HIGH PERFORMANCE CATAMARANS FOR MARINE OPERATIONS: PROS, CONS AND DESIGN ASPECTS

Albert NAZAROV
Naval Architect, Ph.D., MRINA, MSNAME
Albatross Marine Design

CONTENTS OF PRESENTATION

Discussion of catamaran design issues from the point of view of practicing boat designer.

- Catamaran applications;
- Stability;
- Performance;
- Seakeeping;
- Controllability;
- Structures;
- Hull shape design;
- Design samples

<u>Target audience:</u> specialists involved in design, productions, sales and operation of catamarans

WHY A CAT?

The advantages of catamarans:

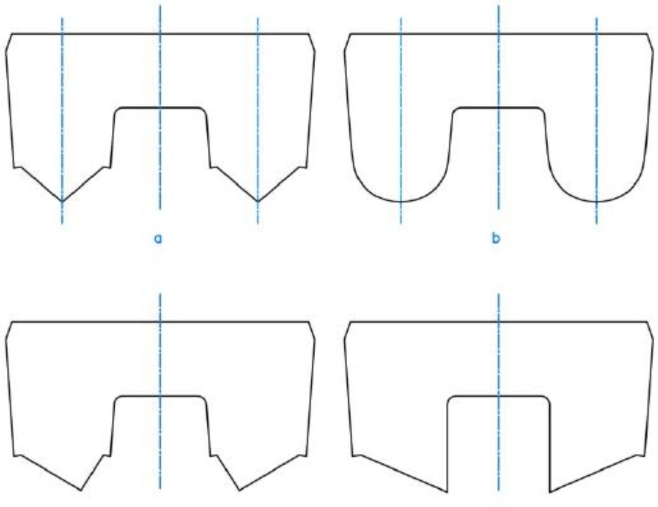
Performance – reduced hydrodynamic resistance and thus more speed or less required power;

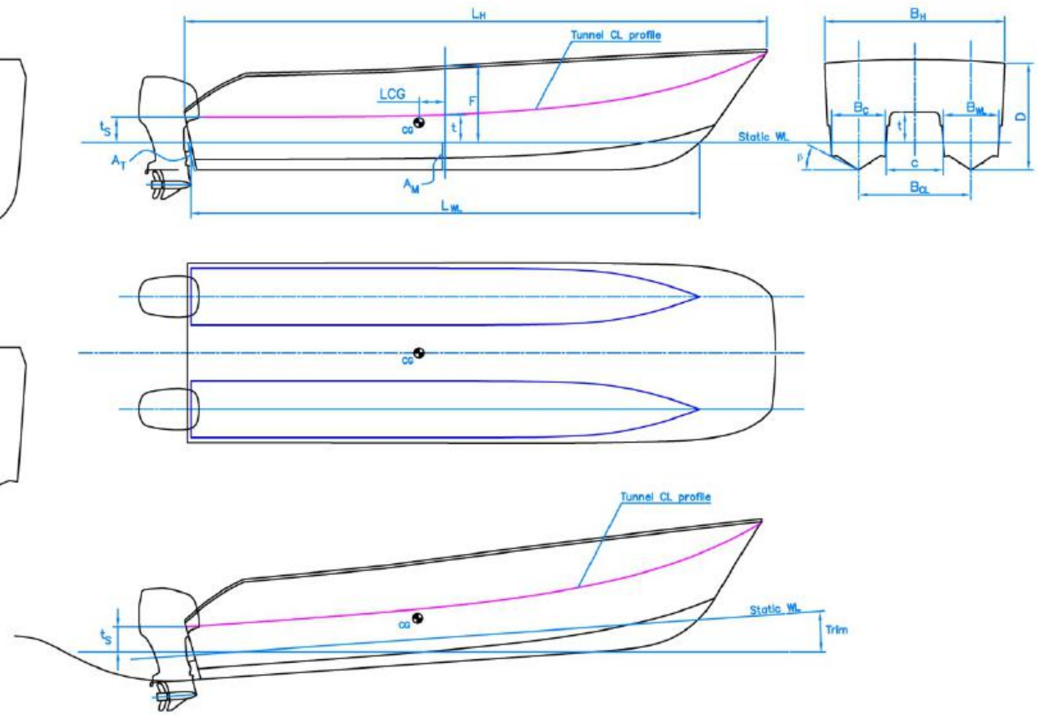
Soft ride - reduced vertical accelerations on seaway;

Safety - high initial stability, higher freeboard and flotation, duplicate propulsion units, etc.;

Comfort - excellent accommodations on deck/saloon/flybridge area;

CATAMARAN PARAMETERS AND DEFINITIONS





- Displacement - $Fn_V < 1$
- Semi-planing - $Fn_V = 1 \ldots 3$ (2.5)
- Planing - $Fn_V > 3$ (2.5)

