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The Naples warped hard chine hulls systematic series

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ABSTRACT

An experimental study was carried out to evaluate still water performance of a Systematic Series of hard chine hulls in planing and semiplaning speed range. Models of the Naples Systematic Series (*NSS*) were of varying length-to-beam ratios of the parent hull. The parent hull, shaped with warped bottoms, was derived from a pre-existing hull extensively tested in a towing tank. This hull was validated by many work boats built in the last fifteen years. To simplify the construction of vessels with rigid panels (aluminium alloy, plywood or steel) the original hull form was transformed to obtain developable hull surfaces. The models were tested at Re > 3.5×10^6, in speed ranges Fr=0.5–1.6 and Fr_∇=1.1–4.3. The series studies the influence of L_P/B_C and Ⓜ ratios that vary respectively in the ranges of 3.45–6.25 and 4.83–7.49, for two positions of CG. All the models were tested both with and without interceptors. To enable model-ship correlation following the ITTC recommendations, in addition to the resistance coefficients of the models, dynamic wetted lengths and surfaces were provided as tables. To facilitate the implementation of Velocity Predict Programs, all the data (resistances, lengths and surfaces) were also furnished in polynomial form. In addition to the use of series in the design field, this study was done to provide data to improve the numerical simulations of a planing craft. With this aim, in addition to the resistance data, the wave profiles, obtained by wave cuts, were provided to carry out validation procedures.

1. Introduction

The design of high-speed craft is strongly conditioned by two anti-synergetic needs: reduction of fuel consumption (for economic and environmental considerations) and improvement of comfort on board (that with high speeds has typically got worse). To reach an effective balance between these needs, it is important to increase the deadrise angles from stern to bow. It is possible to do this containing the rising deadrise in the forward part of the hull (monohedral hull) or to do the same variation of deadrise on the whole length (warped hull). The warped solution enables to shape the forward of the bottom with higher deadrise angles respect the mean value chosen. This option needs the utmost attention to avoid inadequate sectional area curve (typically evaluated by A_T/A_X ratio) as shown in Begovic and Bertorello (2012). Often, to balance the sectional area curve, the best option is rising of the keel line towards the stern. The combination of these solutions (warped bottom and rising keel line) improves the comfort minimizing the vertical accelerations but reduces the hull efficiency due to the rising of the dynamic trim that increases the resistance induced by the lift, the main component of the pressure resistance on high speed planing crafts.

To overcome this shortcoming, the interceptors have proved high effective working as trim correctors and as high lift devises (De Luca and Pensa, 2012). Both these actions reduce the resistance induced by the lift particularly in the speed range of Fr=0.5–0.8 (Fr_∇=1–3), where the trim angles are high and the lift has not completely replaced buoyancy.

Consistent with these aims, a new systematic series of hard chine hulls (*NSS*) was designed at the naval division of the *Dipartimento di Ingegneria Industriale* (*DII*) of the *Università degli Studi di Napoli "Federico II"*. The parent hull, designed taking into account the use of interceptors, is characterized by deadrise angles constantly growing from astern to forward and by an A_T/A_X that is lower, but near to 1.0. Both these characteristics assure good performance over a wide range of speeds if an interceptor is working on the hull.

Unlike the *NSS*, the more well known systematic series with a single chine (Hubble, 1974; Keuning and Gerritsma, 1982; Keuning and Alii, 1993; Taunton and Alii, 2010) – has a constant β along the third astern of the hull. This is also true on a series whose A_T/A_X is lower than 1–(Clement and Blount, 1963); on these hulls the reductions of A_T/A_X are obtained by homothetic reductions of the transversal sections that keep β constant. Two Series, the *USCG* Series, (Kowalyshyn and Metcalf, 2006) and the double chine *NTUA* Series (Grigoropoulos and Loukakis, 2002), are exceptions: the bottom of the *USCG* is quite – but not absolutely – monohedral whereas on the *NTUA* Series it is markedly warped. For both series, the A_T/A_X ratio loses its content because A_T

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Nomenclature

A_T	area of transom
A_X	area of maximum transverse section
B_{CT}	chine breadth at transom (m)
B_C	maximum chine breadth (m)
B_{WL}	maximum waterline breadth (m)
CG	centre of gravity
C_A	correlation allowance coefficient
C_F	frictional resistance coefficient
C_R	residuary resistance coefficient
Li	length of interceptor (% B_{CT})
L_P	maximum chine length (m)
L_{WL}	waterline length (m)
L_{WLD}	dynamic waterline length (m)
i	depth of interceptor (mm)
i_E	half angle of entrance (deg)
L_{CG}	longitudinal position of centre of gravity (m)
Fr	Froude number
Fr_∇	Froude displacement number
Re	Reynolds number
R_P	pressure resistance
R_P	pressure resistance
R_T	total resistance
R_{Ti}	total resistance of model with interceptors
S_W	wetted surface (m^2)
S_{WD}	dynamic wetted surface (m^2)
T_H	height of towing point from baseline (mm)
T_L	towing point distance from transom (mm)
V_M	model speed (m/s)
V_S	ship speed (m/s)
W	weight of the model (kg)
β_T	deadrise angle at transom (deg)
$\beta_{0.5}$	deadrise angle at 50% L_{WL} (deg)
$\beta_{0.75}$	deadrise angle at 75% L_{WL} (deg)
λ	scale factor
ν_S	kinematic viscosity (salt water)
τ_S	trim at rest (deg)
τ	dynamic trim (deg)
∇	hull volume of displacement at rests (m^3)
Ⓜ	length-displacement ratio ($L/\nabla^{1/3}$)
DII	Dipartimento di Ingegneria Industriale
NSS	Naples Systematic Series

