Abstracts: 1st Chesapeake Sailing Yacht Symposium

On The Handicapping of Distance Racing Yachts A Proposal for IOR IV

Bennett Fisher, NAYRU Offshore Racing Rating Rule Committee

This is a proposal for a complete system for handicapping Distance Racing Yachts using the present NAYRU time allowance tables. It includes measurement, rating and the procedure for correcting ratings before and after races. The objectives and means of judging rating rules are outlined. Faults in the present rule are listed and suggestions for improvements are made. The five major parameters; length, sail area, displacement, underbody configuration and weight distribution are explained. The present and proposed rules are compared and the probable effect on existing yachts is discussed.

Handicapping Rules and Performance of Sailing Yachts

John S. Letcher, Jr., Formerly with Henry R. Hinckley & Co., Southwest Harbor, Maine

The structure of some past and present rules is discussed and the general problem of optimum performance under the rule is considered. This requires a rational performance model, which would itself form the most equitable rating rule possible under the existing level of technical understanding of mechanics of sailing.

The theory of sailboat performance estimates is outlined and surveyed. New theories are presented on the performances of geometrically similar vessels and on the implications of optimum sail trim. Two rational ways are proposed for averaging performance over a probability distribution of operating conditions appropriate to different types of races. The theory suggests a new form for a rule, in which multiple ratings are assigned characterizing average potential speeds in various ranges of operating conditions.

Analysis of Chesapeake Bay Racing Results 1972 and 1973 Seasons

Robert W. Peach, NKF Engineering Associates, Inc., Silver Spring, Maryland

An analysis of racing on the Chesapeake Bay was performed covering the three handicapping rules used for the 1972 and 1973 seasons. The actual average speeds of each yacht were determined and then normalized to obtain season average performances. This average performance with the yacht's rating was used to determine the least squares best fit for a power curve to show how each rule actually worked when corrected for the time allowance used by each class.

Yacht Rating

Daniel D. Strohmeier, Scarsdale, New York

"Yacht measurement and its necessary companion, time allowances, form the spice of the sport of yachting and cannot be overlooked," – N. G. Herreshoff. By sport of yachting he

meant, of course, racing. Yacht measurement, or rating, has had a continuous influence on yacht design since handicap yacht racing began a century and a half ago. Beginning with custom house measurement, yacht ratings have evolved to linear ratings, thus lending themselves to a semi-rational system of time allowances based on speed-length ratio. The complex laws of yacht behavior preclude the probability of a perfect handicapping system under which skill alone will determine the winner among dissimilar yachts.

Measurement Parameters of the I. O. R. Rule

Olin J. Stephens II, Sparkman & Stephens, Incorporated, New York, New York

The substance of this paper is the description of the measurement parameters of the I. O. R. Rule in the course of which the effort is made to cover their derivation and to indicate the reasons for taking the measurements called for under the Rule. In the course of this review, suggestions are made in regard to the background of the rule, primarily in relation to the earlier C. C. A. Rule. The conclusion touches briefly on future possibilities.

Booms are Obsolete

Frank R. MacLear, MacLear & Harris Inc., New York, New York

Booms are dangerous and can now be done away with. The mainsail is trimmed by three sheets to three permanent backstays, (see Fig. 1). A mainsail that is luff roller furling on a rotating jackstay that is aft and parallel to the mast can be furled of reefed in seconds, (see Fig. 2). The best rig for this system is a cutter rig with three roller furling stays. The other two roller stays are in tandem far forward and go to the top of a very tall mast that is stepped well aft. The outer headstay has huge roller furling jibs for downwind work. The inner headstay has heavier medium sized sails for upwind work and storm conditions. This rig can be handled by far fewer people and can easily set far more sail than cruising boats ever could before.

A Breakthrough—Slotted Headsail Luff Support Systems

Alan MacKenzie, Murphy & Nye Sailmakers, Annapolis, Maryland

For many years, jibs and Genoas have been attached to headstays with end-pull hanks. In the last few years on small boats, we have begun to use tape straps with snaps and other similar devices. All of these share several problems:

1. They are aerodynamically unclean—they all present the headstay and the luff of the sail to the wind separately—with a gap in between. Beyond the turbulence caused in this way, the hanks and snaps themselves add to the disturbance of air flow.
2. They are potentially unsafe—the hanks can catch and tear other sails being hoisted (particularly spinnakers)—the distribution of hanks along the luff of the sail tends to load the sail and the stay very unevenly (There are, for example, cases of rod headstays shearing under the strain of the bottom or top hank).

3. They make sail changing quite difficult—it is necessary to drop and unhank the old sail before hoisting the new one.
4. They are expensive for sailmakers to install.

The solution to these problems is the Slotted Headsail Luff Support System. The development of these systems has proceeded at an extremely rapid rate. Starting with the Sea Stay and proceeding through the Stream Stay, Head Foil, Sail Leda, and Micro Foil, etc. Some of the new systems replace the headstay entirely while others fit on over (around, etc.) the existing headstay. This report establishes a framework for evaluating these systems and reports on certain physical features of the more prominent ones.

In effect, all of the Slotted Headsail Luff Support Systems (SHLSS) permit replacing the old-style end-pull hanks with a bolt rope which slides up inside either a plastic or metal groove which is held to the headstay in a variety of ways. The groove is permanently in place and the sails are run up and down much in the same way that mainsails have for many years been run up and down in a grove on the aft side of the mast. This in itself is a major advancement; however, it did not generate a great deal of excitement until roughly a year ago when several people realized that it would be possible to hoist a second sail in the groove or in a parallel groove without first dropping the original sail. Extended to its logical conclusion, this ability to hoist a second sail eliminates almost all of the problems of changing headsails which were encountered in the "hanks era". Successful users of the most advanced grooved systems would never have to use an interim sail or be bald-headed for a period of time between sails. Beyond this, there would be a greater flexibility in choosing exactly the right Genoa since the pain associated with making an error in choice or in changing from one sail to another would be relatively small.

To date, the major entries in this second generation of SHLSS are Stern Sailing Systems with the Twin Stay, Hood Yacht Systems with the Sea Foil, Hyde Products with the double-grooved Stream Stay, and Otto Engineering with the Luff Slot. At this point in the developmental process, no really conclusive performance comparison tests have been run, and there is really insufficient history of use of any of these devices to permit real evaluation of durability and other factors that are only revealed over a period of time.

It is tempting to throw up one's hands and give up on analyzing the various systems until the situation stabilizes and further information can be gathered; however, there are several important things which can be done even today. First of all, the general framework for analysis and evaluation can be established, and secondly, physical features, price, and other similar information relating to each of the systems can be compared.

The accompanying chart is in effect, a comparison of the physical features of the more prominent U.S. systems. Below we have gone through a general presentation of a framework for future evaluation of the various systems.

Some Observed Effects of Foil Control on Hydrofoil Sailing Vehicle Performance

W.S. Bradfield, State University of New York, Stony Brook, New York

Fixed lifting foil sailing vehicles are at about the same stage of development as were catamarans about 15 years ago. So far it has been established (experimentally) that fixed foil vehicles do "fly"; that there exists an optimum take off speed corresponding to each given hull configuration; that for a given catamaran configuration with and without foils the sailing performance is somewhat improved by foils in true wind speeds in excess of 15 knots; and that the observed improvement is not equal to that predicted.

The present paper concludes on the basis of timed runs that the discrepancy between predicted ideal and observed performance is due to lack of control of vehicle stability and balance in the hard and gusty winds required for top speed. Herein, are developed some simple ideas for improving sailing hydrofoil performance with minmal helmsman control of foil incidence and dihedral. The design and development of two hydrofoil sailboats incorporating these ideas is described and the results of comparative predicted and measured performance of one of them is presented.

Scale Experiments with the 5.5 Metre Yacht ANTIOPE

Karl L. Kirkman, Hydronautics, Incorporated, Laurel, Maryland

A program of experiments with a series of four geometrically similar yacht hull models was conducted in the HYDRONAUTICS' Ship Model Basin with the aim of improving engineering methods for model/full-scale correlation.

The paper presents a brief review of the background of existing hydrodynamic performance prediction methods, outlines a number of scaling problems, and presents results from the family of models tested.

The Performance of Sailing Yachts in Oblique Seas

David R. Pedrick, Sparkman & Stephens, Incorporated, New York, New York

Differences in the effects that rough water has on similar sailing yachts has been one of the intriguing puzzles that sailors, designers, and researchers have long tried to understand. It is not uncommon that two yachts whose performance is equal in smooth sea conditions will have their speed or pointing ability reduced by different amounts when encountering waves. To investigate the causes of such behavior, it is important to have a rational procedure to analyze how changes in hullform, weight distribution, rig, and other design features affect the speed and motions of sailing yachts.

This paper discusses the relationship of wind to rough water and of motions and added resistance to wave length and height. It then describes a procedure to predict motions, sailing speed, and speed-made-good to windward in realistic windward sailing conditions. The procedure utilizes results of heeled and yawed model tests of twelve

meter yachts in oblique regular waves to predict performance in a Pierson-Moskowitz sea state corresponding closely to the equilibrium true wind speed.

Directional Stability and Control of Sailing Yachts

Walter H. Scott, Irwin Yacht and Marine Corp., St. Petersburg, Florida

Modern ocean racing yachts often encounter considerable difficulty in steering and directional stability. In order to understand and correct these difficulties, it is necessary to identify these separate force and moment components of the hull, keel, rudder/skeg combination and the sail plan. This paper concentrates on the underwater forces and moments, using a combination of tank test data and aircraft analysis techniques. Sample calculation results are presented for a typical One Ton yacht. The influence of the sail plan is discussed. The direction for possible improvements are shown and recommendations are made as to the type of generalized hull and sail data which are required to improve this basically simple static analysis.

Abstracts: 2nd Chesapeake Sailing Yacht Symposium

Theory of Sailing Applied to Ocean Racing Yachts

Hugo A. Myers, IBM Federal Systems Division, Gaithersburg, Maryland

A systems analysis approach is used to study the performances of ocean racing yachts, and to support a rating system which considers wind conditions and course angles. Basic aerodynamic and fluid-dynamic theory is applied to derive an engineering mathematical simulation of a boat's performance. The result is a set of five equations in five unknowns. Given the true wind velocity and course sailed, the equations are solved for boat speed, apparent wind speed, apparent wide angle, leeway angle, and heeling angle.

The theory is compared with full scale towing tests and sailing measurements for several yachts, ranging from a 23-foot cruiser to a 68-foot (12-meter) racer. The theoretical results fall within the measurement conditions. Yacht performance curves are then compared for the detailed effects of windward capabilities and rig variations for various true wind speeds. A "rating matrix" approach is discussed, which could be used to rate fairly a wider range of yacht sizes, types, wind conditions, and course angles than present rating systems can accommodate.

Organizing to Win

Richard T. duMoulin

An America's Cup campaign is a total effort that involves challenges of design, construction, sailmaking, steering, tactics, crewwork, tuning, fund raising, and management. Failure in any one of these areas can and usually does handicap an effort, resulting in a certain visit by the Selection Committee to thank the crew for their (unsuccessful) participation. The "Summer of '74" was no exception to this rule. Obstacles arose in every one of these areas at some point for each yacht; in certain cases they were either fatal or at least crippling:

- In design…the failure of MARINER's radical stern configuration resulted in a rebuilding that for all intents and purposes ended her summer…
- In construction…both MARINER and COURAGEOUS were completed behind schedule, resulting in tremendous time pressures relative to INTREPID…
- In steering and tactics…several skipper and afterguard changes were caused in part by a new level of match racing aggressiveness (that also resulted in many protests)…
- In crewwork…everyone watched COURAGEOUS pull her crew together in the nick of time to defeat a well-prepared INTREPID…
- In tuning…experts shuddered to see MARINER depart for her last race with the mast moved as a last ditch effort to attain a racing time…
- In fund raising…the newspapers covered COURAGEOUS's near death in the height of the fuel crisis when construction was barely beginning…

- And finally, in management…this past summer demanded an unprecedented number of difficult decisions that had to be made under tremendous pressure, decisions involving all the above issues.

In the remainder of this discussion, I will approach the issues just touched upon by presenting a combination of descriptive comparisons of the three American twelve meter efforts and my interpretations of that material. Organizing to win, selection of personnel, methods of evaluation, the use of time and money, and the impact of major changes will be explored.

Lastly, let me emphasize that the opinions and conclusions drawn within this article are my own, possibly shared by no one else. My experience aboard MARINER (and VALIANT) and later INTREPID gave me a rare opportunity to examine two efforts involving three twelve meters from the inside. Although it is often difficult, I will try to be objective and not abuse 20/20 hindsight.

Design and Construction—The First Race

David R. Pedrick, Sparkman & Stephens, Incorporated, New York, New York

The design and construction of a Twelve Meter Yacht is achieved through a remarkable combination of talents and efforts. To convert concepts of performance into an actual America's Cup contender is a complex process whose coordination and timing are crucial to its success. This section of the America's Cup Overview will provide some explanation of the general development and construction stages, including the people involved and the timing of the work. A great deal of credit is due the many participants who put forth tremendously dedicated effort, be it model testing, design work, hull and rig fabrication, sailmaking, or other facets of this project. Every person involved is glad to see his part over, but proud of his share in creating one of man's most magnificent objects of science and art.

A Cruising Boat

RADM. Charles A. Curtze, Formerly with the U.S. Navy Bureau of Ships

Any aspiring cruising boat owner with a reasonable library can vicariously circumnavigate the world compiling his own compendium of cruising sail boat attributes without leaving the security of his favorite den chair.

Some will never buy. These comprise the most avid and obdurate group. A few will enter the market with quite firm convictions of type, rig, acceptable accommodations and services. A still smaller number, not satisfied to judge by number of bunks, "bulkhead to bulkhead" amenities and monogrammed tea service will buy, sell and alter until they find their own right mix. Very few support their convictions with their money in a "one-off" boat.

Included among the already well known exceptions are the "Yankees", the "Wanderers" and "Angantyr". A recent exception is "THULE" so named because the years of gestations made her seem chimeric to the author's friends. Some of the thinking underlying her design follows.

Vane Self-Steerers for Cruising Yachts

Gererd Ratcliffe, Ratcliffe Marine Design, Pembroke, Massachusetts

This paper presents some of the things the designer or purchaser of a cruising yacht should keep in mind when vane actuated self-steering is to be installed. First, the characteristics of various types of rudders, pendulum-fins, trim-tabs, and wind vanes are compared. These components are then linked to form different types of self-steerers. These are the simple vane steerers, trim-tab steerers, and pendulum-fin steerers. The auxiliary rudder is a special type of trim-tab steerer.

The linkage between the wind-vane and the trim-tab or fin is designed to make the most efficient use of the main active components, and to stabilize the control. Basic feedback theory is applied to yacht steering to show the relationship between all of the factors that determine the heading. Some of the basic requirements for self-steereing: sensitivity, adequate power, and system "stiffness" are briefly analyzed, and the degree to which these requirements can be met by the different self-steering systems is compared.

Several examples are used to show how technical and dimensional factors, such as hull shape, rudder location, and clearance for the wind vane, determine the type of self-steering gear most suitable for a particular boat. In addition, the intended use, whether for a single handed crossing, or occasional week-end trips, may be an important factor, especially if the installation is complex and expensive.