APPLICATIONS OF HIGH SPEED CATAMARANS

AR980 – 9.8m
pleasure catamaran

AT1150 – 11.5m
passenger catamaran

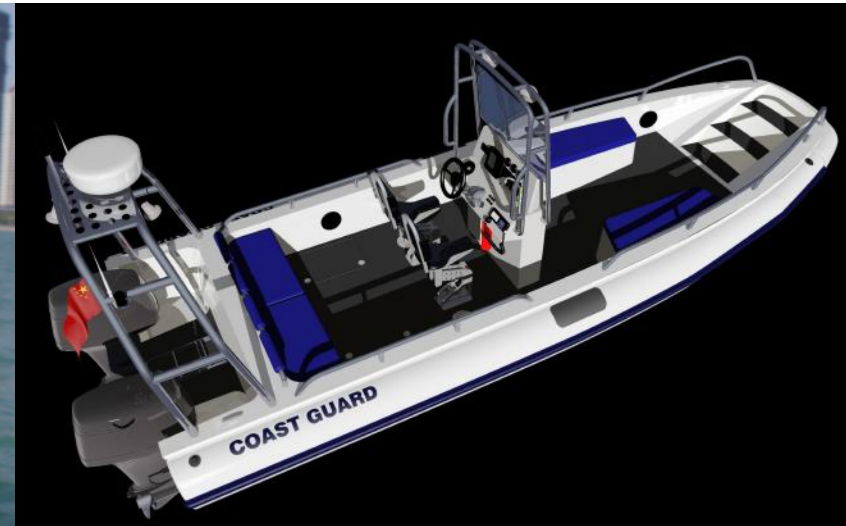
APPLICATIONS OF HIGH SPEED CATAMARANS

R38 – 12.3m rescue/paramedical catamaran

APPLICATIONS OF HIGH SPEED CATAMARANS

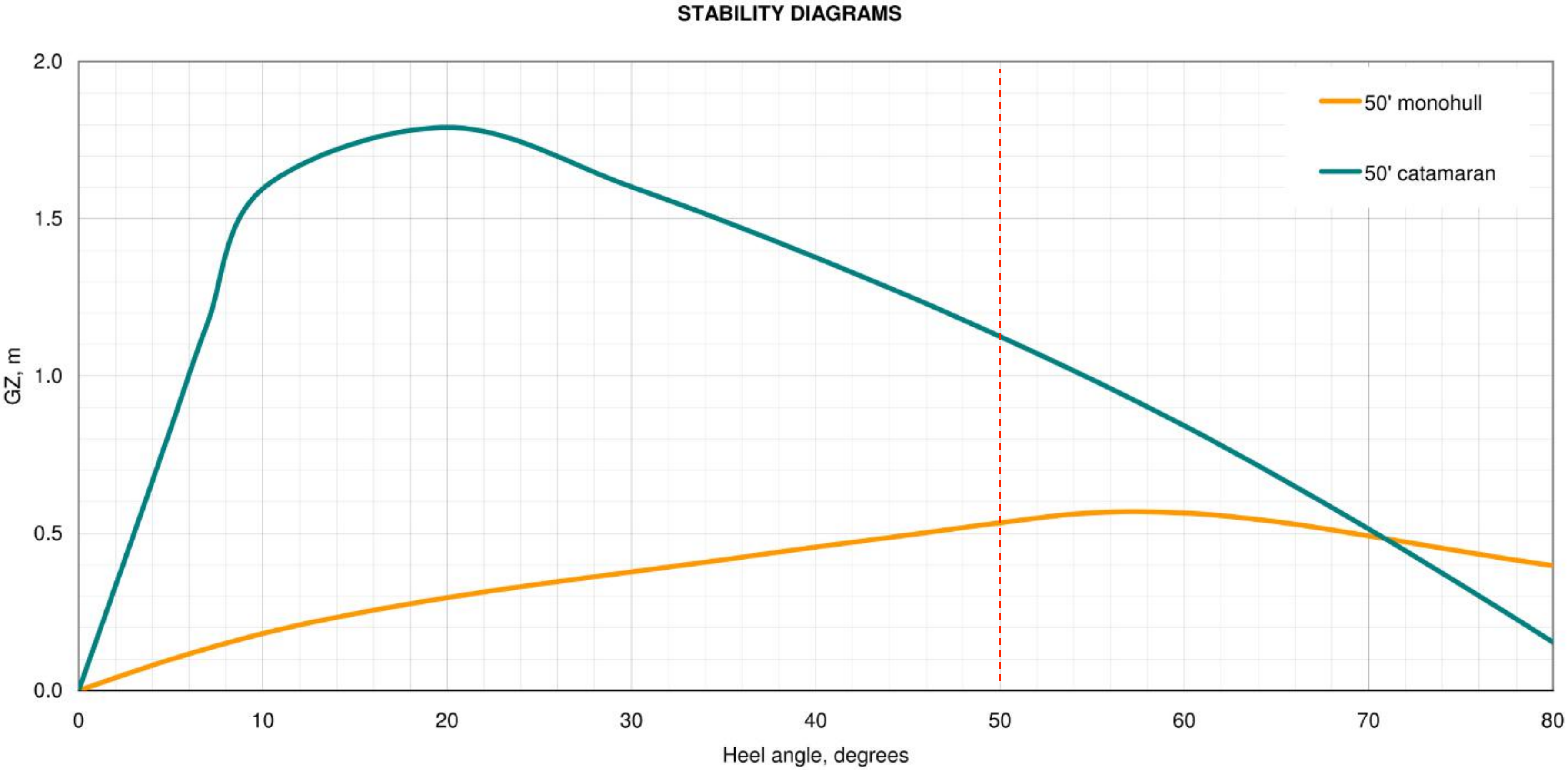
O1150 – 11.5m landing craft catamaran

APPLICATIONS OF HIGH SPEED CATAMARANS



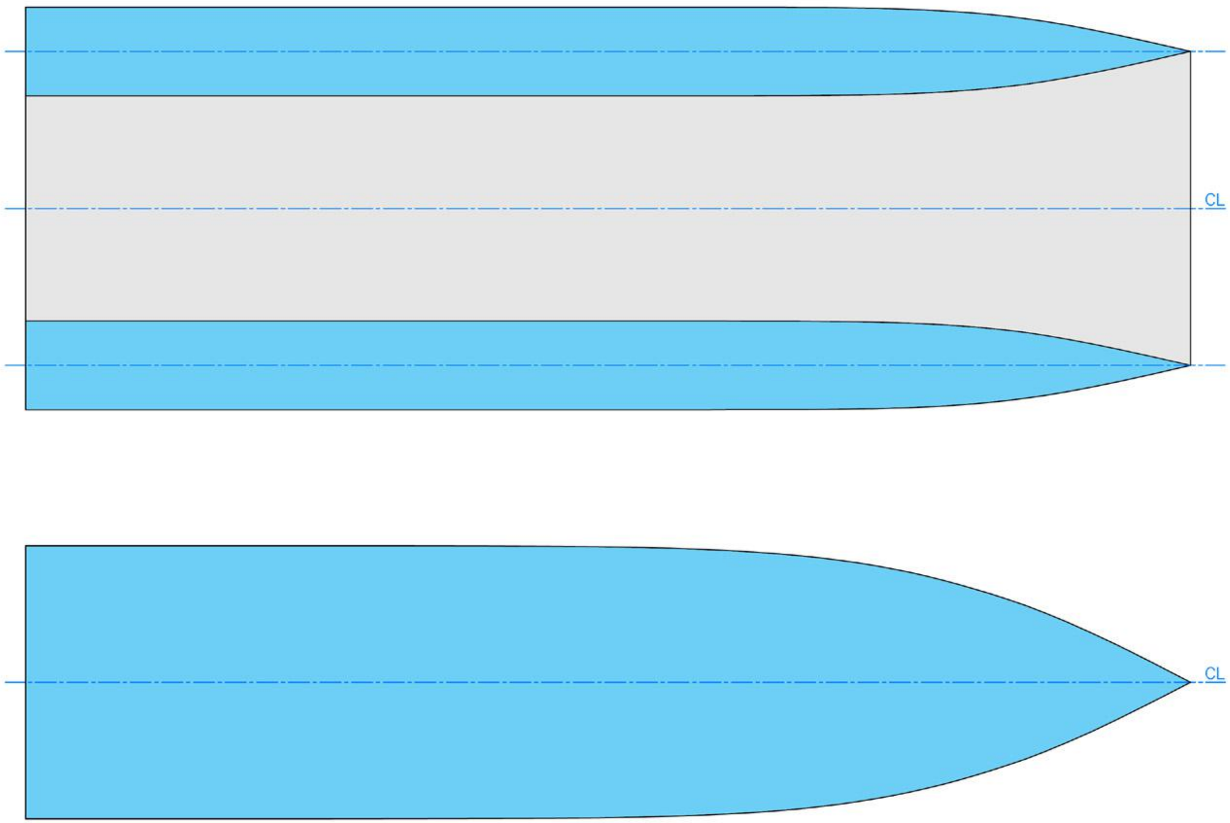
NS680 – 6.8m
RIB-catamaran
with bow ramp

STABILITY



