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Improved design of a Search and Rescue boat for the Royal Netherlands Lifeboat Institution

door

Jan Alexander Keuning

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THE THIRD CHESAPEAKE POWERBOAT SYMPOSIUM

June 15-16, 2012

St. John's College, Annapolis, Maryland, USA

PROGRAM

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THE THIRD CHESAPEAKE POWERBOAT SYMPOSIUM

June 15-16, 2012

St. John's College, Annapolis, Maryland, USA

Symposium Schedule

Time	DAY 1 - Friday, 15 June 2012
7:00	Registration Begins
7:30	Continental Breakfast
8:00	*Dean M. Schleicher* Bringing Science and Technology to the Waterfront – Donald L. Blount
8:45	*Daniel Savitsky* The Effect Of Bottom Warp On The Performance Of Planing Hulls
9:30	*Toru Katayama, Yoshitaka Nishihara, Takuya Sato* A Study On The Characteristics Of Self-Propulsion Factors Of Planing Craft With Outboard Engine
10:15	BREAK
10:30	*Ron Grifka* Practical Application Of Interceptors On A Small Non-Planing Powerboat
11:15	*Gregory J. White, William E. Beaver, David N. Vann* An Experimental Analysis Of The Effects Of Steps On High Speed Planing Boats
12:00	LUNCH
1:00	*John Zseleczky* Behind The Scenes Of Peak Acceleration Measurements
1:45	*Michael R. Riley, Timothy W. Coats* A Simplified Approach For Analyzing Rigid Body Accelerations Induced By Wave Impacts In High-Speed Planing Craft
2:30	BREAK
2:45	*Leigh McCue, Don Jacobson, Charles Weil, John Zseleczky* A Look At The Impact Of Filter Selection On Peak Identification Of High Speed Craft Vertical Accelerations
3:30	*Michael R. Riley, Timothy W. Coats* A Method For Computing Wave-Impact Equivalent Static Accelerations For Use In Planing Craft Hull Design
4:15	*Eric Giesberg, Raju Datla* Development Of Empirical Equations For Planing Craft Motions In Irregular Waves Through Genetic Algorithms
5:00	ADJOURN

Papers That Will Qualify For SNAME Continuing Education Points

Resistance and Propulsion

Seakeeping

THE THIRD CHESAPEAKE POWERBOAT SYMPOSIUM

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Symposium Schedule

Time	DAY 2 - Saturday, 16 June 2012
7:00	Registration Begins
7:30	Continental Breakfast
8:00	*Carolyn Q. Judge* Static And Dynamic Forces And Wetted Lengths For A Planing Hull Model Forced In Roll
8:45	*Christopher S. Chaney, Konstantin I. Matveev* Modeling Of Vertical-Plane Motions Of Tunnel Hulls
9:30	*Jeffrey Bowles* Turning Characteristics And Capabilities Of High-Speed Monohulls
10:15	*William Burns, T.J. Perrotti, Chris Todter, Daniel Casal, Johnny Smullen, John G. Hoyt III* M Ship's Rapid Empirical Innovation (Rei) Open Water Model Test Platform
11:00	*Romain Garo, Raju Datla, Leonard Imas* Numerical Simulation Of Planing Hull Hydrodynamics
11:45	*Thomas T. O'Shea, Kyle A. Brucker, Donald Wyatt, Douglas G. Dommermuth, Thomas C. Fu* A Detailed Validation Of Numerical Flow Analysis (Nfa) To Predict The Hydrodynamics Of A Deep-V Planing Hull
12:30	LUNCH
1:15	*Frank DeBord, Karl Stambaugh, Chris Barry, Eric Schmid* Evaluation Of High-Speed Craft Designs For Operations In Survival Conditions
2:00	*Tony Caiazzo, Sid Charbonnet, Lou Codega* Design, Construction And Testing Of The Advanced Composite Riverine Craft
2:45	*Albert Nazarov* On Application Of Parametric Method For Design Of Planing Craft
3:30	*Jan Alexander Keuning* Improved design of a Search And Rescue boat for the Royal Netherlands Lifeboat Institution
4:15	*Christopher D. Barry* Composite Techniques For Affordable Limited Production, Sustainable High Performance Yacht Construction; Not What You Might Think
5:00	ADJOURN

Papers That Will Qualify For SNAME Continuing Education Points

Dynamics and Testing Techniques

Numerical Analysis and Computational Fluid Dynamics

Design and Production

THE THIRD CHESAPEAKE POWERBOAT SYMPOSIUM

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Abstracts

Albert Nazarov

On Application Of Parametric Method For Design Of Planing Craft

Paper describes features of parametric method based on combined analysis of main dimensions and volumes, weight components, performance and range predictions, seakeeping and construction cost of planing craft. Method is derived from statistics of designs of special, pleasure and small commercial monohull craft with hull length below 30m, developed by Albatross Marine Design. Dimensions of hull are defined from usable areas and essential volumes, with recommendations provided for different architectural types of boats. Equations are proposed for weight groups based on hull dimensions, horsepower, type of propulsion system, level of accommodations and furnishing, required payload, etc. Approaches for preliminary estimate of powering, range, fuel efficiency, ride stability are provided. Method proved to be efficient tool for analysis, optimization and feasibility check of design requirements. Case studies are presented illustrating application of parametric approach for different designs.

Jan Alexander Keuning

Improved design of a Search And Rescue boat for the Royal Netherlands Lifeboat Institution

The Royal Netherlands Sea Rescue Institution (KNRM) exploits a fleet of lifeboats around the North Sea coast of the Netherlands. The majority of this fleet consists nowadays of so called Rigid Inflatable Boats "RIB's". The largest vessels in the fleet are from the "Arie Visser" class, with a length of around 18.5 meters and a maximum speed of 35 knots. These are all weather boats on the North Sea and its coastal areas and self-righting. The Lifeboat Institution plans to replace the 10 boats in this class in the next 10 years. So an improved design (if possible) is sought for.

A design group has been composed for this purpose consisting of the Shiphydromechanics Department of the Delft University of Technology, Design office W. de Vries Lentsch, (the designers of the existing boats) and the High Speed Craft Department of Damen Shipyards.

Based on the requirements of the Sea Rescue Institution (KNRM) the group developed two new designs. These designs were initially derived using computer simulations and calculations. The emphasis in these new designs was on improved operability of the Search and Rescue boats in their typical working environment and improved habitability (i.e. noise and vibrations).

To assess the differences in performances of these designs in calm water and in waves an extensive test program has subsequently been set up and carried out with the three designs: i.e. the existing design Arie Visser and the two new designs.

Extensive full scale measurements on the existing boats of the "Arie Visser" class had already been carried out in the past and these results were used to specify the behavior of the existing boats as a bench mark. Then the three designs, i.e. the Arie Visser, the Concept 1 and the Concept 2, have been tested for their resistance, sinkage and running trim in calm water. In addition their behavior with high forward speeds in head irregular waves have been tested with emphasis on measuring motions and vertical accelerations.

Next their behavior in high stern quartering, following and beam seas has been investigated with free sailing models in the Ship Model Basin of MARIN to compare the new designs with the existing one for difference in a possible tendency for bow diving and broaching behavior in these high seas.

In addition severe breaking waves have been simulated in the towing tank and the models run through these both in head as well as following waves conditions.

The findings based on the computer simulations have been compared with the results from the measurements. The results of this research project will be summarized and presented in the present paper.

THE THIRD CHESAPEAKE POWER BOAT SYMPOSIUM

ANNAPOLIS, MARYLAND, JUNE 2012

Improved design of a Search And Rescue boat for the Royal Netherlands Lifeboat Institution

Jan Alexander Keuning, Shiphydromechanics Department, Delft University of Technology, Delft, Netherlands

ABSTRACT

The Royal Netherlands Sea Rescue Institution (KNRM) exploits a fleet of lifeboats around the North Sea coast of the Netherlands. The majority of this fleet consists nowadays of so called Rigid Inflatable Boats "RIB's". The largest vessels in the fleet are from the "Arie Visser" class, with a length of around 18.5 meters and a maximum speed of 35 knots. These are all weather boats on the North Sea and its coastal areas and self-righting. The Lifeboat Institution plans to replace the 10 boats in this class in the next 10 years. So an improved design (if possible) is sought for.

