A SYSTEMATIC SERIES OF EXPERIMENTAL WASH WAVE MEASUREMENTS FOR HIGH SPEED DISPLACEMENT MONOHULL AND CATAMARAN FORMS IN SHALLOW WATER.

A.F. Molland, P.A. Wilson and D.J. Taunton

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NOMENCLATURE

\( F_{nL} \)  
Froude Number, \( \left[ \frac{U}{\sqrt{gL}} \right] \)

\( F_{nH} \)  
Depth Froude Number \( \left[ \frac{U}{\sqrt{gLH}} \right] \)

\( R_n \)  
Reynolds Number, \( \left[ \frac{U}{\nu} \right] \)

\( U \)  
Velocity \( [\text{m s}^{-1}] \)

\( W \)  
Tank width \( [\text{m}] \)

\( H \)  
Water depth \( [\text{m}] \)

\( L \)  
Length on waterline \( [\text{m}] \)

\( A \)  
Static wetted surface area \( [\text{m}^2] \)

\( B \)  
Demihull maximum beam \( [\text{m}] \)

\( T \)  
Demihull draught \( [\text{m}] \)

\( S \)  
Separation between catamaran demihull centrelines \( [\text{m}] \)

\( V \)  
Volume of displacement \( [\text{m}^3] \)

\( \Delta \)  
Mass displacement in freshwater \( [\text{kg}] \)

\( C_B \)  
Block coefficient

\( C_P \)  
Prismatic coefficient

\( L/\sqrt{V}^{1/3} \)  
Length : displacement ratio

\( R_T \)  
Total resistance \( [\text{N}] \)

\( C_T \)  
Coefficient of total resistance, \( \left[ \frac{R_T}{\frac{1}{2} \rho U^2} \right] \)

\( C_{T\infty} \)  
Coefficient of total resistance in deep water, \( \left[ \frac{R_T}{\frac{1}{2} \rho U^2} \right] \)

\( R_W \)  
Wave resistance \( [\text{N}] \)

\( C_W \)  
Coefficient of wave resistance, \( \left[ \frac{R_W}{\frac{1}{2} \rho U^2} \right] \)

\( R_{WP} \)  
Wave pattern resistance \( [\text{N}] \)

\( C_{WP} \)  
Coefficient of wave pattern resistance, \( \left[ \frac{R_{WP}}{\frac{1}{2} \rho U^2} \right] \)

\( C_F \)  
Coefficient of frictional resistance, [ITTC-57 Correlation line]

\( C_R \)  
Coefficient of residuary resistance

\( R \)  
Resistance in general \( [\text{N}] \)

\( g \)  
Acceleration due to gravity \( [9.80665 \text{ m s}^{-1}] \)

\( \rho \)  
Density of freshwater \( [1000 \text{ kg m}^{-3}] \)

\( \nu \)  
Kinematic viscosity of freshwater \( [1.141 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}] \) at 15°C
1 INTRODUCTION

Work on the resistance of high speed displacement catamarans has been ongoing over a number of years at the University of Southampton [1-4] in an effort to improve the understanding of their resistance components, seakeeping performance and to provide design and validation data.

This report describes an extensive series of wash wave measurements for monohull and catamarans models travelling in shallow water. The models were chosen from the series used in [1, 4], for which extensive resistance and wave characteristics in deep water are available.

The tests covered a range of length: displacement ratios $[L/\sqrt[3]{\Delta}]$ and catamaran separation: length ratios $[S/L]$ at two shallow water depths. The model speeds and water depths tested led to a range of Froude Numbers (based on length) of $F_{nL} = 0.25 - 1.2$ and a Froude Number (based on water depth) of $F_{nH} = 0.5 - 3.2$. The experiments entailed the measurement of wave profiles at seven transverse positions, model total resistance, sinkage and trim.

The work described forms part of a wider research programme, funded by EPSRC and industry and managed by MariNetech South Ltd over a two year period, which includes the development of theoretical methods for the prediction of the wash and wave resistance of catamarans. The theoretical work is the subject of a separate report [5].

2 DESCRIPTION OF MODELS

Details of the models used in this investigation are given in Table 1.

The models were constructed using an epoxy-foam sandwich skin. Models 4b, 5b and 5s are 1.6m in length. The length of model 6b was increased to 2.1m in order to achieve a satisfactory weight – displacement balance.

It should be noted that Models 4b, 5b and 6b had already been used for resistance tests in deep water and their results published in [6]. Some of the results for these models are used in the present report for comparison and discussion.

The models were of round bilge form with transom sterns, Figure 1, and were derived from the NPL round bilge series [7] and the Series 64 round bilge series [8]. These hulls broadly represent the underwater form of a number of catamarans in service or currently under construction. The models were first tested as monohulls and then in catamaran configurations with Separation: Length ratios $(S/L)$ of 0.2 and 0.4.

The model towing force was in the horizontal direction. The towing point in all cases was situated at the longitudinal centre of gravity and at a height of 1.5 times the draught above the baseline. No compensation was made for the
vertical separation of the tow point and the propeller thrust line. The tow fitting allowed free movement in sinkage and trim whilst movements in surge, sway, roll and yaw were restrained. The models were fitted with turbulence stimulation comprising trip studs of 3.2mm diameter and 2.5mm height at a spacing of 25mm. The studs were situated 37.5mm aft of the stem. No underwater appendages were attached to the models. The weight of the towpost was 2.045 Kg.

3 FACILITIES AND TESTS

3.1 General

The model experiments were carried out in the GKN-Westland Aerospace test tank on the Isle of Wight, which has the following principal particulars:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>200m</td>
</tr>
<tr>
<td>Breadth</td>
<td>4.6m</td>
</tr>
<tr>
<td>Water depth</td>
<td>1.7m</td>
</tr>
<tr>
<td>Maximum carriage speed</td>
<td>14m s(^{-1})</td>
</tr>
</tbody>
</table>

In the current tests, water depths of 400mm and 200mm were used.

The tank has a manned carriage which is equipped with a dynamometer for measuring model total resistance together with various computer and instrumentation facilities for automated data acquisition. For these shallow water tests a Wolfson Unit MTIA dynamometer was used which was attached to an aluminium alloy frame situated under the main carriage.

Calm water total resistance, running trim, sinkage and wave pattern measurements were carried out for all the models. All tests were carried out where possible over a speed range of 1m\(s^{-1}\) to 4m\(s^{-1}\) corresponding to a length Froude Number range of \(F_{nL}\) 0.25 to 1.0 and a depth Froude Number range \(F_{nH}\) 0.2 to 2.8. Over the Froude Number range 0.25 to 1.0, the corresponding Reynold’s Number range for the models was \(1.54*10^6\) to \(6.18*10^6\) for the 1.6m models and \(2.03*10^6\) to \(8.11*10^6\) for the 2.1m model.

3.2 Wave Pattern Measurements

Extensive wave profile measurements were carried out to establish a wide database of wash wave characteristics in shallow water, which would be suitable for design and validation purposes. Such an extensive set of wave data would also facilitate the description of the near field wave pattern in three dimensions from the experimental results and facilitate the interpolation of the experimental data at various transverse positions.

