainfoil at full speed.
Extensive sea-trials were run including also wake-wash tests which had been very important at the time. The E-Hysuwac had a 50% reduced wake flow due to the foils.

However, Halter went bankrupt and was taken over by a Singapore company who abandoned the fast craft division.

6) *MILESTONES IN THE HYSUCRAFT DEVELOPMENT*

After the BMI-Hysucat appearance the company T-Craft Marine (Cape Town) who had built sea going catamarans required a foil system for a 10m Game Fishing Cat for a client in Mosselbay. In a rescue operation the client out-ran the harbor police boat which had the same hull.
Back in the harbor the police looked at his engines and were astonished that the boat had the same engines. The client explained the foil system.
A year later all harbor police boats were equipped with our foil system and T-Craft offered only Hysucats of 10m, 12m, 20m Offshore Navy Patrol Boats, see Fig. 10 and Fig. 11 with the 20m foil system.
T-Craft also built the 36m Luxury Yacht with foils the "Chief Flying Sun" (Fig. 12) but ran into financial trouble after delivering and was closed down.

A German group, called "Hysucat Engineering Germany (HEG)" took a patent license from the University and requested a design for a Thai Navy Patrol Boat of 19m. In collaboration with the Lùrssen Shipyard/Germany FASTcc produced the design and ran extensive model tests in the

WS – Berlin (Berlin Towing Tank) in 1985. The ship was launched in September 1986 and performed very well after a reduced model hull had been tested first in rough water, see Fig.13.

HEG developed in collaboration with FASTcc the 19m Yacht "Ultimaratio", see Fig. 14. The River Ferry "Rheinjet" for 60 passengers and 40 knots, see Fig. 14 and the 22m North Sea ferry "Nordblitz", 110 passengers, see Fig. 16. The so-called Canard Hysucat foil system of Nordblitz is shown in Fig. 17.
These two ferries had Servogear C.P. propellers which are most effective also at hump speed and therefore best suited for Hysucats.

A Hysucat RIB was designed in 1996 and developed in collaboration with Malan Conradie of Stealth Marine in Gordon's Bay, RSA.
This was based on a double sized Hysucat RIB to be built by Konitek in Somerset West for a record attempt of a global circum navigator.
However Komitek never brought a boat to the water but had retarded the RIB development as they had sole right for 5 years which ended in 1996.
The first 6,5m Hysucat prototype is shown in Fig. 18 on initial trials. Also shown is the jumobdized 8,5m Hysucraft RIB.
The 6,5m Hysucat RIB with twin 50hp Outboards reached fully laden 40 knots and had the best sea-keeping in rough water. Over the years about 800 to 1000 boats were built and mostly exported but the company changed investors and CEO's several times, but this was the most successful Hysucat so far.

Stealth Marine also developed a 7,5m Hysucat and a 12m Hysucat Yacht which ran 42 knots with twin Yanmar Diesel engines 2 * 420hp and Seafury SP System and a full load of 11,5 [t], see Fig. 19.
Stealth Marine also took over the mould of a 15m Hysucat Yacht developed by Tallie Marine (a Trawler company in Stompnose Bay!) However, Stealth Marine ran into financial trouble and was taken over by Stealth Yachts Mr. Ian Stopforth who finalized the Yacht and extended it to 16m, see Fig. 20.

Stealth Yachts also developed a 16m Ferry, the so-called Stealth Yacht 520. Propulsion is by twin Yanmar 820 hp Diesels and Q-Speed Surface Drives and lately in-house developed own Surface drives. These Hysucats reached up to 45 knots and the latest version 49 knots with twin 820hp MAN Diesels and a full load weight of 22 to 24 [t].

A foil system was developed for the 64' Prout Panther of Prout Catamarans in England. Most of these luxurious Yachts are in the UAE and Arabia.
The 35 [t] Yacht is propelled by twin MTU 1150hp Diesels and waterjets (different makes) and reached a top speed of 31 knots fully laden, with Hysucat foils, it achieved 42 knots, see Fig. 21.
Seven of these Yachts were equipped with our foil systems.

The Kingcat luxurious Yacht built in Sable d'Ologne in France by Max Rez got a foil system consisting of a mainfoil about midships and a full beam adjustable rearfoil, see Fig. 22.

The foils brought the speed up from 31 knots to well over 40 knots. Propulsion was by 4 * 800hp MAN Diesels and four Lips waterjets.

More Hysucraft applications can be seen on the FASTcc website: www.hysucraft.com

More recently some U.S. Army Corps of Engineers (USACE) Survey Boats were designed as Hysucats by Kvichak Marine, see Fig. 23, in Seattle/USA and the Geo Shipyard in Louisiana, see Fig. 24.

Nowadays new Survey Boats are in development.

Also in development is a Super Yacht 80' called Alpha Yacht in collaboration with Luiz De Basto Design, shown in Fig. 25.
The estimated full load is 63,25 [t] and propulsion by Caterpillar Diesels with twin 1428 kW for a full load top speed of 55 knots with KaMeWa Waterjets A3NP, Twin 45A3. Fig. 26 shows the typical performance diagram indicating the critical hump speed range which can lead to waterjet cavitation if the boat is wrongly laden.
LCG position has to be between 38% and 40% of the chine length.
The project is retarded by the financial crisis.