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KEY WORDS

Seakeeping, Fast ships, Search and Rescue, Broaching, Design

1 INTRODUCTION

In the design of high speed ships the hydrodynamics always play an important role, presumably more important than with the more conventional designs. The aim to reach high speeds at reasonable cost calls for optimal calm water performance. Providing the capability to maintain this high speed and operability (and safety) in a severe seaway often calls for ingenious hydrodynamic approaches. In the present paper, the emphasis will be on the hydrodynamics involved in the design of the new life boat. Life boats are an even more special design case because they need to be safe and acceptably comfortable in the "average" conditions in which most of their duties are carried out, but also be safe and operable in even the most extreme conditions that can be met in their operational areas.

The operational area for the Royal Netherlands Sea Rescue Institution (KNRM) is the Dutch Coastal area and the southern part of the North Sea. This is a notoriously dangerous area due to the presence of many estuaries, shoals, associated strong tidal currents and the fact that usually in the most severe conditions (i.e. gales and storms from the West through North West to the North) the Dutch coast is a lee shore. In addition it is one of the busiest shipping areas of the world with a high occupancy of recreational craft in particular in the summer. This calls for good operability in a wide range of operational conditions and a large fluctuation in ships sizes and types to be assisted or rescued. Typical design characteristics of the "Arie Visser" class boats are: maximum speed up to 35 knots, overall length around 19 meters, occupancy of 6 crew, twin engines with water jets, full 180 degrees self-righting capability, good sea keeping capabilities, high speed to be maintained in head seas, and excellent manoeuvring behaviour in all conditions up to waves of 10 meters high.

Two decades ago, the emphasis for life boats was not so much on crew accommodation and comfort as it was on survivability. The present "Arie Visser" class designs, which were designed by the office of W de Vries Lentsch are typical examples of that philosophy. A photograph and the linesplan of one of these boats is presented in Figure 1 together with some main particulars in Table 1.

Table 1. Main particulars "Arie Visser" class design

Designation Design	Symbol -	Unit [-]	**Arie Visser**
Overall Length	Loa	[m]	18.8
Overall Breadth	Boa	[m]	6.1
Draft	T	[m]	1.07
Weight	W	[ton]	28
Longitudinal Center of gravity	LcG	[m]	6.12
Wetted Area with zero speed	S	[m^2]	60.9
Metacentre Height	GM	[m]	1.77

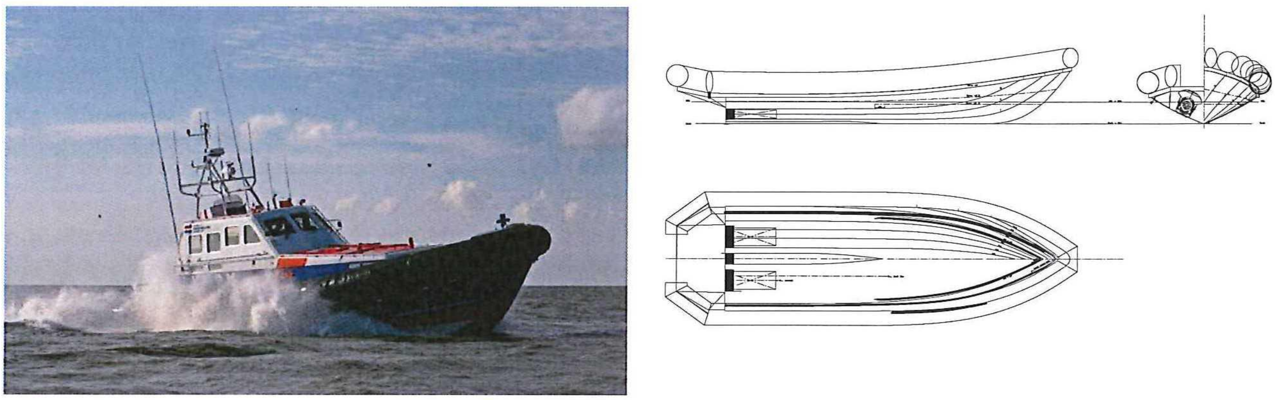

Fig. 1. Linesplan and photograph of the "Arie Visser" class design.

The operational achievements of these boats met the requirements of the KNRM to a certain level and the crews were generally satisfied with the performance of these boats and certainly fully confident in their safety. However from a series of full scale experiments conducted by the Shiphydromechanics Department over the years it became evident that higher achievements with respect to sea-keeping behaviour could be possible. Also there is the noticeable change in present day crew composition from primarily fishermen to a wider cross cut through the society including higher educated people, office clerks and women. This implied higher requirements from the crew for more general standards for minimal on-board accommodation (i.e. toilets, acceptable ship motions, minimizing the on-board noise levels, etc,) which have to be met.

This led the Royal Netherlands Sea Rescue Institution (KNRM) in 2009 to initialize a large project for the conceptual development, design, engineering and finally construction of a new Search and Rescue lifeboat for the North Sea capable of meeting these new requirements in the 10 – 20 years to come. In addition every way to improve on their operability in a seaway should have to be investigated.

To start the process an intensive questionnaire has been send around amongst the coxswains and crews of all Search And Rescue boats including the technical and supporting staff of the KNRM to acquire more knowledge about the possible short comings of the existing fleet and the wish list about the future design. In short the most important design objectives for the new designs became:

- Length around 20 meters over all
- No greater draft than 1.10 meter
- Maximum attainable speed of 35 knots
- Range at full speed of circa 600 miles
- Crew of 6 persons, seated in the wheelhouse (maximum suggested capacity of rescued persons on board circa 120!)
- Two engines with water jets in two separate engine rooms
- Noise levels in the wheelhouse not above 70 dBa
- Fully self-righting over 180 degrees of heel
- Improved sea keeping performance in head and bow quartering waves with higher sustainable speed
- At least a similar performance to the existing boats in large and steep stern quartering and following waves (i.e. broaching and bow diving), preferably with increased course keeping capabilities at high speed
- Good manoeuvrability at both low and high speeds also in large waves

With these design objectives now available a design team was composed, consisting of the Hydrodynamics Department of the Delft University of Technology (DUT), the High Speed Craft Department of Damen Shipyards and the designers of the existing boats De Vries Lentsch Design Office. This team, with the assistance of the KNRM, took up the task to design the new boat. Recent developments in the hull form design of fast ships were introduced and considered in combination with fixed and moveable appendages. New calculation and experimental techniques were used to be able to predict, compare and verify the hydrodynamic behaviour of the various design variations.

2 THE DESIGNS

The principal decision about the design procedure was to make at least two full design alternatives to the existing boat the "Arie Visser" and to compare these alternative designs in their behaviour in both calm water and waves in all the calculations and the model tests with the "Arie Visser". In this way the "Arie Visser", of which design also very much full scale data, obtained during many tests at sea, were available, served in the process as the benchmark for the evaluation of the merits or shortcomings of the other designs.

A design objective was to investigate whether the application of the Axe Bow Concept could be effective for these Search and Rescue boats.

The application of the Axe Bow Concept has been proven very successful for improving the operability in a seaway with fast Patrol Boats and Fast Crew Suppliers over the last decade. But these were generally bigger ships (35-55 meters Loa) and the Search and Rescue boats of the KNRM must be capable of dealing with very (more) rough conditions such as breaking waves.

The development of the Enlarged Ship Concept and Axe Bow Concept has been adequately described in various earlier publications by the author, amongst others Ref [2] and Ref [3]. Therefore only a very short resume will be given here.

The development of the Enlarged Ship Concept and Axe Bow Concept was based on the observation made during numerous full scale measurements onboard fast patrol boats that the speed reduction sailing in waves was for 85% voluntary, i.e. applied by the crew. In addition it was shown from these results that this voluntary speed reduction was primarily provoked by the occurrence of rarely occurring events in the vertical accelerations (high slamming) irrespective of the significant or "average" value of the vertical accelerations. Yet in the design evaluations made for comparing fast ships designs these significant values were the basis of the operability limiting criteria used

As an illustration of this the following figure is presented, giving the distribution of the peaks in a vertical accelerations signal measured onboard a fast ship. On the horizontal axis it presents the percentage of the total peaks in that given time trace of the elaborated signal a certain value of the vertical acceleration (on the vertical axis) is exceeded.

