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Amsterdam, 18 & 19 November 2002

PROCEEDINGS

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Delft University of Technology
Ship Hydromechanics Laboratory
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PROGRAMME

17th International HISWA Symposium on “Yacht Design and Yacht Construction”.

Monday 18th and Tuesday 19th November 2002

Monday 18 November 2002

ROOM A

Chairman: Jack Somer

10.00 – 10.15 hrs Opening words
Word of welcome by Jan Alexander Keuning

Session 1
10.15 – 10.45 hrs Prof. Fabio Fossati, University Cantania, Italy and Demenico Vitalone, Harken, Italy
SAILBOAT RIGGING AND FITTINGS DESIGN OPTIMIZATION: AN EXPERIMENTAL APPROACH

10.45 – 11.15 hrs Coffee break

Session 1
11.15 – 11.45 hrs Tyler Doyle, Stanford University, United States of America
OPTIMIZATION OF YARD SECTIONAL SHAPE AND CONFIGURATION FOR A MODERN CLIPPER SHIP

Session 1
11.45 – 12.15 hrs Eric Hall, Hall Spars, United states of America
HIGH PERFORMANCE CARBON FIBER SPAR MANUFACTURING

12.15 – 14.00 hrs Lunch break and opportunity to visit METS exhibition
Session 2
14.00 – 14.30 hrs
Prof. P.A. Wilson, Paolo Manganelli e.a., University of Southampton, UK
INVESTIGATION OF SLAMMING LOADS USING SLAM PATCHES ON A SCALE MODEL OF AN OPEN 60 CLASS YACHT

Session 2
14.30 – 15.00 hrs
Frans Verbaas and Tjepko van der Werff, Lloyd’s Register, Rotterdam, The Netherlands
STRUCTURAL DESIGN AND LOADS ON LARGE YACHTS

15.00 – 15.30 hrs
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Session 2
15.30 – 16.00 hrs
Dr. M. Hobs and L. McEwen, SP Technologies, England
WORKING LOAD TO BREAK LOAD: SAFETY FACTORS IN COMPOSITE YACHT STRUCTURES

Session 2
16.00 – 16.30 hrs
Prof. Richard Birmingham, Prof. Tony Roskilly, Ben Webster and Emrys Jones, University of Newcastle, England
THE APPLICATION OF ARTIFICIAL INTELLIGENCE TO ROLL STABILISATION FOR A RANGE OF LOADING AND OPERATING CONDITIONS

Session 2
16.30 – 17.00 hrs
Jan Alexander Keuning and Kees Jan Vermeulen, Delft University of Technology, The Netherlands
ON THE BALANCE OF LARGE SAILING YACHTS

17.00 – 18.00 hrs
Welcome drinks

18.00 – 18.30 hrs
Lecture by Mr.drs. J.H.J. Verburg – The deputy of state of the Province of Noord Holland (North-Holland)
18.30 – 18.55 hrs  Boarding the canal boat
19.00 – 20.00 hrs  Boat trip through the Amsterdam canals
20.00 hrs  Dinner at Restaurant the “Vijff Vlieghen”

Tuesday 19 November 2002

Chairman:  Jack Somer

Session 3
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DESIGN ASPECTS ON FAST MEGA YACHTS WITH HYBRID PROPULSION ARRANGEMENTS

Session 3
09.30 – 10.00 hrs  Jeroen de Vos and Gijs Nijsten, Gerard Dijkstra & Partners, Amsterdam, The Netherlands
PROPULSION ASPECTS OF LARGE SAILING YACHTS

10.00 – 10.30 hrs  Coffee break

Session 3
10.30 – 11.00 hrs  Rudy Czerny, Czerny Consultants, Germany
LIGHTWEIGHT A-60/A-0 INSULATION SYSTEM WITH HIGH ACOUSTICAL PERFORMANCE
Abstract.

The size of the sailing yachts now a day's is strongly increasing. The "scaled" draft of these large yachts, desirable for a good performance under heel and leeway, becomes more and more prohibitive for sailing in favored sailing areas, for entering harbors and mooring places of interest. This leads to owner stipulated draft restrictions for most of these larger yachts, resulting in a low span and so less efficient and less prominent keels and rudders. Also the "total" sail area tends to be distributed of more and smaller sails hoisted at more various rig layouts. In addition the classic designs are becoming more and more popular for the large cruising yachts, with their very different appendage and rig layouts.

