ANALISYS OF THE OPERATIONS OF A CATAMARAN IN SERVICE IN THE NEAPOLITAN GULF; COMPARISON BETWEEN FULL SCALE TRIALS AND TOWING TANK TESTS

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SUMMARY

This paper presents a further step of the Research carried out in the *Dipartimento di Ingegneria Navale* of Naples (DIN) on the energy monitoring of the naval traffic in the Neapolitan Gulf, financed by the Regione Campania – Italy. In particular, in the scene of this activity, the P_E/P_D efficiency has been evaluated by comparing the towing test and the full scale tests data.
In order to do so, a series of tests were carried out onboard a catamaran in service in the Neapolitan Gulf and on model in the towing tank, at the same load and trim conditions. Custom instrumentations, designed and built in the DIN, were used both for sea trials and towing tank tests.

1. INTRODUCTION

The experimental prediction of performances of catamarans propelled by waterjets suffers from the consequences of the reproduction of the ship in reduced scale, among them, the towing direction control. Moreover, for ship propelled by waterjets the prediction of the propulsive efficiency is more difficult.
Such condition makes it less accurate the evaluation of the power to install onboard since, generally, only the effective power is known from towing tests.
In order to evaluate the effect coming from the different towing techniques, the DIN is carrying out a Research with the main aim of evaluating both the influence of the direction of the towing thrust and, more generally, the reliability of the predictions obtained by the P_E/P_D values.

L_{WL} [m]	35.87
T [m]	1.58
B_{WL} [m]	10.50
B_{WL} demihull [m]	3.30
S (Distance between centreplanes of demihulls) [m]	7.03
S_W [m^2]	272
∇ [m^3]	133.7
L_{WL}/B_{WL}	3.15
B_{WL}/T	7.20
$L_{WL}/\nabla^{1/3}$	7.010
<u>Main Engines</u>: 2 x MTU 16V396, 2000 kW, 2000 rpm ; 2 x KaMeWa 71 SII Waterjets, 860 rpm	

Table 1 - Characteristics of the ship at Δ = 137 t

In order to obtain the desired results, it was necessary to raise the quality of full scale measurements and towing tank experimental procedures so as to reach a better reliability of the prediction of the powering performances. With these aims, towing tank and a full scale tests were set up and carried out on the catamaran "Achernar" whose characteristics are given in table 1.

2. FULL SCALE TESTS

Since a complex data logging campaign requires a very reliable measurement system, the instrumentation was previously developed and tested in laboratory; in each campaign a lot of variable were logged, continuously and with a sample rate of 2 sample/s:

inlet air temperature	J T/C
exhaust gas temperature	K T/C
propeller torque	torquemeter
engine rpm	pick-up
fuel flow	flowmeter
freeboards	Manual
static and dynamic longitudinal trim	electronic level
ship speed	GPS

Table 2 - Parameters logged and sensors

In order to supply a "cross control" on the logged values of the torque (and, definitively, of the power), four flowmeters were used in order to measure the fuel supply and its return from the pumps; the comparison between the working point logged in full scale and the one drawn from the bench tests of the engines, confirmed the good quality of the data.
The overall arrangement of the data logging system is given in fig 1.
Note that, since the torquemeters (based on strain gauge systems) are fitted in the final part of the jet axle, between gearbox and gland, the measured power coincide with P_D (without considering the loss in the gland – figure 2).
The only problem related to the measure of the torque is that the point where the strain gauge is stuck is relatively close to the coupling; this may create a little variation in the reading of the deformation of the axle (and, as a consequence, of the torque).