What really counts for the good operability is the right hand corner of this distribution, i.e. the (large) magnitude of the rarely happening events. These should be lowered as much as possible and in that respect the black boat is significantly better than the red boat, even though at the "significant" level (at roughly 13% probability of exceedance) the black boat is somewhat worse.

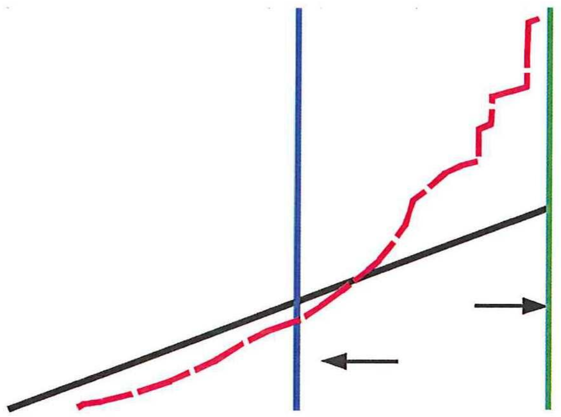

Fig. 2. Distribution plot for bow vertical acceleration

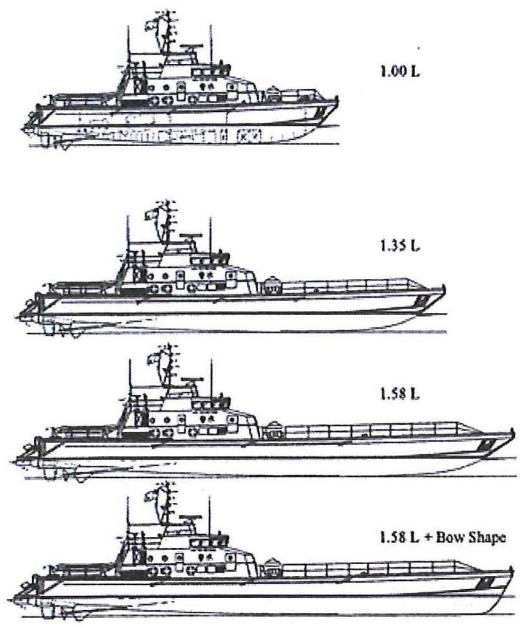

Fig. 3. The Base Boat and Enlarged Ships used in Ref [2]

Along these lines the Enlarged Ship Concept and Axe Bow Concept have been developed and with the aid of the developed mathematical model a hull shape could be designed that meets these requirements.

The Enlarged Ship Concept aims at lengthening the hull substantially (25% or 50%) without any change in the functionality, the speed and the beam of the craft. This turned out to have a significant effect on the operability in a seaway (35%-65% better) without a major effect on the building cost (+3% till +6%). As a bench mark the StanPatrol 2600 from DAMEN Shipyards was used and the plans of the Enlarged Concepts are shown in figure 3.

The results of this study are summarized in Figure 4, in which the length, the building costs, the operational costs, the transport efficiency and the operability on the North Sea are compared with the base boat as bench mark.

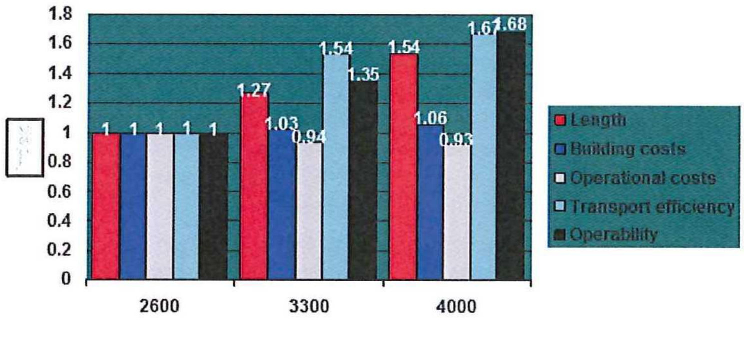

Fig. 4. Results of the Enlarged Ship Concept study

From this the benefits of the Enlarged Ship Concept became obvious. Since in particular at the fore ship void space is being created, room became available to shape the bow sections in such a way that slamming was reduced to a minimum. This lead to the AXE Bow Concept, in which very deep fore sections, with no flare and a downwards sloping centreline are introduced.

A typical lines plan of the Axe Bow Concept is presented in Figure 5.

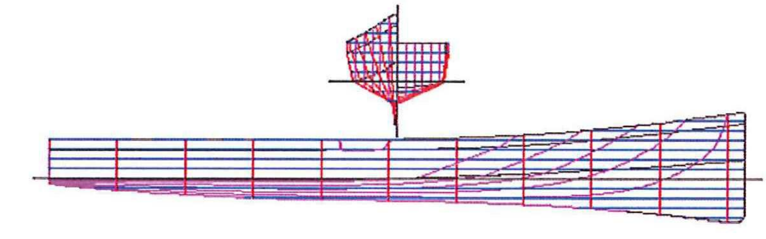

Fig. 5. Typical hull shape Axe Bow Concept

The full scale experience with these craft showed the benefits to their full extend, so the aim of the new design for the KNRM was to see to which extend this design philosophy could be applied for their new boat.

The main dimensions of the new design were more or less stipulated by the set of design objectives so the most important considerations were on the hull shape and in particular on the bow shape of the new designs. From the existing design it was known that the relatively full bow sections introduced violent motions and high vertical accelerations in head and bow quartering waves, which usually led to a significant voluntary speed reduction by the crew in anything above 2.0 meters significant wave height. On the other hand this bow shape guaranteed in high and steep following waves sufficient reserve buoyancy to prevent bow diving.

From experience gained over the last decade with ships build according to the Enlarged Ship Concept (Enlarged Ship Concept) and the AXE Bow Concept (Axe Bow Concept) the positive effect on sea keeping performance of lengthening the ship, increasing the Length to Beam (L/B) ratio and the Length Displacement Ratio ($L/\Delta^{1/3}$) combined with significantly increasing the deadrise of the bow sections and reducing the bow flair is known. So it was decided to apply these new insights in two respective steps to the new Search and Rescue design and to investigate the effect on performance. The full shape of the AXE Bow, i.e. with the downward slope in the forward contour could not be applied for the Search and Rescue design, because these boats operate often at very shallow areas (and even go aground) and so the draft restriction was very stringent. The increase in the freeboard height forward and the reduction in bow flare however could be applied.

So two alternatives to the base boat the "Arie Visser" (Arie Visser) arose: the Concept 1 (Concept 1), with a sharper bow and deeper fore foot but only modified modestly (this design was therefore nicknamed "Evolution"), and Concept 2 (Concept 2), with the Axe Bow philosophy applied but without the negative contour forward (nicknamed "Revolution"). Both the Concept 1 and Concept 2 design had an increased length (Enlarged Ship Concept) to improve their L/B and $L/\Delta^{1/3}$.

Another important consideration was the application of a tube, so typical for the RIB concept. A careful weighing of the pro's and con's was carried out. Every now and then structural problems with the tubes did arise in particular with respect to wear and tear but also the connection to the rigid structure gave problems. For a Search and Rescue boat coming alongside other vessels often the advantage of having an around fender is clear. However from a hydro dynamical point of view the benefit of a tube is not so obvious. The blunt intersection between the underside of the tube and the hull may generate high impulsive hydrodynamic forces when the ship is performing large relative motions at high speed in waves and from a point of view of wave excited forces the influence is actually disadvantageous in particular at the bow. The influence on the static stability of the tube at larger angles of heel (and pitch) is obvious but it is not necessary to derive the desired GZ curves through the use of the tube and the reserve buoyancy can be also be generated in other ways. Therefore it was decided to minimize the size and the volume of the tube as much as possible and to do so particularly in the forward third part of the hull. The reserve buoyancy was created (as is the design practice in the Axe Bow Concept) through significantly increasing the freeboard forward.

The weight distribution of the ship and the transverse moment of inertia of the water plane area and beam were chosen carefully to achieve a minimum value of the static GM value of at least 1.75 meters at zero speed. An important aspect for the safety of life boats is the Ultimate Stability, i.e. the stability at extreme values of heeling angle and their capability to recover from a full 180 degrees capsize. In first instance this is driven by the position of the centre of gravity of the boat and the shape and volume of the superstructure. Strict criteria are not available for the values for GZ at 180 degrees of heel but care should be taken to make these not too large because the self-righting motion, i.e. roll, can become very violent. The "Arie Visser" survived over the years various 180 degrees knock downs so here GZ values were considered to be appropriate and taken as the ones for the others to meet.