As a result of all this the prediction of the "balance", i.e. the equilibrium in the yaw motion, under various sailing conditions becomes more and more a challenge in the early design stages. Knowing how much rudder has to be applied under given conditions to keep the yacht on a desired course without loosing too much on the performance is an essential, design issue. In addition it is a safety aspect to know "how much rudder (yaw moment) is still available for maneuvering" under those conditions.

The present paper describes the results of a study carried out to improve the frequently used prediction method for the longitudinal position of the Center of Lateral Resistance (CLR) of a sailing yacht hull. Use is being made from the extensive database of the Delft Systematic Yacht Hull Series (DSYHS) containing this kind of measurements under various conditions with respect to speed, heeling angle and leeway. This data has been used to formulate additional procedures and formulations for the existing method as presented by J.Gerritsma (1971) and K.Nomoto (1979) respectively. The outcome of the modified procedure is compared with the experimental results obtained both within the DSYHS and the Delft Systematic Keel Series (DSKS). In the DSYHS one keel and rudder have been tested under a variety of hulls and in the DSKS a variety of keels have been tested under one particular hull.

By matching these hydrodynamic data with the wind tunnel results on the position of the Center of Effort (CoE) of the sails and it change due to heeling angle a better analysis of the balance of the yacht can be made. In the present paper the results of this study and the analysis of the results will be presented.

1 - Introduction

One of the challenges the designer has to deal with in the design process of a sailing yacht is finding the best longitudinal position of the sail plan with respect to the under water body of the ship. The problem is introduced by the fact that from "simple" calculations neither the exact position of the Center of Lateral Resistance (CLR) of the forces on the under water body nor the longitudinal position of the Center of Effort (CoE) of the aerodynamic forces on the sails is known. The problem is even further aggravated by the fact that both the CLR and the CoE may change considerable under the influence of variations in the forward speed, the heeling angle, the angle of incidence of the sails and the leeway angle of the hull. In particular the heeling angle has a considerable influence on the yaw equilibrium of the yacht. From the well known picture of the physics and forces involved, as depicted in Figure 1, it is clear that the working lines of the driving force on the sails and the resistance force on the hull move away from each other when the yacht is
heeled over and rotates along a longitudinal and horizontal axis. Through this a considerable yaw moment is introduced. In addition also the CLR and the CoE change due to the asymmetry introduced by the heeling angle in general bringing a further increase of the yawing moment. The yaw equilibrium may now only be “restored” by either changing the sail settings (and so most likely introducing loss of propulsive power) or by a controlled (and limited) application of a rudder angle. In the case of “simple” rigs and efficient underwater shapes this generally does not introduce overwhelming problems and yawing equilibrium may be achieved with limited sail and rudder adjustments. With the recent increase of yacht size, the desire for limited draft and the complexity of rig layouts both these yawing moments and the possibilities to counteract with the rudder become more and more limited. This calls for an early assessment of the possible yaw (in)-balance of the sailing yacht under consideration in view of the desired performance (speed) as well as the safety (maneuverability).

Up till now a more or less “exact” determination of the CLR and the CoE can probably best be obtained with the aid of towing tank tests with the hull and wind tunnel tests on the rig. These can be carried out in a large number of different conditions and the resulting driving- and side-forces and the associated yawing- and heeling-moments determined. By equating these forces and moments generated by the hull and the sails the final equilibrium situation may be obtained and evaluated for their applicability. These tests however will probably only be carried out in a later stage of the design process. An extensive change in appendage design and appendage layout is often carried out during these tests in order to optimize the final design. In particular wind tunnel tests may be necessary for those conditions in which large separation of the airflow over the sails will occur (i.e. broad reaching and running).

In other conditions a more theoretical solution may become available through the extensive use of Navier-Stokes solvers, which may yield sufficiently reliable results now or in the foreseeable future. The use of these Navier-Stokes solvers is made necessary by the inevitable and relative important contribution of the viscous effects involved in both the CLR and the CoE. This approach however is certainly at present not particularly feasible for the earlier stages of the sailing yacht design process, in
which a relatively large number of design variations have to be considered in a relatively short time. Probably an experimental validation of the results obtained from these calculations will be necessary or asked for.

Both methods are generally time consumptive and expensive. So for most designs of competitive or performance orientated sailboats frequent use is being made of simpler and more easy to use assessment methods for both the CLR and the CoE.