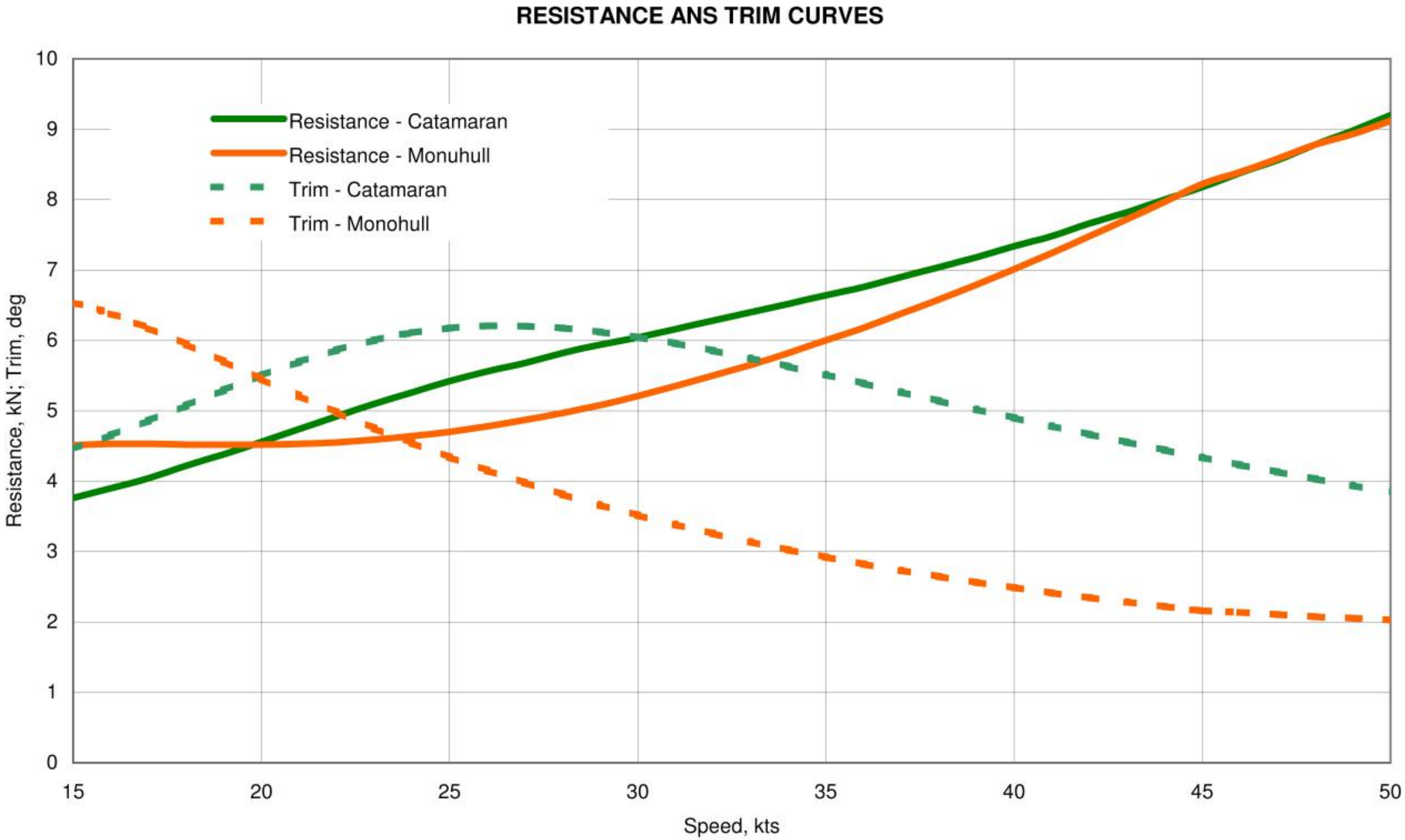
Catamarans possess high initial stability;
stability at large angles of heel is comparable with monohull craft

LOAD CARRYING CAPACITY



Catamarans possess ~30% smaller waterplane area compared to monohulls.;
This means higher immersion or lower load carrying capacity

PERFORMANCE: RESISTANCE AND PROPULSION



Planing catamarans present no advantages in terms of resistance, but catamarans provide stable ride are capable to maintain higher speed on seaway.