Extended Cruising-An Overview

Kenneth E. Court, Westinghouse Electric Corp., Annapolis, Maryland

The author discusses some ideas about cruising yachts and cruising yachtsmen and the preparations and paraphernalia necessary for extended cruising. His purpose is to illustrate how simple it can be to embark on a successful voyage provided one has a good boat, the right temperament, a fair degree of seamanship, and a minimum of sophisticated gear. These observations are based on personal experience including a four-year cruise from Hawaii to the Chesapeake via the Red Sea.

Seakeeping and the Sailing Yachtsman

Roger Compton*, Bruce Johnson*, and Carl Van Duyne**, *U.S. Naval Academy, Annapolis, Maryland, , **Graduate Student, Stanford University, Palo Alto, California

Waves cause undesirable forces and motions on yachts which vary in severity from mildly uncomfortable to catastrophic. The problems created by waves are receiving serious and increasingly analytical attention from the naval architects who design oceangoing ships. Many of the physical phenomena and engineering principles used to describe and analyze ship seakeeping performance are applicable to the sailing yacht.

Discussion and explanation of such phenomena and principles are the subjects of this paper.

Yacht Keels—An Experimental Study

Pierre DeSaix, Stevens Institute of Technology, Hoboken, New Jersey

Model tests are presented for a series of nine keels; three aspect ratios, three sweep angles; all at constant lateral area, taper ratio and thickness ratio. The series is shown to bracket current design trends.

These keels are all tested on the same canoe body, over a range of heel angles, leeways, and speeds. The results are presented in terms of full-scale sailing performance with due allowance for a reasonable ballast ratio and resulting vertical center of gravity for each keel. Optimum sweep angles for each aspect ratio are found.

A second series of three keels, geometrically similar but varying in lateral area, is provided. Predictions of windward performance demonstrate the effect of keel size. An optimum size is found for three wind strengths.

The results are for one hull form only. However, a method is suggested for estimating the effect of keel size and shape for any proposed design.

Kevlar 49 Aramid, A New Material for Boat Hull Construction

Louis H. Miner, Robert A. Wolffe, and James V. Woodrick, E.I. du Pont de Nemours & Co., Inc., Wilmington, Delaware

The utility of Kevlar 49 aramid fibers as a lighter, stronger, and stiffer substitute for glass fibers in reinforced plastic products has been demonstrated in the aircraft and aerospace industry since 1972 (Ref. 1, 2, 3). As productivity increased, “Kevlar” 49 began to gain acceptance in numerous commercial applications, and its potential as a boat hull reinforcement was recognized. This paper will outline the characteristics of “Kevlar” 49 and describe how it can be used in solid laminates and sandwich contructions.

Flotation for Ballasted Sailing Yachts?

Vance O. Wilson and Wolfgang Reuter, Department of the Navy, Naval Ship Engineering Center, Hyattsville, Maryland

The thought of accidentally sinking after being damaged makes every skipper shudder at his probably helplessness in staying afloat. Sooner or later, Yachtsmen will demand positive flotation for all boats through 65 feet in length. What should the Naval Architect be doing and what can the builders expect in new materials and arrangements for flotation?

This paper will review the state-of-the-art and encourage further research and planning by attempting to show a need, feasibility considerations, and fringe benefits.

Flotation after damage for ballasted yachts has, for years, been only a dream because of lack of flotation space in sailboat hulls that are already volume critical, as compared with similar length power boats. It is hoped that new low density materials, as available, and arrangement considerations in the original design will make this safety feature a reality.

Abstracts: 3rd Chesapeake Sailing Yacht Symposium

Aluminum Construction

Gilbert Wyland, Sparkman & Stephens, Inc., New York, New York

By no means is the complete history of aluminum vessels and yacht development, material, specifications, design, construction and durability, as well as other facets, covered in full. It is proposed to discuss some of the more important development aspects, scantling requirements, construction problems, corrosion control and material problems which we have experienced in design of aluminum yachts and commercial vessels up to something over a hundred feet in length and speeds of over 50 knots, both power and sail.

Sailing Yacht Construction in Fiberglass

William J. Goman, C&C Yachts Manufacturing Ltd., Oakville Ontario, Canada

A method for developing fiberglass laminates for various displacement sailing yachts which accounts for differences in mechanical properties obtained and thickness of core material is outlined.

The various glass fiber products, their properties and handling characteristics are discussed along with a simple technique for determining laminate properties in the shop from laminate density.

Surfing: Motions of a Vessel Running in Large Waves

John S. Letcher, Jr., Letcher Offshore Design, Southwest Harbor, Maine

Starting from the assumption that certain time and length scales for the vessel and its wave pattern are short compared with the time and length scales of the wave motion, the theory models the vessel as a point mass constrained to move on a surface governed by the hydrodynamic equations of wave motion. Normal and tangential equations of motion are derived, and their solutions investigated, for the general case of an arbitrary two-dimensional wave motion, then specialized to periodic progressive waves. The relevant resistance characteristics of the vessel are identified, and a new type of towing-test series using a single model ballasted to several different displacements is proposed to predict surfing performance. Numerical solutions are presented for the case of sinusoidal progressive waves, using an assumed resistance function and coefficients representing a "Cal-40" class sailing yacht.

The Preservation of Chesapeake Bay Watercraft

William A. Baker, Hart Nautical Museum, Massachusetts Institute of Technology, Cambridge, Massachusetts

The logo for this Third Chesapeake Sailing Yacht Symposium, the profile of a rakish sailing log canoe superimposed on that of a modern racing sloop, vividly illustrates the difference between the past and the present. Some might say good riddance to the past but there are many good reasons for trying to preserve something of our maritime heritage, not only the larger vessels such as the whaler Charles W. Morgan and the smaller working watercraft as well. Although the Constellation was built in the Bay region, she was designed as a normal ocean-going ship for naval service; she has none of the unique features of Bay naval architecture hence is outside the scope of this paper.

In the days of our grandfathers the Chesapeake Bay region was the home of a multitude of watercraft employed for a wide variety of pursuits from general freighting to crabbing. There were rams, pungies, schooners, sloops, bugeyes, brogans, canoes, bateaux, skiffs, and scows. Of the skiffs alone, it is said that fourteen different designs were recognized on the Bay. While large numbers of these working boats and vessels have disappeared, it is only on Chesapeake Bay, of all the waters of the United States, that a fair variety of local watercraft can be found. Here there is still a chance of preserving for posterity more than isolated examples.

Ocean Racing

Daniel D. Strohmeier, Consultant, Scarsdale, New York

Today’s intense competition in ocean racing is dominated, as in any sport by those who are fairly new at it. Many of the aspects of today’s sport are also new. This paper is not a manual on how to do it, but will attempt to give perspective to the sport by tracing its growth, including design trends, rating and handicapping, effect of new materials, navigation, gear and above all the fierce competitive spirit that has emerged from one in which comfortable, well-found cruising yachts would have an occasional “go” at one another off-shore to one involving the flat-out, all-or-nothing yachts of today.

Principles of Sail Design

Stephen Haarstick, Haarstick Sailmakers, Ithaca, New York

Sail design involves two processes: first to determine the proper sail shapes for a given set of conditions such as sail plan, point of sail, wind range, sea state, and hull characteristics that will produce optimum performance; and second to design the panel curvatures necessary to reproduce these chosen shapes from an elastic material on the boat. This paper discusses the various approaches to these design steps, the problems confronted and various possible solutions by offering specific cases and showing a designer’s thought process.

Wing Sail Versus Soft Rig: An Analysis of the Successful Little America's Cup Challenge of 1976

W.S. Bradfield, State University of New York, Stony Brook, New York
Suresh Madhavan, State University of New York, Stony Brook, New York

The successful 1976 challenge was an excellent test of the modern wing sail concept of the Australian boat vs. the equally modern and sophisticated "soft" sail rig of the U.S. challenger. The very complete data taken on site by the designer of Miss Nylex during the races has been compared with computer predictions of the comparative performance of the two boats based on aerodynamic and weight differences. The predicted outcome is in good agreement with the observed result. The analysis illustrates the points of comparative superiority and weakness of the two configurations quite clearly, prompting a prediction of the future course of developments for both rigs.

Analyzing a Yacht for Hydrodynamic Characteristics that Effect What Type of Sails and Rigs Will Work Best

Robert E. Doyle, Hood Sailmakers, Inc., Marblehead, Massachusetts

The purpose of this paper is to present a very general overview as to how basic concepts of aerodynamics and hydrodynamics can be utilized in the selection and trim of sails. I have used the term selection to go all the way back to the routes of designing and selecting a rig for a given boat. The paper introduces absolutely no data and, in fact, does not explore any existing data in detail. Its main purpose is to show that almost any decision on rig or sails on a small boat is always a compromise of varying forces. Sometimes these compromises are conflicting dynamics of the hull and sails, other times the forces are man-made such as rule parameters.

Perhaps I could have done a more scientific job by choosing just one set of parameters that are in conflict and explored these in great detail showing how a conclusion can be reached from all the varying inputs into one particular problem involving rig, sails or hull. This type of thorough analysis, which would obviously require more exacting research to prove the hypothesis once defined, is not my strength. Therefore, it would be inappropriate for me to do such an analysis. My strength is in actually applying a large range of sailing theory to actual on-the-water sailing conditions.

What I hope to accomplish by this paper is to let sailors realize that when making a decision on a rig, a particular sail, or how to trim a particular sail, they first must decide what they want to accomplish with the rig, sail or sail trim. They must think about it in general terms as to what direction they should take aerodynamically or hydrodynamically to get the forces they want to achieve. Then they must go about the task with the full realization that there is no preset answer and that they must be willing to experiment in order to none in on the optimum. The input variables of the hydrodynamics of a pitching yacht going to weather in a moderate breeze that is constantly receding and increasing in velocity as well as direction defies simple solutions. Thus, the best compromise is usually the best solution.

Abstracts: 4th Chesapeake Sailing Yacht Symposium

Evolution of Offshore Ratings—To the Limit

David R. Pedrick, Pedrick Yacht Designs, Newport, Rhode Island

The evaluation of yacht hydrodynamics, aerodynamics, and equilibrium through a few empirical formulae called rating rules is quite obviously an oversimplification of nature, and is vulnerable to flaws. Because the flaws exist, the task of rulemakers has been to minimize the harmful effects of the flaws by encouraging or rewarding wholesome and desirable types of yachts and penalizing undesirable ones. The game of owners and designers has been to exploit the flaws for the pure minimization of rating versus performance. Where the limits of the game are drawn is quite subjective and requires constant adjustment to maintain fair racing. This paper traces some of the matches that have been engaged in what Nathanael G. Herreshoff referred to as "a subject never to be fully settled", with emphasis on the current status of the International Offshore Rule.

A Summary of the H. IRVING PRATT Ocean Race Handicapping Project

Justin E. Kerwin and John N. Newman, Massachusetts Institute of Technology, Cambridge, Massachusetts

Research has been carried out to provide improved engineering methods for handicapping ocean racing yachts. A velocity prediction program (VPP) has been developed to stimulate the sailing performance of a given yacht, in terms of parameters which represent its hydrodynamic and aerodynamic characteristics. Race results have been analyzed to validate the VPP, and also to optimize time allowance formulae. An electro-mechanical hull measuring device has been developed to facilitate the measurement of hull offsets in a complete and precise manner. These results of the Pratt Project already have found application, especially in the USYRU Measurement Handicapping System (MHS).

The Measurement Handicapping System of USYRU

Daniel D. Strohmeier, Consultant, Scarsdale, New York

In 1976 the United States Yacht Racing Union mandated a new handicapping system for offshore sailing yachts. The purpose was to provide equitable racing among yachts of diverse designs, a feature not possible under the existing International Offshore Rule. Making full use of the Pratt Project for sailing yacht research at the Massachusetts Institute of Technology, USYRU evolved the Measurement Handicapping System, in which ratings are expressed, not in linear measure as in past rules, but in predicted speeds on various points of sailing and in different wind velocities. The MHS was first used in the 1978 Bermuda Race. A feature of MHS is a set of regulations to require adequate cruising accommodations.

Selecting a Keel Appendage for a Cruising Yacht From a Standard Keel Series

Deborah W. Berman, SUNY Maritime College, Bronx, New York

The purpose of this paper is to describe the results of model tests for a series of three keels; two at constant draft; two at constant aspect ratio; all at constant taper ratio and thickness ratio. These keels form part of a standard series developed by Pierre De Saix at Davidson Laboratory, Stevens Institute Technology in 1974 and originally tested on a 5.5 meter hull.

The three keels were all tested on the model of a small cruising yacht over a range of heel angles, leeways and speeds. An analysis is made of the expanded model data and a comparison presented of the forces and moments operating on the deepest keel and the two keels of constant draft.

Yacht Structural Design for Light Scantlings

Halsley H. Herreshoff, Herreshoff Designs, Bristol, Rhode Island

The structural design of adequately strong, light weight yachts is studied with emphasis upon optimum strength to weight tempered by the practical considerations of cost, durability and construction capabilities. The properties and relative weights of the principal construction materials are reviewed. Design philosophy and its implementation for the hull, deck and hard points are developed. Specific examples of interest for rational design are offered. Builder’s problems of materials and craftsmanship are discussed.

Theoretical Estimation of the Influence of Some Main Design Factors on the Performance of International Twelve Meter Class Yachts

Peter van Oossanen, Netherlands Ship Model Basin, Wageningen, The Netherlands

A theoretical study is carried out to determine the influence on performance of some main design factors of International Twelve Meter Class Yachts, such as length, sail area, beam, draft and stability. This is realized by designing a series of Twelve Meter Yachts in which the length, sail area, beam, draft and the position of the vertical center of gravity are systematically varied. For the design of the canoe body, a mathematical procedure is used. The yachts of this series are each analyzed with respect to the various points of sailing. On comparing boat speed, speed made good to windward, heel and leeway angles for the different yachts for various true wind speeds, a number of conclusions are reached on the optimum values of the design factors investigated. A main result of the study is that the most important question to be answered in designing a Twelve Meter is whether the yacht must perform best in the close-hauled condition in true wind speeds in excess of about 15 knots, or whether the yacht must perform best in wind speeds not exceeding 15 knots, in which case no differentiation is necessary between the different points of sailing.

Photographic Essay; Ship Training on the Tall Ship GAZELA PRIMEIRO

George J. Roewe, Jr., Wilmington, Delaware

The Gazela Primeiro, an 1883 Portuguese fishing vessel, is owned by the Philadelphia Maritime Museum and is being used as a living museum, allowing modern day sailors to experience yesteryears' sailing life. The Gazela winters in Portland, Maine and sails each year with a complement of 40. the author shows and tells of shipboard life and the trip from Portland to Norfolk visiting ports along the way. The officers and training crew are Maine windjammers teaching Naval Sea Cadets from Philadelphia and Kansas City how to "let go and haul" while tacking ship. In three weeks, the crew experiences weather that goes from force 8 to a three day calm; she's greeted by a one fire boat salute in New York City's Harbor and is narrowly missed by a modern day cargo ship. Excitement, thrill, and hardships are packed into these three weeks aboard the Gazela Primeiro.

A Microcomputer Beats to Windward

Milton U. Clauser, Jack's Peak Consultants, Carmel, California

One of the new single chip microcomputers and a new single chip A-D converter have been used to help a small boat owner trim the sails and steer to improve the velocity made good to windward. The system also could have been programmed for reaching and running sailing conditions. The readily reprogrammable memory will make it easy to add further modifications and sophistication. Although use of the instrument does not assure a first place, it should help a knowledgeable skipper get his boat into the groove. With its low power and small size it could be used on any boat that could support battery operated instrumentation.

