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The results of the Delft Systematic Deadrise Series

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The Results of the Delft Systematic Deadrise Series

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In the present paper the development of the Delft Systematic Deadrise Series (DSDS) is described. The DSDS has been under development for decades by now and consists of a large family of systematically varied hard chine planing monohulls, based on the original research by Clement and Blount, which have all been tested in the same speed range, changing the same parameters and using the same experimental set up. The rationale behind the DSDS is highlighted. The DSDS contains up to now some 24 different models in 350 different conditions all tested in the same speed range between $Fn_\nabla = 0.75$ and $Fn_\nabla = 3.0$.

Recently there has been a new extension to the DSDS with the inclusion of more measurements on hulls with twisted bottom and rocker in the aft ship. These results are presented in this paper.

In addition detailed access is facilitated to all the hull geometries used into the DSDS and to all the raw measurement data obtained during the tests by means of free access to a dedicated website.

NOMENCLATURE

β	[°]	:	Deadrise angle of planing bottom with respect to horizontal plane. Measured at Ord. 10
ε	[°]	:	Twist angle, i.e. deadrise at Ord. 10 minus the deadrise at Ord. 0
γ	[°]	:	Buttock angle, average centerline angle from Ord. 10 to Ord. 0 with respect to the baseline. Positive for a draft at Ord. 0 greater than draft at Ord. 10
A_P	[m^2]	:	Projected planing bottom area, excluding area of external spray strips
$A_p/\nabla^{2/3}$	[-]	:	Loading Coefficient
B_{pa}	[m]	:	Mean breadth over chines, A_p/L_p
B_{pt}	[m]	:	Breadth over chines at transom, excluding external spray strips
B_{px}	[m]	:	Maximum breadth over chines, excluding external spray strips
C_{ap}	[%L_p]	:	Centroid of planing area, A_p

dθ	[°]	:	Running trim angle, relative to its value at zero speed. Positive for bow down.
dZ	[m]	:	Sinkage, relative to its position at zero speed. Positive out of water
Fn_∇	[-]	:	Froude number based on displacement
g	[m/s^2]	:	Gravitational acceleration, 9.81m/s^2
L_c	[m]	:	Dynamic wetted length over chine
L_k	[m]	:	Dynamic wetted length over keel
L_P	[m]	:	Length of projected planing bottom area, length over chines
L_p/B_{px}	[-]	:	Length to Beam Ratio
LCG	[%L_P]	:	Longitudinal Center of Gravity from Ord. 10
S_{wet}	[m^2]	:	Dynamic wetted surface area, measured at speed.
v	[m/s]	:	Speed
Δ	[N]	:	Weight of displacement
∇	[m^3]	:	Volume of displacement

1 INTRODUCTION

Since the Second World War there has been a growing interest in the application of hard chine planing hulls as a method to achieve high speeds over water at a reasonable cost. Reputable systematic research efforts to facilitate the design of such boats were, amongst others, carried out by Savitsky and Clement and Blount in the 1960's. Savitsky based his results on a large database of tests with planing wedges yielding very usable data in particular at high speeds (Savitsky 1964) and Clement and Blount based their results on tests with actual planing hull forms (Clement & Blount 1963).

The results published by Clement and Blount of an extensive research project carried out at the David Taylor Model Basin (DTMB) in Washington DC on the calm water resistance, the running trim and the sinkage of five systematically varied hard chine planing hull forms became known as Series 62. Designers frequently used these results because it covered a large speed range of interest. In their series the Length to Beam ratio (L_p/B_{px}) of the chine area of the models was varied between 2.0 and 7.0. This range corresponded quite well with that of small boats with outboard engines up to larger patrol craft. The deadrise angle of all the models was fixed to 12.5° at midships, a quite favored deadrise angle at that time and the models all had a prismatic aft body, i.e. the deadrise between midships and stern was kept constant. In the series the Longitudinal position of the Centre of Gravity, (LCG) and the relative weight or Loading Factor ($A_p/\nabla^{2/3}$) were varied. The lines plans of the models of Clement and Blount are depicted in Figure 1.
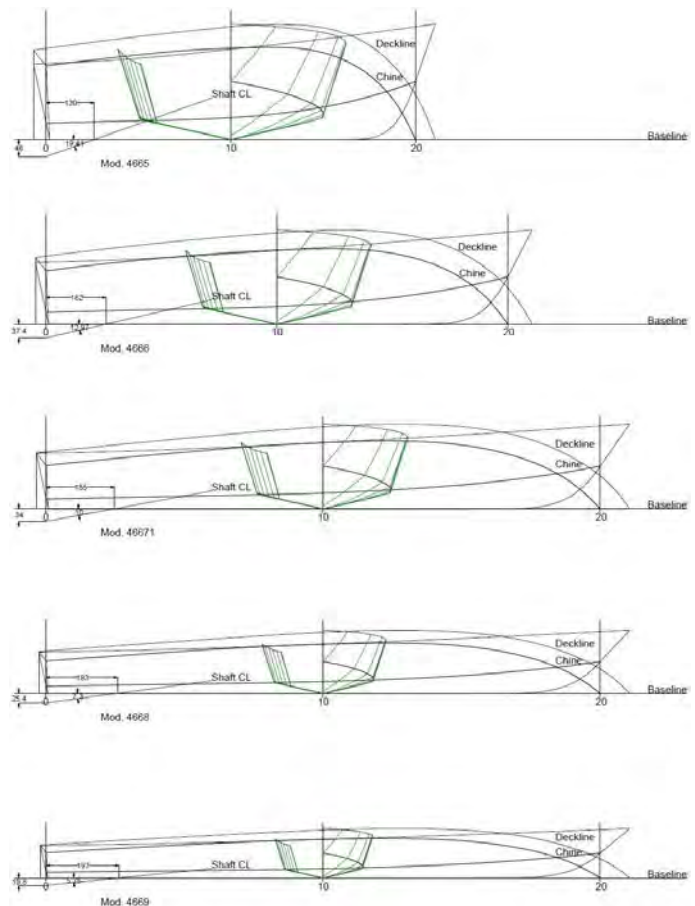

Figure 1: Clement & Blount, 12.5° degrees deadrise series (1963)

From later research carried out in the 1970's and 1980's on the behavior of planing boats in waves it became evident that in particular the deadrise angle was a paramount parameter for improving the seakeeping behavior of these fast planing boats. Until then the emphasis in the design had been mostly put on minimizing the calm water

resistance or maximizing speed. Being able to maintain this high forward speed as long as possible when operating in more exposed areas gradually became more of an issue when the operation of these fast planing monohulls shifted from naval to civil applications.