PERFORMANCE: RESISTANCE AND PROPULSION

For purposes of calculations, total resistance R_T of catamaran is presented as:

$$R_T = 2(R_R + R_F) + R_C + \sum R_{APP} + R_{AA} + R_{AW}$$

where R_R – residual resistance of isolated hull; R_F - frictional resistance of isolated hull; R_C – additional resistance of catamaran; R_{APP} – resistance of appendages; R_{AA} – aerodynamic resistance; R_{AW} – additional resistance of waves. The first three terms represent hydrodynamic resistance of the catamaran body on flat water. For displacement catamarans additional resistance R_C can comprise (-10…40)% of total resistance; for planing catamarans about (-5…20)% of total resistance.

Factors, influencing specific additional resistance R_C of catamarans:

- Interaction of wave systems of isolated hulls, effecting mainly wave resistance;
- Increase of water flow speed between hulls, effecting mainly frictional and viscous resistance;
- Increase of wetted surface due to spray and ‘tunnel riding’, effecting frictional resistance.

PERFORMANCE: RESISTANCE AND PROPULSION

PLAY

RESISTANCE PREDICTION METHODS

For displacement and semi-planing catamarans:

Molland's catamaran series based on systematic models tests performed at Southampton Institute of Higher Education test tank. Parent model is NPL-series model, round-bilge with submersed transom. Parameters of series are: $L/V^{1/3}$=6.27…9.50; L/B=7.0…15.1; B/T=1.5…2.5, LCB=0.064; CP=0.693; B_{CB}/L=0.2…0.5; tested at Fn_L=0.20…1.0.

VWS catamaran series 89' by Müller-Graf and based on systematic models tests carried out at Berlin model basin. Few parent models were used, representing symmetrical and asymmetrical shapes with different variations. Parameters of series are: L/B=7.55…13.55; B/T=2…3.5; transom draft to hull draft ratio T_{TR}/T=0.54…0.95, LCB=0.38…0.445; midship deadrise β_M=16…38°; Fn_L=0.25…1.35. Biggest disadvantage of method is fixed spacing between hull c/L_{WL}=0.167 that is serious limitation for design analysis.

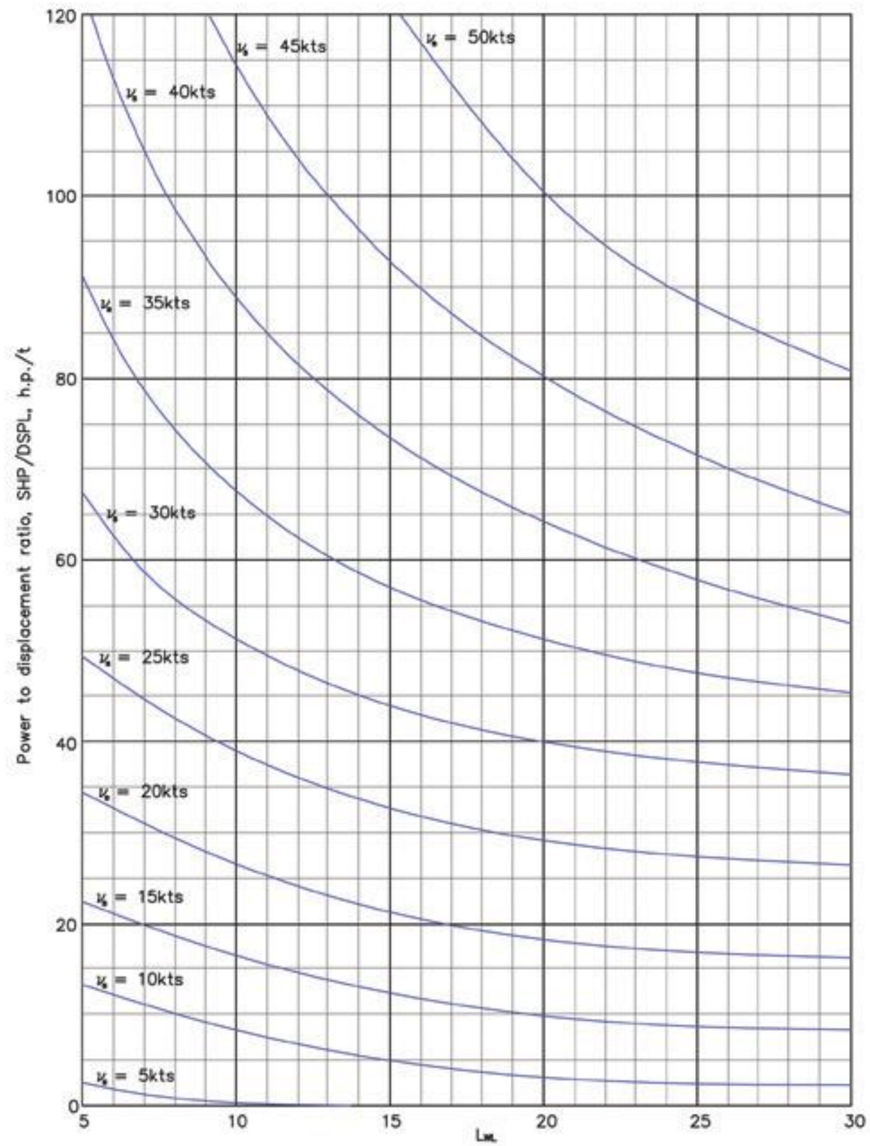
Pham's method based on serial resistance predictions by CFD code SHIPFLOW. Parameters of series are: L/B=6…12; B/T=1…3; CB=0.33…0.45; B_{CB}/L=0.2…0.5; Fn_L=0.2…1.0. All models derive from same parent model that is sharp-chine semi-planing shape.