A Computer-Based Method For Analyzing The Flow Over Sails

D. F. Thrasher, Graduate Researcher Assistant, D. T. Mook, Professor, A. H. Nayfeh, University Distinguished Professor, Engineering Science and Mechanics Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

The use of the nonlinear, steady vortex-lattice technique to treat close-coupled sails is described. The sails are modeled as highly clambered, twisted lifting surfaces. The aspect ratio and planform can be arbitrary. The technique is limited by the angle of attack as long as separation occurs along the leech only. Due to the aerodynamic interference of the various sails, the wakes adjoining the leeches are an important feature of the flow. Here we obtain the vortex strength in, and the shape of, the various wakes as part of the solution. Moreover, the vortex lines representing the sails lie on the surface of the sail; they are not projected onto a plane surface. Numerical results for an arbitrarily chosen ketch rig are given. These results include the shapes of the wakes and a typical chordwise pressure distribution.

The Evolving Role of the Towing Tank

Karl L. Kirkman, Hydronautics, Inc., Laurel, Maryland

The towing tank has been used regularly to attempt to refine sailing yacht forms almost since its introduction as a Naval Architectural tool.

Unfortunately, the yachtsman's affair with tank testings has run hot and cold based upon misunderstandings of the correct role of model testing and economic considerations.

Recent research work has caused profound change in the method for using the tank for design assistance, but the tank retains a necessary and economically suitable place in the design cycle if properly used.

The paper explains the changing role of the tank and appropriate means of using model tests in light of our contemporary understanding of scale effects.

Abstracts: 5th Chesapeake Sailing Yacht Symposium

Design Development of a 40m Sailing Yacht

Jay R. Benford, Naval Architect, Friday Harbor, WA

The development of the design of the 40 meter (13 foot) ketch ANTONIA is followed from the commission to the beginning of construction. The requirements of the client are reviewed against the final design. The scantlings for the basic structure are presented, along with their evolution. The progression of the rig from the original thoughts to the final version is presented. The stability and floodable length curves are shown.

Lines, construction, sail plan, in addition to a call for designers to resume a more constructive attitude towards publishing original design work for the advancement of the profession.

Yacht Performance Analysis with Computers

David R. Pedrick, Pedrick Yacht Designs, Newport, RI
Richard S. McCurdy, Consultant, Darien, CT

Advances in computer technology continue to expand the every-day application of electronic calculation and programming. With everything from home computers to automotive diagnostic devices, hand-held Pong games, and calculator wristwatches now being big sellers, it is no surprise that computer-based marine popularity. This paper describes some current developments in electronics to evaluate the performance of sailing yachts, ranging from basic digital displays to full-blown shoreside computers.

Geometry of Sailmaking

Ted Andressen, St. Petersburg, FL

The aerodynamic force developed by a sail depends on the sail's shape. The horizontal cross-sectional shape is of particular importance in determining sail performance. Two methods of measuring the shape are outlined. The current practice of using edge rounding and broadseaming is described and four solutions to the problem of creating faster shapes are presented. First, the pragmatic approach which uses an interactive search for the fastest edge round and broadseam pattern is examined. Three other approaches that model the sail as a mathematical surface and use geometry to compute the patterns are presented. Here the sail is treated as a stack of horizontal arcs with precisely defined shapes. In one method, a path excess equation is used to calculate the luff round for a mainsail. Another approach plots the geodesic paths on the sail's surface and computes the seam-by-seam broadseaming. Lastly, an integral method is employed to find the broadseaming for a sail based on the Penguin mainsail. Measurements of the sail made by this method are presented and discussed.

Sailing Yacht Capsizing

Olin J. Stephens, II. Karl L. Kirkman, Hydronautics, Inc., Laurel, MD
Robert S. Peterson, NSRDC, Bethesda, MD

The 1979 Fastnet focused attention upon yacht capsizes and resulting damage and loss of life.

A classical stability analysis does not clearly reveal some of the characteristics of the modern racing yacht which may exacerbate a capsizing tendency. A review of the mechanism of a single-wave-impact capsize reveals inadequacies in static methods of stability analysis and hints at a connection between recent design trends and an increased frequency of capsize.

The paper traces recent design trends, relates these to capsizing by a description of the dynamic mechanism of breaking wave impact, and outlines the unusual oceanography of the 1979 Fastnet which led to a heightened incidence of capsize.

Kinetics in Small Boat Racing

Peter G. Smith, William E. Cook, Inc., Greenwich, CT

In the early 1960s, new techniques involving body movements and rapid, repeated trimming of the sails were developed in order to sail a small boat faster than ever before. Because these kinetic techniques drove a boat measurably faster, their use rapidly spread from class to class amongst the top competitors. In an attempt to try to stop small boat sailing from turning into a strictly athletic contest, the International Yacht Racing Union introduced a rule in 1965 governing the use of kinetics.

Since then, newer techniques have been developed that are not covered by the previous rule. Because these new methods are substantially faster, many top competitors are increasing their use of them. As the top sailors increase their winning margins, the rest of the fleet is often forced to use kinetics in order to keep up. As a result of their rapidly spreading use, the IYRU has readdressed itself to this problem and has drafted a new proposal. Hopefully, this new rule, if adopted, will clearly define when the present techniques may be used and yet still allow for future developments in kinetic techniques.

RED HERRING, High Performance Cruising Ketch

David W. Hubbard, Sealion Association, Stamford, CT

The design, construction and performance of a narrow, fast cruising 55 foot cat ketch is discussed. Stability is provided by ballast on a long blade that can be tilted laterally and also lifted to achieve shoal draft. A parametric design procedure and a graphical performance method is presented.

Mathematical Hull Design for Sailing Yachts

John S. Letcher, Jr., Letcher Offshore Design, Southwest Harbor, ME

Mathematical representations of hull surface shape have largely supplanted graphical fairing and lofting of lines in the shipbuilding and aircraft industries, but have had little application so far to small craft. Past methods of hull design are surveyed to put mathematical design into historical perspective and point up its many advantages. The basic concepts of analytic geometry of surfaces needed for yacht hull design are briefly introduced with references. Several special aspects of the geometry of yacht hulls, arising from considerations of aesthetics, hydrodynamics, and construction methods are discussed and cast into analytic form for inclusion in a hull design scheme. The paper explains in detail a particular representation system called FAIRLINE/1, simple enough to fit into the program and memory limitations of a TI-59 calculator, yet extremely versatile. A program listing and several example hull designs created with this program are presented.

A Design Guide for Estimating Speed Made Good for a Sailing Yacht

Deborah W. Berman, Webb Institute of Naval Architecture, Glen Cove, NY

This study develops a simplified comparative procedure for use in preliminary yacht design to predict Equilibrium sideforce, resistance, leeway angle and speed made good to windward for a canoe hull sailing yacht within specific form parameters on any of five standard series keels.

These forces, angles and speeds are predicted for any yacht, hull resembling on of nine models- ranging from light to medium-heavy length to displacement ratio- (190 to 351)- is numerical data. The forces are calculated at speed to length ratio of 1.3 and heel angle of 30 degrees to enable the designer to make use of existing comparative sail plan and rigging data.

The five keels of varying aspect and area ratio, spanning current design practice, are part of a matrix developed at the Davidson Laboratory.

In this paper, a canoe yacht hull from similar to Model 7 of the Deft Series is tank tested on 3 Standard Series keels and compared to results obtained from testing a 5.5 m hull, which is similar to Model 8, on the same keels. A prediction procedure is developed and checked against test results.

A few Equations, selected values from included tabulations, a calculator, pencil and paper will yield quantitative information for the yacht designer in the selection of a keel for the hull of a sailing yacht.

Abstracts: 6th Chesapeake Sailing Yacht Symposium

Analysis of Steady Flow Over Interacting Sails

David S. Register, Richard K. Irey, Department of Mechanical Engineering, University of Florida, Gainesville, FL

Inviscid lifting surface techniques are applied to strongly interacting multiple sail configurations. A computer program is developed to solve the resulting non-linear potential flow problem. It is employed to predict the pressure distributions for a number of single and multi-sail rigs. Empirical stall prediction and correction methods are proposed and implemented.

Catboat rigs are found to be superior to sloop rigs in lift coefficient, while sloop rigs show a lower drag coefficient. A finite optimum mainsail aspect ratio is predicted for masthead and 7/8 rigs, but not for a ¾ fractional rig. The region of significant perturbation of the onset flow field is shown to extend as much as eight chord lengths ahead of the mainsail of a cat-ketch rig.

Yacht Design with Computers: New Methods For New Tools

George S. Hazen, Hazen Technical Yacht Design Inc., Annapolis, MD
Steve Killing, Killing Yacht Design, Midland, Ont.

From the perspective of the design office, this paper examines the manner in which computers are streamlining and changing the design process for today's sailing yachts. Starting with preliminary design and progressing through the more detailed aspects of final design, the computer's varying roles in the design process are traced with examples drawn from currently implemented programs. In addition to its customary role as a bookkeeper, the computer's remarkable graphics capabilities are highlighted. The authors offer a glimpse of what programs and hardware tomorrow's yacht designer will use as frequently as his curves and battens. The paper covers such subjects as design follow-up, sailing analysis and feedback into the original design process. Since designers are not the only ones to benefit from the computer revolution, the authors have included sections on computer generated sailing aids for the yachtsman and possible CAD/CAM applications for the boatbuilder.

Marine Electronic Navigation—A General Overview

Thomas H. Closs Jr., Nautical Electronics Co., Baltimore, MD

The evolution of techniques and skills in the art of marine navigation spans centuries. However, in the last thirty years, the science of navigation has been advancing faster than ever before. We have moved into the electronic age and have many marvelous systems and devices to help the navigator make informed decisions quickly and accurately. This paper discusses many different electronic navigation systems and equipment. It is intended to give a general understanding of what these systems are and how they operate, as well as some of their limitations and misconceptions. Currently, the most popular system among yachtsmen is loran, and it will be the subject of the oral presentation.

Sailing Yacht Capsizing

Karl L. Kirkman, Hydronautics, Inc., Laurel, MD
Toby Jean Nagle, DTNSRDC, Bethesda, MD
Joseph O. Salsich, U.S. Naval Academy, Annapolis, MD

A joint SNAME/USYRU Project for Safety From Capsizing has led to significant progress in an understanding of the causes and mechanism of the single wave impact capsize.

The paper traces the background of the project, outlines the approach selected in pursuing answers to the concerns of the yachting community, presents related findings from other research and describes capsizing model tests and the linear regression of the Fastnet '79 data.

Rowing and Sailing Craft of the Chesapeake Bay

Frederick Tilp, Alexandria, VA

This paper is written with the hope that it may inspire younger generations to preserve for posterity something of the history and development of traditional Chesapeake Bay rowing and sailing craft. My first awareness of these vessels, 1920, came during m grammar school days, while researching the history of my birthplace, Bladensburg, the first sizeable tobacco seaport in Maryland.

Extensive research into records and collection of oral history has been combined into a comprehensive review of various types of craft found on the Bay.

Design and Engineering Aspects of Free-standing Masts and Wingmasts

Eric W. Sponberg, Sponberg Yachts, Newport, RI

Since their appearance in the mid-1970s, free-standing masts and wing-masts have become available on a number of production and custom sailboat designs. Being made primarily of composite materials, their engineering and development is complex and subject to much trial and error. Yet practically nothing of this development has been written down outside of what the various manufacturers have recorded for themselves.

This paper outlines the basic criteria for free-standing mast and wing-mast engineering and design, discusses current rig arrangements, materials and manufacturing methods, and gives two design examples. Weaknesses in the engineering process are also delineated and guidelines are given for future research which could eliminate those weaknesses.

Construction Design Approach for Contemporary Yacht Hulls

Russell Bowler, Bruce Farr & Associates, Inc., Annapolis, MD

My first impression of the widely accepted rules for sizing structural members in the construction of sailing yachts was that it was the world of empirical mystery that arrived at structural solutions that would survive most normal events through sheer quantity of structure. Nevin's rules, Herreshoff's rules, Lloyd's rules all offered quick and useful solutions for sizing structural members for the style of yacht materials available at the time the rules were created. Applied to the current popular style of relatively light displacement, fin keel/spade rudder cruising or racing yacht these rules gave solutions that were often clumsy and quite obviously well outside the range of interpolation intended for the rules.

The approach our office has taken to structures is based on Lloyd's, and more recently the ABS Guide, heavily influenced by firsthand experience on boats over a lot of heavy air ocean racing, and colored to some degree by my training as a Civil Engineer.

As a starting point we sought to determine actual loadings that occur on a hull and then organize a structure capable of resisting these loads with whatever factors of safety are appropriate. Other influencing factors such as the nature of the load, resilience and stiffness of the material, and type of structure should all be accounted for in determining scantlings.

Basing our philosophy on the engineering logic of:
Load x how safe x to last how long = structure
we have outlined in the following our approach which we are filling out and refining in the process of conducting our business. We have tailored this approach to sailing yachts in the medium to light displacement range with fin keels, spade rudders, with or without partial skeg. Any application outside this style must be done with care – less witchcraft, more science.

FRP Bottom Blistering

Com. A.B.F. Fraser-Harris, Annapolis, MD
James H. Kyle, Cape Dory Yachts, East Taunton, Mass.

A discussion on the causes of "Osmosis" the appearance of blisters on the bottoms of fiberglass yachts both power and sail alike.

A description of symptoms observed by a Marine Surveyor during the last few years of practice, a simple explanation of the probable causes, followed by a technical discussion of the problems faced by industry in their attempt to eliminate the disease.

Finally, some suggestions as to prevention and cure in existing vessels and those still to come off the production lines.

Abstracts: 7th Chesapeake Sailing Yacht Symposium

Experimental Analysis of Five Keel-Hull Combinations

Prof. Ir. J. Gerritsma and Ir. J.A. Keuning, Delft University of Technology, The Netherlands

Model tests with five different keels in combination with one particular hull form have been carried out in the Delft Towing Tank. The variations include a plain deep keel, a keel-center board, a plain restricted draft keel, a "Scheel" keel and a "winglet" keel. Based on the experimental results performance predictions are given for a 63 ft. yacht for windspeeds up to 25 knots. The measured side force and resistance as a function of heeling angle, leeway angle and forward speed are used to analyze the relative merits of the considered keel-hull combinations.

Sailboat Bow Impact Stresses

Professor L.W. Ward, Webb Institute of Naval Architecture, Glen Cove, NY

A study is made of the dynamic stresses due to water impact forces on the bow sections of offshore racing sailing yachts going to windward using an unsteady model of a pressure loading traveling across a beam. Results show a decided reduction compared to the static loading solution where the load travel rate is rapid and for large unsupported spans. The latter is compared to recent proposed changes in the American Bureau of Shipping (A.B.S.) Scantling Rules and some qualitative agreement is found. Recommendations for future investigations are made.

Selection Criteria For Plastics Used In Through-Hull Fittings

Com. A.B.F. Fraser-Harris, Annapolis, MD, and Jerry J. Leyden, Smithers Laboratories, Akron, OH

The growing use of various plastics used in fittings for modern yachts has been of increasing concern to marine surveyors and yacht owners alike. Although desirable from a cost and corrosion resistance standpoint compared to bronze, the selection of suitable materials is confusing and complex. Based on consideration of appropriate properties, viable choices should be limited to fiberglass reinforced nylons, acetals and PBT's.

Sailboards, Inventions, Yachts, and Exotic Craft

Diana Russell, Wing Systems, Oyster Bay, NY

A discussion of some concepts that apply to the development of small high speed sailing craft in general and to sailboards in particular and an analysis of the design and performance of ordinary, everyday sailboards as well as high speed ones.