In 1970 J. J. van den Bosch (Bosch 1970) tested a model very similar to the Clement parent and a high deadrise derivative of this in waves and demonstrated the highly beneficial effect of an increased deadrise on the motions and accelerations in waves: a higher deadrise reduced the peaks in the vertical accelerations in head waves to a large extend and improved the operability of these craft in a seaway. However a higher deadrise also has a strong influence on the calm water resistance of the boat: i.e. the higher deadrise generally results in a higher resistance. So a compromise between these two is sought. To be able to do this more information on both the effect of the deadrise on resistance as the effect on seakeeping behavior was needed.

To investigate this further Keuning and Gerritsma (Keuning & Gerritsma 1982) extended the original series of Clement and Blount in 1982 with identical tests on an additional series of 5 different planing hull forms using the same parent hull shape as Clement and Blount but now having 25.0° of deadrise. Their parent model was obtained from the parent hull of Clement and Blount by means of affine transformation techniques (Versluis 1977). In these new hull shapes the deadrise was changed (increased) while the vertical projection of the chine area and the hull shape above the chine were kept equal to the Clement and Blount hulls. The lines plans of this series are depicted in Figure 2. This new series was now tested in the Delft Towing Tank of the Delft University of Technology in the Netherlands. All parametric changes on these new models were identical to those tested by Clement and Blount. However due to physical limitations of the Delft Towing tank the speed range in these new series of tests was now limited from $Fn_\nabla = 0.75$ to $Fn_\nabla = 3.0$.

The hard chine planing hull form became at that time increasingly popular as a relatively cheap and reliable concept for fast hull applications for commercial and patrol ships. The parent hull shape as chosen in the DSDS experiments, based on the original Clement and Blount Series 62 parent hull, was developed a little bit too much with (very) high speeds in mind. For those high speeds a constant deadrise is a good option. However most commercial designs are operating at a large speed range and are often sailing a considerable amount of time at relatively lower speeds.

From dedicated research projects in the 1980's it was found that applying twist and rocker in the aft ship had a profound effect on the hydrodynamic performance of hard chine planing hulls, especially in the lower Froude range. This lead designers to applying twist and rocker in the aft ship to reduce resistance at lower speeds. Furthermore it became known from real-life experience that most designers of commercial planing hulls often applied both twist and rocker in the aft ship in order to be able to use larger propeller diameters without protruding these too much below the hull and/or having to deal with too large shaft inclinations. Considering developments in the design of hard chine planing hull forms highlighted above and the fact that all the models in the DSDS series so far had prismatic aft bodies, i.e. constant deadrise angle from midships to transom, the practical use of the DSDS database at that time was limited .
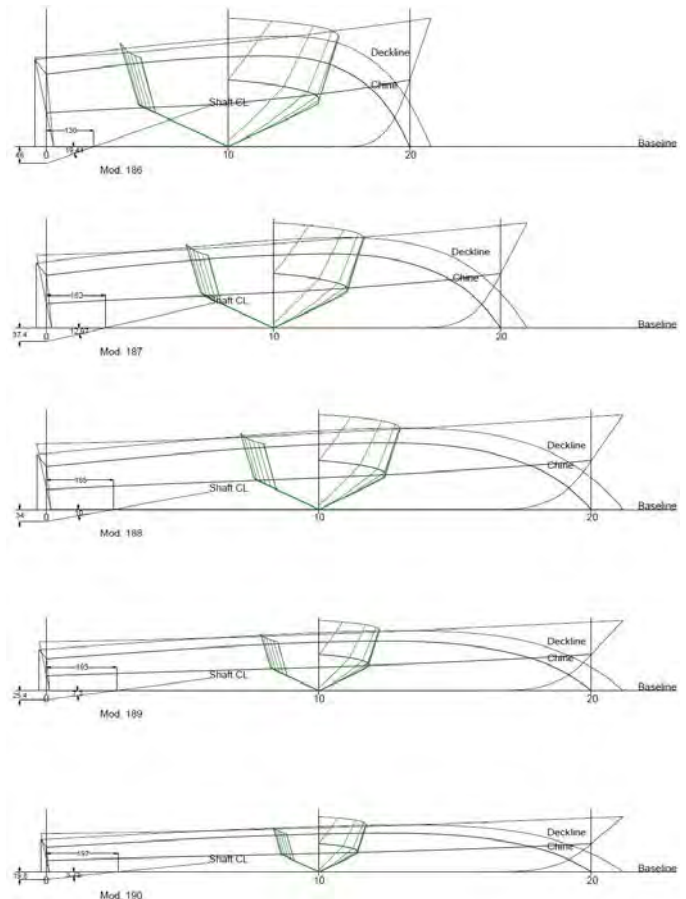

Figure 2: Keuning an Gerritsma, 25.0° deadrise series (1982)

Keuning e.a. extended the series in the beginning of 1986 (Keuning 1986) by testing a limited "sub-series" in which they used the 25.0° deadrise $L_p/B_{px} = 4.09$ parent hull as a parent, to investigate the effect of this "twist" and "rocker" in the aft ship on the resistance, sinkage and trim. By doing so it became possible to derive a "correction" polynomial for this twist and rocker, which can be applied on the

results obtained for the prismatic hulls. The parameters used to define the twist and the rocker in the aft ship were: the twist angle (ε) and the buttock angle (γ). This buttock angle is further clarified in Figure 3
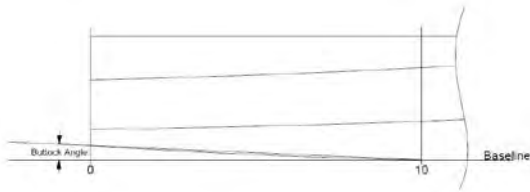