Various modifications to the designs were carried out during the process using hydrostatic calculations, resistance calculations and motions prediction analyses by using the non-linear time domain motion prediction program FASTSHIP as described in Reference [1] and [3]. This program has been validated extensively and was proven to be sufficiently accurate for the use in the design stage for comparing fast ships on their performance in calm water and waves and proved very use full for the purpose in particular through its short CPU time needed. One of the design considerations left for the new designs to be decided on was whether it was beneficial to aim for the lightest ship possible within the range of feasible designs. From a calm water resistance point of view it could be expected that the lightest ship would perform best but from a sea keeping point of view and in particular the important level of accelerations on board of the ship this was not so obvious. Therefore a simulation was carried out using the FASTSHIP code to compare the accelerations on board of three almost identical designs except for their weight, varied in the realistic weight range for these designs. The comparison is of course always a bit hampered through the fact that exactly similar ships in all aspects except one parameter is not possible, but these results are presented in Figure 2 and Figure 3. Here it shows a slight preference, i.e. lower accelerations for the heavier design. This result has been used in the setup of the designs.

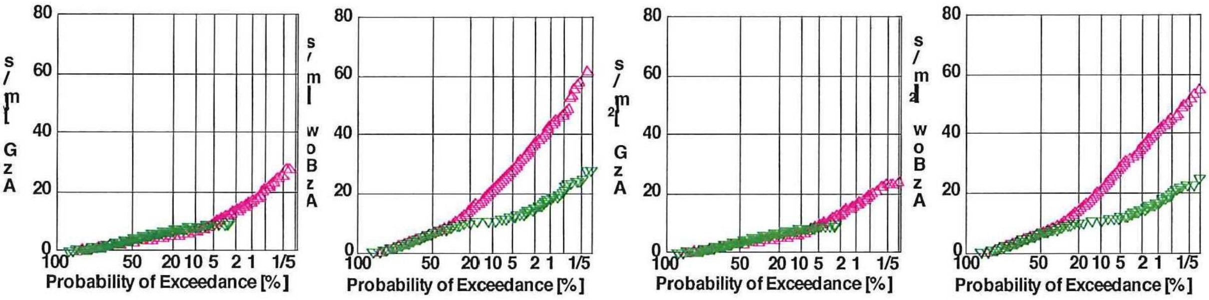

Fig. 6. Rayleigh Distributions with Displacement respectively 26.3 tons and 29.3 tons

All these considerations (and of course many more) led to the final development of the lines plans of the new designs Concept 1 and Concept 2 respectively. The lines plans and a rendering of the two designs are presented in the Figures 7 and 8. The main dimensions are presented in Table 2.

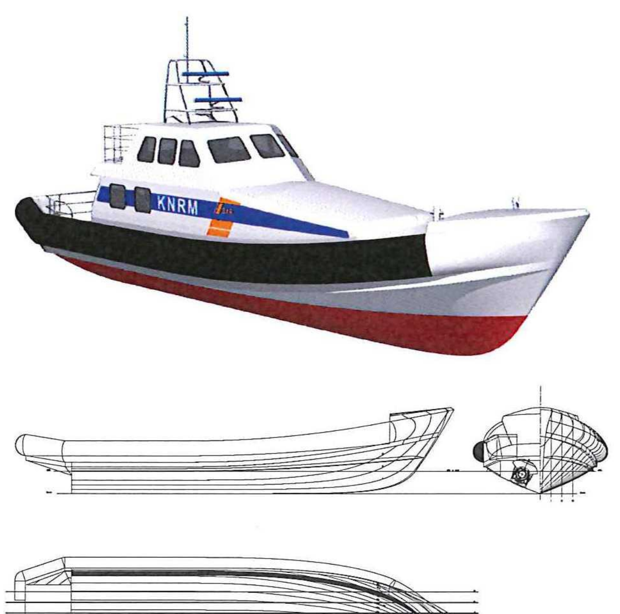

Fig. 7. Linesplan and photograph of "Concept 1"

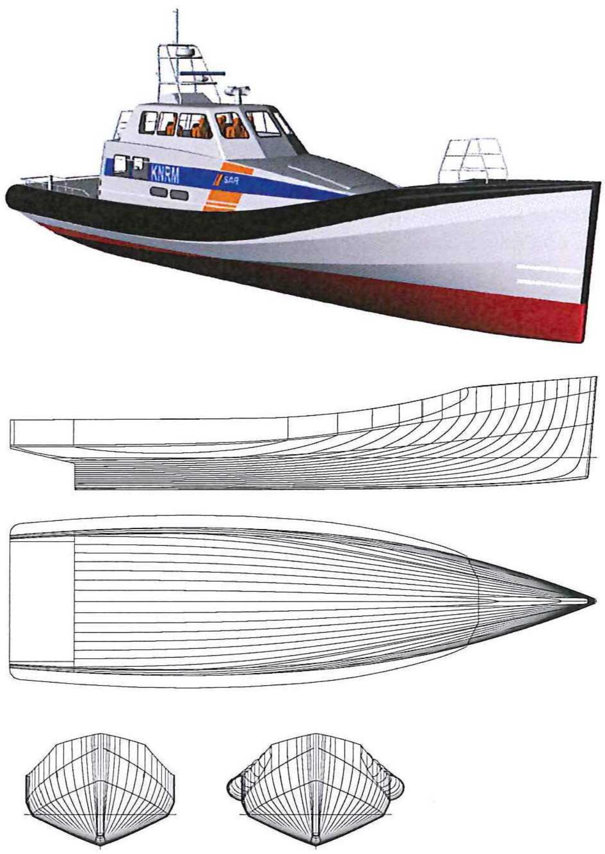

Fig. 8. Linesplan and photograph of "Concept 2"

Table 2 Main particulars "Concept 1" and "Concept 2

Designation Design	Symbol	Unit [-]	**Concept 1**	**Concept 2**
Overall Length	Loa	[m]	20.45	21
Overall Breadth	Boa	[m]	6.25	6.35
Draft	T	[m]	1.14	1.17
Weight	W	[ton]	38.7	39.9
Longitudinal Center of Gravity	LcG	[m]	6.66	6.891
Wetted Area at Zero Speed	S	[m^2]	72.73	78.57
Metacentre Height	GM	[m]	1.82	1.46

The construction material of the boats is aluminium alloy for both the hulls and the superstructures just as with the Arie Visser (Arie Visser). The increase in the overall weight that becomes apparent from the comparison of the values in these tables with those of the Arie Visser, as presented in Table 1, can be largely attributed to the considerable amount of sound insulation that has to be applied in the new designs to reduce the noise levels to the desired rate, which in its turn led to heavier engines, bigger water jets and more fuel. This is the well-known downwards spiral!

3 THE EVALUATIONS OF THE DESIGNS

The evaluation of the designs has been carried out in first instance on a number of different aspects, i.e. the (ultimate) stability, the calm water performance, the behaviour in head waves under more or less "usual" working conditions and the behaviour in large following and stern quartering waves with an emphasis on a possible tendency towards broaching.

The principal aim of the evaluation was to discover if the new designs could yield a significant improvement in sea keeping performance under "usual" conditions without losing any performance in large following and stern quartering waves. Hereto the Arie Visser design is incorporated in all results to serve as the bench mark.