The wave profiles were measured using resistance type wave probes with a length of 300mm coupled to a Churchill wave probe monitor. The data were acquired and stored using a laptop computer situated at the side of the tank adjacent to the wave probes. The signals were acquired at a sampling rate of 100Hz. The acquisition program allowed a run time of up to 40 secs to be used.
During each test run, seven longitudinal wave profiles were measured, with transverse positions (Y) relative to the centreline of the tank as shown in Figures 2a, 2b and 2c. Relative to model length, these positions have values of Y/L = 0.43, 0.55, 0.68, 0.80, 0.93, 1.05 and 1.18 for Models 4b, 5b and 5s and Y/L = 0.33, 0.42, 0.52, 0.61, 0.71, 0.80 and 0.90 for Model 6b. The longitudinal position of the wave probes in the tank are shown in Figure 2c. This position allowed adequate time for the wave system to settle before measurements commenced.

### 3.3 Trim and Sinkage Measurements

Trim and sinkage were monitored for all of the tests. Trim (positive bow up) was measured by means of a potentiometer mounted on the tow fitting; accuracy of the measurement was within ±0.05°. Sinkage (positive downwards) was measured by means of a potentiometer and a track on the towpost; accuracy of the measurement was within ±0.1mm.

### 3.4 Trim changes

A limited series of tests were carried out with model 5b and 5s at 200mm water depth for the cases of significant bow and stern trim. These would provide information on the influence of trim changes on the model resistance and the measured wash waves.

### 4 DATA REDUCTION AND CORRECTIONS

#### 4.1 Coefficients

All resistance data were reduced to coefficient form using fresh water density (ρ = 1000 kg m⁻³), static wetted surface area (A) and model speed (U):

\[
\text{Resistance Coefficient} = \frac{\text{Resistance}}{\frac{1}{2} \rho A U^2}
\]  

(1)

Noting A is the wetted area of both demihulls in the case of the catamaran.

Corrections were applied as necessary to the measured data and these are described in the following sections:

#### 4.2 Temperature Correction

During the tests the water temperature varied from 18°C to 20°C. The total resistance measurements were corrected to the standard temperature of 15°C by modifying the frictional resistance component. The correction which has been applied is as follows:

\[
C_{T_{15}} = C_{T_{\text{test}}} - C_{F_{\text{test}}} + C_{F_{1.5}}
\]  

(2)
The correction should be slightly larger due to the form factor being greater than unity. However, the correction is in any case small and the above equation is considered to be sufficiently accurate.

4.3 Resistance due to Turbulence Studs

Turbulence studs were attached to all the models as described in Section 2. A detailed investigation of their influence on model drag was carried out, and is described in [6]. It was found that, whilst there was additional drag on the studs, this is to a certain extent negated by the laminar region upstream and the boundary layer momentum thickness increase downstream due to the studs.

4.4 Wetted Surface Area

Static wetted surface area was used to non-dimensionalise the resistance measurements. A detailed investigation into the use of running wetted surface area is described in [6]. The conclusions in [6] indicate that whilst the use of running wetted surface might provide a better understanding of the physical components of resistance, the use of static wetted area does not have a significant effect on model to ship extrapolation providing both model and full scale coefficients are based on static wetted surface area. Running wetted surface area is difficult to measure experimentally in a routine manner, and will not be available for a new design. From a practical viewpoint it is necessary to use the static wetted surface area, and it has therefore been applied in the current work.

5 PRESENTATION OF DATA

The basic presentation of the experimental resistance data is as follows:

\[ C_T = C_F + C_R \] (2)

The wave profiles are presented in terms of wave height (mm) to a base of distance (m).

The measured experimental wave cuts are presented in Figures 3 to 174. Figures 3 to 72 present the experimental data for a water depth of 400mm and Figures 73 to 153 present the experimental data for a water depth of 200mm. Figures 154 to 174 present the experimental wave cuts for Models 5s and 5b trimmed by the bow and stern. For all 1.6m models, wave cuts were measured at the following Y/L positions of 0.426, 0.551, 0.676, 0.801, 0.926, 1.051 and 1.176 from the centreline of the tank. The 2.1m Model 6b used Y/L=0.33, 0.42, 0.52, 0.61, 0.71, 0.80 and 0.90.

The measured experimental resistance and sinkage/trim data are presented in Figures 175 to 236. Figures 175 to 182 give the total resistance for the demihulls (or monohulls) in isolation at the two water depths whilst Figures 183 to 198 give the data for the catamaran configurations. The running trim and
sinkage have been plotted against length Froude number $F_{nL}$, Figures 199 to 206 and 207 to 222. Dynamic sinkage has been presented as a percentage of the draught of the vessel. Figures 223 to 230 present the resistance, dynamic sinkage and trim for Models 5s and 5b catamarans at a separation to length ratio (S/L) of 0.2 with static trim applied. The models were run with a nominal static trim of 2° bow down and 2° bow up.

The residuary resistance coefficients $C_R$ derived from the experimental data are plotted in Figures 231 to 236.

Figures 237 and 238 show typical wave patterns for monohull forms travelling at sub-critical and super-critical speeds.

6 DISCUSSION OF RESULTS

6.1 Wave profiles

The longitudinal wave profiles are shown in Figures 3 to 174 for different models, a range of speeds and two depths of water at seven transverse positions from the centreline of the track of the model.

These profiles provide a wide range of data for input to wave propagation models, for assessing the effects of changing the hull parameters and for the validation of theoretical methods.

In Figures 239 and 240, the seven 2-D longitudinal wave profiles have been used to create 3-D representations of the wave patterns. Figure 239 shows a sub-critical case and Figure 240 a super-critical case. This type of presentation is useful in the validation of theoretical methods.

It should be noted that at or close to critical speed [$F_{nH}=1.0$], solitary waves (solitons) were generated which moved on ahead of the model, Figure 241. As it is likely that this phenomenon was amplified due to operation in a relatively narrow tank, discussion of the origins and behaviour of the solitary waves is not taken further in this report.

6.2 Total Resistance

The total resistance $C_T$, has been plotted against length Froude number $F_{nL}$. The non-dimensional total resistance $C_T$ has been compared with the total resistance $C_{T\infty}$ in deep water. The deep water results are plotted as a dotted line on the graphs in Figures 175 to 198 and 223 to 226. These deep water $C_{T\infty}$ values were obtained from earlier tests as reported in [6] and [4]. From these results it is seen that near the critical speed there is a significant increase in shallow water resistance over the deep water result. At higher Froude numbers the $C_T$ in shallow water generally approaches the deep water $C_{T\infty}$ value. With forced static trim changes, Figures 223 to 226, bow up trim led to significant increase in resistance whilst bow down trim led to relatively small changes. Similarly, increases in the wave height occur for the bow up conditions compared with the level trim case, Figures 244 and 245.
6.3 Running sinkage and trim

Like the resistance results, the trim and sinkage values, Figures 184 to 207, show significant changes around the critical speed, although they tend to settle at about the deep water values at higher speeds.