Figure 3: Buttock Angle per definition. Negative as shown above

The lines plans of these models are depicted in Figure 4.
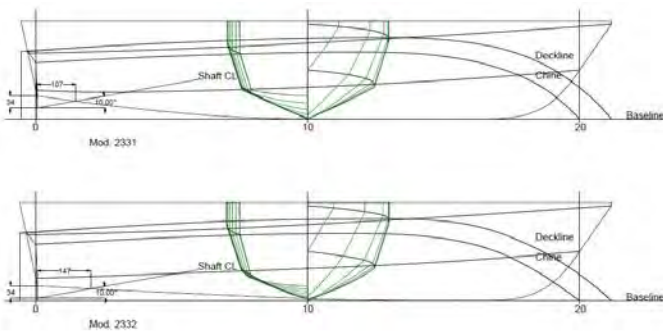

Figure 4: Keuning and Gerritsma, 25.0° deadrise with twist and rocker (1986)

Late 1986 it was decided by Keuning and Gerritsma, to extend the database once more, now by adding four new models with a (constant) deadrise of 30°. This has been done using an identical transformation procedure and testing technique as has been used for the experiments carried out in 1982 and the beginning of 1986 to ensure the systematic approach was continued. The lines plans of this series are depicted in Figure 5
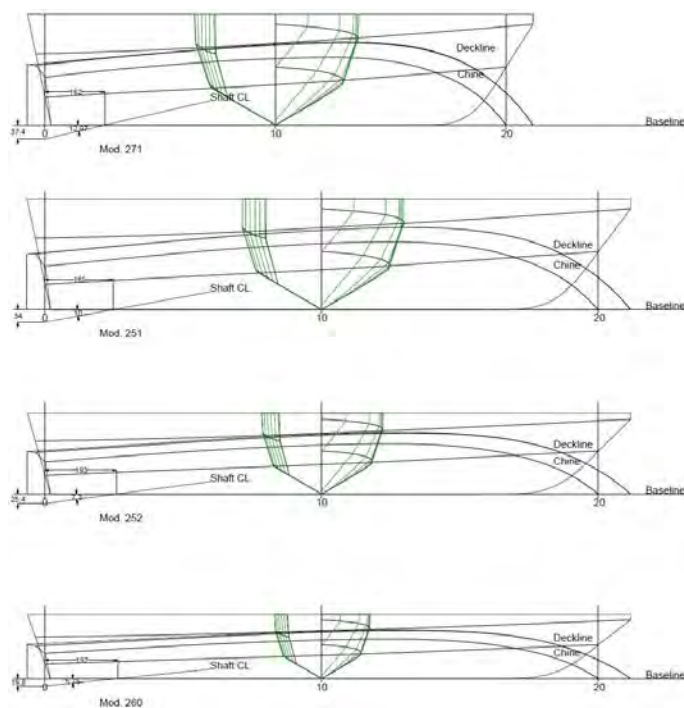

Figure 5: Keuning and Gerritsma, 30° deadrise series(1986)

In combination with the results of the original Clement and Blount research, an extensive database on resistance, trim and sinkage of planing hulls was now available. Using this database a new assessment method for the hydrodynamic performance of planing boats usable in the design phase was developed. This new assessment method makes use of speed independent polynomial expressions for resistance, sinkage and trim of which the coefficients are derived using regression methods. This program became known as the "Planing Hull Forms" program (i.e. PHF). The database on which it was based became known as the Delft Systematic Deadrise Series (DSDS). In 1993 J.A. Keuning, J. Gerritsma and P.F. van Terwisga published this resistance, trim and sinkage assessment method together with results from the experiments carried out in 1986 (Keuning, Gerritsma & Terwisga 1993)

To achieve an even better fit over the entire range of all the deadrise angles used in actual designs and in particular because of the fact that a considerable amount of hard chine planing hulls were designed around the 20 to 25 degrees of deadrise range, it was decided in 1996 that the DSDS database was again to be extended along the original lines with a similar series but now with 19° of deadrise to better "fill the gap" between 12.5° and 25° of deadrise. The lines plans of this series are depicted in Figure 6.
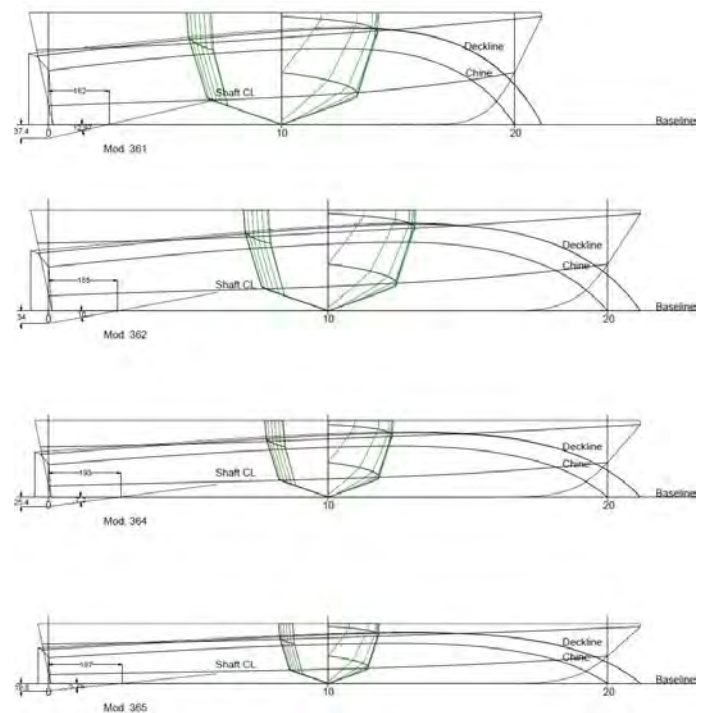

Figure 6: Keuning and Gerritsma 19.0° deadrise series (1996)

After this research effort the entire Delft Systematic Deadrise Series contained now information about 20 different hulls with 12.5°, 19.0°, 25.0° and 30.0° of deadrise at midships

respectively, all tested in a speed range from Fn_∇ = 0.75 to Fn_∇ = 3.0 with 4 different displacements and 4 different *LCG* positions.