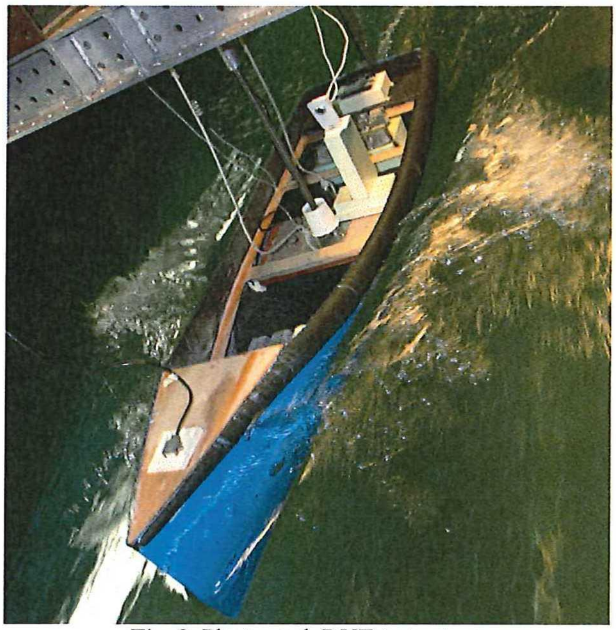

Fig. 9. Photograph DUT test set-up

Fig. 10. Photograph MARIN SMB test set-up

All experiments have been carried out with 1:10 scale models of the three designs. This scale has been chosen to suit the capabilities of the various experimental facilities used for the experiments. Part of the tests have been carried out in the large towing tank of the Delft University. This tank is 145 meters long, 4.25 meters wide and has a waterdepth of 2.5 meters. The maximum speed of the towing carriage is 8.0 m/s. There is a hydraulically activated wave generator at one end of the tank. The tests carried out in Delft were: the resistance tests and the sea keeping tests in head and following waves. The experiments in stern quartering waves have been carried out in the Ship motions and Manoeuvring Basin (SMB) of MARIN in Wageningen. This facility is 225 m long, 50 meters wide and 5 meters deep. Maximum speed of the towing carriage is 6.0 m/s. Waves can be generated from any direction.

During the Delft tests the models were connected to the towing carriage in such a way that they were free to heave and pitch but restrained in all other modes of motion. Therefore these tests were carried out with constant forward speed. A photograph of this setup is shown in Figure 6. During the tests in the SMB completely free sailing models have been used with an on board measurement system for all the motions. These models were equipped with engines and water jets and autopilots. The inputs for the auto pilots were the yaw, the yaw velocity and the cross track error (sway). A photograph of this setup is shown in Figure 7.

The maximum wave height attainable during the tests both in Delft and in Wageningen was about 4.0 meters at full scale. This was not high enough for testing the models in the most extreme conditions.

3.1 The Static Stability Curves

The static stability curves of the three designs are presented in Figure 8. These are the GZ curves for the design condition over the full range of 180 degrees.

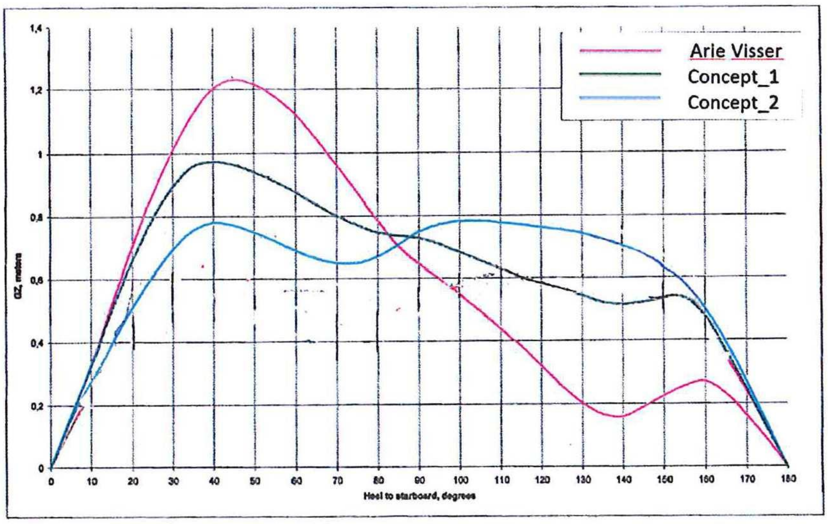

Fig. 11. Stability-curves, "Arie Visser", "Concept 1" and "Concept 2"

From these results it is clear that all three designs are full self-righting and that Concept 2 has the best characteristics for the up side down condition. In the normal working range say up to 30 degrees of heel there are no significant differences between the designs.

3.2 The Calm Water Resistance, Sinkage and Trim

The results for the sinkage, trim and resistance of the three models are presented in the Figure 9, as function of the forward speed.

For the extrapolation to full scale the Froude's method has been used, using the ITTC-57 friction line and the dynamic wetted area at each speed as measured during the runs.

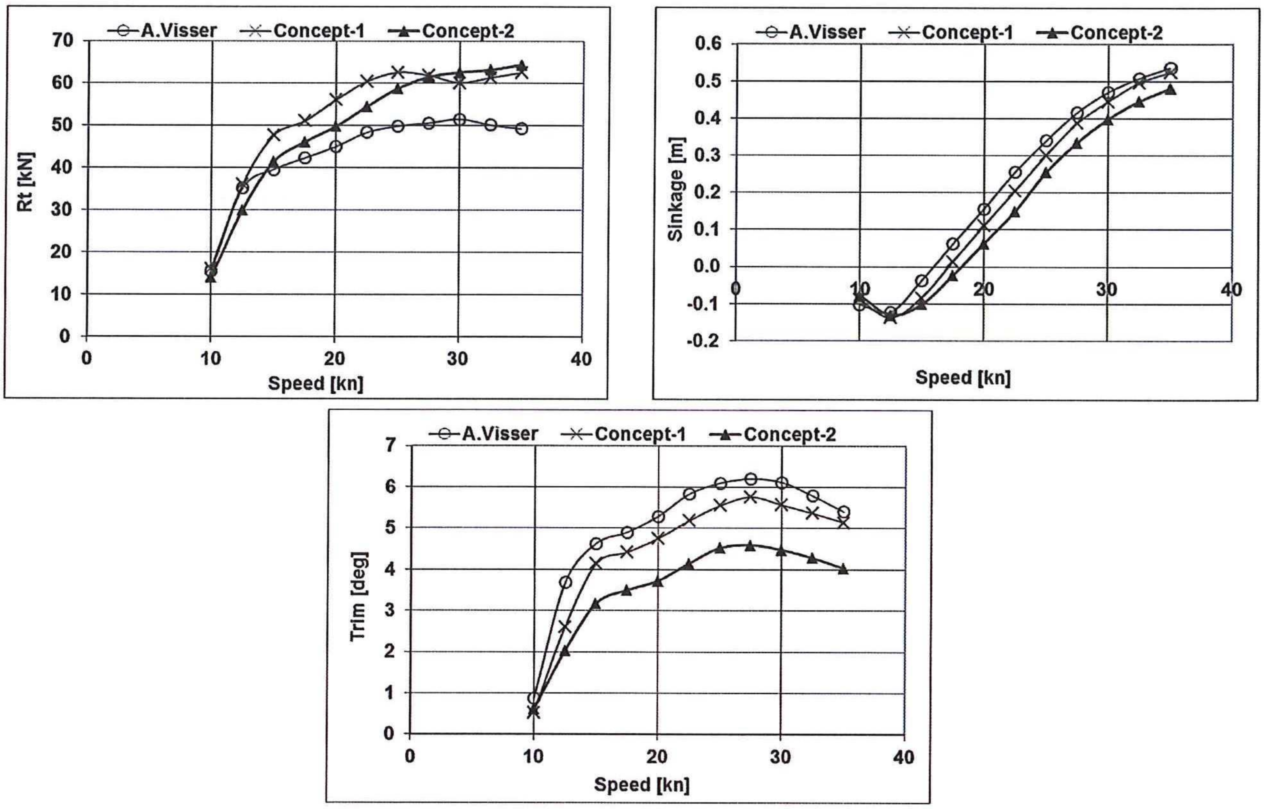

Fig. 12. Resistance, Trim and Sinkage results, "Arie Visser", "Concept 1" and "Concept 2"

From these results it can be seen that the Arie Visser comes out of the water more than Concept 1 and Concept 1 on its turn comes more out of the water than Concept 2. A similar trend can be observed with the running trim. This is in line with the expectations because the hull of the Arie Visser is designed to generate more hydrodynamic lift than that of Concept 1 and the hull of Concept 2 is designed to yield the lowest lift. The maximum trimming angle of the Arie Visser and also the Concept 1 are above the optimum values generally accepted. The resistance of the Arie Visser is over the whole speed range considerably lower than of the other two. This can largely be attributed to the considerable difference in displacement and the more hydrodynamic lift generating hull. The difference between Concept 1 and Concept 2 is dependent on the speed range: below 27 knots Concept 1 performs better than Concept 2 above that speed this trend is reversed.