6.4 Residuary Resistance: Effect of Hull Parameters

The coefficient of residuary resistance \( C_R \) (derived as \( C_R = C_T - C_F \)) has been plotted in Figures 216 to 221. Like the total resistance curves, the residuary resistance curves again illustrate the significant amplification of the resistance around the critical speed, \( F_{n_H} = 1.0 \). These figures show that the coefficient of residuary resistance increases with reducing \( L/\sqrt[3]{V} \). It is however seen that changes in hull shape for the same length: displacement ratio, Models 5s and 5b, have relatively little influence on the coefficient of residuary resistance.

7 CONCLUSIONS

7.1 A large database of experimental wash wave measurements for ship models travelling in shallow water has been established. The experiments covered a range of displacement monohull and catamaran forms over a wide range of speeds.

7.2 The data should prove useful for assessing the effects of changing principal hull parameters, for the validation of theoretical wash prediction methods and for input into wave propagation models.

7.3 Significant changes in model behaviour occurred at or near critical speed, \( F_{n_H} = 1.0 \). There were large increases in resistance and wave height and significant changes in sinkage and trim.

7.4 In the main, at higher speeds well beyond critical, the shallow water results for resistance, sinkage and trim tend to settle at about the deep water values.

ACKNOWLEDGEMENTS

The work described in this report covers part of a research project funded by EPSRC and industry and managed by Marinetech South Ltd. The assistance of Pauzi Abdul Ghani and Sattaya Chandraprabha, postgraduate students at the University of Southampton, who contributed to both the theoretical and experimental work, is gratefully acknowledged.
REFERENCES


## TABLES

<table>
<thead>
<tr>
<th>Model</th>
<th>4b</th>
<th>5b</th>
<th>6b</th>
<th>5s</th>
</tr>
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<tbody>
<tr>
<td>L [m]</td>
<td>1.6</td>
<td>1.6</td>
<td>2.1</td>
<td>1.6</td>
</tr>
<tr>
<td>B [m]</td>
<td>0.178</td>
<td>0.146</td>
<td>0.160</td>
<td>0.125</td>
</tr>
<tr>
<td>T[m]</td>
<td>0.089</td>
<td>0.073</td>
<td>0.080</td>
<td>0.063</td>
</tr>
<tr>
<td>V [m³]</td>
<td>0.0101</td>
<td>0.00667</td>
<td>0.0108</td>
<td>0.00667</td>
</tr>
<tr>
<td>Δ [Kg]</td>
<td>10.10</td>
<td>6.67</td>
<td>10.75</td>
<td>6.67</td>
</tr>
<tr>
<td>L/V^{1/3}</td>
<td>7.4</td>
<td>8.5</td>
<td>9.5</td>
<td>8.5</td>
</tr>
<tr>
<td>L/B</td>
<td>9.0</td>
<td>11.0</td>
<td>13.1</td>
<td>12.8</td>
</tr>
<tr>
<td>B/T</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
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</tr>
<tr>
<td>C_B</td>
<td>0.397</td>
<td>0.397</td>
<td>0.397</td>
<td>0.537</td>
</tr>
<tr>
<td>C_P</td>
<td>0.693</td>
<td>0.693</td>
<td>0.693</td>
<td>0.633</td>
</tr>
<tr>
<td>C_M</td>
<td>0.565</td>
<td>0.565</td>
<td>0.565</td>
<td>0.848</td>
</tr>
<tr>
<td>A [m²]</td>
<td>0.338</td>
<td>0.276</td>
<td>0.401</td>
<td>0.261</td>
</tr>
<tr>
<td>LCB [%]</td>
<td>-6.4</td>
<td>-6.4</td>
<td>-6.4</td>
<td>-6.4</td>
</tr>
</tbody>
</table>

Table 1 Principal particulars of Models (demihulls)
FIGURES

Model: 4b

Model: 5b

Model: 5s

Model: 6b

Figure 1: Model Bodyplans and Notation
Figure 2a: Schematic of GKN-Westland tank (cross Section)

Figure 2b: View of model passing probe array from beach.
Figure 2c: Schematic of GKN test tank
Model 4b monohull
Water depth = 400mm
$V = 1.03\text{ms}^{-1}$, $F_{nl} = 0.26$, $F_{nh} = 0.52$

Figure 3
Model 4b monohull
Water depth = 400mm
V = 1.73 ms$^{-1}$, Fnl = 0.44, Fnh = 0.87

Figure 4
Model 4b monohull
Water depth = 400mm
V = 1.85ms⁻¹, Fnl = 0.47, Fnh = 0.93

Figure 5
Model 4b monohull
Water depth = 400mm
$V = 2.04\text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.03$

Figure 6
Model 4b monohull
Water depth = 400mm
\( V = 3.12 \text{ms}^{-1}, \ F_{nl} = 0.79, \ F_{nh} = 1.58 \)

Figure 7
Model 4b monohull
Water depth = 400mm
\( V = 4.05\text{ms}^{-1} \), \( F_{nl} = 1.02 \), \( F_{nh} = 2.05 \)

![Graphs of wave height vs. distance for different water depths](image)

Figure 8
Model 5b monohull
Water depth = 400mm
$V = 0.87\text{ms}^{-1}$, $F_{nl} = 0.22$, $F_{nh} = 0.44$

Figure 9
Model 5b monohull
Water depth = 400mm

$V = 1.50 \text{ms}^{-1}$, $F_{nl} = 0.38$, $F_{nh} = 0.76$

Figure 10
Model 5b monohull
Water depth = 400mm
V = 1.76ms\(^{-1}\), Fnl = 0.44, Fnh = 0.89

\[ y/l = 0.43 \]

\[ y/l = 0.55 \]

\[ y/l = 0.68 \]

\[ y/l = 0.80 \]

\[ y/l = 0.93 \]

\[ y/l = 1.05 \]

\[ y/l = 1.18 \]

Figure 11
Model 5b monohull
Water depth = 400 mm
$V = 1.92 \text{ms}^{-1}$, $F_nl = 0.49$, $F_nh = 0.97$

Figure 12
Model 5b monohull
Water depth = 400mm
V = 2.01ms\(^{-1}\), Fnl = 0.51, Fnh = 1.02

Figure 13
Model 5b monohull
Water depth = 400mm
\( V = 2.01 \text{ms}^{-1}, F_{nl} = 0.51, F_{nh} = 1.02 \)

\( y/l = 0.43 \)

\( y/l = 0.55 \)

\( y/l = 0.68 \)

\( y/l = 0.80 \)

\( y/l = 0.93 \)

\( y/l = 1.05 \)

\( y/l = 1.18 \)

**Figure 14**
Model 5b monohull
Water depth = 400mm

$V = 2.20 \text{ms}^{-1}$, $F_{nl} = 0.56$, $F_{nh} = 1.11$

Figure 15
Model 5b monohull
Water depth = 400mm
V = 3.11 ms$^{-1}$, Fnl = 0.78, Fnh = 1.57