Later, the correction polynomial introducing the effects of twist and rocker on the calm water resistance, trim and sinkage was considered to be based on too small amount of data to yield accurate results over the entire range of parameters used. In 2013 it was therefore decided to extend this twist and rocker sub-series once again and to test a larger series of models with rocker and twist in the aft ship but now with more L_p/B_{px} ratios (see Figure 7). The deadrise at midships, however, was still kept the same for all these "twisted" models, i.e. at 25°. The extension of the database was aimed at improving the aforementioned "correction polynomial".

Based on this extended database of the DSDS and now with more data on hull shapes with the possibility to introduce twist and rocker an updated version of PHF has been made.
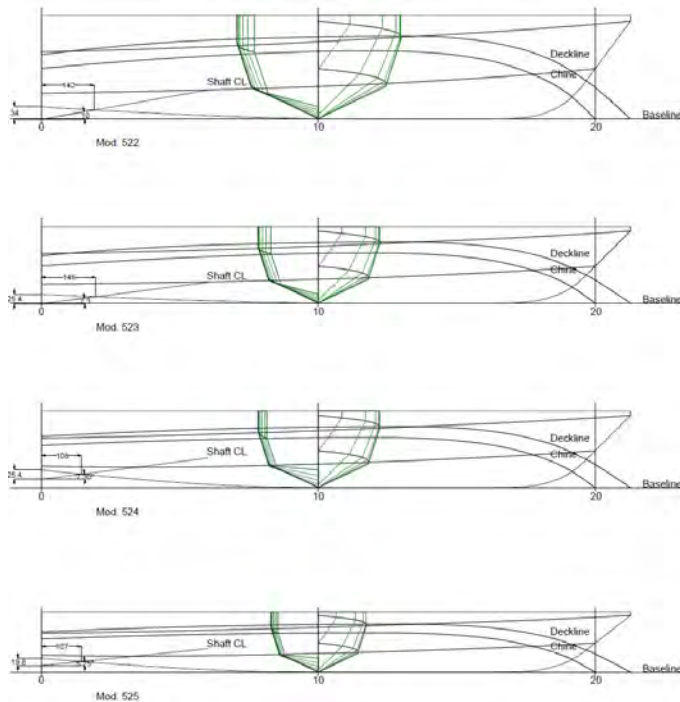

Figure 7: Keuning and Den Ouden, 25.0° deadrise series with Twist varied for 10° and 20° (2013)

2   THE MODELS

The parent model for the entire DSDS is the Parent model of Clement and Blount from their Series 62. This parent model has a deadrise at midships of 12.5°, a prismatic aft body and a Length to Beam ratio over the chine of L_p/B_{px} = 4.09. To keep the designs of all the parent models used in the DSDS as much identical as possible the following characteristics have been kept the same compared to this parent as far as the models without twist and rocker are concerned:

– The length and beam over the chine L_p/B_{px}
– The vertical projection of the chine A_p
– The vertical projection of the deck line
– The center line, except in the foremost part where it has been modified to yield the appropriate length over the chine when different deadrise is introduced
– All the models have developable surfaces as hull surfaces (plating)
– The transom slope
– The length of the prismatic aft body

The models with twist and rocker deviate from these characteristics. For their shape reference is made to Figure 4 and Figure 7. The twist and rocker is applied on models with varying L_p/B_{px} so information becomes now available on the effect on resistance, sinkage and trim from L_p/B_{px} = 4.09 till L_p/B_{px} = 7.0.

The lines plans and body plans of all prismatic parent hull forms are depicted in Figure 8.

In Figure 1, Figure 2 and Figure 4 to Figure 7 the shaft line for all hulls has been depicted. This imaginary shaft line was used to determine the height of the towing point of the models as used in the experiments. The main particulars of all the physical models (24 in total) present in the DSDS are presented in Table 1, Table 2 and Table 3. All models had spray strips over the entire length of the chine. The bottom of these spray strips was an extension of the bottom of the hull from the transom (ordinate 0) to ordinate 10 (midships) and was horizontal from ordinate 12 to the bow, with a transition region between ordinate 10 and 12. The spray strips had a width of approximately 4 mm. and they had very sharp edges.
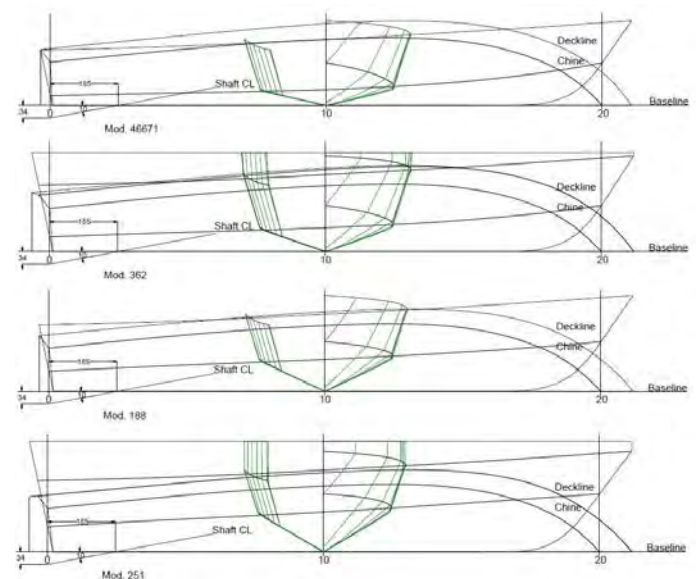

Figure 8: Prismatic Parent Hull Forms of the DSDS

During the entire duration of the testing of the models different materials for model construction have been used, ranging from transparent trovidur plates to glass fiber reinforced polyester with no gelcoat. The hulls were therefore transparent and this enabled "through hull" photography during the tests runs to determine the actual dynamic wetted area of the model, i.e. the wetted area at speed, during each test.