From these results it can be concluded, as is generally known of course, that from a calm water resistance point of view reducing the weight remains important (considering the results for Arie Visser) and that over a large speed range the Concept 2 performs better than the Concept 1 except for the highest speed range. The running trim angle of the Arie Visser and the Concept 1 are uncomfortably high in the hump region. This may even be aggravated by the addition of the trimming effects caused by the water jets not present during these tests. From full scale measurements with the Arie Visser these trim angles are confirmed. The negative influence of a large running trim on the motions is known but for the sake of comparison no trim tabs were added to the other designs as well because the Arie Visser does not have them. In the selected final design of the new boat adjustable trim tabs will be added to control the trim angle over a wide range of speeds It should be noted however that none of the crews of the 12 existing boats ever complained about the running trim angle. .

3.3 Comparison of the performance in head waves

During the design process various motion assessments were performed using the FASTSHIP code. Based on these computational results the Concept 2 outperforms the two other models significantly when the vertical accelerations at the bow and in the wheelhouse are concerned. Nevertheless it was decided still to carry out these tests with the three models in irregular head waves in order to be able to verify those findings.

For these tests, to limit the amount of experimental work, a selection of three environmental conditions with corresponding average forward speeds has been made. These combinations of wave climate and speed were known to be more or less realistic for the Arie Visser from full scale measurements and they are summarized in the Table 3 below:

Table 3. Test conditions DUT

Condition [-]	Vs [kn]	Hs [m]	Tp [s]
1	35	0.93	7.62
2	25	1.84	8.11
3	17.5	2.64	8.67

In particular the wave Condition 2 is close to an environmental condition which is quite often met at the North Sea by the Search and Rescue boats of the KNRM during their operations.

In each generated wave spectrum at least 12 different test runs have been carried out with every model. Each test performed in a different part of the spectrum realization. Care has been taken that all three models met exactly the same parts of the realization so that an accurate comparison of their behaviour became possible.

The need was felt to check on the validity of the FASTSHIP simulations, because these results were extensively used in the design stage. As a typical result of this validation the vertical accelerations at the bow in wave Condition 2 (both measured and simulated) for the Arie Visser, Concept 1 and Concept 2 are presented in Figures 10, 11 and 12.

The results are plotted as distributions on an adjusted horizontal scale, which would yield a Rayleigh distribution for the crests and troughs as a straight line. The deviation of the actual plot from a straight line is therefore a measure of the non-linear behaviour of the system output signal under consideration because the incoming surface waves (the input) are supposed to be Rayleigh distributed.

The purple lines in these figures depict the distribution of the peaks of the upward accelerations and the green line the distribution of the peaks (troughs) of the downward accelerations as found in the time trace of the signal under consideration. This is the case with all these kinds of distribution plots presented in the present paper.

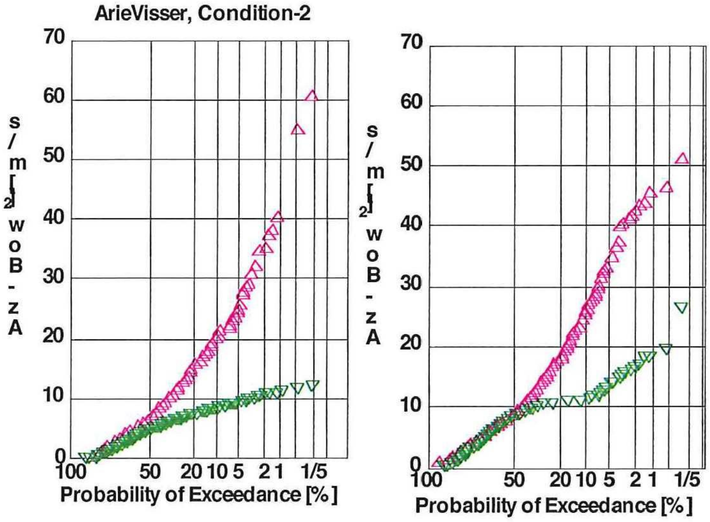

Fig. 23. Az_Bow measured (left) and calculated (right), "Arie Visser"

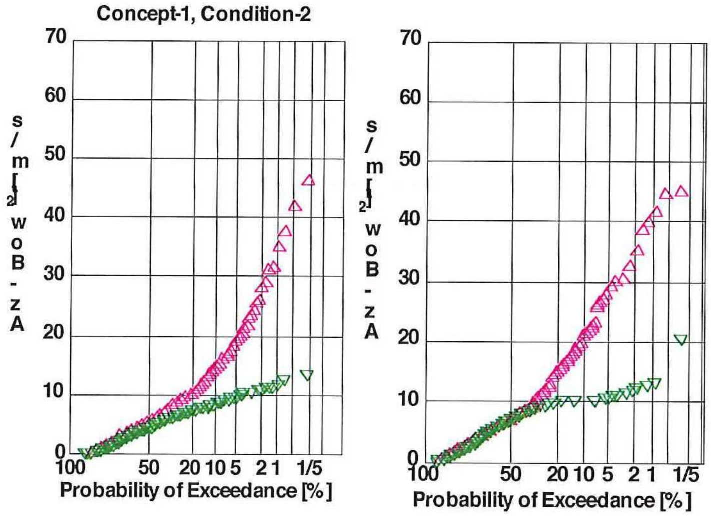

Fig.14. Az_Bow measured (left) and calculated (right), of "Concept 1"

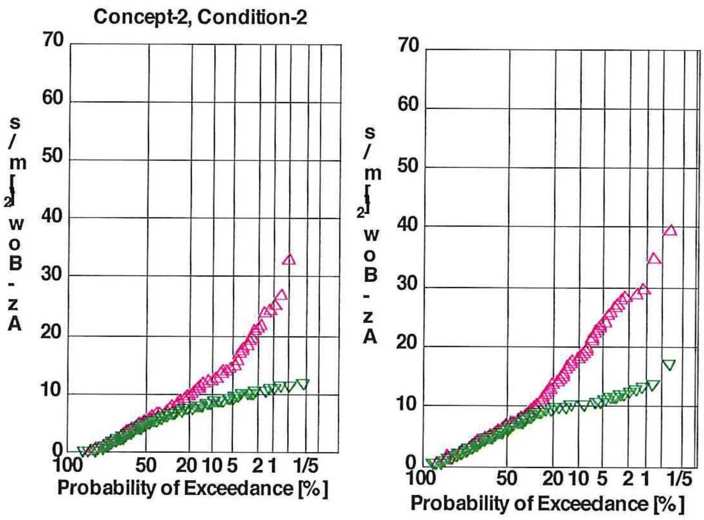

Fig.15. Az_Bow measured (left) and calculated (right), of "Concept 2"

As can be seen from these distributions the similarity between the measurements and simulations is satisfactory although the absolute values may differ to some extent. In all cases however the trends in the differences in behaviour between the various designs are identical.

It is known from real life experience and full scale measurements that most speed reductions on board fast ships in head and bow quartering waves (and hence the loss of full operability) are voluntary and imposed by the crew. The driving factor in this speed reduction is the occurrence of high peaks in the vertical accelerations irrespective the average or significant magnitude of the accelerations at the time. Minimizing these high peaks with a low(er) chance of occurrence, i.e. in the right hand corner of the distribution plots, is of prime importance for optimizing operability. Therefore the emphasis in the comparison of the three designs is in that region of the distributions.

To show the differences in behaviour in that respect between the three designs in the Figures 13, 14 and 15 distributions of the vertical accelerations in the CoG (close to the wheelhouse) and at the bow (at 10% of Loa aft of the stem) are presented.

The results for the other conditions showed a similar tendency. From all these results it became obvious that the Concept 2 outperforms the other two designs to a large degree.

