TURNING SEAWAYS INTO FREEWAYS

THE 90 KNOT ZERO-WASH FERRY

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Overview
This paper sets out the development and potential application of a new marine vehicle that is able to provide operating speeds in excess of those offered by road transport, with high efficiency and without wash.

Introduction
Marine transport has long held second place to that of road transport. Cars, buses and lorries offer utility, convenience and efficiency, but most particularly speed and comfort that is hard to rival in the marine field. Yet land based transport is not ideal. More roads mean more traffic, and road systems can get overloaded. Terrain, geography, or ecology handicaps some countries - or they may simply lack money for the large infrastructure investment necessary for land based schemes. Others seek to circumvent land congestion issues through new sea based ‘modal shift’ initiatives.

But the marine solution is not ideal either. A hull passing through the water interacts hydrodynamically with its surrounding environment. This is most obviously manifested in wake/wash that impacts the ecology, the seaway infrastructure (e.g. erosion) and other water users (e.g. other vessels). In the past this has led to incidents in which people have been drowned, allegedly by the wake emanating from fast ferry vessels. This has led to restrictions on, and resistance to, the introduction of fast ferries to some parts of the world. Past solutions to this problem include the refinement of hull form to minimise resistance and wake, while more radical methods of reducing the hulls involvement with water have included the use of hydrofoils and air cushions but these have fallen from favour. Whilst a lot of very good work has gone into exotic low wash hull shapes, wash remains an inevitable consequence of most fast ferry proposals.

What if there was a ferry that operated efficiently at 90 knots and left no wash at all?

There is no trickery in this paper. The 90-knot zero-wash marine vessel is a very real craft indeed. The technology presented here is already developed and proven on both small and large scale. All that is needed is a little imagination to see it into commercial service.

Technology
The technology involved is ‘Ground-Effect’ (short for ‘Wing-in-Ground Effect’, or WIG).

Through many years of research and practical prototyping, Fischer Flugmechanik/AFD Airfoil Development GmbH have evolved their WIG technology into a marine vehicle that, with the launch of their Airfish AF8(FS8) 8-10 passenger craft in 2001 became the worlds first WIG vessel to achieve a Certificate of Class by Germanischer Lloyd (Dec 2001), and Lloyd's Register (May 2002) (Figure 1). This craft will go into licensed series production. During the course of development the FF/AFD concept
has evolved away from an initial sea-skimming aircraft design. The capability for free flight has been removed, to be replaced by the power-efficiency, simplicity and economy of a pure ground effect surface vessel, constructed and certified for operation as a boat.

Figure 1: Airfish 8/Flightship 8, eight passenger vessel launched in 2001

FF/AFD have evolved two strands of WIG technology: the first generation ‘Airfish’ concept and the second generation ‘Hoverwing’ concept. This paper concerns the Hoverwing concept. FF/AFD are now seeking strategic partners for the construction and operation of 20-passenger and 80-passenger craft based on this technology.

What is Ground Effect?
A ‘ground effect’ (WIG) vehicle can be thought of as a ‘dynamic’ hovercraft. Unlike a conventional hovercraft that generates a static cushion which is pulled around within a skirt, the WIG generates a ‘dynamic cushion’ between itself and the surface below it by virtue of its own forward passage. The WIG utilises ‘wing-in-ground effect’, a phenomenon that relates to the airflow around a wing when it flies in close proximity to a surface, wherein the presence of the surface distorts the downwash from the wing and inhibits the formation of vortices. This effect dramatically increases the lift and reduces the drag compared to that attainable by a wing in conventional flight, and so is the basis of self-stability in cruising height/wave clearance (at about 10% wingspan) and power efficiency. As sea clearance is a function of the scale of the craft, larger craft will have greater sea state capability. When cruising in ground effect, the only noticeable wake is a trace of small surface ripples behind each wing tip created by the action of the confined wing tip vortices (Figure 2). This dissipates within a few seconds of the vessels’ passing.

Figure 2: Illustration of how downwash vortices from a wing are affected by the presence of the water surface. This causes a dramatic increase in lift/drag ratio.