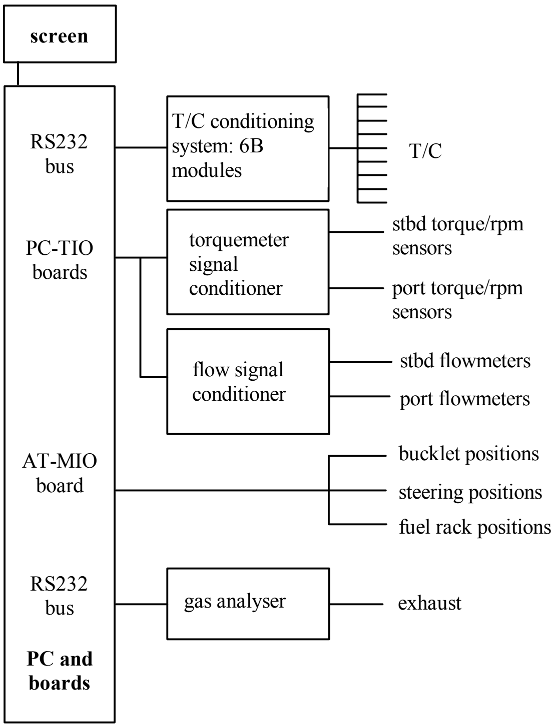

Figure 1 – layout of the data logging system

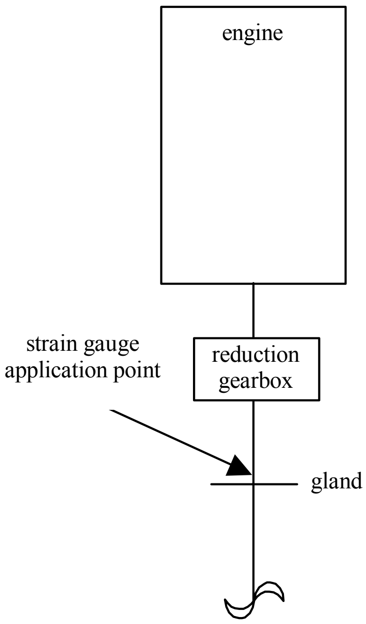

Figure 2 – Measurement point of the torque

However, we plan to investigate on the behaviour of the axle where strain gauges are stuck by calibrating the axle itself (or, probably, a sample) and reproducing the relative position of the strain gauge and the coupling; the goal is to know the exact deformation of the axle (and the related value of the torque) in this particular configuration.

The ship position and speed were determined using a GPS.
The displacement of ship was evaluated by reading each day the astern and bow immersion and updating this value keeping into account the main reasons causing changes of displacement: weight of the liquids onboard (fuel, mainly) and passengers.
The weight of the fuel was determined (for each instant of the course) starting from the value of the oil consumption (logged for each course) and by assuming an overall linear trend of the oil consumption; the number of passengers was determined by the Company log of passengers. Both values, together with the weight drawn out from the immersion, were taken into account to calculate the displacement of the ship in each course. Even the change in displacement due to passengers in the intermediate stops were considered.
Data reported in this text have been collected during two full scale test campaigns carried out in March, with the ship in service on the routes Naples-Capri and Naples-Procida-Ischia.
Of course, any run has been characterised by a value of displacement (depending on the number of passengers onboard in that run, on the level of the service fluids, etc.), by the wind and sea conditions, in general, by the condition of the ship in that particular course.
This justifies some spread in the distributions of power and displacement due to the abovementioned conditions.
During sea trial tests, we asked the Capt. to take the value of the engines rpm at a particular constant value for a certain time in order to be able to log the behaviour of the ship at constant speed, in (almost) constant conditions (constant speed tests); for any condition (each took about 5 – 10 min) we calculated the mean value of all parameters logged and, in particular, those of ship speed, power and rpm (for both the engines).
So, in order to represent the campaign of tests, two kinds of diagram are reported. The first (fig 3 and 4) synthesises all the tests made by reporting the main parameters logged during the “constant speed tests”; the second are diagrams related to whole runs of the catamaran in normal service.
In figure 3 the values of the propeller power as a function of the ship speed are reported, referred to the values of the displacement; for displacement 156 and 157 t the relationship between ship speed and power is evident; for other displacements the sea and wind conditions are more influent.
Figure 4 reports the correlation between rpm and rated power (right and left sides) for each condition logged.
Figures 5 to 8 report two courses between Naples and Capri (March 20th, 2003) and two Naples – Procida – Ischia (March 21st, 2003); each of them report the main parameters involved in the navigation and the propulsion of the ship, as a function of the time. Note that, in some cases the values of ship speed are not available close to the arbour of Naples, this is due to the fact that GPS, close to main harbours, is darkened for military reasons.