Extended Cruising The Second Time Around

Kenneth E. Court, Harwood, MD

Some years ago, in 1975, I presented a paper and a slide show at an earlier sailing yacht symposium in Annapolis. The subject was a four-year, 28,000 mile cruise I had made in the years 1965- 1968 most of the way around the world: Hawaii and the South Pacific, New Zealand, Australia's Barrier Reef, the Indian Ocean, the Red Sea, the Mediterranean, including the Greek Islands, an Atlantic crossing to Barbados from the Canary Islands, to the Caribbean, and home to the Chesapeake. The paper I wrote then was entitled "Extended Cruising: An Overview" and contained sketches and data from my logs. It was some 55 pages long and talked about many facets of cruising from my vantage point, primarily as seen from the decks of Mamari, the 28 foot ketch I had bought in New Zealand.

Lest Mamari's size appear too small, which perhaps would make me seem heroic, recognize that in displacement and accommodations Mamari was the equivalent of a 33 foot boat. To dispel one other misconception, be advised that I normally sailed with a crew of two, sometimes more, and only sailed two legs single-handed, of about 500 miles each, one from Tonga to Fiji in the Pacific, the other in the Gulf of Suez and from Port Said to the Greek Islands.

The 1975 paper reflected my background as a naval architect, combined with my experience as a sailor. I told of things I learned from others. I analyzed log data, presented photographs, drawings and tables, and wrote a series of "yarns" such as sailors spin about their travels. The paper is touched with a flavor of the sea, a flavor of talk over rum or coffee in a snug anchorage or on a shared night watch. That 1975 paper makes good reading, and much of the information is still valid. It could be reprinted and if there is enough interest I will do so (contact me).

This present paper is a brief look at my experiences on a series of sailing trips, but in particular a one year voyage in a 37 foot yawl from Turkey to the Chesapeake via the West Indies in 1980-81. The paper answers the question posed at the 1975 symposium, would I do the trip again? Then, I thought so, but could not be sure, now my reply is, "of course."

The Calculation Of Sail Panels Using Developed Surfaces

George Clemmer, Horizon Sails, Norwell, MA

A method for the calculations of panel shapes for sail cutting purposes is presented. Each panel in the three-dimensional sail is modeled by a series of planar patches which approximate a developable surface. An algorithm for distributing these patches is described. A sample sail design is presented in detail. The method has been found to perform well in practice, and is employed routinely in production by Horizon Sails.

Stress Analysis For Light Alloy 12 M Yacht Structures. Comparison Between A Transverse And A Longitudinal Structure

Dario Boote, and Professor Vincenzo Ruggiero, University of Genoa, Genoa, Italy
Nicola Sironi, and Andrea Vallicelli, Rome, Italy
Bruno Finzi, Milan, Italy

A stress analysis has been carried out for the 12 meter yacht “Azzurra”, the Italian Challenger to the America’s Cup 1983.

Two different structural arrangements have been investigated. One is the existing transverse-framed, and the other is a study in which both longitudinal and transverse stiffeners have been included.

The structural models have been analyzed with two different calculation systems under the same loads. The first method is a classical naval architecture direct calculation, while the second is a Finite Elements Method analysis.

A measurement sea trial to evaluate the stresses in various points of the yacht structure has also been performed on “Azzurra” to obtain a feed-back able to check the results given by the numerical analysis.

Some comments and conclusions on the behavior of the two types of structure are presented.

The Development of the 12 Meter Class Yacht “Australia II”

Dr. Peter van Oossanen, Netherlands Ship Model Basin

In this paper the development of the 12 Metre Class Yacht “Australia II” is described as it took place at the Netherlands Ship Model Basin in Wageningen, The Netherlands, under the direction of Ben Lexcen. An account is given of the adopted design process and the technology involved. Particular attention is given to the adopted towing tank procedures and calculation techniques for predicting performance. A description is also given of the computer monitoring system used to evaluate “Australia II’s” performance while sail-tuning and racing in Australia and Newport in 1982 and 1983.

Abstracts: 8th Chesapeake Sailing Yacht Symposium

The Application Of VPPs To Practical Sailing Problems

Karl L. Kirkman, M. Rosenblatt & Son, Arlington, VA

The velocity prediction program, VPP, appeared on the yachting scene about ten years ago and it now dominates design and sailing. Originally implemented as a handicapping tool under the Measurement Handicap System, now accepted internationally as IMS, it has seen widespread acceptance for many other uses, from design to tuning and racing.

This capability means that it is productive, even necessary, for the typical sailor interested in good performance to understand how to apply a VPP to his activities. To do so requires an appreciation of how a VPP functions and how it is applied to practical sailing problems, such as sail selection or tactics.

The paper presents a review of VPP fundamentals and then treats the following applications:

- Sail selection and strategy for offshore yachts
- Tuning and optimization of all boats

It is the goal of the paper to impart a working understanding of the VPP to many sailors so that they can take advantage of the technology in their normal activities.

An Assessment Of The Progress In Yacht Design Through An Examination Of Model Yacht Characteristics

Andrew Claughton, University of Southampton, UK
Ian Howlett, Beaulieu, UK
Roger Stollery, Godalming, UK

The ‘A’ class model yacht racing rule devised in 1923 is described and its parallels with their full size metre class rules are discussed. Unlike their full size counterparts, successful model yachts from all decades of the rule’s existence survive in good condition. This provides an opportunity to assess progress in yacht design using towing tank techniques. Six championship winning models, representative of typical types, were tested in the towing tank and the results are presented. Windward sailing performance prediction calculations for the models are also carried out using representative soft sail force coefficients. The developments in hull design, sail materials and hull construction leading to the latest ‘A’ class models are described. The use of model sailing trials as an aid to the design of full size yachts is also discussed.

Dinghy Design And The International Fourteen

Robert M. Ames and Paul F. Weiss, Annapolis, MD

A review is made of dinghy design parameters and practices that include: hulls, rigging systems, sails, rudders and centerboards. This is followed by an in-depth review of the International Fourteen class. The International Fourteen class was selected for design comparison because of its open design rules and its broad variation of past and present designs. A number of selected International Fourteen hullforms are computer modeled for performance characteristics and trends. From this data, correlations between primary shape driving parameters and performance are made. Fourteen structural design and construction methods are discussed. Topics include loading considerations and material selection. Design topics include hull skin, framing, decking, and rigging.

The Comparison Of Potential Driving Force Of Various Rig Types Used For Fishing Vessels

C.A. Marchaj, MacAlister Eliot and Partners Ltd, Lymington, England

This paper examines platform and aspect ratio effects on potential power of a number of rigs- Bermudan, Lateen, Spirit, Gunter, Dipping Lug and Crab Claw rigs, some with modifications (Figure 1). Coefficients of effective driving force, based on wind tunnel testing, are established for those rigs for a range of courses from close hauled to running. A comparative assessment of aerodynamic merits and demerits of various rigs is made. Also an attempt is made to find correlation between the potential power of the rigs in question, and the speed performance of a given hull driven by these different rigs.

Brushfire—An Experience In Building A Masthead Cutter

John J. Williams, Associate Professor, Defense Institute of Security Assistance Management, Dayton, OH

To say that building a sailboat forty feet long was an experience is a severe oversimplification. A fellow stopped by during construction of the hull, and after observing me for a while asked, “Is this a business?” My reply was that I wouldn’t do this again for anyone. However, after turning the hull upright I admit I contemplated marketing the completed project and building a 50-footer. I quickly regained senses. My wife and I much prefer sailing to building. That doesn’t mean that building it can’t be fun. It certainly doesn’t need to monopolize your life. Curing our project we took time out one year to vacation in Paris and to cruise aboard both a chartered boat and a boat owned by friends. This paper describes the approach we applied in this project which took five years to complete.

Keel Design For Low Viscous Drag

Clifford J. Obara, PRC Kentron, Inc., Hampton, VA
C. P. van Dam, University of California, Davis, CA

In this paper, foil and planform parameters which govern the level of viscous drag produced by the keel of a sailing yacht are discussed. It is shown that the application of

laminar boundary-layer flow offers great potential for increased boat speed resulting from the reduction in viscous drag. Three foil shapes have been designed and it is shown that their hydrodynamic characteristics are very much dependent on location and mode of boundary-layer transition. The planform parameter which strongly affects the capabilities of the keel to achieve laminar flow is leading-edge sweep angle. The two significant phenomena related to keel sweep angle which can cause premature transition of the laminar boundary layer are crossflow instability and turbulent contamination of the leading-edge attachment line. These flow phenomena and methods to control them are discussed in detail. The remaining factors that affect the maintainability of laminar flow include surface roughness, surface waviness, and freestream turbulence. Recommended limits for these factors are given to insure achievability of laminar flow on the keel. In addition, the application of a simple trailing-edge flap to improve the hydrodynamic characteristics of a foil at moderate-to-high leeway angles is studied.

The Interpretaion Of Results From Tank Tests On 12m Yachts

Ian Campbell and Andrew Claughton, University of Southampton, UK

Current Wolfson Unit tank test techniques are described and results presented that demonstrate how reliable data can be obtained from yacht models using simple equipment and measurement systems. The results presented are from models of 12m Yachts tested at both 1:10 and 1:4 scale. The correlation with full scale performance is shown for a 12m Yacht with a conventional keel. The induced and heeled components of resistance, obtained from tests at both scales, are compared for both the conventional and a winged keel. The interpretation of various characteristics in the tank data and the use of flow visualization and measurement techniques are discussed.

The Analysis Of Wave Resistance In The Design Of The Twelve Meter Yacht *Stars & Stripes*

Carl A. Scragg, Science Applications International Corporation, La Jolla, CA
Britton Chance, Jr., Chance and Company, Inc., Essex, CN
John C. Talcott and Donald C. Wyatt, Science Applications International Corporation, La Jolla, CA

During the design of the Twelve Meter yacht STARS & STRIPES, the design team placed great emphasis upon the minimization of all forms of hydrodynamic resistance: skin friction, lift-induced drag, form drag, and wave resistance. In this paper, the authors discuss methods used to measure, predict, and minimize the wave resistance of Twelve Meter yachts. After a brief review of wave resistance theory, the authors discuss a method by which the wave resistance was determined directly from measured wave-profiles. Numerical techniques used to theoretically predict the curves of wave resistance from the yacht designers' descriptions of hull geometry are examined and the predictions are compared to the experimentally determined wave resistance. Finally, the authors discuss hull optimization techniques, based upon the minimization of the theoretical wave designers to develop hull shapes of minimum wave drag.

Stars & Stripes '87; Computational Flow Simulations For Hydrodynamic Design

Charles W. Boppe, Bruce S. Rosen and Joseph P. Laiosa, Engineering Design & Analysis Consultants, Smithtown, NY
Britton Chance, Jr., Chance & Company, Inc., Essex, CN

Computerized flow simulation methods have been developed, refined, and implemented as an aid for hydrodynamic optimization of the 12-metre yacht "Stars & Stripes '87". Forming one element of a triad, computational analyses and Velocity Prediction Program trends were complemented with 1/3 scale towing tank models and full scale field testing. A background analysis of the yachts "Liberty" and "Australia II" provides a foundation for understanding relative performance issues. In particular, the wave resistance and lift-induced drag (vortex and wave) levels are quantified. Techniques involving Fourier analysis, integral methods, panel methods, and finite difference schemes are described. Parametric studies illustrating trends are augmented with a fundamental description of component-induced flow fields. Two appendices provide details on automation of computational model definition and a new free-surface analysis scheme for predicting wave resistance effects due to volume, lift, and heel. It is shown that the primary benefit of the computational effort is improved performance by means of a systems approach involving element decomposition, sub-optimizations, and element linking based on sensitivity information.

Data Collection And Analysis For The 1987 *Stars & Stripes* Campaign

John S. Letcher, Letcher Offshore Design, Southwest Harbor, ME
Richard C. McCurdy, Ockam Instruments, Inc., Milford, CN

Data collection from full-scale 12-meter yachts was an important part of the project that led to the America's Cup challenger Stars & Stripes. A data system was developed around Ockam on-board instruments with a telemetry link to two DEC Microvax II computers, one aboard the tender and one on shore. Applications of the data obtained include validation and improvement of computer models and towing tank tests used in design; discrimination of performance differences associated with hull, keel and sail changes; and development of on-board computer systems to assist decision-making during races.

Abstracts: 9th Chesapeake Sailing Yacht Symposium

Fiber Reinforced Plastic Sailing Yachts—Some Aspects Of Structural Design

Robert Curry, American Bureau of Shipping, Paramus, NJ

This paper discusses various aspects of the structural design of fiber reinforced plastic (FRP) offshore racing and cruising yachts. Items discussed are materials, laminates, structural details, and rudders and keels. Emphasis is on those aspects that have been found to deserve attention in that they: are not covered in specific detail in the ABS Guide for Building and Classing Offshore Racing Yachts; are covered but are sometimes not complied with; or are outside the scope of the Guide.

The approach is to review the standard and advanced composite materials as they are currently used for ocean racing yachts and for ocean cruising/racing yachts. Various terms and aspects of laminate design are discussed. By their nature this is particularly applicable to advanced composites for which it is not only necessary to make fullest use of their advantageous properties but also to be aware of and consider in design their less obvious restraints.

Typical structural arrangements are mentioned, structural design and structural detail are discussed, again with emphasis on the advantages of the various materials and details, and the pitfalls to be avoided. Due to their detail, focusing on certain features that could be or have been known as a source of past problems.

The ABS Guide for Building and Classing Offshore Racing Yachts is briefly referred to in its role of providing the standards for the structural design of ocean racing yachts and in its applicability to cruising racing yachts.

For those interested, an appendix gives a brief history of the Guide and the role of the Offshore Racing Council and ABS in its development and current use.

Guides To The Approximation Of Sailing Yacht Performance

Olin J. Stephens, II, Putney, VT

Two computer programs are presented for use, either singly or in sequence. The first will derive, from minimal data, a consistent set of parameters which, entered into the second, a velocity prediction program (VPP), will predict a sailing yacht's speed and course over a full range of wind strength and direction. Due to the limited input data as well as to the simple form of the VPP, approximate results must be accepted. The design program combines guidance with flexibility so that reasonably accurate and consistent dimensions, largely empirically derived, including weight and stability estimates, are quickly produced and tested, by the VPP, for performance.

Scientific Sail Shape Design

David S. Greely, Atlantic Applied Research Corp., Burlington, MA
Karl L. Kirkman, Science Applications International Corp., Annapolis, MD
Alan L. Drew, Doyle-Allan Sailmakers, Annapolis, MD
John Cross-Whiter, Atlantic Applied Research Corp., Burlington, MA

Perhaps no area of yachting has reached harder for technology, and grasped lass, than sail shape design. The combination of the obsession with secrecy, the background and training of those in the business, the economic characteristics of the marketplace, and the intractability of the problems is formidable and has made scientific sail engineering a grail.

This paper will not solve those problems; rather it reports on an attempt to begin an attack on the fundamental problems and to report the outcome. Thus, the paper will:

- describe the fundamentals of the sail shape design problem so that practical sailors can, with some study, grasp the nature and difficulty of the problem to the extent that claims can be evaluated thoughtfully; and
- report on a research program intended to put the art onto a solid engineering basis by formulating the problem and beginning work on solutions.

The Design And Construction Of The Second *Pride Of Baltimore*

Thomas C. Gillmer, Annapolis, MD

The *Pride Of Baltimore II* was ordered to be built as a result of the tragic loss of her predecessor. She is not, however, a simple replacement. The purpose is, of course, to continue and extend the mission so successfully advanced during the more than nine years of nearly continuous sailing commission of “PRIDE I”. This program is at the core of her design.