Figure 16
Model 5b monohull
Water depth = 400mm
V = 4.04 ms\(^{-1}\), Fnl = 1.02, Fnh = 2.04

Figure 17
Model 5b monohull
Water depth = 400mm
\[ V = 1.85 \text{ms}^{-1}, \ F_n = 0.47, \ F_{nh} = 0.93 \]

Figure 18
Model 6b monohull
Water depth = 400mm
$V = 1.03\text{ms}^{-1}$, $Fn_l = 0.23$, $Fn_h = 0.52$

Wave height [mm]

Distance [m]

Figure 19
Model 6b monohull
Water depth = 400mm
$V = 1.87\text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 0.94$

Figure 20
Model 6b monohull
Water depth = 400mm
$V = 2.04\, \text{ms}^{-1}$, $F_{nl} = 0.45$, $F_{nh} = 1.03$

Figure 21
Model 6b monohull
Water depth = 400mm
$V = 3.13\text{ms}^{-1}$, $F_{nl} = 0.69$, $F_{nh} = 1.58$

Figure 22
Model 6b monohull
Water depth = 400mm
V = 3.12 m s⁻¹, Fnl = 0.69, Fnh = 1.58

Figure 23
Model 6b monohull
Water depth = 400mm
\( V = 4.05\text{ms}^{-1} \), \( F_{nl} = 0.89 \), \( F_{nh} = 2.05 \)

Wave height [mm]

\( y/l = 0.32 \)
\( y/l = 0.42 \)
\( y/l = 0.52 \)
\( y/l = 0.61 \)
\( y/l = 0.71 \)
\( y/l = 0.80 \)
\( y/l = 0.90 \)

Figure 24
Model 5s monohull,
Water depth = 400mm, \( V = 1.01 \text{ms}^{-1} \), \( F_{nl} = 0.25 \), \( F_{nh} = 0.51 \)

Figure 25
Model 5s monohull,
Water depth = 400mm, $V = 2.02 \text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.02$

Figure 26
Model 5s monohull,
Water depth = 400mm, $V = 3.11\text{ms}^{-1}$, $F_{nl} = 0.78$, $F_{nh} = 1.57$

[Graph showing wave height vs. distance for different $y/l$ values: $y/l = 0.43$, $0.55$, $0.69$, $0.80$, $0.93$, $1.05$, $1.18$, $1.30$.]

Figure 27
Model 5s monohull,
Water depth = 400mm, V = 4.03ms\(^{-1}\), Fnl = 1.02, Fnh = 2.03

Figure 28
Model 4b Catamaran S/L=0.2
Water depth = 400mm
$V = 1.03\text{ms}^{-1}$, $F_{nl} = 0.26$, $F_{nh} = 0.52$

Figure 29
Model 4b Catamaran S/L=0.2
Water depth = 400mm
\( V = 1.48 \text{ms}^{-1}, F_{nl} = 0.37, F_{nh} = 0.75 \)

Wave height [mm]

Distance [m]

Figure 30
Model 4b Catamaran S/L=0.2
Water depth = 400mm
V = 1.73ms$^{-1}$, Fnl = 0.44, Fnh = 0.87

Figure 31
Model 4b Catamaran S/L=0.2
Water depth = 400mm
V = 1.86ms⁻¹, Fnl = 0.47, Fnh = 0.94

Figure 32
Model 4b Catamaran S/L=0.2
Water depth = 400mm
$V = 2.04\text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.03$

Figure 33
Model 4b Catamaran S/L=0.2
Water depth = 400mm
V = 3.13ms⁻¹, Fnl = 0.79, Fnh = 1.58

Figure 34
Model 4b Catamaran S/L=0.2
Water depth = 400mm
V = 4.06ms$^{-1}$, Fnl = 1.02, Fnh = 2.05

Figure 35
Model 5b Catamaran S/L=0.2
Water depth = 400mm
V = 1.72ms\(^{-1}\), Fnl = 0.43, Fnh = 0.87

Figure 36
Model 5b Catamaran S/L=0.2
Water depth = 400mm
\( V = 1.85\text{ms}^{-1}, F_{nl} = 0.47, F_{nh} = 0.93 \)

\[ y/l=0.43 \]
\[ y/l=0.55 \]
\[ y/l=0.68 \]
\[ y/l=0.80 \]
\[ y/l=0.93 \]
\[ y/l=1.05 \]
\[ y/l=1.18 \]

Figure 37
Model 5b Catamaran S/L=0.2
Water depth = 400mm
$V = 3.12 \text{ms}^{-1}$, $F_{nl} = 0.79$, $F_{nh} = 1.57$

![Graphs showing wave height vs. distance for different y/l values](image)

Figure 38
Model 5b Catamaran S/L=0.2
Water depth = 400mm
\(V = 4.04\text{ms}^{-1}, F_{nl} = 1.02, F_{nh} = 2.04\)

<table>
<thead>
<tr>
<th>Wave height [mm]</th>
<th>y/l=0.43</th>
<th>y/l=0.55</th>
<th>y/l=0.68</th>
<th>y/l=0.80</th>
<th>y/l=0.93</th>
<th>y/l=1.05</th>
<th>y/l=1.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance [m]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 39
Model 6b Catamaran S/L=0.2
Water depth = 400mm
V = 1.03ms⁻¹, Fnl = 0.23, Fnh = 0.52
Model 6b Catamaran S/L=0.2
Water depth = 400mm
V = 1.73 ms$^{-1}$, Fnl = 0.38, Fnh = 0.87
Model 6b Catamaran S/L=0.2
Water depth = 400mm
$V = 1.86\text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 0.94$

Wave height [mm]

Distance [m]

Figure 42
Model 6b Catamaran S/L=0.2
Water depth = 400mm
\( V = 2.04 \text{ms}^{-1}, F_{nl} = 0.45, F_{nh} = 1.03 \)

\[ \text{Wave height [mm]} \]

\[ \text{Distance [m]} \]

Figure 43
Model 6b Catamaran S/L=0.2
Water depth = 400mm
\[ V = 3.13 \text{ms}^{-1}, \text{Fnl} = 0.69, \text{Fnh} = 1.58 \]

Wave height [mm]

\[ y/l=0.32 \]
\[ y/l=0.42 \]
\[ y/l=0.52 \]
\[ y/l=0.61 \]
\[ y/l=0.71 \]
\[ y/l=0.80 \]
\[ y/l=0.90 \]

Distance [m]

Figure 44
Model 5s Catamaran S/L=0.2,
Water depth = 400mm, $V = 1.02\text{ms}^{-1}$, $Fnl = 0.26$, $Fnh = 0.51$

![Graph showing wave height vs distance for various y/l values.](image-url)
Model 5s Catamaran S/L=0.2,
Water depth = 400mm, V = 2.02ms⁻¹, Fnl = 0.51, Fnh = 1.02