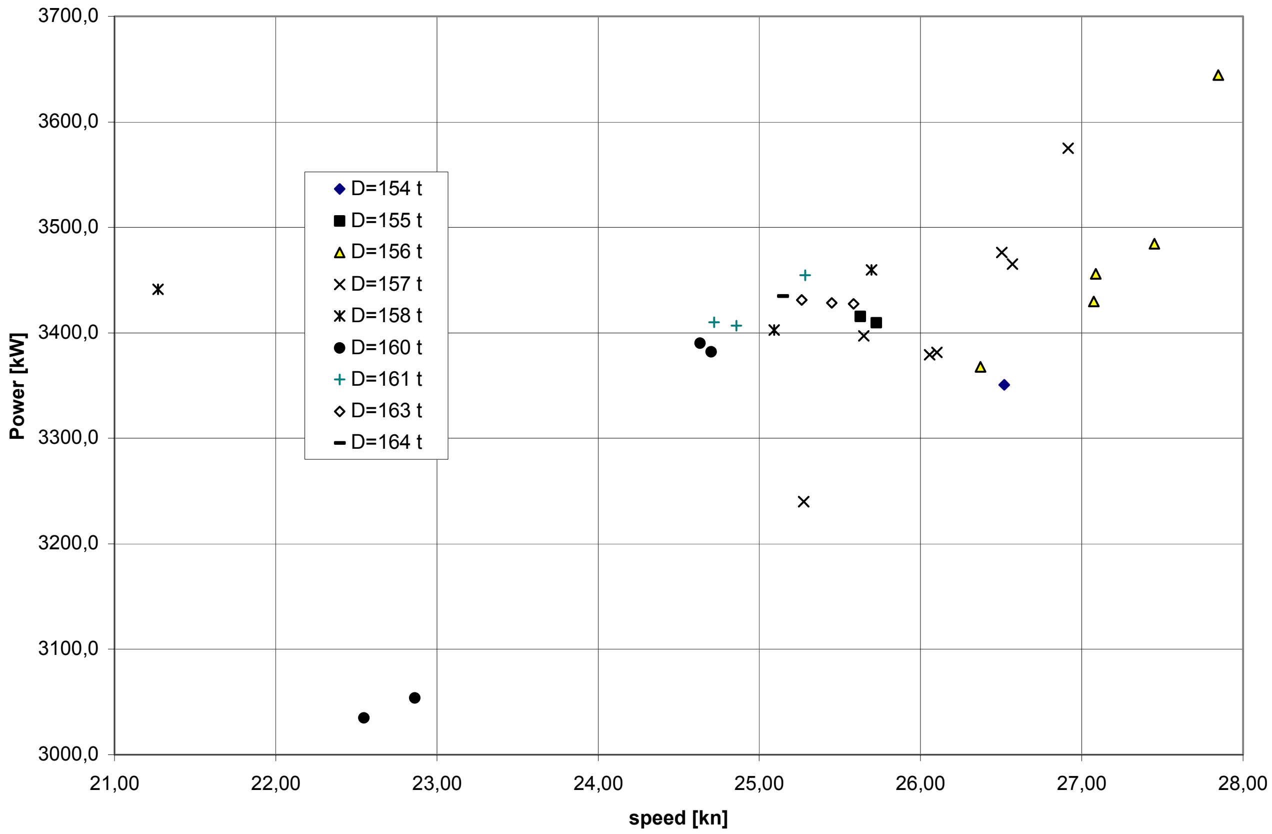

Figure 3 – Power vs. speed (for various displacements)