She is, in configuration, sailplan, and material, a traditional fore-topsail schooner, typical of those built in Baltimore early in the 19th Century. She is very much in appearance like the first vessel, built 1976-77, which she replaces. Her design and structure, however, are considerably more advanced. Using contemporary techniques and tools in both design and construction she is, we believe, one of the finest wooden schooners of this size to be built. It is the purpose of this paper to describe some of the design and construction features that make this vessel unique.

The Planning Design And Construction Of The 44-Foot Offshore Training Craft For The U.S. Naval Academy

Ian McCurdy, McCurdy & Rhodes, Inc., Cold Spring Harbor, NY
John Bonds, Capt., USN (Ret.), USYRU, Newport, RI

This paper includes a brief history of the types of vessels used by the Naval Academy’s sailing program and their uses, the development of the criteria used to define the yawl replacement vessel. This class of vessel will eventually replace all of the Academy yawls and the other sail training craft now used by the Sailing Squadron.

The Effect Of Counter Length On Hull Resistance

Andrew R. Claughton, Wolfson Unit, MTIA, University of Southampton, England

Towing Tank tests on a single 2.4 m LOA model hull form with 3 alternative rudder configurations have been carried out in the Southampton Towing Tank. The results were used to derive predictions of full scale resistance curves for a 10m LWL racing yacht. In addition to the resistance data, sinkage and, trim were measured. Wave profile measurements were also made to determine the influence of counter length on the hull generated waves. The resistance curves are presented for the 5 configurations investigated and the results are compared with published regression analysis methods of estimating hull resistance based on geometric hull parameters.

Performance Prediction Method For Multihull Yachts

Clay Oliver, Yacht Research International, Annapolis, MD

A new performance prediction method for multihull yachts is described. The methods described here, and performance predictions based on these methods were used in the design and modifications of the 1988 America's Cup Defender Stars & Stripes. The method incorporates the type of solution procedures used in state-of-the-art monohull velocity prediction programs. The various models used for hydrodynamic and aerodynamic forces are briefly discussed. The predictive method is validated using full-scale data from C-Class catamarans, a Formula 40 catamaran, a 75-foot "maxicat", and Stars & Stripes with a soft-sail rig. Several examples of design studies are presented.

Abstracts: 10th Chesapeake Sailing Yacht Symposium

Gyradius Measurements Of Olympic Class Dinghies And Keel Boats

Peter F. Hinrichsen, University of Montreal, Quebec, Canada

Modern construction techniques allow dinghy hulls to be built well under the minimum weight specified by the class rules. This has lead to a trend, notably in the Olympic dinghy classes, towards hulls with light ends, especially light bows. A number of classes, of which the Finn was the first, have therefore introduced means of measuring the fore and aft weight distribution. Measurements of the pitch and yaw gyradii of Flying Dutchman hulls made at the 1976, 1984 and 1988 Olympic regattas, as well as data for a number of other classes are presented. The various methods used for gyradius measurement are compared, with a special emphasis on their precision, accuracy, worldwide reproducibility and the systematic corrections required. Calculations of the contribution of each of the components, including the crew, to the total moment of inertia are presented for Flying Dutchmen.

Structural Design And Construction Of America's Cup Class Yachts

Prof. Ronnal P. Reichard, Florida Institute of Technology, Melbourne, FL

The new America's Cup Class Rule specifies a modern, light weight, fast monohull sloop somewhere between an IQR Maxi and an ULDB. The performance of the boat will be highly sensitive to weight, thus there is a premium optimization of the structure. The structural section of the rule calls for a thin skin sandwich laminate with minimum skin and core thickness and densities, as well as maximum core thickness, fiber modulus, and laminate cure temperatures. This paper presents the initial phases of material selection, structural analysis and design, and manufacturing engineering in the development of a competitive America's Cup Class Yacht.

The Delft Systematic Yacht Hull (Series II) Experiments

Prof. Ir. J. Gerritsma, Ir. J. A. Keuning and R. Onnink, Delft University of Technology, Delft, The Netherlands

The Delft Systematic Yacht Hull Series (series I) has been extended with six hull forms which cover a range of medium to very light displacements.

Upright and heeled resistance, as well as side force and stability have been measured for a large range of forward speeds.

Polynomial expressions for the upright resistance, based on the combined Series I and II, are given for Froude numbers up to Fn = 0.60.

The measured side force and induced resistance are analysed, and velocity predictions using Series I and II results are discussed.

A New Technique For Testing A Sailing Yacht In Waves

G. K. Kapsenberg, Maritime Research Institute, Wageningen, The Netherlands

A new experimental technique is presented to test sailing yachts in waves. The method is suitable for the investigation of ship motions in all six degrees of freedom and added resistance for the close hauled condition. Measurements can be made both in regular waves and in irregular seas. The technique has been tried out on a model of a 12-Meter class yacht and showed a resistance increase for the yacht sailing to windward in a wind generated sea of 90% of the calm water resistance.

Magic III – An Old Man's Day Sailer

Capt. Richards T. Miller, USN (Ret), Annapolis, MD
Harold M. Whitacre, III, Kaufman Design Inc., Annapolis, MD

Because it has been one of the most successful of International class racing boats, the STAR offers many out-classed but still sound hulls available for recreational sailing. Based on nearly sixty years experience with nine different racing and cruising boats, Dick Miller decided that one of those hulls could be converted to an ideal "old man's" day sailer. The basis for his design, changes made in rig and hull, and the resulting MAGIC III are described in this paper.

A Numerical Approach To The Design Of Sailing Yacht Masts

Dario Boote, University of Genoa, Italy
Mario Caponetto, Genoa, Italy

In this paper a complete procedure for the design of sailing yacht rigs is presented. The procedure starts from the definition of the load model and the determination of the aerodynamic forces developed by sails and continues the non-linear domain. For the correct calculation of the sail forces a program has been realised by the authors on the basis of the lifting surface theory. For stress analysis, another dedicated program has been developed starting from a multi purpose finite element code operating in the non-linear domain. A peculiar characteristic of this procedure is that it can be run on a personal computer.

Model Test Techniques Developed To Investigate The Wind Heeling Characteristics Of Sailing Vessels And Their Response To Gusts

Barry Deakin, Wolfson Unit, University of Southampton, England

During the development of new stability regulation for the U.K. Department of Transport, doubt was cast over many of the assumptions made when assessing the stability of sailing vessels. In order to investigate the traditional methods a programme of work was undertaken including wind tunnel tests and full scale data acquisition. The work resulted in a much improved understanding of the behavior of sailing vessels and indeed indicated that the conventional methods of stability assessment are invalid, the rules now applied in the U.K. being very different to those in use elsewhere.

The paper concentrates on the model test techniques which were developed specifically for this project but which will have implications to other vessel types. The tests were of two kinds: measurement of the wind forces and moments on a sailing vessel; and investigation of the response of sailing vessels to gusts of wind.

For the force and moment measurements models were mounted in a tank of water on a six component balance and tested in a large boundary layer wind tunnel. Previous tests in wind tunnels have always concentrated on performance and the heeling moments have not normally been measured correctly. As the measurements of heeling moment at a range of heel angles was of prime importance a new balance and mounting system was developed which enabled the above water part of the vessel to be modeled correctly, the underwater part to be unaffected by the wind, and the interface to be correctly represented without interference. Various effects were investigated including rig type, sheeting, heading, heel angle and wind gradient.

The gust response tests were conducted with Froude scaled models floating in a pond set in the wind tunnel floor. A mechanism was installed in the tunnel which enabled gusts of various characteristics to be generated, and the roll response of the models was measured with a gyroscope. These tests provided information on the effects of inertia, damping, rolling and the characteristics of the gust.

Sample results are presented to illustrate the uses to which these techniques have been put.

Sailboat Performance In A Current

James P. Nolan, Nolan Associates, Bethesda, MD

Tidal and other surface currents may have a profound influence on the effective performance of a sailing vessel. This illustrated paper discusses in sailors' terms some situations of interest to racing sailors. Is it always advantageous to have a "fair current"? Under what circumstances is it a good thing to "lee bow" a tide? How can you improve your "velocity made good" in the presence of a current? What are your options in a current with no wind? What should Race committees know about currents and how might this knowledge influence judgment in setting a course? Might it be a good thing to tack downwind against a foul tide? How might a current affect the calculation of "target speeds" and "optimum VMG"? This paper covers these and other related circumstances in which calculation of current effects may affect decision making while under sail.

Sailboat Hydrodynamic Drag Source Prediction And Performance Assessment

Charles W. Boppe, International Numerics Corp., Smithtown, NY

Velocity Prediction Programs used for sailboat hull, sail, and keel sizing trades, have found an important place in the designer's toolbox. Sail designers now recognize the benefits of applying aerodynamic panel methods. In addition, the 1983 and 1987 America's Cup competitions have drawn attention to use of computerized flow simulation methods for improving hydrodynamic performance. This paper highlights characteristics of methods capable of predicting sailboat hydrodynamic drag forces. Taken together, the resistance components predicted include appendage surface friction drag, configuration and component wave drag, hull-keel lift-induced drag, and configuration trim drag. All of the computer programs discussed in this paper were originally developed for aircraft aerodynamic applications. Since each method is based on some approximate model of real world flow physics, the need to establish a simulation experience base is emphasized and illustrated. VPP polar diagrams are used to link drag source benefits and penalties to sailboat performance. Micro-computer execution times are provided because the methods described operate on machines commonly found in the naval architect's office.

The Effect Of Pitch Gyradius On Added Resistance Of Yacht Hulls

James F. Moran, Designers & Planners, Arlington, VA

The purpose of this investigation was to determine the effect of pitch gyradius on added resistance of yacht hulls. Tank testing of a model yacht in head seas was performed in the Webb Robinson Model Basin. The model was tested in regular waves at two speeds and five variations of gyradius. The model was also evaluated in irregular seas of the Pierson-Moskowitz spectrum at various speeds with two gyradii. Response Amplitude Operators were developed from the regular wave data and comparisons made. The irregular wave data were analyzed for the effect of speed on the difference in added resistance between the maximum and minimum gyradius settings.

Several conclusions were arrived at after analyzing the data. The Response Amplitude Operators shift as the gyradius changes. In regular waves, at low frequencies of encounter, a lower gyradius resulted in less added resistance. However, at higher frequencies of encounter in regular waves, this trend reverses itself and the higher gyradii result in reduced added resistance. The peaks of the RAO curves shift to higher frequencies at higher gyradii. It was also concluded that at the higher speed, Froude Number of 0.3, the added resistance was lower relative to the still-water resistance for each gyradius tested. The irregular wave testing revealed the effect of the lower frequencies dominating the irregular wave spectrum. The minimum gyradius, in irregular seas showed less added resistance than the maximum gyradius. In addition, the irregular wave testing verified the reduction of added resistance, relative to still-water resistance, at increasing speeds for both the minimum and maximum gyradii.

Abstracts: 11th Chesapeake Sailing Yacht Symposium

Applications of Relational Geometric Synthesis in Sailing Yacht Design

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Relational Geometric Synthesis (RGS) is a new logical framework for building up precise definitions of complex geometric models from points, curves, surfaces and solids. RGS achieves unprecedented design flexibility by supporting a rich variety of useful curve and surface entities. During the design process, many qualitative and quantitative relationships between elementary objects may be captured and retained, such that they c an be utilized for automatically updating the complete model geometry following changes in the shape or location of an underlying object. Capture of relationships enables many new possibilities for par; metric variations and optimization. Examples are given of many potential applications in sailing yacht design: hull designs; deck and cabin models; interior partitioning and planning; keel model; with bulbs and winglets; hull and keel paneling for flow analysis; plating layout for metal hulls; mast and rigging models; white sails and spinnakers.

Refinements in the Techniques of Tank Testing Sailing Yachts and the Processing of Test Data

James R. Teeters, Sparkman & Stephens, Inc., New York, New York, USA

The Partnership for America's Cup Technology (PACT) undertook a tank test program in conjunction with the 1992 defense of the America's Cup. The focus of this program was on:
establishing baseline data, in both calm water and waves, for the American defense syndicates; addressing the "tankery" issues of test reliability and accuracy and expansion to full scale; developing the test program so that the tank serves as a more capable partner with computational fluid dynamics (CFD); improving the techniques of processing test data.

This paper reviews the results of the PACT program that pertain to the methods of calm water testing. Solutions to specific problems of handling tank data are discussed. Traditional methods used to predict viscous drag are compared with those developed by PACT, which include dynamic wetted area and wetted length, refinement of appendage drag estimates and the use of multiple canoe body form factors. The revised residuary drag that results from these improved methods is directly compared with CFD estimates.

Lastly, a mathematical model, employing least squares regression techniques, is discussed as a method for fairing and representing tank test data.

SPLASH Free-Surface Flow Code Methodology for Hydrodynamic Design and Analysis of IACC Yachts

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A unique free-surface flow methodology and its application to design and analysis of IACC yachts are discussed. Numerical aspects of the inviscid panel code and details of the free-surface boundary condition are included, along with enhancements developed specifically for the '92 America's Cup defense. Extensive code validation using wind tunnel and towing tank experimental data address several areas of interest to the yacht designer. Lift and induced drag at zero Froude number are studied via a series of isolated fin/bulb/winglet appendages. An isolated surface piercing foil is used to evaluate simple lift/free-surface interactions. For complete IACC yacht models, upright wave resistance is investigated, as well as lift and induced drag at heel and yaw. The excellent correlation obtained for these cases demonstrates the value of this linear free-surface methodology for use in designing high performance sailing yachts.

IACC Appendage Studies

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E. G. Sevigny, The Boeing Company, Seattle, Washington, USA
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Experimental and computational studies of several representative IACC appendage geometries were carried out to establish baseline data and verify computational models and methods.
Wind tunnel tests of an unheeled, unswept, constant section, rectangular planform keel mounted on a ground plane included force and moment measurements, and wake surveys at various angles of attack. Test configurations (all at constant draft) included the addition of ballast bulbs and winglets.

Correlations of computational results with experimental wind tunnel data were made. A502/PAN AIR potential flow induced drag predictions proved to be in good agreement with the wind tunnel data. Comparisons are also presented between A598 (A502 + boundary layer), wind tunnel results and empirical predictions . Again good agreement was shown for cases within the limitations of the boundary layer method.

Modeling IACC Sail Forces by Combining Measurements with CFD

Jerome H. Milgram, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA Donald B. Peters, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA D. Noah Eckhouse, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

A sailing dynamometer with a 42% scale model of an International America's Cup Class rig is

used to measure sail forces and moments in actual sailing conditions. The sailing dynamometer is a 35-foot boat containing an internal frame connected to the hull by six load cells configured to measure all the forces and moments between the frame and the hull. All sailing rig components are attached to the frame, so that the sail forces are measured. Sail shapes in use are determined by computer-interfaced video. Computational fluid dynamics performed on the measured shapes provides the induced drag. This allows the measured drag to be decomposed into induced and form-and-parasitic components, which is necessary for generating a mathematical sail force model for a velocity prediction program (VPP). It is shown that VPP results using these new sail force coefficients are in better agreement with actual performance than are VPP results based on traditional sail force coefficients.

