

# Preface

In the last half-century, high-speed water transportation has developed rapidly. Novel high-performance marine vehicles, such as the air cushion vehicle (ACV), surface effect ship (SES), high-speed monohull craft (MHC), catamaran (CAT), hydrofoil craft (HYC), wave-piercing craft (WPC) and small water area twin hull craft (SWATH) have all developed as concepts, achieving varying degrees of commercial and military success.

Prototype ACV and SES have achieved speeds of 100 knots in flat calm conditions; however, the normal cruising speed for commercial operations has remained around 35–50 knots. This is partly due to increased drag in an average coastal seaway where such craft operate services and partly due to limitations of the propulsion systems for such craft. Water jets and water propellers face limitations due to cavitation at high speed, for example. SWATH are designed for reduced motions in a seaway, but the hull form is not a low drag form suitable for high-speed operation.

So that seems to lead to a problem – maintain water contact and either water propulsion systems run out of power or craft motions and speed loss are a problem in higher seastates. The only way to higher speed would appear to be to disconnect completely from the water surface.

You, the reader, might respond with a question about racing hydroplanes, which manage speeds of above 200 kph. Yes, true, but the power-to-weight ratio is extremely high on such racing machines and not economic if translated into a useful commercial vessel.

Disconnection of the craft from the water is indeed a logical step, but it has its consequences. The craft must be propelled by air and it will have to be supported by air as well. A low flying aircraft? In some ways – yes – but with a difference. When an airplane flies very close to the ground a much higher pressure builds up under the wings – ground effect. Some early hovercraft were configured to capture air as they moved forward – captured air bubble craft.

Combine ground effect with a geometry specifically designed to enhance the effect and you have a craft that might be able to achieve much higher cruising speed. Flying above waves, its motions might also be much reduced. This idea gave birth to the wing-in-ground effect (WIG) craft.

The original type of WIG can be traced from at the beginning of last century. Actually, in 1903, the Wright Brothers flew their first airplane over relatively long

distances in the surface effect zone. Engineer Kaario of Finland started tests of craft lifted by ground effect in the middle of 1930s. However, due to limitations in the efficiency of structural materials and available engine power, the WIG was not developed further until the beginning of the 1960s.

These were ideas that excited Alexeev in Russia in the 1960s and 1970s after his institute had developed several series of hydrofoil designs. Alexeev and his team of Russian pioneers in this new vehicle technology were interested in very high speeds, and their programme was developed directly from hydrofoil research. The craft were christened “Ekranoplan”. Parallel efforts on prototype craft and theoretical analysis gradually built experience and understanding through the 1970s and 1980s leading to the first military service craft based in the Caspian Sea. This was a truly outstanding technological achievement delivered through visionary support from the Russian Navy.

In Germany, also in the 1970s, research and prototype craft aimed at using ground effect was also carried out. Rather than the large military budget available in Russia, the German programmes were funded privately and later with low level support from government. This work led to ground effect craft suitable for high-speed coastal patrol, though in limited sea conditions.

At the beginning of 1970s, Russian engineers Bartini and R.Y. Alexeev invented power-assisted lift arrangements for WIG craft by mounting jet engines in front of the main wing to feed engine exhaust air into the air channel under the wing to create the so-called power-augmented ram wing-in-ground effect craft (PARWIG). This augmented lift improved the take-off and landing performance by reducing take-off speed and distance.

The full story of Alexeev’s craft is outlined in Chapter 2 together with other developments from around the world. The technical achievements were highly significant, and it is a pity that the economic situation in Russia through the 1990s was such that the programme had to be stopped. It may be some time before we see machines to equal the KM and Spasatel.

In recent years, researchers in China and Russia have mixed air cushion technology into the WIG to create the dynamic air cushion craft (DACC) and dynamic air cushion wing-in-ground effect craft (DACWIG) to produce craft with amphibious capability and much higher transport efficiency at medium cruise speeds in the range 150–250 kph.