	Model	4665	4666	46671	4668	4669	361	362	363	364
β	[°]	12.50	12.50	12.50	12.50	12.50	19.00	19.00	19.00	19.00
ε	[°]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
γ	[°]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaft angle	[°]	19.41	12.97	10	7.3	5.75	12.97	10	7.3	5.75
L_P	[m]	1.192	1.825	2.438	2.438	2.438	1.250	1.500	1.500	1.500
B_{PA}	[m]	0.504	0.495	0.305	0.363	0.285	0.340	0.299	0.223	0.175
B_{PX}	[m]	0.596	0.596	0.596	0.443	0.348	0.408	0.367	0.273	0.214
B_{PT}	[m]	0.477	0.422	0.381	0.285	0.224	0.288	0.236	0.175	0.137
L_P/B_{PA}	[-]	2.365	3.690	5.000	7.720	8.560	3.676	5.011	6.737	8.588
L_P/B_{px}	[-]	2.000	3.090	4.090	5.500	7.000	3.060	4.090	5.500	7.000
B_{PX}/B_{PA}	[-]	1.180	1.210	1.220	1.220	1.220	1.200	1.226	1.226	1.225
B_{PT}/B_{PX}	[-]	0.800	0.710	0.640	0.640	0.640	0.706	0.643	0.641	0.640
A_P	[m²]	0.601	0.903	1.189	0.884	0.695	0.425	0.449	0.334	0.262
C_{AP}	[% L_p]	47.500	48.200	48.800	48.800	48.800	48.08	48.733	48.733	48.667
$A_p/\nabla^{2/3}$	[-]	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5
LCG	[-]	0 – -12	0 – -12	0 – -12	0 – -12	0 – -12	0 – -8	0 – -8	0 – -8	0 – -8
Fn_∇	[-]	0 – 6	0 – 6	0 – 6	0 – 6	0 – 6	0 – 3	0 – 3	0 – 3	0 – 3

Table 1: Model Properties of the DSDS; Clement and Blount (1963) Keuning and Gerritsma (1996)

	Model	186	187	188	189	190	271	251	252	260
β	[°]	25.00	25.00	25.00	25.00	25.00	30.00	30.00	30.00	30.00
ε	[°]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
γ	[°]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaft angle	[°]	19.41	12.97	10	7.3	5.75	12.97	10	7.3	5.75
L_P	[m]	1.000	1.250	1.500	1.500	1.500	1.250	1.500	1.500	1.500
B_{PA}	[m]	0.430	0.342	0.300	0.223	0.175	0.300	0.300	0.223	0.175
B_{PX}	[m]	0.500	0.408	0.367	0.273	0.214	0.367	0.367	0.273	0.214
B_{PT}	[m]	0.400	0.290	0.235	0.175	0.137	0.260	0.235	0.175	0.137
L_P/B_{PA}	[-]	2.372	3.653	5.000	6.726	8.560	4.170	5.000	6.726	8.571
L_P/B_{px}	[-]	2.000	3.064	4.087	5.494	7.010	3.410	4.090	5.500	7.000
B_{PX}/B_{PA}	[-]	1.164	1.192	1.220	1.220	1.220	1.220	1.220	1.220	1.220
B_{PT}/B_{PX}	[-]	0.800	0.711	0.640	0.640	0.642	0.710	0.640	0.640	0.640
A_P	[m²]	0.430	0.428	0.450	0.335	0.263	0.384	0.450	0.335	0.263
C_{AP}	[% L_p]	47.113	47.879	48.800	48.800	48.800	47.900	48.800	48.600	48.600
$A_p/\nabla^{2/3}$	[-]	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5
LCG	[-]	0 – -12	0 – -12	0 – -12	0 – -12	0 – -12	0 – -8	0 – -8	0 – -8	0 – -8
Fn_∇	[-]	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3

Table 2: Model Properties of the DSDS; Keuning and Gerritsma (1982) and Keuning and Gerritsma (1986)

	Model	2331	2332	522	523	524	525
β	[°]	25.00	25.00	25.00	25.00	25.00	25.00
ε	[°]	20.00	20.00	10.00	10.00	20.00	20.00
γ	[°]	-4.93	-2.61	-2.2	-1.69	-3.41	-2.68
Shaft angle	[°]	10	10	10	7.3	7.3	5.75
L_P	[m]	1.500	1.500	1.500	1.500	1.500	1.500
B_{PA}	[m]	0.306	0.303	0.312	0.231	0.237	0.186
B_{PX}	[m]	0.367	0.367	0.367	0.273	0.273	0.214
B_{PT}	[m]	0.320	0.310	0.276	0.202	0.229	0.180
L_P/B_{PA}	[-]	4.900	4.900	4.808	6.503	6.338	8.065
L_P/B_{px}	[-]	4.090	4.090	4.090	5.500	5.500	7.000
B_{PX}/B_{PA}	[-]	1.200	1.200	1.176	1.184	1.154	1.151
B_{PT}/B_{PX}	[-]	0.872	0.844	0.752	0.740	0.839	0.841
A_P	[m²]	0.459	0.454	0.468	0.346	0.355	0.279
C_{AP}	[% L_p]	48.800	48.800	47.467	47.467	46.667	46.667
$A_p/\nabla^{2/3}$	[-]	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5	4 – 8.5
LCG	[-]	0 – -12	0 – -12	0 – -12	0 – -12	0 – -12	0 – -12
Fn_∇	[-]	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3	0 – 3

Table 3: Model Properties of the DSDS; Keuning and Gerritsma (1986) and Keuning and Den Ouden (2013)

3 EXPERIMENTAL SETUP

All tests in the DSDS have been carried out in the #1 towing tank of the Delft Ship Hydromechanics Laboratory of the Delft University of Technology. The dimensions of this tank are: length 142 meters, width 4.25 meters and maximum water depth 2.5 meters. The maximum attainable speed of the towing carriage is 7.0 m/sec.

The models were connected to the towing carriage in such a way that they were free to heave (sinkage) and pitch (trim) but restrained in all other modes of motion. The pivot of this construction that connected the model to the towing carriage was positioned at the intersection of the (assumed) shaft line and the cross section in the Longitudinal position of the Centre of Gravity (LCG). Thus the towing point changed with every change in Longitudinal Centre of Gravity.

A strain gauge type dynamometer was used for measuring the resistance force at the pivot point. The sinkage and the trim of the model were measured in the earlier tests with vertical displacement meters fore and aft of the "wire over potentiometer" type and in the later tests (after 1995) with an optical tracking system. The presented values are averages over at least 10 seconds extending to 20 seconds for the tests with lower speeds.

No turbulence stimulation has been applied on the models and no towing speeds below 1 m/sec have been used.