Figure 46
Model 5s Catamaran S/L=0.2,
Water depth = 400mm, $V = 4.04\text{ms}^{-1}$, $F_{nl} = 1.02$, $F_{nh} = 2.04$

![Graphs showing wave height vs distance for different $y/l$ values](image_url)
Model 4b Catamaran S/L=0.4
Water depth = 400mm
V = 1.03ms^{-1}, Fnl = 0.26, Fnh = 0.52

Figure 49
Model 4b Catamaran S/L=0.4
Water depth = 400mm
\( V = 1.58\text{ms}^{-1}, F_{nl} = 0.40, F_{nh} = 0.80 \)

Wave height [mm]

Distance [m]

Figure 50
Model 4b Catamaran S/L=0.4
Water depth = 400mm
$V = 1.72 \text{ms}^{-1}$, $F_{nl} = 0.43$, $F_{nh} = 0.87$

Figure 51
Model 4b Catamaran S/L=0.4
Water depth = 400mm

$V = 1.76 \text{ms}^{-1}$, $F_{nl} = 0.44$, $F_{nh} = 0.89$

Figure 52
Model 4b Catamaran S/L=0.4
Water depth = 400mm
V = 2.04ms⁻¹, Fnl = 0.51, Fnh = 1.03

Figure 53
Model 4b Catamaran S/L=0.4
Water depth = 400mm
$V = 3.13\text{ms}^{-1}$, $Fnl = 0.79$, $Fnh = 1.58$

Figure 54
Model 4b Catamaran S/L=0.4
Water depth = 400mm
$V = 4.04\text{ms}^{-1}$, $F_{nl} = 1.02$, $F_{nh} = 2.04$

Figure 55
Model 5b Catamaran \( S/L = 0.4 \)
Water depth = 400mm
\( V = 1.02 \text{ms}^{-1} \), \( F_{nl} = 0.26 \), \( F_{nh} = 0.52 \)

Figure 56
Model 5b Catamaran S/L=0.4
Water depth = 400mm
V = 1.72ms⁻¹, Fnl = 0.43, Fnh = 0.87

Figure 57
Model 5b Catamaran  S/L=0.4
Water depth = 400mm
V = 1.85ms\(^{-1}\), Fnl = 0.47, Fnh = 0.93

Wave height [mm]

Distance [m]

Figure 58
Model 5b Catamaran  S/L=0.4
Water depth = 400mm
V = 2.03ms$^{-1}$, Fnl = 0.51, Fnh = 1.03

Figure 59
Model 5b Catamaran S/L=0.4
Water depth = 400mm
\[ V = 3.12\text{ms}^{-1}, F_{nl} = 0.79, F_{nh} = 1.57 \]

Figure 60
Model 5b Catamaran S/L=0.4
Water depth = 400mm
V = 4.04ms$^{-1}$, Fnl = 1.02, Fnh = 2.04

Figure 61
Model 6b Catamaran S/L=0.4
Water depth = 400mm
V = 1.03ms⁻¹, Fnl = 0.23, Fnh = 0.52

Figure 62
Model 6b Catamaran S/L=0.4
Water depth = 400mm
V = 1.98ms$^{-1}$, Fnl = 0.44, Fnh = 1.00

Figure 63
Model 6b Catamaran S/L=0.4
Water depth = 400mm
$V = 1.86\text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 0.94$

Figure 64
Model 6b Catamaran S/L=0.4
Water depth = 400mm
V = 2.04ms\(^{-1}\), Fnl = 0.45, Fnh = 1.03

Figure 65
Model 6b Catamaran S/L=0.4
Water depth = 400mm
V = 3.13ms$^{-1}$, Fnl = 0.69, Fnh = 1.58

Figure 66
Model 6b Catamaran S/L=0.4
Water depth = 400mm
V = 3.51ms\(^{-1}\), Fnl = 0.77, Fnh = 1.77

Wave height [mm]

Distance [m]

Figure 67
Model 6b Catamaran S/L=0.4
Water depth = 400mm
$V = 4.06\text{ms}^{-1}$, $F_{nl} = 0.89$, $F_{nh} = 2.05$

Figure 68
Model 5s Catamaran S/L=0.4, Water depth = 400mm, $V = 1.01\text{ms}^{-1}$, $Fnl = 0.25$, $Fnh = 0.51$

Wave height [mm] for different $y/l$ ratios:
- $y/l = 0.43$
- $y/l = 0.55$
- $y/l = 0.69$
- $y/l = 0.80$
- $y/l = 0.93$
- $y/l = 1.05$
- $y/l = 1.18$
- $y/l = 1.30$

Figure 69
Model 5s Catamaran S/L=0.4,
Water depth = 400mm, V = 2.02ms⁻¹, Fnl = 0.51, Fnh = 1.02

Figure 70
Model 5s Catamaran S/L=0.4,
Water depth = 400mm, \( V = 3.11\text{ms}^{-1} \), \( F_{nl} = 0.78 \), \( F_{nh} = 1.57 \)

Wave height [mm]

Distance [m]

\( y/l=0.43 \)
\( y/l=0.55 \)
\( y/l=0.69 \)
\( y/l=0.80 \)
\( y/l=0.93 \)
\( y/l=1.05 \)
\( y/l=1.18 \)
\( y/l=1.30 \)

Figure 71
Model 5s Catamaran S/L=0.4,
Water depth = 400mm, V = 4.03ms$^{-1}$, Fnl = 1.02, Fnh = 2.03

![Wave height vs Distance graphs for y/l values 0.43 to 1.30](image)

Figure 72
Model 4b monohull
Water depth = 200mm
$V = 0.98\, \text{ms}^{-1}, \, F_{nl} = 0.25, \, F_{nh} = 0.70$

Figure 73
Model 4b monohull
Water depth = 200mm
$V = 1.33 \text{ms}^{-1}$, $F_{nl} = 0.34$, $F_{nh} = 0.95$

---

**Figure 74**
Model 4b monohull
Water depth = 200mm
V = 1.41 m s\(^{-1}\), F_{nl} = 0.36, F_{nh} = 1.00

Wave height [mm]

Distance [m]

Figure 75
Model 4b monohull
Water depth = 200mm
$V = 1.41\text{ms}^{-1}, F_{nl} = 0.36, F_{nh} = 1.01$

Wave height [mm]

Distance [m]

Figure 76
Model 4b monohull
Water depth = 200mm
$V = 1.41 \text{ms}^{-1}$, $F_{nl} = 0.36$, $F_{nh} = 1.01$

$y/l = 0.43$

$y/l = 0.55$

$y/l = 0.68$

$y/l = 0.80$

$y/l = 0.93$

$y/l = 1.05$

$y/l = 1.18$

Figure 77
Model 4b monohull
Water depth = 200mm
$V = 2.03 \text{ms}^{-1}$, $Fn_l = 0.51$, $Fn_h = 1.45$

Wave height [mm]

Distance [m]

Figure 78
Model 4b monohull
Water depth = 200mm
$V = 3.12 \text{ms}^{-1}, F_{nl} = 0.79, F_{nh} = 2.23$

