

Performance,
Technology and
Application of
High Performance
Marine Vessels
Volume One

Performance, Technology and Application of High Performance Marine Vessels Volume One

Edited by

Liang Yun, Raju Datla and Xinfu Yang

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The search for greater speed—humanity has a tendency always to want to go faster—has been enabled through increasingly efficient and lightweight power plants such as high speed diesel and gas-turbine engines, and lighter and stronger structural materials (aluminum alloy, GRP, titanium alloy), which have enabled the designers of fast boats, hydrofoils (HYC), and air

cushion craft (ACC) and wing in ground effect craft (WIG) to develop performance close to the physical limits of speed on a seaway.

Over the last 30 years or so, a revolution in electronics has given us the possibility for automated stabilization of motion that was simply not possible before, together with big strides in power plant efficiency, not to mention satellite navigation. These have been important enablers of comfort at higher speeds and high-speed vessel development.

Over the last century, and particularly heavily over the last 50 years, designers, scientists, and various organizations, including commercial, military, and governmental, have dedicated resources to find ways in which combinations of hull geometries, hydrofoils, and static or dynamic air cushions can be used to deliver high-speed vessels that can perform very challenging missions. This work continues, still strongly driven by military objectives, and increasingly now by energy efficiency and environmental impact rather than simply the mission envelope defined by speed, payload, environment, and range.

A series of new variations of high-speed craft, or high-performance marine vessels (HPMV) have been developed in the last half century around the world, including improved high-speed monohull (HSMH) and planing monohull craft (PMC) from the 1940s, hydrofoils (HYC) from the 1950s, air cushion vehicles (ACV) and surface effect ships (SES) from the 1960s, small water plane area twin-hull craft (SWATH) from the 1970s, high-speed catamarans (HSCAT) from the 1980s, wave-piercing craft (WPC) from the 1990s, high-speed trimarans (HSTRI) in the first decade of the twenty-first century, and wing in ground effect craft (WIG) from the 1970s to the present. These various concepts and hybrids form an interacting group of vehicle concepts.

In this book we refer to this family of craft as *high-performance marine vessels* (HPMV), as the vessels not only are built for high speed but also may have other attributes, such as amphibious capability (air cushion vehicles) or extreme seaworthiness (SWATH). Specialists from some countries refer to such craft simply as high-speed craft (HSC); however, as use of the term *high-performance marine vessels* (HPMV) is now more common, we will use that description and acronym in this book.

Due to the increasing development of HPMV around the world, the International High-Performance Marine Vessels (HPMV) Conference—organized by The Royal Institute of Naval Architects, UK (RINA), Shanghai Association of Shipbuilding Industry (SASI) of China, Ship Design Academy Committee of CSNAME, and China Boat Industry and Trade Association (CBITA)—has since 1997 been held annually eighteen times in Shanghai, China. In that time we have collected about 500 papers

contributed by hundreds of authors from various countries and regions around the world.

We know that many people have a strong interest in this technology; however, while many HPMV are in operation in different parts of the world, until now there has not been a publication giving an overview and discussing the performance, design, hydrodynamics, technology, and applications of various HPMV, as well as the differences and special features of them, and the approach to selection taken in various cases for both civil and military applications. Therefore, we have utilized the hundreds of papers presented by worldwide specialists at these conferences held over the past dozen years to create the present book—*Performance, Technology, and Applications of High-Performance Marine Vessels*—for readers around the world. Since the contents are so comprehensive and large, the book has been divided into two volumes, concerning the whole HPMV family. The book is ordered as follows:

Volume One

Chapter 1: High-Speed Monohull Craft (HSMH)

Chapter 1 covers the performance, technology, and application of conventional high-speed displaced monohull craft; deep-V monohull craft; planing hulls with and without steps, “M” craft, and other transit operation mode monohulls; axe bow shape monohulls; and other appendages and installations for improving the performance of high-speed monohulls, as well as their development evolution and prospect, and so on.

Chapter 2: Multihull Craft

Chapter 2 covers the evolution of trimaran craft around the world, the theoretical and experimental investigation of wave-making, wave-making interference between trihulls, and its drag as well as sea-keeping quality, and maneuverability of trimarans and pentamarans; the practical design of both trimaran ferries and main hull form and side hull form arrangement and investigation; and evolution and performance, technology of slice craft, and so on.

Chapter 3: Hydrofoil Craft (HYC)

Chapter 3 covers the development, research, and design of various types of hydrofoil craft, such as surface piercing HYC, automatic-control deep-submersible HYC, single and twin foils as well as triple-foil HYC, and foil-assisted catamarans; the theoretical and experimental investigation

and design of hydrofoils, practical applications of hydrofoil craft, and so on.