In using these methods, for instance, the CoE of the complete sailplan may be approximated by calculating the geometric center of a standardized set of simplified sails. For instance often only the 100% fore triangle is used.

For assessing the CLR different methods are used. By far the simplest one is taking the geometric center of the underwater profile of the boat. This will certainly not coincide with the actual one. A more sophisticated method is the one introduced by prof. J.Gerritsma in 1971 best known as the Extended Keel Method, in which the foils are isolated and calculated using general wing theory and the contribution of the hull is accounted for by extending the keel to the undisturbed waterline. This yields very good results for the calculation of the sideforce versus leeway relationship, but the CLR is less well predicted, in general it tends to be too far aft. This was attributed to a not proper representation of the yaw moment generated by the hull. So to improve on this calculation of the CLR prof. K.Nomoto introduced in 1979 an improvement on Gerritsma method in which he separated the forces on the foils (keel and rudder) and the sideforce and yaw moment of the hull. This showed a significant improvement on the calculation of CLR when compared with measured data. For non standard hull forms and appendage layouts however still a relevant discrepancy between measured and calculated CLR was found. In particular for deeper hulls and shallow drafts the discrepancy still existed.

The first challenge therefore lies in a more correct prediction of the CLR or the yaw moment of an arbitrary sailing yacht with arbitrary hull geometry and arbitrary appendage shape and layout in the upright position as function of leeway angle and forward speed.

So the present study is aimed at formulating a still empirical and easy to use assessment tool of the CLR or yaw moment but for a larger variety of underwater hull and appendage shapes as an extension of or an addition to the already existing methods.

In the present paper a short summary of a few of the fore mentioned methods is given in combination with some of the results obtained. Then a refinement of this method using the results of the DSYHS is presented. The results here of will be compared with the measured data of some of the models tested in the DSKS.

2 – Calculation methods.

In 1971 Prof J. Gerritsma presented a method to assess the hydrodynamic efficiency of sailing yacht hulls using the formulations used for lift and lift curve slope arising from This method is generally referred to as the Extended Keel Method (EKM). In wing theory as presented among others by Whicker and Fehler in 1958, Reference [4], this method he considered the primary lift generating devices of a sailing yacht to be the keel and the rudder. If these were of a large enough aspect ratio then he proposed to calculate the hydrodynamic effectiveness of the sailing yacht, i.e. the lift generated per degree leeway, using this wing theory concept. To take into account the end plate effect of the hull on the hydrodynamic performance of the fins the actual planform of
the keel and the rudder is mirrored with respect to the endplate to obtain an Effective Aspect Ratio (AR_e) in the lift curve slope formulations. To take into account the side force production of the hull itself Gerritsma suggested to mirror the foils (keel and rudder) with respect to the waterplane at rest and to take the effective aspect ratio of this new “double” fin into the formulations for the determination of the lift curve slope and the (induced) resistance coefficients. In the actual lift the area of the foils used in the lift calculations is taken to the waterplane also. By doing so the part of the fin area extended “inside” the hull was considered to take account for the side force production of the hull. In order to be able to account for the downwash (sidewash) effect of the keel on the rudder a correction on the effective angle of attack of the rudder with 60% of the leeway angle was suggested by Gerritsma. This correction coefficient was obtained from tests with yacht hulls having a “normal” separation (distance) between the keel and the rudder as used in the DSYHS. An additional reduction for the rudder lift was proposed, due to the wake of the keel, by using only 90% of the free stream velocity on the rudder.

The outline of this procedure and the definition of the quantities used in the formulations are specified in Figure 2. The lift curve slope of the two foils is determined using:

\[
\frac{dC_l}{d\alpha} = \frac{5.7 \times a_e}{1.8 + \cos \Lambda \sqrt{\frac{a_e^2}{\cos^2 \Lambda}} + 4}
\]

In which:
- \(C_l\) = lift coefficient
- \(\alpha\) = angle of attack
- \(\Lambda\) = sweep back angle of quarter chord line
- \(a_e\) = effective aspect ratio of foil
The yaw moment is obtained by combining the moments produced by keel and rudder taking as moment arm the distance between the midship section and the center of effort on both foils situated on the quarter chord line at 43% of the total draft. A full description of the method is presented in Reference [1].