Figure 79
Model 4b monohull
Water depth = 200mm
\[ V = 4.04\, \text{ms}^{-1}, \quad F_{nl} = 1.02, \quad F_{nh} = 2.89 \]

Wave height [mm]

Distance [m]

Figure 80
Model 5b monohull
Water depth = 200mm
V = 1.23ms\(^{-1}\), \(F_{nl} = 0.31\), \(F_{nh} = 0.88\)
Model 5b monohull
Water depth = 200mm
$V = 1.33\text{ms}^{-1}$, $Fn_l = 0.34$, $Fn_h = 0.95$

Figure 82
Figure 83
Model 5b monohull
Water depth = 200mm
$V = 1.61 \text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 1.15$

Wave height [mm]

Figure 84
Model 5b monohull
Water depth = 200mm
$V = 2.02 \text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.45$

Wave height [mm]

Distance [m]

Figure 85
Model 5b monohull
Water depth = 200mm
V = 3.11ms\(^{-1}\), Fnl = 0.79, Fnh = 2.22

Figure 86
Model 5b monohull
Water depth = 200mm
V = 4.03 ms\(^{-1}\), Fnl = 1.02, Fnh = 2.88

Wave height [mm]

Distance [m]
Model 6b monohull
Water depth = 200mm
\( V = 1.03 \text{ms}^{-1}, F_{nl} = 0.23, F_{nh} = 0.74 \)
Model 6b monohull
Water depth = 200mm
$V = 1.34 \text{ms}^{-1}$, $F_{nl} = 0.30$, $F_{nh} = 0.96$

Wave height [mm]

Distance [m]

Figure 89
Model 6b monohull
Water depth = 200mm
\( V = 1.41 \text{ms}^{-1}, F_{nl} = 0.31, F_{nh} = 1.01 \)
Model 6b monohull
Water depth = 200mm

$V = 2.04 \text{ms}^{-1}, F_{nl} = 0.45, F_{nh} = 1.46$

Wave height [mm]

Distance [m]

Figure 91
Model 6b monohull
Water depth = 200mm
V = 3.13ms\(^{-1}\), Fnl = 0.69, Fnh = 2.24

Figure 92
Figure 93
Model 5s monohull
Water depth = 200mm
\( V = 1.02 \text{ms}^{-1}, \ F_{nl} = 0.26, \ F_{nh} = 0.73 \)

Figure 94
Model 5s monohull
Water depth = 200mm

V = 1.02 ms\(^{-1}\), Fnl = 0.26, Fnh = 0.73

Figure 95
Model 5s monohull
Water depth = 200mm
V = 1.40 ms$^{-1}$, Fnl = 0.35, Fnh = 1.00

Figure 97
Model 5s monohull
Water depth = 200mm
\( V = 2.03\text{ms}^{-1}, F_{nl} = 0.51, F_{nh} = 1.45 \)

Figure 98
Model 5s monohull
Water depth = 200mm
$V = 3.12\text{ms}^{-1}$, $F_{nl} = 0.79$, $F_{nh} = 2.23$

Distance [m] vs Wave height [mm] for different values of $y/l$.
Model 5s monohull
Water depth = 200mm
\( V = 4.04 \text{ms}^{-1}, \ F_{nl} = 1.02, \ F_{nh} = 2.89 \)

\[ y/l=0.43 \]

\[ y/l=0.55 \]

\[ y/l=0.68 \]

\[ y/l=0.80 \]

\[ y/l=0.93 \]

\[ y/l=1.05 \]

\[ y/l=1.18 \]

Figure 100
Model 4b Catamaran S/L=0.2
Water depth = 200mm
$V = 1.33\text{ms}^{-1}$, $F_{nl} = 0.34$, $F_{nh} = 0.95$

Figure 101
Model 4b Catamaran S/L=0.2
Water depth = 200mm
V = 1.02ms$^{-1}$, Fnl = 0.26, Fnh = 0.73

Wave height [mm]

Distance [m]

Figure 102
Model 4b Catamaran S/L=0.2
Water depth = 200mm
V = 1.40 ms$^{-1}$, Fnl = 0.35, Fnh = 1.00

Figure 103
Model 4b Catamaran S/L=0.2
Water depth = 200mm
V = 2.03ms\(^{-1}\), Fnl = 0.51, Fnh = 1.45

Figure 104
Model 4b Catamaran S/L=0.2
Water depth = 200mm
V = 3.12ms⁻¹, Fnl = 0.79, Fnh = 2.23

Figure 105
Model 4b Catamaran S/L=0.2
Water depth = 200mm
V = 4.04 ms$^{-1}$, Fnl = 1.02, Fnh = 2.89

Figure 106
Model 5b Catamaran S/L=0.2
Water depth = 200mm
V = 1.03ms$^{-1}$, Fnl = 0.26, Fnh = 0.74

Figure 107
Model 5b Catamaran S/L=0.2
Water depth = 200mm
$V = 1.34\text{ms}^{-1}$, $F_{nl} = 0.34$, $F_{nh} = 0.96$

Figure 108
Model 5b Catamaran S/L=0.2
Water depth = 200mm
V = 1.41ms⁻¹, Fnl = 0.36, Fnh = 1.01

Figure 109
Model 5b Catamaran S/L=0.2
Water depth = 200mm
$V = 2.04\text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.46$
Model 5b Catamaran S/L=0.2
Water depth = 200mm
V = 3.13ms$^{-1}$, Fnl = 0.79, Fnh = 2.24

Figure 111
Model 5b Catamaran S/L=0.2
Water depth = 200mm
V = 4.06ms\(^{-1}\), Fnl = 1.02, Fnh = 2.90

Figure 112
Model 6b Catamaran S/L=0.2
Water depth = 200mm
$V = 1.41 \text{ ms}^{-1}$, $F_{nl} = 0.31$, $F_{nh} = 1.00$

---

Figure 113
Model 6b Catamaran S/L=0.2
Water depth = 200mm
V = 1.02 ms\(^{-1}\), Fnl = 0.23, Fnh = 0.73

![Graph of wave height vs. distance for different y/l ratios](image)

**Figure 114**
Model 6b Catamaran S/L=0.2
Water depth = 200mm
\( V = 1.33 \text{ms}^{-1}, \ F_{nl} = 0.29, \ F_{nh} = 0.95 \)

Figure 115
Model 6b Catamaran S/L=0.2
Water depth = 200mm
$V = 2.03\text{ms}^{-1}$, $F_{nl} = 0.45$, $F_{nh} = 1.45$

Figure 116
Model 6b Catamaran S/L=0.2
Water depth = 200mm
$V = 3.12\text{ms}^{-1}$, $F_{nl} = 0.69$, $F_{nh} = 2.23$

Figure 117
Model 6b Catamaran S/L = 0.2
Water depth = 200mm
\( V = 4.04 \text{ ms}^{-1}, \ F_{nl} = 0.89, \ F_{nh} = 2.89 \)