For planing catamarans:

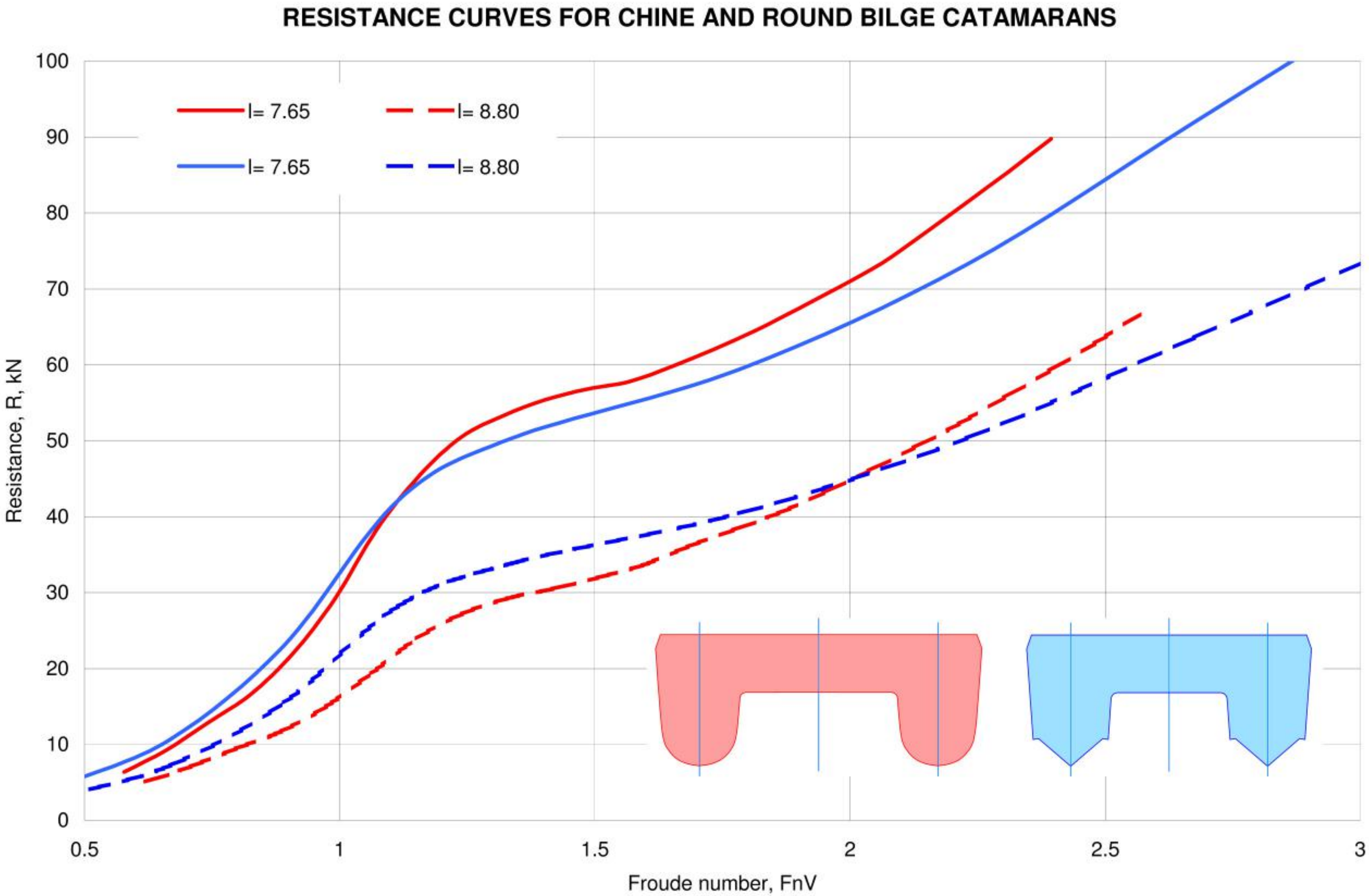
Savitsky method for prismatic planing hulls, with some corrections from Sherman or Ermolaev.

POWER-SPEED ESTIMATE

From the diagram - input is length of boat L_{WL} and desired speed v_S; the output is required power per unit of displacement. The diagram works for craft fitted with propellers, including sterndrives and outboard engines.