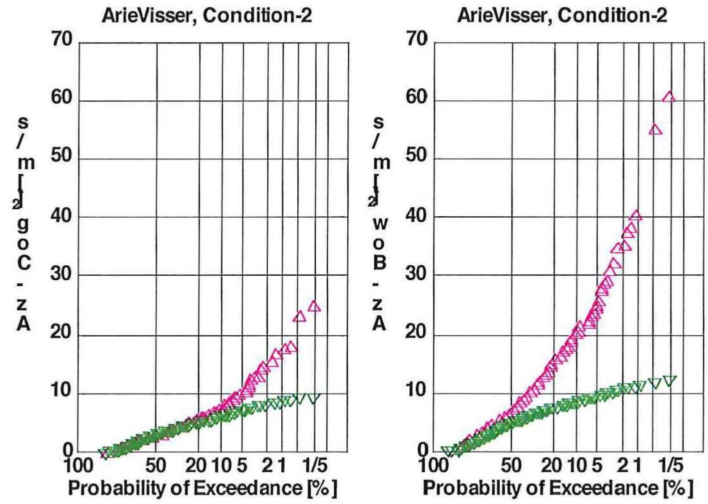

Fig. 36. Az_CoG and Az_Bow for "Arie Visser"

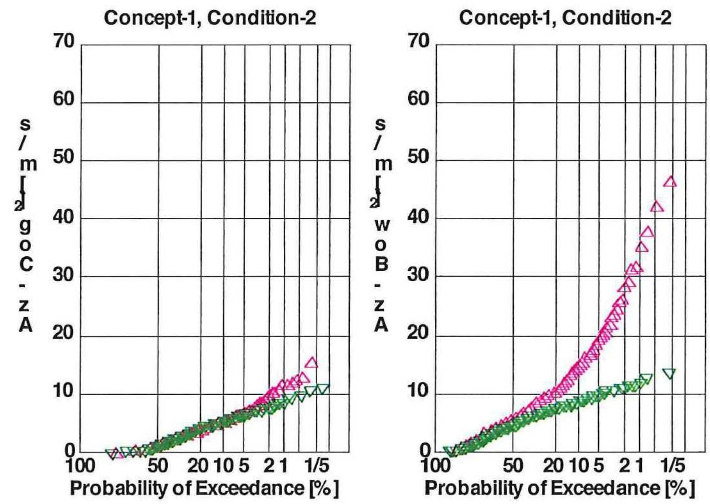

Fig. 47. Az_CoG and Az_Bow of "Concept 1"

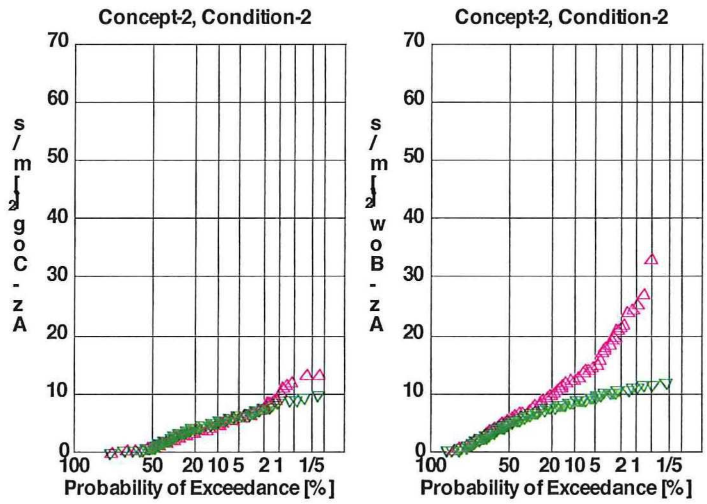

Fig. 58. Az_CoG and Az_Bow of "Concept 2"

3.4 Tests in following waves

To check on the possible tendency to bow diving and make a comparison in this aspect between the three designs, tests in high following waves have been carried out in the Delft tank. The conditions have been chosen in such a way that two situations did occur: one in which the ship was slowly **overtaken by** the wave and one in which the ship was slowly **overtaking** the wave. These tests have been carried out with a constant forward speed in the Delft tank. The speed during the tests was chosen at 18 and 25 knots respectively. The waves generated were a so called "bi-chromatic wave train". By generating two regular waves with a small difference in frequency the amplitude of the resulting wave is slowly varying in time. The capabilities of the wave generator to generate the maximum wave height possible determined the selected frequencies. The maximum wave height encountered was roughly 3.5 to 4.0 meters at full scale, this being the maximum capability of the wave generator at this scale and this wave length. The wave length was between 75 and 90 meters at full scale. In the actual realisation of the waves care has been taken that the highest wave would indeed be met during the runs. This procedure eliminated the otherwise inevitable necessity of carrying out an extreme large number of runs to gain sufficient statistical worthy information when carrying out the tests in a real spectrum due to the very low frequency of encounter between the ship and the waves. Care has been taken again that all models were tested in exactly the same wave realisations. So for the sake of comparison these test procedure proved very feasible and useful.

Presentation of the results of these tests is rather cumbersome, because sensible statistical elaboration of the signals is not possible due to the limited amount of fluctuations and tests carried out. The most important output is the video taken from all runs. On these videos it is evident that not one of the models had any tendency to bow diving. This was certainly also true for model Concept 2, which was prior to the tests suspected of this possible tendency due to the sharp bow sections. One possible way of presenting the results of such is shown in Figure 19 in which the time traces of the signals for the heave, the pitch, the wave and the relative bow motion are presented for each of the models for one particular run. As can be seen from this plot the difference between the three models are marginal.

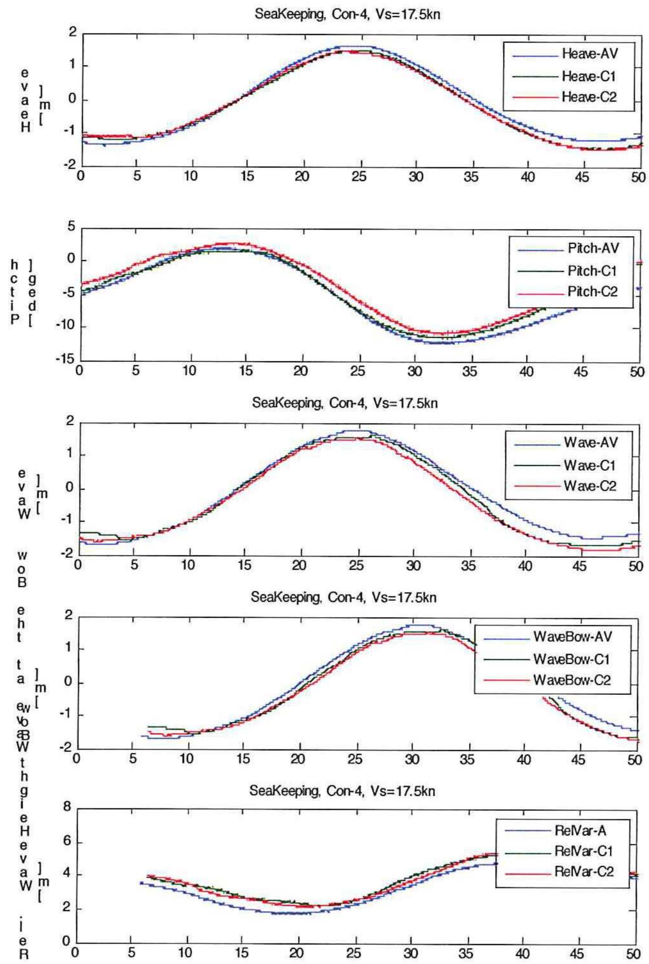

Fig. 69. Following waves Results 17.5 kn

3.5 Comparison with free Sailing Models in stern quartering Waves

Additional tests have been carried out with free sailing models in the SMB of MARIN at Wageningen. For these tests MARIN had developed a new measurement setup allowing the models to broach without being restrained by the measurement setup. This implied that there was no connection between the model and the towing carriage, which followed the model through the tank. The models were under control of an autopilot and the motions were measured using an inertia measurement system. During these tests also the worst possible environmental conditions, which could be realized in this specific facility, with respect to the possibility of broaching have been sought. This meant significant wave heights up to 3.5 meter, peak periods Tp of the Jonswap spectrum of 7.0 seconds and forward speed (average) around 20 knots. The wave incidence angles were 0 degrees (following) and 45 degrees (stern quartering) respectively. In each condition at least 15 different runs have been made, for all models in exactly the same part of the spectrum realisation. For these free sailing tests the models Concept 1 and Concept 2 were equipped with two skegs aft to increase their directional stability. For the Arie Visser design these were not applied because all except one of the existing Arie Visser boats sail without them and for the benchmark role it was considered sensible to keep as close to real life experience as possible.