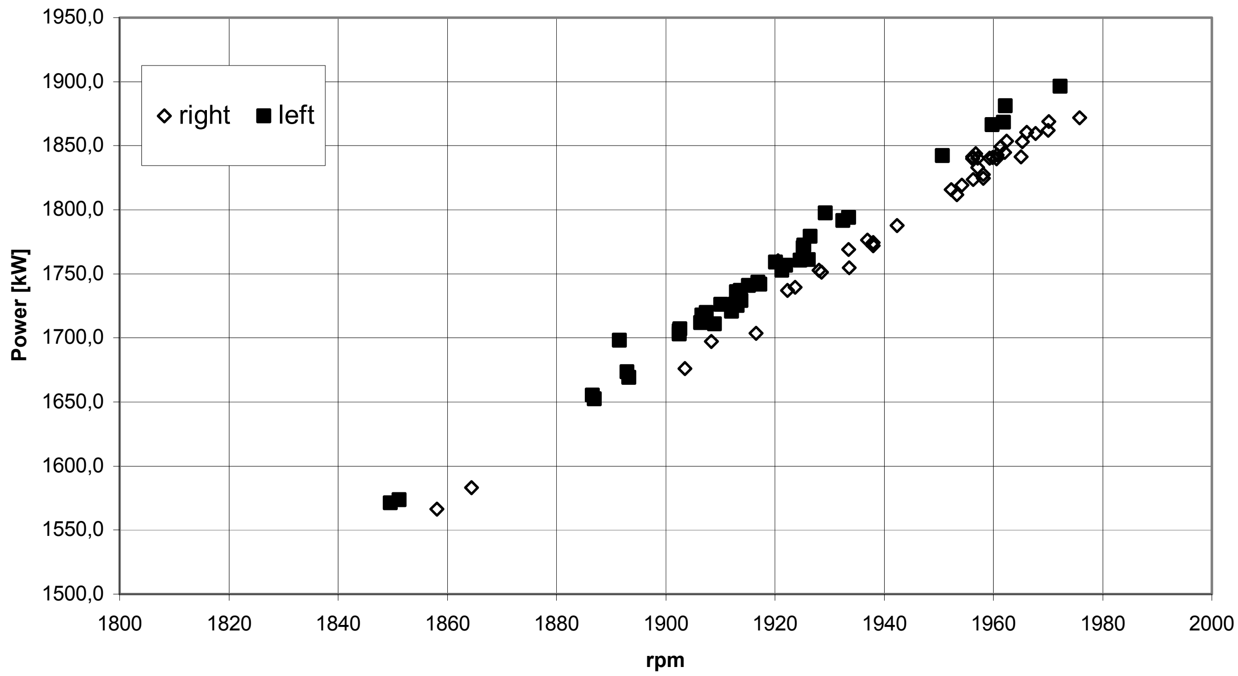

Figure 4 – Power vs. rpm (right and left)