PERFORMANCE: RESISTANCE AND PROPULSION

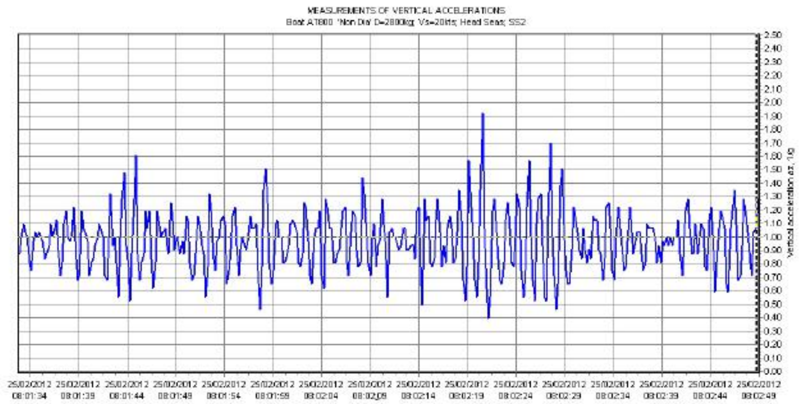


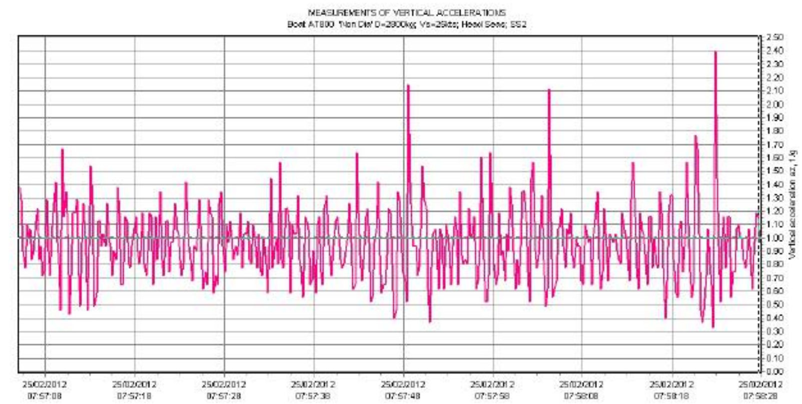
SEAKEEPING

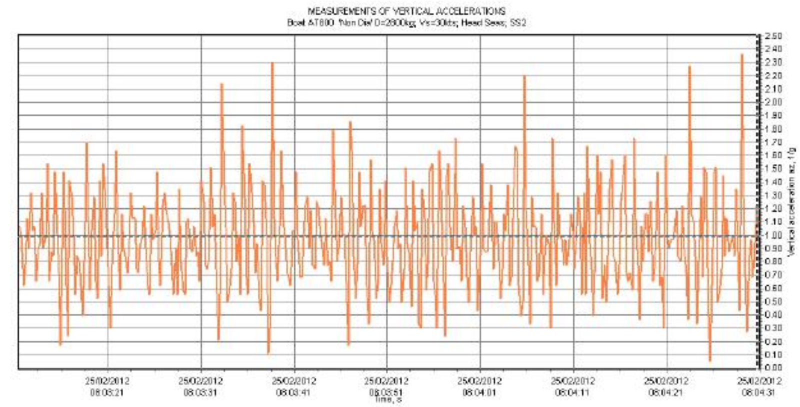
- **Vertical accelerations**
- **Wetness**

Due to higher deadrise and narrow chine beam catamarans possess 30…50% lower vertical accelerations compared with similar size monohulls

Figures: measurements of vertical accelerations on 8.1m catamaran at $h_{1/3}$=0.5m, head wave







SEAKEEPING: WHY CATS ARE SOFTER?

In design practice, the most widespread way to evaluate vertical accelerations on planing craft is Savitsky-Borwn formula:

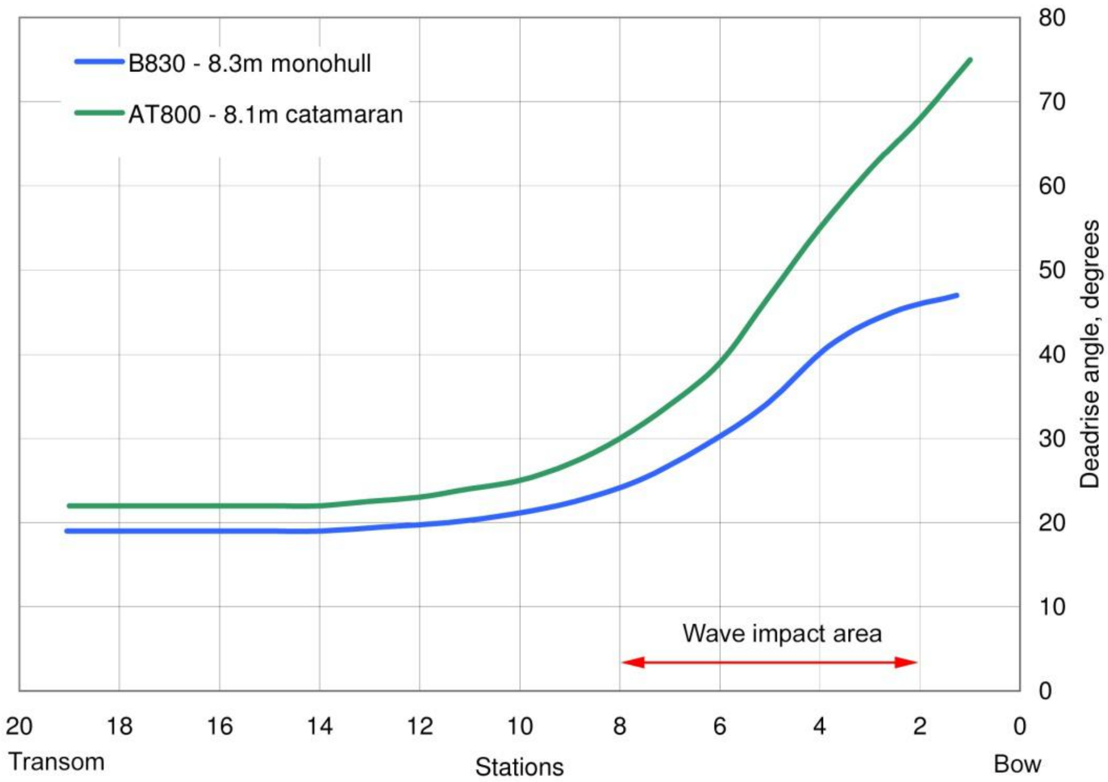
$$\frac{a_{CG}}{g} = 0.0104\left[\frac{H_{1/3}}{B_C} + 0.084\right]\frac{\tau}{4}\left[1.67 - \frac{\beta_5}{30}\right]\times\left[\frac{v_S}{\sqrt{3.28L}}\right]^2\frac{L}{B_C C_\Delta}$$

where a_{CG}/g is average impact acceleration at center of gravity related to gravity acceleration g; $H_{1/3}$ – significant wave height, m; τ - trim angle, taken τ=3…4° for preliminary estimates; B_C – beam of chine, m; L – length of craft, m; v_S – speed of craft, kts; β_5 - deadrise at half of waterline length, deg; C_Δ – static load factor $C_\Delta = V/B_C^3$; V – volume displacement, m/s