A typical result is presented in the Figure 17 in which the distribution of the roll and yaw motion are presented for the tests with 045 degrees wave incidence. It should be noted that the number of variations in these combined runs is still rather limited due to the low frequency of encounter between model and waves.

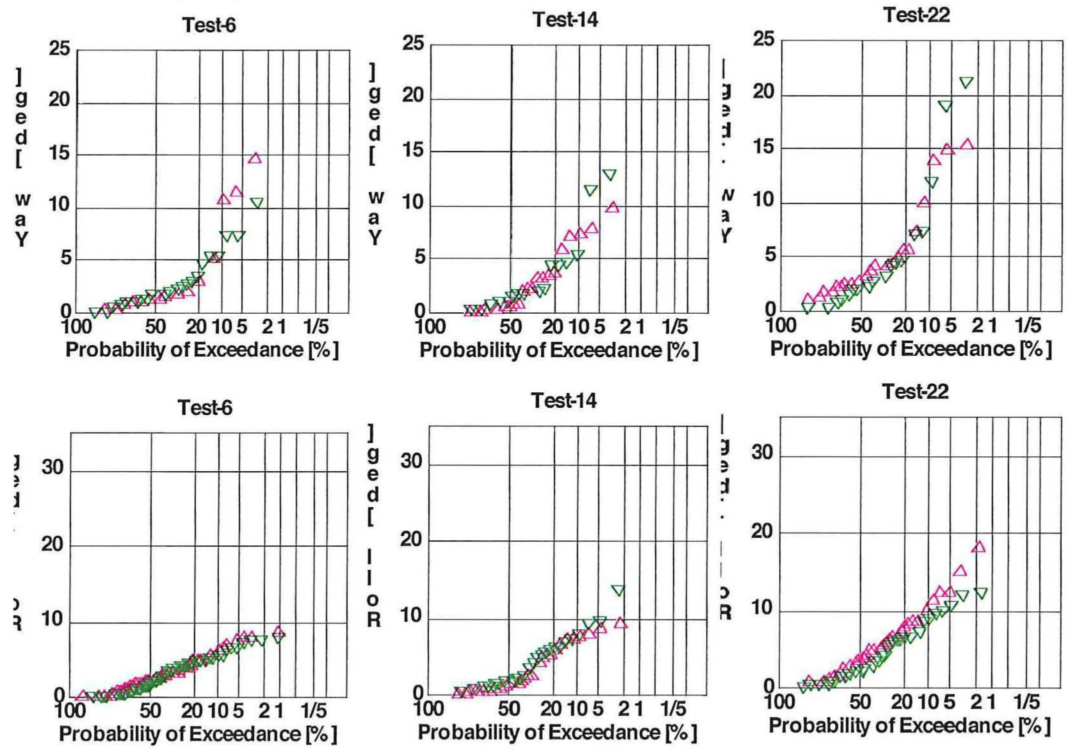

Fig. 20 Results stern quartering waves tests SMB; Test-6 Arie Visser, Test-14 Concept 1, Test-22 Concept 2

As can be seen from these results the Arie Visser rolls up to 10 degrees and Concept 1 slightly more. The Concept 2 model rolls considerably more, up to 18 degrees. A similar difference can be seen for yaw: the Arie Visser has maximum values of 15 degrees, Concept 1 has slightly lower yaw angles and Concept 2 exceeds them both will yaw angles up to 20 degrees. These differences can be attributed to a large extend to the difference in transverse stability: the GM values of the Concept 2 model was some 20% lower than those of the other models. This was actually below the design criteria set at the beginning of the project but proved difficult to achieve in the design process. The positive effect of the skegs explains the difference in yaw between Arie Visser and the Concept 1 model.

The maximum values of both roll and yaw are still relatively small considering the severe conditions the models were sailing in and it should be noted that from the visual observations and the video's no real broach has been observed during any of these tests. The only model that came actually close to a broach twice was the Arie Visser, but unfortunately this happened during a breakdown of the on board measurement system so these are not included in the results.

Based on these results and the requirements of the coxswains of the KNRM a slightly different design was developed along the lines of Concept 2. Originally the coxswains wanted a larger ship then the Arie Visser but later that changed. Because most of their missions nowadays were involving yachts, the coxswains wanted in the end not a longer but a boat of a similar size of the Arie Visser. Therefore the new design, Concept 3, was slightly smaller, i.e. 1.5 meters, was considerably lighter, i.e. 20% less weight made possible by the introduction of a GRP super structure, it has smaller and lighter engines and carried less fuel. This became possible through a change in the design specifications aiming at reducing the weight. Originally the high speed and the long range called for heavy engines and tons of fuel. By reducing the overall weight smaller and lighter engines became possible consuming less fuel. Also the desired range was reduced.

All these changes resulted in a 9 tons smaller displacement and a similar GM value compared to the Arie Visser class. This new design was called Concept 3 and most of the tests as carried out previously have been repeated with this design too. These results showed in all motions and behaviors improved values when compared to Concept 2. So for the final tests this became the desired model and all the further tests and the comparisons have finally been made between the Arie Visser and Concept 3.

3.6 Tests in extreme waves

Finally a series of tests have been carried out in the Delft towing tank in extreme waves. The aim of these tests was to compare the behavior of the Arie Visser and the Concept 3 in head waves for bow submergence and in following waves for broaching.

Hereto a special waves train has been generated in the towing tank with resulted in an very short series of extreme breaking waves at one particular place in the towing tank and a one particular instant. Using this method it was possible to generate extreme wave heights up to 8 meters at full scale. The models were remotely controlled and free sailing and the crux of the experiments was to be with the models at speed at the right time at the right place. When successful this resulted in an extreme situation for the designs. These tests were carried out a considerable number of times to account for errors in the timing. During the tests motions and accelerations were measured and video recordings made.

Fig. 21 "Arie Visser" in extreme head wave

Fig. 22 Concept 3 in extreme head wave

Fig. 23 "Arie Visser" broaching in following breaking wave

Fig. 24 Concept 3 in following breaking wave

Of some of these tests videos "stills" are presented in the following figures, which show the Arie Visser and the C 3 in head waves and following waves respectively. The tests in head waves showed that nor the Arie Visser nor Concept 3 ever dug its bow into the waves. In addition the combined heave and pitch motion at the bow were considerably more modest with Concept 3 then for the Arie Visser. Also the surge motions was considerably less. This improved behavior of Concept 3 was certainly true for the vertical accelerations at the bow. It is also worth noting that in 80% of the tests in following waves the Arie Visser made a broach while Concept 3 never broached.

The videos of some of these tests were these "stills" come from will be shown during the presentation.

4 CONCLUSIONS

The result of this project is that a rather sensible and feasible method has been found to analyse and compare the performance of relatively small and fast ships in average and more extreme conditions. This has been achieved within a limited amount of time and with a limited budget.

Some of the results of the tests with the models are summarized below. To apprehend the differences between the behaviour in waves of the several designs and in particular with respect to the accelerations and extreme motions in waves it is better to look at the presented Rayleigh distribution plots, because they draw a more complete picture. In the Table the calm water resistance at 30 knots, the peak acceleration exceeded in 1 % of the total measured both in the wheelhouse and 10% of the length aft of the bow and the tendency to broach or bow dive in either following or head extreme waves are presented.

	Rt 30kn Calm water	Az CoG 1% exceed	Az Bow 1% exceed	Broach? Freak wave	Bow Dive? Freak wave
ArieVisser	50 kN	19 m/sec^2	40 m/sec^2	yes	no
Concept 1	61 Kn	14 m/sec^2	38 m/sec^2	Not tested	Not tested
Concept 2	62 kN	11 m/sec^2	26 m/sec^2	no	no
Concept 3	53 kN	10 m/sec^2	24 m/sec^2	no	no

It is obvious from the results that Concept 3 design is the best for application as Search and Rescue boat, because this hull shape has a much better performance in head and bow quartering seas without losing any performance in following and stern quartering seas.

The results of these tests with Concept 3 also showed the beneficial effect of less displacement and in following waves these tests showed that indeed the transverse stability is important for preventing extreme motions in following waves at high speeds.

The new design Concept 3 has been found superior to the Arie Visser and Concept 1 and 2 in all aspects.

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THE THIRD CHESAPEAKE POWERBOAT SYMPOSIUM

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