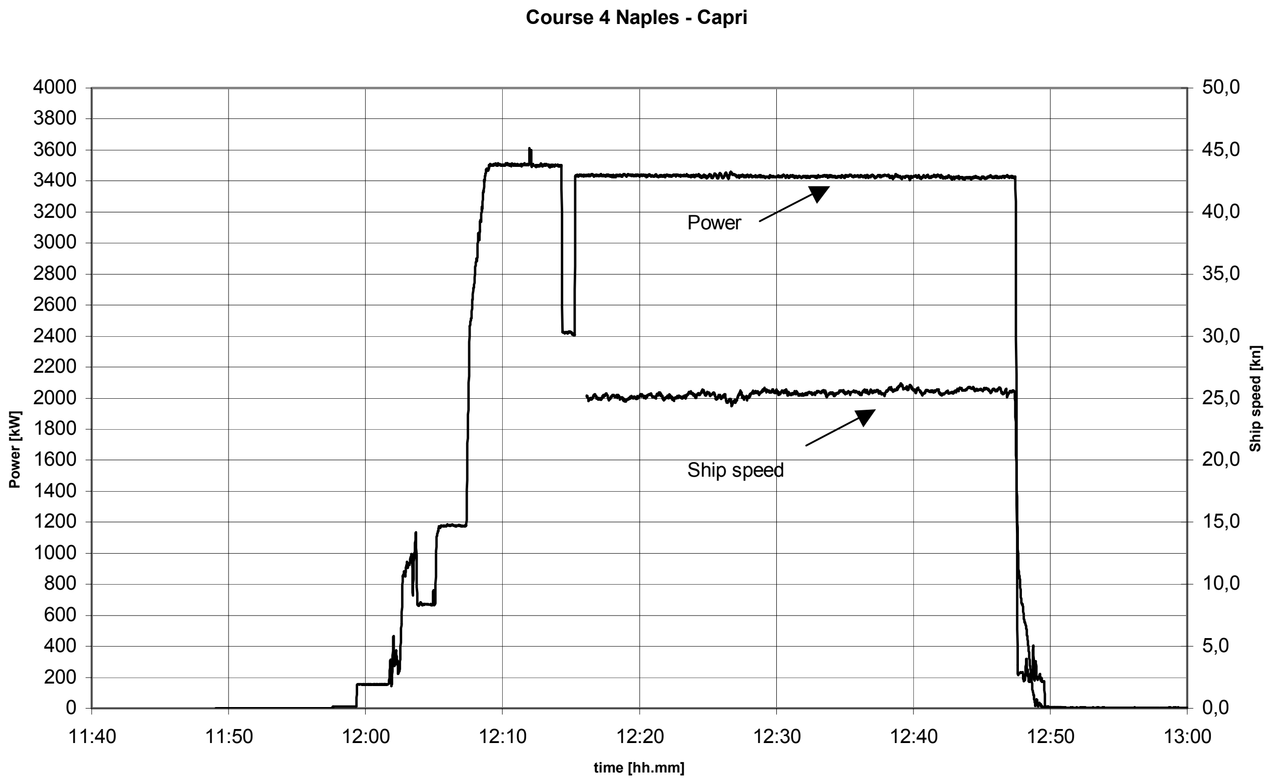

Figure 5 - Power and ship speed vs. time (course Naples – Capri)

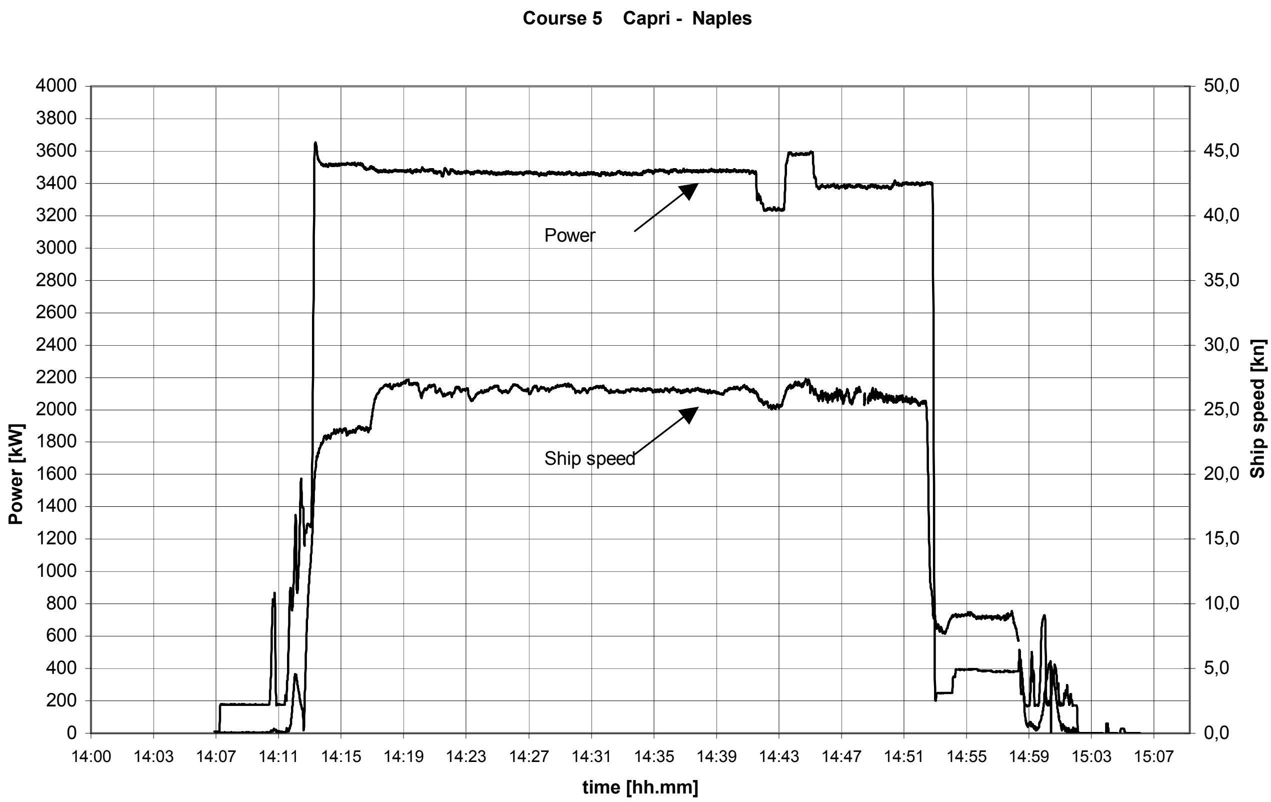

Figure 6 - Power and ship speed vs. time (course Capri – Naples)