Figure 118
Model 5s Catamaran S/L=0.2
Water depth = 200mm
V = 1.03ms⁻¹, Fnl = 0.26, Fnh = 0.73

Figure 119
Model 5s Catamaran S/L=0.2
Water depth = 200mm
V = 1.33ms⁻¹, Fnl = 0.34, Fnh = 0.95

Figure 120
Model 5s Catamaran S/L=0.2
Water depth = 200mm
$V = 1.41 \text{ms}^{-1}$, $F_{nl} = 0.36$, $F_{nh} = 1.01$

Figure 121
Model 5s Catamaran S/L=0.2
Water depth = 200mm
\( V = 2.03\, \text{ms}^{-1}, \, F_{nl} = 0.51, \, F_{nh} = 1.45 \)

\[
\text{Distance [m]} \\
\text{Wave height [mm]}
\]

\( y/l = 0.43 \)
\( y/l = 0.55 \)
\( y/l = 0.68 \)
\( y/l = 0.80 \)
\( y/l = 0.93 \)
\( y/l = 1.05 \)
\( y/l = 1.18 \)

Figure 122
Model 5s Catamaran S/L=0.2
Water depth = 200mm
$V = 3.13 \text{ms}^{-1}$, $F_{nl} = 0.79$, $F_{nh} = 2.23$

- $y/l = 0.43$
- $y/l = 0.55$
- $y/l = 0.68$
- $y/l = 0.80$
- $y/l = 0.93$
- $y/l = 1.05$
- $y/l = 1.18$

Figure 123
Model 5s Catamaran S/L=0.2
Water depth = 200mm

\[ V = 4.06 \text{ms}^{-1}, \quad Fn_l = 1.02, \quad Fn_h = 2.90 \]

Figure 124
Model 4b Catamaran S/L=0.4
Water depth = 200mm
$V = 1.40 \text{ms}^{-1}$, $\text{Fnl} = 0.35$, $\text{Fnh} = 1.00$

![Graph showing wave height vs distance for different y/l values.

Figure 125
Model 4b Catamaran S/L=0.4
Water depth = 200mm
V = 1.02ms⁻¹, Fnl = 0.26, Fnh = 0.73
Model 4b Catamaran S/L=0.4
Water depth = 200mm
$V = 0.78 \text{ms}^{-1}$, $F_{nl} = 0.20$, $F_{nh} = 0.56$

Figure 127
Model 4b Catamaran S/L=0.4
Water depth = 200mm
V = 1.33ms^{-1}, F_{nl} = 0.33, F_{nh} = 0.95
Model 4b Catamaran S/L=0.4
Water depth = 200mm
$V = 2.02\text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.44$

Figure 129
Model 4b Catamaran S/L=0.4
Water depth = 200mm
V = 1.47ms$^{-1}$, Fnl = 0.37, Fnh = 1.05

Figure 130
Model 4b Catamaran S/L=0.4
Water depth = 200mm
V = 3.11 ms⁻¹, Fnl = 0.79, Fnh = 2.22

Figure 131
Model 4b Catamaran S/L=0.4
Water depth = 200mm
V = 4.03ms⁻¹, Fnl = 1.02, Fnh = 2.88
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 1.03\text{ms}^{-1}$, $F_{nl} = 0.26$, $F_{nh} = 0.74$

Wave height [mm]

Distance [m]

Figure 133
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 1.34 \text{ms}^{-1}$, $F_{nl} = 0.34$, $F_{nh} = 0.96$

---

Wave height [mm]

Distance [m]
Model 5b Catamaran S/L=0.4
Water depth = 200mm
\[ V = 1.42 \text{ms}^{-1}, \ F_{nl} = 0.36, \ F_{nh} = 1.01 \]

Figure 135
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 1.62\text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 1.16$

Wave height [mm]

Distance [m]

Figure 136
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 2.04\text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.46$

Figure 137
Model 5b Catamaran S/L=0.4
Water depth = 200mm
V = 3.13m s\(^{-1}\), Fnl = 0.79, Fnh = 2.23

Figure 138
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 4.05\text{ms}^{-1}$, $F_{nl} = 1.02$, $F_{nh} = 2.89$

Figure 139
Model 5b Catamaran S/L=0.4
Water depth = 200mm
V = 1.34 ms$^{-1}$, Fnl = 0.34, Fnh = 0.96

Figure 140
Model 5b Catamaran S/L=0.4  
Water depth = 200mm  
V = 1.03ms$^{-1}$, Fnl = 0.26, Fnh = 0.74

Figure 141
Model 5b Catamaran S/L=0.4
Water depth = 200mm
V = 1.42m s^{-1}, Fnl = 0.36, Fnh = 1.01

Figure 142
Model 5b Catamaran S/L=0.4
Water depth = 200mm
$V = 1.62\text{ms}^{-1}$, $F_{nl} = 0.41$, $F_{nh} = 1.16$

![Graph showing wave height vs distance for different y/l values.](image)

Figure 143
Model 5b Catamaran S/L=0.4
Water depth = 200mm
\[ V = 2.04 \text{ms}^{-1}, \ Fnl = 0.51, \ Fnh = 1.46 \]

Wave height [mm]

Distance [m]

Figure 144
Model 5b Catamaran S/L=0.4
Water depth = 200mm
\( V = 3.13 \text{ms}^{-1}, \ F_{nl} = 0.79, \ F_{nh} = 2.23 \)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Figure 145}
\end{figure}
Model 5b Catamaran S/L=0.4
Water depth = 200mm
V = 4.05 ms$^{-1}$, Fnl = 1.02, Fnh = 2.89

Figure 146
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 1.02\text{ms}^{-1}$, $F_{nl} = 0.26$, $F_{nh} = 0.73$

Wave height [mm] vs Distance [m]

Figure 147
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 1.33 \text{ms}^{-1}$, $F_{nl} = 0.34$, $F_{nh} = 0.95$

Figure 148
Model 5s Catamaran S/L=0.4
Water depth = 200mm
V = 1.41 ms$^{-1}$, Fnl = 0.36, Fnh = 1.01

Figure 149
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 1.72\text{ms}^{-1}$, $F_{nl} = 0.43$, $F_{nh} = 1.23$

![Wave height vs. Distance](image)

Figure 150
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 2.03\, \text{ms}^{-1}$, $F_{nl} = 0.51$, $F_{nh} = 1.45$

![Graphs showing wave height vs. distance for different y/l values: y/l=0.43, y/l=0.55, y/l=0.68, y/l=0.80, y/l=0.93, y/l=1.05, y/l=1.18.](image)
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 3.13 \text{ms}^{-1}$, $F_{nl} = 0.79$, $F_{nh} = 2.23$

Wave height [mm]

Distance [m]

Figure 152
Model 5s Catamaran S/L=0.4
Water depth = 200mm
$V = 4.05\text{ms}^{-1}$, $F_{nl} = 1.02$, $F_{nh} = 2.89$