Since a WIG has several operational modes (floating hull, cushion and planing, and air-borne modes), the craft design is rather more complex than aircraft or other marine craft. A WIG normally just transits through all the modes except flying in ground effect, but unfortunately the drag forces and motions are the greatest at speeds below take-off, so effective design for the conditions met during the take-off and landing runs is essential to a successful WIG design. The challenges are not over though – quasi-static and dynamic stability of a WIG when flying is strongly influenced by both the flying height and the craft pitch angle.

Research into these areas is at an early stage and much more knowledge in the different areas is needed. In this book, we give an outline of the knowledge as it

exists right now. This provides a starting point, though readers are encouraged to seek out further sources for themselves!

Some accidents have occurred on full-scale WIG craft, so that there is some uncertainty as to the safety of WIG for potential operators at present. This is being addressed by a technical committee of the International Maritime Organisation (IMO) who have published a safety code in the form of guidelines for WIG in 2003.

The technology is indeed still somewhat experimental and needs a build-up of operational experience, even if it is at relatively small scale, in order to develop confidence for the commercial industry to gain enthusiasm for this new form of transportation. The IMO guidelines should help a lot in this respect, but practical operations, perhaps following the example of the many SR.N6 hovercraft trials operations and expedition journeys in the 1960s and 1970s, will be needed to prove their capability and value to society.

On an international basis, the WIG craft is now recognised basically as a high-speed marine vehicle and will be certified as such, rather than being certified by aerospace authorities. This has significant cost and operational advantages that should assist in the craft's commercialisation.

WIG are based upon a combination of aircraft and marine technology while being different from either. WIG operate both on water and in air as well as on the edge of both media. A WIG is neither an airplane nor watercraft as such. It is rather different either from airplane industry (sophisticated lightweight structures, high power intensity, automated, heavy certification requirements, expensive construction etc.) or from watercraft (experience based design, relatively heavy structure, robust, low cost, etc.). The WIG borrows from both technologies to achieve a high speed and lightweight, yet low-cost marine vehicle.

Our book begins with a general review of ground effect technology and a historical review to give a background to the main body of the text covering the theory, as well as a design approach for WIG. This is the first major text on this subject outside Russia, so we hope to reach a worldwide audience and encourage interest in this technology in between the marine and aerospace worlds!

There are this Preface, 13 chapters and Backmatter in the book. We introduce WIG craft concepts and background development in Chapters 1 and 2. From Chapters 3, 4, 5, 6, 7, 8 and 9, the book describes trim and longitudinal force balance, static hovering performance, aerodynamic characteristics, stability, drag and powering performance, seakeeping quality and manoeuvrability, and model experimental investigations. The materials and structures, power plant selection, and lift and propulsion system selection are introduced in Chapters 10, 11 and 12. In these chapters, the issues related to WIG design are considered as a derivation from aircraft or marine design rather than giving a detailed treatise. In Chapter 13, a general approach to WIG concept specification and design is described.

The Postscript discusses prospects for the future and a series of technical issues concerned with the development of WIG that face researchers and engineers in this area at present. There is so much to work on at present. The WIG principle can be applied to a wide envelope of operational speed and environmental conditions,

leading to craft as different as gliders and jet airliners in the aircraft world. In addition, if long distance transportation is to become reality, WIG will need a new form of “traffic lane” agreed at international level and documented on charts. Significant opportunities await us!

A comprehensive listing of references is included at the end of the book, classified by chapter. These should be useful to the reader to provide more detailed information and support for the analysis and design.

The authors aim with this book to provide a useful reference for engineers, technicians, teachers and university students (both undergraduate and postgraduate), involved in the marine engineering world who are interested in WIG research, design, construction and operation.

Since the WIG is a novel technology and still in its initial development, the presentation of some of the theory should be considered as statement of current state of (limited) art, so readers should take care to check for themselves the validity of the theories presented here. The authors will be pleased to have comments and feedback from readers.

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