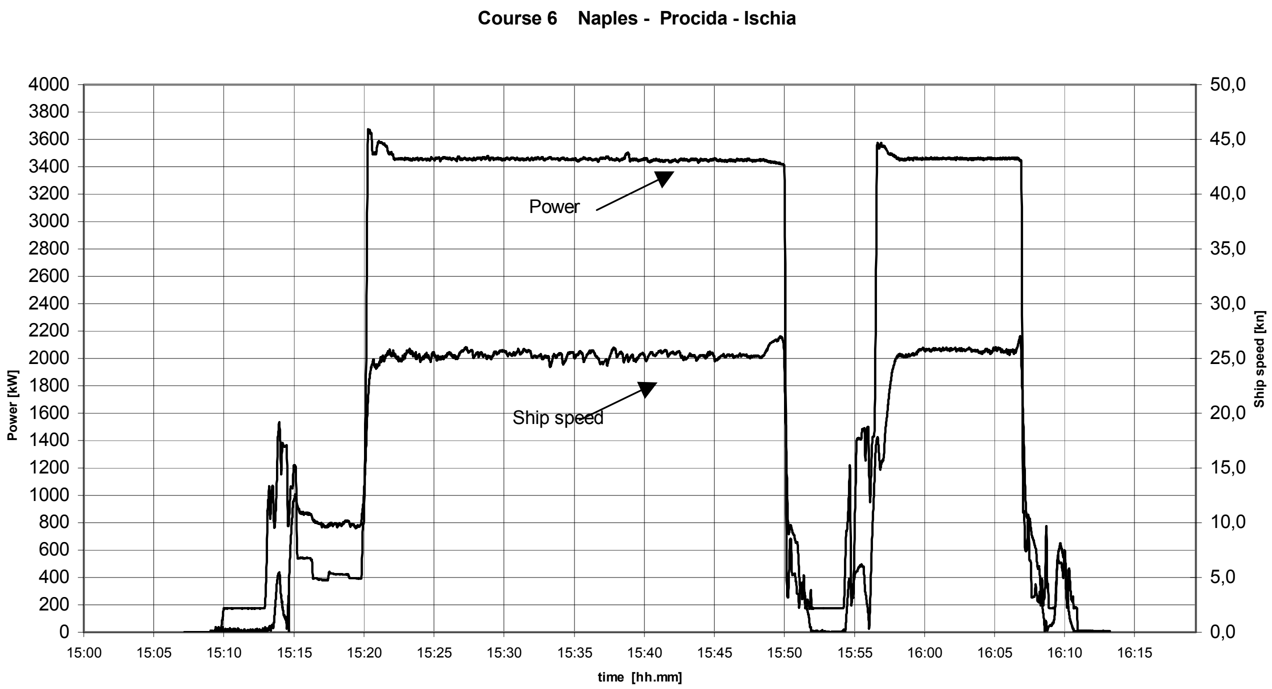

Figure 7 - Power and ship speed vs. time (course Naples – Procida – Ischia)