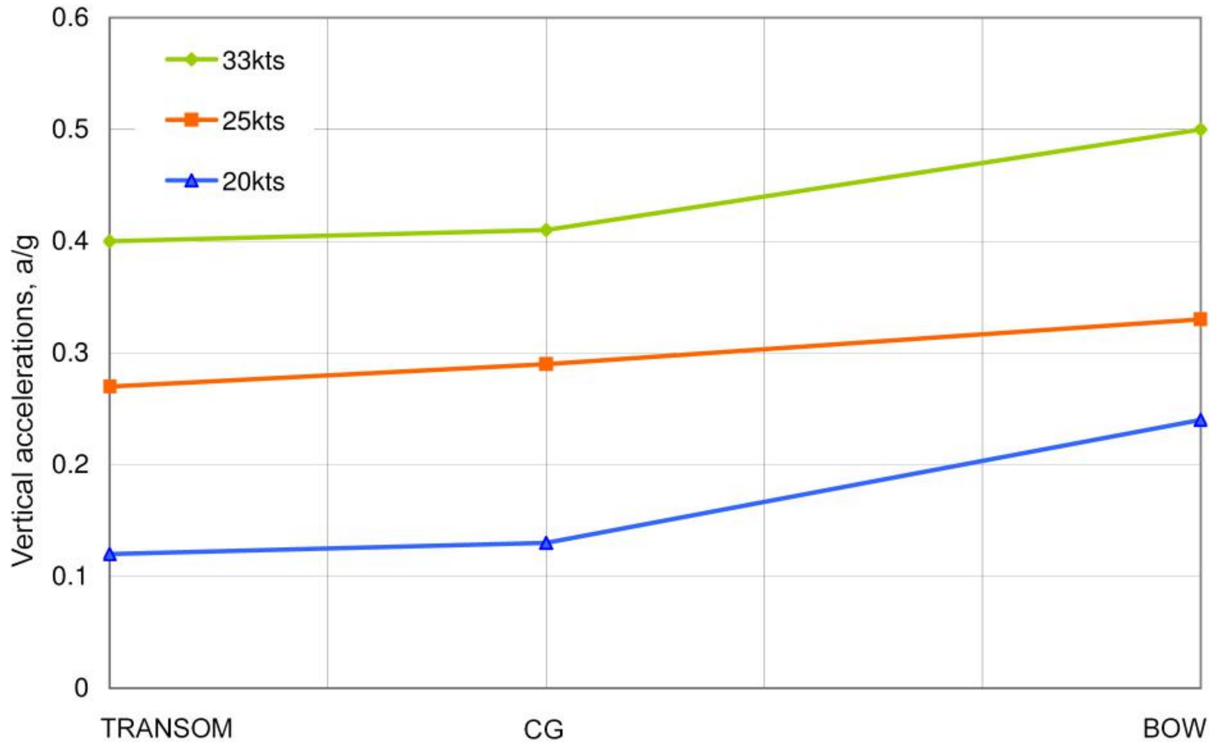
Measures to reduce vertical acceleration for planing craft at given speed, seastate and wave heading would be: increase of displacement V; increase of deadrise angle β especially at bow, decrease chine beam B_C.

SEAKEEPING: BOTTOM SHAPE

Figure: deadrise angles distribution on 8m monohull and catamaran

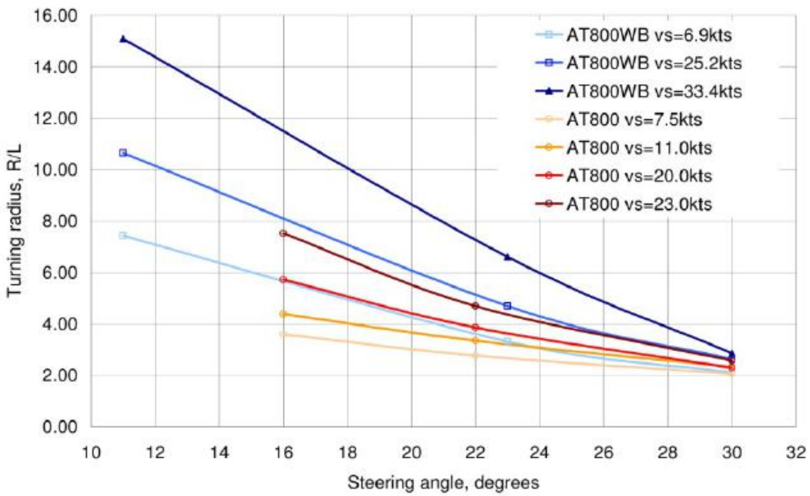


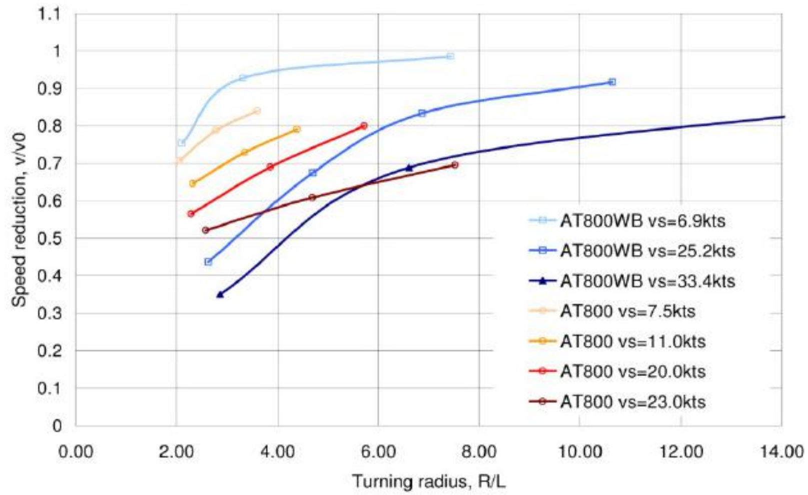
SEAKEEPING: LONGITUDINAL DISTRIBUTION OF ACCELERATIONS

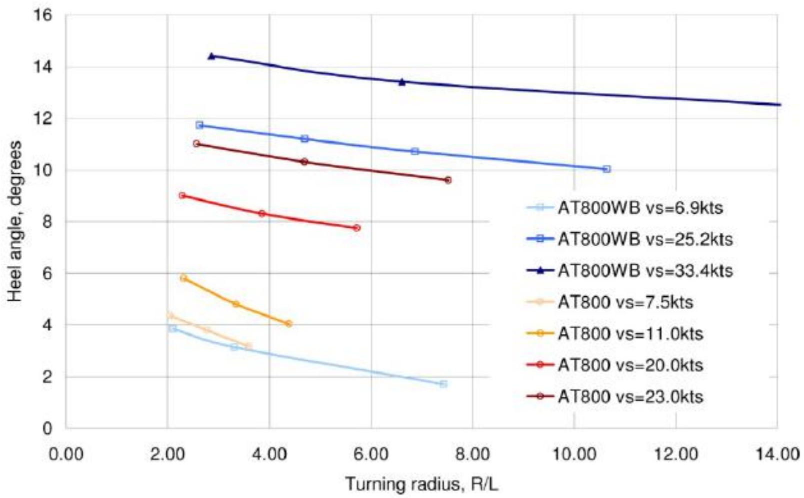


Measurements of vertical accelerations on 8m catamaran at $h_{1/3}$=0.5m, head wave