Although such aerodynamics may be unfamiliar to those currently in the marine business, the technology at the heart of this marine vehicle is no more complex than that of a conventional boat, as illustrated by Figure 3. The result is a rugged craft with stubby wings that is well suited to a marine environment.
The Second Generation ‘Hoverwing’ Concept
Getting a WIG craft to cruise efficiently is one thing; getting one to take off efficiently from the water is another. The power required to take off can be significantly larger than that required for efficient cruise. To help overcome this, FF/AFD’s research led to the development of the Hoverwing concept. This incorporates a retractable SES type air cushion between catamaran hulls which is used during takeoff (Figure 4).

The lift/drag increase afforded by this system minimises the mismatch between takeoff and cruising power and so reduces the installed power requirement by 45% (Figure 5). Initially 7% of the propeller stream is diverted and guided between catamaran hulls to produce a static air cushion that supports 80% of the craft weight. As the vehicle accelerates during takeoff, the dynamic air pressure replaces the static air pressure, the sealing skirts are retracted automatically, the diversion duct is closed and the craft makes a seamless transition to ground effect cruise mode. This system also allows the craft to cruise efficiently in ‘step-taxi mode’ as a wing-assisted high-speed boat at speeds below the takeoff speed.
The HoverWing Hull
By combining catamaran hulls with a blended body/lifting body shape, the hull of the Hoverwing contributes 40% of total lift in Ground Effect, and at the same time offers a very large internal payload volume. This approach also enables a highly integrated mechanical construction in which masses and lift forces are concentrated together. This minimises bending stresses, which in turn minimises airframe/hull weight. Because bending stresses have been minimised in this way, the wings and tail of the Hoverwing can be made to fold (for docking) using simple mechanisms (Figure 6).

![Fig. 6: The HW-80 showing the blended/lifting body/hull and folding wings](image)

Manoeuvrability
A single combined flap/rudder control enables the craft to make co-ordinated banked turns of less than 300m radius while cruising at 90 knots. Such banked turns do not subject the passengers/crew to uncomfortable G forces. In 1997, as part of a project funded by the German Ministry of Research and Development, a two-manned ‘proof of concept’ test craft, the Hoverwing 2VT, was built (Figure 7). This craft underwent extensive trials and has ‘flown’ more than 3,000 km. Figure 8 shows the GPS track of a Hoverwing 2VT flight, where several turns with less than 300m radius were recorded. In addition, by using the kinetic energy in cruise mode, it is also possible to give the vehicle the ability to jump up for vertical obstacle avoidance.

![Fig. 8. Manoeuvrability - GPS track of HW2VT trials](image)
Figure 7: The HW 2VT 2 seat technical demonstrator in 1997. This was a scale model of an 80 seat concept.

Features, Benefits and Uses
The Hoverwing concept is aimed at medium/short-range applications such as river, coastal, inter-island, delta/estuary transport in parts of the world where the sea-state permits. The relationship between span and wave clearance makes the extent of these operational areas dependent on the size of the craft (future large craft may well have greater weather capability). Examples of such areas include the Gulf of Mexico, the Caribbean, East Asia and the Mediterranean, as well as the thousands of miles of major rivers in each continent.

The principle advantages offered by the Hoverwing concept are:
• High cruising speed, circa 90 – 100 knots:
  • Ability to cover a wide area within a short time – point to point speed competitive with helicopter/light aircraft
• No water contact Cruise mode:
  • Little sea motion; no seasickness, leading to low crew/personnel fatigue
  • No wake / wash
  • No environmental damage
• Good load carrying capacity (relative to aircraft)
• ‘Boat’ simplicity:
  • Low maintenance
  • Low training requirement
• Efficiency:
  • Low power consumption
  • Low fuel cost
  • Low maintenance
• Low cost (relative to aircraft/helicopter)
• One craft could do the work of several conventional craft
• Offers a unique passenger experience

Some Applications are suggested below:
• Passenger Ferry/Water Taxi – services between population centres
• Freight/Workboat – e.g. high value/time sensitive freight and mail
• Tour boat – e.g. able to take passengers from cruise liners to remote destinations in short space of time
• Resort boat – ferry passengers from airport to hotel beach
• Dive boat – Reach remote reefs, follow reef activity
The Hoverwing Program
FF/AFD currently propose the development of two types of vessels:

- The Hoverwing HW-20: This is a 20 seat passenger/freight civil craft with a cruising speed of 90 knots in waves up to 2 m and a useful load of 2.5 tonnes (Figure 9). [See also Appendix 1]

  Figure 9: The Hoverwing HW-20

- The Hoverwing HW-80: The HW-80 will accommodate 80 civilian passengers or up to 10 tonne payload (Figure 10) [See also Appendix 2]. The craft will have a modular payload system and could be adapted to carry small vehicles (cars, Land Rovers etc.). The HW-80 craft will have a cruising speed of 96 knots in wave-heights up to 2.5 m and takeoff wave-heights up to 1.85 m. A cargo variant is possible for freight operations. Large gull-wing doors facilitate easy access for freight and a dedicated system of purpose built lightweight plastic moulded containers and nylon roller tracks can be installed. FF/AFD have considered scaling the concept to 200 seats. Those sceptical about the use of the concept on a large scale should note that behind the Iron Curtain the Soviet Central Hydrofoil Design Bureau built and operated a 550 tonne ground-effect ‘ekranoplan’ craft at 150 knots in 1966. That was nearly two years before the UK launched the first ‘fast ferry’, the 60 knot 165 tonne SRN4 Hovercraft.

  Figure 10: The Hoverwing HW-80
Operational Considerations
The Hoverwing is a radical marine vessel and, until some operational experience has been gained, all the issues that might arise out of its use cannot yet be identified. HA/AFD/FF therefore seek a close working relationship with operators and classification societies in order to explore its full potential. This in turn will lead to development of the vessel and operating procedures. Some key issues include: accurate knowledge of weather and sea conditions, interaction with other vessels, route planning, classification/certification, and crew training. Skills and knowledge gained in these areas would be transferable to conventional operations, and would open the door to larger craft.

Business, Markets and Industry: Seaways to Freeways
Transport is fundamental to the economic development of any region. But there are many regions that are handicapped by terrain, geography, or simply the lack of money for high-speed transport systems.

The Hoverwing brings the speed and comfort of freeway travel, but without having to build the freeway first, or having to sink vast amounts of money into fixed infrastructure assets like roads or airports. Nor does it necessitate the huge environmental destruction inherent in building and operating most transport infrastructure schemes. Indeed, at 90 knots the speed of the service offered is about twice the legal road speed limit in most countries.

Because the investment is in the vehicle and not in the ‘freeway’ infrastructure, it means that Hoverwing can provide a very quick, flexible solution that does not require the kind of studies that go into making fixed asset investment (e.g. the time span, depth of analysis, political leverage etc). A Hoverwing service can be introduced or re-deployed at short notice and the service evaluated by practice rather than by theoretical projection.

One example taken from a study of the Baltic Sea illustrates how coastal high speed transport beats conventional road and ship transport. On the Arhus-Kopenhagen route, the Hoverwing would only take one fifth of the travelling time of train or ship. It would also have the lowest travel cost (Figure 11).

WIG and The New Fast Marine Business
In many respects the Hoverwing WIG craft sit between conventional boat and aircraft. The Hoverwing is a marine surface vessel and will be classified as one, but the development and adoption of it serves as an illustration of how the fast ferry business is evolving and beginning to blend together the values of both the marine and aviation industry.
The traditional marine industry is a very incremental one. Each boat is built as an increment on the one that went before. There is little fundamental research and development, and the cost of that which does take place is funded from the sale of that particular vessel. The aviation industry is somewhat different. Each new model requires extensive research and development, and this can only be funded through pre-selling series production. In the case of WIG, and some other cutting-edge marine developments, a higher proportion of ‘fundamental’ R&D investment means that the marine business model must be changed. Beneficially, this brings the possibility of moving from an industry structure that has low barriers to entry and competition, to an industry structure that has high barriers to entry and competition. With it can come sustainable strategic advantage, strong brand identity plus spin-offs into lower end technology. With a little imagination and adoption of aviation type values, the new fast marine business model could be quite different to the old.