![Graphs showing wave height vs. distance for different $y/l$ values: $y/l = 0.43, 0.55, 0.68, 0.80, 0.93, 1.05, 1.18$.](image)
Model 5b Catamaran S/L=0.2 trimmed bow up 2°
Water depth = 200mm
V = 1.02ms⁻¹, Fnl = 0.26, Fnh = 0.73

Wave height [mm]

Distance [m]

Figure 154
Model 5b Catamaran S/L=0.2 trimmed bow up $2^\circ$
Water depth = 200mm
$V = 1.40\text{ms}^{-1}$, $F_{nl} = 0.35$, $F_{nh} = 1.00$

Figure 155
Model 5b Catamaran S/L=0.2 trimmed bow up 2°
Water depth = 200mm
V = 2.03 ms⁻¹, Fnl = 0.51, Fnh = 1.45

Wave height [mm]
Distance [m]

Figure 156
Model 5b Catamaran S/L=0.2 trimmed bow up 2°  
Water depth = 200mm  
V = 3.12ms⁻¹, Fnl = 0.79, Fnh = 2.23

Wave height [mm]  
Distance [m]

Figure 157
Model 5b Catamaran S/L=0.2 trimmed bow down 2°
Water depth = 200mm
V = 1.02 ms⁻¹, Fnl = 0.26, Fnh = 0.73

Figure 158
Model 5b Catamaran S/L=0.2 trimmed bow down 2°
Water depth = 200mm
V = 1.41ms⁻¹, Fnl = 0.36, Fnh = 1.00

Figure 159
Model 5b Catamaran S/L=0.2 trimmed bow down $2^0$
Water depth = 200mm
$V = 2.03\text{ms}^{-1}, Fnl = 0.51, Fnh = 1.45$

Figure 160
Model 5b Catamaran S/L=0.2 trimmed bow down $2^0$
Water depth = 200mm
$V = 3.13\text{ms}^{-1}$, $F_{nl} = 0.79$, $F_{nh} = 2.23$

Figure 161
Model 5s Catamaran S/L=0.2 trimmed bow up $^1$°
Water depth = 200mm
$V = 1.01\text{ms}^{-1}$, $F_{nl} = 0.26$, $F_{nh} = 0.72$

Figure 162
Model 5s Catamaran S/L=0.2 trimmed bow up 1°
Water depth = 200mm
V = 1.40ms⁻¹, Fnl = 0.35, Fnh = 1.00

Wave height [mm]
Distance [m]

Figure 163
Model 5s Catamaran S/L=0.2 trimmed bow up 1°
Water depth = 200mm
V = 2.02ms⁻¹, Fnl = 0.51, Fnh = 1.44

Figure 164
Model 5s Catamaran S/L=0.2 trimmed bow up 1°
Water depth = 200mm
V = 3.11ms⁻¹, Fnl = 0.79, Fnh = 2.22

Figure 165
Model 5s Catamaran S/L=0.2 trimmed bow up 2.4°
Water depth = 200mm
V = 1.02ms⁻¹, Fnl = 0.26, Fnh = 0.73

Figure 166
Model 5s Catamaran S/L=0.2 trimmed bow up 2.4°
Water depth = 200mm
V = 1.40ms⁻¹, Fnl = 0.35, Fnh = 1.00

Figure 167
Model 5s Catamaran S/L=0.2 trimmed bow up 2.4°
Water depth = 200mm
V = 2.02ms⁻¹, Fnl = 0.51, Fnh = 1.45

Figure 168
Model 5s Catamaran S/L=0.2 trimmed bow up 2.4°
Water depth = 200mm
V = 3.11m s⁻¹, Fnl = 0.79, Fnh = 2.22

Figure 169
Model 5s Catamaran S/L=0.2 trimmed bow down 1.2°
Water depth = 200mm
V = 1.02 ms\(^{-1}\), Fnl = 0.26, Fnh = 0.73

Figure 170
Model 5s Catamaran S/L=0.2 trimmed bow down 1.2°
Water depth = 200mm
V = 1.40m/s, Fnl = 0.35, Fnh = 1.00

Figure 171
Model 5s Catamaran S/L=0.2 trimmed bow down 1.2°
Water depth = 200mm
V = 2.02 ms⁻¹, F nl = 0.51, F nh = 1.44

Figure 172
Model 5s Catamaran S/L=0.2 trimmed bow down 1.2°

Water depth = 200mm

V = 3.11ms⁻¹, Fnl = 0.79, Fnh = 2.22

Figure 173
Model 5s Catamaran S/L=0.2 trimmed bow down $1.2^\circ$

Water depth = 200mm

$V = 4.03 \text{ms}^{-1}, \ F_{nl} = 1.02, \ F_{nh} = 2.88$

Figure 174
Model 4b monohull, Resistance coefficients, depth=400mm

Model 4b monohull, Resistance coefficients, depth=200mm

Model 5b monohull, Resistance coefficients, depth=400mm

Model 5b monohull, Resistance coefficients, depth=200mm

Model 5s monohull, Resistance coefficients, depth=400mm

Model 5s monohull, Resistance coefficients, depth=200mm

Figure 175
Figure 176
Figure 177
Figure 178
Figure 179
Figure 180
Figure 181
Figure 182
Model 4b catamaran $S/L=0.2$, Resistance coefficients, depth=400mm

Model 4b catamaran $S/L=0.2$, Resistance coefficients, depth=200mm

Model 5b catamaran $S/L=0.2$, Resistance coefficients, depth=400mm

Model 5b catamaran $S/L=0.2$, Resistance coefficients, depth=200mm

Model 5s catamaran $S/L=0.2$, Resistance coefficients, depth=400mm

Model 5s catamaran $S/L=0.2$, Resistance coefficients, depth=200mm
**Figure 199**

Model 4b monohull, Sinkage

Model 4b monohull, Trim angle

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**Figure 200**

Model 5b monohull, Sinkage

Model 5b monohull, Trim angle

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**Figure 201**

Model 5b monohull, Sinkage

Model 5b monohull, Trim angle

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**Figure 202**

Model 6b monohull, Sinkage

Model 6b monohull, Trim angle

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**Figure 203**

Model 5s monohull, Sinkage

Model 5s monohull, Trim angle

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**Figure 204**

Model 5s monohull, Sinkage

Model 5s monohull, Trim angle

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**Figure 205**

Model 5s monohull, Sinkage

Model 5s monohull, Trim angle

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**Figure 206**

Model 5s monohull, Sinkage

Model 5s monohull, Trim angle

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Model 5s catamaran, S/L=0.2, trimmed bow up
Resistance coefficients, depth=200mm

Model 5b catamaran, S/L=0.2, trimmed bow up
Resistance coefficients, depth=200mm

Model 5s catamaran, S/L=0.2, trimmed bow down
Resistance coefficients, depth=200mm

Model 5b catamaran, S/L=0.2, trimmed bow down
Resistance coefficients, depth=200mm

Model 5s catamaran S/L=0.2, Sinkage

Model 5b catamaran S/L=0.2, Sinkage

Model 5s catamaran S/L=0.2, Trim angle

Model 5b catamaran S/L=0.2, Trim angle