Chapter 4: Air Cavity Craft (ACC)

Chapter 4 covers the basic principles of low-speed air-lubrication craft and high-speed air cavity craft and their classifications; the evolution of and prospects for ACC; the research, design, production, and application of ACC in Russia, Ukraine, and Norway; experimental investigation of drag-reduction technology on both high-speed and non-high-speed craft through the use of air lubrication technology and sea-keeping of ACC, and so on.

Chapter 5: Wing in Ground Effect Craft (WIG)

Chapter 5 covers the development, research, design, and production of classic WIGs, power-augmented-ram wing in ground effect (PARWIG), dynamic air cushion wing in ground effect craft (DACWIG), and amphibious WIG (AWIG) in countries including Russia, Germany, China, and Japan; theoretical and experimental investigation of WIG craft on longitudinal stability, automatic control conception, and take-off ability improvement of the crafts, and so on.

Volume Two

Chapter 6: Air Cushion Vehicles (ACV), Surface Effect Crafts (SES), and Amphibious Seaplanes (ASP)

Chapter 6 covers the evolution and development of ACV, SES, and ASP; the research and design of the ACV and its skirt system as well as automatic control system for improving motion of ACV; concept design of large-type SES; theoretical and experimental investigation of speed performance, stability, impact of loads on amphibious seaplanes during take-off, and so on.

Chapter 7: Small Waterplane Area Twin-Hull Craft (SWATH), and Semi Small Waterplane Area Twin-Hull Craft (SEMI-SWATH)

Chapter 7 covers the development, research, performance, technology, and application of SWATH in China and around the world; experimental investigation of SWATH and power-performance compared with slice craft; the research and experimental investigation of the sea-keeping quality of SWATH; research and design of Semi-SWATH “X” craft for Littoral warfare requirement, and experimental investigation of Semi-SWATH crafts for the Taiwan Strait, and so on.

Chapter 8: Wave-Piercing Craft (WPC) and conventional catamarans

Chapter 8 covers the evolution and development of conventional catamarans and WPC; theoretical and experimental investigation of the powering performance and sea-keeping quality of conventional catamaran, and WPC; investigation, design, and optimization of hull lines of WPC; design of large-type WPC ferry crafts for civil applications in Taiwan Strait, and so on.

Chapter 9: Other Hybrid High-Performance Marine Vessels

Chapter 9 covers development, research, design, performance, technology, and application of various hybrid HPMV, such as planing catamarans (PCAT), supercritical planing twin-hull craft (SPTH), hydrofoil submersible SWATH (HYSWAS), high-speed trimarans with anti-wave-making hydrofoil craft, and so on.

Chapter 10: Material and Hull Structure on High-Performance Marine Vessels

Chapter 10 covers the research and design of special characteristic steel and GRP materials that apply to HPMVs; the research and design of aluminum hull structures of ACVs using extruded panel structures; theoretical and experimental investigations on wave-induced loads, dynamic response, and hull-structure analysis of SWATH, HSMH, and also HSCAT. It also considers mechanical impedance analysis methods applied to hull design of HPMVs, and hydro-elastic analysis of SWATH hull structure in waves.

Chapter 11: Propulsion and Power Plant on High-Performance Marine Vessels

Chapter 11 covers CFD and the dynamic simulation of water inlets and water pipelines of water jet propulsion systems; water jet propulsion technology and its application to HPMVs; study of two-phase-flow water-jet propulsion; the latest development of surface-piercing propellers at the China Ship Scientific Research Center (CSSRC), the introduction of air fan propulsion on ACVs; simulation study of intelligent control water jet propulsion system of WPC, and on the lift and propulsion power installation of the control system of an ACV.

Chapter 12: General survey

Chapter 12 covers the general description of HPMVs; classification, development, performance, technology, and application of HPMVs; test methods of HPMVs; some HPMVs and technical themes that are not

covered in other chapters, such as some additional appendages for improving performance of HPMV, and so on.