**Project Status**
At the present time Hypercraft Associates/AFD are seeking strategic partners for the manufacture and operation of the civil craft.

In addition to the civil applications mentioned in this paper Hypercraft Associates/AFD are also exploring the paramilitary use of the Hoverwing concept. In this field the zero-wash sea-skimming and comfort combine in a vessel that offers rapid response, endurance, stealth (wake is often the most visible sign of ship activity) and the genuine capability to intercept almost all other marine vessels (see Appendix 3).

**Conclusions**
This paper presents the Hoverwing as a 90-knot zero-wash high-speed marine vessel. The technology to produce and operate ‘zero wash’ Hoverwing has already been proven and is scaleable up to 200 seats. With no sea motion fatigue and high speed, they offer a unique passenger experience. The craft can be used for ferry, water taxi, resort craft and other applications on new or existing routes, including environmentally sensitive and poorly served areas of the world, wherever the sea conditions permit. All that is needed is the courage to step outside the traditional marine business model.

No longer does the marine industry have to accept second place to the speed and utility of road transport. The Hoverwing technology really does have the capability to ‘Turn Seaways into Freeways’, and without the cost, time delay and environmental damage associated with building a freeway the hard way.

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APPENDIX 1: HOVERWING 20

Hoverwing 20 is the first production craft of the second generation Hoverwing ground effect concept.

This technology has been developed between the companies Fischer Flugmechanik and AFD under the sponsorship of the German Ministry of Research and Development, and the proof of concept has been made with the manned test craft Hoverwing 2VT.

For commercial operation, certification by the naval societies will be applied under +100 AO WIG-A, WH 0.75/2.5 EXP

Hoverwing 20 will operate as a small ferry and high speed water taxi and is suitable for river, estuary/delta, coastal and inter-island applications.

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<th>Performance:</th>
<th>Specifications:</th>
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<td>Cruise Speed</td>
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<td>Range (no Reserves)</td>
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<td>Efficient Cruise height</td>
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<td>Max wave height take-off</td>
<td>Height 4.94 m</td>
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<td>Max wave height cruise</td>
<td>Payload 2,460 kg</td>
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<td>Take-off weight 8,994 kg</td>
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<td>Cruise power 465 hp</td>
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Cruise Speed 175 km/h 94 knots
Range (no Reserves) 500 km
Efficient Cruise height 1.75 m
Max wave height take-off 0.75 m
Max wave height cruise 2.50 m
A feasibility study by the German Ministry of Economics proved that a high-speed vessel operating on the Baltic Sea at 180km/h with 80 passengers over wave heights of up to 2.5m would be a profitable and future orientated product.

To verify the results of the experimental and theoretical studies for the HW-80 design, a two-seat test craft Hoverwing 2VT was built and successfully tested during more than 3000 km of trials.

The HW-80 offers plenty of volume to accommodate up to 80 passengers or payloads of 8-10 tonnes. The HW-80 will incorporate a modular approach to payload management that enables rapid reconfiguration to match operators passenger/mixed freight requirement.

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<td>Width 31.9 m</td>
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<td>Payload 8,000 kg</td>
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<td>Max wave height take-off 1.50 m</td>
<td>Take-off weight 30,2028 kg</td>
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<tr>
<td>Max wave height cruise 2.50 m</td>
<td>Cruise power 1,300 hp</td>
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Hoverwing 20 Mil

Hoverwing technology has been developed by AFD’s sister company Fischer Flugmechanik under sponsorship of the German Ministry for R & D.

Outline Specifications:
This sea-skimming craft will have a cruising speed of 90 knots. The vehicle can carry a dozen fully armed troops, can be fitted with an assortment of weaponry or equipment, and has stealth possibilities. Paramilitary applications include anti-drug running, anti-piracy, border patrol, interception, search and rescue, pollution / environmental monitoring, covert and special operations. The high speed no-water-contact, zero wake cruise mode provides high crew comfort and genuine ability to intercept almost all other vessels.

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