During each and every run a "through hull" photograph has been taken to enable the determination of the actual wetted surface of the hull at speed (i.e. dynamic wetted area) as well as the wetted length over the centerline (L_k) and the chine (L_c). The dynamic wetted surface has been used in the extrapolation of the measured results to full scale. No form factor has been determined and consequently also not used in the extrapolation procedure. For the extrapolation of all measured data, when applicable, the Froude extrapolation method has been used using the ITTC-57 friction line. For the determination of the characteristic length in the Reynolds number the average of the wetted length over the centerline and the wetted length over the chine has been used.

4 MEASUREMENT SCHEME

The tests program for each sub-series of the DSDS consisted over all possible combinations of the parameter variation shown in Tables 1 to 3 (one should take notice of the fact that the number of combinations of twist, rocker and L_p/B_{px} are limited):

Some of these test conditions appeared to be unrealistic and unworkable for the tests. For instance high displacements with an extreme aft position of the Center of Gravity often caused submergence of the aft deck at rest. These conditions have therefore been omitted from the test program. All test conditions have been kept the same as with the tests carried out by Clement and Blount, except for the forward speed. Due to the limitations of the Delft towing tank the forward speed has been limited to $Fn_\nabla = 3.0$ as a maximum. This is considerably lower than in the Clement and Blount tests. From a practical point of view this was not considered to be a too large restriction because this speed range covers already most commercial applications.

5 RESULTS

As will be presented later in this report under "RELEASE OF THE RESULTS OF THE DSDS" the Delft Ship Hydromechanics Laboratory has decided to make all the measured data obtained within the DSDS available through a website. This includes also all the results of the latest tests with the models with twist and rocker. Therefore no results of these tests will be presented in this paper separately, except for some figures to demonstrate the (measured) effects of the twist and rocker on the resistance, the sinkage and the trim of the models as function of the L_p/B_{px} ratio. These results are depicted below. Please note that all data in these figures is for a deadrise at midships of 25 degrees.
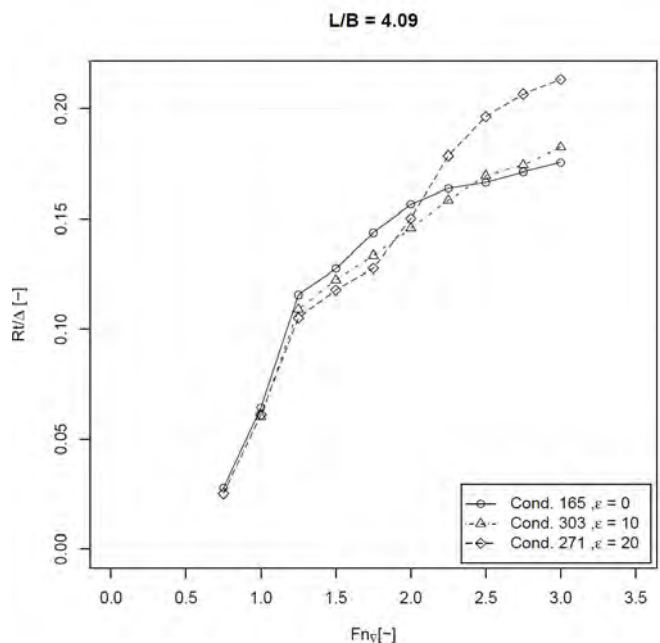

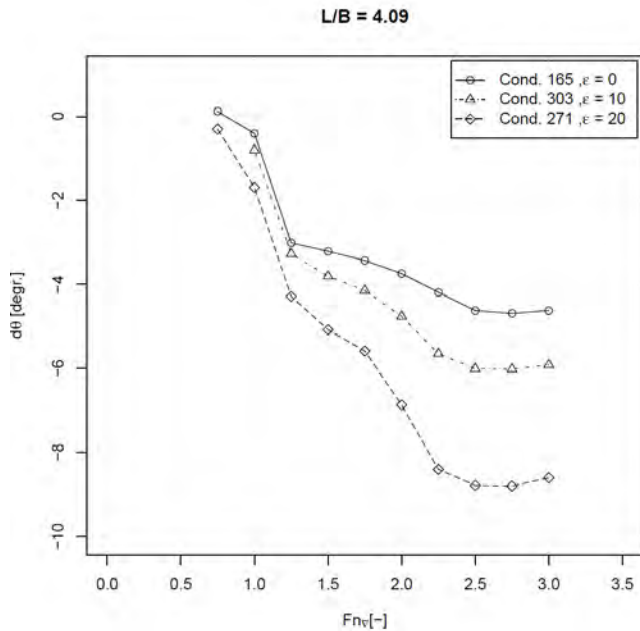*Figure 8: Change in Resistance due to Twist and Rocker*

Figure 9: Change in Trim due to Twist and Rocker

Figure 11: Change in Trim due to Twist and Rocker

In Figure 8 and Figure 9 the change in R_{tot}/Δ and running trim is shown for models with an L_p/B_{px} ratio of 4.09 and *LCG* of -4% with an increasing twist angle ranging from 0 degrees (i.e. the prismatic aft body) to a twist of 10 and 20 degrees respectively. The data presented is for a "medium" displacement, i.e. for $A_p/\nabla^{2/3} = 5.5$. The rocker is increasing from zero degrees, to 2 degrees and finally 4 degrees. In Figure 10 and Figure 11. similar results are shown but now for a L_p/B_{px} ratio of 7. These plots clearly show the trends for the application of twist and rocker.

In the lower speed range the resistance decreases with twist and rocker in particular for the lower L_p/B_{px} hull, presumably primarily caused by the decrease in submerged transom area
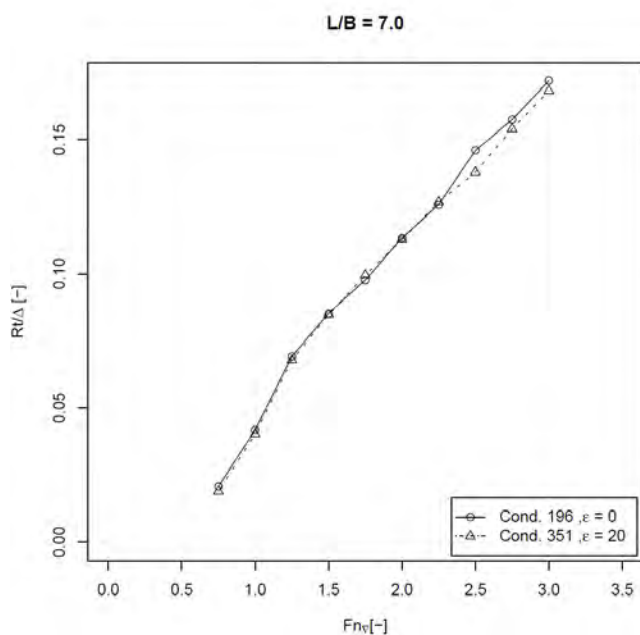