Towards a Rational Upwind Sail Force Model for VPPs

Steven E. Euerle, Atlantic Applied Research Corporation, Burlington, Massachusetts, USA
David S. Greeley, Atlantic Applied Research Corporation, Burlington, Massachusetts, USA

A method for generating upwind sail force coefficients for arbitrary fore-and-aft rigs is presented, requiring a minimum amount of empirical data. Example calculations for an IACC boat showed that the resulting sail force model was quite realistic, and did not require any "tuning" of coefficients. Further developments of this technique are suggested, as well as the extension to off-wind sailing.

Numerical Approach to Aeroelastic Responses of Three-Dimensional Flexible Sails

Toichi Fukasawa, Kanazawa Institute of Technology, Ishikawa, Japan
Masanobu Katori, Yamaha Motor Company, Ltd., Shizuoka, Japan

Aeroelastic responses of 3-dimensional flexible sails are investigated by means of numerical simulations. An incremental finite displacement theory using the Finite Element Method is adopted to describe the structural behavior of the sail. A modified Vortex Lattice Method is used to calculate the aerodynamic pressures on the sail. Combining these two methods, the structural and aerodynamic responses of the sail are solved simultaneously.

Numerical simulations are performed for actual 3-dimensiona1 sails. Deformations and stresses of the sail in steady flow are calculated. Unsteady sail dynamics are also investigated in the case where the sailing vessel is pitching and rolling in a seaway. The effects of the flexibility of the sail upon the lift, induced drag and the center of effort are clarified.

A Review on Il Moro di Venezia Design

Mario Caponnetto, University of Genoa, Genoa, Italy

The design of a boat for the America's Cup has always been a challenging task for any naval architect. While in the past the success of the boat was mainly a question of sensibility and experience of the boat designer, lately the increasing technologies and economical means usually

at the disposal of the syndicates provides great potential. Both experimental and theoretical tools require a specific technical knowledge of the matter, which leads to the involvement of many specialised people in different fields. For this reason a big managerial effort is required to organize and collect data and ideas coming from different fields.

This paper summarises the first experience of the "Il Moro di Venezia" syndicate in dealing with the design methodologies from the Hydrodynamic point of view. While a great part of the collected data are still of confidential nature, here a brief history of the design work and some peculiar aspects regarding the use of tools like the towing tank, the wind tunnel, the CFD codes and the VPP are presented.

The Nippon Challenge America's Cup 1992 - Progress in Hull Development

Yoshihiro Nagami, Yamaha Motor Company, Ltd., Shizuoka, Japan

In 1992, the class rule for the America's Cup was changed to the IACC. The Nippon Challenge decided that in order to build a successful challenger to a new class rule, the design would have to rely heavily on the results of a systematic series of tank and wind tunnel testing. The results of these simulations would then be used to build full scale boats which would be tested. The results of the full scale trials would be used to adjust the simulation techniques to fine tune the final design.

The data from the model tests were used to develop the input parameters for a Velocity Prediction Program (VPP) . The VPP was used to determine the specifications for the design of the first two boats. After full scale testing, the VPP was compared to the results for about 6 months. After this verification and refinement of the VPP, a final boat was built. Finally, the results of the race were evaluated and confirm that the basic design development process was correct.

How to Go Cruising

James O. Hays, Annapolis, Maryland, USA
Anne M. Hays, Annapolis, Maryland, USA

What follows is based upon our own experience and observations while cruising to the Hudson River and the Great Lakes, up and down the East Coast to Maine and around to the west coast of Florida, and across the Gulf Stream to the Bahamas and twice to the Caribbean. We are well aware that we have not learned everything that the cruising life has to teach - and we hope to go back for further lessons. Our goal is simply to pass along whatever we have learned that might be of interest to others who may wish to go cruising, and we ask you to read it in that context.

Notes on Sailing Ship History: Academy Versus Shipyard

Olin J. Stephens, II, Hanover, New Hampshire, USA

The history of sailing ships exhibits separate, but roughly parallel, paths toward the present: the academic or technical and the actual, i.e. the way vessels have been built. It is this paper's objective to sketch the development of these two courses and to suggest the interaction of theory and experience as one approach influenced the other, and to point out the growing influence of theory and the still required place of experience and even art.

The A-Class Catamaran: Development of Serious Fun

Robert G. Beadling, Annapolis, Maryland, USA Walter H. Beadling, Stuart, Florida, USA

The A-Class Catamaran is the most popular development class of sailing catamaran in the world today. This paper is a comprehensive look at the history of the class in terms of both its technical development and the progression of its racing activity. Discussion of design elements and performance characteristics of this 18 foot singlehander are also provided along with speculation on the direction of future development.

Dynamic Performance of Sailing Cruiser by Full-Scale Sea Tests

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The sailing performance of a 10.6m-LOA cruiser was evaluated by sea test and the results were compared with calculated values and numerical simulations. The sea test was carried out to examine the steady sailing performance as well as the dynamic performance which includes the motion in waves and tacking maneuverability of the boat. The sailing state parameters at the steady condition were compared with the results of the velocity prediction program, and the results were in good agreement.

The motion of the boat in waves was assessed in conjunction with wave measurements using a throw-in type wave meter. These data were analyzed by means of spectral analysis. The results indicated the sail damping effect on the rolling motion quantitatively.

The tacking motion of the boat was also investigated. The trajectory of the boat was measured using differential GPS receivers, and these results were compared with the numerical simulation. The simulation showed good agreement with the sea test data.

Hazards and Challenges of Cruising the Northeast Coast of North America

Edwin C. Jordan, Marine Independence Associates, Chevy Chase, Maryland, USA Mary K. Jordan, Marine Independence Associates, Chevy Chase, Maryland, USA

This paper is not intended to cover the basics of cruising or even the basics of long distance cruising. We hope it is a more advanced discussion of strategies and equipment which we have found useful in meeting the challenges of our trips. These cruises have been from the Chesapeake Bay to Massachusetts, Maine, Nova Scotia and, this past summer, to Newfoundland. The paper is not about racing, nor is it concerned with any type of racing/cruising. We will be

concerned not only with the hazards and challenges of cruising and what works in meeting these challenges, but also how to have a good time in addition to being safe. Both offshore sailing and harbor hopping will be included, seen from the perspective of a couple and their friends who have accompanied them on selected legs of seven different trips north.

The Partnership for America's Cup Technology: An Overview

James A. Gretzky, Gretzky and Associates, Inc., Baltimore, Maryland, USA John K. Marshall, The Hinckley Company, Southwest Harbor, Maine, USA

A discussion is presented on the organization and operation of the Partnership for America's Cup Technology (PACT). Founded in February 1990 when individual American syndicates were unable to fund productive research and design programs, PACT'S mission was to help the U.S. America's Cup Defense overcome the technical lead held by several foreign challengers in the new International America's Cup Class (IACC). PACT was to conduct cooperative technology development projects relevant to IACC yacht design to support all U.S. syndicates competing to defend the America's Cup.

PACT had four major programs: gathering site specific environmental data; testing parametric series of hulls or appendages with associated improvements in testing methods; developing Computational Fluid Dynamics tools benchmarked by suitable experiments; developing and maintaining VPP centered design evaluation software.

Since PACT was not involved in design itself, American syndicates maintained their own proprietary high level design programs. In areas where syndicates did not have comparable research programs, PACTs work was integrated into the syndicate design process and often played a role in their final designs. When PACT programs overlapped existing syndicate research, PACT provided a valuable second opinion.

Planning and conducting PACT research was a team effort involving syndicate representatives and independent researchers. Regularly scheduled meetings and formal reports were used to distribute information to the American Syndicates.

Stars and Stripes Design Program for the 1992 America's Cup

Chris Todter, Team Dennis Conner, San Diego, California, USA David Pedrick, Team Dennis Conner, San Diego, California, USA Alberto Calderon, Team Dennis Conner, San Diego, California, USA Bruce Nelson, Team Dennis Conner, San Diego, California, USA Frank Debord, Team Dennis Conner, San Diego, California, USA Dave Dillon, Team Dennis Conner, San Diego, California, USA

The Team Dennis Conner (TDC) design program for the 1992 America's Cup is presented in an overview form. The team members are listed. The spectrum of design tools available are discussed, highlighting the usefulness and emphasis of each. The design tradeoffs will be presented in general form, including a discussion of the monoplane/multiplane appendage tradeoffs. The importance of the structural design aspects and methods will be presented. An

appreciation of the full size performance feedback to the design will be covered.

Elements of Resistance of IACC Yachts

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Resistances due to hull friction, appendage friction, wavemaking, heel and side force, and sea waves are considered. Comparative values of each of these resistance components for four boats, including one with two different sets of appendages, are shown. Most of the resistance components are accurately determined by a combination of theory, numerical computation or model testing. An exception is the resistance due to sea waves for which nonlinear effects not accounted for in present theories appear to be significant. Some design features which increase resistance have associated speed-increasing effects. An example is increasing the vessel beam which increases wetted surface, and therefore the frictional resistance, but has an associated increase in potential sail power. This demonstrates the necessity of evaluating the entire system with a good velocity prediction program rather than using an evaluation based on a few resistance components.

Sailing Yacht Performance in Calm Water and in Waves

J. Gerritsma, Delft University of Technology, Delft, The Netherlands J. A. Keuning, Delft University of Technology, Delft, The Netherlands A. Versluis, Delft University of Technology, Delft, The Netherlands

The Delft Systematic Yacht Hull Series has been extended to a total of 39 hull form variations, covering a wide range of length-displacement ratios and other form parameters. The total set of model-experiment results, including upright and heeled resistance as well as side-force and stability, has been analysed and polynomial expressions to approximate these quantities are presented. In view of the current interest in the performance of sailing yachts in waves, the added resistance in irregular waves of 8 widely different hull form variations has been calculated. Analysis of the results shows that the added resistance in waves strongly depends on the product of displacement-length ratio and the gyradius of the pitching motion.

Seakeeping and Added Resistance of IACC Yachts by a Three-Dimensional Panel Method

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A three-dimensional panel method developed for the prediction of the seakeeping properties of conventional ships has been extended to predict the motions and added resistance of IACC Yachts. The method solves the three dimensional unsteady potential flow around the yacht in monochromatic oblique waves. Predicted quantities include the heave and pitch motion amplitudes and phases and added resistance over a broad range of wave frequencies yacht speeds. Computations have been carried out for a series of IACC hull shapes studied by PACT

(Partnership for America's Cup Technology) and correlations with experimental measurements are found to be very satisfactory. The same method was also used to study the added-resistance properties of hull shapes supplied by the America3 Foundation. A sensitivity analysis was carried out of the added resistance on the principal yacht hull shape parameters, including the slenderness, displacement, LCB-LCF separation and pitch radius of gyration.

The Effects of Flare and Overhangs on the Motions of a Yacht in Head Seas

John C. Kuhn, Science Applications International Corporation, San Diego, California, USA
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The coupled heave and pitch motions of hull forms with flare and overhangs are examined numerically. The presence of flare and overhangs is numerically modelled with nonlinear hydrostatic and Froude-Krylov forces based on integrals over the instantaneous wetted surface. Forces due to radiation and diffraction are computed with a linear strip-theory. These forces are combined in two coupled nonlinear differential equations of motion that are solved in the time domain with a fourth-order Runge-Kutta integration method. An assessment of the impact of flare and overhangs on motions is obtained by comparing these nonlinear solutions with solutions of the traditional linear equations of motion, which do not contain forces due to flare and overhangs. For an example based on an International America's Cup Class yacht design, it is found that the nonlinear heave and pitch motions are smaller than the linear motions. This is primarily due to reduced first-order response components, which are coupled with nonlinear response components. Comparisons of these results with towing tank data demonstrate that the nonlinear procedure improves prediction quality relative to linear results. In support of this numerical work, the hydrostatic and Froude-Krylov force integrals are expanded in Taylor series with respect to wave elevation. These results indicate how hydrostatic and Froude-Krylov forces change with changing flare and overhang angles, revealing that sectional slope has second and third-order effects on forces while sectional curvature and overhang angles produce third-order effects.

Analysis of Lift and Drag on a Surface-Piercing Foil

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Carl A. Scragg, Science Applications International Corporation, San Diego, California, USA

Hydrofoils operating at shallow depths (e.g. keels and rudders) will be affected by the interactions between the lifting surfaces and the free surface. This problem is approached computationally and experimentally by examining the simple case of a surface-piercing hydrofoil operating at steady forward speeds and small angles of attack. It is shown that there are two contributions to the lift and drag on the foil, one due to the vorticity shed into the wake and another due to the port/starboard asymmetry of the radiated wave field.

The mathematical problem is specified as a linearized boundary-value problem to be solved numerically. The two contributions to the lift and drag on the foil are determined independently from far-field momentum integrations. Calculations of the lift and drag on surface-piercing foils with variations in aspect ratio and heel angle are compared to experimental results. Comparisons of the predicted and measured radiated wave fields generated by the foils are also presented. It is found that the efficiency of the foil is reduced by the presence of the free surface and that the use of simple reflection-plane models can lead to significant errors.

Performance Prediction Software for IACC Yachts

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The performance prediction software development effort undertaken by the Partnership for America's Cup Technology (PACT) is reviewed. First, PACT'S origin, members, and mandate is covered, interspersed with a historical perspective of prediction software. Next, the new IACC rule with constraints is given. The Hydrodynamic model format used in the software is described. Based on PACT tank test data, improved formulations for viscous drag, utilizing dynamic wetted area and length for canoe body drag and a 'stripping' method for appendage drag are presented. Corrections for Froude number and heel effects on induced drag are summarized. A new upwind sail model and added resistance model are discussed. The use of a race modeling program is illustrated with results from three separate design studies: a geosim family, a length scaling family, and an appendage study. Typical upright resistance, drag polar plots, lift plots, sea spectra, and added resistance data are presented. The final section describes current developments including speed enhancements, improved portability, and use of a multi-variable, non-linear optimization scheme to search the design space.

Abstracts: 12th Chesapeake Sailing Yacht Symposium

Scoring IMS Regattas - An Empirical Study of Alternative Methods

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The International Measurement System (IMS) uses a computerized velocity prediction program (VPP) to calculate the performance of a measured hull and rig in winds from six to twenty knots, at any sailing angle. A regatta is scored by comparing a yacht's performance with predictions of the VPP. The winner is the yacht whose performance, relative to its VPP predictions, is the best, compared to all other yachts in its class or division.

This paper discusses different methods of making the comparison and accounting for various factors in the race such as wind shifts and current on the course. Decisions made by race managers and/or developers of scoring programs can significantly impact results. Illustrative examples show the effects that these decisions can have.

In 1994 the number of data points available for use in scoring yachts in custom courses doubled. Alternative ways of using these data are illustrated by application to a sample regatta.

Drawing with Performance Prediction

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We describe some advances in Performance Prediction Programs - "PPP"1 for sailing yachts2 - primarily integrating PPP analysis into drawing and providing new sculpting operations in which fairness and desired hydrostatic and other performance determining characteristics are maintained - the shape remains a boat or a ship of the desired kind during reshaping.

Our building blocks for such an integration are: a thousand-fold increase in PPP speed3, new editing tools which maintain Boatness, and an accessible modularization of the engineering physics of the PPP within a new programming environment which allows immediate changes by designers.

Specifically, these new functions are introduced at the boundary of Drawing and (the PPP:

- A live knotmeter is displayed with each design variant on the drawing board - alongside it's antagonist - Rating.
- Continuously updated hydrostatics (including the speed determining factors LSM, wetted surface, stability, prismatics, ..) are displayed with the knotometer, with the 'positive' factors (like length) graphically opposing the 'negative' (like wetted surface.)