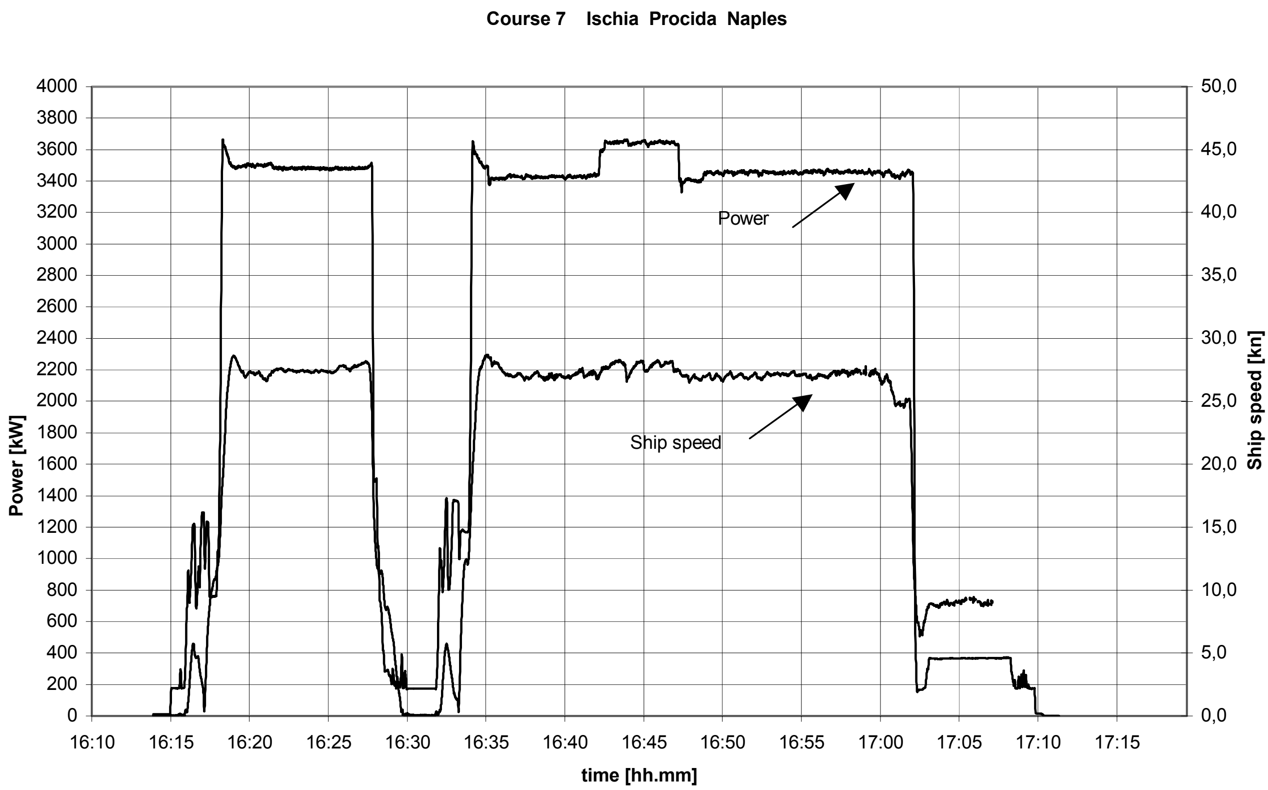

Figure 8 - Power and ship speed vs. time (course Ischia – Procida – Naples)

3. TOWING TANK TESTS

Towing tests were carried out in the towing tank with a model scaled λ =13 (minimum Rn = $6.5 \cdot 10^6$). The model was equipped, like the ship itself, with flaps and stabilisers. In previous tests, the towing force, like in most towing tanks [1], was permanently horizontal and applied cross deck, with the application point remarkably higher than the centre of resistance. This creates a moment that generally reduces the longitudinal trim and produces undesired and unpredictable changes in the model resistance.

3.1 EXPERIMENTAL PROCEDURE

In order to prevent such undesired effects and to underline the importance of the towing technique two different experimental tests, a) and b), were carried out with the same displacement:

a) horizontal force at the height H = 6.11 m on the baseline (H/T = 0.17)

b) towing force in the direction of the waterjet thrust applied in their action point (H = 1.47 m; H/T = 0.04)

In order to perform procedure b) a special equipment was made at the DIN with an automatic and continuous control of the towing inclination.

Figure 9 shows the trend of the R_{HS} and of the longitudinal trim experimentally evaluated by the different procedures. It can be observed that the R_{HS} curves differ remarkably. Particularly at a speed of 28 and 32 kn the differences are respectively of 6% and 7% while for the trim the differences raises to 23 % and 22%.

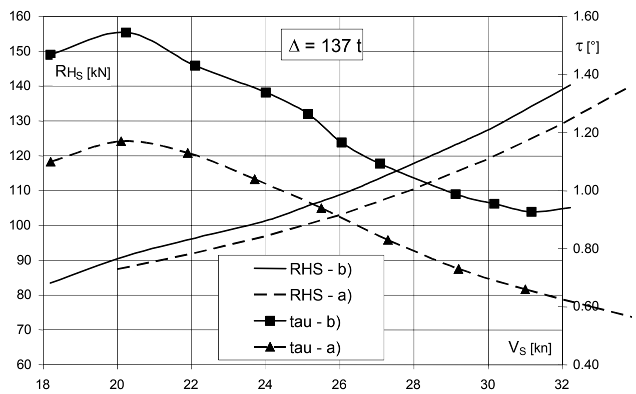

Figure 9 – Comparison between a) and b) procedures

It can be observed that the dependence of the waterjet efficiency on the ship speed makes the underestimating of the resistance particularly harmful. In fact the lesser speed due to a higher resistance creates a lesser waterjet efficiency which increases the evaluating error.