In general this method yields very good results for the side force production of sailing yachts with a variety of underwater body shapes and appendages. The CLR however is generally predicted too far aft even with the 60% reduction applied on the rudder force.

K. Nomoto e.a. (1979) considered this difference in the calculated versus the measured CLR to be primarily caused by the fact that the side force produced by the underwater body of the hull was not properly taken into account. He therefore proposed to add to J. Gerritsma’s method the hydrodynamic forces acting on the fore body of the underwater hull. These forces and moment were calculated using the so-called “slender body” theory. In the literature this potential contribution to the side force and yaw moment is known as the Munk Moment. This Munk Moment arises from the fact that in an ideal (nonviscous) fluid an elongated 3 dimensional body at an angle of attack experiences a pure couple, which tends to increase its angle of attack. This couple is composed of two equal but opposite in direction forces acting over the bow half and the stern half of the ship. This implies that in an ideal fluid there is no resulting force but a significant moment. This situation is depicted in Figure 3.

Figure 3. Force distribution on slender body in oblique flow

This physical explanation of this Munk moment is based on the assumption of an ideal, potential flow calculation and thus with an inviscous fluid. In a real and thus viscous fluid, vortices and a certain amount of flow separation will occur downstream along the body, which will result in a reduction of the pressure on the aft body as depicted in Figure 3.

In the slender body theory, which is used by Nomoto to calculate the Munk moment, the basic assumption is that of the “dynamic displacement” effect. Static displacement produces buoyancy and dynamic displacement induces a change of momentum of the (incoming) fluid, which in turn leads to a force on the body under consideration. The same idea is used by Wagner to calculate the hydrodynamic forces (lift) on surfaces
penetrating the free surface such as the hydrodynamic lift on planing surfaces and to calculate the lift on very low aspect wings.

Consider now a slender body, i.e. a body of which the beam and draft are many times smaller than its length, moving in an oblique flow. This makes it possible to simplify the physics to observing a 2-D flow in each cross section of the body. Considering the hydrodynamics involved it can now be stated that the lateral momentum of the fluid in a plane perpendicular to the body axis is equal to \( vA(x) \) in which \( v \) is the velocity perpendicular to the body axis and \( A(x) \) is the added mass of the cross section at length \( x \) of the body. The rate of change of the lateral moment of the fluid then becomes: \( uv \frac{d}{dx} A(x) \). This is depicted in Figure 4.

Figure 4. Slender body theory fluid momentum

Nomoto simplifies the formulation for the added mass of the cross section by taking the formulation for an ellipsoid, i.e.: \( A(x) = \pi \rho h^3(x) \) and so the formulations for the lateral force and the yaw moment become:

\[
Y = \pi \rho u \int_0^x v \frac{d}{dx} h^2(x) dx \quad \text{and} \quad N = \pi \rho u \int_0^x vx \frac{d}{dx} h^2(x) dx
\]

When these integrations are being carried out (over the entire length of the body) no lateral force is found but a significant moment. This moment is called the Munk Moment. In a real viscous fluid the flow around the bottom of the body will generate vortices and these will reduce the effect of the cross flow when going more to the after body of the underwater hull and will therefore reduce the transverse velocity component \( u\beta \). Nomoto adapts this assumption and deals with it by taking both the integrals only to the deepest section of the hull, with depth \( h_m \), located probably close to the midship. This results in the following expressions:

\[
Y = \pi \rho u^2 \beta h_m^3
\]

\[
N = -\pi \rho u^3 \beta \left\{ x_m h_m^2 + \int_{x_m}^x h^2(x) dx \right\}
\]

The lateral force is now no longer zero and the yaw moment is smaller than the original Munk moment.
The results found with this method showed a good agreement with the towing tank measurements carried out by Nomoto on two models of contemporary yacht hulls. Similar results were found by D.C. McMillan in 1991, Reference [3], who carried out extensive model experiments in the wind tunnels of Auckland University in New Zealand. He concluded that the methods of Gerritsma and Nomoto yielded by far the best results when compared with several others, at least for the geometries tested by him. His conclusions were based solely on side force production. His restrictive remark on the general conclusions concerned the ratio between the canoe body depth and the total draft of the models he tested, which was rather large, i.e. deep keels with a geometric aspect ratio larger than ARG > 0.8 placed underneath relatively shallow hulls.