• Dimensions for PPP use are calculated automatically from the shape at hand - in particular: appendage dimensions, hydrostatics, and so forth
• Bounding limits are set for a design optimization by drawing two or more outlier yacht forms. The space in between can be explored by hand or automatically.
• Local optimums of Speed against rating are provided as a 'Snap' function. This is the one dimensional version of automatic exploration for optima.
• Intermediate shapes are also controlled during design optimization to maintain realism and performance constraints on type, fairness, 'look', speed producing shape measures like prismatic and displacement etc., and even handicap.
• Immediate feedback is available if one chooses to exploit the new programming environment to make aero hydro model changes or extensions to the internal PPP mechanisms while drawing and exploring.

Design Criteria for Composite Masts

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Composite materials such as fiberglass have been used in recreational marine craft for over 30 years. Only within the last decade however have composites found applications in mast construction. This application to masts is due to the lighter weight possible by using composites such as carbon fiber/epoxy that have higher stiffness-to-weight rations than the traditional aluminum and wood mast materials. Composites use in masts has not been without problems however as designers and manufacturers learn the techniques necessary to produce reliable structures. As with any maturing technology, empirical developments will eventually result in acceptably reliable structures.

This paper uses a reliability-based design criterion to aid composite mast development. The basic approach characterizes the uncertainties and variabilities of mast design (loads, materials, analytical models, etc.) to predict a total uncertainty called "the probability of failure." The total probability of failure is then compared to "acceptable' probabilities of failure generated from existing aluminum mast designs to determine an appropriate factor of safety.

This approach takes the guesswork out of factor of safety selection, giving the mast designer an important tool. By using reliability-based methods the influence of each part on the overall probability of failure can be determined. This allows for intelligent selection of design areas to improve that provide the biggest potential gain in reliability, cost or weight, and decreases the likelihood of either an overly-conservative, heavy mast, or an under-designed mast.

The paper begins with the causes of mast failure and then presents the impact of load modeling, material properties and structural modeling on predicted mast reliability. An example mast design is used to illustrate the method, with the result that a composite mast can be designed at nearly the same factor of safety as an aluminum mast.

The Development of the B&R Rig, Structural Space Frame and Tripod Support System with Integrated Boom

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Sven Olof Ridder, B&R Mast and Rigging Designs, Sarasota, Florida, USA

B&R Designs began business in the early sixties when Sven Ridder and Lars Bergstrom began sailing after studying aeronautical engineering. The principles learnt during their aeronautical studies were applied to sailboats and the goal, for them, has been to take up the structural loads in the most constructive way. Access to the wind tunnels, test tanks and structural testing facilities at the Royal Institute of Technology in Stockholm enabled them to develop and test many ideas. One of these ideas evolved into the B&R rig.

The objective was to develop a rig that was more 'user friendly'. Sailboats, thirty years ago and even today, are often fitted with inner forestays and running backstays requiring careful attention by the crew when tacking or jibing. A rig with less demands was the goal, one that was simpler and any mistakes made when tacking or jibing would not jeopardize the boat or crew. Also a simpler rig would require fewer crew members. Safety was another important consideration - a rig that was simple, easy to manage, suitable for a couple or family for cruising.

During this rig development period the first application of the rigid boom vang concept was used on Sven Ridder's own sailboat 'Christina Windex'. Calculations and model testing of rigs were carried out. Optimizing the aerodynamic effect in the most favorable way was a very important aim. A series of wind tunnel tests were done to optimize the shape of mast sections. Because of the low wind speeds over a mast, laminar separation occurs very easily. Air scoops were set up on either side of the mast to achieve an attached flow. The best results occurred with an oval shaped mast section, fitted with a sail groove recessed in a V shaped area at the rear of the mast section.

The Alexandria Class Dinghy - A Design For Change

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The trade and skills of wooden boatbuilding began to die with the development of fiberglass reinforced plastic boats, and long before 1992 wooden boatbuilding was considered a dead industry. Still, the building of a wooden boat was something that could catch a child's attention; to build and sail a boat of one's own could be a consuming project that would set a pattern for life. In 1990 a program began to build on this premise: to reach out to the troubled youth of the inner cities, teach useable skills, self confidence, and pride of accomplishment by teaching youths to build small wooden boats, then teaching them to sail the boats that they built.

Design, Construction, and Performance of a 27' MORC Boat

Brian A. Jones, Annapolis, Maryland, USA

This paper describes the design, construction, and performance of the 27 foot sailboat "Problem Child". The design segment includes the reasons for undertaking such a project, the thought processes that shaped the boat, and the tools used to put the ideas on paper. The construction portion describes building the strongback, laying up the hull and attaching the keel, deck hardware and mast and the launching. A description of construction materials and processes is also included. Finally, an analysis of the performance, strengths and weaknesses and lessons learned provide feedback to assess the original design concept.

Imagine - an Open Class 60 BOC Racer - Design and Program Management - Lessons Learned

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This paper describes the creation of the Open Class 60 (BOC 60) racing yacht "Imagine". She was conceived to win the 1994 BOC singlehanded round the world race, an ambitious goal since the French sailors have dominated the race since its inception. This paper will examine the design of this complex racing machine, and the management of the project. The project produced a boat that was capable of attaining the goal of winning, but when the project management office failed to adhere to the project plan, the project unravelled and collapsed.

In a squall at sea, at night, off Cape May, New Jersey, "Imagine's" boom failed, the main sail was dropped, and in the resultant short steep seas, "Imagine" slammed badly, dishing plating at both ends of the vessel, causing two forward frames to trip, and resulting in other structural damage to forward deck longitudinals and in the cockpit. "Imagine's" hull remained watertight, and she returned to Norfolk under short sail. Upon arrival she was inspected, and the necessary repair steps were outlined. These were discussed the following day with the project office and the ABS inspector. Within days drawings were provided to the project office for repair and to ABS for review. At that point matters stalled, no repair was started and within two weeks the project office announced their intent to abandon the project.

The project plan will be reviewed, the basis for the design will be discussed, the incident at sea which precipitated the project's disbanding will be examined, and an analysis of the resultant damage given. Lessons learned from the project will be discussed.

The actual design of the boat was interesting and rewarding, but it was a small part of the goal of the project. The goal was not attained, and when the BOC race started from Charleston in September 94, "Imagine" remained at the dock, her outfit and development incomplete. This paper will attempt to evaluate the reasons why. Two central themes repeat: lack of funds and lack of sea trials. In our opinion it was this lack of funds, that

led the project office to eliminate carefully planned steps in "Imagine's" development, specifically the sea trials. This also lead them to attempt an offshore voyage from Norfolk, Virginia to Newport, Rhode Island in November 1993, prior to sea trials, with a known defective boom, and a jury rigged boom vang.

The Design of Yacht Sailplans for Maximal Upwind Speed

Dr. Sandy Day, University of Strathclyde, Scotland

A great deal of research, both computational and experiment based, has been carried out on the optimisation of hull geometry for minimal hydrodynamic resistance; however, rather less effort has been expended on the equivalent problem of optimising the sailplan geometry. The goals of the optimisation procedures which have been adopted for sail optimisation are somewhat diverse; some researchers have concentrated on the maximisation of aerodynamic drive force, with or without constraints on heeling moment, whilst other approaches have included simple representations of hydrodynamic sideforce and induced drag. Much of the work has concentrated on optimisation of the distribution of aerodynamic lift over the sailplan without specifying how the lift distribution may be achieved in practice -if indeed the lift distribution can be obtained within the practical constraints of conventional rig technology.

It is argued here that, from the point of view of yacht design, an appropriate goal for the optimisation is the selection of the sailplan geometry which yields the best performance for a given hull form over a suitably weighted range of windspeeds. In this work, the aspect of performance considered as being of primary importance is upwind speed. A method is presented by which the principal dimensions of the rig - luff length, foot length etc. - may be chosen so as to maximise upwind or close reaching speed for a particular yacht in a given wind strength.

The aerodynamic performance of the rig is predicted using a non-linear vortex lattice model; viscous effects, including the effect of the mast, are included using an ad hoc approach based on two dimensional experiment data. The hydrodynamics and hydrostatics of the hull are obtained using a performance prediction approach based on the well known Delft yacht hull series. Optimisation of the rig geometry is carried out using a stochastic technique known as a structured genetic algorithm.

Results are presented for two variations on the sloop rig; the first employs a mainsail with an essentially triangular planform, whilst the second allows the inclusion of a substantial roach, leading to sails of the form normally associated with full length battens. The hull forms considered include typical examples of both modern and slightly older racing yachts. The sensitivity of the geometries obtained to constraints unrelated to upwind speed - such as structural integrity or Offwind sail carrying capability - is also illustrated.

Tacking Simulation of Sailing Yachts - Numerical Integration of Equations of Motion and Application of Neural Network Technique

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The question, "What is the best tacking procedure?", has challenged sailors for a long time. In order to answer this question, it might be best to clarify the mechanism of tacking motions of sailing boats theoretically. However, tacking is a complicated maneuvering motion. Many factors affect tacking, including maneuverability, rolling characteristics, sail performance, etc. The first step to tackle this problem, therefore, is to make a proper model which represents tacking motions. In the present paper, two models are proposed to represent the tacking motions of sail boats. One is a mathematical model and another is a neural net work model.

In the mathematical model, the tacking motion of the boat is described by partial differential equations with the coordinate system using the horizontal body axes. The hydrodynamic derivatives of the equations are mainly given by model test results and/or full scale measurements. Such coefficients as added mass and added moment of inertia are calculated using the strip method. These equations are integrated using a time integration method.

In the neural network model, on the other hand, the tacking motion of the boat is regarded as a neural network system consisting of several layers. In the present paper, two hidden layers are used besides the input and output layers. The network constants are tuned using back-propagation procedure. If the rudder angle is inputted, the boat motion can be obtained step by step using the network.

Comparing the results obtained by these two methods with the full-scale experiments of a sailing boat, the merit and the demerit of these models are discussed.

Wing - Body Interaction on a Sailing Yacht

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Model tests have been carried out in the Delft Shiphydromechanics Laboratory with a 3.5 meter model of an 1992 America's Cup yacht. The keel (without the bulb) and the rudder have been islolated from the hull and connected to seperate force transducers placed inside the hull in order to be able to measure the lift, the drag and the moment around a horizontal axis on these appendages while being in their regular position underneath the model, as well as on the model as a whole. The experiment consisted of the regular "upright" and "under leeway and heel" tests as customarily performed in the standard testing routine for sailing yachts of the Delft Shiphydromechanics Laboratory. The model tests have been carried out with four different configurations of the model, i.e.:
hull with keel and rudder

hull with keel alone
hull with rudder alone
bare hull

By combining the results of all these tests it became possible to evaluate the drag- and lift-interaction of the appendages on the hull and from the hull on the appendages under all conditions of sailing. The results of this analysis of the measurements will be presented in the paper.

In addition these results will be compared with the results obtained from calculations using the CFD panel methods DAWSON and RAPID.

Improvement of Sailing Yacht Performance Prediction by Including Force-Moment Equilibrium for the Calculation of Helm Angle in a Velocity Prediction Program

Dr. Peter van Oossanen, Van Oossanen & Associates, Wageningen, The Netherlands

Contemporary Velocity Prediction Programs (VPP's) consider the equilibrium of forces acting on a sailing yacht in the thrust direction and in the direction of the developed side force on canoe body and appendages. In addition, force-moment equilibrium is considered in the transverse plane of the yacht. In this way a solution is found for the three main unknowns in performance prediction, viz: boat speed, leeway angle and heel angle. The impact of helm angle on performance is herein ignored.

In the velocity prediction program developed by Van Oossanen & Associates, a fourth equilibrium condition is included, viz: force-moment equilibrium in the horizontal plane for the calculation of the helm angle required for the equilibrium sailing condition. In this paper a description is given of some of the main problems that need to be solved when introducing this fourth equilibrium requirement. One of these is associated with the development of accurate mathematical expressions for the calculation of rudder side force and resistance, as influenced by heel angle and the proximity of the free surface. Model tests can be utilized for obtaining insight into the physical phenomena involved in such cases. Model tests were carried out; in the context of an optimization study for the design of a yacht according to the International Level Class 40 (ILC40) Rule, under the International Measurement System (IMS). The analysis of some of the results of these tests with respect to improving the mathematical model for rudder side force and resistance, is described in the paper.

The effect of including this mathematical model in a VPP is demonstrated in the paper by providing the results of calculations which reveal that a variation in rudder angle causes significant speed differences. It is shown that the IMS VPP that is used to calculate the rating and speed potential of ILC40 and other IMS Class yachts, in not taking into account the significant variations in performance associated with different values of the equilibrium rudder angle (and the associated rudder side force and resistance), is not sufficiently accurate.

YACHT97: A Fully Viscous Nonlinear Free-Surface Analysis Tool for IACC Yacht Design

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A novel free-surface computer program, used to calculate the viscous flow field about a full configuration sailing yacht, is presented. The numerical techniques incorporated into the computer program - YACHT97 - facilitate accurate quantification of the residuary and the frictional drag components through the use of a "moving" computational grid which conforms to the exact wetted surface area of the hull. Use of a full field approach, whereby the entire flow domain is discretized, permits the simulation of the boundary layer and wavemaking interaction as well as the onset of vortex structures which appear downstream of lift producing appendages. A recently implemented free-surface discretization permits the bow wave evolution to proceed to the near-breaking point. Computed results include comparisons between the inviscid and viscous flowfields about a bare-hull configuration and a full configuration with keel and rudder appendages.

Abstracts: 13th Chesapeake Sailing Yacht Symposium

On Test Measurements in Full Scale Sailing Test Programs

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At Mystic Seaport Museum a project was begun in 1992 to determine sail coefficients for schooners for sailing technology research and historical vessel research. Since computational fluid dynamics techniques and wind tunnel techniques have not yet been developed to the point where sail coefficients can be developed accurately, the experimental approach was adopted. Full-scale sailing tests of schooner Brilliant were performed at Mystic, Connecticut. Tow-tank tests of a 1/9 model were completed at Davidson Laboratory, Hoboken, New Jersey. Three previous experimental programs for sloops were reviewed, notably Gimcrack (Davidson, 1936), Bay Bea (Kerwin, 1974), and Standfast (Gerritsma, 1975).

One goal of the Brilliant program was to reduce uncertainty in sail coefficient measurement. The uncertainty in previous programs illustrates the inherent difficulties. Despite the uncertainty the results were extremely useful and provided a benchmark for further improvements in sail coefficient programs.

Procedures used are described. Preliminary results indicate that the uncertainty is reduced to about 10%.

The topics covered are: (1) a description by Olin Stephens of previously unpublished details of the equipment and methods used to take data on the sloop Gimcrack, as applied by Davidson reported in his landmark 1936 paper, and some thoughts on the way the information gained from early studies was used; (2) extension of the Gimcrack sail coefficients to the heel plane; (3) a review by Howard Grant of the measurements in the schooner Brilliant program, including correction for ship/wind interference, use of cross checks including chase boat true wind solutions and internal consistency techniques (Ockam, 1992), and unique time-correlations to handle non-steadiness; (4) a hindsight view of program shortcomings, which included the omission of measurements at several heights above the deck of wind and sail shape that would have been helpful to CFD studies of sail aerodynamics.