3.2 SHIP-MODEL CORRELATION

The ship-model correlation has been made according to the ITTC '57 procedure ($\Delta C_F = 2 \cdot 10^{-4}$). The resistance to the air and wind R_{AA} has been added as evaluated by the Hughes expression [2].

Consequently, in order to evaluate the efficiency P_E/P_D we proceeded as follows:

$$P_E = R_{TS}\, V_S$$
$$R_{TS} = R_{HS} + R_{AA}$$
$$R_{HS} = (C_R + C_{FS} + \Delta C_F)\,(0.5\, \rho\, V_S^2\, S_{WS})$$

Where: P_E = Effective Power
R_{TS} = Total Ship Resistance
R_{HS} = Hull Resistance (with appendages)
R_{AA} = Wind or Air Resistance
S_{WS} = Wetted Surface

while the delivered power P_D was taken in full scale.

The following picture, taken from [3], shows the values of the ratio P_E/P_D obtained. These values are selected, among the available data, to represent the most significant operative conditions of the ship.

The picture shows also the curve traced by the authors of the present paper, which has to be understood as the bound of the optimal performances.

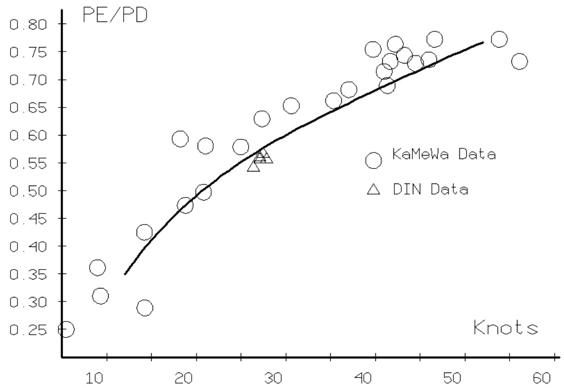

Figure 10 – Comparisons between the evaluations of P_E/P_D

The following table shows the values of P_E/P_D obtained and the ratios between such values and the reference values belonging to the curve (P_E/P_D rif.).

V_S [kn]	P_E [kW]	P_D [kW]	P_E/P_D	$\frac{P_E/P_D}{P_E/P_D \text{ rif.}}$
26.4	1824	3367	0.54	0.96
27.1	1921	3429	0.56	0.98
27.1	1922	3456	0.56	0.97
27.5	1972	3485	0.57	0.98
27.8	2027	3645	0.57	0.96

Table 3 – Synopsis of experimental data

As the graph and the table show, the experimental values of the efficiencies are just a little below the reference curves. It has to be underlined that the evaluation of the resistance to air and wind has been made by an expression non specific for catamarans. Supposedly, the aerodynamic interference phenomena (between demihulls and between cross-deck and sea surface) can take meaningful proportions. More particularly, it seems very important to evaluate the lift (and the resistance due to it) with wind incidence angles less than 40 ÷ 45 degrees from the centreplane. In the case under study, the resistance evaluation has been made practically without wind, nevertheless, the dynamic consequences of the acceleration of the flow in the tunnel between the demihulls should be evaluated. To estimate the sensitivity of the results in relation to the air resistance, it has been shown that an overestimation of the R_{AA} of about 35% takes the values of P_E/P_D to the reference curve.

4. CONCLUSIONS

The towing tank technique influences the prediction of performances: it has been observed that a relevant error can be made if the consequences of the application point and of the direction of the towing force are neglected.
The values of the efficiency P_E/P_D obtained are close to those available in the bibliography.
The values of P_E/P_D, although similar to the reference ones, result slightly lower (2-4%). However, it has been observed that such differences can depend on the accuracy in the evaluation of some elements like air or wind resistance, elastic behaviour of the axle, etc.
Most of all, the necessity to study the phenomenon of the aerodynamic interference between demihulls and between the cross-deck and the sea surface has been emphasised.

AKNOWLEDGMENTS

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