has the highest value of the sectional area curve.

The following tables summarize the main hull data of the series for reference (Table 1).

Beyond the evident task to make available a number of hulls that meet contemporary needs, the *NSS* was designed from *ITTC Resistance Committee* recommendations that push for new benchmarks for validation of numerical simulation, particularly in a speed range where hydrodynamic lift is significant (De Luca and Alii, 2016). For a more in-depth study on the reliability of CFD procedures, in addition to the resistance data, experimental wave elevations obtained by longitudinal cuts of wave patterns are provided in Appendix E.

Finally, to facilitate the implementation of the performance of *NSS* within the Velocity Predict Program (*VPP*), the complete set of data required for model-ship correlations are given in polynomial forms.

Table 1
(a, b) Hull data for reference series.

Series	L/B range	Ⓜ range	B_{TC}/B_C
Clement & Blount; 1963	2.00	2.97	0.66
	7.00	8.46	
Keuning & Gerritsma; 1982	1.95	2.99	0.66
	6.82	8.36	
Keuning & Alii; 1993	3.41	3.29	0.66
	7.00	8.25	
Hubble – A; 1974	3.20	4.0	0.35
	9.26	10.0	
Hubble – B; 1974	2.32	4.0	1.00
	9.28	10.0	
Kowalyshyn & Metcalf; 2006	3.24	4.98	0.96
	4.50	0.87	
Taunton & Alii; 2010	3.77	6.25	1.00
	6.25	8.70	
Grigoropoulos & Loukakis	4.00	6.18	*
	7.00	10.00	
NSS	3.24	4.83	0.95
	5.86	7.49	

Series	A_T/A_X	β_T (deg)	$\beta_{0.50}$ (deg)	$\beta_{0.75}$ (deg)
Clement & Blount; 1963	0.8	12. 5	13.0	19.2
Keuning & Gerritsma; 1982	0.8	25.0	26.0	30.7
Keuning & Alii; 1993	0.8	30.0	31.2	35.8
Hubble – A; 1974	0.100.12	14.627.9	14.829.9	22.038.0
Hubble – B; 1974	1.0	16.330.4	21.237.4	35.053.0
Kowalyshyn & Metcalf; 2006	*	16.6	22.5	34.4
Taunton & Alii; 2010	1.0	22.5	22.5	35.3
Grigoropoulos & Loukakis	*	10.0	22.5	38.0
NSS	0.94	13.2	22.3	38.5

2. Tested models

2.1. Parent hull

The parent hull of the series, C1 model, was derived from a pre-existing model, C954, that had shown good performance, registered by an intensive experimental program in a towing tank, with and without interceptors (De Luca and Alii, 2010). The C954, designed in 1995, were also frequently chosen as a working boat hull assuring good performance in still and rough waters (especially in short sea conditions). To simplify building of the hulls, the C954 hull form was changed to obtain the plating as developable surfaces. Fig. 1 shows the not-developable zones (red colour) that are those most drastically changed. Evaluation of the developability of the surfaces was done thru analysis of the Gaussian curvature. Fig. 2 shows a comparison between

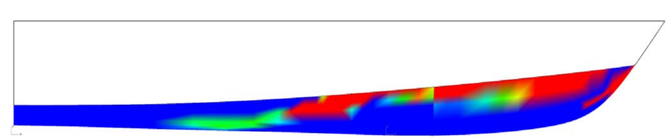

Fig. 1. C954: Variations of the Gaussian curvature. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article).

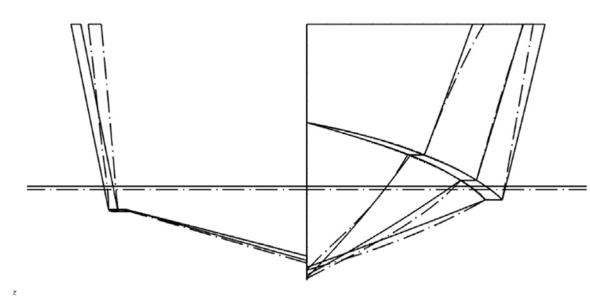

Fig. 2. Comparisons between C1 (solid line) and C954.