The possible readers of this book

The book is written particularly for the following readers:

- Students and teachers in naval architecture and marine engineering, aviation engineering, mechanical engineering, and other concerned faculties of universities and institutes
- Staff members, technicians, engineers, researchers of marine transportation units, shipping companies, shipyards, and ship and aviation research institutes, as well as other concerned units for both civil and naval organizations
- Everyone who is interested in HPMVs in both military and civil applications

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94	Rixiu	Guo	National Laboratory of Hydrodynamics	China	4.8
95	Xiwu	Liu	National Laboratory of Hydrodynamics	China	4.8
96	Yangchun	Yu	China Ship Scientific Research Center	China	4.9
97	Lijian	Wang	China Ship Scientific Research Center	China	4.10
98	Shengzhong	Li	China Ship Scientific Research Center	China	4.10
99	Yajun	Shi	China Ship Scientific Research Center	China	5.2, 5.7
100	Wei	Zhang	China Ship Scientific Research Center	China	5.2
101	Xitunai	Ye	China Ship Scientific Research Center	China	5.2
102	Enguang	Wang	Aviation Industry Corporation of China Special Vehicle Research Institute	China	5.3
103	Lintang	Chu	Aviation Industry Corporation of China Special Vehicle Research Institute	China	5.3
104	Mingde	Song	Aviation Industry Corporation of China Special Vehicle Research Institute	China	5.3
105	V. V.	Kolganov	Joint Stock Company "Research & Production Complex "TREK"	Russia	5.4
106	V. G.	Sergeev	Joint Stock Company "Research & Production Complex "TREK"	Russia	5.4

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107	Hiromichi	Akimoto	Department of Applied Mathematics & Physics, Faculty of Engineering, Tottori University	Japan	5.6
108	Syozo	Kubo	Department of Applied Mathematics & Physics, Faculty of Engineering, Tottori University	Japan	5.6
109	Takahiro	Taketsume	Department of Applied Mathematics & Physics, Faculty of Engineering, Tottori University	Japan	5.6
110	Xinfa	Xu	China Ship Scientific Research Center	China	5.7, 5.8
111	Changhua	Yuan	China Ship Scientific Research Center	China	5.7, 5.8
112	Qian	Zhou	China Ship Scientific Research Center	China	5.8

PREFACE



TREVOR BLAKELEY FRINA FIMAREST, FIMECHE CENG

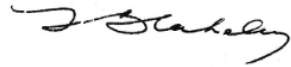
Chief Executive, Royal Institution of Naval Architects

Over the past twenty years, the high-speed sector of the maritime industry has seen much development in the design, construction, and operation of commercial, military, and recreational marine vessels, as it has responded to the challenge of operators, regulators, and society for greater efficiency and safety and, increasingly, the protection of the environment. Such development has sought to reduce production costs, extend operating envelopes, reduce downtime, and increase comfort, reliability, and safety. In more recent years, the sector has also faced the challenge of society to reduce the environmental impact of operating high-performance marine vessels through reducing emissions.

The high-speed sector has responded successfully to these challenges, and a key to that success has been the innovation that the sector has readily sought and adopted. Essential to that innovation has been research and development. The High-Performance Marine Vessels (HPMV) Conferences have provided a valuable opportunity for individuals from all parts of the sector to exchange and discuss the technical and scientific information that has resulted from that research and development.

As well as providing a record of the technical and scientific information presented at the HPMV Conferences, the book also serves to chart the development of the high-speed sector over 20 years, recording its success in meeting the challenges it has faced. The book is also a

testament to the contribution that the HPMV Conferences have made to the successful development of the sector. The Royal Institution of Naval Architects is proud to have been associated with the HPMV Conferences as a co-organizer.

A handwritten signature in black ink, appearing to read "J. Stalsky". The signature is written in a cursive style with a long, sweeping underline.

December 2, 2016

PREFACE



GUO DA-CHENG

President of China Association of the National Shipbuilding Industry

Since 1996 the Royal Institution of Naval Architects (RINA), UK, the China Boat Industry and Trade Association, and the Ship Design Academic Committee and Mechanics Academic Committee of the China Society of Naval Architecture and Marine Engineering (CSNAME) have jointly held the China International Annual High-Performance Marine Vessels Conference (HPMV) in Shanghai, China. The exploration and persistence exhibited over the past twenty years have developed the conference into a famous academic event in China's high-performance shipbuilding industry. The HPMV Conference has published 19 proceedings with more than 553 papers from 30 countries and regions across the world. It reflects the continual endeavors and hard work of specialists and organizers in China and around the world who are dedicated to the high-performance shipbuilding industry. The HPMV proceedings have been recognized not only by the Royal Institute of Naval Architects (RINA) but also by domestic universities, research institutes, and the manufacturing industry. The collected papers have been enthusiastically spread and exchanged.

Therefore, Cambridge Scholars Publishing has decided to sponsor the publication of the HPMV Collected Papers. The first volume contains

papers that have been selected from among those on many types of high-performance vessels, on new materials, new technologies, new design ideas, new equipment, new structural styles of the HPMV, and so on. This first volume of the Collected Papers will be distributed globally. It not only encourages Chinese professionals engaged in high-performance ship research circles, but also promotes high-performance ship research worldwide. Furthermore, Cambridge Scholars Publishing promotes worldwide academic exchange with charity. We do hope that the publication of the anthology will motivate more extensive academic exchanges and interaction between people around the world. HPMV is a great worldwide event in the field of high-performance ship research and industry that is highly deserving of recognition and celebration and is of far-reaching significance.