CONTROLLABILITY



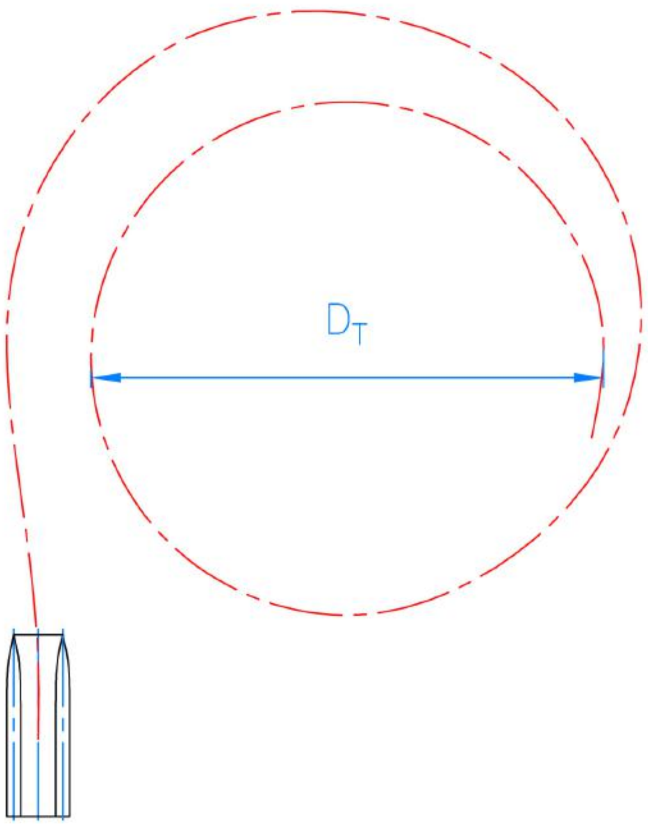




Results of maneuvering tests for 8m power catamarans

Two catamarans with same demihulls L_{WL}=7.0m, B_C=0.78m , displacement during tests 3,150 kg. The difference is B_{CB}=1.55m for normal AT800 model and B_{CB}=2.01m for widened AT800WB model. Both catamarans are driven by outboard engines, AT800 by 2x140HP and AT800WB by 2x175HP

SOME CONCLUSIONS ON CONTROLLABILITY



Wider catamarans - bigger turning radius *R*/*L*;

Turning diameter of planing catamaran at full speed and maximum steering/drive angle - D_T=3…5 lengths.

Planing catamarans with symmetrical hulls possess outwards heel during turns; split hulls could heel inwards. Catamarans stay flat during circulation, heel does not exceed 2…5° at maneuvering speeds.

Reduction of speed during turn v/v_0 depends on turning radius *R*/*L* and initial speed of catamaran v_0. Speed reduction can reach v/v_0=0.4 for ‘normal’ catamarans; for most of real-life maneuvering cases it would be v/v_0=0.6…0.8.

Transverse accelerations do not exceed 0.2*g* for normal (not extreme) maneuvers.

Catamarans show excellent maneuverability at slow speeds.

STRUCTURES

Design loads:

Local loads on bottom, sides, deck, cabins - estimated as for monohull boats;

Local strength of tunnel – specific slamming loads for catamarans;

General strength of catamaran with special attention to transverse bending, shear and torsion.

General loads (ISO12215):

$$M_{tb} = 2.5\Delta B_{CL} n_{cg}$$

$$M_{tt} = 1.25\Delta L_{WL} n_{cg}$$

$$Q_t = 2.5\Delta n_{cg}$$

Conditions of general strength are by default satisfied for small craft ($L_H \leq 24$m) with length to depth ratio $L/D<12$.

DESIGN SAMPLE: O860 RESCUE/FIREFIGHTING CATAMARAN

Aluminum catamaran designed for railway transportation. Main particulars: length maximum/hull – 9.95/8.60m; beam – 3.95m; draft fully loaded – 0.63m; displacement – 3.4/6.2t; engines – 2x190HP; speed – 35kts.

DESIGN SAMPLE: AT800 RESCUE CATAMARAN

FPR catamaran designed for beach rescue. Main particulars: length maximum/hull – 9.00/8.10m; beam – 2.55m; draft fully loaded – 0.80m; displacement – 2.1/3.8t; engines – 2x140HP; speed – 37kts.

DESIGN SAMPLE: PC930 POLICE CATAMARAN

Main particulars: length maximum/hull – 10.32/9.36m; beam – 3.51m; draft fully loaded – 0.89m; displacement – 3.8/6.2t; engines – 2x350HP; speed – 40kts; hull material – FRP.

CONCLUSIONS

Fast catamarans have proved to be efficient and reliable craft with plenty of operational advantages for different applications – pleasure, special and small commercial craft.

Publications:

1. Nazarov A. Application of catamaran concept for small commercial, special and pleasure craft// 16th High Speed Marine Vessels Conference (HPMV-2011) - Shanghai, China, 2011. – E18.
2. Nazarov A. Comfort on boats and yachts: design factors //Australian Power Multihull Vol.17. – May 2011.
3. Nazarov A. Power catamarans: design for performance// 2nd Chesapeake Power Boat Symposium - Annapolis, USA, 2010.