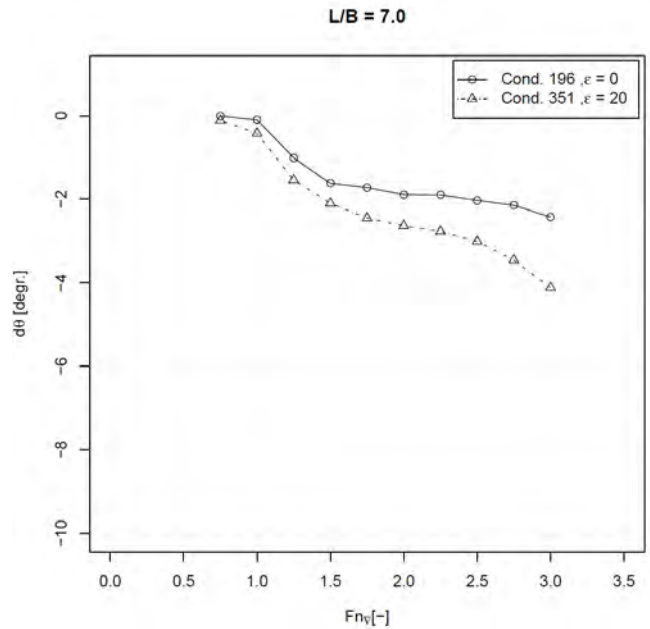*Figure 10: Change in Resistance due to Twist and Rocker*

At higher speeds the resistance increases significantly with the increase in twist and rocker. This may be associated with the decrease in the development of hydrodynamic lift due to the upsloping bottom area aft. It should be noted that the lower L_p/B_{px} (i.e. $L_p/B_{px} = 4.09$) hull is a more effective lift producer than the high L_p/B_{px} hull (i.e. $L_p/B_{px} = 7.0$) so the effects are more strongly felt.

These effects can also be clearly seen when the running trim is concerned: for the lower L_p/B_{px} of 4.09 an increase in running trim to almost 8 degrees (an increase of almost 100%) can be observed while for the high L_p/B_{px} hull (i.e. $L_p/B_{px} = 7.0$) the increase in trim is smaller. The effects on the resistance are much lower for the high L_p/B_{px} hull

6 POLYNOMIAL MODEL FOR ASSESSING THE RESISTANCE, TRIM AND SINKAGE OF AN ARBITRARY HULL

Using now the results of the entire database of the DSDS a new version of the earlier polynomial expression has been developed aiming at an improved prediction for hulls with twist and rocker.

The procedure followed to assess the specific resistance, the running trim and the sinkage of an arbitrary hull is similar to the one formulated previously by Keuning, Gerritsma and Terwisga in (Keuning, Gerritsma and Terwisga 1993):

First the specific resistance, i.e. the resistance per ton of displacement, the running trim and the sinkage for a prismatic hull is approximated using a polynomial expression containing only L_p/B_{px},

$A_p/\nabla^{2/3}$ and *LCG* as the parameters, also to higher orders and in combinations with the other parameters. The expressions used are shown below. Regression techniques are used to determine the values of the various coefficients. In the present approach the regression is applied over the data of each of the separate sub-series, i.e. one for each of the four deadrise angles tested. The total resistance is assessed here, there is a set of coefficients for a large number of different displacements ranging from 2.5 to 5000 cubic meter displacement. Intermediate values for different displacements and intermediate deadrise angles are obtained by linear interpolation.

Secondly, a correction polynomial has been formulated to assess the effect of twist and rocker. This effect is accounted for in the present approach as a change (i.e. generally an increase) on the values found for the prismatic hulls. This procedure was adopted because these corrections were only known for the 25 degrees deadrise models. These corrections were consequently assumed to be equal for all the other deadrise angles.

Compared to the polynomials published by Keuning, Gerritsma and Terwisga (Keuning, Gerritsma and Terwisga 1993) the current correction polynomials for the change in resistance, trim and sinkage caused by the application of twist and rocker have been expanded by adding L_p/B_{px} as parameter in the formulation. This was enabled by the extra information gathered by Keuning and Den Ouden in 2013.

Furthermore, the regression coefficients for the prismatic polynomials have been updated enabled by the availability of extra information from the experiments carried out by Keuning and Gerritsma in 1996 (deadrise = 19.0°). After extensive work put in analysing the results obtained with various formats of the polynomial expressions It was concluded that there was no need to change the structure of the present polynomials.

The polynomials for resistance, sinkage and trim as well as the correction polynomials for twist and rocker are presented here below. The polynomial expressions used for assessing the trim (dθ) and sinkage (RCG/$\nabla^{1/3}$) are the same as for R_{tot}/Δ presented here below.

As a typical result of the results obtained for the resistance for a boat not belonging to the DSDS the result of resistance measured and calculated of a 20 meter SAR boat and a 35 meter patrol boat are presented in Figure 12 and 13. Besides the measured results obtained in the towing tank also the outcome of the original PHF assessment and the present assessment method (DSDS) are depicted.