McMillan however did not validate the results of the predictions for the yaw moment or the CLR with his measurements. Considering the results obtained by Nomoto himself it is concluded that the yaw moment is still being under predicted, so CLR is generally too far aft. The improvement in the prediction in this respect, when compared to the results obtained with the method introduced by Gerritsma, however are still significant.

3 – Present Method

For the present study it was decided to validate the results obtained with Nomoto’s method with the results obtained in the towing tank with the models of the Delft Systematic Yacht Hull Series. The results in this report are restricted to the upright, zero heel condition at different forward speeds of the models. Some twenty models of the DSYHS have been used for this validation. The models used come from Series 1 (model #1 till #22), Series 2+3 (model #23 till #39) and Series 4 (models #42 till #50) of the DSYHS. These three are sub-series within the complete DSYHS, each sub-series having it’s own parent model. A selection has been based on variation in Beam to Draft ratio, Length Displacement ratio, Longitudinal Position of the Center of Bouyancy and Prismatic Coefficient. For a complete reference to the geometry parameters of these models reference is made to Keuning and Sonnenberg, 1998, Reference [5]. A bodyplan of the three different parent models of each sub-series is depicted in Figure 6.

It should be noted that each of the models in Series 1 has the same midship section coefficient CM, i.e. 0.646. In Series 2+3 this CM varies between 0.67 and 0.69 and Series 4 between 0.71 and 0.77. When calculating the side force and the yaw moment for these 20 models of the DSYHS using both the Gerritsma method and the Nomoto method and comparing the calculated with the measured results, obtained within the DSYHS, it showed that in general Gerritsma’s method yielded better results for the side force and Nomoto’s method for the yaw moment. This method in general still under predicted the yaw moment of the yachts but over predicted in general the side force production of the yachts. So a slightly different procedure was adopted:

The basic idea, adopted by Nomoto e.a., is to carry out the integrations only over the forebody of the slender body, because the lateral flow at the aft body is considered to be too strongly influenced by shed vortices forward and subsequent flow separation. This assumption is frequently used and it most probably originates from experience with maneuvering (naval) ships and fully submerged bodies, such as submarines.
When maneuvering these vessels operate however in general at much higher angles of attack (drift angles) than is to be expected in the case of a sailing yacht hull.

Figure 6. Body plans of the parent hulls of the DSYHS

Within the naval architecture community this is not without debate. Others such as Crane, Eda and Landsberg in Principles of Naval Architecture Reference [6], point out that a general accepted simplification in naval hydrodynamics is that the potential flow effects (ideal fluid) and the viscous flow effects, at least in dealing with the maneuvering forces, are to be considered as independent of each other. Hence they assume that the lateral force in the ideal fluid, as approximated by the slender body theory, is independent of the lateral force caused by the vorticity in the real viscous fluid. The total yawing moment on the body in a real fluid is than to be taken as the sum of these two components. The real fluid viscous lateral force is related to the cross flow drag over the under water part of the hull. From the published data on this cross flow drag force it may be considered, as a first approximation, to contribute very
little to the side force and the yaw moment on a sailing yacht hull operating at relative small leeway angles. So the following modification is adopted to Nomoto’s method:

**Modification 1:**

In this study we adopted the approach to carry out the integration of the change in lateral fluid momentum over the full underwater length of the hull. As a result this yields very little change in the side force, actually zero, but a significant change in the yaw moment. The side forces and their contribution to the yaw moment are considered to originate solely from Gerritsma’s assumptions in the Extended Keel Method.

To compare the results of the calculations with the measurements of the DSYHS, the following procedure was used:

- The forces on the keel and the rudder were determined using Gerritsma’s Extended Keel Method. In the calculation a correction factor on the rudder force due to downwash and wake effects was applied of 0.4.
- The resulting yaw moment was calculated from the fins, taking the CE on the quarter chord line on 0.43 times the draft of the (extended) fins.
- The resulting side force and yaw moment were subtracted from the measurements carried out in the DSYHS yielding the side force and yaw moment contribution of the hulls.
- The yaw moment was calculated using Nomoto’s method but with an integration over the entire waterline length.

The results obtained with this procedure have been plotted as side force divided by the dynamic pressure $q = \frac{1}{2} \rho V^2$ and as yaw moment divided by $q * l = \frac{1}{2} \rho V^2 * l$.

From the comparison it showed that the side force was very well predicted for almost all hulls with B/T ranging from 2.5 (DSYHS hull number 27) to 11 (DSYHS hull number 24).