As one of the largest and oldest domestic and international academic conferences, the HPMV Conference has set up an effective international academic exchange platform and has provided an opportunity for circulating the most cutting-edge technologic research and development information. It will promote the healthy and sustainable development of China's high-performance shipbuilding industry effectively. My hope is that that HPMV conference will continue to be organized better and better and will attract even more professionals from home and abroad engaged in the field. At the same time, excellent results can be applied to social practice. The HPMV Conference will become a compass for leading high-performance ship research and design in China.

With sincere thanks to Cambridge Scholars Publishing for their understanding, support, and philanthropic action.

A handwritten signature in black ink, consisting of four Chinese characters: 高洪成 (Gao Hongcheng).

December 28, 2016

PREFACE



HUANG PING-TAO

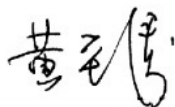
Chairman of China Society of Naval Architecture and Marine Engineering
(CSNAME)

With the growth of the Chinese economy and the expansion of the shipbuilding industry, high-performance marine vessels are gradually growing and developing. Last century, in the mid-1990s, hydrofoil crafts appeared on the Pearl River Delta, then hydrofoils and hovercrafts; second-hand hydrofoils purchased from Russia operated in the Chongqing area. After the highways were completed along the Yangtze River, these high-speed ships soon disappeared. Nevertheless, the curtain had been raised on research and construction of high-performance ships in China. Next came high-performance ships, including SWATH, catamarans, wave-piercing catamarans, high-speed crafts with jet propulsion, semi-submersible propeller ships, and deep-V boats, as well as wing in ground effect craft and other high-performance ships with maximum speeds up to 70 kn. These craft were used not only as commercial passenger ships, yachts, and workboats, but also for military applications. Since 1996 the Royal Institute of Naval Architects (RINA), the China Boat Industry and Trade Association, the Shanghai Association of Shipbuilding Industry, the Ship Design Committee of China Society of Naval Architecture and Marine Engineering (CSNAME), and the Mechanics Committee of CSNAME have co-hosted the International Annual Conference on High-

Performance Marine Vessels (HPMV). The HPMV Conference has been held successfully for twenty-one years. The work of the organizing committee is very insightful and fruitful. The HPMV Conference has effectively strengthened exchanges and communications between domestic and overseas technology circles on the research, design, application, and development of high-performance ships.

Here, we would like to thank Prof. Yun Liang. Many years ago, in the late 1950s, when I was a student, Professor Yun researched and developed the hovercraft. He was engaged in the research, design, development, and application of high-performance ships for 60 years. As the organizer of the HPMV Conference he has done a great deal of work, and has obtained the support of Cambridge Scholars Publishing to issue the Collected Papers of the HPMV Conference. This is a highly influential and meaningful event for domestic scientists, engineers, and technicians in the field of high-performance marine vessels. The Collected Papers presents the latest achievements in the research, design, and application of high-performance ships at home and abroad, which is helpful for the innovation of ideas, technology, and application in this field. At same time we also thank the authors; the papers are the crystallization of their many years of labor, their experiences of success and failure, and their extremely hard work.

The publication of the collection is also a powerful push and inspiration for the HPMV Conferences; it will appear as a new starting point, and inspire greater and newer results.

A handwritten signature in Chinese characters, likely '黄云' (Huang Yun), written in a cursive style.

December 28, 2016

PREFACE



ZHANG GUANGQIN 张广钦

Former Vice Minister of the Commission of Science, Technology, and Industry for National Defense of the People's Republic of China

Former Deputy General Manager of China Shipbuilding Industry Corporation

Former President of China Association of National Shipbuilding Industry

The International Annual Conference on High-Performance Marine Vessels, held in Shanghai, China, has collected around 553 papers over the past 21 years. During that time the proceedings of the conference have presented the research, development, and design results of both Chinese and overseas experts on the technology of high-performance marine vessels. The papers gathered from the conference are not only the witnesses of history but also the crystallization of the authors' sweat and wisdom.

Research on high-performance marine vessels is an endless business. I hope that the publication of these Collected Papers will push and spur on the spirit of innovation and creativity in the Chinese shipbuilding industry. At the same time, we firmly believe that the papers will assist the industry's most outstanding talents to study hard, boldly innovate, and