Prismatic:

$$\frac{Rt}{\Delta} = a_0 + a_1 LCG + a_2 LCG^2 + a_3 \left(\frac{Lp}{Bpx}\right) + a_4 \left(\frac{Lp}{Bpx}\right)^2$$

$$+ a_5 \left(\frac{Lp}{Bpx}\right)^3 + a_6 \left(\frac{Ap}{\nabla^{\frac{2}{3}}}\right) + a_7 \left(\frac{Ap}{\nabla^{\frac{2}{3}}}\right)^2 + a_8 \left(\frac{Ap}{\nabla^{\frac{2}{3}}}\right)^3$$

$$+ a_9 \left(LCG \cdot \frac{Lp}{Bpx}\right) + a_{10} \left(LCG \cdot \frac{Ap}{\nabla^{\frac{2}{3}}}\right)$$

$$+ a_{11} \left(\frac{Lp}{Bpx} \cdot \frac{Ap}{\nabla^{\frac{2}{3}}}\right)$$

Twist and rocker:

$$\frac{dRt}{\Delta} = b_0 \gamma + b_1 \varepsilon + b_2 \left(\gamma \cdot \frac{Ap}{\nabla^{\frac{2}{3}}}\right) + b_3 \left(\gamma \cdot LCG\right)$$

$$+ b_4 \left(\gamma \cdot \frac{Lp}{Bpx}\right) + b_5 \left(\varepsilon \cdot \frac{Ap}{\nabla^{\frac{2}{3}}}\right) + b_6 \left(\varepsilon \cdot LCG\right)$$

$$+ b_7 \left(\varepsilon \cdot \frac{Lp}{Bpx}\right) + b_8 \left(\gamma \cdot \left(\frac{Ap}{\nabla^{\frac{2}{3}}}\right)^2\right)$$

$$+ b_9 \left(\gamma \cdot LCG^2\right) + b_{10} \left(\gamma \cdot \frac{Ap}{\nabla^{\frac{2}{3}}} \cdot \frac{Lp}{Bpx}\right)$$

$$+ b_{11} \left(\gamma \cdot \frac{Ap}{\nabla^{\frac{2}{3}}} \cdot LCG\right) + b_{12} \left(\gamma \cdot LCG \cdot \frac{Lp}{Bpx}\right)$$

As can be seen from these figures the assessment yields reasonable results and the new data base yields slightly better results than the previous ones.

By releasing all the results and data of the DSDS, as presented here below, it becomes possible for everyone interested to elaborate end analyse the assessment \method for obtaining better results.

7 RELEASE OF THE RESULTS OF THE DSDS

The Delft Ship Hydromechanics Laboratory of the Delft University of Technology has decided to release all the data of the Delft Systematic Deadrise Series. This includes the sets of all coefficients necessary for using the various polynomial expressions and all model data, geometries and hydrostatics involved.

KNRM-NH1816

Figure 12: Total resistance prediction of a 20 meter SAR boat using models PHF and DSDS
No twist and rocker

Stan Patrol 3507

Figure 13: Total resistance prediction of a 35 meter Patrol boat using models PHF and DSDS
15 degrees of twist and 3 degrees of rocker

The aim is to present all this data on an easily accessible way to all those interested. A similar procedure has been chosen as the one used for distributing the data of the **Delft Systematic Yachts Hull Series.** All the data becomes available through the release of a dedicated website. This website will be: **http://dsds.tudelft.nl**

By doing so any possible addition to or change in the distributed data can be easily handled by the Delft University of Technology. The users will be consequently informed of this by an email.

Access to this website can be obtained by sending an email to the following address: **J.G.denOuden@tudelft.nl**

A **user id** and **password** will then be supplied by the DUT which will subsequently give the enquirer access to this website. Additionally some kind of user agreement will have to be signed to guarantee proper use of the data.

From this website all the relevant data can be downloaded

There are no costs involved.

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Keuning, J.A., Gerritsma, J. and Terwisga, P.F. (1993), *Resistance tests of a series planing hull forms with 30 degrees deadrise angle and a calculation model based on this and similar series, Report No. 95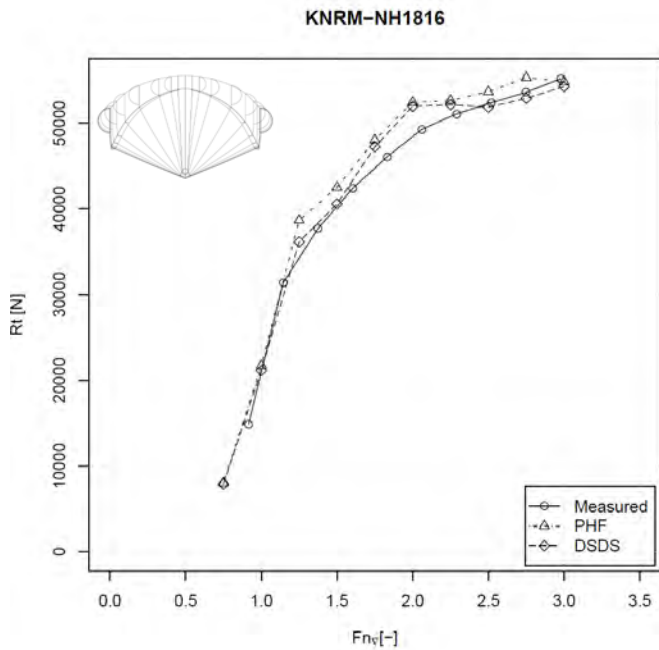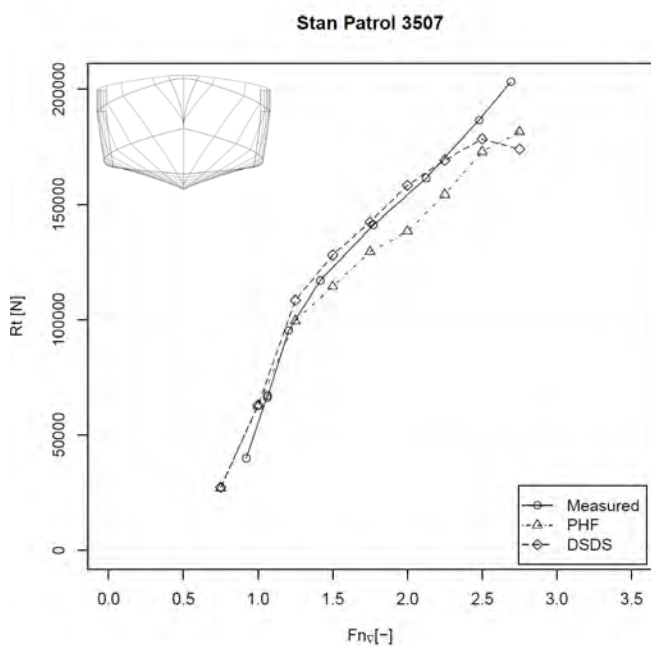9, Delft University of Technology*