Full Scale Measurement of Sail Force and the Validation of Numerical Calculation Method

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Sail forces were measured in a full-scale sailing boat with the use of a sail force dynamometer. This apparatus consisted of an aluminum frame fixed to the hull by way of several load cells. The sailing boat was modified so that the dynamometer frame could be installed inside the hull. The mast, stays, winches, and other sailing rig were fixed on the

frame so as to transmit all the forces acting on sail to the frame. By transforming the measured forces, the lift force, drag force, thrust, side force, or the center of effort of the sail force could be obtained. The sailing conditions of the boat, such as the boat speed, heel angle, wind speed, wind angle, and so on, were also measured.

Sail shapes of the boat in the up-wind condition were also measured with the use of CCD cameras installed in the boat. The sail shape images taken by the cameras were transformed to bit-map files, and then processed by an SSA-2D, a sail shape analyzing software. With the use of this software, sail shape parameters were obtained. The relationship between the measured sail forces and the sail shape parameters is discussed in this paper. Moreover, the measured sail shapes were used as the input data for the numerical calculations.

Numerical calculations were performed to estimate the sail forces of the boat. In the calculations, two sails, a mainsail and a jib, were modeled in the form of a vortex lattice. The vortex lattice method was adopted as the numerical calculation method. Step by step calculations were conducted up to attaining the steady state of the sail in steady wind. Calculated sail forces were compared with the measured forces, and the validity of the numerical method was studied.

An Investigation of Full Scale Forces Produced by a Sail

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Ian Mutnick, David Taylor Model Basin (CRDKNSWC), West Bethesda, Maryland, USA

The problem of accurately predicting the performance of a sailing vessel has been researched since the turn of the century. Improvements in sail construction and materials have placed greater importance on optimizing sail aerodynamics. The goal of this research was to devise a testing method which would allow simple, inexpensive testing of sails to be conducted. This effort culminated in the design and construction of an outdoor sailing dynamometer which can measure all of the forces and moments produced by a sail. The apparatus is capable of testing full-size dinghy rigs or scaled-down offshore racers. It may be used both for rig selection and for the evaluation of different sail designs. High quality results may be achieved with a minimum expenditure of time and capital.

Optimisation of a Sailing Rig using Wind Tunnel Data

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A number of wind tunnel tests have been conducted by the Wolfson Unit in aid of the development of sailing rigs for both cruising and racing boats, including recent tests for the United States Sailing Association as part of the joint IMS/PHRF research programme. In the process of these tests developments have been made in both the test techniques and the analysis methods, which have enabled the components of drag to be identified for different sail settings. This paper describes the tests for evaluating the upwind rig performance of a sloop and compares the components of drag with those in the

aerodynamic model used in the IMS VPP. The aerodynamic behaviour of the rig is described using plots of the variation of sail forces and moments with sail settings with the aim of helping sailors understand the effects of changing sail settings. It is shown that the wind tunnel data match closely the IMS aerodynamic model and that this model can be simply programmed by sailors and designers into a spreadsheet to enable the rig planform to be optimised for particular conditions. The results are compared with those obtained using a full VPP calculation.

Model Tests in Support of the Design of a 50 Meter Barque

Barry Deakin, Wolfson Unit MTIA, University of Southampton, UK

This paper describes a programme of model tests and computer predictions which was designed to assist in the selection of a hull design for a new ship, and ensure that it would meet the owner's requirements. Whilst that is a common requirement of model tests, this case was unusual because the subject was a 50 metre wooden sailing ship for disabled crews, and a choice had to be made with regard to a wide range of operational requirements.

The paper describes the background to the project, the scope of the testing, the presentation of the results, and their implications for the design. A general outline of the whole project is given, rather than details of specific tests or results, because of the dual limitations of space and confidentiality to the client, Tony Castro Ltd. It is hoped that the paper will provide an illustration of the range of investigations which are now available to assist in the design stages of any sailing vessel.

The Restoration of AVEL

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Avel is a fine example of early yacht construction; fitting into the evolution of boatbuilding practices found in the pilot cutters and other working craft being built in the late 1800's in the British Isles. She was even built with similar materials: English white oak and elm, American long leaf yellow pine, and wrought iron drifts. Her salon paneling of teak and long-leaf yellow pine could have been found on Rene B, a pilot cutter from Barry. Chief differences would have been her teak topsides, non-ferrous plank fastenings, and perhaps her wrought iron floors, hanging, and lodging knees. This paper with it's complimentary slide show is a thorough description of Avel's restoration, in which approximately 70% of the original fabric of her hull and interior were kept intact.

BATOPERF, A Performance Prediction Software and Its Influence on Modern Yacht Design

Sylvain Fargeas, Juan Kouyoumdjian Yacht Architecture, La Rochelle, France Juan Kouyoumdjian, Juan Kouyoumdjian Yacht Architecture, La Rochelle, France

BATOPERF considers the equilibrium of the forces acting on a boat when sailing in the thrust and in the canoe body and appendages side force directions. A transverse plane force moment equilibrium is also considered solving for three principal unknowns: boat speed, leeway and heel.

In this paper an overall description will be given of the fundamental solving principles of BATOPERF and its force models.
Finally a comparison will be made against the IMS VPP in the context of the importance of accurately predicting boat speeds when designing an IMS boat.

Development of Proposed ISO 12217 Single Stability Index for Mono-Hull Sailing Craft

Dr. Peter van Oossanen, Van Oossanen & Associates, Wageningen, The Netherlands

For more than 5 years now, Working Group 22 of Technical Committee 188 of the International Standards Organization (ISO) has been developing a standard for the assessment and categorization of the stability of pleasure craft with a length up to 24 m. This work became necessary when the European Union decided to issue a Directive on Pleasure Craft, facilitating the export and import of pleasure craft to and from the various countries comprising the European Union. All newly-built pleasure craft up to 24 m in length, to be marketed in the European Union, must comply with the stability standard being developed, and some 50 other ISO standards, covering all aspects of structure, materials, equipment, etc, as of June 1998.

To support the work of Working Group 22, The Netherlands carried out a comprehensive study for Part 2 of ISO 12217, covering the stability of mono-hull sailing craft. Together with the French, Swedish and UK delegates, this work finally lead to the development of a single stability index. Working Group 22, in September 1996, unanimously agreed to adopt this concept for the assessment and categorization of the stability of mono-hull sailing vessels. This paper gives a description of some of the work that was carried out by the Netherlands in this regard and gives a description of the single STability IndeX (STIX) concept and the way the STIX value is determined from the various stability and buoyancy properties of sailing vessels.

The Cogito Project: Design and Development of an International C-CIass Catamaran and Her Successful Challenge to Regain the Little America's Cup

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In January 1996, Cogito, the U.S. challenger, defeated the Australian defender, Yellow Pages Edge, by the score of 4-0 in the twenty-second running of the International Catamaran Challenge Trophy. This brought the trophy better known as the Little America's Cup, back to the United States after an eleven year stay in Australia.

The Cogito project was three years in length and encompassed the design/construction phase, initial sailing and tuning at her home the Bristol Yacht Club in Bristol, Rhode Island, and the final training and competition at the race venue, McCrae Yacht Club on Port Philip Bay south of Melbourne, Australia. This paper will cover all phases of the project from the design through the racing.

The Institute for Marine Dynamics Model Yacht Dynamometer

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The National Research Council of Canada's Institute for Marine Dynamics in December 1992 undertook to design and commission a new generation model yacht dynamometer capable of testing one third scale models of International America's Cup Class yachts in waves, and half scale models in calm water. A performance specification was set, and it was decided to base the design on flexible link technology similar to that used in wind tunnels. Finite Element models of the design were constructed and theoretically loaded to determine natural frequencies in drag, lift, and roll, as well as system compliance under static loads. The dynamometer is a four-component balance (lift, drag, roll moment, and yaw moment) with a theoretical minimum crosstalk determined by the ratio of flexural to axial compliance of the flexible links, approximately 23,000:1. In individual cells this reduces the moment delivered to the load cells. In the system, it reduces crosstalk, the theoretical minimum is approximately 1:4600. In practice, however, the measured cross-talk did not approach the theoretical limit of the dynamometer and a calibration rig was designed to determine the actual crosstalk to be used in software correction of the data.

This paper covers the basic design of the dynamometer, error analysis, calibration and crosstalk determination, and repeatability of results. The conclusion is that it is now possible to obtain a quality of data from the tow tank previously obtainable only in wind tunnels. Not only has this made possible a better job of the types of experiments previously done in tow tanks, but has also made possible new experiments. In particular the evaluation of lifting surfaces in the presence of the free surface, and experiments on devices such as strakes to reduce interference drag due to viscous effects, are now possible.

Model Tests of the PACT Base America's Cup Hull in Following Seas

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Model tests were conducted at the Davidson Laboratory to investigate the effect of following seas on the added resistance of the PACT (Partnership for America's Cup Technology) base America's Cup hull. A 1:8 scale model of an International America's Cup Class yacht was provided by Team Dennis Conner and was refinished with funding from US Sailing to its original lines as the PACT base hull. Using this hull (canoe body with no appendages), model tests were conducted in the following seas condition. Upright resistance tests were carried out at constant speed in both smooth water and regular waves of varying length and slope. The model was free to heave and pitch while restraining all other degrees of freedom.

The data analysis revealed that at wavelengths approximately greater than two model lengths, the added resistance of the model is negative. A negative added resistance implies that the average drag force of the model in a particular following sea is less than the still-water drag of the model at the same speed. At wavelengths below this point, the added resistance of the model is greater than the still-water resistance. Furthermore, the form of the data suggests that at waves longer than were tested in this experiment (wavelengths greater than five model lengths), the added resistance of the model converges to the still-water resistance. The experiment also verifies that the added resistance is proportional to the square of the wave height.

The pitch and heave characteristics of the model as expressed in the form of response amplitude operators are independent of wave slope. This is to say that for a particular motion, the response amplitude operators for each wave slope overlap one another.

The results of these model tests were to be used as a database for the IMS Pitching Moment Project established in an attempt to quantify the sensitivity of radius of gyration on yacht performance. Also, these results were to be used to validate CFD estimates of added resistance.

Appendage Resistance of a Sailing Yacht Hull

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Since the introduction of the resistance calculation for yachts based on the results of the original Delft Systematic Yacht Hull Series (DSYHS), as presented by Gerritsma et. al. in 1979, 1985 and 1992, considerable changes have taken place in the design of both the shape and size of the appendages, i.e. keel and rudder. For the sake of consistency the original DSYHS was tested with one and the same set of appendages for all models, necessary for the heeled and yawed tests, which in design reflected the standards of the mid seventies for a hull like the Parent Model #1.

The wide variety of shapes of appendages used now-a-days made it necessary to be able to differentiate in the calculation routine between all these different configurations. Therefore the Shiphydromechanics Laboratory of the Technical University Delft decided to test a large number of the models of the DSYHS again, but now without appendages.

The implicit difficulty by doing this was that the resistance of the keel and rudder had to be added on. Although a large part of the appendage resistance originates from the viscous resistance, the residuary resistance of the appendages was not well known, neither the absolute magnitude nor the dependency on hull and keel geometry. This study tries to shed some light on the subject by reporting on a number of model experiments and calculations carried out to define the resistance of four different appendages under two different hulls.

Hull - Appendage Interaction of a Sailing Yacht, Investigated with Wave Cut Techniques

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The research explained in this paper was carried out to investigate the effects of hull-appendage interaction on the resistance of a sailing yacht, and the effects these changes have on the velocity prediction for a sailing yacht. To accomplish this aim a series of wave-cut experiments was carried out and analysed using a modified procedure. The processed results have then been incorporated into an existing velocity prediction program. For the purposes of this research two variables were investigated for the Australian Maritime Engineering Cooperative Research Centre (AMECRC) parent model 004, a model derived from the Delft IMS series of yachts.

Wave-cut procedures inevitably raise questions about scaling procedures for full scale extrapolation as the inviscid wave-pattern resistance is calculated to be less than the residuary or wave resistance. These questions have been dealt with by an approximate method, briefly explained in this paper.

SPLASH Nonlinear and Unsteady Free-Surface Analysis Code for Grand Prix Yacht Design

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The SPLASH free-surface potential flow panel code computer program is presented. The 3D flow theory and its numerical implementation are discussed. Some more conventional applications are reviewed, for steady flow past solid bodies, and for classical linearized free-surface flow. New free-surface capabilities are also described, notably, steady nonlinear solutions, and novel unsteady partially-nonlinear solutions in the frequency domain.

The inviscid flow method treats both free-surface waves and lifting surfaces. The calculations yield predictions for complex interactions at heel and yaw such as wave drag due to lift, the effect of the free-surface on lift and lift-induced drag, and unsteady motions and forces in oblique or following seas. These are in addition to the usual predictions for the simpler effects considered separately, for example double-body lift and induced drag, and upright steady wave resistance or added resistance in head seas. For prediction of total resistance, the use of computed variable wetted areas and wetted lengths in a standard semi-empirical, handbook-type "viscous stripping" algorithm provides a more accurate estimation of viscous drag than is possible otherwise.

Results from a variety of IACC and IMS yacht design studies, including comparisons with experimental data, support the conclusion that the free-surface panel code can be used for reliable and accurate prediction of sailboat performance.

The Effect of Pitch Moment of Inertia in Body Axes on the Performance of a Yacht in Waves

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Observation of full size yachts sailing upwind in a seaway has shown that, because of the presence of the sails, the yacht is constrained to move in body axes (parallel to the mast) rather than in earth axes (normal to the water). It is thought that this is due to the effect of the sails in the air and the keel and other appendages in the water providing a large damping force which resists any motion normal to the mast line. An experimental project has been carried out therefore to investigate the effect of this change in motion axes on the forces and motions induced by the seaway.

The experiments were carried out on a model of an IACC class hull in regular head waves for a range of wave heights in both earth and body axes using a recirculating water channel. The magnitudes and phase angles of resistance, side force, pitch, heave and heel moment were measured. Comparisons between the results of the present work and previous experimentation, with motion in earth axes, showed similar trends. However the results from the experiments using motion in body axes showed marked changes in the measured motion and resistance characteristics when compared to the earth axes data. It is thought that this difference could well affect the order of merit when comparing the performance of two hulls and it was concluded therefore that the change to measurement in body axes is important for the correct prediction of the performance of a yacht in a seaway.

The effect of the pitch moment of inertia on the motion and forces on the model was then studied, first using motion in earth axes and subsequently using motion in body axes. In general it was found that in both earth and body axes there was a strong cross coupling between the pitching motion and the heave motion and that a low gyradius resulted in smaller motions and a reduced added resistance; however the effect of any change in pitch moment of inertia was

more significant in body axes. The results showed that a yacht optimised for low pitch moment of inertia would have superior performance in comparison with a yacht which has a high inertia under identical wave conditions.

Experimental Determination of Sail Performance and Blockage Corrections

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The United States Sailing Association (US SAILING), under the direction of Karl Kirkman, has undertaken a program of experimental determination of sail force coefficients for representative rigs which are intended to serve as the beginning of a multi-stage effort to better understand, and eventually predict, sail forces. US SAILING is the governing body of yacht racing in the United States and is interested in understanding and improving sail performance in support of its efforts to handicap racing yachts and to improve U.S. Olympic Sailing Team competitiveness.

The Glenn L. Martin Wind Tunnel (GLMWT), located at the University of Maryland College Park, is participating in this sail force prediction project as part of the US SAILING University Research Program. The GLMWT effort is primarily in three areas which will be described in detail:

1. Development and evaluation of advanced wind tunnel boundary corrections schemes;
2. Model Test Rig design and construction, and GLMWT Main Tunnel Balance interface;
3. Plans for the determination of sail force coefficients for a series of sail models provided by US SAILING and analysis of results. This initial entry will repeat tests performed by US SAILING at the University of Southampton