It also however showed that for Series 2+3 and Series 4 the results for the yaw moment were worse than those obtained in Series 1. This lead to an investigation into validity of the approximation of the yaw added mass as used by Nomoto. To investigate this a little further all DSYHS hulls were checked on their sectional sway added mass and it’s distribution over the length of the hull with the aid of a 2-D strip theory computer program. The computer program used for these calculations was SEAWAY, as developed by Journee, Reference [7]. The sectional sway added mass was obtained by using various methods, among which several Lewis transformations and a Close-Fit procedure.

The results so obtained have been compared with the same results using Nomoto’s assumption. From this comparison between the two calculations it turned out that the assumption made by Nomoto for the calculation of the yaw added mass, based on the ellipsoidal shaped body, was an over simplification. It was shown that the sway added mass was strongly dependent on the area coefficient of the section under consideration. For a sailing yacht hull this may vary considerably over the length of the yachts hull. So the following modification was adopted:

**Modification 2:**

A correction coefficient, as function of the sectional area coefficient, on the assumed "canoe body draft squared" assumption for the sway added mass was adopted. This
correction coefficient was established by regression on the relation between the calculated results for the sway added mass with SEAWAY and Nomoto's approximation. This coefficient is shown in Figure 7.

![Figure 7. Sway added mass correction coefficient.](image)

This type of approach was chosen for in the content of this study because the goal was to deliver a designers tool. Using a correction on the depth squared assumption makes it still possible for the designer to use the proposed method without the necessity to run a 2-D strip theory computer program.

For the twenty models or so selected from the DSYHS the calculations according to this adopted procedure have been carried out. The results of the calculations have been compared again with the measurements of the DSYHS. Due to the limited space available in this paper not all these results can be shown here, but a few characteristic results are shown for four models with different sections shapes and Beam to Draft Ratio's.

In general however it may be stated that both the side force and the yaw moment are rather well predicted by this new approach and in general it yields more accurate results than the original Nomoto method.
Figure 8  Side Force and Yaw Moment of DSYHS Model 15
Lwl / Bwl = 3.16 ; Bwl / Tc = 3.68
Figure 9. Side Force and Yaw Moment of DSYHS Model 24
Lwl/Bwl = 3.49; Bwl/Tc = 10.96
Figure 10. Side Force and Yaw Moment of DSYHS Model 25
Lwl / Bwl = 4.00; Bwl / Tc = 5.39
Figure 11. Side Force and Yaw Moment of DSYHS Model 27

Lwl/Bwl = 4.50; Bwl/Tc = 2.46
To check the applicability of the method on other hulls and appendages a calculation is performed for three of the keels tested in the Delft Systematic Keel Series.

In this series a variety of keels have been tested under one and the same hull. The hull was the hull of the “Yonder” a design from Dutch designer Jac. de Ridder from Vollenhove. The main particulars may be found in the report of J.Gerritsma and J.A.Keuning from 1985, Reference [8].

The three keels selected for the present comparison are:
- The standard IOR Keel
- A Shallow Draft Keel (without the Centerboard)
- A Shallow Draft Keel according to a Design of H.Scheel

The main particulars of these keels are presented in the Figure 12.

Figure 12. Layout and Main Parameters of Three Keels tested in the DSKS
Figure 13. Calculated Results versus Measurements for the Three Keels of the DSKS
In Figure 1.3 the results of the calculations for the yaw moment are presented and compared with the measurements of the DSKS. For the sake of the comparison between the respective methods the calculated results using Gerritsma’s, Nomoto’s method are presented together with the present method.

4 – Conclusions.

A comparison is made between two existing methods to calculate the side force production and yaw moment of a sailing yacht. Based on a comparison with measured results in the DSYHS an addition to these methods is formulated.

From a comparison of the results from these methods, it may be concluded that for the variety of keels presented in this study, the changes in the calculation procedure, as suggested in this study, yields an improvement in the prediction of the yaw moment when compared with the other two.

In the present study the comparisons with the measurement is restricted to leeway angles of circa 6 degrees. Since only the upright condition is concerned (or small heeling angles) this seems a justifiable restriction so far. For the assessment of the yaw moment at higher leeway angles an additional approach will have to be formulated. The same holds true for the assessment of the forward speed influence, which so far has not been taken into account by any of the fore mentioned methods.

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